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Mining, macro-regional interaction and ritual practices in the South-central Andes: The first evidence for turquoise exploitation from the Late Prehispanic and Inca periods in North-western Argentina (Cueva Inca Viejo, Puna de Salta)

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ABSTRACT

In this article, we present the first and only documented source of turquoise exploited in Northwest Argentina (NOA) from the Late Prehispanic and Inca periods (ca. 900–1532 CE). The evidence for turquoise mining comes from Cueva Inca Viejo, an archaeological site located in the highlands of Province of Salta. Turquoise is a valuable mineral that has been exploited for millennia in the Andean region. Until now, there was no evidence for Prehispanic sources of this material being exploited in Northern Argentina. Due to this, all the turquoise found at Argentine archaeological sites was interpreted as allochthonous. The evidence presented here contributes to discuss this issue at a regional scale. Primarily, we analyse and discuss the role played by Cueva Inca Viejo in the mining and use of this mineral, and its links with macro-regional interaction processes and ritual practices. Physicochemical analysis (SEM-EDS and XRD) allowed us to identify turquoise from the cave wall, and from the archaeological layers. Likewise, we found stone hammers, the most important artefacts closely associated to Prehispanic mining. Among the archaeological materials recovered in Cueva Inca Viejo, it is important to highlight the rock-art with representations of llama caravans and anthropomorphic figures, as well as the discovery of feathers and *cebil* seeds (*Anadenanthera colubrina*) in archaeological contexts, both originary from the lowlands. We conclude that the expansion of the Inca Empire in the area was linked to the mining and the control of ritual activity. In this regard, we highlight the presence of a ceremonial structure with stairs, located outside the entrance of Cueva Inca Viejo. Our results show that there was a narrow relationship between mining, macro-regional interactions and ritual, at least, from the Late pre-Inca Period through to Inca expansion in the region.

1. Introduction

The extraction and use of varied minerals with ornamental value has been documented since the Prehispanic Period in the South-central Andes (e.g. Lechtman and Macfarlane, 2005). This is the case with turquoise – hydrous phosphate of copper and aluminium –, a much prized mineral that has been exploited for millennia across the world. In the Southern Andes, turquoise mines have been recorded in Northern Chile (Nuñez, 1994), while there was no evidence for turquoise deposits from North-western Argentina (known as the NOA and referred as such in this article), nor was there evidence that it was exploited in this area during the Prehispanic Period (López Campeny et al., 2014).

In NOA archaeological sites, turquoise is usually found as ornamental beads, and in relation to ritual evidence (López Campeny et al., 2014). For example, turquoise beads were found in funerary contexts in the Eastern Salta Valleys (Ventura and Oliveto, 2014), Tucumán (Domínguez Bella and Sampietro Vattuone, 2005), and in the Puna de Catamarca (López Campeny et al., 2014). However, at a site in the Barrancas River basin (Puna of Jujuy), a turquoise bead was found in a domestic Late Prehispanic/Inca context (Yacobaccio et al., 2015).

Copper and associated mineral beads, such as turquoise, were linked to processes of macro-regional interaction. It has been proposed that these mineral resources circulated – both in a worked (such as beads) and unworked state – from the Atacama region in Northern Chile to NOA and the Southern Bolivian puna areas, as well as to the Eastern valleys and tropical forests (Albeck, 1994; Nuñez, 1994). This material

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has been found in rockshelters, mountain passes and in association with caravan sites. Furthermore, these contexts are usually related to ritual practices associated to caravans and mobility within a macro-regional context (Nielsen, 2013). The circulation of copper minerals between the highlands and lowlands has been documented for both Prehispanic and historical periods (Albeck, 1994; Angiorama, 2006; Angiorama and Becerra, 2014; Berenguer, 1994; Núñez, 1994; Salazar and Vilches, 2014; Ventura and Oliveto, 2014).

Given the presence in Northern Chile of mining sites dedicated to the Prehispanic extraction of copper and turquoise, and the supposed absence of similar sites in the NOA, the hypothesis was always that these materials circulated in a West-East direction (Albeck, 1994). Copper and turquoise mines are common in Atacama, Northern Chile; these include the sites of Chuquicamata, El Abra and Mina Las Turquesas, among others (González and Westfall, 2008; Nuñez, 1994; Núñez, 1999; Figueroa et al., 2013; Salazar and Vilches, 2014; Salazar et al., 2013). Consequently, the presence of turquoise at NOA sites has been considered allochthonous, and essentially derived from the Chilean Atacama region (Domínguez Bella and Sampietro Vattuone, 2005). Salazar and Vilches (2014) state that there is evidence for extraction of turquoise from Northern Chile, dating to the Formative, Late Intermediate and Inca periods. These researchers highlight the appearance of stone hammers as one of the more reliable indicators for the presence of Prehispanic mining. In the case of copper mining sites such as Chuquicamata 2, Núñez et al. (2003) suggest that these are camp sites for mining colonists coming from villages located in the Loa River and at San Pedro de Atacama. This copper extraction is related to llama caravans that moved, together with other objects, this material to different parts of the Altiplano and coast, thereby '…strengthening the seigniorial regime of the local chiefs…' (our translation) (Núñez et al., 2003: 32). From this perspective, turquoise and other copper minerals were considered elite luxury and prestige goods (Núñez, 1999).

Alternatively, Nielsen (2007) reinterprets the different strands of evidence at the macro-regional level arguing for corporative social formations rather than chiefdoms or a seigniorial regime for these human groups. In corporative societies, the power of chiefs does not lie in co-opting communities through the force; rather they are brought together using symbols and rituals associated with ancestors. In this context, objects with high symbolic value might have played this role.

The Inca Period (ca. 1430–1532 CE) involved a re-ordering of social groups to a new reality. The Inca Empire expanded the scale of mineral exploitation. Indeed, mineral wealth has been cited as one of the principle reasons for Inca expansion into North-western Argentina and Northern Chile from Peru (Raffino, 1978). Mineral extraction became a form of tribute for the empire. Exploitation implied obtaining resources coveted for their high ornamental value, while restricted access to minerals such as turquoise would have accrued greater status to the people that did have access to them (e.g. the Inca elite). The macro-regional evidence indicates the symbolic importance of turquoise for the Incas, and its role in social interaction processes and ritual practices. For Andean people, turquoise was a prized exchange good. This mineral is relatively scarce across the Andes (including in Peru), this explains why a turquoise source in the region would have such importance for the Incas.

Within this framework, the Puna (high-plateau) was a crucial region as a source of turquoise. In turn, the mountains with mining potential located in the Puna were used by local people to carry out rituals. These places (also known as *huacas*) constituted sacred points. The relationship between mining and ritual practices was common along the Andes (Cruz, 2013; Salazar et al., 2013; Vaughn et al., 2013). The ethnographical and archaeological records suggest that Andean pastoralists and farmers leave ritual offerings alongside their economic activities (Salazar et al., 2013; Soto and Salazar, 2016). The links between the economic and symbolic dimensions – such as the one mentioned above – have been denominated *rituals of production* (Martel, 2011; Van Kessel, 1989). In northern Chile, there is an important corpus of Prehispanic archaeological evidence of mining associated with ritual practices (Soto and Salazar, 2016); however, in northern Argentina this data is still scarce (Angiorama and Becerra, 2014).

The general aim of this article is to present the first and only documented source of turquoise exploited in Northwest Argentina (NOA) from Prehispanic periods. The evidence for turquoise mining comes from Cueva Inca Viejo, an archaeological site located in the highlands of the Province of Salta (Ratones Basin). Until now, there was no evidence for Prehispanic sources of this material being exploited in Northern Argentina. Due to this, all the turquoise found at Argentine archaeological sites was interpreted as allochthonous. The data presented here contributes to evaluate this issue at a regional scale. Complementarily, the archaeological indicators coming from Cueva Inca Viejo and other site of the Ratones Basin (Abra de Minas) allow us to discuss large-scale social interaction processes and ritual practices. As we have previously seen, the link between economic activities (e.g. mining), social interaction and ritual is an important topic in the Andean region. In this sense, Cueva Inca Viejo brings together these three themes providing us with the evidence necessary to discuss the link between them.

2. Study site, materials and methods

2.1. The Cueva Inca Viejo site

The Cueva Inca Viejo site is a cave located in the Puna de Salta, NOA, at 4312 m asl. Specifically, the site is on the Western slope, along the Northern sector of Mount Inca Viejo (summit height 4525 m asl; 25° 08′ 40″ S, 66° 45′ 45″ W), abutting the Salar de Ratones (Fig. 1). The cave entrance is 6.3 m wide, with the cavity getting bigger inside, and it has a maximum depth of 13 m. The main cave chamber makes for a good natural refuge. Towards the back of the cave, there is an increase in the number of galleries, enlarged by mining. Indeed, some areas of the cave – especially in one of the galleries – show signs of having been picked at through mining.

The cave was formed in the intrusive subvolcanic stock of Mount Inca Viejo. This stock is a porphyric dacite that contains copper minerals and gold, and constitutes the Fm. Inca Viejo (Middle Miocene, 15 ± 0.2 Ma). The stock is hosted in metasedimentary and igneous rocks of the Lower Palaeozoic basement (Chabert, 1999; Sillitoe, 1977).

The main porphyric body, of which Mount Inca Viejo is part of, is a rock outcrop of 2200 m along a North-South alignment that is between 250 and 500 m wide. Petrographically, this rock has been defined as biotite dacite porphyry (Cécere, 1980 in Chabert, 1999: 1431). The porphyry and the country rock contain numerous veins of quartz, oxidised iron, copper sulfhides (boxworks) and copper oxide assemblage with chrysocolla, malachite, azurite and turquoise. There is also considerable iron oxides, goethite, hematite and jarosite in mineralised veins (because it is an area that has suffered oxide leaching of hypogene sulphides ore minerals). In Inca Viejo, the sub-parallel quartz and limonite veins contain mineralised gold. Apparently, these were formed at a later period than the mineralization of copper, but this subject is not explored in further detail here. Geochemical and geophysical explorations looking for copper and gold were undertaken during the last decades of the 20th Century (Chabert, 1999).

2.2. Brief presentation of the archaeological evidence in Cueva Inca Viejo: indicators of macro-regional interaction and ritual

The cave includes rock-art and other evidence of processes of broader social interaction and ritual practices (López et al., 2015). Following a distributional methodology, 0.5 × 0.5 m test-pits have been excavated in different areas of the cave ($N = 11$), these yielded a single radiometric date of 860 ± 60 year BP (LP-2909, calibrated to 1 sigma 1179–1273 CE, Layer B) (López et al., 2015). In the excavated areas, two layers – A and B – were differentiated by their sediment

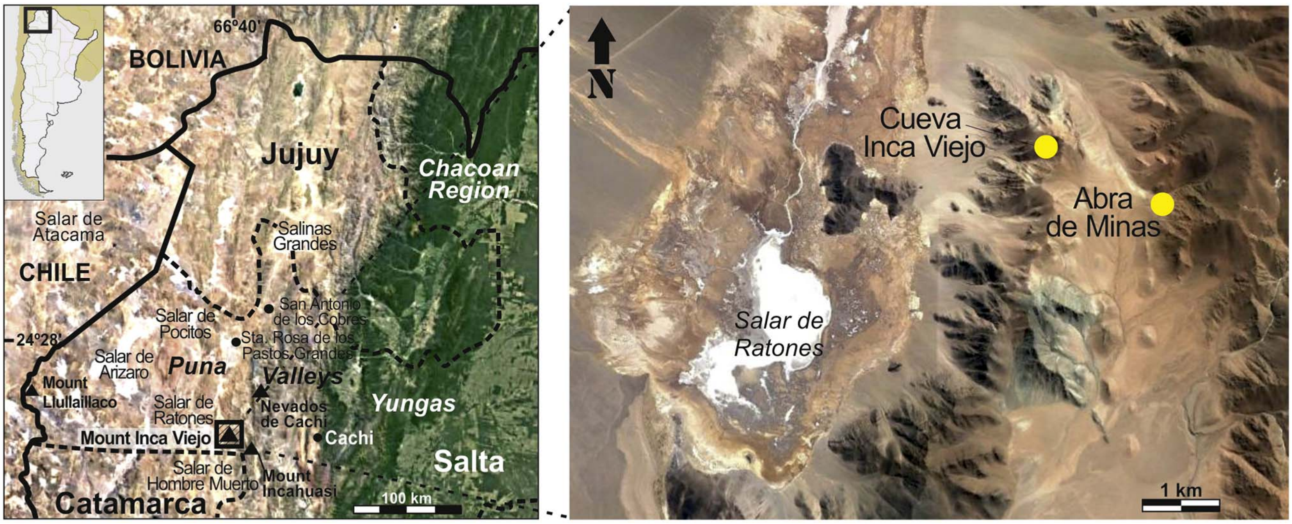

Fig. 1. Map of the region showing the location of Mount Inca Viejo (left), and Cueva Inca Viejo and Abra de Minas sites (right).

characteristics. We expect to shortly increase the number of radiometric dates available for the site. Nevertheless, the archaeological material recovered securely indicates at least two occupation phases, a pre-Inca and Inca one (for more details on the excavations and stratigraphy, see López et al., 2015).

The pre-Inca evidence is supported by the radiocarbon date, corresponding to the Late Prehispanic Period (ca. 900–1430 CE), for which there is evidence of an increase in llama caravans and the movement of goods, information and resources between different and distant regions (see Nielsen, 2013). The cave was part of this process, with black painted representations of llama caravans led by anthropomorphic figures (Fig. 2A) and an ample range of allochthonous goods (see López et al., 2015). The llama is a domesticated camelid that was used during the Prehispanic Period to transport cargo and exchange goods between different areas (Nielsen, 2013). Aside from the caravan representations, Cueva Inca Viejo also displays other dynamic scenes such as examples of llama coitus (López et al., 2015); these sexual motifs have been linked to fertility at other sites (Aschero, 2007).

On the other hand, the Inca evidence is remarkable for the archaeological record of the cave and its surroundings; for example, the path to the cave is demarcated by a double wall with worked stones and mortar, which extends > 200 m. Likewise, the pottery recovered from the cave displays typical characteristics of Inca forms and styles as an aribalo neck-sherd (Fig. 3A). Besides, there is Inca architecture in the Mount Inca Viejo and at the Abra de Minas site, located 2 km away (Fig. 1). Abra de Minas is characterised by the presence of > 90 architectural structures, among them some typically of Inca manufacture such as Compound Perimeter Enclosures (RPC). In this sense, the presence of other Inca characteristics such as double walls and worked stone was observed (López and Coloca, 2015). Abra de Minas presents a wide diversity of Inca pottery, with typical forms such as duck dishes and aribalos. This site has a planned construction layout by the Inca Empire at 4250 m asl, superimposed over previous occupations (López and Coloca, 2015). This is supported by architectonics characteristics, radiocarbon chronology and ceramic forms and styles (Coloca, 2017; López and Coloca, 2015). The radiocarbon dates indicate human occupations from ca. 650 CE to 1450 CE (Coloca, 2017). Until now, the modifications produced by the Inca settlement in the site have prevented to characterize the previous occupations (for more details see Coloca, 2017, López and Coloca, 2015). On the other hand, Abra de Minas is located alongside a main North-South imperial road. A further secondary road would connect it to sites located in the middle Calchaquí Valley, these links probably existed even before the arrival of the Incas (Cremonte and Williams, 2007; Williams et al., 2014).

Recently, we discovered a ceremonial structure with novel features for the context of the Argentine Puna, located outside the entrance of Cueva Inca Viejo (Fig. 4A and B). This ceremonial structure was hidden beneath a pile of loose rocks removed during the 2017 field season (Fig. 4A). Its maximum height is 5.70 m. It is an Inca-type building (possibly an *ushnu*) located on the slope that runs from the cave to a walled flat sector which overlooks the salt flats (Salar de Ratones). This ceremonial structure is composed of: 1) a 2.12 m high wall that impedes visually the Cueva Inca Viejo access (Fig. 4A–C), 2) a rectangular platform of > 2 m in length located just below the previously described wall (Fig. 4C), 3) a smoothed ramp (Fig. 4B) and, most strikingly, 4) one stone staircase that starts at the walled flat sector and finishes at a small

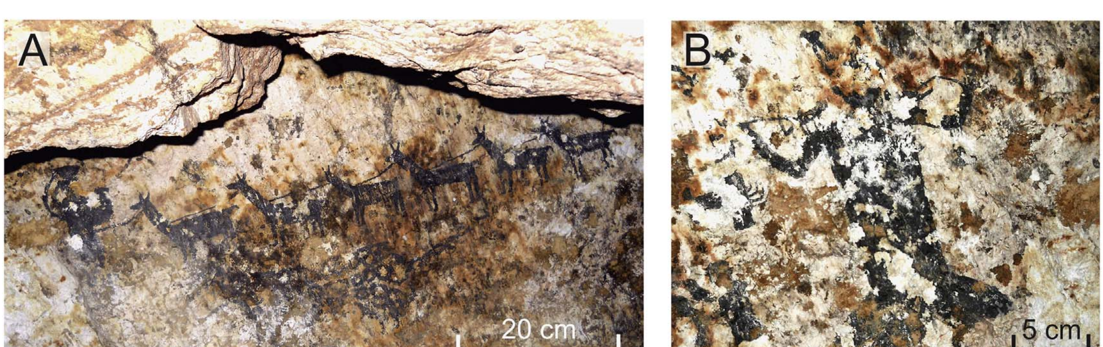

Fig. 2. Rock-art at Cueva Inca Viejo. A) Llama caravan led by an anthropomorphic figure and a jaguar motif (lower part). B) Anthropomorphic figure with arms overhead.

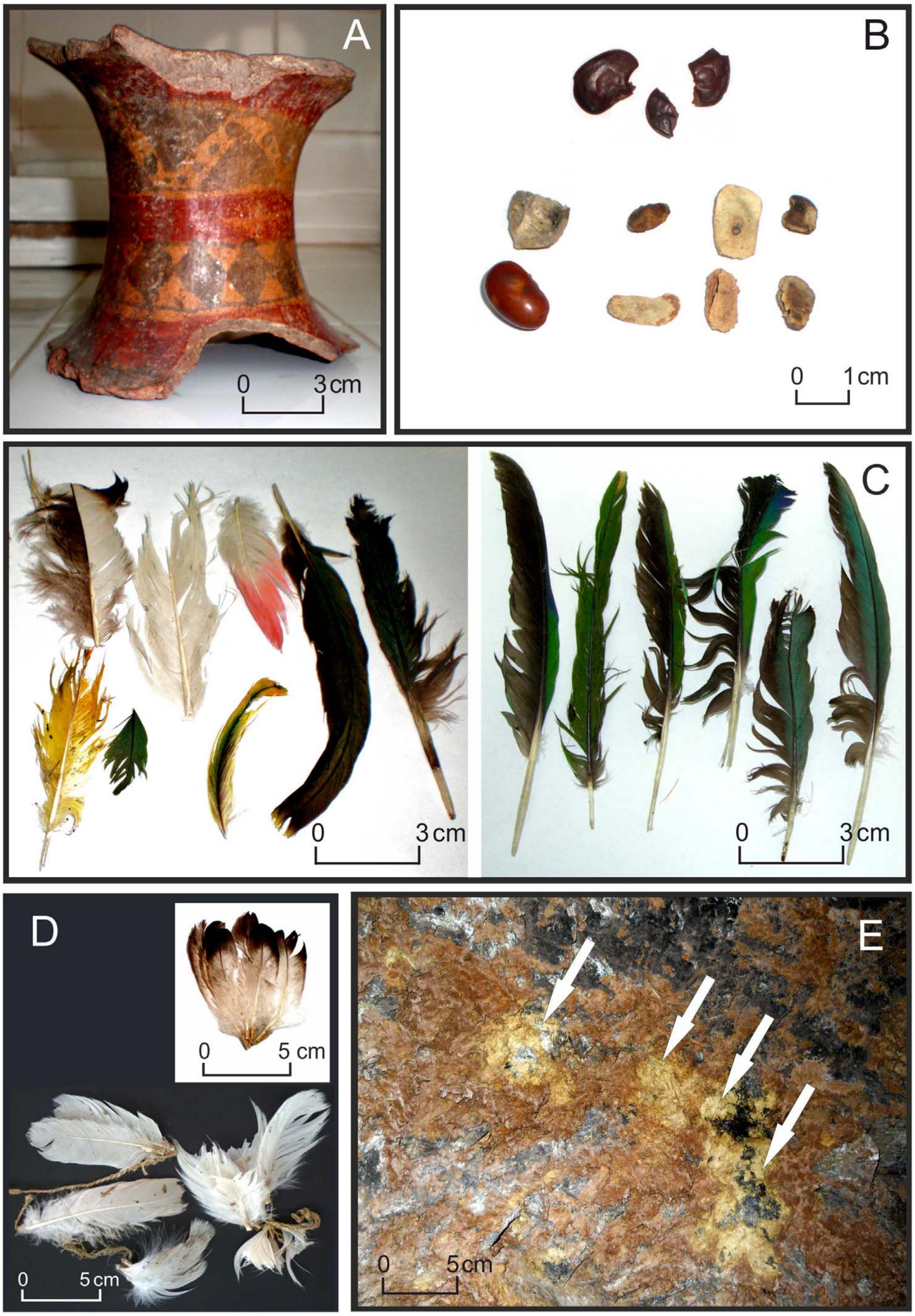

Fig. 3. A) Aribalo. B) Cebil seeds (top) and other seeds (bottom). C) Feathers from test-pits. D) Braided and ties feathers. E) Pusno.

enclosure abutting the platform itself (Fig. 4D). This staircase has at least 15 steps and a double wall along each side. The presence of an analogous staircase along the other side of the platform has not been ruled out. In synthesis, this structure with stairs is crucial evidence for the ritual and symbolic importance of Cueva Inca Viejo to the Incas.

Likewise, Mount Inca Viejo, and especially the cave, constituted a sacred or ritual space since the pre-Inca Period. As seen in the rock-art, among the anthropomorphic figures, some share similarities with others found at pre-Inca sites in the Andean region, such as the "sacrificer" or the "lord of the jaguars and camelids" (Fig. 2B). We also highlight the figure of a jaguar in the rock-art. These figures are common in the Middle Prehispanic Period (ca. 600–900 CE) but are also represented in the Late Prehispanic Period (ca. 900–1430 CE). Until now, the absolute chronology of these paintings has not been determined with certainty. The figure of the jaguar is also important (Fig. 2A), as this creature is native to the tropical forest lowlands, situated 300 km from the site. Jaguar iconography is related to elite ritual practice and the use of hallucinogenics such as cebil (Anadenanthera colubrina), is related to elite ritual practice and the use of hallucinogenics such as cebil (*Anadenanthera colubrina*) (Pérez Gollán, 1986). In this respect, it is necessary to note the discovery from stratigraphic contexts of cebil seeds at the site (Fig. 3B, top). The importance of ritual practice at the site is not only highlighted by the cebil and the various rock-art iconographic motifs, but also due to the feathers found in secure stratigraphic contexts (Fig. 3C and D). These feathers are from two parrot species (*Amazona aestiva* and *Primolius auricollis*), and a bird of prey (*Buteo magnirostris*). All these birds are native to the lowlands, located 300 km distant. Flamingo

Fig. 4. Ceremonial structure with stairs located outside the entrance of Cueva Inca Viejo. A) View of the ceremonial structure prior to complete removal of the loose rocks that hidden it. B) View of complete ceremonial structure: 1. Wall, 2. Platform, 3. Ramp, 4. Staircase, 5. Entrance of the cave (situated behind the wall). C) Detail of the wall (1) and the platform (2). D) Detail of the staircase.

(*Phoenicopterus* sp.) feathers were also found, these birds frequent the nearby *puna* salt-flats. Most of the feathers were found together and, some of them, were braided (Fig. 3D). In one case, the feathers were jumbled together with a series of camelid bones, and wrapped in a straw packet; this was interpreted as a ritual offering (López et al., 2015). Other ritual practice indicators were the adhesion on the cave walls of semi-digested plant matter from the stomach of the camelids; this is known as a "pusno" by the locals (Fig. 3E).

Among the allochthonous elements present at the site were other foreign seeds and fruits such as chilli (*Capsicum* sp. aff. *Chacoense)*, carob (*Prosopis* spp.), chañar (*Geofroea* sp. *decorticans/spinosa)*, squash (*Lagenaria siceraria)*, beans (*Phaseolus vulgaris)*, pumpkin (*Curcurbita* sp.) and corn cobs (*Zea mays)* (Fig. 3B, bottom). These resources came from the meso-thermal valleys, at a distance of ca. 100 km. Carob seeds have signs of having been processed for the preparation of beverages such as the *aloja* (alcoholic drink) and the *añapa* (Araya, 2017). The use of these beverages is documented in Andean ritual contexts (Capparelli et al., 2015; Lema and Capparelli, 2012). Araya (2017) proposed that drinks made from the carob were used in feasts or ritual ceremonies in Cueva Inca Viejo.

In summary, Cueva Inca Viejo has archaeological evidence for macro-regional processes of interaction and ritual practices. Proof of llama caravans, used in transporting cargo and for exchange of goods from distant places, can be seen in the rock-art, as well as in the existence of ropes, possibly used to tie up animals. On the other hand, ritual was evident seen in such indicators as: the ceremonial structure with stairs, the presence of seeds linked with ceremonies, the offerings of straw with feathers and camelid bones, the pusno, among others. This evidence would not be complete without the many indicators of Prehispanic turquoise mining, a mineral frequently used in ritual contexts. First of all, to understand this issue it is essential to determine the presence of turquoise not only in the cave's rock wall but also in the archaeological layers. Moreover, any interpretation about the mining in the site requires proof of turquoise exploitation, which comes from the application of analytical techniques for its physic-chemical determination and other indicators. For this reason, in the following sections we will focus in this issue. Finally, we discuss the role of Cueva Inca Viejo considering three aspects linked along the Andes: mining, social interaction and ritual practices.

Table 1
Some physical properties of turquoise. Taken from http://www.hudsonmineralogy.org and http://webmineral.com/data/Turquoise.

Chemical classification	Phosphate
Series Turquoise – Chalcosiderite	$CuAl_6(PO_4)_4(OH)_8$. $4H_2O$ (turquoise) – $CuFe_6^{3+}(PO_4)_4(OH)_8\cdot 4H_2O$ (chalcosiderite)
Series Turquoise – Planerite	$CuAl_6(PO_4)_4(OH)_8$. $4H_2O$ (turquoise) – $Al_6(PO_4)_2(HPO_4)_2(OH)_8\cdot 4\ H_2O$ (planerite)
Crystal system	Triclinic - Pinacoidal. Cryptocrystalline. Minute crystals are known to occur, but they are rare.
Habit	Massive - Uniformly indistinguishable crystals forming large masses.
Luster	Subvitreous in crystals, resinous, dull to waxy in massive varieties, earthy.
Diaphaneity (Transparency)	Transparent, translucent and opaque.
Colour	Bright blue, sky-blue, pale green, blue-green, turquoise-blue, apple-green, green-grey.
Colour variation	Ferric iron substitution may cause the colour to be green.
Streak	Pale greenish blue to white.
Hardness (Mohs)	5–6
Tenacity	Brittle
Fracture	Irregular/uneven, sub-conchoidal.

Table 2
Sample, sample provenance, and analytical techniques applied.

Sample	Description	Provenance	Petrographic analysis	Physical and chemical techniques	
				EDS	XRD
M1a	Blue turquoise colour mineral	Wall rock inside cave	x	x	
M1b	Turquoise colour mineral	Mineral filling a wall rock fissure		x	x
M2	Turquoise colour mineral	Test pit 9 - Layer B		x	x
M3	Turquoise colour mineral	Test pit 9 - Layer B		x	x
M4	Turquoise colour mineral and wall rock	Test pit 2 - Layer A		x	
M5	Green colour mineral and wall rock	Test pit 8 - Layer B		x	
M6	Green colour mineral and wall rock	Test pit 8 - Layer B		x	
M7	Dark green colour mineral	Test pit 11 - Layer B		x	x
M8	Dacite	Wall Rock (idem M1a)	x	x	

2.3. The greenish blue mineral

Turquoise is the best known of the copper hydroxyphosphates. Its chemical formula is: $CuAl_6(PO_4)_4(OH)_8{\cdot}4H_2O$, although this varies widely. It is rare and valuable in finer grades and has been appreciated as a *gem* and ornamental stone for thousands of years owing to its unique hues of blue, blue-green, and yellow-green. It is a secondary mineral formed in the potassic alteration zone of hydrothermal porphyry copper deposits. Turquoise is found as thin veins and nodules in fissures and cavities. The formation of turquoise, besides copper, requires relatively high concentrations of Al^{3+} (or Fe^{3+}) and $PO_4{}^{3-}$. It is therefore, usually formed by the action of surface (meteoric) waters in arid regions, on aluminous igneous or sedimentary rocks. Natural turquoise invariably consists of components along the turquoise-chalcosiderite solid solution series (Table 1). The turquoise group has the general formula: $(AB)_7(XO_4)_4Z_q{\cdot}xH_2O$. In the crystal structure, the divalent cations Cu, Fe^{2+} and Zn may be present in the *A-site* occupancy, and the trivalent cations Al, Fe^{3+} and Cr^{3+} in the *B-site* occupancy. Its molecular structure also permits the inclusion of calcium (Ca), magnesium (Mg), manganese (Mn), silicon (Si) and zinc (Zn). As with iron, these additional elements, when incorporated in the molecular structure of turquoise, influence its colour and hardness. So, colour is variable, ranging from white to a bright blue, and from blue-green to a yellowish green. The blue colour is attributed to idiochromatic[1] copper, while the green colour may be the result of either iron impurities (replacing aluminium), or dehydration (water content also modifies the blue colour). Turquoise often contains embedded shiny pyrite flakes or black oxide veins running through it, and appears sometimes as intergrown crystals together with other secondary copper materials, especially chrysocolla (Abdu et al., 2011; Brodtkorb, 2006; Foord and Taggart, 1998; Mineral Data Publishing, 2000, Posner et al., 1984; http://www.minerals.net/mineral/turquoise.aspx).

2.4. Analytical methods

The petrographic characterization of the wall rock was performed with a Leica DM750P polarizing microscope. The turquoise colour minerals scattered in the wall rock, or filling fissures, and the turquoise to green fragments found in layers were analysed by Energy Dispersive X-Ray Spectrometry (EDS) in a Philips 515 Scanning Electron Microscope (SEM) with EDAX system. Based on these EDS results, four samples were selected for further analysis by X-Ray Diffraction (XRD) with Philips X'PERT MPD equipment provided with a Cu X-Ray tube (Table 2).

2.5. Other archaeological indicators

In parallel, the varied archaeological indicators of mining activity at the site were studied, as were the stone hammers, one of which was recovered from a stratigraphically secure context. These stone hammers are one of the more reliable signs for Prehispanic mining (Figueroa et al., 2013; Salazar and Vilches, 2014). Therefore, a thorough description of these tools was necessary for understanding the techniques employed in the exploitation of minerals such as turquoise during the Prehispanic Period. Likewise, other archaeological materials uncovered at the Cueva Inca Viejo site were described, such as the leather strips, possibly used to fix the handle to the hammer. Alongside, there were other indications of mining, such as pick-marks on the cave walls, and the mining pits found nearby.

3. Results

3.1. The cave wall rock with turquoise mineral

M1a sample is a thin section of the dacite rock from the interior of the cave. It has isolated microcrystalline aggregates ($<$ 1,5 mm) of blue turquoise mineral which infills small holes and interstices within the rock (Fig. 5).

This grey rock is a porphyric dacite (or dacitic porphyry) composed of euhedral and subhedral plagioclase phenocrysts, embayment quartz and dark mica (possibly, biotite); as well as low quantity of uncoloured mica and subordinated and denaturalised amphibole. All these components are included in a fine-grained quartz-feldespate groundmass. The most representative phenocrysts are phantoms of skeletal plagioclase crystals with patches and non-oriented relicts of the same mineral. The rock also contains iron oxides, granitic xenoliths, and others with vitreous-cryptocrystalline matrix that includes tiny biotite crystals, iron oxides and opaque minerals (n/d = not determined).

This petrographic description of the wall rock – porphyric dacite– is in keeping with the information given in 1980 by Cécere (in Chabert, 1999: 1431). According to this researcher, "*The rock is compact and has porphyric texture*; *it has a grey-coloured aphanitic paste and phenocrystals*, *of between 3 and 5 mm in diameter of quartz, plagioclase and biotite, presenting few compositional or textural variations*." (The translation is ours). Furthermore, and based on field survey, Chabert (1999) states that it is a biotitic dacitic porphyry, that is intercut by veins and fissures infilled by quartz, with considerable remains of fully oxidised sulphides, and a large quantity of limonite[2].

[1] Idiochromatic: Colour produced by a specific element – chromophore – that is essential to mineral composition, e.g. pink rhodocrosite due to Mn.

[2] Limonite: an iron ore consisting of a mixture of iron (III) oxide-hydroxide in varying composition.

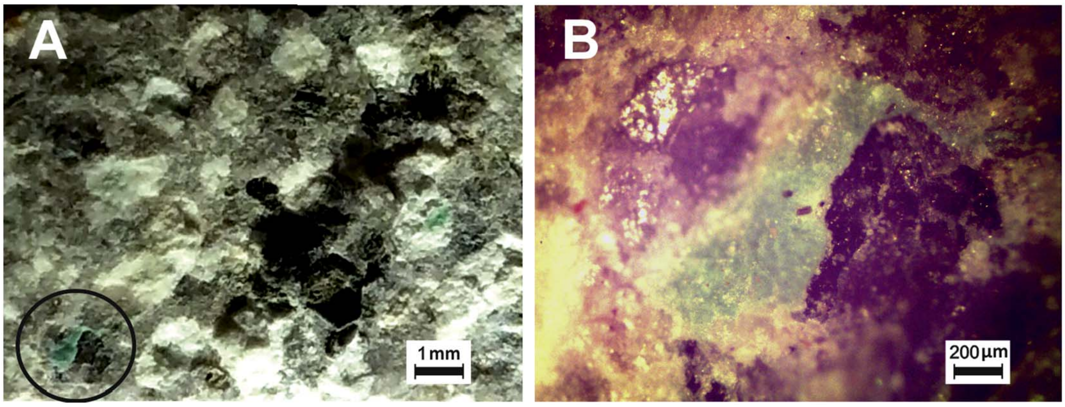

Fig. 5. A) Turquoise in the dacite (M1a). B) Detail under stereoscopic microscope (50 ×).

Table 3
EDS elemental quantification (wt%).

Sample	Element												
	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu
M1a	–	–	22.56	24.57	12.70	0.88	–	4.74	3.59	0.94	–	11.65	19.68
M1b	–	1.55	27.50	29.27	14.75	1.94	–	3.51	1.40	1.11	–	12.14	6.84
M2	–	–	28.08	29.17	20.24	–	–	1.86	3.46	–	–	6.96	10.20
M3	–	–	29.92	6.85	28.02	0.50	0.60	1.66	6.65	–	–	8.27	18.47
M4	–	–	17.40	21.28	15.86	0.95	0.50	3.13	14.78	–	–	14.96	11.15
M5	–	–	38.30	3.63	37.71	–	–	–	1.74	–	–	5.50	13.13
M6	–	–	27.28	17.89	26.93	–	–	2.03	2.60	–	–	10.85	12.50
M7	–	–	2.57	15.26	5.21	1.90	0.92	0.45	9.59	–	4.00	0.68	60.12
M8	1.08	1.46	29.86	57.11	–	–	–	1.23	1.98	0.30	–	6.99	–

3.2. Elemental composition of turquoise minerals

Samples listed in Table 2 were analysed by SEM-EDS technique; the calculated compositions of light blue turquoise minerals in wall rock sample M1a, in material filling the fissures M1b, and in fragments of turquoise and green colour minerals found in layer, M2, M3, M4, M5, M6 and M7, are shown in Table 3. Cave rock itself was as well analysed (M8).

The results in Table 3 for samples M1 to M6 show high levels of Cu and P, compatible with the dominant presence of copper phosphate; as Al is also a major element, we can assume the probable presence of turquoise mineral; meanwhile M7, with extremely high values of Cu but low P, could have a significant lower proportion of this compound or even lack of it.

Table 4 shows compositions expressed taking into account only the characteristic elements of turquoise mineral: Al, P and Cu. A high concordance is observed across samples M1 to M6 with stoichiometric composition of turquoise mineral; possible substitutions of trivalent Al and Fe, and divalent Cu, Fe and Zn should be considered, as well as inclusions of other elements, as it was previously said. General composition of these samples, with variable contents of Si, Ca and Fe also indicate the presence of wall rock or other/others mineral/s associated with the predominant turquoise. Sample M7 shows a much higher Cu percentage than the rest of the samples; relatively low values of Al, Fe, P and Si, and high Mn. These data suggest the presence of another Cu and/or Mn mineral beside the assumed turquoise.

Despite EDS results for dacite, the wall rock of the cave shows high content of Al and low content of Si with respect to an average dacite composition. It should be noted that the wall rock was extracted from the cave, located in the biotitization zone of the dacite porphyric body which, in addition, presents superimposed clay alteration. As a consequence, values in Table 3 represent the composition of the dacite modified by hydrothermal alteration in Mount Inca Viejo.

Table 4
Comparison with stoichiometric turquoise.

Sample	Element		
	Al	P	Cu
M1a	41,0	23,0	36,0
M1b	56.2	30.1	14.0
M2	48.4	34.4	17.5
M3	39.2	36.7	24.1
M4	39.2	35.7	25.2
M5	42.9	42.2	14.7
M6	40.9	40.4	18.7
M7	3.8	7.7	88.4
Stoichiometric turquoise	44.2	33.8	17.2

Table 5
XRD results.

Sample	Minerals (XRD)		
	Major minerals	Minor minerals	Accessory minerals
M1b	Turquoise	Woodhouseite	Quartz Mica (Phogopite?) Feldspar (Sanidine?)
M2	Turquoise		Quartz
M3	Turquoise		
M7	Pseudomalachite	Apatite	Quartz Amorphous material

3.3. Mineral composition of the turquoise specimens

The X-Ray Diffraction results undertaken on the sample M1b, scrapped from a fissure in-fill of the cave's wall rock, indicate turquoise mineral in association with another hydrous alumino-phosphate-

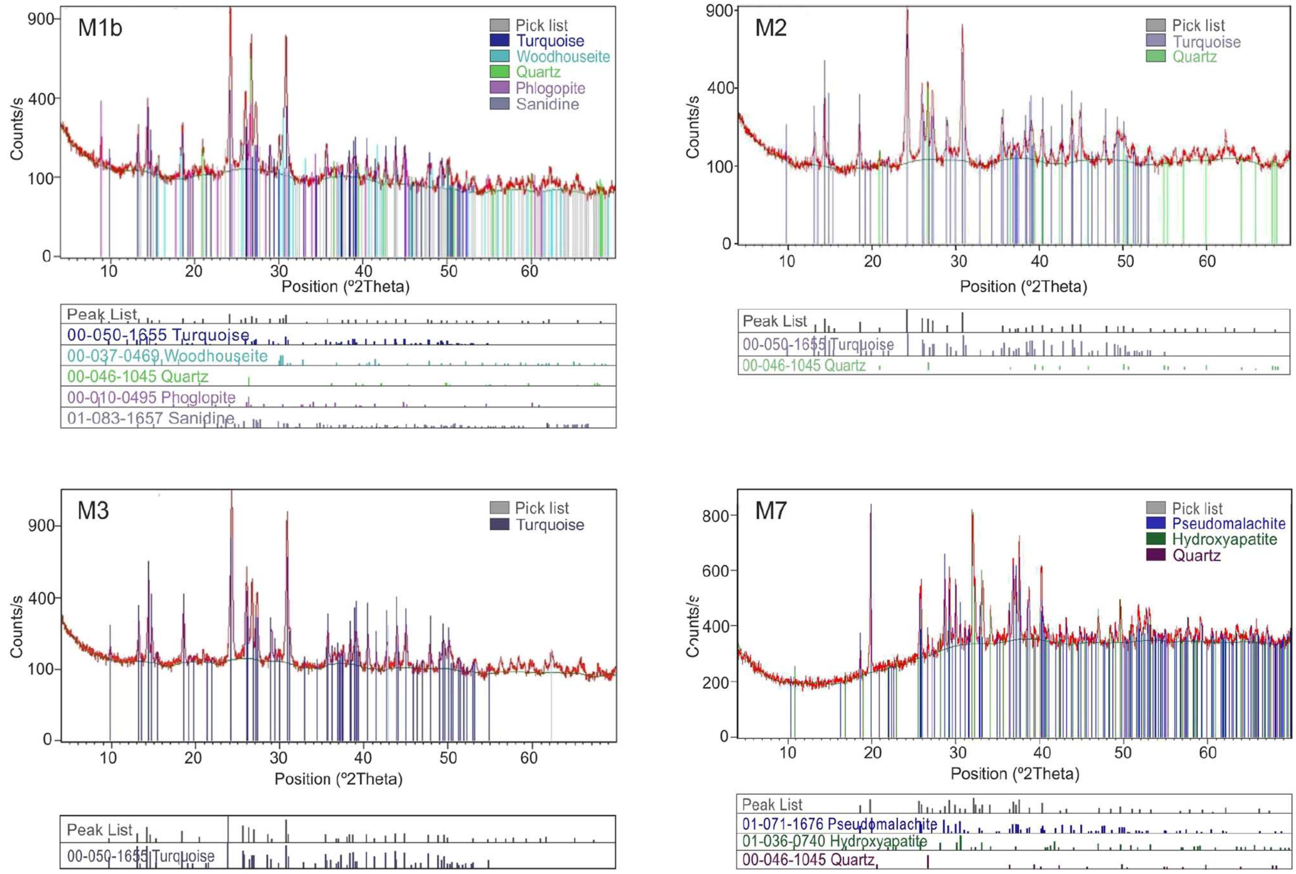

Fig. 6. Diffraction patterns: A) Turquoise filling mineral in wall rock fissure (M1b). B) Turquoise fragment (M2, layer B). C) Turquoise fragment (M3, layer B). D) Pseudomalachite fragment (M7, layer B). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

sulphate mineral, woodhouseite, and a minor quantity of quartz, mica (possibly phlogopite) and feldspar (possibly sanidine). Samples M2 and M3 have the characteristic diffractogram of turquoise. Finally, sample M7 has a more complex composition, although no turquoise was present; it includes pseudomalachite (copper phosphate hydroxide), apatite, quartz and amorphous material (Table 5, Fig. 6).

The rare woodhouseite $[CaAl_3(PO_4)(SO_4)(OH)_6]$ is a secondary mineral of pseudocubic rhombohedric habit (white, rose or colourless) formed during early diagenesis because of the flux in meteoric water below the water table. Woodhouseite derives from the oxidation of very early diagenetic pyrite, and phosphate from the dissolution of apatite; it is detected in zones of sulphuric acid leaching in porphyry copper deposits (Komov et al., 1994). It is a difficult mineral to classify because it has both a phosphate anion group and a sulphate anion group; nevertheless, woodhouseite is included in the Phosphate Class of minerals.

The low quantities of quartz, mica (possibly phlogopite) and feldspar (possibly sanidine) in sample M1b is in part due to the minerals that constitute the dacite rock, which were also sampled when extracting the sample of turquoise mineral. These results complete the petrographic analysis, given that sanidine [(K,Na)(Si,Al)4O8], a high temperature sodio-potassic feldspar (commonly found in acidic and intermediate vulcanites), could be the feldspar (n/d) of the mesostasis of the dacitic rock.

Likewise, the phlogopite mica $[KMg_3AlSi_3O_{10}(OH)_2]$, identified using XRD, could be the dark mica observed in thin-section; it should be noted that the biotite (MgFe) - phlogopite (Mg) series is a solid solution that makes identification of these minerals difficult. In samples M2 and M3, turquoise is the major mineral, this tally well with the EDS data.

Hydrous copper phosphate pseudomalachite $[Cu_5(PO_4)_2(OH)_4 \cdot H_2O]$ is a dark green mineral, resembling malachite. It is also a secondary mineral found in oxidised zones of copper ore deposits. In M7 (layer B), the presence of this copper phosphate, together with apatite and quartz, is consistent with the EDS analysis (high Cu, Ca and Si). The "amorphous material" detected by XRD in the same sample could be related to the presence of manganese oxhydroxides (amorphous or cryptocrystalline), as indicated by the Mn content. Furthermore, we do not rule out the presence of chrysocolla – for the silicon percentage detected (see Table 3) –, which usually appears as cryptocrystalline to amorphous mineral (Table 5).

3.4. Description of the archaeological evidence associated to mining activities

Aside from the analysed samples of turquoise, other possible fragments of this mineral were uncovered within the different excavated test-pits (Fig. 7). In some cases, these were associated in-layer with other materials such as feathers, seeds and fruits, linked to ritual practices.

In total, 67 fragments of turquoise colour minerals were recovered from archaeological layers, including a fragment of bead pre-form (Fig. 7B). The fragment's measurements vary between 3 and 35 mm in length, with widths of between 3 and 28 mm, and a thickness of between 1 and 18 mm. In general, these materials have vetiform structures with wall rock relicts. This allowed us to relate the fragments found in archaeo-sedimentary contexts to the mining practices undertaken at Cueva Inca Viejo in Prehispanic times. In this regard, the only date from the site was 860 ± 60 years BP – a Late Prehispanic context – which was obtained from bones of camelids recovered from one of the test-pits layers that included turquoise. Up to now, we have not been able to determine the presence of different archaeological components in the sediment layers distinguished during excavation (A and B). In fact, the turquoise fragments and other archaeological materials linked

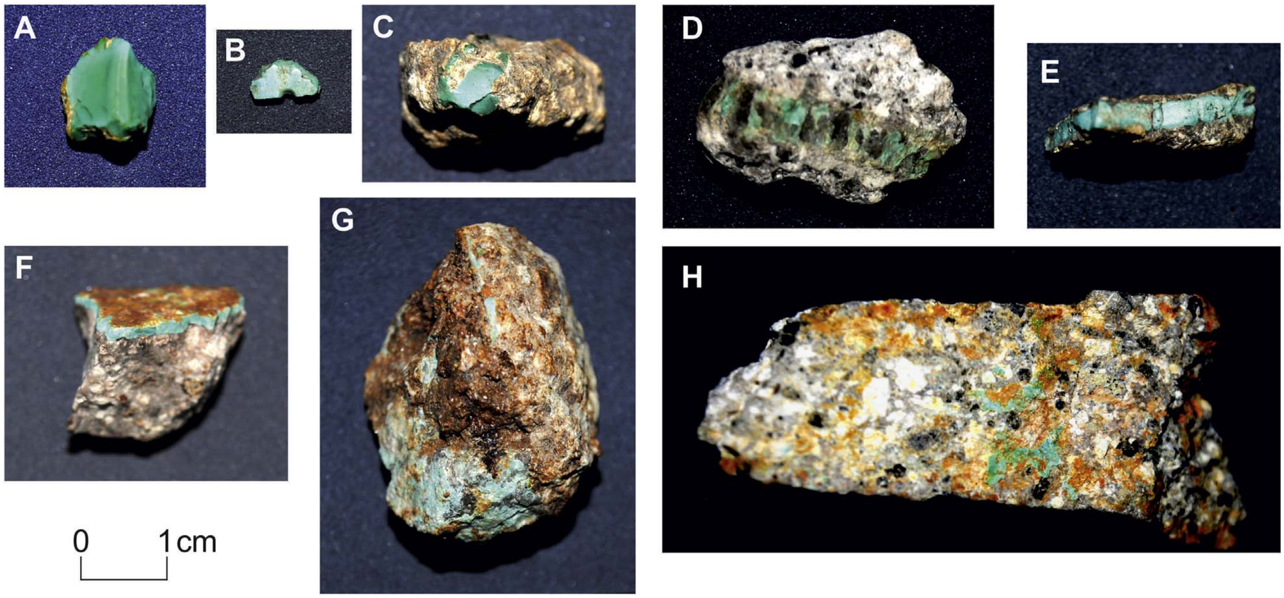

Fig. 7. Fragments of turquoise colour minerals recovered from test-pits within Cueva Inca Viejo (A, C–G). B) Fragment of bead pre-form. H) Cave wall rock.

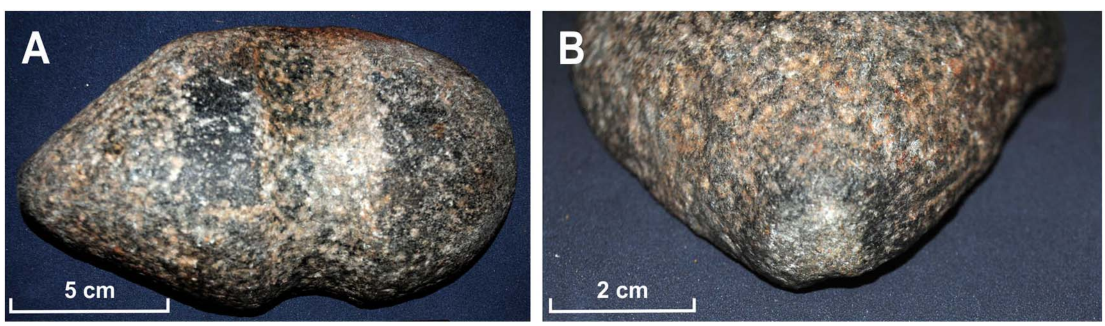

Fig. 8. Stone hammer. A. General view of hammer. B. Detail of point of percussion.

to ritual practices were found in both layers. Nevertheless, there is archaeological evidence for earlier human occupation (e.g. some of the motifs in the rock-art such as the "sacrificer or lord of the jaguars and camelids"), as well as for a later one, for example, an Inca aribalo neck (for more details see López et al., 2015). Chronological variations aside, all the data from the test-pits confirm that they belonged to Prehispanic occupations.

The discovery of a lithic hammer in an archaeological layer at Cueva Inca Viejo, in association with turquoise fragments and other objects, is crucial evidence for Prehispanic mining activity (Fig. 8). The hammer is 151 mm long and 89 mm wide, its ovoid form converges into a conical shape towards the point of percussion. At its central point, the hammer has an abrasion groove of 33 mm in width, probably due to hafting (Fig. 8A). The artefact is fragmented longitudinally, a break that possibly occurred during use. The point of percussion is characterised by a flat impact surface, which is relatively circular in section, with a diameter of 13 mm (Fig. 8B). Likewise, there are other traces of impact such as striation and marks due to use. We infer that the raw material of this hammer is the local granitic rock (Paleozoic granodiorites and granites).

In the interior, and external to the mouth of the cave, at least five (5) others, less well made, hammer fragments were found. All of them had groove and hafting marks. We also found three fragments that could have been used as an anvil, given that they had a well-worn flat surface.

Other archaeological materials associated to the hammers were leather fragments that could have been used in the hafting (Fig. 9A and B). These braided leather strips were uncovered in one of the test-pits. In Northern Chile, hammers tied with leather strips have been found in situ (Figueroa et al., 2013). These constitute compelling comparative evidence for the leather fragments found at Cueva Inca Viejo. Some leather strips from the cave have camelid fibre remains and tied human hair (Fig. 9A). This reinforces the relation between mining and ritual practices.

Likewise, mining activity in the cave is further supported by the galleries whose walls have evidence of picket marks. Also, near the cave there are several circular pits, related to mining probes. Yet, in these pits we cannot confirm a Prehispanic chronology, even though its proximity to Cueva Inca Viejo would suggest that were in use from the Prehispanic Period through to modern times.

4. Discussion and conclusion

The physico-chemical studies undertaken during this research have been crucial in determining the turquoise mineral in the cave wall rock as fissure-fill and as veinlets in the same rock. Likewise the light-blue to greenish blue mineral fragments uncovered in the archaeological sediments of the site have been identified as turquoise. The geological background of the Inca Viejo Cu-Au deposit has the following general mineral association: azurite/malachite, biotite, chalcocite, chalcopyrite, chrysocolla, goethite/limonite, gold, hematite, jarosite, malachite, molybdenite, pyrite, sericite, tourmaline and turquoise (Singer et al., 2008). The mineral paragenesis found in the oxide zone of this porphyry copper deposit includes turquoise as a secondary mineral. So, the turquoise formed in the biotitization zone (equivalent, in this subvolcanic body, to a weak potassium zone with an overlap of clayey

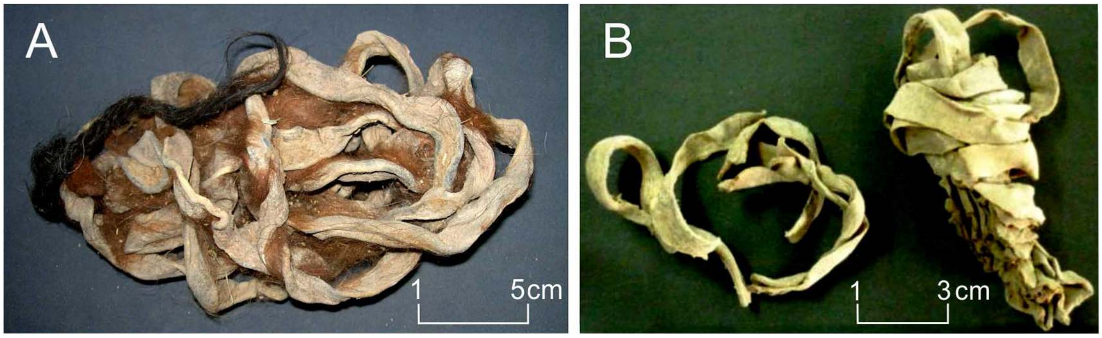

Fig. 9. Braided leather strips from Cueva Inca Viejo. A) Braided leather strips with camelid fibre remains and human hair tied (left), B) Leather strips, single and braided.

alteration), just where the cave is located, and the archaeological evidence suggest that, at least, an important part of the mineral was extracted from the Cueva Inca Viejo.

In the Argentine puna, and within moderate distance of Mount Inca Viejo, there are other sources of porphyry copper with both copper and iron mineralization that contain turquoise (among other minerals). For example, Alto de Soncaiman (Jujuy) located 115 km North of Inca Viejo, Las Burras Copper-gold Porphyry (Salta) at 130 km in a NNE direction, and Diane Mine (La Poma, Salta) located 70 km NE; and at 700 km outside of the Puna, this mineral has been found in the Cerro Blanco Pegmatite District (Tanti, Córdoba) (Godeas et al., 1999; Quiroga and Ruíz, 1994; Schalamuk, 1970; Singer et al., 2008). Nevertheless, none of these have evidence for the systematic exploitation of turquoise during the Prehispanic Period. It is in this remit, that Mount Inca Viejo acquires relevance and significance, essentially in its role as a source of turquoise for the puna and meso-thermal valleys. Likewise, we have here the first mention of turquoise-woodhouseite paragenesis in veinlets of the Inca Viejo Porphyry copper. Woodhouseite, a rare mineral with no value as a *gem*, has also been detected in veinlets of the Agua Rica polymetallic deposit (Catamarca) (Franchini et al., 2011), located 250 km South of Inca Viejo; nevertheless, the Agua Rica paragenesis does not include turquoise, as is the case with the material obtained from the Cueva Inca Viejo rock (M1b).

The existence of turquoise, both in the cave wall rock and within Prehispanic archaeological contexts, links in well with other indicators of mining, such as lithic hammers. This data is strong evidence for Prehispanic mining in the NOA. Similarly, the discovery of a turquoise mining site in the region is also important in the discussion about the provenance for turquoise beads recovered in different sites of the NOA. As mentioned at the beginning, until now, turquoise found on archaeological sites in the NOA was assumed coming from Northern Chile. Even if this was true for many cases, the discovery of the first source with evidence for turquoise exploitation in the NOA itself raises interesting questions for this discussion.

Another important topic relates to Inca presence in the area. Scholars have suggested Inca expansion from Cuzco to the Southern Andes was primarily for the extraction of minerals (e.g. Raffino, 1978). Until now, aside from Cueva Inca Viejo, only Abra de Minas has evidence of Inca occupation around the Salar de Ratones (López and Coloca, 2015). The large size of the Abra de Minas settlement, a site located at 4250 m asl, is primarily explained by the presence of the Cueva Inca Viejo mine. Moreover, we propose that turquoise mining was the main reason behind Inca expansion in the area. This hypothesis is based on the high degree of modification at both sites undertaken by the Incas. Turquoise was an ornamental mineral much prized by Inca elites, therefore a source of this mineral in the Ratones Basin would have been of great importance to them. In this respect, it is relevant to note that turquoise sources are also rare in Peru, the core of the Inca Empire (Stöllner et al., 2013). This was probably a motivating factor in the Incas interest for extracting this mineral from the Southern Andes. Nevertheless, it is possible that future research in Peru might reveal new information concerning Prehispanic turquoise mines. Similarly, prior to this study, there was no evidence for the turquoise mining in Northern Argentina.

Other subject relative to mining in Mount Inca Viejo is linked to Prehispanic gold extraction. The geologist M. Chabert (1999), based on the 1990 mining survey of porphyry copper, mentioned quartz veins with free gold in the Inca Viejo Formation. Up to now, we have no evidence for Prehispanic mining of this noble metal from the cave, yet this is another topic for future study.

This cave would have played an important role in the movement and circulation of information, goods and resources from the Late pre-Inca Period, and possibly from even earlier periods. In this remit, it is important to highlight the rock-art with llama caravan motifs and the different archaeological material found within the cave that supports the existence of macro-regional contacts. This evidence, together with other indicators, also suggests that the site was used for ritual activities. The ritual relationship between caravans and mountain passes has been documented ethnographically in Southern Bolivia (Nielsen, 1997–1998). At these sites, the caravan pastoralists left ritual offerings, and also overnighted. In the case of Cueva Inca Viejo, the importance of the turquoise as a precious stone would have contributed value to this site as a place of high symbolic significance, materialised through ritual practices.

Mountains and high passes, such as the location of Cueva Inca Viejo site, have traditionally been considered "*huacas*" by Andean people. Among other interpretations, *huacas* is a generic term for sacred places. The sacred nature of the site would have lent itself to a symbolic appropriation of it by the Incas, similar to what was done at other places throughout the NOA (Williams et al., 2005). During the pre-Inca occupation of the area, this site also had ritual importance. However, the Incas magnified this connotation. In this regard, the presence of a ceremonial structure with staircase, platform and wall at the entrance of the cave is the strongest evidence for the sacred significance and the ritual practices undertaken at this place by the Incas.

Evidence for that appropriation can also be seen in the intensity of building undertaken at Abra de Minas, in the discovery of an Inca aribalo neck within the Cueva Inca Viejo site (a ceramic form associated to feasts and ritual practices), and in the construction of a clearly demarcated path with double walls towards the cave. These characteristics show high labour investment in the area, reinforcing the importance of this place for the Incas. Specifically, Salazar et al. (2013) highlight Inca State control over rituals associated to mining *huacas*, and the installation of state sites on nearby places. This would have been the case between Abra de Minas and Cueva Inca Viejo.

In conclusion, Cueva Inca Viejo has the first evidence for Prehispanic mining of turquoise from North-western Argentina, while at the same time it presents new data towards understanding the process of circulation of ideas, resources and goods in this Andean region. Similarly, it allows us to understand the interaction between the economic and symbolic dimensions, referred to as *rituals of production* (Martel, 2011; Van Kessel, 1989). The sacralisation, or symbolic domination of this place, would have been an important factor in its economic exploitation and mining, especially during Inca expansion. As a consequence, we propose that there was a narrow relationship between Prehispanic mining, ritual and caravanning linked to macro-regional interaction. The interconnectedness of these three issues was crucial in understanding the importance of this site for the pre-Inca, and especially for the Inca Period.

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