CONSERVATION-RESTORATION APPLIED TO A FOSSIL ADHERED TO A SPELEOTHEM (MIDDLE PLEISTOCENE) FROM POSTES CAVE (FUENTES DE LEÓN, SPAIN)

Maria Cruz Ortega Martínez¹,²*, Monica Villalba de Alvarado³,⁴*, Hipolito Collado Giraldo³,⁵,⁶,⁷, José Ramon Bello Rodrigo³,⁵,⁷, Isabel Domínguez García³,⁴, Luis F. Nobre da Silva³,⁴, Ángel Carmelo Domínguez García³,⁴, Lázaro Rodríguez Dorado³,⁴, José Manuel Torrado Cárdeno³,⁴, Jairo González Márquez³,⁴, Elena García Domínguez³,⁴ & Elena Garrido Fernández³,⁴

¹ - Centro Mixto UCM-ISCIII de Evolución y Comportamiento Humanos, 28029 Madrid, Spain.
² - IEA (Instituto de Evolución en África), Museo de los Orígenes, 28005 Madrid, Spain.
³ - Instituto de Estudios Prehistóricos (ACINEP), 06800 Mérida, Spain.
⁴ - Centro de Estudios para el Medio Ambiente y la Cultura (CEMAC), 06280 Fuentes de León, Spain.
⁵ - Grupo de Investigación CUPARQ.
⁶ - Grupo de Investigación Quaternario-Pre-Historia.

Emails: mcortega@isciii.es (MCOM); monica17villalba@gmail.com (MVdA); hipolito.collado@igotbex.es (HC); jrbellor@gmail.com (JRBR); isabeldoga@gmail.com (IDG); luissnobre@sapo.pt (LFD); acdomgar@gmail.com (ACDG); lazrodor@gmail.com (LRD); chematorrado@gmail.com (JMTC); jefer_mss@hotmail.com (JGM); elena_qd@hotmail.com (EGD); elena.839@hotmail.com (EGF)

* MCOM and MVdA contributed equally to this work.

ABSTRACT

The conservation-restoration methodology used on most Middle Pleistocene layers from the Postes Cave site fossils is minimal intervention. The fossils from Stratigraphic Unit Pleistocene 1 layer are covered by a 0.3 m-thick speleothem around the bones.

This work describes four restoration treatments applied to one of the fossils from this layer since its discovery, to reverse fossil deterioration and/or total or partial loss. To extract the bone it was necessary to hit the speleothem and fracture it, damaging and breaking the fossil into small fragments. These treatments consisted in the application of a bandage in situ, removal of the bandage, cleaning, consolidation and reconstruction in the research laboratory.

We have recovered and stabilized the fossil so we can take, touch and move them to carry out a taxonomic study. These studies have resulted in the identification of the fossil as an Ursus arctos tibia.

Keywords: fossil; Middle Pleistocene; restoration; reconstruction

RESUMO [in Portuguese]

A metodologia de conservação e restauração efetuada na maioria dos fosseis da gruta de Postes, Extremadura, é a mínima intervenção nos níveis de Plistoceno médio. Este nível está coberto por um espeleotema de 0,3 m com ossos completos aderidos, Unidade Estratigráfica Plistoceno 1.

Este trabalho descreve quatro tratamentos de restauração levados a cabo num dos fosseis deste nível desde seu descobrimento, para prevenir a sua deterioração e/ou total ou parcial perdida. Para remoção de osso foi necessário bater o espeleotema e fraturá-lo, danificando e quebrando o fôssil em fragmentos de pequeno tamanho. Os tratamentos consistiram em vendagem in situ e limpeza, consolidação e reconstrução no laboratório de investigação.

O fóssil foi recuperado e estabilizado e agora pode-se manipular. Os tratamentos permitiram identificar o osso como uma tibia de Ursus arctos. Ademais o fóssil e o espeleotema foram analisados.

How to cite this paper: Ortega Martínez et al. (2016). Conservation-restoration applied to a fossil adhered to a speleothem (middle pleistocene) from postes cave (fuente de León, Spain). Journal of Paleontological Techniques, 15:68-83.

Copyright (c) 2016 by Ortega Martínez et al. This work is made available under the terms of the Creative Commons Attribution 3.0 Unported License, http://creativecommons.org/licenses/by-sa/3.0/.

www.jpaleontologicaltechniques.org

ISSN: 1646-5806
INTRODUCTION

Archeo-paleontological remains are important because they provide essential information to understand an archeological site, and a certain time period. In many cases these fossil remains, must be treated in situ, given the fossil condition or the logistics of the site itself. The fossils found in limestone caves are often in contact with speleothems or calcic carbonate concretions. The fossil removal is difficult because the speleothem is harder than the bone. In order to extract them, it is usually necessary to use pneumatic hammers, screws and chisels that impart forces that can damage the materials. After an assessment of the fossil preservation, the integrity of the remains and stability must be ensured as much as possible until it is treated in the laboratory, with the purpose of carrying out scientific studies.

This work describes the required conservation-restoration treatments applied to a tibia inlayed in a speleothem from Postes Cave. The methodology accomplished follows the basic principles of the intervention methodology based in the modern discipline of conservation that appears in various official documents such as those from the International Council of Museums (ICOM-CC, 1984, 2008), European Confederation of Conservator-Restorers’ Organisations (ECCO, 2003), and the American Institute for Conservation (AIC, 1994; López-Polín et al., 2008).

Postes Cave is part of the Natural Monument Fuentes de León Caves (DECRETO 124/2001; Badajoz, Spain) situated in the south of Extremadura, 7.5 km from the municipality of Fuentes de León. The caves are located in Cambrian grey and white limestone (between 500-540 Myr) and dolomite, with Quaternary grounds composed of decalcified clays (Figure 1; Díaz del Olmo et al., 1994; Algaba Suarez et al., 2000; Fernández-Amo and Rebollada, 2005; Durán, 2006; Fernández et al., 2007; Rebollada Casado et al., 2010).

The cave has an area of 180 m$^2$, divided in two stretches. The first one descends to a chasm filled in with clays. The first excavation was developed there within an area of 20 m$^2$ by 4.1 m of sedimentary potential, dated in the Holocene epoch. It is composed of Roman remains (Collado Giraldo, 2014; Collado Giraldo et al., 2015: 26) and a previous occupancy with an approximate chronology of 4140 +/-35 to 7780 ± 60 BP, dated by C$^{14}$ with AMS and U/Th and anthracological results (Duque Espino, 2011; Collado Giraldo et al., 2015: 22-25). The second stretch finishes in two rooms with a different level separated by stalactite columns (Figure 2; Algaba Suarez et al., 2000).

Figure 1 - Geographical location of Postes cave. From left to right, photos taken from "Programa conoce Extremadura: rutas por áreas protegidas de Extremadura (2012)" and Google Earth (2014).
Figure 2 - Postes cave planimetry. Zone 1 indicates the first excavation area with Holocene layers. Zone 2 "Hueco Eulogio" indicates a posterior excavation, with Holocene and Pleistocene layers. Planimetry made by Samuel Pérez Romero under the direction of Hipólito Collado Giraldo. Photographs show the inside of the cave.

Figure 3 - A) Holocene and Pleistocene layers from Hueco Eulogio, eastern side. Pleistocene layer UE 1 is sealed by a speleothem dated to 192,986 +/-15,451-13,837 BP and a second one dated to 244,191 +/- 2261 BP. B) Pleistocene layers: Pleistocene UE 1- 7. Only the upper three layers containing remains so far are highlighted. C) Upper view of Pleistocene UE 1.
From 2009 to the present, a second excavation took place in an area of approximately 6 m² by 6 m of sedimentary potential, named “Hueco Eulogio”. It contains Holocene and Pleistocene layers. Holocene layers are 450 mm high, and are composed of three basic stratigraphic units: UE 1 - UE 3 dated in Neolithic chronology (Duque Espino, 2011). Pleistocene layers are 4.7 m high, they are sealed by a calcitic crust dated to 192,986 +/- 15,451-13,837 BP and is approximately 0.3 m thick (Collado Giraldo et al., 2015: 26). It is composed of seven stratigraphic units (Pleistocene UE 1-7) with dates between 192,986 and 244,191 +/- 2261 BP obtained by U/Th (Figure 3).

The upper three layers, Pleistocene UE 1-3, contain black lithics made from silex, fossilized faunal remains, and a human phalanx (Collado Giraldo, 2014; Collado Giraldo et al., 2015: 26). Pleistocene UE 1 is composed of a speleothem where fossils are totally or partially adhered (Figure 4). The lower part of these fossils rest in a fill of lithified clay soil (Figure 5). It is composed of quartz, calcite, gypsum, feldspar (albite), hematite, cuprite and phyllosilicates (illite, kaolinite, smectite; Soutullo, 2013).

**MATERIALS AND METHODS**

The fossil treated is a complete left tibia belonging to and adult *Ursus arctos* (inventory number: Postes/12/Hueco Eulogio Pleistoceno/1/156) found in Zone 2 Hueco Eulogio, at the base of the speleothem and the roof of the clay soil from Pleistocene UE 1 layer, in the year 2011 (Figures 3 and 5). The removal of the speleothem was carried out by breaking it mechanically with a pneumatic hammer, screws and chisels. These actions broke the fossil in specific areas (Figure 5). Therefore, the conservation treatments and excavation had to be accomplished with close cooperation between archaeologists and conservators.

Figure 4 - Material adhered to the speleothem. A) First proceedings to break the speleothem by using a pneumatic hammer. B-D) Pleistocene UE 1 layer with fossils adhered to the speleothem.
The bone’s state of conservation was delicate, covered and adhered to the speleothem by both epiphyses, excluding the lower part that rested in the clay soil (Figures 3 and 5). The tibia is white, with black dots, possibly manganese. It presents fissures, fractures, grooves and dirt. The bone has a maximum length of 278.8 mm from the medial condyle to the medial malleolus, 76.9 mm high in the proximal epiphysis from the lateral condyle to the medial condyle, 44.4 mm high in the distal epiphysis and 25.6 mm high in the diaphysis (Figure 5).

As a conservation factor, environmental agents are kept stable in cave sites so that fossils do not become deteriorated when they are exposed during excavation work and conservation-restoration treatments (Ortega et al., 2009). This fact avoided further major deterioration during their extraction.

Conservation-restoration treatments were accomplished in two phases. The first one was in situ and consisted in consolidation and the application of bandage. The second phase was in the restoration laboratory and consisted of the removal of the bandages, further consolidation, cleaning, reconstruction and

Figure 5 - A-B) Bone’s state of conservation during the archaeological work. The fossil is still adhered to the speleothem in its epiphyses. C) The top of the diaphysis has been cleared revealing some new and older fractures D) fissures and E) grooves (Image credit José Enrique Capilla).
application of a protective layer. Bone deterioration was evaluated, while different treatments were accomplished. They were carried out simultaneously preventing the disintegration of the small fragments. Prior to the interventions, an evaluation of the state of conservation and/or deterioration of the bone was made, in order to act accordingly.

For consolidations, adhesions and reconstructions we used the acrylic resin Paraloid B-72® in varying proportions diluted in CH$_3$COCH$_3$ (acetone; Storch, 1983; Koob, 1986; Johnson, 1994; Kres and Lovell, 1995; Down et al., 1996; Davidson and Alderson, 2009; Davidson and Brown, 2012; López-Polín, 2012). For the removal of the bandage and cleaning we required the same solvent, CH$_3$COCH$_3$, which was used to dissolve the Paraloid B-72.

**In situ treatments**

During the removal of the fossil, the speleothem was fractured with a hammer and chisel, leaving the diaphysis surface of the bone isolated. During this work the tibia broke into pieces, losing part of the bone in both epiphyses which were adhered to the speleothem (Figure 5).

Damages and possible consequences of the forces and pressures imparted in the fossil during the extraction were analyzed together with the archaeologists. We made a bandage to completely envelop and reinforce the bone against continuous hits. Before this, we applied a layer of consolidant over the surface with 5% Paraloid B-72 diluted in acetone. The bandage was carried out with gauze strip bandages (about 5-10 cm long) intertwined, attached with 15% Paraloid B-72 diluted in acetone applied by brush (Figure 6).

The fossil was pulled out in one piece. For that to happen, we had to hit the speleothem and fracture it. After applying pressures on the bone in diverse directions we observed a fracture and displacement in the diaphysis medial area (Figure 7). The fossil was packed and transferred to the laboratory.

Figure 6 - Bandage in situ. Application of medium-sized strip bandages over the whole surface and reinforcement of the epiphysis with larger strips (Image credit José Enrique Capilla).
Treatments in restoration laboratory

The bone state of conservation was evaluated in the research laboratory. The fossil consists of a gauzed main fragment and 20 isolated fragments, most of them from the epiphysis without gauzed, and speleothem remains. The bone presents a displacement in the diaphysis medial area and various fractures (Figure 7).

In the laboratory, we removed the bandage, cleaned, consolidated, and glued the fragments, reconstructed and laid out a protective layer. Some of these treatments were carried out simultaneously to prevent the disintegration of small fragments.

Removal of the bandage. Bandage removal consisted in the impregnation of the gauzed surface with acetone applied with brushed-on solvent until several layers could be separated with the help of tweezers. We started in the diaphysis medial area due to the bone’s distortion in that region. We used scissors to cut the strips, separating the fossil in two parts (Figure 9). At the same time a thick layer of 5% Paraloid B-72 diluted in acetone was applied between the fragments to prevent their detachment. Treatments continued in both parts separately (Figures 8 and 9).

The bone conservation state after the bandage treatments was unstable. The fossil was fractured in small fragments, these fractures were new, several fragments were displaced and some of them presented laminations. There is loss of bone in specific areas. In the caudal view of the proximal tibia we could see loss of the lateral condyle, not seeing the facet for articulation with the fibula (Figure 10). The lateral view of the distal tibia possibly presents loss of bone in the cochlea. There are remains of calcitic concretions in the central and cranial intercondylar area. The lateral view of the proximal tibia presents a displacement of the fragments inside, and the surface was filled in with sediment and consolidant. Finally, the entire fossil presented superficial dirt with remains of sediment, consolidant and threads (Figure 10).
Figure 8 - A-B) Removal of the bandage in the caudal view. It Presents loss of bone and fractures with small fragments. C) Detail of the loss of bone in the diaphysis.

Figure 9 - A) Separation of the fossil in two parts during the removal of the bandage. B) Both parts of the fossil after the removal of the bandage.
Figure 10 - Diagnosis of the fossil before the cleaning and reconstruction.
Cleaning and reconstruction. Cleaning and reconstruction were achieved simultaneously in both parts of the fossil. Cleaning treatments consisted in the removal of the dirt, consolidant and threads. We impregnated the surface with solvent using a brush and cotton swabs, which were able to sweep along the dirt until it was eliminated (Figures 10 and 11). In some areas we had to clean, consolidate and fill some gaps with adhesive. At the same time some fragments were relocated. In other areas a sketch was made to make the posterior separation of the fragments easier prior to the cleaning and reconstruction (Figures 11-17). We explain the treatments made in specific areas of the fossil, proximal and distal parts and the joint of both, below.

After the cleaning we observed that the fragments from the surface between the diaphysis and the proximal epiphysis had been displaced inside, which had caused an obvious deformation. Its separation was difficult, so we decided to separate the lateral condyle to simplify the task. Previously we made a sketch, giving a number to each fragment and to aid future reconstruction (Figure 12 A-F). After cleaning treatments that favored a good fit, we decided to apply adhesive in all of the fragments and adhere them at the same time (Figure 12 G).

The same procedure was achieved in the diaphysis and distal epiphysis that presented a displacement of some of their fragments (Figure 13).

In the distal fragment we proceeded with the distal diaphysis reconstruction. This part was the most vulnerable during the excavation work. Therefore, it presented new fractures made up of small and displaced fragments, loss of bone in specific areas and adhered sediment that did not allow them to fit together. A sketch of the area was made, followed by separation of the fragments, cleaning them individually and joining them together, while we corrected the displacements. The millimeter-size fragments from the interior of the bone that didn´t allow good fitting were removed (Figure 14). A big fragment from the diaphysis was adhered, and a chopstick was placed to avoid movements (Figure 15).

Figure 11 - During cleaning treatments. A) Superficial cleaning. B-C) Cleaning of the distal epiphysis. D-F) Removal of the sediment from the proximal epiphysis, cranial view.
Figure 12 - Reconstruction of the proximal epiphysis. Lateral view: A) Sketch with the fragments numbered. B) Separation of lateral condyle. C-F) Cleaning and removal of the displaced fragments. G) Epiphysis view after restoration treatments.

Figure 13 - Reconstruction of the distal epiphysis: A-B) Distal epiphysis before the cleaning and reconstruction. C) Cleaning and relocation of the fragments from distal epiphysis.
Figure 14 - Cleaning and reconstruction of the distal diaphysis: A) Sketch of the numbered fragments. B-G) Cleaning and separation of displaced fragments for the posterior right position. H) Diaphysis view after the reconstruction.

Figure 15 - A) Incomplete distal epiphysis. B) Additional support used to adhere a big fragment from the diaphysis.

The same approach was taken in the medial diaphysis, and new fittings were found for isolated fragments. While the reconstruction of this area was achieved, we were checking the good fit of both halves of the diaphysis. To prevent movements, the fragments were held with a clear plastic sheet and an elastic band (Figure 16).
Figure 16 - A-B) Adhesion of some fragments form the proximal diaphysis, lost during the excavation work. Those areas that present loss of bone are marked with arrows. C) Fastening of the fragments adhered in the diaphysis with a clear plastic sheet and an elastic band.

Figure 17 - Final result of the left tibia. Left to right: medial, cranial, lateral, caudal views.
Reconstruction treatments were finished by joining together both distal and proximal parts (Figure 17). Their surfaces were protected with a thin and homogeneous layer of consolidant (3% Paraloid B-72 diluted in acetone).

Preventive conservation measures were taken to protect the fossil in its housing, with an expanded polystyrene package able to minimize movements. It was stored in a box to block the entrance of dust (Figure 18). It is recommended to keep it in constant environmental parameters, a temperature of 18º to 21°C with a fluctuation of 1,5º and a relative humidity of 45 - 55% out of direct sunlight.

RESULTS

The intervention in the tibia was carried out in two phases; the first one was achieved in situ and consisted in the protection of the fossil with a bandage that prevented the deterioration and made its extraction from a calcitic matrix easier. Fossils located within these speleothems often get fractured or even lost. In this case, the fossil broke into numerous small fragments and suffered displacement. The bandage managed to maintain a unified structure during the excavation work.

The second phase was accomplished in the laboratory and consisted in the removal of the bandage, which served to evaluate the damage and continue with the cleaning and reconstruction treatments simultaneously.

These treatments required the ability to diagnose bone alterations and solve the problems in both the extraction procedures, and in the conservation treatments. This also requires the knowledge of conservation techniques and products plus knowledge of the bone material itself (López-Polín et al., 2008).

After conservation-restoration treatments the bone presents more optimal state of conservation. Moreover, this work has allowed us to recover the whole anatomy of the fossil, it can now be studied by hand, and suitable for accomplishing paleontological studies. It has been taxonomically determined to be an Ursus arctos left tibia.

DISCUSSION AND CONCLUSIONS

Conservation treatments achieved in the tibia here described were necessary since the removal of the fossil in situ. Stabilization of the bone was greatly affected by the stalagmitic crust that covered it. This is a common characteristic within karst sites. In such a situation we found pertinent that excavation and conservation staff work together to be able to analyze the state of conservation precisely and prevent the potential deterioration during excavation. In addition, the skills in the methodology and the knowledge of the bones morphology is essential when they are inlayed in calcitic matrix.

We hope that this study will provide a valuable contribution in the field of conservation, and will serve not only as a standardized set of protocols relevant to the protection of paleontological material, but also to bring to attention the importance of the conservation process in the preservation of the fossil specimens, from the moment of excavation, to their deposition in a research center (Ortega et al., 2009).

In any case, the intervention was accomplished having in mind the bone stability and its needs. Deterioration was prevented and a whole view of the fossil was obtained. It is available for scientific studies that will provide a better understanding of these Pleistocene periods.
ACKNOWLEDGMENTS

We would like to thank the Mixed Centre UCM-ISCIII laboratory “Evolution and Human Behaviour”, in particular J. L. Arsuaga for providing this center to this research, N. García for her taxonomical work with the Ursus arctos. Part of this research was financed by the Ministerio de Ciencia e Innovacion of the Government of Spain Grant number: CGL2012-38434-C03-01 and CGL2015-65387-C3-2-P (MINECO/FEDER). General Direction of Library, Museums and Cultural Heritage of Junta of Extremadura Secretaria General, ACINEP, Origenes Project, and CEMAC. We would also like to thank J. E. Capilla for his help taking the photographs in the site, S. Pérez for his work with the topography. B. Soutullo from X-ray Diffraction Laboratory of UCM Crystallography and Mineralogy Department for his sedimentological research, G. Sarmiento from UCM University department of Paleontology, D. Duque and J. J. Enríquez from Extremadura University department of History, and J. M. Fernández from Madrid Polytechnic University. Finally we are pleased to thank the responsible from Natural Monument of Fuentes de León E. Oyola, M. Giles, R. Montero, C. Castaño, and the researchers, M. Fernández, M. Nacarino, E. Rivera, R. C. Fernández, A. Cristo and P. Garrido.

REFERENCES CITED


Ortega Martínez et al. 2016: CONSERVATION-RESTORATION OF FOSSIL FROM CAVE


ICOM-CC. 1984. The conservator-restorer: a definition of the profession. 7th Triennial Conference.


Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/