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Geoarchaeological reconstruction of the Caverna de las Brujas (Mendoza, Argentina) for the planning of an archaeological intervention

José Luis Peña-Monné [a,*], Carlos Sancho-Marcén [b], Víctor Durán [c], Raúl Mikkan [d]

[a] Departamento de Geografía y Ordenación del Territorio, Universidad de Zaragoza, Pedro Cerbuna, 12, 50009 Zaragoza, Spain
[b] Departamento de Ciencias de la Tierra, Universidad de Zaragoza, 50009 Zaragoza, Spain
[c] CEIDER-CONICET, Arqueología, Universidad Nacional de Cuyo, 5500 Mendoza, Argentina
[d] Departamento de Geografía, Universidad Nacional de Cuyo, 5500 Mendoza, Argentina

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ABSTRACT

Archaeological prospection and excavation in the Caverna de las Brujas (southern part of the province of Mendoza, Argentina) has offered the first known data on human presence in this cave. This is of great interest for understanding the evolution of peopling in the southern Mendoza province during the Holocene. Four archaeological pits were excavated, two in the gallery known as the Sala de la Virgen and another two near the cave entrance. Three volcanic ash levels were dated by TL techniques (7780 ± 600, 4700 ± 500; 765 ± 200 years) and a level with enough organic material was dated by ^{14}C analysis (3695 ± 65 years BP). The available data is sufficient to establish the origin and make a geomorphological reconstruction of the Holocene levels. At the same time, a hypothetical model is proposed that uses geomorphological criteria to predict the stratigraphy of the unexcavated lower levels at the cave entrance. The aim of this model is to help direct future archaeological excavations of the cave's oldest deposits.

1. Introduction

The karstic area of the Caverna de Las Brujas (The Witches' Cave) lies in the limestone reliefs of Bardas Blancas, to the south of Malargüe, Mendoza Province, Argentina (35° 48′ 02.3″ S: 69°49′ 13.7″ W). It is part of the Andean mountain range with heights of between 1500 m a.s.l. (Río Grande) and 2517 m a.s.l. (Pico Moncol) and it is also part the tributary network of the Río Grande (Fig. 1A). The Caverna de las Brujas belongs to a protected area (Monumento Natural Caverna de las Brujas) and is only partially open to visitors. Geological, geomorphological, and archaeological studies have been made in this region, and there is a considerable body of data concerning the Quaternary evolution (Mikkan et al., 2001).

Archaeological studies in this region have shown a lack of information for the time gap that spans from 7000 to 4000 BP. This data void has been related to an increase in aridity (Gil, 2000; Neme and Gil, 2001; Gil and Neme, 2002); an increase in volcanic activity (Durán, 1997); or just the unfortunate circumstance that no sites preserving information on this period have yet been found by researchers (Durán and Altamira, 2001). Therefore one of the most interesting aspects in the current study of the Caverna de las Brujas is the opportunity to recover archaeological remains to complete our data and understanding of human presence in Malargüe area during the Middle Holocene.

2. Objectives and methodology

One of the objectives of this study is to establish a reconstructive model of Holocene evolution at the Caverna de las Brujas. With this aim in mind, since 1997 several surveying, cartographic, and sampling seasons have been conducted for a regional geomorphological study.

Another objective concerns the archaeological aspects of the cave and its context. The discovery of knapped obsidian and opal remains in the cave surroundings led to the planning of excavations to complete the regional archaeological information. The specific objectives are to establish the occupation time of the karst cave and determine the origin of the raw materials used for the lithic tools.

Four pits were dug in the cave to obtain stratigraphical data suitable for establishing a sequence of tephra layers, as well as levels containing archaeological material. Tephra layers were dated using TL techniques, and a complementary date was acquired from a ^{14}C sample. The interpretation of this data enables us to create a general evolutionary model of the filling processes and chronological stages for the entry area of the Caverna de las Brujas. This

* Corresponding author.
E-mail address: jlpena@unizar.es (J.L. Peña-Monné).

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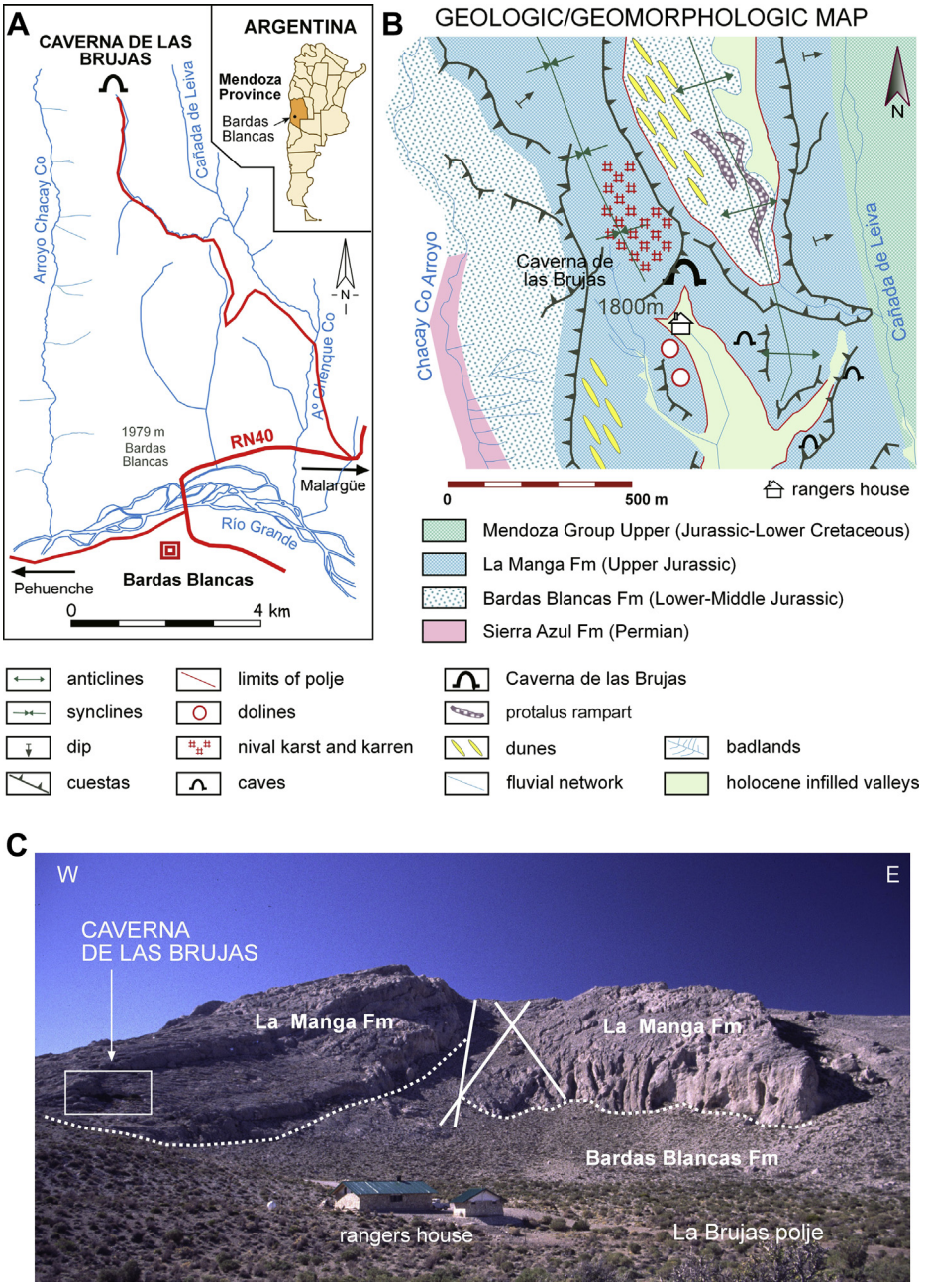

Fig. 1. A. Situation map of the Caverna de las Brujas in the Bardas Blancas region. B. Geologic/geomorphological map of the Caverna de las Brujas sector. C. Geological schema of Las Brujas karst region. White lines correspond to faults; white discontinuous lines correspond to the contact between two geological formations.

evolutionary model can be related to other sites in the Río Grande basin (Durán, 1997, 2000).

The final objective is to develop a hypothetical reconstructive model of the lower and more ancient part of the sedimentary sequence – which has not been yet reached by excavations. It is thought that these untouched levels could reach 7000 BP. The above mentioned data and evolutionary model were analyzed using geomorphological criteria: reconstruction of the ancient shape and dimensions of the cave entrance, estimation of the original position of the fallen blocks at the cave entrance, and a correlation of stratigraphic sequences. This hypothetical reconstructive model will help plan further interventions in the cave with the aim of finding archaeological data in the untouched sediments and filling the informational void of the Middle Holocene.

3. The geological and geomorphological features

From a geological point of view, this region is located in the northernmost sector of the Neuquén Basin. It is mainly composed of Jurassic and Cretaceous formations (Dessanti, 1973; Raviolo, 2000) which are laid on a Permian volcanic substratum (Sierra Azul Fm). The Lías-Dogger is made up of grey-yellowish sandstone and micro-conglomerates (Bardas Blancas Fm). The Malm is composed of grey limestone (La Manga Fm) where the main karstification is generated (Fig. 1B and C). The pulsations of Andean tectonics, from Upper Cretaceous to Pliocene, have generated fold and fault structures from north to south (Ramos, 1999).

In the carbonate formations, large structural paleopoljes, dolines, and nival karren (Mikkan, 1995; Peña-Monné et al., 2001) are found,

as well as karst cavities, among which the Caverna de las Brujas stands out (Fig. 1B and C). Several periglacial protalus rampart stages remaining in the slopes of the valleys are a testimony to the cold Pleistocene phases. Finally, there are dunes, mainly climbing dunes on the slopes, which result from the aeolian transport of volcanic ashes from recent Andean eruptions (Peña-Monné et al., 2001). There are some precedent studies of the morphostratigraphic, mineralogical, and chronological characteristics of the speleothemic deposits in the internal gallery network of the Caverna de las Brujas (Siegel et al., 1968; Forti et al., 1993), but further research has been done in this direction to improve the understanding of these topics. The most important speleothemic development period took place between 67,000 and 34,000 BP, during a wetter and warmer stage (Peña-Monné and Sancho, 2001; Sancho et al., 2002, 2004). The current climate is semiarid, with an annual average rainfall of 300 mm and an annual average temperature of 11.9 °C, and a strong temperature fluctuation (around 24 C°) (Mikkan and Alessandro, 1998). The combination of these climate characteristics and the hanging position of the cave above the present drainage level ensure that hydrological and speleothem activities are very limited. Moreover, in this climatic environment, soil development and vegetation are scarce, except in some valley bottoms. Erosion processes are therefore intense on the slopes; these circumstances are even more accentuated on limestone, which is almost always exposed.

4. Results

The gallery network of the Caverna de las Brujas is vast and comprises several levels due to the deepening of karstification during the Quaternary. Its course is aligned with the geological fractures. A small part of this complex network, between 1800 and 1850 m a.s.l., is suitable for public visits (Fig. 2A). The Sala de la Virgen (the hall of the Virgin Mary) is approximately 50 m from the entrance and stands out among the other rooms of the cave because of its dimensions.

The information on the Holocene evolution of the cave relies on data obtained in the archaeological excavations and the volcanic tephra levels. Between 1997 and 2002 four archaeological seasons were carried out in the Caverna de las Brujas (Peña-Monné et al., 2003). Four exploratory pits were dug: two of them (pits 1 and 2) in the interior of the cave (Sala de la Virgen) and the other two (pits 3 and 4) in the entry area.

4.1. Pits 1 and 2

Pits 1 and 2 were dug in the *Sala de la Virgen* gallery in the interior of the cave (Fig. 2A and B). No evidence of human occupation was found, but in Pit 1 a layer of ash and lapilli was discovered making a wider excavation necessary (Pit 2). This

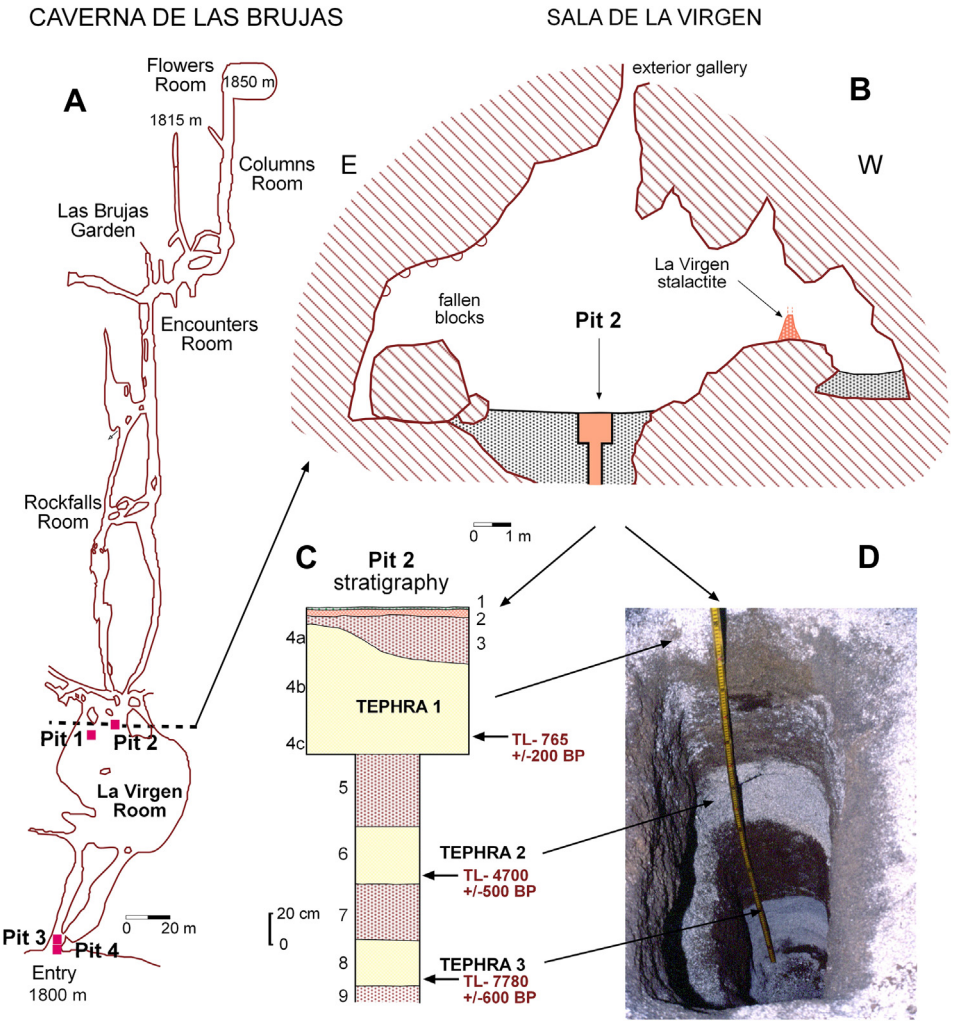

Fig. 2. A. General map of the cave rooms and galleries and situation of the pits excavated in the entrance and Sala de la Virgen. B. Schematic profile of the Sala de la Virgen and Pit 2 location. C. Pit 2 excavation, with the different tephra levels and their chronology. D. Tephra levels during the Pit 2 excavation.

second pit (Fig. 2B–C–D) was dug under a large crack in the roof of the room which could have enabled a major entry of ashes into the *Sala de la Virgen*. In this place traces of a former excavation were found and some ash layers were visible and thought to belong to 1932 Quizapú eruption, documented in this region by Sruoga et al. (1993) and Suriano and Ferpozzi (1993). Pit 2 was then set out in a surface area of 1.5 × 1 m where a sedimentary column of 2.45 m was documented. Three tephra levels (CLB-T1, CLB-T2 and CLB-T3, Fig. 2C–D) were distinguished and later dated by TL (Laboratorio de Termoluminiscencia de la Universidad Católica de Chile) giving the dates shown in Table 1.

Trace element analyses have been carried out (Durán and Mikkan, 2009) on the tephra samples from Pit 2 by means of neutron activation and X-ray fluorescence (XRF) in Missouri University. The results were compared with those obtained from samples in nearby volcanic areas. The conclusion is that the tephras in the Caverna de las Brujas cave could have been expelled from the Laguna del Maule volcanic complex and the Descabezado Grande/Azul/Quizapu group some 80 km away on the Chilean side of the Andes (Table 1). Volcanic eruptions have been described in this area from Upper Cenozoic (Ramos and Nullo, 1993) and continuing until present times with significant explosive events related to caldera generation, lava emission, and pyroclastic deposits (Bermúdez and Delpino, 1990; Sruoga et al., 1993).

4.2. Pits 3 and 4

Pits 3 and 4 were excavated in the entrance area. The entrance of the cave is at 1800 m a.s.l. on a south-facing slope with visual control of the bottom of the alluvial polje of Las Brujas (Fig. 1B and C). The mouth of the cave opens in the limestone of La Manga Fm in the nucleus of a syncline structure. It has an arch shaped roof that creates an outstanding rockshelter (Fig. 3B) while its base is flat. However Pit 4 shows that the flanks of the mouth are bent towards the centre of the opening, so it can be supposed that the original shape of the entrance was ellipsoidal, corresponding to a phreatic gallery related with the main functional periods of the karstification process in the massif. The gallery was later left hanging by the incision of the fluvial network and the hydrokarstic system.

Pit 3 was dug 2 m to the interior of the metallic gate that now closes the cave. No positive results were acquired from this pit because the sediments were shallow and had been recently turned over. Pit 4 was much more complete and informative. The pit was dug at the foot of the mouth of the cave rockshelter (Fig. 3D), approximately 1.5 m outside the metallic gate. The excavation covered a surface of 3 × 1 m and reached a depth approaching 1–1.3 m. From that base a minor drilling was made to 2.2 m, and not reaching the bedrock. Five levels have been distinguished (Fig. 3C):

Level I (0.60/80 cm). Sand to silty sand sediment. The sand fraction has a volcanic origin and has undergone aeolian transport and resedimentation which has darkened the original colour of the clasts. There are a significant number of angular blocks of different sizes (rockfalls due to gravity) and stalactite fragments with an irregular distribution (Fig. 3E). The 80 cm sequence contains archaeological material. Significant concentrations of carbonates are displayed forming thick sheaths encrusting not only the blocks but also the archaeological material. The ^{14}C dating carried out in the Geographische Institut Laboratory (Zürich-Irchel Universität, Switzerland) on charcoal samples shows an age of 3695 ± 65 BP only 15 cm from the surface (Table 2). In the archaeological record, lithic material is predominant (Fig. 3F) and some very fragmented large mammals (especially Lama *sp.*) were found without consumption or usage traces, as well as micromammals brought into the cave by non-human predators. An adult and infant's human skeletal remains were found in the first 10 cm of the sequence. As far as charcoal is concerned, it is irregularly distributed and in no case could it be associated with combustion structures. No evidence of space conditioning of any kind is found.

Trace elements analysis carried out on obsidian tools show that this raw material could have been obtained in the Laguna del Maule volcanic area (Seelenfreund et al., 1996). Extraction of stone flakes and the production preforms from opals available in the outcrops near the cavern seems to have been the predominant activities.

Level II (60/80 to 85/110 cm). Dun silty sand layer, containing some clay. It has angular blocks and carbonates clasts detached from the walls and the roof of the cave. Anthropogenic material appears, although the proportion is less than in the previous layer. Charcoal presence is minimal.

Level III (85–100/110 cm) Grey silty clay layer, without rock detachments. Minimum traces of anthropic material.

Level IV (100/110–180 cm) Brown silty clay layer with carbonates, whitish lines and stains, presenting scarce anthropic material.

Level V (180–220 cm) Yellowish tephra layer (Tephra 4), whose base was not reached. Neutron activation and X-ray fluorescence (XRF) analysis carried out in Missouri University show that the tephra in Pit 4 (CLB-T4) (Table 1) is affine to the chemical characteristics of Tephra 2 (CLB-T2) in Pit 2. Both have their origin in the volcanic eruptions in the Quizapú group (Durán and Mikkan, 2009). TL dating (Table 1) gives a result of 5000 ± 550 years, which can be related to the date provided by Tephra 2 in Pit 2 (4700 ± 500 years).

5. Interpretation and discussion

The four pits dug in the Caverna de las Brujas have already shown a sedimentary record from 7780 to 765 years. From an archaeological point of view, the findings recovered raise important data for the upper limit (3695 ± 65 BP) of a poorly documented period of time in this region (7000–4000 BP). However, the existence of lower stratigraphy makes it possible to find older archaeological remains in future and deeper excavations. Some 3490 spalls and 20 typological artefacts have been recovered (among them 2 stemmed points, 4 bifacial artefacts, 3 scrapers, 1 racloir and 1 bead). Local opal is the dominant raw material and it has been knapped inside the cave, as is shown by the many recovered spalls. Some typological artefacts, such as arrow tips, are made in obsidian which is not locally available and was not knapped in the cave, so it must have been brought already shaped from other places in the region. The origin of the obsidian of the southern sector of Mendoza province has been studied by Durán et al. (2004) and Barberana et al. (2011). More precisely, trace elements of the obsidian objects recovered in the cave show that their origin is in Laguna del Maule, approximately 80 km to the west on the Chilean side of the Andes (Seelenfreund et al., 1996). It is thought that adverse climatic conditions sometimes made it almost impossible to reach and work the obsidian quarries. Therefore the use of opals rather than obsidian was preferred. The same hypothesis was proposed by Fernández (1991) for caves at Neuquén (Argentina). Environmental reconstructions for this sector of the Andes between 5000 and 3000 BP suggest a climate with more winter precipitations and

Table 1
TL chronology and origin of tephra samples from pits 2 and 4 of the Caverna de las Brujas.

Sample	Pit	origin and distance	TL chronology	Laboratory reference
Tephra 3 CLB-T1	Pit 2	Maule 65 km	7780 ± 600 a	UCTL 1170
Tephra 2 CLB-T2	Pit 2	Quizapú 95 km	4700 ± 500 a	UCTL 1169
Tephra 1 CLB-T3	Pit 2	Quizapú 95 km	765 ± 200 a	UCTL 1171
Tephra 4 CLB-T4	Pit 4	Quizapú 95 km	5000 ± 550 a	UCTL 1787

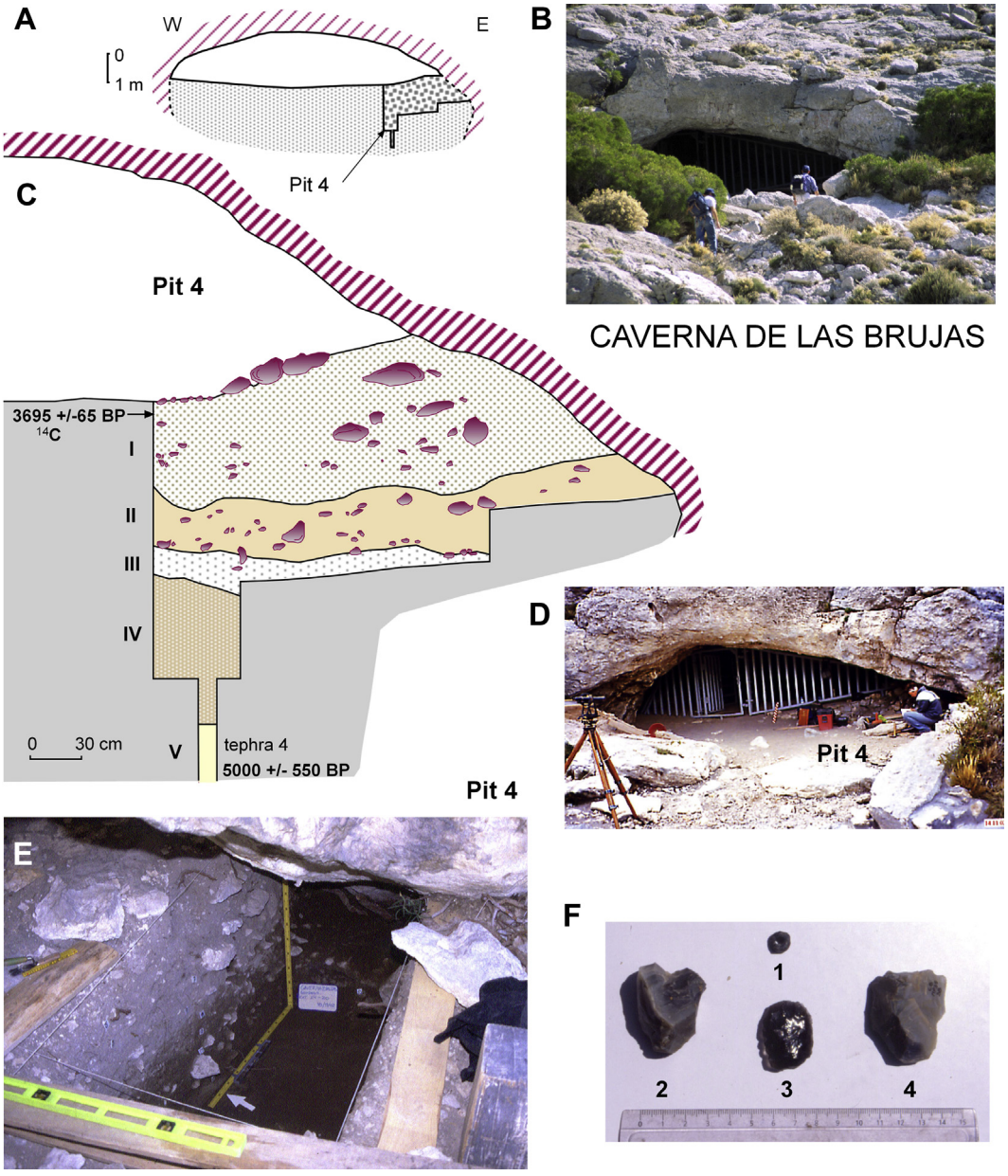

Fig. 3. A. Schematic reconstruction of the mouth of the cave and Pit 4 location. B. Rockshelter of the cave. C. Stratigraphic levels and ^{14}C dating in Pit 4. D. Pit 4 situation in the entrance of the cave. E. General view of the Pit 4 during 2002 excavation season. F. Different artefacts from the Level I. (1) Bead in soft Stone; (2 and 4) Local opal core fragments; (3) Fragmented obsidian stemmed point.

lower summer temperatures than the current values (Markgraf, 1983; Zárate, 2002). These climatic conditions and the need for raw materials might have favoured the existence of a settlement system that included habitats in different locations including this cave.

The problem posed in the Río Grande valley is a 3000 year gap in the available archaeological information (Durán, 1997, 2000) beginning after the initial occupations of the Gruta de El Manzano, dating approximately 7200 BP (Gambier, 1980, 1985, 1987). This problem is common to other nearby regions and it has become one of the outstanding archaeological questions of the southern Mendoza (Gil, 2000; Gil and Neme, 2002). The first hypothesis to interpret this lack of information was to consider a depopulation due to an intensification of the volcanic activity in the region and its environmental impact (Durán, 1997). In the sector just by the Río Grande valley more than 28 volcanic eruptions have been recorded in historical times. Among these events, the explosive eruption of Quizapú in 1932 stands out as it covered the south of Mendoza with ashes (Sruoga et al., 1993), as well as large areas of the Pampa plain (Suriano and Ferpozzi, 1993) and had effects on the global climate (Kelly and Sear, 1984). Tephras are documented in the palynological and archaeological record of neighbouring areas (Lagiglia, 1997; D'Antoni, 1980, 1983; Markgraf, 1983; Fernández, 1991) and in the

Table 2
^{14}C chronology of the Pit 4 sample of the Caverna de las Brujas.

Sample	^{14}C chronology	Laboratory reference
Charcoal BR3	3695 ± 65 BP	UZ-1893

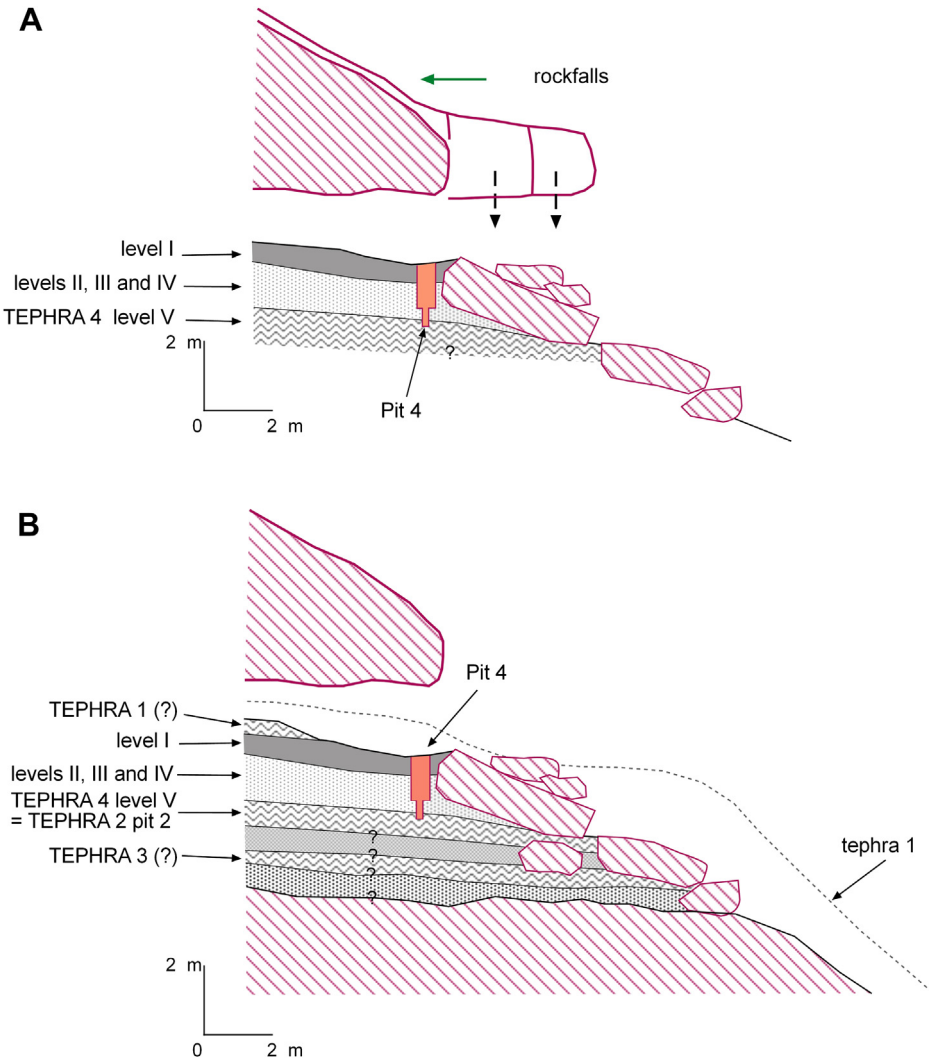

Fig. 4. Morphological evolutionary reconstruction of the rockshelter and stratigraphic interpretation of the sedimentary levels in the entry area to the cave. B. Hypothetical reconstruction of the stratigraphy of the upper and lower levels in the entry area as suggested by the correlation between the levels observed in pits 2 and 4.

basin of Río Grande (Durán, 1997; Durán et al., 2001). Their sequence began in the Lower Holocene with an excellent chronological correlation (7200 BP) between the case of the Arroyo del Manzano valley and Tephra 3 level dates of the Caverna de las Brujas (which are some 30 km away). Even though these catastrophic events can explain the depopulation of wide sectors of the region during short periods of time, it is nowadays thought that these volcanic phenomena on their own could hardly have created a void of information so wide. Rapid recuperation after such eruptions has been observed, as was the case of the above mentioned 1932 Quizapú eruption (Suriano and Ferpozzi, 1993).

The interpretation of the problem that this dark period poses in the south of Mendoza province may be solved through a methodical excavation of the Caverna de las Brujas. The first documented evidence throws doubt on the preservation of such an ancient fossil record. The rocky substratum seemed to come to the surface at the foot of the rockshelter and the shape of the cave suggested a thin accumulation. However, the existence of 1.65 m of sediments under a level dated approximately 4000 BP now leads to the supposition that some or the most of the sediments were deposited during the Lower and Middle Holocene. If this is true, Caverna de las Brujas can provide new information on the peopling and depopulation of this region and period. Therefore, it is worthwhile intervening to confirm the existence of these levels among the deeper layers of sediments.

With this aim in mind, the possibilities of success in the deepening of the archaeological excavation have been analysed with geoarchaeological criteria:

1. The removal of sediments is revealing the morphology of the cave. The shape of the walls indicates that the base of the cave is not flat, as previously thought, but curved so that the cave has the typical elliptical shape of a phreatic gallery (Fig. 3A). This morphology has already been observed in the internal galleries of the cave (Peña-Monné and Sancho, 2001; Sancho et al., 2004). As a consequence of the hypothetical extension of the profile of the cave, it is estimated that the position of the basal rocky substratum is 0.85–1.10 m under the level 5 reached in Pit 4 (that is 3–3.1 m of total depth under the present surface). The accumulation therefore seems much thicker than previously thought.
2. What was formerly considered rocky substratum outcrops in fact correspond to large blocks detached from the rockshelter while the entrance of the cave was moving back towards its

current position. The reconstruction of the position of the fallen blocks (Fig. 4A) indicates a larger cave mouth, both in terms of the depth of the rockshelter and in the height of the cave entrance. The external area might have been filled by gravity blocks that would possibly cover former and synchronic sediments. These blocks worked as a retaining barrier holding back the sediments at the cave mouth. Pit 4 reached sedimentary levels in a lower position than the fallen blocks at the entrance. This fact is a positive sign for the chances of a good preservation of sedimentary layers older than those already excavated.

3. The finding of a layer of Tephra 4 in level 5 of Pit 4 (Fig. 3C) indicates that the lapilli from the volcanic eruptions entered the cave not only through the cracks in the roof of the Sala de la Virgen, but mainly through the mouth of the cave until it reached the interior galleries. The recent aeolian morphologies observed in the nearby slopes suggest that this volcanic material came up and into the cave as climbing dunes in epochs subsequent to the volcanic eruptions. These dunes entered the cave, deposited their materials, and the cave preserved them.
4. The thickness of the aeolian deposits of volcanic material could have completely covered the entrance and the Sala de la Virgen. The height of the sediments on the sides of the entry gallery of the Sala de la Virgen supports this idea. Another important point is the date of level 1 at Pit 4 which is only 15 cm under the surface (3695 ± 65 years BP). Such an old date for such a superficial layer suggests that more recent upper levels have been removed recently in order to allow entry to the cave. These removed levels could correspond to Tephra 1 of Pit 2 or even more recent sediments (Fig. 4B).
5. Finally, it must be highlighted that the tephra layer in level 5 of Pit 4 must be older than the above mentioned date of level 1 of that pit, and it can be correlated with Tephra 2 in Pit 2 (Fig. 2C) by means of their stratigraphic position, TL dating, neutron activation, and X-ray fluorescence (XRF) results. This would imply that there is a wide sedimentary sequence left to reach the equivalent level of Tephra 3 of Pit 2. The chance of continuing the excavation of these deep layers is of great interest for the chronological extension of our archaeological understanding of the cave and the region.

With this interpretative data it is possible to propose the model shown in Fig. 4B. It can serve as a guide for the planning of further archaeological interventions with the objectives of proving its plausibility and gaining access to information regarding the Lower and Middle Holocene.

6. Conclusion

The Caverna de las Brujas is placed in a karstic area with evidence of intense phases of exokarstic karstification: paleopoljes, dolines, and limestone pavements. Its genesis seems related to nival fusion. The interior of the cave shows initial phreatic dynamism that modeled the main erosive forms. On these erosive forms, the speleothemic accumulations of the vadose stages are superimposed. The most important speleothemic phase occurred between 67,000 and 35,000 BP, during MIS 3 that corresponds in this region to the last interstadial period (Peña-Monné and Sancho, 2001; Sancho et al., 2002, 2004). The record of cold climatic conditions is completed with morphologies that are typical of periglacial and nival environments, such as protalus ramparts, that can be related with the last glacial maximum.

The archaeological interventions carried out in the Sala de la Virgen (Pit 2) show the presence of, at least, three levels of Holocene tephras from the Andean mountain range volcanic eruptions. This volcanism, as deduced from the drillings carried out at the mouth of the cave, must have coexisted with human occupation in the Río Grande region, and, despite being sometimes interpreted as a regional limiting factor, the data provided by the Caverna de las Brujas expands the prospects for archaeological research in this region.

Pit 4 excavation at the entrance of the cave, has generated significant results about its original dimensions from its profile reconstruction and the presence of blocks detached from the rockshelter. The depth and visible units in Pit 4, initiated around 3695 ± 65 BP, and the correlation of volcanic ashes of Tephra 4 (Pit 4, level 5) and Tephra 2 (Pit 2, level 6) suggests an important sedimentary thickness that will provide new data about occupation in this area in the Middle Holocene. The future planning of this cavity excavation should take into account the geoarchaeological interpretations offered in this study, which suggests the existence of a wider sedimentary sequence covering several chronological periods scarcely documented in this region.

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