Symposium Volume

2nd INTERNATIONAL CONSERVATION SYMPOSIUM-WORKSHOP
Natural History Collections
6 - 9 May 2015 BARCELONA - SPAIN

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www.jpaleontologicaltechniques.org ISSN: 1646-5806
IN SITU CONSERVATION STRATEGIES AT THE PLEISTOCENE SITES OF PINILLA DEL VALLE, MADRID (SPAIN)

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ABSTRACT

The aim of this study is to describe the conservation and restoration procedures applied to the Pleistocene archaeological sites of Camino Cave, Navalmaíllo Rock Shelter and Buena Pinta Cave of Pinilla del Valle, Madrid (Spain). Clear-cut and timely decisions must be made when retrieving fossils and the close collaboration of a multidisciplinary team is the key to success. Early diagnosis is made in situ to determine the state of conservation and decay. A balance is sought between what the bones need, the available resources and the scientific data requirements of each site.

The principle of minimum intervention is followed throughout the entire process. Sub-fossils that were not successfully extracted were sent to the laboratory where a new diagnosis was performed. Previously collected on-site data provide helpful information for performing treatments that ensure the material's structural stability. The last step is careful packing of the bones pending further study.

Keywords: conservation; archaeological; preservation; sub-fossil; multidisciplinary approach; bones

RESUMO [in Portuguese]

O objetivo deste estudo é a descrição dos procedimentos de conservação e restauro aplicados aos sítios arqueológicos Pleistocênicos de Cuevas del Camino, Abrigo de Navalmaíllo e Cueva de Buena Pinta em Pinilla del Valle, Madrid (Espanha). No momento de recuperação dos fóssíveis é necessário tomar decisões efetivas de forma rápida e a colaboração com uma equipe multidisciplinar é a chave para o sucesso. É realizado um diagnóstico in situ para determinar o estado de conservação e deterioração. Procura-se um equilíbrio entre as necessidades dos materiais, os recursos disponíveis e as exigências científicas de cada sítio.

O princípio da mínima intervenção é aplicado ao longo de todo o processo. Os fósseis que não passaram com sucesso a fase de extração são enviados para o laboratório onde é realizado um novo diagnóstico. Os dados recolhidos no site fornecem informação útil na realização de tratamentos que asseguram a estabilidade estrutural do material. O último passo é o acondicionamento cuidado do material pendente de estudos futuros.

How to cite this paper: Ortega et al. (2016). In situ conservation strategies at the Pleistocene sites of Pinilla del Valle, Madrid (Spain). Journal of Paleontological Techniques, 15:84-111

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ISSN: 1646-5806
INTRODUCTION

Archeological and/or paleontological remains from the Pleistocene provide invaluable information that aids us in comprehending past occurrences at the sites. This information allows us to increase our understanding of hominid behavior and their relationship with their environment. Many of the materials, particularly bone remains, must be treated during the excavations (in situ and at the field laboratory). In these interventions, assessment by different members of the team, such as paleontologists, archeologists and geologists, is essential for the performance of diverse studies.

In order to develop a correct work methodology, establishing a rapid and precise appraisal of the fossils’ state of conservation and/or decay is important, starting from the very moment they are found. In some cases, they must be immediately protected to avoid their decay. These urgent treatments must not damage the integrity of the bone material and therefore the products that are applied must be compatible with the material, reversible and must not interfere with future analyses. Furthermore, the procedures that are performed must be appropriately documented, so that all the professionals involved have access to this information. Throughout the entire process, the basic principles of conservation must be followed, in accordance with official conservation requirements (i.e., ICOM-CC, 1984, 2008; AIC, 1994; ECCO, 2003), and adapted to the specific issues pertaining to the archeological and/or paleontological sites of Pinilla del Valle.

GEOPHYSICAL AND GEOLOGICAL FRAMEWORK

The archeological and/or paleontological sites at Pinilla de Valle are located at an altitude of approximately 1100 m at the Calvero de la Higuera, which forms part of the central sector of the Valle Alto (High Valley) of the Lozoya River. This is located in the Sierra de Guadarrama, a mountain range in the Spanish Central System (Pérez-González et al., 2010). The first site to be discovered was Camino Cave, which was excavated during the 1980s and 1990s by Prof. Dr. Alférez (Alférez et al., 1982, 1985; Alférez and Roldán Garrido 1992). In 2002, a new phase of studies initiated, which is continued today by the interdisciplinary team directed by J. L. Arsuaga, E. Baquedano and A. Pérez-González. In the following years, new sites were discovered and their excavations were initiated: the Navalmaíllo Rock Shelter, Buena Pinta Cave and Des-Cubierta Cave.

These sites are a reference point in the study of the Upper Pleistocene ecosystems on the Iberian Peninsula. Camino Cave was a hyena den, Navalmaíllo Rock Shelter served as a Neanderthal campsite, and Buena Pinta cave hosted sporadic settlements of hominids, as well as a hyena den. Des-Cubierta Cave was the last site to be discovered, and it is currently being studied (Figures 1, 2; Baquedano et al., 2010, 2011; Arsuaga et al., 2011, 2012; Márquez et al., 2013, in press; Laplana et al., 2016; Arriaza et al., in press).

Figure 1 - Morphogeographic location of the Pinilla del Valle sites in the High Lozoya Valley (Sierra de Guadarrama).
The Camino Cave site is part of the Calvero de la Higuera archaeological complex located in the Upper Valley of the Lozoya River. Geologically, the upper valley of the Lozoya river lies within the Shale-Grauváquico Complex of the Central Iberian Zone. The Calvero de la Higuera sites are associated with cavities that evolved from the Late Cretaceous carbonate rocks. The
resulting relief has been dissected by the Lontanar and Valmaíllo streams (Arsuaga et al., 2010).

The Camino Cave site is located 130 m north of the Navalmaíllo Shelter, 6-7 m above the Valmaíllo and Lontanar valleys. The original karst has suffered a high grade of erosion that hinders recognition of the original morphology (Alférez et al., 1982, 1985; Alférez and Roldán Garrido 1992; Arsuaga et al., 2012). The Cueva del Camino site is formed by four sectors (Figure 3): North, Central, Diáclasa Roja and South sectors. The stratigraphic sequence of the karstic sedimentary fill includes levels 3 to 9, thermoluminescence analysis has been performed on level 5 dated to 90961 ± 7881 ka. This level concentrates the major part of the paleontological finds (Pérez-González et al., 2010).

The Navalmaíllo Rock Shelter site was discovered in 2002 by the current research team, located 8 meters above the Navalmaíllo Stream Valley. The shelter, one of the cavities in the Calvero de la Higuera slope, occupies an area of some 300-400 m² (Baquedano et al., 2010, 2011, 2014; Huguet Pàmies et al., 2010; Arsuaga et al., 2011; Márquez et al., 2013). The stratigraphic sequence includes 8 levels: A to F, plus Alpha and Beta (Figure 4). Hearth structures and burned bones with cut marks have been found in the fertile levels. The high degree of fragmentation and distribution of the bone remains provides a clear evidence of human activity, pointing out that the shelter was occupied by Neanderthal groups. Level F, which has provided the largest amount of the archaeological remains, has been dated to 71685 ± 5082 and 77230 ± 6016 ka by thermoluminescence (Baquedano et al., 2010, 2011, 2014; Huguet Pàmies et al., 2010; Arsuaga et al., 2011; Márquez et al., 2013; Arriaza et al., in press).

The Buena Pinta Cave was discovered in 2003 as a result of the archaeological surveys carried out by the Pinilla del Valle Research Team. The phreatic cavity, with a 1.5 elliptical cross-section, is 10 meters long and opens to the N-NE through the Cretaceous carbonate rocks. Five levels have been found, showing a stratigraphic continuity both at the external chamber and the gallery (Figure 5; Pérez-González et al., 2010; Arsuaga et al., 2011; Baquedano et al., 2011; 2014; Laplana et al., 2016). Levels 2 to 5 are rich in late Pleistocene macro- and microvertebrate remains (Laplana et al., 2016). Level 3 has been dated to 63451 ± 5509 ka by thermoluminescence (Pérez-González et al., 2010).
THE MATERIAL AND ITS STATE OF CONSERVATION

The sub-fossils presented in this article have been recovered in excavation campaigns that took place between 2006 and 2014. They belong to Camino Cave, Navalmaíllo Rock Shelter, and the Buena Pinta Cave. Knowing how the space was used at the different sites is important, because their past occupation directly impacted the type of objects found and was reflected in their state of preservation and/or decay.

During treatment, our main priority is to stabilize the fossils, but the scientific needs of each site have also to be taken into account. In a site occupied by carnivores, such as Camino Cave and partially Buena Pinta Cave, the finds included exclusively bone material and coprolites. Conservation aims to preserve the taphonomic information, which is why the fossils should all remain in situ as a whole, allowing for a complete overview of bone positioning.

In a site that had been occupied by humans, such as Navalmaíllo Rock Shelter, bone and lithic materials both occur, with the latter occurring in greater proportion. The sub-fossils are fragmentary and there is a scarcity of complete bones and teeth. Here, the scientific needs are archeological, taxonomic and taphonomic, and interventions are minimal due to the bones’ good state of preservation.

Another important factor includes changes in moisture in the depositional environment during sedimentation and before excavation; if the sub-fossils are found in environments with the aforementioned changes, decay is caused by cracking: the bones crack and even fracture in a mosaic pattern.

Bone material from Camino Cave included in this study was recovered between 2006 and 2009. This assemblage is composed of fragments, some of them quite complete, e.g. the cranial-dental bones, the long bones, and a limited representation of small bones. Decay, due to fissuration or fracturation in the long bones, was longitudinal and transversal (separating bones in two). The main alterations we found were superficial and associated with diagenetic modifications: concretion crust produced by carbonates, crenulated edges and polished surfaces, root marks, cracking and exfoliation, along with marks of carnivore activity (> 70%), such as punctures, perforations, pitting, scoring and fractures (Figure 6; Table 1; Arsuaga et al., 2012).
The fossils of **Navalmailllo Rock Shelter** presented here were recovered between 2006 and 2014. The bones treated during these years came all from level F, which corresponds to the main occupation of the rock shelter by a group of Neanderthals. The best preserved fossils were fragments from large-sized mammals, especially cranial and appendicular bones with a predominance of long bones (Huguet Pàmies et al., 2010). The fractures, mostly of anthropogenic origin, are longitudinal with straight angles or curved with oblique angles. Anthropogenic marks have been documented, such as fractures due to impact and percussion in long bones (tibiae and metapodia from large and medium-sized animals); fractures due to flexion (peeling) in flat bones (caused during efforts to obtain nutrients); and cuts due to disarticulation in the epiphysis. Surface analysis denotes scarce carnivore activity (Huguet Pàmies et al., 2010). Some bones associated with hearths present multiple fractures and a change in color caused by combustion. Lithic industries are very abundant and their state of preservation was relatively good in those elements, whose raw material consists of mono-mineral rocks (e.g. quartz, quartzite) or those that are predominantly composed of microcrystalline textures. However, lithic artefacts made of large-grain, poly-mineral rocks (i.e. gneiss) were not as well preserved. Abundant sediment concretion was often observed on the surface of the lithic artefacts, which initially hampered morphological determination and wear analyses until this concretion could be removed (Figure 7; Table 1; Huguet Pàmies et al., 2010; Márquez et al., 2013).
Figure 7 - Left: Evidence of anthropogenic activity in the Navalmaíllo Rock Shelter: A) and B) long bones of a large-sized animal with cut marks, C) long bone of a large-sized animal with anthropogenic fracturation, D) percussion cone, E) burned bones with distinct levels of blackening. Right: lithic tools manufactured in quartz from level F of the Navalmaíllo Rock Shelter: A and B) Denticulate tools, C) Sidescraper, D) Centripetal core (Huguet Pàmies et al., 2010; Baquedano et al., 2011).

Figure 8 - Evidence of the presence of carnivores in Buena Pinta Cave: A) bitten and licked cervid antler, B) bovid phalange altered by stomach acids, C) bitten and fractured cervid humerus, D) Hyaenidae radius with diaphysary cylinder morphology due to the consumption of its epiphysis, E) fragments of a digested long bone, F) Panthēra leo humerus with the distal epiphysis consumed and pitting on the diaphysis, G) fragment of a Crocuta crocuta maxilla. (Huguet Pàmies et al., 2010).
The fossils from Buena Pinta Cave considered in this paper were recovered between 2009 and 2014. The main occupation of this site was by carnivores, mainly hyenas (*Crocuta crocuta*; Huguet Pàmies et al., 2010; Baquedano et al., 2010, 2011), which modified the fossils characteristically.

The fossils in the site, which in large part were of medium size (37.7%), consisted of fragmented bones; whole bones, carpals, tarsals and phalanges were scarce. Fractures were transversal with straight angles and irregular planes or longitudinal with straight angles and soft planes. Fractures made by carnivores were of a helicoidal shape, and puncture marks were also observed. Other marks include bite marks (scores, punctures), and marks caused by the action of digestive acids (crenulated and/or polished). Manganese oxide spots of a postdepositional nature were also present, and the longitudinal and mosaic cracking in the bones is due to differential changes in moisture (Figure 8; Table 1).

### TREATMENTS

Intervention strategies on the sub-fossils undergo different stages: in situ intervention, treatment in the field laboratory, in the restoration laboratory or at the research center. The objective of these treatments is to prepare the bones for the performance of scientific studies on them and/or for their exhibition and display (Graphic 1).

<table>
<thead>
<tr>
<th>Site</th>
<th>State of preservation</th>
<th>Type of fossil</th>
<th>Main alterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camino Cave</td>
<td>Good</td>
<td>Teeth</td>
<td>- Fissures and fractures (abundant, especially transversal and longitudinal)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long bones lacking epiphysis</td>
<td>- Crenulated edges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small-sized bones</td>
<td>- Polished surfaces</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>Long bones</td>
<td>- Root marks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flat bones</td>
<td>- Exfoliations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cranial bones</td>
<td>- Carnivore marks (&gt;70%): punctures, perforations, pits, scores</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>Diaphysis</td>
<td>- Manganese oxide spots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long bones</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cranial bones</td>
<td></td>
</tr>
<tr>
<td>Navalmaíllo Rock Shelter</td>
<td>Good</td>
<td>Frag. Long bone diaphysis</td>
<td>- Decay associated with the small size of the fragments.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dental bones</td>
<td>Multifragmentation.</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>Cranial bones</td>
<td>- Anthropic marks: fresh fracture deriving from lamination.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Appendicular bones</td>
<td>- Dark spots due to the presence of hearths and combustion.</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>Small-sized bones</td>
<td>- Porosity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flat</td>
<td>- Manganese oxide spots</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buena Pinta Cave</td>
<td>Good</td>
<td>Carpals/Tarsals/Phalanges</td>
<td>- Transversal and longitudinal fractures.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maxillaries/Dental pieces</td>
<td>- Carnivores: bite marks, scores, punctures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coprolites</td>
<td>- Digestion: crenulated and polished</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>Cranial bones</td>
<td>- Manganese oxide spots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flat bones</td>
<td>- Changes in moisture: longitudinal and mosaic cracking.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Appendicular bones</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>No remain is unrecoverable</td>
<td></td>
</tr>
</tbody>
</table>
Our main objective for treatments applied at sites during excavation is the stabilization of the fossils. A criterion of minimum intervention is followed from the very moment of discovery. In order to carry out scientific taphonomic and taxonomic studies, it is very important to quickly evaluate the state of conservation and/or decay in an individualized manner, and execute different processes accordingly. In some cases, the team will act on the entire fossil and in others just on certain isolated areas. These treatments consist of preventative gauze coatings and/or applying adhesive to surface areas (morphological conservation); isolated adhesion of fragments to avoid their dispersion and/or loss (facilitating the definitive adhesion in the laboratory); consolidation to maintain cohesion and mechanical resistance; and in all cases extraction with a packaging composed of tissue paper and aluminum foil as a kind of frame (Graphic 2). As a conservation strategy, an effort is made not to leave fossils on the surface from one excavation season to the next. In cases, where parts of some fossils remain in situ, they are protected by a gauze coating applied directly to the bone surfaces with Paraloid B-72® at 15% in acetone and/or consolidation, in addition to cover layers of geotextile and plastic to buffer against climatic variables.

The materials were transferred to the field laboratory, where they were unpacked under controlled conditions for their acclimatization to their new environment. Later, a diagnosis is made, accompanied by graphic documentation. All of that is included in the project's common database, which is available for all researchers to consult. The bones receive intervention treatments establishing priorities, evaluating the resources at hand, including human and material resources, in addition to available time. Treatments that are carried out include: unpacking, cleaning (elimination of sediments and surface dirt), consolidation, adhesion of fragments and/or reconstruction and packaging.
for their transfer to the Museo Arqueológico Regional de la Comunidad de Madrid (MAR). The purpose of these treatments is to preserve as much information these fossils provide us as possible, respecting the surfaces so that they may be analyzed, adapted to each particular material and keeping in mind its state of preservation or decay. Use of chemicals is kept to a minimum, opting for compatibility and reversibility as in the case of the acrylic resin Paraloid B-72® (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) and occasionally cellulose nitrate (used for temporary adhesions in the field). Likewise, in the case of solvents, we always seek to use the least toxic: acetone, demineralized water and alcohol (Table 2).

Conservation treatments are performed alongside taphonomic and taxonomic studies, which are made possible by supplementary work performed by the interdisciplinary team. Multi-disciplinary work, in which a dialog amongst experts is established, takes place during the reconstruction treatments, the taphonomic interpretation of the decay of the fragments, and later during taxonomic studies. Finally, the bones are deposited in the MAR. We then proceed to revise the sub-fossil and their documentation. Initial treatments are supplemented, and treatments that had been impossible to apply in situ are performed. In each case, the intervention is carried out considering the stability of the bones and their needs in order to maintain all the information needed for scientific studies, and allowing for their exhibition and dissemination in society. The examples discussed in this article are a representation of the different interventions carried out on bone materials at three analyzed sites.

Here we describe in detail the procedures applied to some of the fossils from the Camino Cave, Navalmaíllo Rock Shelter and Buena Pinta Cave sites in Pinilla del Valle.

<table>
<thead>
<tr>
<th>Treatment/ Context</th>
<th>In situ</th>
<th>Field laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consolidation</td>
<td>- 5% Paraloid B-72® in acetone - 10% Paraloid B-72® in acetone (Very decayed) - Undiluted cellulose nitrate. Surface union of fragments in situ by way of protective film the adhesive. It can be reinforced with gauze on the surface as a kind of hinge. - Paraloid B-72® at 50% in acetone.</td>
<td>-3% Paraloid B-72® in acetone -5% Paraloid B-72® in acetone</td>
</tr>
<tr>
<td>Gauze Coating</td>
<td>-10% Paraloid B-72® in acetone with organic gauze (different since, maximum adaptability). -20% Paraloid B-72® in acetone (second layer, maximum resistance)</td>
<td>-10% Paraloid B-72® in acetone with gauze. In case the sub-fossil is transferred to an institution’s laboratory, given its fragility.</td>
</tr>
<tr>
<td>Adhesives</td>
<td>Cellulose nitrate</td>
<td>- Adhesive HMG Paraloid B-72® in tubes. - Paraloid B-72® at 50% in acetone.</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Mechanical dry cleaning: paintbrushes, brushes, orange tree stick, bamboo stick, dental tool</td>
<td>Mechanical dry cleaning: paintbrushes, brushes, orange tree stick, bamboo stick, dental tool, micro lathe, ultrasound, engraver. - Chemicals/Mechanical wet cleaning. Water: Alcohol (1:1), Alcohol, Acetone (for previously consolidated bones).</td>
</tr>
</tbody>
</table>
CAMINO CAVE: CASE STUDIES

In Camino Cave, the selected fossils are found complete or almost complete, piled on top of one another, which complicates their extraction. Furthermore, in some cases, they are much fractured and after taking off the sediment, the fragments detach, causing significant loss of taphonomic and taxonomic information (Figure 9). In order to perform taphonomic analyses on the bones as a whole, they must stay in position for some time to accurately establish the topological relationships among the distinct elements. For the purpose of taxonomic analysis, extracting the bones is essential in order to study the marks on their surfaces. In many cases, this particularity implies the need to place occasional isolated gauze coverings or line-of-sight surface coverings to stabilize the morphology.

Below, we describe some examples of intervention in situ belonging to levels 3-5 of the central sector (Figure 3) and in the field laboratory at Camino Cave.

Metapodial of Equidae

Here, we present a complete metapodial from an adult individual from the 2009 excavation season. The state of preservation was poor, with several old fractures. One fracture was transversal, approximately halfway through the diaphysis, separating the fossil in two main parts, which changed the angle of the slope on two planes. Additionally, the metapodial exhibited various longitudinal fractures that ran along the length of the bone, leaving fragments joined together by sediment; bone material was missing in an isolated area of the distal diaphysis. Sediment had adhered to the surface and also in the interior of the bone (Figure 10).

After evaluating the state of the decay, it was decided to place gauze coating on the two parts of the bone. Before carrying out this process, the bone surface was consolidated with Paraloid B-72® at 5% in acetone. The gauze coverings consisted of cotton gauze strips of varying sizes applied in a criss-crossed manner (which facilitates its removal) with B-72 consolidant at 10% and 15% in acetone (Figure 10A). In some cases, the team was unable to place the gauze coverings all at once and so this was done over time as the fossil was being excavated. The need to visualize the fossil with respect to the entire set of bones from this area, in order to carry out taphonomic studies, caused the gauze covering to be removed at a certain time. To that end, we dissolved the consolidant adhering the gauze to the surface with a paintbrush, until the different layers of the coating separated (Figures 10B, 10C). The gauze coating on the largest-sized fragment was removed without difficulty. However, the smaller assemblage of bones fragmented during that process (Figures 10D, 10E). Therefore, this assemblage was extracted, the sediment from the bone’s interior and cortex was removed, and the fragments were consolidated and joined with cellulose nitrate adhesive in situ (Figures 10G-I). Finally, this fragment was returned to its original position in the site so that all the relevant studies to be conducted (Figure 10J).

Figure 9 - Left: Accumulation of fossils in squares C3 and D4, some bones are partially covered in gauze during the 2008 excavation season. Right: A large accumulation of long bones is shown in detail (at least three metapodia are represented), which is characteristic of the central sector (pulled apart 1, Figure 3). Scale in centimeters (Arsuaga et al., 2012; Photos PVRT).
The results were good, though it is unusual to place gauze coatings and remove them from fossils in situ. Finally, the metapodial was moved to the laboratory for cleaning with acetone, which served to remove adhesive residue as well as the consolidant from the surface, after the placement of the gauze coating. In this case, the reconstruction - the joining of both parts - was interrupted by taphonomic studies.

**Humerus of *Bos primigenius***

The following case is a complete *Bos primigenius* humerus from an adult individual recovered during the 2006 excavation season. The state of conservation of the fossil was regular. Some of the bone material was missing: the proximal epiphysis and certain areas of the distal epiphysis (where the condyles are located). It had old fractures in different areas: one longitudinal, which ran along the length of the fossil on both sides and another that was diagonal in the diaphysis and filled with sediment. Furthermore, the most proximal fragment showed several fractures with distortions (Figures 11J-K). This breakage could be due to continuous pressure, leading to an internal microfragmentation. There were also fractures in the distal epiphysis, which hindered the maintenance of its complete morphology during the extraction process.

After considering the general condition of the bone, it was decided to partially coat the fossil with gauze in isolated areas on both ends in order to render the recovery possible. Very specific areas were gauzed: the distal epiphysis and the diaphysis from mid-length to the near end in order to support and restrain the fragments as much as possible (Figures 11A-C). In order to avoid possible morphological losses, the object was extracted together with the sediment, supporting the fossil with aluminum foil to ensure integrity until arrival at the field laboratory, where the packaging was removed and the sub-fossil documented, carrying out a new appraisal of its state of preservation (Figure 11D) after extraction - in accordance with our protocols. In the laboratory, it was decided to eliminate the sediment from the surface and stabilize the fossil (Figures 11F-I). No other intervention was carried out, since the fossil was scheduled for taphonomic studies (Figures 11J, 11K).
Crocuta crocuta hemimandible

This case is an example of minimum intervention, which involves a right mandible from an adult hyena, Crocuta crocuta, from the 2007 excavation season. The mandible had longitudinal fractures joined together by hardened sediment and another transversal fracture that separated the fossil in two halves. It was extracted in two parts with abundant sediment on one of its sides (Figures 12A-C). It was unnecessary to consolidate it or cover it in gauze, since the sediment worked to cement it and the bone material was found in a very good state of preservation. After its transfer to the laboratory, some mechanical cleaning work was conducted with a scalpel point, wetting the sediment surfaces with demineralized water, leaving the fossil pristine for its taphonomic study and subsequent definitive adhesion (Figures 12E-H).

Ruminant atlas

The following case is a description of the intervention carried out on a complete atlas belonging to an adult individual of a ruminant from the 2010 excavation season. This subfossil had old fissures and fractures in all directions, most of which were supported by sediment. It was extracted from the site with excess sediment, especially in the foramen (Figures 13A, 13B). It was transferred to the laboratory and, after performing an organoleptic exam with optical magnifiers, cleaning treatments took place. The sediment was eliminated by wetting it with water to soften it and extract it mechanically with a scalpel point, and then with a wooden toothpick once closer to the bone surface (Figures 13C, 13D). Afterwards, it was consolidated with Paraloid B-72® at 5% in acetone using a syringe on the interior and permeating the exterior of the fossil (Figures 13E-G).

NAVALMAÍLLO ROCK SHELTER: CASE STUDIES

Below are some examples of both in situ interventions and interventions performed subsequently in the field laboratory at Navalmaíllo Rock Shelter. At this site, complete fossils were scarce. Most of the bones were fragments, and were mostly teeth of large-sized fauna. There were accumulations of bone fragments in isolated areas of the site. Some accumulations were found in hearths. Thus, maintaining them in the site was important in order to conduct scientific studies, particularly taphonomic studies.
Upper right premolar of a large bovid (Aurochs or Bison)

The following is a description of the intervention carried out on a premolar from a large bovid, comprised of 12 fragments. It was found in square B21 during the 2010 season. This tooth displayed old fractures and surface dirt. Conservation treatments performed were minimal: cleaning with water and reconstruction with Paraloid B-72® adhesive at 30% in acetone (Figure 14). Conservation work served to identify the taxon.
Bones in square C18

Here, we will discuss a group of bones exposed in square C18 during the 2014 season (Figure 15, left). This is a set of bone fragments possibly belonging to different individuals. The state of preservation of some of them was regular as they presented old fractures, laminations and fissures, as well as some recent fractures. There was sediment between the fossils (Figure 15A). The team opted to demarcate each bone fragment and later individualize the treatments. Regarding the bone fragment located in the center (the largest as observed in Figure 15A), consolidation with Paraloid B-72® at 5% in acetone applied with a syringe on the interior, and permeating the exterior of the fossil of consolidant with Paraloid B-72® at 15% in acetone was decided upon in order to avoid further decay, as well as to join the fragments with new and old fractures to avoid displacements (Figures 15B, 15C). In the other two cases, the decision was made to coat them with gauze, one in an isolated area and another on all visible bone surfaces. These treatments were performed to avoid the loss of fragments (Figures 15E-G). The fossils were extracted separately and transferred to the laboratory.

The results were good as the bones were stabilized by the treatments performed (the consolidation, adhesion and gauze) and losses were avoided. In this square, four fossils received interventions out of a total of 92 that were found; thus, intervention was minimal.

Accumulation of bones in square B20

An accumulation of bones was found in 2014 in square B20. This included an assemblage of bone, lithic and blackened limestone fragments, small in size, most of them burned, which were believed to belong to a hearth. All of the bones were found thermally altered (Figures 16A-C).

Their state of preservation was generally poor. Different levels of decay and alterations on the bones were present, e.g. discoloration produced by combustion (darkening of the bone surface all the way up to complete blackening, even calcination; Figure 16F). In addition, the bones were found fractured, fissured, with root marks,
etc. Due to the delicate state of preservation of some of the bone fragments, not all could be saved; therefore, it was necessary to collect information about the set in the site itself. At the end of the 2014 season, there had been one day of torrential rains and, despite having covered the site with plastic tarps, the water penetrated the site and carried the sediment and some materials all over the square from North to South, causing some dislocation. The square was left to dry at ambient temperature for two days, after which it was confirmed that some bones could not be saved (Figures 16D, 16E).

Figure 16 - left: ground location of the accumulation of bones from the possible hearth in square B20 of the Navalmaillo Rock Shelter: A) superior view of the square; B) and C) details of the hearth with the lithic and bone; D) and E) details of the square after a big storm; F) remains of a bone fragment with discoloration caused by fire after treatment.

Figure 17 - Assemblage of bones in squares AN-AN 30. A-C) Views of the gauzing procedures and D-G) extraction of some fossils during the 2013 campaign. Fossils as they arrive at the laboratory (Photos: PVRT).
Assemblage of bones in squares AN-AÑ 30

In this last case, we will discuss another concentration of bones (accompanied by lithic finds): the bone assemblage in squares AN-AÑ 30, exposed during the 2013 and 2014 excavation seasons. This involved a set of fragments, especially parts of a diaphysis of a long bone (Figures 17, 18). They were found at different orientations and slopes. Some were piled up and/or superimposed. Most of the fossils exhibited fissures, laminations, and old fractures with imbricated sediment. The fractures were longitudinal, transversal and diagonal. In many cases they were very small, which is why, during the excavation, fragments tended to separate from the set, which resulted in bone decay and loss of information (Figures 17, 18). In this case, the state of preservation was evaluated as the bones were exposed. At the outset, it was decided to place gauze on those bones that were found in the worst state of preservation (Figures 17A-C) in order to facilitate continuity in the excavation work. Later, they were collected and wrapped in tissue paper and aluminum foil to properly support the fossils, and they were placed in a perforated polyethylene bag with an identification tag for their transfer to the laboratory (Graphic 1; Figures 17D-G).

The importance of this assemblage and its resulting taphonomic study required that the bones remained in situ. However, application of gauze in the other cases would have prevented a complete interpretation of the context. Therefore, rather than placing gauze on the bones in the following interventions, we opted for applying an adhesive layer (cellulose nitrate or Paraloid B-72® at 40-50% in acetone) on the surfaces in the following interventions to protect the bone surfaces, as well as to keep them in their positions, allowing a complete interpretation of the context and future taphonomic studies (Figures 18B-H). All of these processes were accompanied by exhaustive graphic and photogrammetric documentation.

This assemblage suffered the consequences of a large storm that caused mud to infiltrate many areas of the site at the end of the 2014 season. Squares AN-AÑ 29-30 was covered in mud despite the site being covered by plastic tarps (Figures 18A-D). After assessing the damage, it was decided not to excavate for two days and to leave them uncovered to air-dry (Figures 18I, 18J). In the following, the mud covering the surface was removed, using wooden toothpicks to prevent damaging of the bone surface. In some cases, ethanol was applied to the bones by dripping to accelerate evaporation and to remove moisture from the fossils. Once they were dry, they were extracted from the site, leaving only the bones at the center of the excavation in situ (Figures 18I-L, bottom).
Most of the treated fossils were extracted without difficulty. The bones that remained on the surface were protected with geotextile, Arlite®, and expanded polyurethane. Thanks to the treatments, taphonomic and archeological studies were made possible.

**BUENA PINTA CAVE: CASE STUDIES**

Some examples of interventions in situ at the Buena Pinta Cave and at the field laboratory are described. Bone representation at this site was fragmentary, with very few complete bones: tarsals, carpals and phalanges, as well as an occasional mandible.

**Maxillary fragment of a hyena (Crocuta crocuta)**

The first example presented from this site is a maxilla of the species *Crocuta crocuta* (hyena), from an immature individual, exposed during the 2006 excavation season. The bone had sediment on its surfaces along with root marks (Figures 19A, 19B).

Stabilization treatments performed to conserve it for its future study included local cleaning with demineralized water, without completely submerging the fossil, and surface consolidation (Figure 19). This case did not present difficulties, but the importance of the fossil made a taxonomic study essential.

**Tortoise shell fragments**

On the last day of the 2013 season, fragments of a tortoise shell and a long bone were exposed in square G51. The team opted not to retrieve them because it was suspected that there would be more fragments belonging to the same individual. The fragments were protected by applying Paraloid B-72® at 30% in acetone to the surfaces (Figures 20C-F). Finally, they were covered with geotextile. At the beginning of the 2014 season, the site was uncovered and the fragments were found. Subsequent work revealed numerous fragments belonging to the same fossil. All of the fragments were left in situ until a sketch was made for future handling and studies. Then they were extracted and packaged in independent polyethylene bags, accompanied by identification tags (Figures 20G-I).
Figure 20 - Tortoise fragments. A,B) Excavation process; C-F) Temporary coating with cellulose nitrate applied in 2013; G-I) Fossil fragments undergoing the excavation process in 2014; J) Fragments after excavation (Photos PVRT).

Figure 21 - A-C) Bones in situ: maxilla, vertebra, long bone and vertebra; D-F) Bones after their extraction with sediment; G-I) Cleaning processes (Photos PVRT).
Maxilla, vertebra and long bone fragment of Equus hydruntinus

The set of bones from Equus hydruntinus (Hidruntinus) is composed of a maxilla, a vertebra and a long bone fragment from the 2009 excavation season, when they were found piled up in the NW corner of square 352. There were several fragments with old fractures held together by sediment (Figures 21A-C). The treatments of these fossils were performed in three stages: excavation in situ, elimination of the sediment in the field laboratory, and cleaning and reconstruction in the research center laboratory, which allowed for their recognition as three bones (Figures 21-23).

On site, the team decided to extract the bones in two stages: first, the exterior part of the maxilla with the teeth attached and second, the rest of the assemblage, with excess sediment to prevent fragments from detaching (Figures 21A-C). They were packaged and moved to the field laboratory, where the excess sediment was eliminated and all the fragments were separated from each other (Figures 21D-I). They were packaged and then brought to the research center, where cleaning treatments with demineralized water were performed. The teeth were cleaned by submersion, but the bone fragments were cleaned with a paintbrush to minimize the addition of moisture and to facilitate their drying. Once they were dried at ambient temperature in a controlled manner (avoiding heat from the light). They were consolidated and reconstruction commenced on each bone separately (Figures 22, 23A-C).

Figure 22 - Different views of the vertebra (A-C) and the long bone (D); E-F) packaging after their intervention of vertebra and long bone of Equus hydruntinus (Photos PVRT).

Figure 23 - Maxilla of Equus hydruntinus. A-C) Assemblage process; D-G) Maxilla after the conservation process (Photos PVRT).
The results were optimal, as it was possible to conduct taxonomic studies. Consequently, a first vertebra (atlas; Figures 22A-C), a diaphysis of a long bone (Figure 22D), and a maxilla (Figures 23D-G) of a horse were identified as belonging to the species *Equus hydruntinus*. After the study, the maxilla became part of a permanent collection at the MAR in Alcalá de Henares.

**PREVENTATIVE CONSERVATION AT THE PINILLA DEL VALLE SITES: STATISTICS AND SPATIAL CONSERVATION.**

In this brief section, some data will be presented, as well as the first conclusions concerning a conservation methodology that is starting to be applied in the field of conservation, and which we hope provides good results in upcoming on site work during excavation. It is important to highlight the documentation of the work carried out in the field laboratory. The processes associated with conservation are conducted in the field and they are recorded in a log that, in turn, is integrated into the excavation's general field log. The information collected in the log is associated with extractions, bones that will remain in situ, water run-offs, changes in sediment (geological/archaeological levels) or any unforeseen event that must be noted for future study.

In the laboratory, we work with a FichaModelo© (Model Form) modified from the Atapuerca team that is integrated into a general database. Thus, relevant information about each fossil, including archaeological, paleontological, taphonomic, and conservation information, is always kept together, which facilitates interdisciplinary work. For us, this is a key factor for creating preventative strategies.
Members of this team already presented this format at the past CotArq Conference (Other Archaeologies; Pastor Pérez and Canseco Domínguez, in press). In this regard, we have developed a method, which we call "spatial conservation" that combines the use of GIS with statistics applied to conservation-restoration interventions, allowing for mapping by area in each of the sites (Figure 24).

For this mapping, which is still in experimental stages, different variables are taken into account, and are combined to designate a risk level in each one of the squares in our sites. To work with this data, we have chosen a Northern sector of the Navalmailllo Rock Shelter and calculated the statistics in accordance with the fossils that have been treated, because, for us, this is more representative from a risk assessment standpoint (this can also be done following other criteria).

There are various possibilities since we also provide an analysis by square (Figure 24, left), comparing different treatments applied to the same elements: consolidation in situ or in the laboratory, states of preservation, or the total amount of treatments carried out on the finds / objects from a quantitative point of view (Figure 24, right). Furthermore, we can make comparisons among squares and work with the chronological variable to plan upcoming seasons ahead of time.

As can be observed in the figures, not all of the squares can be mapped because in some cases, there are not enough samples available for study, mainly because the state of preservation of most of the fossils does not require any treatment.

Working with the same tools used by our teammates, such as archeologists and paleontologists, facilitates conservation work at all levels and improves communication between different specialists. All of these actions have a very positive impact on the conservation of the extracted materials.

RESULTS

To conclude, we present a synthesis of the methodology followed by this team since 2006, which was when the current restoration team started. In the analysis, the number of excavators and sites excavated annually must be kept in mind. The opening of a new site, Des-Cubierta Cave, in 2009, and the need to broaden the areas of excavation caused us to reconsider the need to increase the number of people participating in the excavation seasons each year. In other words, in 2006, the team was formed by approximately 20-25 people, of which two or three were from the conservation team. The members of the team progressively increased until reaching its current size of approximately 80 people, of which between six and ten were conservators in 2014. These data are reflected in the increase of extracted materials and therefore the increase in fossils, along with the resulting conservation treatments.

A constant factor in our work at these sites is the completion of organoleptic analyses on the state of conservation before, during and after excavation in the laboratory; it is a system that is not only used to evaluate the state of the fossils, but also to evaluate the treatments we perform on them.

As we have seen over the course of this work, the pathologies that are produced in each one of the three sites are very distinct, just like each fossil found there, depending on its positioning and morphology. Each one of the discussed interventions is conditioned by multiple factors. Fossil recovery with minimum intervention and the preservation of the integrity of all parts of the bones is our main priority/objective, but in each case, we must adapt to the rest of the team's needs. When contemplating the study of the position of a bone deposit, we consider block consolidations or extractions, in which we use more chemicals.

On the contrary, when we have to extract a fossil from an assemblage, we opt for isolated consolidation or temporary adhesion, which facilitates its reconstruction in the laboratory. We constantly rely on sketches of the objects, made on polyethylene film, or on colored photographs. All of this documentation later accompanies the object to the laboratory or to its definitive storage, facilitating its future
review. In many cases, it becomes necessary to leave the fossil semi-exposed until the following season, which forces us to place high resistance gauze coatings as well as a protective framework with polyurethane foam which, when mixed with Arlite®, provide a buffer against climatic effects and the presence of snow during the winter in the Lozoya Valley.

The effectiveness of the conservation strategy implemented by this team between 2006 and 2014 is analyzed below (Figure 25). The database represents the state of conservation for a total of 36,011 records, with only 450 cases (1.25%) of in situ intervention and/or field laboratory treatment. These data confirm that in the cases, in which the archaeological and/or paleontological materials have been treated, the principle of minimum intervention has also been followed, meaning that preventative or curative conservation processes took precedence over those of restoration.

Camino Cave, as we have seen, presents its own issues within the sites of Pinilla del Valle due to the large amount of complete fossils recovered. The supervision of each and every one of the 1856 objects has been constant, which has allowed us to reduce direct intervention to the indispensable minimum: in this case, just 110 fossils (9% of the total; Figure 26). This represents the highest percentage out of the three sites and it mainly encompasses actions associated with the consolidation and placement of gauze on the materials in situ allowing for information to be preserved that otherwise would have been lost in the process of excavation and study.

At Navalmaillo Rock Shelter, which is still under study, the same strategy has been followed as at the previous site, recording a total of 26,079 objects. Interventions have only been carried out when necessary. The general state of preservation of the extracted bones is good, which has made it possible to restrict direct intervention to 256 fossils (2% of the total; Figure 27). We can highlight that these actions are often associated with accumulations of bones in certain isolated areas of the site. Additionally, a new methodology has been applied, which consists of the application of an adhesive layer onto the surfaces instead of placing a gauze covering. The results have been optimal as we have prevented the disintegration of the fragments that make up a bone, while they were forced to remain at the site and, at the same time, spatial archaeological and taphonomic studies have been conducted.

Finally, Buena Pinta Cave, like Navalmaillo Rock Shelter, continues to be studied and by 2014, it has the lowest intervention ratio of the three sites, counting just 84 of 1856 fossils (0.3%; Figure 28). The good state of preservation of these bone fossils and the scarce number of complete bones has required direct action only on very few occasions.
Figure 26 - Camino Cave, total of recovered objects vs. treated objects from 2006 until 2009.

Figure 27 - Navalmaíllo Rock Shelter. Total of recovered objects vs. objects that received treatment from 2006 until 2014.
The method of preventive conservation can be very efficient. In the long term, we are attempting to integrate it into a comprehensive risk management plan for the sites. The premise of "anticipating the damage" or prevention requires an initial investment of time and resources, carrying out an exhaustive analysis of the sites that results in long-term conservation strategies. Risk management is being applied to collections, urban landscapes and archaeological excavations in different countries (Kamermans et al., 2009; Michalski & Pedersoli, 2009; Reinar & Westerlind, 2010; Cohen & Fernández Reguera, 2013; Antomarchi et al., 2014), with Petra (Jordan) being perhaps the most significant to date (Cesaro et al., 2012; Paolini et al., 2012). The combination of these methodologies in the Pinilla del Valle sites positively influences both the long-term preservation of the environment as well as the creation of synergies among all members of the technical team.

Since this is an excavation in which experts and many volunteers participate, important education and training is directed at all those students, who wish to collaborate with the conservation technicians. One of the responsibilities of the excavation team includes disseminating the results to the society. The results from each excavation season are presented to the general public and to the press through a selection of materials.

**CONCLUSIONS**

The study of the state of conservation of the materials from the Pinilla del Valle sites has allowed us to gain an understanding of fossil-specific issues, depending on the use or function of each site during the Pleistocene and the concrete post-depositional processes in the different sites. Fossil state of preservation and extent of decay vary, depending on whether it was a space...
occupied by carnivores or by humans, specifically by Neanderthals as was the case here, since each group manipulates bones differently. Another relevant factor that must be taken into account is the type of bone, and if it is complete or fragmented. On the other hand, we must consider whether these fragments are fractured by animals or humans, if the breakage has been produced by collapses, by geological agents or by external agents, etc. In this regard, the specialized training of conservators, as well as knowledge in excavation and fossil analysis, is essential for the assessment of which treatments are necessary to be carried out, in addition to the correct methodology of recovery of the objects and the information they provide.

Understanding fossil morphology is of key importance, because knowledge of the anatomy is the best guide for the proper recovery of the bones. Likewise, we must be aware that these objects will be published in scientific literature, which is why it is important to keep in mind all aspects of the fossil: surfaces, raw material, length, etc. (López-Polín, 2012).

From the aspect of object treatment, ensuring the stability of the fossils has taken precedence, which prevents greater decay and allows for a complete interpretation of the object as a whole. Here, we highlight the importance of exchanging opinions, keeping in mind the needs of each professional involved for the purpose of scientific research. The ultimate goal is to gain a better understanding of the Neanderthal way of life and habits, as well as of the characteristics of their environment.

The present study seeks to provide a contribution to all professionals who work with paleontological material in terms of providing a protocol of the methodologies applied to the preservation and conservation of fossil specimens starting from the moment they are excavated until they are stored at the research center (Ortega et al., 2009). We emphasize the importance of working with a trained professional in this field within an inter-disciplinary scientific team.

ACKNOWLEDGMENTS

This research was conducted under the auspices of the project S2010/BMD-2330 funded by the I+D activities program for research groups run by the Education Secretariat of the Regional Government of Madrid. The study was also partly funded by the following organizations: Museo Arqueológico Regional de la Comunidad de Madrid, Grupo Mahou and Canal de Isabel II Gestión. We want to thank the Pinilla del Valle excavation and restoration team for their work in the field: Rosa Huguet, María del Carmen Arriaza, Marian Galindo, Ana Álvarez, Abel Moclán, Nohemi Sala, Nuria García, Diego J. Alvarez-Lao, Ana Abreuñosa for Portuguese translation and Lauren Ames for the English revision of the text. 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).

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