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ORIGINAL PAPER

First absolute dating of Andean hunter-gatherer rock art paintings from North Central Chile

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Abstract We report the first absolute dating for rock paintings by Andean hunter-gatherer groups. Analysis by Raman spectrometry of remains of black paintings from the center-north of Chile (30° lat. S) allows for the identification of carbon as the raw material. Radiocarbon dating situates these paintings between 1623–1431 BCE and 80–240 ACE, dates that are supported by other lines of independent evidence. These results are consistent with proposals that suggest the appearance and popularization of rock art in various places in the Andes for the temporal transect of 3000–1000 BCE. Finally, these new datings are added to the scant corpus of absolute dates for rock art that exist in South America.

Keywords Rock art · Direct dating · Andean hunter gatherers · Chile

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Introduction

The geochronological dating of rock art is one of the most important issues in the study of rock art. For some authors, the absence of clear chronologies in this material record explains its secondary position in the interpretation of the past (Lorblanchet and Bahn 1993, Whitley 2005). However, the application of a set of chronometric techniques for dating rock art, especially paintings in recent years, has contributed to adjusting the sequences of temporal development for this record and opening new research questions (i.e., Rowe 2001, Bednarik 2002, Aubert et al., 2007, Steelman and Rowe 2012).

Despite these advances, it is true that there is still not a sufficient set of available datings that would allow for a general understanding of the historical development of rock art. A review of the literature shows that obtaining absolute dates has been concentrated in a few places, such as Australia (e.g., Langley and Taçon 2010, David et al. 2013, McDonald et al., 2014), Spain, France (Clottes 1998, Pike et al. 2012, Ruiz et al. 2012, García Diez et al. 2013), North America (Benson et al. 2013, Whitley 2013), and more recently, South Africa (Mazel and Watchman 1997, 2003, Rosina et al., 2014) and China (Taçon et al. 2013). While some of these dates correspond to direct datings of rock art (e.g., Mazel and Watchman 1997, 2003; McDonald et al. 2014), others correspond to indirect datings of accretions arranged on motifs (e.g., Taçon et al. 2013, Benson et al. 2013). Either way, rock paintings are the most commonly dated parietal art.

Within this overall picture, South America shows little advancement. Even though the region has a long tradition of rock art research (Schobinger and Strecker 2001), sequences of rock art have been identified mainly through relative chronologies. These chronologies have combined formal and

contextual analysis and have also used absolute dating from nearby stratigraphic deposits. These methods have allowed scholars to establish historical frames to interpret the sequences and social dynamics associated to rock art (e.g., Guffroy 1999, Berenguer 2004, Aschero 2006), but they have also been object of controversies. They are constantly being revaluated, mainly due to the limitations that relative dating methods used in rock art have. In this context, geochronological datings for rock art are only known for the Atlantic portion of the region, specifically for Argentina and Brazil. In Argentina, one has direct dating of paintings for two rock art sites located in the northeast that are associated with agricultural communities from later periods of Andean prehistory (500–1540 CE). The first dating comes from a black carbon painting from the Alero Los Emplumados site; these paintings dated to cal 127–224 CE (1880 ± 10 BP) (Hernández Llosas et al. 1998). The second dating comes from Cueva La Candelaria. In this rock art site, a white organic pigment was dated to cal 654–883 CE (1330 ± 50 BP) (Hedges et al. 1998).While the second dating has been widely accepted, the first has been the subject of further discussion because of its early character in relation to the dated iconographic repertory (Hernández Llosas et al. 1998).

In recent years in Brazil, a couple of datings have been conducted for organic material present in rock paintings from the northeastern region of the country, providing a set of dates ranging between 2000 to 300 CE (Steelman et al. 2002; Rowe and Steelman 2003).These datings have caused the dismissal of previous indirect dates through thermoluminescence of layers of calcite deposited on the rock art, which had given minimum ages of between 30,000 and 40,000 BCE (Guidon 1987, Pessis 1999, Watanabe et al. 2003). However, new dates for calcites over paintings using thermoluminescence have also given dates of 30,000–40,000 BCE (Cano et al. 2013).

This scarcity of datings stands in contrast to the rich tradition of rock art that is recognized on the continent (Schobinger and Strecker 2001, Green 2001), the abundance of paintings throughout the region, and the significant number of studies existing regarding the physical-chemical composition of the paintings (e.g. Aschero 1983–1985, Wainwright et al. 2000, Yacobaccio et al. 2008, Trujillo et al. 2010, Sepúlveda 2011, Sepúlveda et al. 2012, 2013a; Aldazabal et al. 2014). This contrast can be explained by the lack of organic remains in the paintings, the difficulty posed by the recovery of these components, the contamination of the painting by external agents, and the omission of this subject on the part of some investigators.

In this study, we present two absolute datings for rock art for Chile, corresponding to the first direct dates for rock art by Andean hunter-gatherers. The compositional analysis of a set of paintings sampled from the center-north of the country (lat. 30° S) through Raman spectroscopy allowed for the identification of paintings produced using carbon (Fig. 1).The paintings were later dated by radiocarbon using accelerator mass spectrometry (AMS). The dates obtained are discussed in light of other evidence that supports it. Our results indicate that the appearance of rock art in the center-north of Chile occurred at dates earlier than traditionally thought (Ampuero and Rivera 1971a). Specifically, this would have happened at the beginnings of the Late Holocene. Although for northernmost regions of the Andes scholars have argued that rock art appeared in the Early Holocene (e.g., Yacobaccio et al. 2008, 2012; Podestá and Aschero 2012), our results are in tune with the hypothesis of Schobinger and Strecker (2001), which argues that hunter-gatherer rock art popularizes by the Late Holocene, especially for between 3000 and 1000 BCE, throughout the Andes (see also Aschero 2006, Sepúlveda et al., 2013b). This would show that the appearance of rock art throughout the Andes was a spatially differentiated process, with different temporal rhythms. These results are relevant both for comparing with the stylistic sequences proposed, and because they allow us to locate this rock art more specifically within the regional prehistoric problematic and in the global development of rock art.

The rock art of hunter-gatherer groups from the center-north of Chile

South America presents a rich body of rock art consisting of carvings, paintings, and geoglyphs that have been classified into different areas based on their thematic affinities (Schobinger and Strecker 2001, Green 2001). One of these regions corresponds to the South American Andes, which present a broad sequence of production of rock art that extends from the first Holocene hunter-gatherers to, at least, the agricultural communities that received the Inca influences of the fifteenth century (Schobinger and Strecker 2001). This area is one of the most prolific and spatially wider artistic areas of the continent (Schobinger and Strecker 2001:751).

The rock art of the center-north of Chile, specifically that of the hydrographic basin of the Limarí river (30° lat. S.), is part of the set of Andean rock art defined by Schobinger and Strecker (2001). In this region, there are both paintings and carvings that have been associated with the first agricultural communities that would extend throughout the first millennium of our era (Ampuero and Rivera 1971a). Although over the last decade a number of studies have re-evaluated the chronological filiation of rock art (Troncoso 1999, Jackson et al. 2002, Cabello 2011, Troncoso et al. 2008), these have focused exclusively on carvings, which have been placed within the last 1000 years of the regional chronological sequence (500–1540 CE). The chronology of the paintings not having been discussed in greater depth.

In this region, we have noted a total of 23 sites with rock paintings, which are characterized by a low quantity of

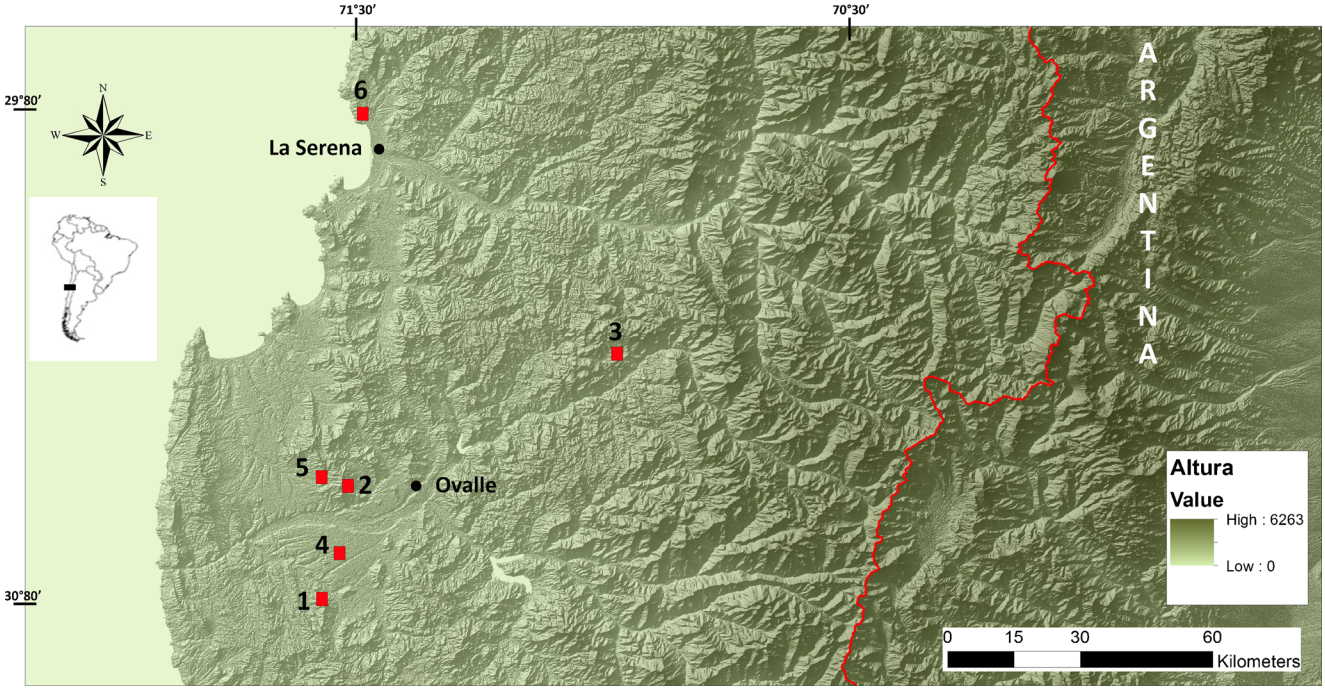

Fig. 1 Map of the area the study showing sites discussed in the text (*1* = Covacha Pintada, *2* = La Placa 5, *3* = San Pedro Viejo de Pichasca, *4* = Valle El Encanto, *5* = Tamaya, *6* = Punta Teatinos). Digital model of terrain based on ASTERGDEM images

marked rocks and painted motifs. These representations have a certain homogeneity, being characterized by correspondence to non-figurative motifs, although there are two positives of hands at the San Pedro Viejo de Pichasca site (Moya et al. 2014). The images identified correspond to sets of lines arranged horizontally and/or vertically, circles with interior lines, or points. In all of these motifs, there is a recurring use of horizontal translation as a tool of symmetry (Washburn 1983). The paintings are mostly monochromatic. The most frequently used color is red, although one also finds, with lower frequency, yellow, black, and green. The few polychromatic paintings recorded combine red with black or red with yellow and/or green. Formal analyses of the paintings show a great homogeneity of the set, suggesting that they respond to the same stylistic set (Moya 2015). This observation is endorsed by the scant presence of overlaps between paintings and by the recurrence of spatial arrangement in their pattern. All of the sites with paintings are located in association with settlements of Late Holocene hunter-gatherers, as evidenced by sites such as Valle El Encanto, Melina, and San Pedro Viejo de Pichasca (Moya 2015, Troncoso et al. 2014). Archeological excavations conducted in these last sites have shown contexts with materials that are characteristics of hunter-gatherers of the Late Holocene, which is supported by the absolute dating that date these contexts between 2000 BCE and the beginnings of the Common Era (Table 1). San Pedro Viejo de Pichasca, although having a long occupation sequence from the Early Holocene, pigments are found in the occupation associated to Late Holocene hunter-gatherers (Ampuero and Rivera 1971b).

Material and methods

To characterize the technology associated with the production of the rock paintings in the area of study, we implemented a research program focused on their physical-chemical characterization. From a total of 19 samples taken for analysis using Raman spectroscopy, two corresponded to black pigments deriving from the La Placa 5 and Covacha Pintada sites. The motifs sampled, as well as the characteristics of both sites, fit the characteristics described in general for the set of paintings from the region.

The La Placa 5 site is a rocky outcropping of granite blocks located in the terrace of a creek that is presently dry (Fig. 2). Petroglyphs were recorded on three of these blocks. One painting was recorded in one of these blocks. It corresponds to a non-figurative bicrome motif (red and black) consisting of a circle with external decoration of geometrical figures (Fig. 2). A sample of black painting was obtained from this motif.

The Covacha Pintada site is a rocky section located in the bed of a creek that is presently dry (Fig. 3). Both its ceiling and its side walls are painted with non-figurative motifs that are red and/or black in color. A sample of black painting was

Table 1 Absolute dating of the Late Holocene occupations associated to contexts with rock paintings and/or with remains of pigments in the stratigraphy (all dates were calibrated with the SHCal 13 curve in Oxcal 4.2)

Site	Provenience	Material	Code	^{14}C year BP	2σ Cal BCE–CE	13C/12C ratio %	Source
Valle El Encanto	PL3: 10–20 cm	Bone of *Lama guanicoe*	UGAMS 9353	3680 ± 25	2127 to 1892 BCE	No available	FONDECYT 1110125
	PL1: 90 cm	Charcoal	AA 95189	2579 ± 36	799 to 514 BCE	−22.6	FONDECYT 1110125
	PL3: 70 cm	Charcoal	UGAMS 05013	2000 ± 25	36 BCE to 129 CE	−22.8	FONDECYT 1110125
	MP1: 35 cm	Charcoal	UGAMS 05014	1890 ± 25	86 to 248 CE	−23.7	FONDECYT 1110125
Tamaya 1	U1: 40 cm	Bone of *Lama guanicoe*	UGAMS 11772	3290 ± 25	1608 to 1432 BCE	−19.7	FONDECYT 1110125
	U1: Feature 1	Bone of *Lama guanicoe*	UGAMS 9352	3200 ± 25	1497 to 1320 BCE	−17	FONDECYT 1110125
Melina 1	U2: 35 cm	Bone of *Lama guanicoe*	UGAMS 11771	1680 ± 25	325 to 537 CE	−22.7	FONDECYT 1110125
San Pedro Viejo de Pichasca	E1D1: 30 cm	Charcoal	I5957	2375 ± 95	767 to 202 BCE	No available	Ampuero and Rivera 1971b
Punta Teatinos	Tomb 146	Human bone	Beta 4514	3320 ± 70	1756 to 1438 BCE	No available	Schiappacasse and Niemeyer 1986
	Tomb 40	Human bone	Beta 4515	3000 ± 70	1414 to 1040 BCE	No available	Schiappacasse and Niemeyer 1986
	Tomb 178	Human bone	Beta 4516	1920 ± 60	43 BCE to 232 CE	No available	Schiappacasse and Niemeyer 1986, Quevedo 1998

obtained from a motifs composed of a red rectangle with interior decoration of red and black lines (Fig. 3).

Samples were taken following respective sampling protocols (Steelman and Rowe 2012, Sepúlveda and Laval 2010). Millimetric portions of paint were extracted to alter the representations as little as possible. Each sample was obtained using a scalpel, the sterile blade of which was changed after each extraction of pigment. Particles were deposited within sterile plastic portable sample tubes that were sealed on-site to avoid possible alterations during their transport to the laboratory.

Previous to its characterization, each sample was observed using a *trinocular* EPI-*fluorescence microscope* (Optika brand, model B-600TiFl), with white light and variable magnification between ×40 and ×400. This first observation sought to identify the presence of paint, to locate the front and back of the samples, and to describe the presence of distinct grains that might constitute the paint or possible patinas deposited on the surface, among other aspects.

Next, the Raman spectra, conducted in the Laboratory for Analysis and Archaeometric Research of the University of Tarapacá (Arica, Chile), were recorded on Renishaw InVia Reflex equipment, with excitation sources of 532, 633, and 785 nm laser lines, equipped with a Leica microscope and an electrically cooled CCD camera. The instrument was calibrated using a silicon wafer and a 50× objective lens. One to 10 scans with durations of between 10 and 30 s were used to obtain the spectra. The power of the 785 nm laser was adjusted between 0.001 and 1 %. The spectra were recorded in the region between 1800 and 200 cm^{-1}. The reproducible spectra from the samples were scanned directly over the samples loaded on a quartz plate, thus attenuating or reducing their natural fluorescence. Wire 3.4 software and GRAMS/AI 8 were used to analyze the spectral information.

All of the samples were analyzed directly without previous preparation to be able to subject them to later analysis. Based on this procedure, the aim was to characterize their structural components, and in turn, we sought to identify the presence of possible organic remains. The analyses performed sought to identify possible samples for dating through C14-AMS, for which the samples were sent to the Center for Applied Isotope Studies at the University of Georgia in the USA.

In turn, to obtain other dates that would allow for comparing the results of the direct dating of the paintings, we extracted two samples of the soot present under the red-colored rock paintings from the roof of the San Pedro Viejo de Pichasca site. This site corresponds to a rock-shelter with three levels of occupation, stratigraphically separated, from the Early Holocene to the Late Holocene (Ampuero and Rivera 1971b). The soot has been the result of combustion activities

Fig. 2 La Placa 5 site and detail of painting sampled. The *right* figure has been digitally enhanced using D-Stretch (Filter LBK, intensity 15)

carried out by the ancient occupants of the site. The rock paintings are located on the roof of the rock-shelter (Fig. 4). The study of the paintings both on the field and with the digital enhancement by the D-Stretch plug-in have allowed us to register a total of nearly 50 motifs, with the color red predominating but with green and yellow noted as well (Moya et al. 2014). The motifs from San Pedro Viejo de Pichasca belong to the same stylistic group as those found in the rest of the paintings from the region, among which are included those at the abovementioned sites of La Placa 5 and Covacha Pintada (Moya 2015).This is expressed in the use of similar colors, motifs, and symmetry patterns if compared to other rock paintings of the region. Archeological excavations showed an abundant set of red pigments remains that have been associated to the production of rock art (Ampuero and Rivera 1971b). As mentioned before, the pigments where found on the Late Holocene hunter-gatherer's level of occupation, dated by Ampuero and Rivera (1971b) between cal. 767–202 BCE (2375±95 BP) (Table 1).

Although these carbons do not represent a unique event and offer a series of limitations to their interpretation, their strategic position in relation to the rock paintings gives an earlier date for the beginning of the production of the rock paintings present at this site.

Results

Raman analysis of the two black samples of paintings from La Placa 5 and Covacha Pintada gave bands close to 1335 and 1595 cm^{-1} (Fig. 5), which are characteristic of the D and G bands of amorphous carbon (Tomasini et al. 2012; Lahlil et al. 2012). The absence of bands close to 960 cm^{-1}, which are characteristic of phosphates present in bony elements, leads us to dismiss the hypothesis that these elements were the raw material of the pigment (Tomasini et al. 2012, Gomes et al. 2013, Lahlil et al. 2012). Characterization of the samples using their obverse and reverse sides did not show the presence of oxalates of calcium that might have contaminated the sample.

The absolute dates obtained for the carbon from the black paintings and the soot extracted from the ceiling at San Pedro Viejo de Pichasca are summarized in Table 2. These datings were calibrated with the SHCal 13 curve in Oxcal 4.2 (Hogg et al. 2013).

Fig. 3 Covacha Pintada site and detail of painting sampled. The *right* figure has been digitally enhanced using D-Stretch (Filter LBK, intensity 15)

Fig. 4 San Pedro Viejo de Pichasca rock-shelter and detail of red painting over soot. The *right* figure has not been digitally enhanced

Discussion

The direct datings of rock paintings from the center-north of Chile show that these paintings were manufactured over a long period of time that extends from the middle of the second millennium before Christ to the beginning of the Christian era. These results would situate the paintings back to earlier dates than those traditionally suggested, within the framework of what is regionally known as Late Archaic (ca. 2000 BCE–100 CE), a period characterized by the presence of hunter-gatherer communities of the Late Holocene. These manifestations are in turn the earliest expression of rock art in the region, whose appearance may go back to at least 1623–1431 BCE. The presence of superpositions at some sites where the paintings are found under carvings reaffirms the earlier character of these paintings (Troncoso et al. 2008).

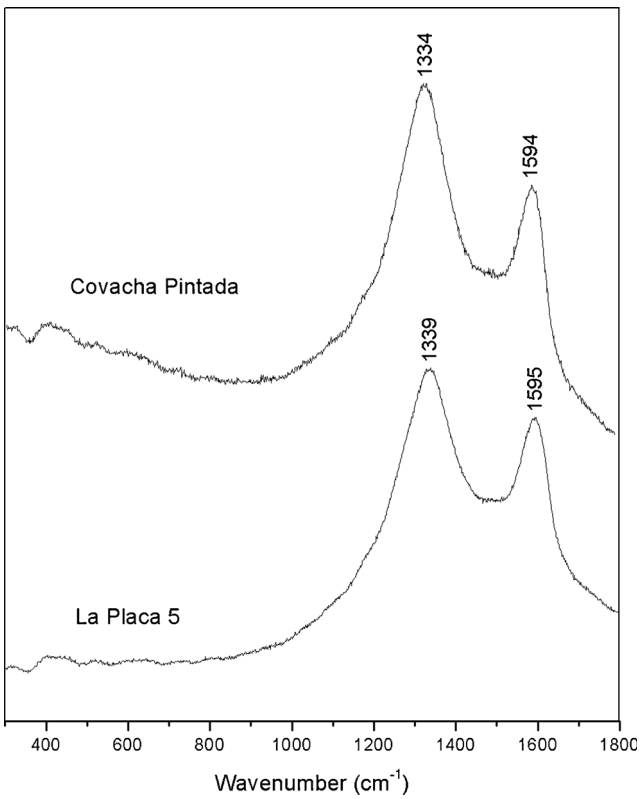

Fig. 5 Results of Raman spectrometry applied to black paintings

The possibility of direct dating for paint manufactured based on an organic pigment such as carbon reduces certain problems associated with the datings of accretions of oxalates, or carbonates associated with the paintings, and of non-specific organic components of the mixtures (Pettitt and Pike, 2007; Taçon et al. 2013). However, eliminating these problems does not resolve all of the concerns traditionally associated with radiocarbon dating, such as contamination by unidentified carbons or old charcoal effects (Pettitt and Pike, 2007; Steelman and Rowe 2012). Thus, we believe it is important to connect the datings obtained with a set of other lines of evidence that allow these datings to be evaluated. As Wyllie (2002) indicates, the use of different lines of independent evidence allows for strengthening archeological interpretations, giving more validity to arrive at interpretations.

A first line of evidence that supports the datings obtained is the fact that red and, on occasion, yellow pigments have been recognized in various settlements and funerary sites associated with hunter-gatherers of the Late Holocene in the region (e.g., Schiappacasse and Niemeyer 1964, 1965–1966). As can be seen in Table 1, dates from these sites are contemporaneous with our two absolute dating of rock paintings. Dates for Tamaya were obtained from mortar with red pigments in a stratigraphic layer and in the surroundings of the site there are rock paintings of the same color. These dates are within the same range as those for Covacha Pintada.

A second line of evidence concerns reviewing other decorated material. In particular, bone tools from contexts dated between 2000 and 100 BCE show decorations and patterns of symmetry similar to some motifs in rock paintings (among others Punta Teatinos see Table 1) (Schiappacasse and

Table 2 Dates of rock paintings (Covacha Pintada and La Placa 5) and soot under paintings in San Pedro Viejo de Pichasca rock-shelter

Lab Code	Site	Rock	Panel	Motif	14C year BP	13C/12C ratio %	2σ Cal BCE–CE
UGAMS 17274	Covacha Pintada	1	2	2	3290 + −40	−24.5	Cal. BCE. 1623–1431 (95.4 %)
UGAMS 17738	La Placa 5	1	1	1	1890 + −30	−25.0	Cal CE 80–240 (95.4 %)
UGAMS 17275	San Pedro Viejo de Pichasca	Roof	Charcoal under red painting		6780 + −90	−23.2	Cal BCE. 5803–5486 (95.4 %)
UGAMS 17276	San Pedro Viejo de Pichasca	Roof	Charcoal under red painting		4140 + −45	−18.8	Cal BCE. 2872–2494 (95.4 %)

Niemeyer 1965–1966; Quevedo 1998) (Fig. 6). Neither the symmetry nor the designs are replicated at earlier or later dates on any material support.

Finally, the carbon datings of the soot from the ceiling at San Pedro Viejo de Pichasca are earlier than those we have obtained for the paintings. In this sense, their dates indicate that the paintings in the rock-shelter were produced after the Middle Holocene. The similarities that the paintings from the site present to other regional rock art allow for extrapolating this situation to the region. The anomalous value obtained for δ13C in the UGAMS 17276 sample may be due to an incorporation of other undetected organic material different than charcoal (e.g., binder from rock painting above the charcoal). This does not undermine the value of the obtained date as a chronological indicator for the rock art.

Thus, the absolute datings obtained are coherent with other lines of evidence that suggest that the paintings were produced in the region by hunter-gatherers of the Late Holocene at least within the date range of 1623–1431 BCE to 80–240 CE. Also, and even though the dates are separated, they are in tune with the temporal distribution of archeological contexts associated to the use of pigments in the region, as well as with the general chronology of the Late Holocene hunter-gatherer occupations, which would have occurred between ca. 2000 BCE and 500 CE (Schiappacasse and Niemeyer 1965–1966, 1986; Troncoso et al. 2015).

The dates for these paintings in the center-north of Chile are coherent with a broader process of the appearance and popularization of rock art in the different parts of the Andes. In fact, although in some regions such as South Peru (e.g.,

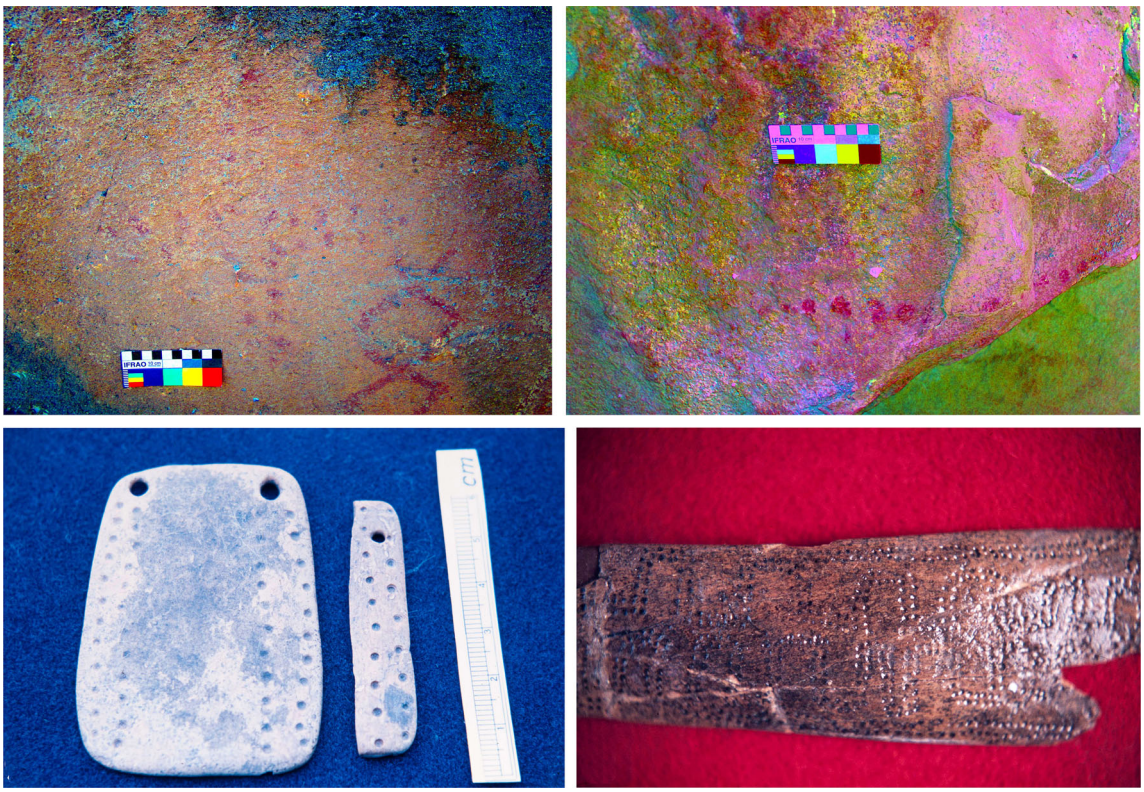

Fig. 6 Similar motifs between rock art (**a**–**b**) and bone tools of late hunter-gatherer communities in the area (**c**–**d**). **a**, **b** Digitally enhanced images using D-Stretch (Filter LBK, intensity 15 and CRBG, intensity 15, respectively). **c**, **d** Hans Niemeyer archive (Museo Nacional de Historia Natural, Chile)

Muelle 1970, Guffroy 1999) and areas of Northwest Argentina some scholars have argued that production of rock art started in the Early Holocene (e.g., Yacobaccio et al. 2008, 2012; Podestá and Aschero 2012), they are scarce. Contrastingly, this artistic production is popularized among the hunter-gatherers of the Late Archaic along the Andes (e.g., Aschero 2000, Gallardo 2001, Berenguer 2004, Aschero 2006, Nuñez et al. 2006, Sepúlveda et al. 2013b). In cases such as in the north of Chile, it is in this period when rock art appear (Berenguer 2004). Schobinger and Strecker (2001) have proposed that between 3000 and 1000 BCE, an important and recurrent tradition of rock art paintings develops in the Andean region that is associated with a series of processes of increasing social complexity that take place throughout this area. In the center-north of Chile, this process can be observed in the demographic growth of the population, the appearance of specialized technologies, an intensification of practices of exploitation of plant resources, and a reduction in the mobility of these populations (Schiappacasse and Niemeyer 1986, Quevedo 1998).

Our dates confirm those proposed by Schobinger and Strecker (2001), although they extend them to the beginning of the Christian era, taking the particular temporal dynamics throughout the region into account. In turn, these dates are the first direct datings for rock paintings by Andean hunter-gatherers.

Concluding remarks

The recognition of carbon as raw material for paintings from the center-north of Chile made it possible to obtain a pair of chronological datings for these paintings. These dates correspond to the first absolute datings for rock paintings from late Andean hunter-gatherers and one of the few chronological references existing in South America for rock art. A set of other evidence recovered for the center-north of Chile allows for appraising the likelihood of the dates obtained, thus avoiding relying exclusively on the radiometric method.

These datings are added to a few other existing dates for South America, allowing us to begin positioning these manifestations within the global history of rock art. Thus, we currently have datings for paintings by hunter groups from lowlands (Piaui, Brazil), paintings from Andean agricultural communities (Argentinian Northwest), and paintings by Andean hunter-gatherers (center-north of Chile), which correspond to three different sets of representations according to the proposals of Schobinger and Strecker (2001).

In the case of rock art of Andean hunters, our results show how temporal dynamics of its appearance and development differ across this territory. While in some areas there are paintings from the Early Holocene (e.g., Guffroy 1999, Yacobaccio et al. 2008, 2012; Podestá and Aschero 2012), in our region, as well as in the north of Chile (Berenguer 2004, Sepúlveda et al. 2013b), this process happened later, during the Late Holocene. To understand the different rhythms associated to the appearance and popularization of rock art in the Andes requires a continuous effort to strengthen and adjust the sequences through relative chronologies, as well as to carry out a systematic program of absolute dating of rock paintings to contrast and tune up the sequences. Continuing chemical studies, as well as exploring other chronometric techniques, is an urgent task for the region. Based on the direct dating of new sets of iconography, one can continue to position local groups within the global history of rock art, opening new questions to guide research. However, these new advances should combine absolute datings with other independent lines of evidence to further strengthen the interpretation of the dates.

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