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PREFACE

This special volume collects the work of some of the attendees and the international guests to the 1st International Conservation Symposium-Workshop in Natural History Collections, organized by the CRIP (Centre of Paleontological Restoration and Interpretation) of Els Hostalets of Pierola, Barcelona (Spain), together with the Museum of Natural History of the Smithsonian Institution of Washington (USA) and the National Museums of Scotland in Edinburgh (UK).

This international symposium aimed to create a workspace and study around the concepts of protection and conservation of Natural History Collections, deepening the knowledge and analysis of the different working methods used in this type of collections.

Participation in the symposium was a great success with over 80 participants from different parts of the world: Norway, Denmark, Sweden, Israel, Germany, England, Portugal, USA, Australia and Spain.

This first international meeting was a great space for discussion and exchange of experiences, very dynamic and profitable, where professionals from around the world debated and reflected around the conservation, preparation and restoration of Natural History Collections, establishing ties of professional and institutional collaborations among the participants.

The symposium organizing committee wishes to thank all participants and collaborating institutions whose participation has made this meeting possible. And also we want to thank the Journal of Paleontological Techniques for the realization of the Symposium Volume. The team of the Journal of Paleontological Techniques put a lot of effort in editing and publishing this volume monograph.

Organizing committee

Sandra Val – Centre de Restauració i Interpretació Paleontològica (CRIP)
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<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preface</strong></td>
</tr>
<tr>
<td>Sandra Val, Steve Jabo &amp; Vicen Carrió</td>
</tr>
<tr>
<td><strong>Table of Contents</strong></td>
</tr>
<tr>
<td><strong>Excavation</strong></td>
</tr>
<tr>
<td>In situ conservation strategies: a case study of archeopaleontological remains from the Early Pleistocene site of El-Kherba (Ain Hanech), Algeria</td>
</tr>
<tr>
<td>Elena Lacasa-Marquina, Pilar Fernandez-Colón, Aldjia Hamlat, Latefa Marouf, Zoheir Harichane &amp; Mohamed Sahnouni</td>
</tr>
<tr>
<td>Bones and sediments: part of a synergetic continuum</td>
</tr>
<tr>
<td>Gail Gali Beiner &amp; Rivka Rabinovich</td>
</tr>
<tr>
<td><strong>Preparation</strong></td>
</tr>
<tr>
<td>Preliminary results on the chemical preparation of dinosaur eggshells</td>
</tr>
<tr>
<td>Sandra Val, Rubén García &amp; Domingo López</td>
</tr>
<tr>
<td>Preparation of a turtle fossil from the Pliocene site of Camp dels Ninots (Caldes de Malavella, Girona, Spain)</td>
</tr>
<tr>
<td>Souhila Roubach, Bruno Gómez de Soler, Gerard Campeny Vall-Llosera &amp; Juan Ignacio Morales</td>
</tr>
<tr>
<td><strong>Conservation</strong></td>
</tr>
<tr>
<td>The Bristol Dinosaur Project – a conservation and preparation overview</td>
</tr>
<tr>
<td>Pedro A. Viegas &amp; Michael J. Benton</td>
</tr>
<tr>
<td>Two examples of preventive conservation actions in the Museu de Ciencies Naturals de Barcelona (MCNB): inspection of specimens and substitution of packaging</td>
</tr>
<tr>
<td>Maria Vila, Marta Pérez, Olga Muñoz &amp; Eulàlia Garcia-Franquesa</td>
</tr>
<tr>
<td>Restauration of mounted animals – new techniques in old taxidermies</td>
</tr>
<tr>
<td>Angel Blanco &amp; Gema Solis</td>
</tr>
<tr>
<td>Procedures and materials used in the mounting of two birds which belong to the Natural Sciences National Museum (MNCN-CSIC) and the Complutense University of Madrid (UCM)</td>
</tr>
<tr>
<td>Rita Gil Macarrón, Sonia Santos Gómez, Luis Castelo Sardina, Margarita San Andrés Moya &amp; Andrés Sánchez Ledesma</td>
</tr>
<tr>
<td>Pollutants in the museum environment – minimizing damage in storage and display</td>
</tr>
<tr>
<td>Pamela Hatchfield</td>
</tr>
<tr>
<td>Exploring the common ground between organic artifacts and natural history specimens: we share problems – can we share solutions?</td>
</tr>
<tr>
<td>Allyson Rae</td>
</tr>
<tr>
<td><strong>Collection Report</strong></td>
</tr>
<tr>
<td>The collections of vertebrates of the Estación Biológica de Doñana (CSIC). Origin and evolution</td>
</tr>
<tr>
<td>Teresa García-Díez, M. Rosario Sempere, José Cabot, Javier Juste &amp; Carlos Ibáñez</td>
</tr>
</tbody>
</table>
IN SITU CONSERVATION STRATEGIES: A CASE STUDY OF ARCHEO-
PALEONTOLOGICAL REMAINS FROM THE EARLY PLEISTOCENE SITE OF
EL-KHERBA (AIN HANECH), ALGERIA

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ABSTRACT

Dated to circa 1.8 million years ago, the site of El-Kherba (Ain Hanech, Algeria) yielded a Plio-Pleistocene fauna
associated with Oldowan stone tools that are pertinent for documenting the earliest human occupation in North
Africa. Some of the remains of large and medium-sized vertebrate fauna present a poor state of preservation due
to three critical factors: 1) the severe contrast between climatic conditions of air and soil ecosystems; 2) the pre-
and post-depositional alterations; 3) the nature and properties of the sub-fossil remains. The Centro Nacional de
Investigación sobre la Evolución Humana (CENIEH, Burgos, Spain) and the Institut d’Archéologie de l’Université
d’Alger 2 (CNRPAH, Algiers, Algeria) have collaborated on a Project funded by the Agencia Española de
Cooperación Internacional para el Desarrollo (AECID) aiming to provide immediate solutions for preserving fragile
sub-fossil bones and to develop conservation strategies in order to ensure the long term preservation of this
valuable archeo-paleontological heritage.

Keywords: In situ conservation strategies, remedial conservation, preservation, agents of degradation, climate
fluctuation, semiarid environment, sub-fossil bone, Early Pleistocene, North Africa

RESUMO [in Portuguese]

Datado de há cerca de 1.8 milhões de anos, o sítio de El-Kherba (Ain Hanech, Argélia) revelou uma fauna do Plis-
pleistocênica associada a indústrias líticas do Olduviense que são relevantes para documentar a ocupação
humana mais antiga no norte de África. Alguns dos restos de fauna de vertebrados de porte médio e grande
apresentam-se em mau estado de conservação devido fundamentalmente a três fatores: 1) o rigoroso contraste
entre as condições climáticas do ar e do solo destes ecossistemas; 2) alterações pré e pós-deposição; 3) a
natureza bem como as propriedades dos restos fósseis. O Centro Nacional de Investigación sobre la Evolución
Humana (CENIEH, Burgos, Espanha) e o Institut d’Archéologie de l’Université d’Alger 2 (CNRPAH, Algiers, Argélia)
estão a colaborar num projeto financiado pela Agencia Española de Cooperación Internacional para el Desarrollo
(AECID) tendo em vista promover soluções e desenvolver estratégias de conservação, com o intuito de assegurar
a preservação a longo prazo deste importante património arqueo-paleontológico.

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INTRODUCTION

The conservation of archeo-paleontological heritage is a discipline that aims at preserving these remains as they hold a wealth of scientific evidence about evolution that must be safeguarded for present and future generations. In this sense, the definition and implementation of an effective conservation management plan, for short, medium and long term becomes particularly important as a measure to ensure their safeguard. The strategies integrated in this plan should provide technical solutions through direct or indirect actions in order to avoid, minimize and arrest the potential and current damaging processes which could affect the remains. All measures and actions should respect the significance and the physical properties of the cultural heritage item (ICOM-CC, 2008). For that reason, a pre-analysis consisting of examining the state of preservation of the archeo-paleontological materials and the identification of the exogenous and endogenous risk factors affecting their physical and chemical integrity, is crucial to define an effective conservation plan.

The collaboration between the CENIEH and the Institut d'Archéologie de l'Université d'Alger 2 has enabled the definition and implementation of a preliminary conservation management plan in order to provide solutions to the specific degradation problems found in the sub-fossil remains of El-Kherba. The pre-analysis includes the evaluation of the state of preservation of a bone sample and the identification of the potential and current risk degradation factor through the study of the geological and sedimentary conditions, the aerial environment, and the interaction between all these factors.

EL-KHERBA SITE BACKGROUND

The site of El-Kherba is located on the edge of the eastern Algerian High Plateaus near the city of El-Eulma in the province of Sétif (northeastern Algeria). It was discovered in 1992 in the course of an archeological survey of the Ain Hanef study area. The site is part of the Ain Hanef Plio-Pleistocene site complex, and situated 350 m south of the classical locality of Ain Hanef (Sahnouni, 1998).

El-Kherba yielded a rich savanna-like, fauna associated with Mode I stone artefacts, technologically and typologically Oldowan (Sahnouni, 1993, 1998, 2006). The faunal assemblage is dominated by large and medium-sized animals (mainly adults), and comprises Proboscidean, Equidae, small and large Bovidae, Giraffidae, Suidae, and Carnivora (Sahnouni and van der Made, 2009).

El-Kherba and Ain Hanef classic site are contemporary, with an estimated age of 1.78 Ma (Sahnouni et al., 2002, 2004, 2011; Sahnouni and van der Made, 2009), and were formed within the Plio-Pleistocene floodplain deposits of Beni Fouda sedimentary basin. They are both contained in the cyclothemic Unit T (Figure 1) of the Ain Hanef Formation, which is of fluvial origin and consists of a stratified medium energy layer in the lower part and a silty deposit in the upper part (Sahnouni and de Heinzelin, 1998). El-Kherba comprises three different archeo-paleontological levels of variable thickness: A=70 cm, B=40 cm and C=50 cm (Sahnouni et al, 2002).
archeological level [X-ray Diffraction analysis (XRD)] indicates the presence of two principal minerals, quartz and calcite, whereas kaolinite is detected in a smaller proportion (Sahnouni, 1998). Additionally, the stratigraphic evidence based on the sedimentary matrix, the taphonomic conditions of the bones and the spatial disposition of the archeological materials, show that the archeo-paleontological remains were buried in primary context and were minimally disturbed (Sahnouni et al., 2013). Likewise, the bone weathering patterns do not infer long sub-aerial exposure, suggesting that the depositional process prior to burial was relatively short, less than three years (Sahnouni and de Heinzelin, 1998). However, the majority of the sub-fossil bones are fractured caused by both biostratinomic and postdepositional taphonomic processes. Taphonomic evidence indicates that early hominins were largely responsible for the modification of animal bones (Sahnouni et al., 2013), but other factors such as sediment compaction could be responsible for their degradation during burial.

MATERIALS AND METHODS

The definition and implementation of conservation strategies required a preliminary analysis of the state of preservation of a bone sample representative of the typical dynamic of degradation at the site of El-Kherba.

Sample
The studied sub-fossil sample comprises 24 bone specimens excavated from level B during the 2012 fieldwork season. According to Collins (1988), a sub-fossil bone is a bone that has been subject to sub-aerial weathering and then burial, but has not been subjected to any secondary mineralization (Shelton and Johnson, 1995). The selection sample was based on the vulnerability degree of the specimens against the external climate degradation agents, and on the technical complexity of the strategies that had to be developed for recovering them and ensure their preservation. The sample includes 12 axial skeleton (50%), six appendicular (25%), and six undetermined bones (25%).

Methods
The methodology includes two interrelated phases. The first phase consists of analyzing the potential alteration risks – before, during and after burial – for understanding the dynamic of degradation of sub-fossil bones. Thus, the study of the state of preservation of the remains is based on the examination of their nature and properties in correlation with the geological and sedimentary context, as well as on the sub-aerial environmental conditions. The analysis for the identification of exogenous agents of deterioration during biostratinomic and diagenetic processes has been performed by consulting the published literature dealing with the geology and archeology at Ain Hanech. The analysis of climate dynamics has been carried out over the 2012 annual period and, more specifically, during the fieldwork season (23rd of June -10th of July). The reference data of temperature (T), relative humidity (RH) and precipitation rate (RRR) were taken from the weather station of Sétif International Airport, located 30 km southwest from El-Kherba. The recorded daily data cover a sampling interval of every three hours during a period of one year representing the natural oscillation cycles: daily, seasonally, monthly and yearly (Table 1). Despite that the distance between the weather station and the archeological site may imply a slight variation of the climatic parameters, we must consider it as an initial approach to understand the environmental regional dynamics. Besides, it can be regarded as an immediate and preliminary technique before develop in situ technical facilities in order to obtain a more detailed study. The quantitative data have been processed for undertaking a statistical analysis based on statistical variables and the interpretation of graphic representations. Characterization - average – and dispersal parameters to deduce disturbances and evaluate the representativeness of the data – maximum, minimum, oscillations and standard deviations.– have been obtained with the aim of determining the environmental conditions, and verifying if these climatic parameters are within the proper range of preservation of the sampled sub-fossil remains (Pastor, 2013). Likewise, the graphical representation of the data has been performed by time-series graphs and histograms. These graphs allow us to detect climatic parameters outside the optimal preservation range and to quantify the relevance of these extreme values. The second phase consists of defining and implementing remedial conservation strategies, in order to arrest or minimize the potential risk agents of deterioration, based on the results obtained in the previous phase.
RESULTS

The results of the organoleptic analysis on the state of preservation of the studied sample present a general degradation stage defined by physical damage such as perpendicular and parallel breaks (Figure 2); split line cracks (Figure 3); exfoliation and delamination of the cortical surface, distortion, loss of external surface, and presence of roots (Figure 4). Likewise, the majority of sub-fossils were covered by a medium hardness layer of calcium carbonate. Over this layer, or directly in contact with the bone, a compact silt-clay sediment matrix with prismatic structure encased the specimens (Figure 5). The quality of the state of preservation of the bone surface depends on the presence of the calcium carbonate layer and on the anatomical part represented. For example, generally teeth and metapodials are in a better state of preservation than ribs.
Based on Ain Hanech and El-Kherba published literature, the study and identification of agents of deterioration during depositional and burial periods allow us to infer that pre- and postdepositional degradation factors would not be decisive to justify the poor state of preservation of sub-fossil bones after unearthing them (Sahnouni, 1998; Sahnouni et al., 2002, 2004, 2011, 2013; Sahnouni and de Heinzelin, 1998; Sahnouni and van der Made, 2009).

The results of the environmental conditions study suggest a climate defined by abrupt daily and seasonal fluctuations of RH and T parameters. The climate in this region is continental with Mediterranean tendency characterized by severe conditions in winter, with snow and frost persisting until spring (Sahnouni, 1998). During 2012, the average RH was 64%, the maximum 100%, and the minimum of 10% on the 6th of August at 4 pm. Likewise, the average T recorded was 14.8 °C, the maximum came to 39.9 °C on the 7th of July at 4 pm, and the minimum reached -9.1 °C on the 13th of February at 7 am. The total RRR was 761 mm and the annual maximum value, 42 mm, was recorded on 31st of January at 7 am. The recorded daily data show that weather during the fieldwork season (23rd of June - 10th of July) was one of the driest and warmest periods throughout the year (Figure 6). The average RH and T were 37.3% and 28.2 °C respectively, and the RRR was almost negligible (2.2 mm). The highest peak of T and lowest of
Table 1: Summary table of climatic data during fieldwork period (23\textsuperscript{rd} of June - 10\textsuperscript{th} of July) obtained from the weather station of Sétif International Airport. The recorded daily data cover a sampling interval of every three hours for T and RH parameters while the RRR is every six hours.
RH occurred during the daylight interval of 1 pm to 4 pm (especially at 4 pm) and they were the opposite at 4 am (Figure 7).

The general criteria for optimal ranges of preservation suggest parameters of RH from 25% to 75% in order to avoid physicochemical damage (Michalski, 2009). The average maximum and minimum RH were 58.3% and 20.5%, respectively. The number of values when the maximum RH was equal or exceeded 75% was at nine out of 143 records, while the minimum RH was equal or below 25% at 40 out of 143 records (Figure 8). In the case of T, the average maximum and minimum were 35.6 °C and 20.3 °C, respectively. The diurnal average variations were 15.3 °C and 37.8% while the maximum reached up to 18.6 °C and 63%. The maximum hourly variation of RH was 34% and the minimum was 12% (Table 2).

<table>
<thead>
<tr>
<th>RH (%)</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Oscillation range</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
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<td>49.9</td>
<td>26.8</td>
<td>23.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Maximum</td>
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<td>84.0</td>
<td>41.0</td>
<td>43.0</td>
<td>11.4</td>
</tr>
<tr>
<td>Minimum</td>
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<td>31.0</td>
<td>12.0</td>
<td>19.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Oscillation range</td>
<td>37.8</td>
<td>63.0</td>
<td>20.0</td>
<td>43.0</td>
<td>10.0</td>
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<tr>
<td>Standard deviation</td>
<td>13.6</td>
<td>22.5</td>
<td>8.4</td>
<td>14.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Maximum hourly variation</td>
<td>21.5</td>
<td>34.0</td>
<td>12.0</td>
<td>22.0</td>
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<table>
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<th>Minimum</th>
<th>Oscillation range</th>
<th>Standard deviation</th>
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<td>31.7</td>
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<td>39.9</td>
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<td>15.5</td>
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<tr>
<td>Absolute Oscillation</td>
<td>24.4</td>
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Table 2: Summary table of the statistical results that are used for characterizing the environmental dynamic during the fieldwork season period (23rd of June -10th of July).
Figure 6: T and RH plot representing the environmental behavior during the fieldwork period. Noted the natural oscillation daily cycles which are typical of an outdoor climatic behavior pattern.

Figure 7: Daily T and RH cycle. Noted the significant correlation between both parameters; when one variable increases the other decreases, and vice-versa.
RH Histogram Field Season Period

<table>
<thead>
<tr>
<th>RH (%)</th>
<th>Frequency</th>
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<tr>
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<td>95</td>
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Figure 8: Graphical representation of frequency distribution of RH data.

T Histogram Field Season Period

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<tr>
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<th>Frequency</th>
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Figure 9: Graphical representation of frequency distribution of T data.
DISCUSSION

The depositional and burial conditions favored preservation of sub-fossil remains. Stratigraphic evidence, sedimentary context, and taphonomic data show that mostly all the alterations documented on the bones did not occur during their accumulation and burial processes. Thus, the alterations due to biostratigraphic and diagenetic processes do not entirely justify their poor state of preservation. Moreover, the physical properties of the soil context – texture, structure and permeability – and also its chemical conditions – pH, RRR, and matrix composition – helped to preserve the sub-fossils and, consequently, a wealth of outstanding information. The sedimentary matrix of level B is mainly formed by silt and clay, which constitute soils characterized by their low-moderate permeability and their ability to retain water. The mineral composition of sediments and the low RRR recorded in the area have favored a tendency towards neutral-basic pH of the soil, optimizing the conditions for preservation of sub-fossil bones. Similarly, the calcium carbonate layer on bones plays a dual role of preservation, as a structural reinforcement and protective coat of the surface, and as a buffering agent of RH.

 Bones are highly vulnerable to external climate changes, especially to RH oscillations, due to their property of hygroscopicity, that is, the ability to absorb or release moisture with changing humidity, swelling or shrinking in response to variations in their moisture content. Thus, the risk of physicochemical damage occurs when sub-fossil remains are subjected to a fluctuation more rapid than their ability to respond evenly (Michalski, 2009). During burial, bones reach a physicochemical equilibrium with the soil context, characterized by almost stable environmental conditions. However, at the moment of their unearthing during fieldwork, sub-fossil specimens are abruptly exposed to new and fluctuating values of climatic parameters. The adaptation process to these new parameters causes the rapid drying of the bones, and consequently, it generates physical damage in the form of exfoliation, cracks, and splits.

The results of the preliminary climatic study show that during the fieldwork season the weather was one of the driest and warmest throughout 2012. Thus, in principle, it may be thought that the climate conditions would be adverse for the preservation of the bones. In particular, the diurnal time interval from 1 pm to 4 pm represents a higher risk of degradation as it shows the lowest values of RH and the highest of T, so the disparity between the values of climate parameters from air and soil context is increased. Also, the results on fluctuation dynamics demonstrate that the climate values of RH are highly and rapidly changeable, both at daily and hourly cycles. Additionally, 34% of the values of these data are outside of the proper range of preservation for bones defined by the general criteria (Michalski, 2009). Nevertheless, the standard deviation and the graphical distribution of histograms show a high dispersion of the data typical for outdoor environments (Figures 8, 9). Therefore, in order to obtain more representative conclusions, it would be advisable to define an environmental monitoring plan, which would cover a sampling interval of one sample of RH and T per hour.

Thus, based on the hygroscopic property of bones, their high degree of vulnerability to rapid fluctuations of RH, and the results of the environmental analysis, we can infer that the climatic factor represents the main risk of degradation for bones. The combination of two factors – the contrasting environmental conditions between air and soil, and the need for bones to reach an equilibrium with the...
surrounding context as a consequence to their hygroscopic abilities – cause the degradation of the El-Kherba vertebrate sub-fossils.

CONSERVATION STRATEGIES

The conclusions of the study on the dynamic degradation of sub-fossil remains within the sedimentary context, and the identification of the real and potential degradation risk factors, have constituted the basis for defining conservation strategies. Likewise, the implementation of treatments was carried out under the principle of minimal intervention and non-interference with future analytical techniques.

The preservation plan includes remedial conservation and restoration measures and actions, as a first step for medium and long terms implementation of preventive conservation treatments. Remedial conservation guidelines are intended to arrest or minimize the effects of the abrupt drying of bones caused by extreme variations in climatic values during their transfer from soil to air settings, and are also intended to reinforce their physical structure. This means that, analyzing local climate allows to establish precautionary rules during fieldwork in order to prevent the exposure of bones to extreme conditions or rapid fluctuations of RH parameters: 1) to refrain from retrieving bones during the driest interval of the day (1 pm – 4 pm), 2) to abstain from extracting bones during elongated time, 3) to avoid leaving the bones overnight in situ so as to prevent potential degradation caused by sharp daily variations.

The remedial conservation treatments carried out at the site consist of implementing rigid jacketing techniques allowing the treated bone specimen to be lifted as a whole and to maintain its anatomy and its original spatial disposition (Shelton and Johnson, 1995; Pedelì and Pulga, 2002; Leiggi and May, 1994;)

Figure 10: Rigid jacketing technique used for the extraction and transport of the sub-fossil sample from the site to the field laboratory.
Laborde, 1986). These techniques act as a structural reinforcement, as a buffering agent of RH and T, and as a proper first packaging layer, which is an essential part of transportation methods for transferring the remains from the archeo-paleontological site to the field laboratory (Figure 10). The appropriate jacketing systems are selected by the size and weight of treated specimens and their structural stability. The procedure involves keeping the sediments and the calcium carbonate layer covering the sub-fossil remains, taking into account the morphology of each sub-fossil (Figure 11) and creating a pedestal for preserving each bone in its sedimentary matrix. The dimension of the pedestal should be equivalent to twice the width of the bone and 10 cm in depth below the estimated thickness of the remains. This helps to improve the maintenance of RH and provides resistance to the prismatic structure of the silt and clay matrix. During the excavation process, the exposed bones should be covered with polyethylene opaque sheeting to avoid the climatic direct effects and the risk of sudden evaporation. Once this is done, the plaster jacketing systems – prepared by several perpendicular and parallel layers of plaster hydrophilic cotton bandages, Hartmann Platrix® – are used for extracting the sub-fossil remains as they provide sufficient rigidity and adhere nicely to the morphology of each bone. The small amount of plaster contained in the bands allows the heat input of the curing process to be almost insignificant, thus not interfering with its role as a buffering agent. However, it is essential to use previously thermal insulator (aluminum foil) as a separator to protect the sub-fossils from wetness and resultant increased humidity, as well as a barrier from moisture and heat input from the plaster bandage (Figure 12). In the case of fragile remains of medium-high volume and weight, a partial or full reinforcement measure is needed using hydrophilic cotton bandages and Paraloid B72® diluted in 10% acetone applied by brush. At this stage of the extraction process, the bottom of the jacketed block needs to be defined before undercutting the pedestal from the in situ rock.

Figure 11: Excavation method is carried out following the natural stratigraphic layers until the bone is isolated on a matrix pedestal. Its position in the stratigraphic section hinders its accessibility at the moment of the extraction.
Figure 12: Plaster jacketing procedure.

Figure 13: Gradual weakening of the matrix pedestal in order to minimize vibration harmful effects on the bone due to mechanical actions.
The use of nails and chisels is required to weaken gradually and systematically the matrix pedestal (Figure 13). Finally, after flipping the jacketed block, the bone specimens are wrapped and sealed with plastic film to keep their RH unchanged and to ensure their safe transfer to the field laboratory where they will receive immediate proper treatments. Thus, remedial conservation treatment were carried out by the gradual removal of the temporary packaging prepared at the site to prevent condensation and to allow the slow loss of humidity until reaching balance with surrounding environment conditions (Figure 14). Finally, when necessary, consolidation and reconstruction treatments are performed for restoring the mechanical strength of treated bone specimens and, thus, ensure their safe transportation to their long-term storage facility (Figure 15).

Figure 14: Field laboratory: gradual removal of the matrix pedestal which is acting as a buffering agent of RH. At this stage, the jacketing plaster system provides structural support to the bone. The picture below shows the calcium carbonate layer covering the specimen surface while progressively drying until reaching an environmental equilibrium.

Figure 15: Restoration actions must keep intact taphonomic evidences. The structural reinforcement comprises volumetric reintegration treatments. A mixture of its own sediment and cohesive materials such as Paraloid B72® diluted in 10% acetone or 5 Minute® Epoxi – exceptionally use in specific heavy weight areas – is applied as a gap-filling material.
CONCLUSION

A conservation management plan should aim to safeguard the archeo-paleontological heritage as they hold a wealth of scientific evidence while ensuring its accessibility to present and future generations.

This paper aims to show the methodological process carried out for defining the basis of effective conservation strategies in the specific case of an archeo-paleontological sample from the site of El-Kherba (Ain Hanech). It should be recalled that the state of preservation of sub-fossil remains is the result of the relation of several endogenous and exogenous factors, namely, the physicochemical structure and properties of bones in correlation with soil and air ecosystem conditions.

The paper also intends to underline the importance of analyzing in-depth all factors of deterioration in order to implement proper conservation treatments and thus to avoid, minimize or arrest any potential or current damage on the remains. The results of our study have allowed us to conclude that severe and rapid daily and hourly fluctuation cycles of RH and T parameters are the main cause of degradation of the sub-fossil sample of El-Kherba.

Far from pretending to establish standard treatments for conservation of archeo-paleontological specimens, this study aims to provide preliminary methodological guidance to other archeological sites located in regions whose climate is continental with Mediterranean tendency and characterized by severe seasonal and daily fluctuations of its environmental parameters.

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

Conservation juggles between fieldwork, work at the lab and the requirements of a frequently-visited research collection. Conservators have little control over field conditions, which are mostly directed by the physical conditions, time limitations and budget restraints. In the field, the actual challenge is to understand the physical conditions, to be aware of the nature of the sediments, their permeability, the effects of hydrological systems, and form an idea of their effect on the condition of the skeletal remains. The conservator has to function in an almost unknown terrain, at least during the first excavation season in a given site. Ideally, research and conservation goals follow the same direction and tempo. In the actual situation, accumulation of taphonomical data of a locality/site is not necessarily in accordance with the process of conservation. Such dichotomy impedes the synergy between research and conservation. Old excavations, revisited several years later, one-day expeditions dealing with incidentally-exposed fossils, long-term excavations: each of these cases poses different challenges. How do these different environments affect the condition of skeletal finds? Can knowledge gained from studies on collagen loss and mineral growth in bone give us insight into taphonomic, as well as diagenetic, processes? Environmental conditions are possibly the main deciding factor for preservation of skeletal material in situ, and therefore also affect working methods on-site. The complex interaction between the environment and the methods we choose for bone conservation merits discussion.

RESUMO [in Portuguese]

A conservação tem de conciliar o trabalho de campo, trabalho de laboratório e os requisitos de uma coleção científica frequentemente visitada. Os conservadores têm pouco controlo sobre as condições no campo, que são maioriaritariamente ditadas pelas condições físicas, limitações de tempo e constrangimentos orçamentais. No campo, o desafio verdadeiro é compreender essas condições físicas, reconhecer a natureza dos sedimentos, a sua permeabilidade, os efeitos do sistema hidrológico e formar uma ideia dos seus efeitos na condição dos restos esqueléticos. O conservador tem de funcionar num terreno quase desconhecido, pelo menos durante a primeira época de escavação numa dada jazida. Idealmente, os objetivos de pesquisa e conservação seguem a mesma direção e tempo. Na realidade, a acumulação de dados tafonómicos de uma localidade/jazida não está necessariamente em concordância com o processo de conservação. Esta dicotomia impede a sinergia entre investigação e conservação. Antigas escavações, revisitadas vários anos depois, expedições de um dia que resultam em exposição de fósseis por acaso, escavações a longo prazo: cada um destes casos coloca diferentes desafios. Como é que estes ambientes diferentes afetam a condição dos achados esqueléticos? Como pode o conhecimento ganho de estudos de perdas de colagénio e crescimento mineral no osso dar-nos pistas sobre os processos tafonómicos e diagenéticos? As condições ambientais são possivelmente o fator decisivo principal para a preservação de material osteológico in situ, e, consequentemente, afetam também os métodos de trabalho na jazida. A interação complexa entre o ambiente e os métodos arqueológicos que escolhemos para a conservação de osso merece discussão.

INTRODUCTION

Efforts at standardizing the assessment of archeological bone have been made (Chavagnac et al., 2007), but they are complicated by the great variety of factors governing taphonomic processes. Current approaches generally tackle geological research and bone preservation as separate entities. This paper aims at considering the possibility of a practical working relationship between these two aspects. Such relationships may be found by looking into the information gained from archeological sites, seeking to understand how they affect bone condition, and in turn considering the implications for bone conservation. Four sites in Israel are presented as examples for this kind of approach, representing different cases of excavation and conservation: long-term excavation, seasonal excavation, renewed excavation and one-day exposure. We will discuss their context and its effect on the condition of the finds. Though spanning a very large time scheme – Miocene to Upper Pleistocene – we will concentrate on the special conditions prevalent in these sites, coupled with modes of conservation and exposure. Most of the material from these sites is under study and the actual identification is incomplete. We will take into account the ongoing nature of the work, and will try to pinpoint possible issues of conflict and suggest ways of reconciliation.

Present day Israel enjoys a relatively high diversity of animal and plant species per square meter. Israel has a small land area, although the country is only about 470 kilometers long, biotopes, topography and climatic elements in it are exceptionally diverse (e.g., Tchernov, 1999:390). Israel is the meeting place of four out of the six phyto-geographical zones existing on our planet: Mediterranean, Irano-Turanian (Steppe), Saharo-Arabian (Desert), and Sudanian (Extreme desert). As such, important landmarks of the hominin species dispersal and exploitation of the environment (hunting, gathering, domestication), are evident in the local archeological sites and form an integral part in discussions on issues such as how and when hominins started hunting, fishing, burying their dead, and when domestication of plants and animals became part of human society.

The following sections will present finds from four prehistoric sites in Israel (Figure 1): Ein Yahav, Revadim Quarry, Erq el Ahmar (EEA) and Nahal Mahanayeem Outlet (NMO). The sites we will discuss are all open-air sites. Under the current climatic system, with short cool winters and long hot summers, the result is difficult conditions for bone survival. Very little organic matter, if any, survives under such conditions. The state of the finds from these sites varied according to the environment, the soil type and the action of water, as well as the type of excavation. The latter factor is the main difference in terms of conservation work.

CASE I: LONG TERM EXCAVATION - REVADIM QUARRY (CA. 300-500 KYA)

Although this was a salvage excavation, the last season had been planned in advance and lasted for several months (Marder et al., 2011). Seasonal changes are complex due to rainfall and the location near a confluence of rivers, with the ongoing work in an active stone quarry adding to the mix. Even the type of sediment from which the bone finds were salvaged, a quartzitic sandy grey loam, is representative of change. This layer was deposited in two stages, the first more humid and the second much drier (Gvirtzman et al., 1999; Marder et al., 2011). Thus, environmental changes were characteristic of this site from the very beginning, and affected the condition of the finds.

Some of the most remarkable finds in Revadim included elephant remains. No conservator was
present on site, but the archeozoologist received a kit including fine medical gauze and Paraloid B72 preparations in acetone, along with work guidelines. Since the descriptions from the site gave a picture of entire, but very cracked and weak bones – instructions were to coat the finds with gauze strips impregnated with Paraloid B72. The point was to keep the cracked parts together until they reached the lab. The gauze system proved very effective in this case and the National Natural History Collections at the Hebrew University, Jerusalem, now include some nearly entire scapulae and pelvises from Revadim.

Some finds were salvaged with one side (the down-facing side) very badly fragmented. An elephant scapula (Figure 2A) was especially fascinating, because cleaning revealed the presence of cut marks (Rabinovich et al., 2012). However, before the cut marks could be seen, there was plenty of grey-brown quartzitic sandy paleosol deposit to be removed. In this case, the matrix had to be removed from in between the fragments. Due to post-depositional processes, some of the matrix accumulation in join areas was not new, and a discussion with the archeologist on morphological traits and the presence of cut marks made it clear that joining the fragments was too important, so post-depositional accumulations were removed from join areas as much as possible. Cleaning involved cotton swabs dipped in acetone plus mechanical cleaning with soft bristle brushes and porcupine quills. The loss of major parts of bone required some creative gap-filling to support the weight of the entire structure. In this case, Japanese tissue dipped in Paraloid B72 and built up in layers proved to be a very efficient, lightweight and cheap filler (as described in Beiner and Rabinovich, 2013). The final result (Figure 2b) was sent out from our lab for photography and 3-D imaging, and was successfully turned over and around by the photographer.

Figure 2: The site of Revadim Quarry, elephant scapula: A) before treatment in the lab; B) after treatment in the lab.

CASE II: SEASONAL EXCAVATION – NAHAL MAHANAYEEM OUTLET (CA. 50 KYA)

The site of Nahal Mahanayeem Outlet (NMO) was exposed during a drainage operation in 1999. NMO is a Middle Paleolithic open air site with faunal, botanical and lithic remains (Sharon et al., 2010; Kalbe, et al., 2013:2). NMO is not under water, at least not during
summer, but it is on the eastern bank of the Jordan River and water wells up from the ground. Every morning, the excavation team bailed out water and continued doing so in intervals throughout the day. Besides the difficulty of distinguishing between the dark brown bone finds and the surrounding dark brown mud (Figure 3A), a main problem was that all exposed material began deteriorating immediately. The condition of the bones seemed pristine, but they tended to fall apart easily when exposed. Valuable morphological and taphonomical data was lost. After several seasons, it became clear that on site constant conservation was required. Paraloid B72 does not work under such conditions, and other more water-friendly products such as Primal WS24 also have a problem if they do not have the time to set before more water enters the system. Communication with underwater marine archeologists in effort to search for solutions yielded that apparently, other than using freshly prepared Plaster of Paris mixture inside plastic bags as a kind of cushion, there are not many possibilities for supporting and consolidation in active waterlogging conditions. Some of the ideas tested included making a temporary jacket (over a barrier layer) out of plumber’s putty, or reinforcing weak areas with cyclododecane (CDD) before they became waterlogged. The putty proved too weak and friable as a supportive jacket for lifting bone. Experiments with CDD actually proved to be of utmost importance. Care was taken to slow down the drying of the bones by putting salvaged finds in containers covered with polyethylene. The polythene layer was slit to prevent mold growth, and no paper bags were used in direct contact with the wet finds. Each find was padded with a good amount of bubble wrap, in an open packaging which made the padded product open enough to allow for air circulation.

Salvaged material is currently being treated in the lab, with damp and semi-dried mud being removed into plastic bags and surfaces cleaned with acetone and saliva on swabs. It appears that the protection offered by the cover of the matrix and the slow-drying in the field lab helped preserve many more features of the bones (Figure 3c).

CASE III: RENEWED EXCAVATION – ERQ EL AHMAR (LOWER PLEISTOCENE)

The Erq el Ahmar (EEA) site was excavated by the late Prof. Eitan Tchernov, following parts of an elephant tusk found during survey. The elephant skeleton parts exposed by the Tchernov expedition had been preserved on a floodplain with active soil formation (pedogenesis) with small fluvial channels nearby, during a regressive phase of the lake (Feibel, 2004:24). Parts were extracted by the Tchernov expedition after coating, or partial coating, in a heavy plaster of Paris jacketing (Figure 4). The jacketed finds were kept in a store until very recently, but had deteriorated very badly within the jackets, presumably due to a process of dehydration connected with the presence of the plaster. Most of the skeleton was left in situ, with an unidentified applied to part of the bones and a cover of newspapers. Some of the bones had been plastered over and marked with metal stakes. At the end of that expedition, the site was covered over with nearby sediments, and further covering occurred as the area eroded out. The previously exposed bones and new parts of the skeleton were uncovered by our team in 2013. It was noticed that although the metal stakes correctly marked out the location of the bones, the plaster had apparently caused serious dehydration and powdering. A conservator (GGB) was part of the 2013 excavation team, so there was an opportunity to try different methods on site. Since the exposed bones were dry and very fragmented, with tendency to powdering, the material of choice was Paraloid B72 (with acetone as a solvent due to safety limitations). The team members were asked to drip or inject Paraloid B72 on exposed bone finds. Our first procedure of choice involved coating large finds with gauze, as in the Revadim Quarry, in effort to
Figure 3: The site of Nahal Mahanayem Outlet, waterlogged scapula: A: In situ, waterlogged; B: Coated with gauze soaked with Primal WS24; C: Scapula from NMO after treatment in the lab.

Figure 4: The site of Erq el Ahmar: finds from the Tchernov expedition, 1989.
keep the fragments together. When a very large tusk was exposed, with at least 4 break areas and some very weak parts, concerns about the weight led to the preparation of a light partial jacket for the more fragmented part out of plaster bandages. As expected, the difficult part involved moving the tusk. We only had ten days of work on this excavation so we could not slow down work to coat the underside and consolidate the tusk completely before moving it. It was moved in three sections, and the underside was damaged in the move. A fourth, but failed, method involved using polyurethane. Barrier layers were created out of aluminum foil and clingfilm, and coated a large tibia bone with polyurethane, but had not succeeded in moving the block out cleanly because the polyurethane cover did not hold the block tightly enough and earth on the underside fragmented when we tried to move the block and turn it over. Finds from this excavation are currently being treated in the Paleontology Lab in Jerusalem.

CASE IV: ONE DAY EXPOSURE - EIN YAHAV (MIocene)

Two teeth from a proboscidean jaw from the site of Ein Yahav, ca. 17-18 myr, were found by an 8-year old walking about looking for hornets' nests with his father. One of us (RR) surveyed the find location and salvaged further parts of the mandible (Figure 5). In this case, no conservator was present on site, but the bone was brought directly to the conservation lab, still covered with the sandy eolian deposit matrix. The teeth sitting in the jaw were coated with a hard sandstone sediment layer, and the bone material was cracked due to post-depositional processes, but the pieces mostly stayed in their correct positions in relation to each other. Despite the damage caused by water percolation in post-depositional activity, this find was relatively stable because its current environment was also relatively stable: arid desert. The result was that both the bone and tooth material were easy to clean mechanically in the lab, using a bristle brush and tools such as porcupine quills and wooden cocktail sticks. The sediment on the teeth was a bit harder, and required a micro-jack tool using air pressure. Several gaps existed in the bone, and these were filled with layers made of strips of fine lens tissue dipped in 30% Paraloid B72 (methyl acrylate/ethyl methacrylate co-polymer) in acetone. Since bits of the mandible were still missing, the three existing fragments were kept apart.

Figure 5: The site of Ein Yahav: find from the one-day expedition, in situ.
DISCUSSION

Because of the potential complex interaction between bone and sediment inherited in their chemical components, humidity, temperature and so on, no simple model can predict how exactly bones are preserved in the sediment. Theories on this subject relate to the action of water, moving organic constituents out from the bone and depositing soluble minerals from the surrounding soil matrix within bone pores (Trueman, 2004:732; Schweitzer et al., 2008:160). As a result, ancient bones end up as bioapatites with abundant authigenic mineral phases both in larger pore spaces in cancellous bone and in smaller vascular pores (Chavagnac et al., 2007:178). Chemical change begins immediately once bones are removed from their in vivo context (Trueman et al., 2008:160), and organic "leaching" appears to occur very quickly once the bone is deposited, as shown by bone exposure experiments. Samples collected five years or more after death already exhibited low organic content, and bones exposed for 26 years or less already undergo considerable physical and chemical changes (Trueman et al., 2004:726, 729).

Generally speaking, modern bone is composed of (soluble) carbonated hydroxyl apatite (Berna et al., 2004), whereas ancient bones typically contain fluorinated apatite (Chavagnac et al., 2007:178), also known as francolite (Berna et al., 2004:868). However, it is recognized that regions of a single bone can vary greatly in preservation (Schweitzer et al., 2008:160). For example, loss of organic content in the same bone can differ considerably, with bone surface losing double the organic content as sub-surface regions of the same bone (Trueman et al., 2004:726). Preservation in different parts of the skeleton may be affected by various factors, ranging from anatomical characteristics such as tooth, tusk or skull morphology versus long bone composition (Rabinovich et al., 2012:2) to microbial action, biogeochemical reactions, cell or tissue breakdown, acid formation, and molecular breakdown processes (Schweitzer et al., 2008:161). The latter taphonomic pathways combine to degrade all organic remains completely. When bone is well preserved, it may be assumed either that the diagenetic processes were halted at an early stage, or that mineralization proceeded faster, preserving the shape of the bone (Schweitzer et al., 2008:161).

Current methods for assessing bone preservation tend to heavily emphasize collagen preservation (e.g., Weiner and Bar-Yosef, 1990; Weiner et al., 1993). Another approach relies on measuring bone crystallinity, which is also considered to be connected with degradation of bone protein (e.g., Trueman et al., 2004) and is even rate-limited by collagen decomposition in the early stages of diagenesis (Trueman et al., 2008:165). However, it has been stated that although loss of collagen weakens the bone structure, destruction is mainly a factor of physical weathering (Trueman et al., 2004:729). Another statement is that long-term preservation, again mainly of organic constituents, depends on the rate at which bone becomes a closed system (Trueman et al., 2008:165).

Studies on the relationship between bone diagenesis and depositional environment often aim at paleoenvironmental, paleoclimatic and paleoecological reconstructions. However, in some cases it may be possible to reverse the relationship and gain some information on the effect of depositional environments on bone preservation. For example, different minerals identified on and within archeological bone may be indicative of the type of taphonomic process, e.g., the mineral Trona (Na₃( CO₃)(HCO₃)•2H₂O) is formed on bone surfaces via evaporation of water containing dissolved calcium and sodium (Trueman et al., 2004:732), indicating that the bone was exposed to air, resting on the soil surface. Following this line of thought, it is interesting to note the finds from the chemical analysis of bones from Revadim. Chemical analysis indicated the presence of the mineral dahllite, and that no collagen was left (Rabinovich et al., 2012:7). Bone crystallinity was assessed according to parameters set by Weiner and Bar-Yosef (1990), and the results indicated severe bone diagenesis, with varying degrees of manganese oxide accumulation (Rabinovich et al., 2012:7). Dahllite tends to accumulate mainly on exterior surfaces and its presence may possibly indicate exposure and weathering processes, as shown by experiments on freshly exposed bone (Trueman et al., 2004:725).

In the EEA locality, previous excavations revealed information on the geology of the site. Generally speaking, sediment accumulation processes by lake margins create good burial and preservation potential (Feibel, 2004: 22). Lake margins exhibit complex sedimentary components, deposited either by water or by air, and modified by the fluctuating lakeshore (Feibel, 2004:22). Although EEA is within a formation characterized by a lacustrine environment, this particular site exhibits sediments with well-developed paleosols (Feibel, 2004:23). Out of 20m of sediments
exposed in the excavation site, the base and top exhibit fully lacustrine character, with a full cycle of transgressive-regressive oscillation in between (Feibel, 2004:24). A good portion of the finds from EEA had a powdery character, flaking easily and requiring considerable consolidation before being touched and lifted. Chemical analysis will be needed to gain better understanding of the situation, but it seems likely that the cyclic nature of the sedimentation may prove to be one of the main causes of this condition.

In contrast, NMO bone-containing sediments were deposited mainly in two levels of a wetland/floodplain to lake environment. The more recent unit 3 consists of a dark grey silt containing montmorillonite, quartz, pyrite and calcite, while the earlier unit 4 contains black argillaceous silt containing also dolomite (Kalbe et al., 2013:3). Bones retrieved from this site are characterized by a dark brown color, similar to the fluvial sediment of the excavation. They are not intensely mineralized, and exhibit good morphological preservation. In other freshwater environments, for example from the Rhine River Valley, bones also exhibited lower levels of change in isotopic phosphate oxygen levels, compared with marine settings (Tütken et al., 2008:266). This possibly indicates that fewer diagenetic processes occur in freshwater environments, at least compared with marine or marine-influenced environments. Apparently, the archeological finds were directly deposited on the floodplain on the margins of a marshy lake, and covered rapidly by a closely packed, fine grained sediment when the lake rose between 70-65 kya (Kalbe et al., 2013:8). In a similar manner, NMO bones exhibit excellent preservation.

Berna et al. (2004) propose a process during which layers of insoluble mineral precipitates are built up within bone pores in repetitive manner, the cycles working along with the hydrological regime to create a process of "recrystallization". According to their research, more recent bone tends to be less stable, with more soluble mineral components than fossilized bone. They postulate that this is due to the much larger surface area to volume ratio in fresher bone and a much thinner layer of crystals (Berna et al., 2004:877). It is not yet clear how the presence of collagen or other proteins affects the recrystallization process, but pH conditions below seven tend to promote bone dissolution and acids are released when collagen deteriorates. In other words, deterioration slows down as diagenesis progresses.

In addition, it has been stated that field observations in archeological sites show that preservation of bones is enhanced by the presence of calcite and authigenic carbonated apatite in the matrix sediments (Berna et al., 2004:867). If bones are deposited in calcite-containing layers, similar to the calcareous soils of Israel, they may possibly remain stable as long as calcite remains (Berna et al., 2004:879). In Ein Yahav, the depositional environment apparently involves eolian sand layering on sediments of fluvial and lacustrine origin with a limestone (calcite) content. This may explain the relatively good preservation of the finds from Ein Yahav.

Taking this information into account, the levels of mineralization not only affect the integrity of the bone, thus influencing preservation of the finds, but also give us better understanding of the effects of the matrix and the hydrological system on bone material. Such understanding will help to determine whether finds are suitable for dating analysis and/or paleoenvironmental studies. Current research on fossilization processes emphasizes three main processes: degradation of the organic component in the bone, mineral accumulation (dark interstitial oxides and oxyhydroxides), and intake of trace elements (Kohn, 2008:3759).

In spite of the high-resolution microscopic examinations currently available, on-site conservation must cope with the actual macro aspect of bone conservation. Perhaps an intermediate medium is required in order to negotiate between the high detail of microscopic information on bone degradation and the external appearance of the bone as exposed during excavations. Conservators need to be aware of the relationship between the matrix and the bone so as to be able to recommend appropriate conservation procedures. As collagen-extraction for early DNA studies and other analytical methods become more and more prevalent, conservation knowledge needs to include better understanding of organic decay in bone material.

ACKNOWLEDGMENTS

We would like to thank the participants of the excavations in case studies that we have described: Revadim Quarry, Nahal Mahanayeem Outlet, Erq el Ahmar and Ein Yahav. The Revadim excavations were directed by Ofer Marder, in collaboration with Ianir Milevski and Hamoudi Khalaily. Conservation
was partially funded by the Israel Antiquities Authority and by the Irene-Levi Sala CARE Foundation. Gonen Sharon directs the continued Nahal Mahanayeem Outlet excavations, and the Ein Yahav and Erq el Ahmar excavations were conducted by our team at the Paleontology lab and the National Natural History Collections of the Hebrew University. Special thanks are due to Rebecca Biton, who is part of our team. We also especially thank Alan Matthews, the director of the collections, for constant support on our projects. Both projects of Erq el Ahmar and Ein Yahav gained valuable support from the local inhabitants. Ein Yahav project is a collaboration with Hanan Ginat, Yoav Avni and Rani Calbo.

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PRELIMINARY RESULTS ON THE CHEMICAL PREPARATION OF DINOSAUR EGGSHells

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ABSTRACT

Traditionally, techniques used in the preparation of fossil eggshells are based on the similarity of the matrix and the eggshells. Often, these techniques involve aggressive preparation and frequently lead to significant dissolution or abrasion of the eggshells. The damage often does not allow proper taxonomical studies, because eggshell features were potentially destroyed. Based on our experience, we propose a new method for the chemical preparation of fossil eggshells, specifically those composed of calcium carbonate.

Keywords: Dinosaur eggshells, chemical preparation, chemical agents, microscopy

RESUMO [in Portuguese]

Tradicionalmente, as técnicas usadas na preparação de cascas de ovo fósseis baseiam-se na semelhança entre a matriz e as cascas de ovo. Muitas vezes estas técnicas envolvem uma preparação agressiva e levam frequentemente à dissolução e abrasão significativas das cascas de ovo. Os danos muitas vezes impedem estudos taxonómicos adequados porque as características das cascas são potencialmente destruídas. Baseados na nossa experiência, propomos um método novo para a preparação química de cascas de ovo fósseis, especificamente as compostas de carbonato de cálcio.

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INTRODUCTION

This work summarizes preliminary results on cleaning fossil eggshells. These treatments can be used for the study of the surface under electronic microscope of both small fragments and complete fossil eggs. Cleaning of the surface of fossil eggshells for electron microscopy is usually very difficult. In order to be able to study its microstructure under the microscope, the elimination of the matrix that covers the eggshells without damaging them is crucial. Eggshells cannot be protected with any resin layer to prevent them from being damaged by cleaning products, since it would prevent thorough cleaning of the eggshell surface, and it would not allow us to clearly observe the structure of the eggshell. The difficulty of the cleaning techniques used in these first tests lies in finding a good cleaning product that could not damage the eggshell. In our case, fossil eggshells are mainly composed of calcium carbonate, and thus very similar to the types of matrix that cover them, which are usually very rich in calcium carbonate (Quinn, 1994).

Traditionally, cleaning fossil eggshells for electron microscopy has been done using organic acids such as acetic acid (Jeppsson et al., 1985; Quinn, 1994; Rutzky et al., 1994; Shelton, 1994). However, this technique usually damaged the eggshells, and did not allow accurate observations of their surface. The research team “Àrea de recerca del Mesozoic” of the Institut Català de Paleontologia Miquel Crusafont (ICP) is continuously studying dinosaur fossil eggshells and, for this reason, members of our team have been working for years trying to find the best cleaning techniques for these fossil eggshells that need to be studied after preparation. Our first studies on cleaning techniques were performed on Titanosaur fossil eggshells from the Fumanya area (Berguedà, Catalonia, Spain), which were embedded in marls with a composition of 50% calcium carbonate and 50% silicate (Val, 2007). During these first studies, we tried to dissolve the noncarbonated part of the matrix in order to prevent damaging the carbonate in the eggshells. To do so, we used chemicals that dissolve the silicate part of the matrix. The results obtained using these alkaline agents were better than other acid cleaning techniques. Highly alkaline agents dissolve silicates converting them into very soluble crystals (San Andres Moya and de la Viña Ferrer, 2004). Afterwards, we performed more cleaning trials with other types of matrix, the results of which were presented in Val et al. (2010). Those essays were performed with carbonated matrices, matrices with a high content of iron oxides, as well as matrices with a high silicic composition. The main feature common to all those matrices was their hardness and their resistance to many cleaning agents and techniques. The herein presented preliminary study consists of an analysis made using an electron microscope to study the effects of various chemical treatments on eggshells.

METHODOLOGY

Preparation techniques were conducted on dinosaur eggshell fragments collected from several Late Cretaceous deposits (Tremp Fm.) in the South-Pyrenean basins (Catalonia, NE Iberian Peninsula; see Figure 1). Sampled localities occur in continental facies that include mudstones, marls, oncolite limestone and fine to medium, well-cemented sandstones. In most cases, eggshells are imbedded in a highly carbonated matrix that strongly hinders the removal of secondary deposits.

The different treatments were conducted with different volume concentrations, starting with 2% until reaching the percentage of optimal cleaning. All the samples were subjected to the same dilution percentage, at the same temperature and the same time of exposition. Following the first standard tests, we tried to find, in each case, the best percentage of dissolution and the best time of exposition of each one. In order to observe the results obtained for each treatment in detail, we used an environmental SEM (FEI Quanta 200) at the Serveis Cientifico Tècnics of the Universitat de Barcelona. We compared the damage suffered by the eggshells with each treatment. An image of a non-treated eggshell was included as control (Figure 2). The optimal cleaning was defined as the one that allowed us to identify the oxygenation channels properly, and where the morphology of the surface of the eggshell was not or minimally altered in comparison with the eggshell used as control.

All trials were made with fragments of similar size (1 cm² approximately) and with a volume of 40 ml of dissolution for the different percentages of each chemical agent. Cleaning essays were performed using ultrasonic baths (with a duration of 15 min), which accelerated the cleaning process and increased the penetration capacity of the cleaning agents. It is important to emphasize that these cleaning techniques are useful for individualized eggshells that need to be studied under the microscope, but when cleaning complete fossil...
Val et al., 2014: CHEMICAL PREPARATION OF DINOSAUR EGGSHELS

Figure 1: Map showing the area where the sites are located. Image by Albert García; Grup Mesozoic ICP.

Figure 2: Non-treated eggshell. Impossible to see details of the relief or to determine the position of the oxygenation channels.
Val et al., 2014: **CHEMICAL PREPARATION OF DINOSAUR EGGSHELLS**

eggs, full immersion is not recommended because it could cause the eggshell to break to pieces. In the case of complete eggs, cleaning techniques are performed using bandages and easy-to-neutralize cleaning agents (Val et al., 2013). It is important to stress that any chemical treatment used must be neutralized in order to prevent future damage to the specimens. During any chemical preparation, health hazards must be known and corresponding actions taken in order to prevent any risk. It is paramount to know the toxicity of the used chemical agents, and the products that can be created in various chemical reactions. Each chemical requires specific security equipment, but as a rule, we perform the tests under a ducted fume hood, and use personal protective equipment to chemical agents such as goggles, gas masks, gloves and acid resistant lab coats. Also, the health and safety regulations must be available for each product.

**RESULTS**

For this paper we have selected the more significant results obtained from all the essays performed. They have been grouped by the treatment used and the problems that arose during the different essays depending on the types of matrix involved.

**Acids: for dissolving carbonated matrices in sandstones**

The carbonates that make up the matrix can be dissolved by acids. Usually, the most commonly

![Figure 3: Eggshells treated with acids. A) Acetic acid at 10%. The relief of the eggshell has been damaged and eroded. B) Hydrochloric acid at 15%. The surface of the eggshell has been highly eroded (arrows). C) Oxalic acid at 10%. The relief of the eggshell could be observed, but the surface was slightly altered (arrows) and the oxygenation channels could not be detected. D) Sodium hexametaphosphate (NaPO₃)₆ at 15%. The relief of the eggshell could be observed, its surface did not seem altered and the oxygenation channels could be detected (arrows).](image-url)
used acids are organic, such as acetic acid CH₃-COOH (CH₃COOH) (C₂H₄O₂) (San Andres Moya and de la Viña Ferrer, 2004). In very hard matrices, inorganic acids have also been used. Some examples are hydrochloric acid (HCl), (Figure 3B) and sulfuric acid (H₂SO₄). We have also tested oxalic acid H₅C₅O₄ (Figure 3C), an organic acid 3000 times stronger than acetic acid, and commonly used for eliminating iron oxide concretions from archeological iron (Mourey, 1987). Nevertheless, there are other agents that can act on calcium carbonate in a less aggressive way, and that transform calcium carbonate into other carbonates that are more soluble in water, and thus easier to eliminate without using acids. One example is sodium hexametaphosphate (NaPO₃)₆ (Figure 3D), a salt that transforms calcium carbonate into sodium carbonate. This agent is commercially available with different pH. For the present study, we used the agent with a pH value of six, and thus slightly acidic. Therefore, we included it among the acids, even though it is not considered an organic acid. The treatment with (NaPO₃)₆ is widely used in other fields of heritage conservation and preparation, and it yielded excellent results when used for eliminating carbonate concretions. In our case, treatments performed using sodium hexametaphosphate (NaPO₃)₆ have been highly effective and poorly aggressive (Val, 2007; Val et al. 2010). Table 1 shows the concentrations working best for each treatment.

Table 1: acidic agents.

<table>
<thead>
<tr>
<th>CHEMICAL AGENT</th>
<th>%</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formic acid</td>
<td>10%</td>
<td>Surface highly damaged (Figure 3A)</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>10%</td>
<td>Surface highly damaged (Figure 3A)</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>10%</td>
<td>Surface highly damaged (Figure 3B)</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>10%</td>
<td>Surface slightly eroded (Figure 3C)</td>
</tr>
<tr>
<td>Sodium Hexametaphosphate (pH 6) (NaPO₃)₆</td>
<td>15%</td>
<td>Optimal cleaning (Figure 3D)</td>
</tr>
</tbody>
</table>

Table 2: alkaline agents.

<table>
<thead>
<tr>
<th>CHEMICAL AGENT</th>
<th>%</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium hydroxide</td>
<td>10%</td>
<td>Optimal cleaning % (Figure 4A)</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>4%</td>
<td>Surface slightly eroded (Figure 4B)</td>
</tr>
<tr>
<td>Sodium hexametaphosphate (NaPO₃)₆</td>
<td>15%</td>
<td>Surface slightly eroded</td>
</tr>
</tbody>
</table>

Alkalies: for dissolving silicates present in matrices composed of 50% carbonate and 50% silicate marls

Alkaline agents dissolve silicates present in the matrix without attacking the calcium carbonate of the eggshells. As can be observed in figures 4A and 4B, the most effective treatments are the ones using potassium hydroxide (KOH; Figure 4A), as shown in the absence of degradation in the surface and the good observation of all microstructures of the eggshell. However, they are difficult to apply and neutralize. In those cases, we highly recommend neutralization using an ultrasound bath twice with 80 ml of distilled water (double the volume) during 30 min (double the time of exposition). Moreover, we tested sodium hydroxide (NaOH; Figure 4B; Fernández et al., 2005), but in a lower percentage, due to its more aggressive character, and because we could note more abrasion on the surface and degradation of the microstructure of the eggshell. Finally, we used Sodium hexametaphosphate (NaPO₃)₆₇, with a pH value of eight, but contrary to the results obtained with the acidic version, the alkaline Sodium hexametaphosphate did not yield positive results. Table 2 shows the concentrations for obtaining the best results for each treatment.

Other chemical agents

Mixtures to dissolve carbonate in hard matrices with ferric iron

The dissolution of matrices containing high amounts of iron oxide is problematic, since there are no established protocols or guidelines for doing so. Thus, we tested new and old treatments used in paleontological conservation/preparation (Rutzky et al., 1994), and also in other fields of conservation/restoration of cultural property (Mourey, 1987). This type of matrix is very hard and resistant to many treatments, including mechanical work. The most commonly used method working with this type of matrix is the Waller Method (see Figure 5A; Waller, 1980; Blum et al., 1989; Rutzky et al., 1994). The Waller method uses a solution of sodium...
Figure 4: Eggshells treated with alkalies. A) Potassium hydroxide KOH at 10%. The relief of the eggshell could be observed, the surface has not been altered and the oxygenation channels were also detected (arrows). B) Sodium hydroxide NaOH at 4%. The relief of the eggshell could be observed, but the surface was slightly damaged (red arrows). The oxygenation channels were observable (yellow arrows). C) Potassium hydroxide KOH at 10%. The relief has not been damaged and the oxygenation channels (arrows) are perfectly observable.

Figure 5: Eggshells treated with mixtures: A) Waller Method: Sodium citrate 71gr + Sodium bicarbonate 8,5gr + Sodium dithionite 20gr. It is possible to observe the oxygenation channels (arrows) and the relief perfectly. B) Ethylenediaminetetraacetic acid (EDTA) at 5%. The oxygenation channels could be detected (yellow arrows) but the relief was highly eroded (red arrows). C) Ethylenediaminetetraacetic acid (EDTA) at 5% with Sodium hydroxide at 4%. The relief of the eggshell could be observed, its surface was somewhat altered (red arrows) and the oxygenation channels could be detected (yellow arrows). D) Sodium hexametaphosphate at 15% + Waller Method. The relief has been partially eroded (red arrows).
Val et al., 2014: **CHEMICAL PREPARATION OF DINOSAUR EGGSH SHELS**

citrate, sodium bicarbonate and sodium dithionite. This method does not use acids, and therefore, dissolution of the calcium carbonate of the eggshell is avoided. Dithionite reduces ferric iron to ferrous iron, which is soluble; citrate sequesters ferrous iron; and bicarbonate buffers the pH to maintain the solution neutral. Additional treatments for dissolving concretions of iron oxides, and tested herein include Oxalic acid (H$_2$C$_2$O$_4$) and ethylenediaminetetraacetic acid (EDTA; see Figure 5B; Mourey, 1987).

However, due to the hardness of these matrices, we had to test EDTA at 5% with sodium hydroxide at 4% (see Figure 5C), in order to dissolve them (Fernández et al., 2005). Sodium hexametaphosphate (NaPO$_3$)$_6$, when used in combination with the Waller Method, had to be diluted at 15% (see Figure 5D), in order to make the products more reactive. Table 3 shows the concentrations and results for each treatment.

**Table 3: mixtures for carbonate in hard matrices with ferric iron.**

<table>
<thead>
<tr>
<th>CHEMICAL AGENT</th>
<th>%</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waller Method:</strong> Sodium citrate 71 gr. Sodium bicarbonate 8.5 gr. Sodium dithionite 20 gr.</td>
<td></td>
<td>Optimal cleaning (Figure 5A)</td>
</tr>
<tr>
<td>Ethylenediaminetetraacetic acid (EDTA)</td>
<td>C$<em>{10}$H$</em>{16}$N$_2$O$_8$</td>
<td>5%</td>
</tr>
<tr>
<td>Ethylenediaminetetraacetic acid (EDTA) Sodium hydroxide</td>
<td>C$<em>{10}$H$</em>{16}$N$_2$O$_8$NaOH</td>
<td>5% 4%</td>
</tr>
<tr>
<td>Sodium hexametaphosphate Waller Method</td>
<td>(NaPO$_3$)$_6$</td>
<td>15% -----</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>H$_2$C$_2$O$_4$</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Table 4: organosulfurs.**

<table>
<thead>
<tr>
<th>CHEMICAL AGENT</th>
<th>%</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimetilsulfoxide DMSO</td>
<td>CH$_3$SOCH$_3$</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Table 5: agents for hard silicate matrices.**

<table>
<thead>
<tr>
<th>CHEMICAL AGENT</th>
<th>%</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrofluoric acid</td>
<td>(HF)</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Organosulfur: for Oncolitelimestones (dissolving very hard matrices)**

Oncolitelimestone matrix is highly carbonated and its dissolution is very difficult without using strong acids. In this case we have used a chemical agent not used in any previous analysis. It is an organic solvent (Dimetilsulfoxide (DMSO): CH$_3$SOCH$_3$) that has been used for the dissolution of very compacted and lithified matrices (Triplehorn, 2002; Triplehorn et al., 2002). Its disadvantage is that it can take weeks to break up the matrix. However, it was the only treatment that worked well with this type of matrix (Figure 6). Table 4 shows the concentration for obtaining the best result with this treatment.

**Agents for hard silicate matrices**

It is known that hydrofluoric acid (HF) is a good silicate solvent. However, it did not provide very good results during our essays. Table 5 shows the concentration and the result with this treatment.

**DISCUSSION AND CONCLUSIONS**

**Carbonated matrices in sandstones**

For this kind of matrix, the best option for its dissolution with acids proved to be the treatment with Oxalic acid (H$_2$C$_2$O$_4$; Figure 3C). This kind of chemical agent is a good alternative to the traditional organic acids used for dissolving carbonated compounds, like acetic and formic. The effect of Acetic acid (CH$_3$-COOH (C$_2$H$_4$O$_2$)) is stronger and more harmful compared to oxalic acid (Figure 3C). However, oxalic acid is difficult to neutralize completely, and thus remains somewhat harmful on the surface of the eggshell (Figure 3C). The worst result was obtained with HCl (Figure 3B). On the other hand, the use of Sodium hexametaphosphate (NaPO$_3$)$_6$ with a pH value of six has proved to be a good cleaning method. It is better than Oxalic acid, because less damage is induced to the surface (Figure 3D).
Silicates present in marls

For dissolving the siliceous part of the marl, the best option resulted to adopt alkaline treatments. These chemical agents do not attack the carbonated part of the matrix, and does thus not attack the calcium carbonate of the eggshells. We have obtained the best results by using Potassium Hydroxide (KHO), which is a great alternative to traditional acid treatments on this kind of matrix. We can observe the microstructure of the eggshell with clarity (Figure 4A), observing even the holes of the oxygenation channels of the eggshell (Figure 4C).

Ferric iron in lithified matrices

It is difficult to find a good dissolution agent for matrices rich in ferric iron. We have done tests with both traditional methods and methods of other fields of preparation, as archeological preparation of iron objects. For this reason we tried Oxalic acid, which is useful to dissolve the matrix, but also attacks the surface of the eggshell. The best result was obtained with the Waller Method (Figure 5A), where we could observe a good dissolution of the matrix and little damage on the surface of the eggshell.

Oncolitelimestones

The eggshells included in this type of matrix were the most difficult to clean, due to the hardness of the sediment. It was necessary to use an inorganic acid because it is more reactive. However, this poses a serious risk to the conservation of the microstructure of the eggshell. For this reason, we tried to find an alternative method like dimethylsulfoxide (DMSO; Figure 6). This method allowed us to clean the surface of the eggshells, without inducing too much damage.

Silicates in lithified matrices

In the last case, due to the composition and hardness of the matrix, we had to use Hydrofluoric acid (HF) 5%, but this did not show satisfactory results (see Figure 7), because the surface of the eggshell was highly damaged after this treatment. Further research is therefore needed for this kind of matrices. Moreover, use of this acid is not recommended due to its high risk for the health.

ACKNOWLEDGMENTS

We would like to thank researchers Dr. Bernat Vila and Dr. Albert Garcia (Àrea de Mesozoic of the Institut Català de Paleontologia Miquel Crusafont) for the electron microscopy pictures, as well as for their help and support regarding several sedimentological aspects of different matrices. We also want to thank Judit Marigó for the English corrections and the reviewers Rui Castanhinha and Femke Holwerda for their useful corrections.
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Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/
PREPARATION OF A TURTLE FOSSIL FROM THE PLIOCENE SITE OF CAMP DELS NINOTS (CALDES DE MALAVELLA, GIRONA, SPAIN)

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ABSTRACT

In order to handle fossils for study and exhibition, a good state of conservation is paramount. In this work, the conservation operations carried out on a turtle fossil, described as *Mauremys leprosa* from the Pliocene site of Camp dels Ninots (Caldes de Malavella, Girona, Spain), are reported and documented. Cleaning, consolidation and preparation of the fossil was carried out, both on site and in laboratory. In particular, this work displays the interest of combining traditional conservation techniques with modern procedures such as 3D scanning. It is shown that the combination of 3D scanning and silicon moulding/casting can be extremely useful in order to document and preserve the anatomical connection of the fossils, especially when such fossils are embedded in fragile laminated or cracked sediment.

Keywords: 3D scanning, Camp dels Ninots (site), conservation, Pliocene, preparation methods, turtle fossil

RESUMO [in Portuguese]

No manuseamento de fósseis para estudo e exposição, um bom estado de conservação é crucial. Neste trabalho, as operações de conservação desenvolvidas numa tartaruga fóssil, descrita como *Mauremys leprosa* da jazida Pliocênica de Camp dels Ninits (Caldes de Malavella, Girona, Spain), são reportadas e documentadas. Limpeza, consolidação e preparação do fóssil foram feitas, tanto na jazida como no laboratório. Em particular, este trabalho mostra o interesse da combinação de técnicas de conservação tradicionais com procedimentos modernos, como a digitalização 3D. É mostrado que a combinação da digitalização 3D e moldagem em silicone pode ser extremamente útil de modo a documentar e preservar a conexão anatômica dos fósseis, especialmente quando esses fósseis se encontram em sedimentos extremamente frágeis ou fracturados.

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INTRODUCTION

Paleontological studies contribute to identify and determine species evolution and chronology, as well as the interactions with other species and with their environment. Therefore, good conservation of fossils is crucial for their manipulation and/or exhibition. However, specimens are often highly fragile when discovered and such fossils often require a certain level of maintenance to give them strength and shock resilience. In this work, the preparation processes carried out, both in situ and in laboratory, on one case of turtle fossil from the Pliocene site of Camp dels Ninots is presented.

The Camp dels Ninots maar site is located in Caldes de Malavella, Girona, NE Spain. Its coordinates UTM31N (ETRS89) are 483202 E and 4631454 N (Figure 1A). The Camp dels Ninots volcano is a part of the Catalan Volcanic Complex which took place between 14 Ma and 10 Ka in NE Spain (Gómez de Soler et al., 2012). The basaltic monogenetic volcanic zone comprises more than 50 well preserved monogenetic cones and some others with both explosive and non-explosive activity phases (detailed references available in Gómez de Soler et al. 2012). It is a volcano maar-type site, formed by phreatomagmatic explosions. These explosions resulted from brief, near-surface magma/water interactions occurring during the ascent of magma towards the surface which in turn led to violent explosions. The presence of groundwater led to the development of a lake inside the crater. The sedimentary infill is characterized by typical vertical stratigraphic succession in maars (Pirrung et al., 2003; Lindner et al., 2006). Syn-/post-eruptive wall rock debris and pyroclastic breccias characterize the bottom deposits and are followed by a fining-upwards sequence of lacustrine muds with coarse layers and final shallow lake deposits (Figure 2). The site has been recently classified as a Konservat-Lagerstätte (Gómez de Soler et al., 2012), and the stratigraphy shows a lacustrine sedimentation in a maar, which are ideal conditions for the preservation of fossils.

Figure 1: Location of Camp dels Ninots site in Spain and north east Catalunya (A) and map of the Can Argilera sector (B).
A large range of skeletons (mammals, amphibians, freshwater fishes, and reptiles) have been recovered, most of them articulated (for more details, please see: Gómez de Soler et al., 2012; Jiménez-Moreno et al., 2013; Campeny et al., 2012, 2013; Gómez de Soler et al., 2014). In terms of flora, both pollen and macroscopic remains have been found. The landscape is characterized by forested vegetation (featuring a forest ratio between 57% and 97%, based on pollen analysis; Jiménez-Moreno et al., 2013). The correlation of paleomagnetic and pollen results with the referred paleontological data gives the Camp dels Ninots site a date ranging from 3.3 to 3.1 Ma (with the sedimentary sequence deposited in 200 kyr) (Gómez de Soler et al., 2012; Jiménez-Moreno et al., 2013). Previous published works report the conservation and storage of a bovid skull from the Camp dels Ninots site (Gomez-Merino et al., 2009), as well as consolidation tests of macroflora (fossil leaves), preserved as impressions in lacustrine clays (López-Polín et al., 2009).

Turtles from the Camp dels Ninots site are freshwater reptiles (*Mauremys leprosa*). The species distribution consists of the Iberian Peninsula and the Maghreb Region of northwest Africa (Fritz et al., 2006). *M. leprosa* of Camp dels Ninots constitute one of the oldest record in Europe of these species (Gómez de Soler et al., 2012).

**MATERIAL AND METHODS**

The turtle fossil (CN’10-Pit7/8-Niv11-M18-nº2) was discovered at level 11 of the Can Argilera sector (Figure 1B), during the 2010 excavation campaign. The units covering the fossil were greenish laminated clays with sandstones (Figure 2).

The turtle fossil appeared complete and in anatomical connection, with the posterior and anterior phalanges located outside the body. Such spatial disposition is a rare occurrence, since in most recovered fossils the phalanges are retracted inside the shell. This fossil is therefore very interesting to document precisely the anatomy of this species. However, bones presented splits, cracks, and were friable in some parts (particularly when the bone and sediment were dry). It is noteworthy as well that most of the fossils were flattened because of diagenetic processes. As such, the turtle fossil was in need of an in-depth preparation in situ and in the laboratory later on.

**In situ treatments**

**Excavation, cleaning and consolidation**

When the fossil appeared, the general surface was delimited with a small trowel and a brush. Then, the bones were excavated superficially from sediment and cleaned using wooden and/or metallic instruments (like scalpels, awls, etc.). The fragile bones were consolidated with Paraloid B72 at 5 to 10% in acetone (applied with a syringe).

**Extraction**

For storage and preparation purposes, the fossil was extracted in its sediment block with a polyurethane support. The surface to extract
was demarcated with a trowel, and then covered with aluminium foil. Then, a cardboard support was constructed in order to contain the sediment block and polyurethane. The polyurethane (polyol and isocyanate) was mixed and poured inside the cardboard support (Figure 3). When the chemical reaction was finished and the polyurethane cold, the block was extracted and turned upside down. The sediment of the underside was then also covered with polyurethane.

Figure 3: Turtle fossil (CN’10-Pit7/8-Niv11-M18-nº2). A) preservation state in situ; B-F) extraction process featuring fossil protection (B-C), cardboard container fabrication (D) and polyurethane pouring (E-F).

Treatments in laboratory

Excavation and cleaning

The preparation started on the upper part of the fossil, by the removal of the polyurethane (Figure 4A). The sediment was excavated until the extents of the fossil were exposed (Figure 4B). Some of the bones presented cracks and splits and were fragile (the superior and inferior parts of the fossil, and the cranium). Hence,
the cleaning was carried out carefully with thin metallic and wooden awls, needles, and brushes. The bones were subsequently cleaned with acetone: a cotton swab was soaked in acetone and was applied to the bone surface with a circular movement (Figure 4C).

Consolidation treatments
During the drying process, the cracked, fragile, and friable bones were consolidated with Paraloid B72 at 5 to 15% in acetone (applied with a syringe) (Figure 4D). The fractured bones were also joined with the same consolidant using higher concentration (50% up to 80%). In order to account for the fragility of the fossil, consolidation and cleaning were applied simultaneously.

During the preparation of the superior part, a serious problem was encountered: the sediment altered when drying and presented horizontal lamination and cracks. The laminations and cracks became larger with time, affecting the stability and anatomical connection of the small bones (particularly the phalanges located outside the body). Therefore, in order to control the sediment alteration, consolidation tests were carried out by injecting different consolidants into the sediment cracks (e.g. Beva 371 in 372 solvent). However, these tests were not fully conclusive and require further investigation. The alternative solution found to temporarily keep the small bones articulated during the preparation process of the fossil was to use paste filler (Modostuc) to replace the sediment between the small bones.

Figure 4: Preparation process of the superior part. Excavation (A-B) and cleaning (C), followed by consolidation (D).
Due to the lack of a satisfying permanent and reversible procedure which would maintain the articulation of the specimen, it was decided to dislocate the bone phalanges after the preparation process. Hence, for the first time at the Camp dels Ninots site, a 3D scan was carried out in order to document the original state of the fossil before the separation of the small bones (phalanges). A Breuckmann smartSCAN 3D-HE mounted with a 250mm FOV was used to create a 3D model of the turtle fossil, and the obtained mesh was processed using Breuckmann Optocat 2012R2 and Geomagic Studio 2013 software packages. The data points acquired were more than 3.5 million triangles for each surface of the fossil, corresponding to a resolution of 4729 points/cm²/cm, equivalent to ca. 0.14 mm spacing between points. It is noteworthy that the resolution is reduced in (Figures 5A, 5B) for visualization purposes.

3D scan

Figure 5: 3D scan; A-B): superior part; C): inferior part.

Silicon mould

However, 3D scanning with the current technology lacks some precision compared to moulds in the angled regions of the fossil (e.g. phalanges and between the cranium and the carapace). In order to record this morphological information, a silicon mould was also made using a two part poured mould with plaster jacket (mother mould) method (Smith and Latimer, 1989; David and Desclaux, 1992). First, the plaster jacket had to be manufactured. Protected by a plastic film, the fossil was covered with plasticine in order to follow the fossil shape without flattening it too much on the bone. Two posts of plasticine were constructed in the top part and joined by plasticine bands, and small keys were also constructed around the fossil. To avoid the coating of plaster in plasticine, a layer of Vaseline was applied with brush. Then, a mixture of plaster-water was applied to form the jacket. Once the plaster got dry, the support, plasticine and plastic film were
removed from the fossil. The turtle fossil was protected by a separator spray (Molykote). The jacket was put again on the fossil and the silicone (Silastic 3481/curetting agent 81-5%) poured slowly inside the plaster jacket through one of the two holes formed by the plasticine posts (Figure 6).

Once the silicon dried, the mould was turned over and the inferior side of the turtle fossil excavated. The same process of excavation, cleaning and consolidation was applied, using the same instruments (metallic and wood awls, needles, brush) and products (acetone, Paraloid B72 at 5, 10 and 80% in acetone) as for the superior part (Figure 7).

When the preparation of the inferior part of the fossil turtle was finished, the 3D scan (Figure 5C) and silicon mould of this part (Figure 8) were carried out using the methods applied for the superior part.
Figure 7: Preparation process of the inferior part: excavation (A-B), cleaning (C-D), and consolidation (E-F).
Casting
Subsequently, a cast was made with an acrylic resin (Acrystal prima 100pp+ Acrystal basic 250pp). The replica was painted using a mixture of natural pigment with alcohol and retouch varnish. In order to obtain a color similar to the sediment, white, black, yellow and blue natural pigment were mixed; for the fossil bones color, a brown natural pigment was used. A layer of retouch varnish was also applied on the replica surface to complete the process (Figure 9).

DISCUSSION
The preparation of the turtle fossil in situ was carried out in order to give it resistance for extraction, transport, and for manipulation (especially when it is turned upside down). Polyurethane protects and gives resistance to
Roubach et al., 2014: **PREPARATION OF TURTLE FOSSIL**

the fossils during transport and short time storage; this method of extraction also allows maintaining the sediment humidity, leading to much easier laboratory work. We used Paraloid B72 for all preparation processes because of its stability and efficiency (Howie, 1984; Horie, 1987; Johnson, 2001). The use of one product as consolidant and adhesive at the same time minimizes the number of products applied, leading to a better control on the paleontological preparation process. Paraloid gives good results in the bones preservation, and the good preparation of the fossils allows manipulating them for both study and exhibition.

We used Paraloid B72 for all preparation processes because of its stability and efficiency (Howie, 1984; Horie, 1987; Johnson, 2001). The use of one product as consolidant and adhesive at the same time minimizes the number of products applied, leading to a better control on the paleontological preparation process. Paraloid gives good results in the bones preservation, and the good preparation of the fossils allows manipulating them for both study and exhibition.

Figure 9: Cast process. A-B) resin preparation; obtained replica during (C) and after (D) painting.

With laminate materials such as the sediment found in the Camp dels Ninots site, it is very difficult to keep the bones articulated. Another way could be to use the so-called Transfer method (Schaal, 2005). It consists in the preparation of one side of the fossil, which is then covered with artificial resin. After hardening of this artificial substrate, the other side of the specimen is prepared. However, the reversibility would be sacrificed in that case. Without a reversible procedure to maintain articulation, it was decided to dislocate the small bone extremities. That decision led to the use of the 3D scanning technique to document the original features of the fossil before and during the preparation. The main advantage of 3D scanning is that it is a non-destructive technique, which can be applied even on very fragile materials. It is also relatively fast, easy to use, can be used in situ (portable apparatus), and does not require physical storage space. Its main drawbacks are the lack of precision especially in the angled parts of the fossil, and the high price of the apparatus. On the other hand, Silicon molding is a more established technique and is more precise than 3D scanning under its current form. However, it is a much slower and potentially dangerous technique on fragile fossils such as the one considered in this work. It requires the use of
products to fix and consolidate the fossil beforehand. The combined use of 3D scanning and silicon moulding allows obtaining a good trade-off, since the original state of the fossil is captured by 3D scanning. Regarding final storage, the turtle fossil and the replica are packed in plastic boxes inside polyethylene support (Ethafoam). This material exhibits a certain number of advantages such as stability, cleanliness, compactness, and ease of use. Digital files are stored on a server in .ply and .stl format (note: this file is also provided with this manuscript and has been optimized for web viewing at 63p/cm²/cm, equivalent to ca. 0.14 mm spacing between points).

**CONCLUSIONS**

In this work, the conservation operations carried out on a turtle fossil, described as *Mauremys leprosa* from the Pliocene site of Camp dels Ninots (Caldes de Malavella, Girona, Spain), are reported and documented. Cleaning, consolidation, and preparation of the fossil were carried out both on site and in the laboratory. The fossil was cleaned with small and thin instruments, and then consolidated with paraloid B72 at 5% up to 15% in acetone. With the laminated sediment found in the Camp dels Ninots site, it is very difficult to keep the bones articulated during the preparation process. Silicon moulding requires the use of products to fix and consolidate the fossil beforehand, and these should be reversible. Moulding is also potentially dangerous with fragile fossils. Therefore, 3D scanning was carried out on the fossil material in combination with silicon molding for both the superior and the inferior part. That way, the articulation of the fossils are documented and preserved. The importance and the preservation state of the fossil are leading to the choice of the conservation actions. Hence, the interventions carried out on the turtle fossil allow applying different conservation methods for the same specimen and featuring a greater versatility: the fossils preparation can be tuned depending on their preservation state and on the final goal of their study. The result is two duplications of the specimen; one digital, and one physical. The former is safe, and easily stored, albeit with lower resolution, while the latter risks damage or disarticulation of the specimen, but provides a higher fidelity cast and physical record.

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Roubach et al., 2014: PREPARATION OF TURTLE FOSSIL


Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/
THE BRISTOL DINOSAUR PROJECT – A CONSERVATION AND PREPARATION OVERVIEW

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ABSTRACT

The Bristol Dinosaur Project involved extensive preparation and conservation of a large collection of macro- and microvertebrate fossils. The starting point was some four tonnes of fossiliferous cave-fill breccia, and the laboratory procedures involved a broad range of physical and chemical approaches to reduce this matrix and extract, conserve, and curate the dinosaur bones and microvertebrate remains. The initial state of the remains, and the laboratory procedures followed provide a good case study of historical collections found in many institutions that are in urgent need of care and dedicated work. The program also provided examples of good and bad practice, while training students in laboratory skills.

Keywords: Cave deposits, Fissures, Triassic, Bristol Dinosaur, Thecodontosaurus, Fossil preparation, Laboratory techniques, Conservation

RESUMO [in Portuguese]

O Bristol Dinosaur Project envolve um amplo programa de preparação e conservação de uma coleção de macro e microvertebrados fósseis. O ponto de partida foram cerca de quatro toneladas de brecha cársica fossilífera, e os procedimentos de laboratório envolvem um amplo espectro de técnicas químicas e físicas para reduzir a matriz, extrair, conservar e curar os ossos de dinossauros e vestígios de microvertebrados. O estado inicial dos vestígios e os procedimentos laboratoriais usados forneceram um bom caso de estudo sobre como proceder em coleções históricas encontradas em muitas instituições e que requerem uma necessidade urgente de cuidados e trabalho dedicado. Também se dão exemplos de boas e más práticas enquanto se treinam estudantes em técnicas laboratoriais.
INTRODUCTION

“Dinosaurs have always been an excellent means of engaging people of all ages, especially children” (Benton et al., 2012:210), but much work by fossil preparators and curators is needed before a dinosaur specimen is ready for research or display. Europe’s museums and universities hold valuable natural history collections, but unfortunately, many of them are in great need of attention from curators, conservators and preparators. This problem can be attributed to a lack of personnel, financial support, and in some cases the lack of institutional interest in undertaking such daunting tasks with older collections.

The Bristol Dinosaur Project (BDP; Benton et al., 2012) demonstrates how funding from a heritage conservation agency, such as the UK Heritage Lottery Fund (HLF), can be vital for rehabilitating unique scientific resources, bringing them to the highest curatorial standards and making them available for research and education. Here we outline the nature of the collections as they arrived from the field, the steps involved in extracting, conserving, and curating the bones, and the many ways in which students were involved.

THE APPARENT CHALLENGE

The Bristol dinosaur collections date back to the 1830s. The first remains of *Thecodontosaurus antiquus* were discovered in 1834, and named in 1836. Through the 1830s and 1840s, hundreds of bones were extracted from the Durdham Downs quarries in the Clifton area of Bristol, and these were largely acquired by the precursor of the current Bristol City Museum and Art Gallery (Benton 2012). The remains were described and illustrated in several scientific publications, but most of the better-quality display material was lost during a bomb attack on the Museum in 1940. The remaining parts of the collection were re-assessed and described in detail later (Benton et al., 1990). In 1975, a fresh collection of bones, presumed to belong to the same dinosaurian species, was found at Tytherington Quarry, near Bristol, and these were delivered to the University. Initial studies were carried out as part of his PhD by Whiteside (1983), but he was only able to prepare a small portion of the bones. Later, funding was obtained from the Leverhulme Trust for a further project, in the 2000s, in which more progress was made in extracting bones from the large rock pile. However, it was only with funding from the HLF, from 2010-2013, that substantial progress in the laboratory work was made.

Initially we were faced with what seemed to be a rather straightforward project. The 1975 Tytherington material fell into two main categories.

(1) The first consignment consisted of approximately four tons of Triassic fissure fill deposits, mostly breccias and conglomerates of different sizes, ranging from small hand-held cobbles to large, heavy boulders. These rocks had not been processed and they would be the target of chemical and mechanical preparation and the recovered bones curated into a new research collection.

(2) The second consignment comprised parts of the Tytherington collection that had been prepared at different times since 1975, and housed partly in the University’s museum and in the old laboratory space. Some specimens had been removed cleanly from the rock, whereas others were partially prepared or variously incomplete.

THE REAL CHALLENGE

On examining the four tons of rock from the 1975 collection, the first issue was the physical state of the specimens, especially those that had been prepared in the last 30 years. These specimens were partly exposed and had been semi-prepared, semi-consolidated or glued with a variety of materials. There was a myriad of crates and boxes with loose, broken bones, tossed in with no order or much care for the physical integrity of the specimens (Figure 1). This mixture of boxes of broken bones, shards and rock dust included in some cases specimens with old collection numbers glued to them, sharing the same box with unidentified specimens, or in other cases loose collection identification numbers lay around in boxes, which were in turn shared by multiple, loose, broken specimens, making it impossible to know which specimen was associated with which number (Figure 2). The storage difficulties had arisen partly because the collection had been moved several times, and had had to be stored in cellars while the Palaeontology Laboratory was reconstructed and refurbished in 2010.

There were also chemical-related problems with many specimens. Some prepared specimens...
Figure 1: Crate with jumbled up prepared, half prepared and unprepared bones and rocks.

Figure 2: Collection problems; a) Boxes with unpadded mixed id and unidentified specimens; b) boxes with identified but missing specimens.
had been glued and/or consolidated using diverse materials. Some of those materials were now very visible and turning some specimens dark in color, or in other cases showing a thin, semi-opaque layer of an unidentified product coating the surface. In other cases, specimens showed a greenish rubbery layer that attached bits of rock or even bone together. To make matters worse, some of these specimens had also been subjected to acid preparation, but had either been immersed without any buffer and/or had not been rinsed properly after the acid bath, resulting in pitted, extremely fragile, brittle specimens.

There were further problems with the University’s registered collection. The first problem was that the existing collection catalog had numerous specimens missing or unidentified (Figures 3a, b). Further, some specimens with accession numbers were housed loose in communal boxes, with no padding or any kind of separation from other accessioned or un-accessioned specimens, causing various degrees of damage by rattling and vibrations against each other or the box walls (Figure 4). Even specimens that had been housed and padded at some point presented problems of their own. Cartons used to house the specimens were broken, torn and had suffered from water damage. Contents varied from non-padded to cotton, wool, paper, plastic bags or too rigid Plastazote®, resulting in badly fitting, loose specimens hovering in the padding material. In some boxes with wool or cotton padding, these materials were saturated with soot, animal droppings and even pests (Figure 5). Specimens inside plastic bags had suffered from rattling and crushing, and in most cases original bags were deteriorating fast, mixing chunks of old plastic and plastic dust with the specimens.

All these unexpected issues created a larger task than expected and that required a whole new conservation and curation plan. Everything had to be redone from scratch, from the cleaning of specimens to their (re)consolidation, (re)gluing and re-housing, and then a new revised database had to be created.

**MAKING IT GOOD – THE SECRET IS IN THE NUMBERS**

The very active phase of the BDP, from 2010-2013, was enabled by a combination of three factors: refurbished laboratory, funding, and volunteers. The Bristol group had acquired a new paleontology laboratory in 1993, converted from space in the so-called Inner Court Building, behind the Wills Memorial Building, which had been occupied by the Department of Biochemistry before. By 2010, this laboratory space had become tired, was over-filled with junk, and was not fully accessible. The University of Bristol invested some £800,000 in entirely rebuilding the paleontology laboratory, enclosing specialized spaces (there used to be a single, open laboratory space), and providing improved services. This refurbishment included contributions from the HLF for laboratory equipment and especially for improving disabled accessibility. The HLF funding (£295,000 in all) paid for two staff, Pedro Viegas, as laboratory technician and Ed Drewitt as learning officer, over three years and nine months, as well as the costs of running events and activities, and all laboratory supplies. The third component, required by the HLF funding, and enabled by a constant supply of enthusiastic students, was volunteering. A new volunteering program was developed and implemented among the University students – in return for their work hours and dedication, students were given access to the newly built laboratory and received a thorough training in handling and preparing micro and macro fossils. Every year, a welcoming session for new students (undergraduates, Masters and PhDs) was arranged, giving an overview of what the project was, what were the aims, goals, the work done so far and how they could contribute and benefit from it. Students were encouraged to enrol in the program and a rota was made based on their time availability. The volunteering program took place from 2010-2013, with hundreds of students and external volunteers working for the project, accounting for more than 6000 work hours per year in mechanical preparation work alone, making it possible to have four tons of rock prepared in just over two years (Figure 6).

At the same time, the new BDP web page was launched (http://www.thebristoldinosaurproject.org.uk/), also created with the knowledge and dedication of an external volunteer, as well as Facebook and Twitter pages. These internet resources were vital to spread the word about the project and give a chance to others, not necessarily from a University background, to join and work with us, something required by HLF, our funding agency.
Figure 3: Rows of missing unknown specimens populated the original files.

Figure 4: Accessioned and un-accessioned specimens sharing the same box with no padding between them. Damage due to rattling, bashing and grinding against each other and walls of the box are evident.
Figure 5: Packing problems: a) and b) boxes showing cotton wool padding presenting signs of rat droppings and pests; a), b) and c) boxes showing signs of water damage; d), e) and f) boxes presenting signs of poor packing methods and wrong choice of Plastazote® density.
Figure 6: Volunteers working on numerous tasks in the Bristol paleolabs.
THE EXISTING COLLECTION

In order to resolve the mix of crates and cabinets with boxed, unboxed, cataloged, uncataloged, and half prepared, unprepared and prepared pieces of bone and rock, everything had to be taken out of the containers, laid out on big tables and sorted (Figure 7a). This sorting had to be done in several sessions since there was not enough table space to accommodate the huge amount of existing material. At the same time, a hugely demanding task began, puzzling bone by bone, shard by shard to figuring out which one would fit with the next bone and in what order (Figure 7b). Bones and shards were glued using Paraloid™ B-72 (B-72) in up to 40% by volume in acetone, and consolidation was made using a 5 to 15% dilution by volume.

Specimens were then sorted into groups of anatomically similar elements, including initially a categorization as vertebrae, ribs, and long bones. These were then sub-divided further into more specialized categories such as tail vertebrae and claws, as readily identifiable anatomical categories (Figure 8). This collection included several specimens that had been subject to some preparation work in the past. Dull, dark, coated specimens were washed with a soft wide brush soaked with either ethanol or acetone (if the ethanol rinse did not affect this dark coating specimens were successfully cleaned with acetone). The difference between the cleaned and uncleaned specimens was impressive (Figure 9). In other cases, specimens had been glued together at the wrong angle or with the wrong bone; these specimens had to have their bonding material removed by diluting it with acetone or softening it with a hot-air gun, and gently pulling the bonding material with tweezers or a pin vice.

After sorting, consolidating, washing and gluing, specimens were housed in plastic Styron™ 678E series (Styron) boxes and padded with Plastazote® foams. Three foam thicknesses and two different densities were used. Plastazote® LD45 (LD45) was used in 5 and 4 mm, the density most commonly used for storage of museum specimens, while a much softer Plastazote® LD15 (LD15), 3 mm thick, was used to pad all cabinet drawers and box bottoms, providing a non-slip, padding layer (Figure 10).

New accession numbers were given to specimens that had not been cataloged yet or had lost their numbers over the years. None of these specimens had been published, and re-numbering happened only after every effort had been made to match broken pieces together, and specimens with numbers.

MICROVERTEBRATE STUDY

The approximately four tons of rock consisted of several dozen blocks, of different sizes, from cobble size to large boulders, and these were in different conservation stages. Some showed various degrees of preparation work that had been done in the past, anything from chisels and air scribe scratch marks to different degrees of previous acid immersions, or in fewer cases presenting no signs of any work besides the quarry extraction and later moves. Since the dinosaur has been known for almost 200 years, but not many studies had considered details of its ecological setting, it was decided to give first priority to investigate the sedimentary characters of the rocks and the associated microvertebrate fauna.

Blocks that could easily be handled by one person and that presented diverse matrix and grain compositions were made the priority. These were placed in buckets, ranging in volume from five to 25 liters, depending on their size, and acid digested using a 5% acetic acid solution buffered with tricalcium orthophosphate. Visible specimens on these rocks were assessed for their condition and capability of withstanding acid digestion cycles prior to any acid immersion. If too fragile, they were removed or cut with the surrounding matrix from the block and mechanically prepared. Specimens that could withstand acid preparation were consolidated if necessary and a thin coating of either Mowital® B60 HH (M-B60) in a 5 to 10% solution in ethanol or B-72 in a 5 to 10% solution in acetone applied to them in order to act as a supplemental acid barrier and prevent any total or partial loss in case a break occurred; the choice of coating agent was determined by numerous factors inherent in the specimens themselves such as conservation state, brittleness, size and anatomy of the specimen. While large, robust, smooth specimens received a coating of B-72, smaller, more delicate, ornamented specimens were generally coated with M-B60.

Acid preparation took over 2 years of daily routines such as solution changes, rinsing, sieving, picking, identification and packing, and produced thousands of microfossils and the creation of a new, Triassic, microfossil research collection at the University. The new laboratory space has great extraction capabilities and all
Figure 7: Restoring the older collections; a) sorting all the collections processed and unprocessed materials; b) puzzling all the broken pieces together.

Figure 8: Organising specimens by their anatomical categories.

Figure 9: Comparison of a dark, dull, unclean specimen next to a bone-white washed one.
acidity digestion was made inside fume cupboards and using the appropriate personal protective equipment (PPE), so health and safety concerns were minimized. Still, it is important to point out that only trained or supervised personnel handled acid, especially in its pure form before it was diluted, and a mandatory requirement for acid preparation was the use of a lab coat and acid-resistant gloves at all times. Goggles were not used, as all operations involving acid were carried out within the laboratory fume hoods.

Microfossils were abundant and in general were smaller than 10 mm. Two years of acid preparation produced a collection with thousands of cataloged specimens that were the subject of Masters degree projects, based on the Tytherington (Van den Berg et al. 2012) and Durdham Down (Foffa et al. 2014) materials, and later of numerous summer research projects all with peer-reviewed publications in mind. Adding to this extensive research work done during the project, a non-biased, ready-to-be-picked microfossil sub-collection was created for future research.

**BREAKING ROCK**

Blocks that were too big for the existing fume cupboards had to be broken down into smaller, more manageable pieces. This was done by resorting to a variety of tools, such as medium-to large-sized (125 to 400 mm) diamond rock cutters, long (1 m) carbide drill bits such as the...
Figure 12: A selection of different tools used for mechanical preparation. a) Some of the airscribes used, secured on their holders inside the prep cabinets; b) power drills with tri-fluted carbide tipped drill bits; c) 300mm angle grinder with segmented diamond disk and sledge hammer for plug & feathers finish; d) large rock saw for reducing larger boulders; e) trimming excess matrix from exposed bones, allowing to leave a certain amount of neatly cut rock surrounding the bone “natural padding”.

Figure 13: Students working in closed and open prep cabinets.
Heller Trijet SDS Plus Hammer or Bosch SDS® Max SpeedX™ and different-sized sledge hammers and chisels to break the cut lines – when operating abrasive wheel machinery it was imperative that the proper PPE equipment was used, and, depending on the situation, the minimum safety equipment required for abrasive wheel handling wereoggles and level P3 dust masks.

Size reduction of the bone-bearing boulders required the use of specialized tools. Several air scribes were used, equipped with different makes and styluses of the Aro model, different-sized Paleo Tools® Micro-Jack (Micro-Jack), Ken Mannion’s Model TT, also with different styluses, plus refurbished, custom-modified PV pens and Dessouters. All these tools served two main purposes, first to give students experience with a wide range of air scribes with different power, precision, vibration and handling styles in order for them to learn that each tool has its own place when preparing, and secondly to break away from the “one tool for all jobs” attitude, which can lead to irreparable mistakes. Other mechanical preparation equipment such as different-sized grinders, rotary “Dremmel®” type multi-tools, different pin vices, and hammers and chisels were all used during preparation work, which allowed students to understand which tools would work best on each occasion, from heavy, bulk matrix removal to fine stereo-microscope aided, pin-vice preparation (Figure 12).

Mechanical preparation work using percussion or rotary tools was predominantly carried out inside custom-made preparation cabinets with attached dust extraction systems. When it was not possible to work inside closed cabinets, because specimens were too large or too small, fragile or intricate, work was done in some cases with one or more dust extraction arms, used as close as possible to the dust source in order to prevent dust and chips from surrounding the preparator. If working with open cabinets, all students and volunteers had to wear safety goggles, ear muffs and level-P3 dust masks (Figure 13) – even though the authors have extensive experience of mechanical preparation work, one event changed the PPE standards. Safety glasses are often used in laboratory spaces, especially when handling smaller micro air scribes and other low-impact tools, due to their lightness and comfortable wear during prolonged working hours. Yet, during the project, a student managed to get a small rock fragment projected at her face, which ricocheted off her glasses and hit her eye. Luckily the situation was not serious, but showed how important it is to use the right equipment and not to underestimate even the smallest, less powerful tools. Glasses are now not allowed and full goggles are mandatory for all laboratory users while doing any mechanical preparation work.

When work was carried out with heavier percussion tools that transmit large amounts of vibrations to the user, a sponge was wrapped around the tool and gel-padded bicycle gloves were worn in order to reduce vibration-related injuries. Vibration injuries are a controversial matter in fossil preparation. During the project, a wide, ongoing, study on this type of injury, and the vibrating tools and equipment to dampen them was started. Numerous gels, gloves and different padding systems are being tested against different tools, used with different matrixes and users in order to understand this poorly studied and incapacitating problem. Vibration-related injuries are a “silent killer” and all care must be taken when handling such equipment. Students and volunteers at the BDP were allowed only half days of air scribing, with pauses during work encouraged, thus minimizing the risk of prolonged injuries. During the entire project only one student showed signs of possible complications with vibration-induced injuries, during his initial induction and training with air scribes, which demonstrates the importance of constant guidance and surveillance with new volunteers, after this he was allocated different tasks for the duration of his volunteering.

For micro-preparation using smaller air scribes and pin vices, different stereo microscopes were used. Wild Heerbrugg M5’s with boom stands were used for cleaner, low dust emission, localized, Micro-Jack or pin-vice preparation, while older Carl Zeiss and a “bullet proof” non-identified “Z.L.U.B. 571” microscope were used inside the preparation cabinets for heavy dust and debris emission jobs. Both microscope types worked very well for teaching labs, but in general the older microscopes proved to be preparation and student proof, which is a dream to know when setting up preparation teaching facilities that will house numerous students and external volunteers such as this one.

**CURATION**

While macro preparation took place, numerous dinosaur bones were extracted from the rock daily. These had to be curated into the new macrofossil research collection.
As was the case for the historical collection, the new macro collection was also housed and packed using differently sized, square Styron boxes, lined with a layer of thin LD15 with top, thicker 5 mm layer of LD45 used to sculpt each specimen’s shape, encasing them in a strong and snug plastic and foam shell. These boxes were placed in existing metal cabinets with sliding shelves, which were in turn lined with LD15 as well, giving extra vibration and sliding-resistant properties to the cabinets.
Microvertebrate specimens were packed using a newly developed micro-storage system, where two layers of 3 mm LD15 would "sandwich" a single microfossil housed in a circular, 2 cm diameter, Styron box. These boxes would then fit into larger square Styron boxes which house 18 of the smaller circular boxes at a time, creating a simple, space saving, very secure system to house microfossils (Figure 11); the production of this system is described in greater detail in Viegas and Clapham (2012). During the specimen packing process, with dozens of students and volunteers, huge numbers of scalpel blades were used to cut the Plastazote; a vast amount of blades were necessary during this process as were equal amounts of paper for risk assessments. Cutting mats, metal rulers and non-permanent pens are all necessary for the custom foam cutting process – permanent pens should be avoided as they can leave a difficult to remove mark on the specimen by ink transfer from the foam’s micro-pores.

B-72 in consolidant or glue dilution was used during preparation and curation work, while Evo-stik contact adhesive was used to glue layers of B15 and B45 together when a thicker padding was necessary. When using contact adhesives, it is imperative that glued layers are left to dry outside plastic boxes and without specimens inside - good air ventilation and/or adequate PPE are necessary while working with it. Water-based contact adhesives are available nowadays and are better to work with in health and safety terms, but bonds tend not to be as strong and glues are less available and more expensive than solvent-based ones.

Four larger blocks were left almost without reduction, because we wanted to retain a few rock samples in the collection and these were the only ones that had a big bone association, rare on these Triassic fissure fills mostly caused by high energy events. These blocks had the visible bones prepared to a certain extent, about 30 to 60%, making them identifiable to researchers, but keeping them in their protective natural encasing. These blocks were placed in large plastic containers with their collection identification numbers.

The macro- and micro-collections from the BDP are housed in the central storage room of the Geology Department (now, School of Earth Sciences) collection, under BRSUG numbers. The catalog is currently available from the curator as an orderly Excel spread sheet, easily searchable and with unique registration numbers, also keyed to the drawers, for rapid retrieval. The catalog information will shortly be made available on the online BRSUG Museum website (http://www.bristol.ac.uk/earthsciences/about/facilities/museum.html).

THE RESULT

After 3.5 years of the Heritage Lottery Fund project (2010-2013), the University now has a new, fully equipped, preparation laboratory. Two new research collections were created, and both are fully curated, with thousands of specimens identified, packed, cataloged and put on to new databases. A microfossil collection was also created, with already prepared, acid digested residue ready to be picked on future research projects. A hand-sized sample of each type of rock prepared during the project was kept as a reference and making them available for future research if necessary.

The collection changed considerably since we first started, and the differences are easily seen, with a transition from dusty, water and pest damaged carton boxes, filled with broken, mixed, loose bones to a fully packed, well-padded, cataloged fossil collection (Figure 14).

ACKNOWLEDGMENTS

We thank the Heritage Lottery Fund for financing this project. A big thank you also to the various colleagues with whom we worked during the project and a special thank you to all the students and volunteers who worked with us in the laboratory – without you we would have never come this far! We also thank the journal referees for very valuable suggestions to improve the MS.

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TWO EXAMPLES OF PREVENTIVE CONSERVATION ACTIONS IN THE MUSEU DE CIENCIES NATURALS DE BARCELONA (MCNB): INSPECTION OF SPECIMENS AND SUBSTITUTION OF PACKAGING

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ABSTRACT

Preventive conservation practices at in the Museu de Ciències Naturals de Barcelona (MCNB) includes various routine tasks. The periodical examination on the collections condition and the replacement of inadequate permanent packaging are only part of those tasks. This paper presents the methods and materials used by the MCNB conservation team for permanent packaging and specimen inspection and how both ensure better long-term conservation of the collections.

Keywords: Preventive conservation, permanent packaging, IPM (Integrated Pest Management)

RESUMO [in Portuguese]

As práticas de conservação preventiva no Museu de Ciências Naturals de Barcelona (MCNB) incluem tarefas rotineiras. O exame periódico da condição das coleções e a substituição de materiais inadequados de acondicionamento permanente são apenas parte dessas tarefas. Este artigo apresenta métodos e materiais usado pela equipa de conservação no MCNB para acondicionamento permanente e inspeção de espécimes e ainda como ambos asseguram uma conservação melhor a longo prazo.


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INTRODUCTION

Preventive conservation is a discipline that aims to improve the conservation conditions of museum collections before any damage or deterioration occurs, and involves the related activities to their surrounding space (ambient climate conditions, illumination, storage systems, etc). Its objectives are to prevent or minimize deterioration and delay aging processes. Actions taken for the dry oological and arthropod collection of MCNB are described herein.

MCNB DRY OOLOGICAL COLLECTION

The MCNB chordate collection consists of 34,500 specimens, of which 724 are bird eggs, corresponding to 632 registered units. This group includes the oological collection which arrived at the museum as a deposit from the Royal Academy of Sciences and Arts on the 22nd of October 1926, as well as specimens from the collection of Barcelona’s Zoological Park, provided over the decades of the 70’s and 80’s.

Actions taken

The majority of the storage materials in this collection were not of the highest quality, thus not ensuring its long-term conservation or facilitating its handling or consultation. Therefore, it was decided that overall actions should be taken towards replacing all the inadequate specimen packaging (Figures 1A, 1C).

In order to improve the collection’s packaging, criteria such as compatibility, quality, durability and harmlessness were taken into account, seeking materials that are chemically neutral and devoid of acids or other harmful components.

Attention was also paid to label and tag visibility. These should be readable without having to remove specimens from their housing and packaging. Standardization of dimensions and type of container, wrapper and/or support, and uniformity of techniques and materials used for each specimen group were also taken into account. This was all done having in mind the saving of space and materials, facilitating access to the specimens and searching for optimal insulation characteristics from temperature, relative humidity (Prieto and Uribe 2009; Szczepanowska et al. 2013) and vibration of the storage area.

Replacement of permanent packaging

The first step was to remove the unsuitable or damaged storage materials in order to proceed with specimen dry cleaning. Subsequently a system of permanent custom made packaging was made for each specimen or specimen group, using polyethylene boxes with a lid (Standard Europe®) (Figure 1D). The interior of such boxes was covered with polyethylene foam, which served as a basis and fixation for the specimen. The contact area between the foam and specimen was secured with polyethylene fabric (Tyvek®) (Figure 1B) and, if necessary, special protections were applied (Fuller et al. 1992; Kishinami 1992; Davidson 2012; Figure 1D).

Results

The entire oological collection has been changed between December 2012 to March 2013 using all the criteria and methodology that we mentioned before. Hence, long-term conservation was assured due to the improvement of storage materials and a minor manipulation of specimens.

MCNB DRY ARTHROPOD COLLECTION

The MCNB arthropod collection consists of nearly two million specimens, the oldest dating back to the late 19th century. For the purposes of this action, approximately 150,000 specimens were selected, encased in 1,145 entomological boxes of different typology and arranged in 28 wooden cabinets.

Actions taken

The objective of this action was the removal of any harmful elements, pest control and improvement of the storage systems. As in the previous case the employed criteria were based on compatibility, quality, durability and harmlessness of the chosen materials, which should be chemically neutral and exempt from acids or other harmful components. The applied methods were adapted to each specimen and container.

Methodology

To improve the storage system, the damaged entomological boxes were repaired or substituted, non-standard outer labels were replaced, the box exterior was cleaned with cellulose paper and glass lid boxes treated with a neutral detergent.
The interior was cleaned with air and fine brushes adapted to the needs of the stored specimens. Elements detached from specimens or labels were collected and placed in small tracing paper packets (made from transparent pulp cellulose with a neutral pH and free of acids and chlorine), which were fixed with entomological pins to the bottom of the boxes to verify the origin of their content. Later, these elements were reattached to their correct place (Figures 2A, 2B). Loose specimens were fixed by means of entomological pins. Insecticide was renewed (a piece of cardboard impregnated with 1.27 g of transfluthrin of the trademark Baygon®) (Figure 2C), and if necessary, preventive quarantine was carried out by means of freezing the prepacked boxes at -18° C for 20 days in airtight bags.
Figure 2: Storage box with arthropods after intervention. A) from Navás collection (Odonata: Platycnemididae); B) from Martorell i Peña collection (Coleoptera: Curculionidae); C) from MCNB collection (Hymenoptera: Scoliinae). Images: MCNB.
After these conservation procedures the specimen’s state of preservation was evaluated in order to establish guidelines for future actions and the whole process was documented for internal archiving of the Museum.

Results

From June 2012 to June 2013, 63 specimen boxes were repaired or replaced. Labels of 732 specimen boxes were changed and 1,145 specimen boxes were cleaned. In 468 specimen boxes, detached elements of specimens were collected and placed in small tracing paper packets. Forty-seven boxes included specimens that needed to be fixed. Insecticide was renewed in 1,145 boxes and quarantine was carried out in 218.

CONCLUSIONS

The preventive conservation actions taken at the MCNB considerably improved the specimen storage conditions, while optimizing the possibilities for their consultation or handling. However, to guarantee long-term preservation it is also necessary to ensure compliance with the recommended environmental standards (Quesada et al. 2011) of relative humidity, temperature and illumination, as well as to improve the pest control. Close monitoring will be essential for the future well-being of the collections at the MCNB.

ACKNOWLEDGMENTS

We would like to thank the symposium conveners for inviting us to contribute to this special volume. Thanks go to the arthropod Collection curators Berta Caballero and Gloria Maso (MCNB) and to Olga Boet, the Chordate Collection documentalist at the MCNB for her assistance during the entire project. We also thank Steve Jabo (Smithsonian National Museum of Natural History) and an anonymous reviewer for providing comments that significantly improved an earlier version of the manuscript.

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RESTORATION OF MOUNTED ANIMALS - NEW TECHNIQUES IN OLD TAXIDERMIES

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ABSTRACT

The present paper explains the techniques and reversible materials used during the restoration of two old shark specimens housed in the collection of the Museo Nacional de Ciencias Naturales of Madrid, Spain (MNCN-CSIC). The detailed account of the methodology is presented herein and can serve as a general protocol to treat old taxidermy specimens, which need restoration and preventive conservation.

Keywords: Restoration, sharks, old taxidermy, reversible materials, MNCN-CSIC

RESUMO [in Portuguese]

Este artigo explica as técnicas e materiais reversíveis usados durante a restauração de dois espécimes velhos de tubarão pertencentes às coleções do Museo Nacional de Ciencias Naturales of Madrid, Espanha (MNCN-CSIC). É apresentada uma detalhada descrição da metodologia que poderá servir como protocolo para tratar espécimes velhos de coleções de taxidermia que necessitem de restauro ou conservação preventiva.


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INTRODUCTION

We present the methodology and materials used during the restoration process of two mounted sharks belonging to the historical collection (18th century, before 1784; Bru de Ramon, 1784) of the Museo Nacional de Ciencias Naturales (MNCN-CSIC) in Madrid, Spain. They correspond to a specimen of Sphyrna mokarran (Great hammerhead) and a specimen of Pristis pectinata (Smalltooth sawfish). These specimens are on display in a new exhibition about biodiversity in one of the showrooms of the Museum and their restoration was crucial for a correct exhibition and preventive conservation. All the techniques, materials and substances used for restoration have been as neutral, reversible and stable as possible. Likewise, a protocol and a condition report has been made so that the information gathered may be used for preventive conservation during exhibition and subsequent storage. The entire restoration process has been supported by extensive references and a photographic archive on the two species.

METHODOLOGY

Previous characteristics of the specimens

*Sphyrna mokarran* MNCN 44129 is 310 cm long, 87 cm wide and 70 cm deep. *Pristis pectinata* MNCN 44130 is 350 cm long, 87 cm wide and 55 cm deep. The specimens lack historical tags, stand or support, but MNCN 44130 was mounted on two supporting metal wires below the pectoral area and the left fins. The specimens were dusty because they were exposed over long periods of time without surface protection. No visible insect infestation (dermestids, termites or moths) was observed. There were chromatic alterations (varnish organic rust) as well as material loss and fragmentation on the right eye and on some areas of the fins of MNCN 44129 and on the left eye, the teeth and some areas of the fins of MNCN 44130.

Analytical samples

Two teeth and a fragment of a pectoral fin were sampled from MNCN 44129. These samples will be used for ancient DNA analysis which is a standard protocol in the DNA service of the Museum, but outside the scope of this paper. No samples were taken from MNCN 44130.

Intervention

A deworming agent using Xylacel® (Xylacel España, Pontevedra; www.xylacel.com) was applied during a period of 24 hours to eliminate any possibility of the presence of insects, although none were observed superficially (Grafia Sales et al., 2008). A chemical cleaning was performed to remove surface dust using alcohol (96%) (Val et al., 2012) and cellulose dressings (see Figures 1A, 2A, 2B). Areas with persistent dirt were cleaned mechanically, using a scalpel and bamboo scraper. The consolidation was made with Paraloid B72 (Room and Haas Co, Philadelphia, US; 7% in acetone; Gómez-Merino et al., 2009; López-Polín et al., 2009), applying it on the stitches, palate and eyes. A second intervention layer was later applied using again Paraloid B72 (7% in acetone). An important adhesion was made on the edge of the fins and on the stitching using Japanese paper and neutral polyvinilical gum (Figures 1B, 1C, 2C, 2D). Subsequently, a volumetric reintegration was made on the right eye and several areas from the stitching of MNCN 44129 (Figures 1C, 1D) and the left eye and stitching and stucco of MNCN 44130 (Figure 2E) using again Japanese paper and neutral polyvinilical gum (Vergara, 2002). Also, a chromatic reintegration on the same eye and stitchings, using acrylic paint, was performed, and finally, a protection layer was applied to the area around the palatine with Paraloid.

Packaging

A covered truck was used for transport. As support structure, a wooden semi-rigid base was used. A 2 cm foam layer was created to cover the base (Figure 1E). The sharks were packaged using a bubble plastic and neutral adhesive tape (Fitzgerald, 1995).
Figure 1: Intervention process in *Sphyra mokarran* (MNCN 44129). A) the ventral area cleaning process; B) reintegration process of the dorsal fin; C) reintegration process on the ventral area sewing; D) reintegration of the right eye; E) packaging of the two animals.
Figure 2: Intervention process in *Pristis pectinata* (MNCN 44130). A) teeth cleaning process of the “saw”; B) cleaning process with cellulose dressings; C) reintegration process of the left pectoral fin and teeth; D) reintegration of the ventral area; E) reintegration of the left eye.
CONCLUSION

We report the interventions on two mounted sharks belonging to the historical and scientific collection of the MNCN-CSIC prior to 1784. Using exclusively reversible, neutral and inorganic materials, we ascertained a better preservation of those specimens. During the whole process, protocols were made so that the institution that hosts the specimens knows at all times the materials used for preventive preservation, subsequent cleaning and further possible restorations.

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PROCEDURES AND MATERIALS USED IN THE MOUNTING OF TWO BIRDS WHICH BELONG TO THE NATURAL SCIENCES NATIONAL MUSEUM (MNCN-CSIC) AND THE COMPLUTENSE UNIVERSITY OF MADRID (UCM)

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ABSTRACT

In this work, the first results obtained in the study of two mounted birds are presented: a golden eagle, made by José María Benedito in 1914, which belongs to the Complutense University (UCM), and a pink flamingo (MNCN-CSIC reference: 7511) dated in 1891, which came from Cuba to Spain and is property of the National Museum of Natural Sciences of Spain (MNCN-CSIC).

Although both birds were mounted in close dates, differences may be observed in the methodology and the materials employed in preparing them (preservatives, internal iron armatures, paint and fillings although it has been determined that both birds contain arsenic-based compounds). These can be either due to geographical reasons (taxidermists could have used different techniques in different places), to historical changes in preparing specimens, or simply due to the factor that they were not created by the same professional. In order to make the comparative study of both pieces and to determine the nature of the materials employed, different analytical techniques have been used: X-ray computed tomography (CT) to study the internal configuration of the pieces (metallic structure and distribution of fillers), stratigraphic study with optical microscopy (OM) and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) to identify the materials used for coloring parts of the animal, preservatives and the nature of the internal armatures, and finally OM for the nature of the internal filler. The characterization of the coatings has been done by using SEM/EDS, Fourier transform infrared spectroscopy (FTIR), gas chromatography/mass spectrometry (GC/MS) and/or OM with selective staining.

Keywords: Conservation, analytical techniques, old taxidermies, Benedito brothers

RESUMO [in Portuguese]

Os resultados para o material de estudo dois pássaros montados são apresentados neste trabalho: uma águia dourada conduzido por J. M. Benedito em 1914, parte da Universidade Complutense de Madrid, e um flamingo rosa (com referência MNCN: 7511), datada de 1891, propriedade do Museu Nacional de Ciências Naturais (MNCN - CSIC).

Embora ambos foram montados em um futuro próximo, ter diferenças metodológicas na morfologia e constituinte (conservantes, armaduras de ferro internas, pintura e recheios, embora tenha sido determinado que ambas as aves contêm compostos à base de arsénio).ou por geográfica, evolução ou porque foram criados pelos mesmos problemas materiais profissionais. Para estudo comparativo de duas peças têm sido utilizados várias técnicas de análise: Raio-X (radiografia, tomografia computadorizada (CT)) para estudar a configuração interna das peças (estrutura metálica e de distribuição de cargas), estudo estratigráfico com microscopia óptica (OM) e microscopia eletrônica de varredura/espectroscopia de energia dispersiva (SEM/EDS) para pesquisar os materiais utilizados nas partes de coloração do animal e conservantes e OM, também para a natureza do material de enchimento no interior, a caracterização das amostras de revestimentos foi realizada utilizando SEM/EDS, transformada de Fourier a espectroscopia de infravermelho (FTIR), cromatografia em fase gasosa / espectrometria de massa (GC/MS) e / ou OM com coloração selectiva.

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INTRODUCTION

The general objective of this study is to make a comprehensive comparative analysis of the methods and products used in the preparation of two birds, stuffed in different historical periods (1891 and 1914). The specific intention is to understand the nature of the materials used and the ways of working to know their aging and, therefore, to apply the most appropriate treatments of conservation to the pieces. One of the pieces, a golden eagle belongs to the Faculty of Fine Arts of the UCM and the other, a pink flamingo, to MNCN-CSIC.

The relation between the Royal Cabinet and MNCN Taxidermy Laboratory and the Faculty of Fine Arts of the UCM

It is important to make an introduction to both institutions, the Royal Cabinet and the Faculty, in order to determine the origin of one of the pieces studied, the golden eagle (*Aquila chrysaetos*; Figure 1). Initially, we found the eagle in the office of a professor of the Faculty of Fine Arts who had just retired, Francisco López Soldado, who remembered that the eagle had been there since the 50s of the XX century. It had no associated information (only the signature and date on the bottom of the base) and was not inventoried as part of the funds of the Complutense University. Therefore, the owner and provenance of the specimen had to be determined, i. e. if the animal belonged to the Faculty of Fine Arts, the private workshop of the Benedito Brothers or to MNCN-CSIC. Two years after the introduction of graduate studies at UCM and remodeling of spaces to adapt the faculty to new necessities, 14 additional pieces appeared. Then, we began to search through the files of MNCN for the output of a batch of birds destined for the Faculty of Fine Arts, either as loans or donations (these were very frequent to other institutions and schools). Also, we proceeded to inspect the invoices and documents in the workshop of José Luis Benedito Bruño, taxidermist and heir of the family business, but unfortunately he died in March 2011. The sudden death of José Luis Benedito made the consultation of the family archive impossible, which is thus still pending.

Figure 1: Golden Eagle prepared by the Benedito brothers, 1914 (UCM).
The Royal Cabinet of Natural History, designed in 1752 by the sailor and naturalist Antonio de Ulloa, was opened as a museum on November 4, 1776. It was installed in the Palace of Count Saceda or Goyeneche Palace, at number 13 of Alcalá Street in Madrid, which previously had already housed the Royal Academy of the Three Fine Arts of San Fernando (now Royal Academy of Fine Arts of San Fernando) and which was also the School of Fine Arts of San Fernando. This explains the physical relationship of the two institutions. The first taxidermists of the museum are unknown. The oldest cabinet dissector known was D. Francisco Eguia, appointed Royal Cabinet of Natural History taxidermist in August 1776. He was replaced by Juan Bautista Bru de Ramon after his death in April 1777. Juan Bautista Bru de Ramon and his brother Mariano were the first documented taxidermists of the Museum, especially valued for having dissected the Java elephant, between 1777 and 1778, which is still exposed in the Natural Sciences Museum of Madrid. This is one of the oldest pieces preserved in the MNCN-CSIC. Since then, various taxidermists worked there. The most famous, both for the quality of their work as for the documentation generated (diaries, workshop notes, etc.), were Juan Ramon Dut, assistant taxidermist and first taxidermist between 1857 and 1871, who performed weekly reports of the work done in the laboratory of taxidermy (stuffed and conservation-restoration of pieces of the Museum) and the Benedito brothers, José María (1873-1951) and Luis Benedito Vives (1885-1955), considered in those days perhaps the best taxidermists of Spain. Although they had their own workshop, both worked at the Sciences Museum, the first from 1907-1943 and the second between 1912 and 1954. The Benedito brothers complemented each other perfectly, since each was specialized in some functions. Whereas Jose María focused on preparation of birds and developed administrative and management tasks (in his own workshop and as the head of the laboratory of taxidermy at MNCN-CSIC), Luis Benedito was considered an artist (taxidermist sculptor). The affable nature of the latter led him to consolidate social relations, so that in 1911 he traveled to Leipzig to learn the art of “dermoplastia” from professor Herman H. Teer Meer (1871-1934), which was usually used for larger specimens. Dermoplastia consists in carving or molding an anatomical body made of plaster, on which the skin was placed, instead of the usual stuffing straw. The pieces created by the Benedito brothers were exceptional, not only for the careful technique applied, but also for the excellent quality of the materials used (they imported materials from other countries, as from Verraux House in Paris, France).

The origin of the Faculty of Fine Arts, where the pieces are located today, dates back to 1752, when it was founded in Madrid’s Royal Academy of Fine Arts of San Fernando. In the beginning it was integrated by the School and the Academy. During the reign of Isabel II, the Moyano law was enacted (1857), which divided the Academy and the School into independent entities, but they continued sharing the same building. Artistic studies rose to the rank of “higher teachings” and the School developed this task. In 1967, the School of Fine Arts of San Fernando moved to Complutense City of Madrid, and today it is still situated in the same place. The Education Law of 1970 transformed the Schools of Fine Arts in faculties and acquired the name of Faculties of Fine Arts (Vian Herrero, 2006).

As can be seen in the accompanying documentation (Figure 2), the school, then called "Special School Painting, Sculpture and Engraving", acquired dissected animals of the Benedito brothers' private workshop. Until a few years, when the school became aware of the importance of these pieces, they were used as props in the composition of still lives in classes at the Faculty of Fine Arts. They have an artistic and historical value as works of art being considered Cultural Asset by national and international legislation, educational value, because of their use in teaching, and are biologically important because several of these specimens, including the golden eagle, are listed as protected species in various international conventions, including CITES. Because some of them are very deteriorated, they are currently being put in value by the faculty for safekeeping through processes of documentation, conservation and restoration.

**MATERIALS**

**Specimens studied**

**Golden Eagle**

The golden eagle (Figure 1) could have been part of a batch purchased in 1914 by the School of Painting, Sculpture and Engraving, from the private workshop of the Benedito brothers (at that time, Jose María Benedito was the head of the Taxidermy Laboratory of the Natural Sciences Museum workshop). It was bought to be used as teaching material in decorative painting classes...
taught by Enrique Simonet. The museum recommended to the School (now Faculty) of Fine Arts the acquisition of the specimens from the Benedito brothers, since that institution could not provide the specimens requested by the faculty (see Figure 2). As already mentioned, José María Benedito was the specialist for birds. He not only paid attention to the reproduction of the animal, but also spent a lot of time to study the habitat and tried to represent the animals realistically, by including elements taken from the animal’s own habitat into the dioramas. The bodies were formed by a metal frame, covered with a filling of jute and straw and/or cotton. They were tied with ropes that gave the filling the shape of tubular hanks. According to some invoices generated by the Benedito brothers during the mounting of the African elephant hunted by the Duke of Alba (between 1923 and 1935), sculptor jute and sisal or hemp rope were used, among other components and ingredients. These hanks were introduced in various regions of the body until the animal acquired the desired shape. To introduce them into narrow areas, arsenic soap was applied on hanks, since it acted as lubricant and facilitated the insertion, in addition to its disinfecting function. In the area of the body, the Benedito brothers applied the soap directly on the back of the skin. The use of arsenic soap in the museum has been reported by the actual preparator of the museum, D. Luis Castelo Vicente. This practice can also be confirmed by observing other pieces of the batch purchased by the Faculty of Fine Arts. Due to their poor conservation state, white putty is observable in the internal side of the skin, which looks quite similar to that found in the eagle (Figure 3). Different types of fillers can also be seen in the interior of the animals, as can the manner in which they have been worked (Figures 4, 5). Presumably, all birds of the same batch were stuffed in a similar way and the research that is being developed will contribute to determine it. Visual analysis reveals that although the eagle
is very damaged (surface dirt, paint stains, amputation of the tongue created by the taxidermist, disheveled and deteriorated feathers, etc.), it has a solid structural configuration. The legs and the cere are colored with yellow. The eyes are made of glass, and at the top of the head and under the tail, the internal metal armor appears. The tongue might be made of wax and wood, but this has not yet been determined. The figure is mounted on a pedestal shaped base, covered with sand.

**Pink Flamingo (Phoenicopterus ruber; Figure 6)**

The pink flamingo is property of the National Museum of Natural Sciences of Spain since January 1891, when the museum bought it from Mr. Moreno Gonzalez, his previous owner, as the identification label indicates. No other associated documentation exists. It appears probable that the flamingo was part of a collection purchased in May of that year (Figure 7), as it was recorded in the book of entries and exits of the Museum. In this list, the name of the seller is not provided. However, additional documentation indicates that the seller was a Cuban military doctor living in Madrid. We are still researching to relate various documents we have found (the label on the specimen and two documents found in the archive of the Museum of Science).

The pink flamingo is in poor condition. It is very unstable, has no base and the neck is broken, having also lost the feathers in this area. It has glass eyes and the taxidermy quality is very rudimentary. At first glance, it seems that areas that are often colored in birds have not been painted. However, along the legs there are two coatings: a lighter and translucent, yellowish layer, and on top of this, a denser thick dark brown layer, on which parallel incisions are present. In the area where the neck is broken, a whitish fiber can be seen as filling. The internal iron armature is of golden color, and protrudes about ten centimeters from the flamingo’s feet. The specimen does not have a base, although holes in the feet indicate that it was affixed to a base or diorama previously.
Figure 4: Inner part of anade performed by the Benedito brothers.

Figure 5: Interior of a Real Owl, in which stuffing straw and a hank of finer straw tied with rope can be seen.
METHODOLOGY

Documentary sources have been used for historical and material study of both pieces, through consultation the archive MNCN-CSIC (see Appendix 1) and specific bibliography (Calatayud, 1987; Barreiro, 1992; Rubio Aragonés, 2001), and by making personal interviews with Josefina Barreiro and Luis Castelo Vicente from MNCN-CSIC. To determine the nature of the constituent materials of both pieces, various analytical techniques have been used.

X-ray radiography and CT were applied to study the internal structure of birds and distribution of fillers. The analyses were made with a fixed X-ray apparatus (Philips Super 100CP; 150kV, 650mA) and with a computed radiography system (Agfa CR30X with display stations and Agfa Drystar NX 5302 laser printer). CT-scans were performed with a Philips MX 4000 Dual Computed Tomography Scanner with the following settings: 120kV/40mA/0.0s/r.WL:400 /WW:1200.

Optical microscopy with selective staining was used in the investigation of the materials used in coating of some parts of the pink flamingo. Also, OM was employed to determine the nature of the filler material. We used a petrographic microscope (OLYMPUS model BX51 with accessory for fluorescence U-MNU2 and digital camera DP21-CU).

SEM/EDS analyses were done in the stratigraphic study of the layers of paint, in the study of the preservatives, and in the identification of the material used in the construction of internal structures of the golden eagle and the flamingo. The samples were analyzed with a JEOL (JSM 6400) with an acceleration voltage of 20 kV, with a LINK, model eXL spectrometer with a resolution of 138 eV to 5,39 KeV.

FTIR was used for the identification of some materials that have been applied over the pink flamingo. It was performed on a Nicolet 6700 spectrometer with a Smart Orbit Diamond 30,000–200 cm–1 ATR (attenuated total reflectance) accessory. The spectra were recorded between 4,000 and 500 cm–1.

GC/MS was used as well for the identification of some materials of the pink flamingo.
An Agilent Technologies GC-6890N–MS 5973 chromatograph, with a HP-5MS (5% phenyl, 95% dimethylpolysiloxane) capillary column (length: 30 m, internal diameter: 250 µm ~ film thickness: 0.25 µm) and with a flow of 1 mL/min of helium as the carrier gas, was used. The oven was programmed to start at 100ºC, held there for 0.5 minute, increased by 40ºC/min to 150ºC, held there for 3 minutes, then increased by 5ºC/min to 300ºC, and held there for 5 minutes. The ionization mode was an electron impact (EI+) m/z range between 50 and 550. The data were acquired and processed with ChemStation Agilent program.

RESULTS AND DISCUSSION

Preservative

Morphology

As can be appreciated in figures 8A and 8C, there are differences in the preservative particles of both pieces: in the golden eagle particles have pyramidal morphology, similar to that observed in an arsenic trioxide microsample (Figure 8B). On the other hand, the morphology of the particles in the preservative for the pink flamingo is lamellar. No particles with this morphology have been detected to date among those that constitute the eagle preservative.

Composition

Arsenic based compounds and calcium compounds were detected in both preservatives (lime has probably also been used as an ingredient). Sodium based compounds are also detected in both, which may derive from the use of soap in the preparation of the preservatives. As is well known, caustic soda is used in the process that produces soaps from fats; this compound reacts with fatty acid and the ester group of glycerides in a hydrolysis process, forming sodium salt of fatty acids. On the other hand, soap is one of the ingredients of arsenic soap. Moreover, in the pink flamingo preservative, the microanalysis detected the presence of potassium, which might indicate that tartar salt (potassium acid tartrate) has been used in the mixture. In the study sample for the golden eagle, tartar salt has been detected, further confirming the use of arsenic soap in the preparation of this preservative.

Figure 8: SEM images of different morphologies of the arsenic particles (BSE detector). A) detail of a laminar particle in the pink flamingo; B) detail of white arsenic powder; C) detail of arsenic particles in the Golden eagle.

Figure 9: Details of the polychrome applied to the legs (A) and beak (B) of the Golden Eagle made by Benedito Brothers.
Figure 10: Stratigraphic test of the painting film on the golden eagle’s legs, made by OM. Sample AD-B. General plane. Incident light, 200X.

Figure 11: Analysis of the coating film of the pink’s flamingo paw: A) sample No. 1, light brown coating from the flamingo’s paw; B) FTIR spectrum made of the total area of the sample No. 1, indicating animal glue.
Figure 12: Various analyses of the coating films of the pink flamingo paw: A) workpiece image, from which the sample was taken; B) sample No. 2, dark brown coating from flamingo’s paw; C) cross section of a portion of the sample in which an acid fuchsin staining was made, in order to delimit the area where the protein is located (the surface of the putty); D) chromatogram obtained from the analysis of the filler (no external coating); E) FTIR spectrum made of the total surface of the sample No. 2. The separate surface material of the sample is animal glue. It is a very fine and pure glue, indicating that it could be a fish glue. F) EDS spectrum obtained from the analysis of the elements present in the putty.
eagle, this compound has not been detected. This suggests that at least in the flamingo, Bécouer arsenic soap may have been used. The Bécouer soap is thought to have been invented in 1743 by Jean-Baptiste Bécouer (1718–1777). This method of conservation, based on arsenic, was popularized in 1830 under the name of the Bécouer recipe and was basically made of white arsenic, tartar salt, camphor, lime and soap (Pérez Moreno, 2012). This hypothesis has to be confirmed by further analysis.

Paint and coatings

In the golden eagle, paint on the beak and feet can be observed. When living organisms die, some body parts lose their coloration or darken, as happens in the case of the legs and some areas of the beaks of birds. The paint layers are possibly oil paint, since they are not water soluble. This has been determined based on solubility tests with water and due to observation with UV light: no fluorescence under UV radiation means that no chromophore groups in composition of colors and these parts have not been varnished or mixed with reactive substances to UV radiation. Also, bills for materials generated by the Benedito brothers preparing other pieces indicate that drying oil and tubes of oil painting were used as binder. For example, these materials are listed in the bills and diaries about the realization of the African elephant hunted by the Duke of Alba in 1913 and performed by Benedito Brothers. In stratigraphic examination of the paint on the leg of the eagle (Figure 10), the following layers were detected: 1) a white coat, made of white lead \( \text{ZnO} \); 2) a yellow layer, in which we detected chrome yellow \((\text{PbCrO}_4)\) and cadmium yellow \((\text{CdS})\) and also white or yellow lead \((\text{PbO})\). Also, some compounds normally used as fillers of chrome yellow were found: gypsum and perhaps also lead sulfate. Finally, a yellow-orange layer was found, which is composed of some chrome yellow and, probably, some lead pigment, perhaps yellow \((\text{PbO})\) or orange \((\text{Pb3O4})\). White lead particles appear to be absent.

In the pink flamingo, as noted above, light brown and translucent material is applied as a coating on the legs. On top of this layer, brown putty is applied. The transparent coating of the flamingo paws is bright on one side and matte and rough on the other, corresponding to the area of contact with the skin of the animal, so that it could be animal skin. Figure 11 shows a sample taken from the flamingo paw (Figure 11A) and the results of the analysis made by FTIR spectroscopy (Figure 11B). In the spectrum obtained characteristic bands of proteinaceous materials can be seen. These are associated to peptide bond: \(\nu\) –NH (ca. 3237 cm\(^{-1}\)), Amide I \((\nu \text{C}=\text{O})\) (ca. 1642 cm\(^{-1}\)): Amide II \((\delta_{\text{in plane} –\text{NH}} \text{and } \nu \text{C}–\text{N})\) (ca. 1534 cm\(^{-1}\)) and Amide III \((\nu \text{C}–\text{N} \text{and } \delta_{\text{in plane} –\text{NH}})\) (ca. 1260 cm\(^{-1}\)). Figure 12 shows a detail of the flamingo’s paw, the sample taken from this area, and the results of the analysis carried out. The spectrum obtained by FTIR confirms the positive staining with fuschine acid, i.e., it is a protein. The bands identified are: \(\nu\) –NH (ca. 3269 cm\(^{-1}\)), Amide I \((\nu \text{C}=\text{O})\) (ca. 1627 cm\(^{-1}\)): Amide II \((\delta_{\text{in plane} –\text{NH}} \text{and } \nu \text{C}–\text{N})\) (ca. 1514 cm\(^{-1}\)) and Amide III \((\nu \text{C}–\text{N} \text{and } \delta_{\text{in plane} –\text{NH}})\) (ca. 1234 cm\(^{-1}\)). To determine the composition of the filler, SEM-EDS was employed for inorganic compounds and GC-MS for the organic part. The dark brown putty is composed of t alc (magnesium silicate) in combination with a mixture of a non-drying fatty material, as shown by GC-MS (Figure 12D). We identified non-drying oil, due to the proportion of the methyl esters of fatty acids azelaic, palmitic and stearic and prevalence of oleic acid and small amounts of cholesterol (present in animal fats). Ratios of P/S greater than three can reveal the presence of little drying fatty material such as animal fat, probably animal fat and resin. The latter was identified as pine resin based on the presence of abietic acid and other derivatives of these (7-oxo dehiuxroabietico, 15-OH dehidropabietico, etc.). Inorganic pigments were not detected. Given the shape and application areas of the brown putty, which is especially thick at the intersection of the leg with the foot, we assume that this dark substance was a subsequent restoration to provide strength to the deteriorated legs. There is also a coiled wire around the leg, which was detected below the putty by means of X-ray (Figure 8B), which probably reinforced the legs.

Analysis of the fillings

Golden eagle neck

Jute fibers (the information has been compared with the sample collection belonging to the Chemistry Laboratory of the Faculty of Fine Arts (UCM)) were identified as fillings in this area. Since there has been no access to other internal parts of the animal’s body, we do not know if other fillings were used as well, but the probability is high because the Benedito brothers usually varied the fillings in different areas of the animal.
Pink flamingo neck
Cotton was used as a filling in the flamingo neck. The rest of the body’s fillings has not yet been studied in detail. However, whitish spots in the X-ray indicate zones with some radiographic density that could indicate a general filling made with cotton bolls.

Figure 13: Fiber corresponding to the golden eagle’s filler: jute.

Figure 14: Fiber corresponding to the pink flamingo’s filler: cotton.

Figure 15: Study of the metal skeleton of golden eagle: A) piece of the metal skeleton of the golden eagle; B) EDS spectrum microanalysis of the armor of the golden eagle.

Figure 16: Study of the metal skeleton of pink flamingo: A) piece of the metal skeleton of the pink flamingo; B) EDS spectrum microanalysis in the armor of the pink flamingo.
Figure 17: Radiography of the golden eagle.
Metal structures

Differences can be observed in their composition. Visual examination and written documentation lead to the identification of the material of the armature of the golden eagle as alloy of iron and zinc. Through bills for materials used in other pieces, we can see that the Benedito brothers used galvanized wire to build the internal structure. Usually a professional is faithful to the use of the same materials for the same function (internal structure). This hypothesis was confirmed later by SEM/EDS (Figure 15B). The armature used in the preparation of the pink flamingo, which is golden in color and malleable, is made of brass (copper and zinc alloy), as the analyses performed have proved (Figures 16A, B).

As shown by radiography, the internal structure made by the Benedito brothers has a vertical central axis that runs from the head to the tail with a twisting shape crossed by two perpendiculars axes that make the legs and wings. Contrary to the complexity and functionality of the framework developed by the Benedito brothers, the pink flamingo has a less elaborate structure. It is probable that the cause of the broken neck and legs with subsequent restorative intervention may be the result of this, and also because of the employment of brass in contrast to the iron alloy used in the eagle (the first has less strength). Both specimens contain bones in the wings and legs and possibly also the skull.

CONCLUSION

Both birds contain arsenic-based compounds. This could imply the presence of arsenic soap, which shows how widespread the use of this product was as preservative and lubricant. Although the time between the execution of two stuffed birds is little, significant differences in terms of materials and stuffing methodology...
were identified for preservatives, internal iron armatures, paint and fillings. These differences may be due to the fact that the specimens were created by different professionals in different places, with different ways of work, or because the taxidermy developed rapidly in a very short time, which led to changes in methodologies and products in just a few years. This last point should be verified by the research in more specimens. Furthermore, the pink flamingo has some added materials, probably as a result of a subsequent restoration intervention. On the other hand, the golden eagle has never suffered any restorative intervention. A deeper study of the fillers is still pending, and will be done if during the restoration process it is considered appropriate to take samples for doing it.

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REFERENCES CITED


Appendix 1

Notes in the archive of MNCN-CSIC, on which identification and history of the specimens are based.

Diario del escultor taxidermista, Luis Benedito, del montaje en el Real Jardín Botánico de la piel del elefante africano regalada al Museo por el Duque de Alba. ACN 0296 003. MNCN-CSIC archive.


Expediente personal de Juan Ramón Dut. Ref. Caja 235-Exp. 45. MNCN-CSIC archive.

Expediente sobre la petición realizada por el Director de la Escuela Especial de Pintura al Director del Museo de Ciencias de pájaros disecados… Ref. ACN 0267 027. MNCN-CSIC archive.

Francisco Martínez Sáez presenta a Miguel Maisterra una lista de objetos procedentes de Cuba y Europa… Ref. ACN 0261 011. MNCN-CSIC archive.


Notas de gasto del montaje del elefante africano donado por el duque de Alba al Museo de Ciencias. Refs. ACN 0296 005, ACN 0296 006, ACN 0296 007. MNCN-CSIC archive.

Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/
POLLUTANTS IN THE MUSEUM ENVIRONMENT – MINIMIZING DAMAGE IN STORAGE AND DISPLAY

Pamela Hatchfield

ABSTRACT

Natural history collections contain the wide spectrum of materials found in most encyclopedic collections. The growing field of preventive conservation addresses the many sensitivities of all kinds of materials found in collections to the environmental agents to which they are exposed over their lifetimes in storage and display. Although mineralogical collections may seem to have little in common with taxidermy, caretakers of these collections require practical, useful information about how to extend the lifetimes of these materials. This paper presents an overview of how and why materials in museum collections may deteriorate, and provides strategies and solutions for minimizing deterioration on display and in storage.

Keywords: Natural history collections, preventive conservation, deterioration, display, storage

RESUMO [in Portuguese]

As coleções de história natural contêm um largo espectro de materiais encontrado na maioria das coleções enciclopédicas. O campo crescente da conservação preventiva aborda as várias sensibilidades de todo o tipo de materiais encontrados em coleções e os agentes ambientais a que estão expostos durante o tempo que passam amazenadas ou em exposição. Embora as coleções mineralógica pareçam ter pouco em comum com a taxidermia, os curadores destas coleções necessitam de informação útil e prática sobre como extender o tempo de vida destes materiais. Este artigo apresenta uma visão global de como e por que os materiais em coleções de museus podem deteriorar-se, providencia estratégias e soluções para minimizar a deterioração na exposição e em reserva.

INTRODUCTION

To those working in cultural institutions, the extent to which environmental factors determine the health and longevity of collection materials is no longer a surprise. In the 1920s, Alfred Lucas, an analytical chemist working with archeologists in Egypt noted the effects of changing environments on the objects he excavated with archeologists like Howard Carter (Lucas, 1924: 45). Pliny, writing in the first century AD noted the corrosion of lead caused by vapors from roof timbers (in Rackham, 1968). Damage from soot, sulfur dioxide and acids seen on paintings and shell collections was documented as early as the 19th century (Eastlake et al., 1850; Kenyon, 1897). By 1971, the first review of damage from volatile pollutants in storage cabinets on collection objects had been published (FitzHugh and Gettens, 1971).

Over time, chemical interactions between the materials of cultural heritage and light, heat (or cold), moisture (or lack of it), and pollutants have played a significant role in the deterioration of collections. This paper focuses on pollutants and their effects on collections: how they interact with materials, and how to mitigate these effects as we make choices about handling, exhibition, storage and packing of the collections in our care. Although sometimes vastly different in scale, paleontological materials, natural history collections, fine art and architecture alike share similar sensitivities to pollutants and will benefit from an informed use of stable, inert materials used in their environments. The presence of pollutants in storage or exhibition cases, together with other factors like high relative humidity causes the formation of unusual organic corrosion products on metals (sodium copper acetate on bronze, for example), the alteration of mineral specimens due to inappropriate relative humidity levels, the presence of sulfur or acids (Waller, 1999), the formation of calcium acetate on shells, also known as Byne’s disease, calcilacte (calcium acetate dichloride hydrate) on limestone (Van Tassel, 1945; FitzHugh and Gettens, 1971).

One particularly dramatic example of irreversible alteration occurred a number of years ago in Verona. The Museo Civico di Storia Naturale in Verona is known for its spectacular collection of marine fossils from Bolca quarry, as well as prehistoric lithic artifacts. In 2008, parts of the collections were moved from their original locations to a newly restored, decommissioned military Arsenal, intended to serve as the permanent site for the archeological section of the museum. The lithic artifacts, including flints, were reorganized and stored in newly prepared cabinets. Soon after the rehousing, an odd and very distinctly blue color was observed on some of the flints (Abbot, 2010, figure 1).

This strange phenomenon created a furor in the national and international news, resulting in a petition to the Italian Minister of Culture to identify the source of the problem, assign blame and provide punitive action for “severe chemical contamination of archaeological material, causing irreversible alteration to the archaeological materials with enormous loss of scientific information and to the National Patrimony” (Drahl, 2010: 32-33). In 2010, samples analyzed at the University of Padua found that the surfaces showed pervasive contamination by various hydrocarbons and plasticizers such as phthalates and BHT (butylated hydroxytoluene; Drah, 2010). Traces of these substances were also found on bones and ceramics stored there, but no color alteration was visible. Most of the time, a dramatic, clearly visible alteration is not evident. However, mechanical and chemical alterations may have taken place unnoticed, and lead to accelerated deterioration of collection materials.

Although work is still ongoing, chemists and geoarcheologists have identified three new pigment molecules by HPLC, which they called Romeo Blue, Juliet Blue, and Flint Blue. They belong to the triphenylmethane dye family, an old class of synthetic colorants related to bromocresol green, the pH indicator. The additive was identified as an antioxidant: 2,2,4-trimethyl-1,2-dihydroquinoline. HPLC identified the three pigments. The color change was traced to an antioxidant added to the synthetic rubber mats used in the armory storage cabinets, which somehow desorbed from the mats to the tools and trimerized to form the blue contaminants (Tapparo et al., 2011). Were it not for the color change of some of the flints, contamination of the archeological objects would probably have escaped detection in the absence of thorough scientific analyses. According to Laura Longo, the former curator of Verona’s Natural History Museum, the adsorbed organic compounds could bias important analytical results such as those conducted on Neanderthal DNA (Lalueza-Fox, 2007), especially those obtained with techniques probing extremely low amount of material (Drah, 2010). Clearly we need to be extraordinarily careful about the materials used in proximity to collection objects, and to understand their history when undertaking preservation activities and analysis.
A pollutant may be defined as an impurity in the environment, derived either from natural or man-made sources. Pollutants are agents of deterioration that have the potential to interact with materials of art in damaging ways. They are reactive chemical compounds, which may be, in a gaseous, liquid or solid state. Liquids may be also vapor based, or in aerosol form. Semi-volatile pollutants such as plasticizers also pose risks. Pollutants are generated in the exterior environment, either from natural, biological sources, or by man-made, industrial processes and activities. The most common pollutants in the environment include sulfurous compounds, nitrogen oxides, ozone, ammonia, formaldehyde and acidic compounds. Some of these species may be damaging on their own, or after interacting with atmospheric moisture to become acids or other harmful species.

Externally generated pollutants range widely outdoors. For example, hydrogen sulfide levels may measure as high as 5000 parts per trillion (ppt) (7.03 µg/m³) in urban areas, but as low as 50 ppt in remote areas. Between 1900 and 1970, nitrogen oxide emissions increased by an alarming 690%, clearly related to industrialization. Since 1970, most emissions have decreased by about 40%, initially due to the oil shortages of the 1970s, and increasing awareness about health and other dangers of air pollution (Gradael et al., 1981, cited in Hatchfield, 2002).

In interior spaces, construction materials, furnishings and combustion activities such as burning fuel for heating generate most pollutants, and they often build up to very high levels in enclosed areas, being unable to dissipate. Sometimes, collection objects themselves generate substances such as sulfur that are harmful to other specimens or other objects. For this reason, it is...
critical to understand the chemical nature of materials found in the collection, in addition to understanding housing materials and the museum environment. Furthermore, many gases considered stable under normal circumstances react readily in the presence of certain chemical species such as free radicals that may be created in photochemical reactions. Light will enhance degradation processes for many materials. For example, the degradation of leather in the presence of sulfur dioxide can produce the phenomenon of red rot (see also Rae, this volume).

It is also important to consider the potential for damage by particulates, or dust. Typically hygroscopic and usually abrasive, they act as nucleation sites for corrosion on metals, or chemical interactions on other materials. They are generated in the exterior environment by biological processes such as combustion, microorganisms and decay, and non-biological elements like salts, vehicular traffic and construction (Table 1). Indoors, they are produced by combustion processes such as cooking or heating, construction processes, soiling and textiles (Table 2). New materials brought into collection environments, either for construction or storage housings contribute significantly to the overall quality of air in the building. Building materials like wood products, insulation, wall coverings, paints, floor finishes or ceiling tiles can be significant sources of pollutants, especially when large surface areas are involved. The volatile organic contente (VOC) of many construction materials may be extremely high. VOCs in construction materials have high vapor pressures and will continue releasing chemicals, attempting to come into equilibrium with their concentration in the surrounding air.

More than 900 VOCs have been identified in indoor environments, 250 of them at greater than 1 parts per billion (ppb). As an example, consider that silver tarnishes at 0.2 ppb hydrogen sulfide. In a typical museum environment, hydrogen sulfide is typically found at higher levels than this, and in some exhibition cases has been measured at as high as 50 ppb. Many other examples of alteration of collection specimens like limestone, metals, organics and synthetic materials have been documented (Hatchfield, 2002: 32-42).

In addition to the collection objects, construction and preparation materials brought in to house objects must be carefully considered. Particularly with old display or storage cases and historic exhibits such as dioramas, construction materials are likely to be a source of pollutants. These may include wood products, oil paints, plant fibers, plastics, oil-based clays, waxes, and many materials used in taxidermy.

Testing for pollutants

Testing for pollutants is often done at the building level. Information about the environment within the building is particularly valuable to compare to the exterior, and also to the pollutant levels within display cases. These comparisons can help identify the locations, if not the sources of problematic pollutant species (Grzywacz, 2006). Rather than requiring sophisticated equipment, some companies offer
environmental testing methods involving the exposure of metal coupons which are sent back to the company for evaluation (www.purafil.com/products/monitoring/air_quality.aspx).

Other simple environmental tests may be done with a minimum of expense or equipment (Hatchfield, 2002: 46-47).

**TESTING MATERIALS**

The idea of testing every product considered for use may be overwhelming, but it is possible to gain considerable insight into the nature of materials by reviewing their product literature and Material Safety Data Sheet (MSDS) or Safety Data Sheet (SDS). These sheets contain information about the physical characteristics, behavior and health risks of products (for example, flammability, reactivity, toxicology and spill procedures). It is important to keep in mind that the information relates primarily to health and safety, not to interactions with materials. For example, many materials giving off acidic vapors might not be considered a health risk, but might very well damage sensitive materials. Nevertheless, examination of the product literature and SDS will reveal information allowing identification of certain classes of materials known to be problematic, such as alkyd resin paints or plasticized polyvinyl chloride. Even in cases where the MSDS indicates a safe material, products must be tested to be certain harmful compounds are not present.

The damaging effects of pollutants may be caused by volatile compounds such as acidic gases, semi-volatile compounds such as plasticizers, or non-volatile components such as fire retardants in fabrics, which may only pose problems through direct contact with objects or specimens. A range of spot tests are simple to conduct; however, these typically test for very specific compounds such as sulfur, chlorine, cellulose nitrate or acetate (Hatchfield, 2002: 45-54). The benefit to these tests is that results are immediately obtained. A more generalized test done in many museums today is an accelerated aging test known as the modified “Oddy Test”, requiring exposure of cleaned, degreased coupons of lead, copper and silver with individual samples under specific conditions at elevated temperature and relative humidity for 28 days. These coupons are compared visually to a control set of metals which were exposed under identical conditions, but without the test material in question (Thickett and Lee, 2004). These tests are typically done without the metals in direct contact with test materials; however, direct contact testing between materials and coupons is often conducted in addition to determine that direct physical contact between artifacts and construction materials will not be problematic.

**Choosing materials for proximity to collections**

Although few materials considered for use in collection environments are truly inert, the term is commonly used to refer to materials with low VOC content, high stability and longevity, and low risk of reactivity. Wood, of course, is one of the most common construction products found in collection construction. Some woods are extremely acidic and have been known to reduce sensitive specimens to dust. Oak, for example, is one of the most acidic woods available, but acid is released from many woods, in varying quantities over time, and depending on many variables including time of year the wood was cut, where in the trunk the wood is harvested, drying and preparation procedures and length of storage prior to use. Published pH levels of woods vary greatly and do not necessarily relate to volatile acidity (Hatchfield, 2002: 67-70). Once combined with adhesives and additives in processed wood products such as particleboard or plywood, acidity may also vary depending on the nature of those additives. In general though, wood products intended for exterior use tend to be more stable and have lower volatile components from adhesive content. Some products marketed as “formaldehyde free” will still evolve significant acid and other compounds, because wood particles and adhesives are still present.

In areas where good air exchange exists, such as open gallery space, the use of such wood products is less problematic than in enclosed areas such as storage or display. Although commercially available coating materials seem an attractive choice to solve the problem of pollutant outgassing from wood products, there is no commercial product available that will prevent the evolution of acids and other pollutants from wood. Products developed for sealing wood are intended to protect the wood itself, not necessarily to prevent evolution of volatile material. Numerous possibilities exist, however, to prevent pollutants from emanating inside exhibition cases. A solid vapor barrier such as an aluminized film can be heat sealed on to all wood surfaces exposed to the interior of the case. Non-wood products such as acrylic, glass, polyvinyl ethylene or aluminum-faced construction panels can be used in place of wood. Fabrics, gaskets, mounting materials,
caulking and all other materials inside exhibition cases should be carefully considered before use. Some very brief guidelines are included here, in addition to a general guide for choosing case materials.

**GENERAL GUIDELINES**

Exhibition cases should be tightly constructed to reduce dust infiltration and the effects of humidity fluctuation on collections and also so microclimates differing from ambient conditions may be created where necessary. Use inert or low reactivity materials whenever possible. These include glass, acrylic sheeting, metal, and powder-coated metal. Minimize the use of wood products in exhibition case interiors. When wood must be used in a display area, it should be completely sealed with a vapor barrier such as the aluminum laminate Marvelseal® or Moistop® to prevent the emanation of pollutants from wood products. All sections of the case accessible to the display area must be sealed with Marvelseal® if wood products are used.

List of currently acceptable materials follow (Tables 3-11). Although certain classes of materials can be recommended for use, materials should always be tested, because product formulations can change without notice. Where microclimates are required, compartments should be built beneath the deck areas to house conservation materials such as silica gel. Access to those compartments should be provided from the case exterior so vitrines and displays are not disturbed. These compartments should be lined with an aluminum laminate such as Marvelseal®. Decks should be pierced with holes or gaps provided around the edges in order to allow air circulation between conservation material compartment and the vitrine area.

<table>
<thead>
<tr>
<th>Table 3: Acceptability of construction materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceptable</strong></td>
</tr>
<tr>
<td>Glass</td>
</tr>
<tr>
<td>Powder-coated metals</td>
</tr>
<tr>
<td>Metals including anodized aluminum, stainless steel, (although some can catalyze reactions with pollutants)</td>
</tr>
<tr>
<td>Wood when completely wrapped with aluminum sheeting or aluminum-polyethylene laminates such as Marvelseal®</td>
</tr>
<tr>
<td>High-pressure phenolic laminates such as Formica</td>
</tr>
<tr>
<td>Aluminum laminates such as Alucobond® or Dibond®</td>
</tr>
<tr>
<td>Tycore® (neutral pH paper honeycomb board)</td>
</tr>
<tr>
<td>Ethafoam® 900</td>
</tr>
</tbody>
</table>
Table 4: Acceptability of support materials

<table>
<thead>
<tr>
<th>ACCEPTABLE</th>
<th>LESS STABLE</th>
<th>UNSUITABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tycore® (neutral pH paper honeycomb board)</td>
<td>Acid-free foam core products</td>
<td>Most other foam core products</td>
</tr>
<tr>
<td>Coroplast® (fluted polyethylene/polypropylene)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archival corrugated cardboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethafoam®</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Construction and support materials (Tables 3, 4)**

In general, metal and glass are materials that can be safely used in enclosures with specimens and artifacts. Wood and wood products are less stable and are likely to off gas acids and pollutants. However, if wood must be used in a display area, it should be coated with an approved water-borne polyurethane or sealed completely with aluminum sheeting or an aluminum laminate (Marvelseal®).

**Plastics**

A list of acceptable plastics is given in Table 5.

**Adhesives (Table 6)**

Adhesives should be water-based or solvented acrylics. Avoid the use of rubber based, polyurethane, or formaldehyde-based adhesives with the exception of phenolic adhesives for plywood.

**Gaskets, caulking, padding and tubing (Table 7)**

Gaskets and tubing should be made from silicone (neutral cure, the type made without acetic acid), polyethylene, polypropylene or Teflon. Test adhesive-backed types before use. Do not use polyvinyl chloride (PVC) products such as Tygon® tubing. These can evolve hydrochloric acid, and plasticizers may migrate from them. Rubber based products require testing before use. If silicone caulk is used, it should be neutral cure (without acetic acid), often specified for electrical applications.

**Coatings, stains, paints and varnishes (Table 8)**

Avoid the use of products containing oils or alkyd resins, including oil stains, oil-modified polyurethanes and oil paints. Some moisture-borne polyurethanes are safer for use. A minimum of three coats should be applied, and surfaces must be aired for at least three weeks before installing works of art. Acrylic paints can be used over sealed case interiors, but also should be allowed sufficient airing time before installation (at least three weeks).

**Fabrics (Table 9)**

Cotton or linen fabrics are often acceptable, but require testing before use. Surface treatments may contain formaldehyde or other volatile substances potentially damaging to works of art. Fire retardants can be extremely corrosive and should be avoided. Some dyes, particularly darker colors, may contain sulfur or acidic components. Wool and silk should not be used.

**Paper products**

A list of acceptable paper products is given in Table 10.

**Other materials**

A list of other acceptable materials is given in Table 11.
Table 5: Acceptability of plastics

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teflon®</td>
<td>Cellulose acetate</td>
<td>Cellulose nitrate</td>
</tr>
<tr>
<td>Polyethylene</td>
<td></td>
<td>Polyurethane foams (ester better than ether, but both unsuitable for long-term proximity)</td>
</tr>
<tr>
<td>Tyvek® spunbonded polyethylene non-corna treated, soft drape (wash first)</td>
<td></td>
<td>Polyvinyl chloride (PVC)</td>
</tr>
<tr>
<td>Polypropylene</td>
<td></td>
<td>Any highly plasticized or chlorinated plastic</td>
</tr>
<tr>
<td>Polyethylene terephthalate (MylarD®)</td>
<td></td>
<td>Sulfur vulcanized rubber</td>
</tr>
<tr>
<td>Acrylics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polystyrene (not a vapor-barrier)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polycarbonate (not a vapor-barrier)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 6: Acceptability of adhesives

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic adhesives (pressure-sensitive not in direct contact)</td>
<td>Some hot melt adhesives based on ethylene vinyl acetate</td>
<td>Urea-formaldehyde</td>
</tr>
<tr>
<td>Some hot melt adhesives based on polyethylene/polypropylene</td>
<td>Polyvinyl acetate-based caulk</td>
<td>Animal glue (sulfur)</td>
</tr>
<tr>
<td>Acrylic emulsion or dispersion adhesives</td>
<td>EPDM</td>
<td>Polyvinyl acetate (PVA or PVAc) emulsion adhesive</td>
</tr>
<tr>
<td>Acrylic caulk</td>
<td></td>
<td>Pressure-sensitive adhesives (contact)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rubber cement</td>
</tr>
</tbody>
</table>

Table 7: Acceptability of caulking and gasketing materials

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral cure silicone caulk</td>
<td>Ethylene-propylene-diene monomer (EPDM - note that some are vulcanized with sulfur)</td>
<td>Sulfur-containing rubber</td>
</tr>
<tr>
<td>Polyethylene foam</td>
<td></td>
<td>Polyurethane</td>
</tr>
<tr>
<td>Silicone foam (extruded)</td>
<td></td>
<td>Oil-based glazing compounds</td>
</tr>
<tr>
<td>Teflon®</td>
<td></td>
<td>Polyvinyl acetate-based caulk</td>
</tr>
<tr>
<td>Acrylic caulk</td>
<td></td>
<td>Tygon® tubing (PVC)</td>
</tr>
</tbody>
</table>

Table 8: Acceptability of coatings, stains, paints and varnishes

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic paints</td>
<td>Shellac (prolonged solvent retention)</td>
<td>Oil-based paints and coatings</td>
</tr>
<tr>
<td>Some water borne polyurethanes</td>
<td>Some polyurethane resins</td>
<td>Alkyd resin paints</td>
</tr>
<tr>
<td></td>
<td>Polyvinyl acetate (PVA or PVAc) emulsion paints</td>
<td>Urea resin</td>
</tr>
</tbody>
</table>
Table 9: Acceptability of fabrics

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undyed, unbleached cotton or linen fabrics (after washing)</td>
<td>Silk (always test first)</td>
<td>Wool</td>
</tr>
<tr>
<td>Some polyesters (always test first)</td>
<td>Fabrics containing sulfur-based dyes</td>
<td></td>
</tr>
<tr>
<td>Hollytex® or Reemay® spunbonded polyester</td>
<td>Fabrics finished with formaldehyde</td>
<td></td>
</tr>
</tbody>
</table>

Table 10: Acceptability of paper products

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid-free (neutral pH) paper products</td>
<td>Buffered papers – avoid use with photographic materials or naturally acidic materials</td>
<td>Glassine</td>
</tr>
<tr>
<td>Neutral pH tissue paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microchamber paper products</td>
<td>Common tissue paper</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kraft paper</td>
<td></td>
</tr>
</tbody>
</table>

Table 11: Acceptability of other materials

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum laminate vapor-barrier sheeting (e.g. Marvelseal®)</td>
<td>Fire retardants (if not direct contact); are non-volatile but toxic</td>
<td>Pesticides, fungicides</td>
</tr>
<tr>
<td>Pacific Silvercloth® (for sulfur scavenging)</td>
<td>Fire retardants (direct contact); can be corrosive</td>
<td></td>
</tr>
<tr>
<td>Corrosion Intercept® (for pollutant scavenging)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

Although the scale may be vastly different, paleontological collections, natural history and fine art collections remain remarkably similar in their sensitivity to environmental agents of deterioration. Particularly when housed in enclosed environments, these substances can accumulate at high levels. While some damage to collections caused by pollutants emanating from display or storage materials may be quite apparent, as in the color alteration of the blue flints in Verona, it may also accelerate aging processes, resulting in increased embrittlement or more subtle color changes. A thorough understanding of the composition of construction and storage materials will allow safe choices to be made in their selection, minimizing damage to collections.

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Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/
EXPLORING THE COMMON GROUND BETWEEN ORGANIC ARTIFACTS AND NATURAL HISTORY SPECIMENS: WE SHARE PROBLEMS – CAN WE SHARE SOLUTIONS?

Allyson Rae

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Email: allysonrae@btinternet.com

ABSTRACT

A combination of feathers, fur, skin and bone is frequently found together in one artifact. What makes it a “museum artifact” rather than a ‘natural history specimen’ and does it matter? In many cases the materials involved are the same as are the problems confronting those responsible for their care. And yet natural history and museum artifacts, such as ethnography collections, have long been treated as separate fields in the museum world. Quite different approaches have been taken to solve related challenges. This paper explores the similarities and differences between taxidermy and skin specimens and ‘artifacts’, looking at the practical, technical and interpersonal factors that draw specialists together and keep them apart.

Keywords: artifact, collaboration, conservation, cooperation, curator, feathers, natural history, preparator, skin, specimen, taxidermy

RESUMO [in Portuguese]

A combinação de penas, pelo, pele e osso é frequentemente encontrada junta num artefato. O que faz dela um “artefato museológico” em vez de um ‘espécime de historia natural’, e, de que maneira esta classificação importa? Em muitos casos os materiais envolvidos são os mesmos, bem como os problemas com que se confrontam os responsáveis pela sua conservação. Ainda assim artefatos históricos e objectos museológicos, tais como coleções etnográficas, são há muito tratados como pertencendo a campos separados no mundo museológico. Abordagens bastante diferentes foram tomadas para resolver desafios que estão relacionados. Este artigo explora as semelhanças e as diferenças entre a taxidermia, espécimes de pele e ‘artefatos’, olhando para os factores práticos, técnicos e interpessoais que aproximam e mantêm afastados os especialistas.

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INTRODUCTION

Professionals who care for natural history specimens and those who care for organic artifacts do not mix very much. In many ways they deal with such similar ‘things’ and yet remain separated. Busy organizations often do not have or make time to share experiences as much as they might aspire to or may not recognize - or want to recognize - any common ground. This paper explores this, at times, sensitive relationship, recognizing where approaches to similar challenges can be beneficial and where they differ. Both the similarities and the differences contribute to the care of some of the most easily damaged ‘artifacts’ and ‘specimens’ in collections, encouraging closer working and cooperation. This is not a scientific paper. It is a paper about people, usually skilled and specialist professionals, and the ways in which they interact with historic materials and each other. In many ways the ideas the paper promotes are just common sense, but they are often not common practice. They are not new, but they are very rarely discussed. There are many logical and illogical reasons for the distances created by and between specialists, which this paper will explore by focusing on organic materials. The term 'natural history' is herein used to refer primarily to taxidermy and skins rather than the broad range of geological, mineral and fossil collections, which also constitute natural history collections.

COMMON GROUND

Functions of collections

Research

It is often said or inferred that the research and scientific value of natural history material is paramount, that the material is there to be studied and that this makes natural history collections different from other collections. However, in many ways the same is true of ethnographic, textile, archeology and library collections, for instance. The numerous type samples, site finds, evidence of use, manufacture, information and history inherent in museum and university collections are only of use if they are studied. Continuing advances in radiography, microscopy and analytical techniques, mean that all collections are providing an increasing level of information for scientists and others. Historic materials become sources of fresh and contemporary interpretation, exemplified by Groombridge’s sampling of feather quills from eighteenth and nineteenth century Hawaiian feather cloaks in museum collections for DNA studies of extinction patterns in Hawaiian bird species (Groombridge, 2008).

Exhibitions and outreach

Collections are also on display whatever the scientific or research focus of the organization may be. Museums of all types need to provide the public with access, to include people rather than exclude them because they do not have the specialist knowledge to understand what they are looking at. There is a shared challenge of demonstrating – justifying – the value of large unseen collections.

Raw materials

Skin, feathers, fur, bone, claws, and scales form the primary components of many and varied collections. Animal, bird, reptile and fish specimens have been prepared and mounted, or retained as study skins, for a very long time as key components of natural history collections. They are also primary materials in many types of artifacts, either whole or in part. Indigenous cultures in particular valued the practical and spiritual attributes of animal materials for utilitarian, symbolic and decorative purposes. Small creatures were sometimes incorporated as complete specimens, as in the instance of desiccated tree frogs forming part of Amazonian necklaces.
(Figure 1), looking remarkably similar to the frog specimens seen in natural history collections.

Western cultures have also made use of these resources, with cabinets of curiosity swelled by natural ‘curiosities’, for instance a chameleon given to Dr. Bargrave, a sixteenth century traveler, and now a delicate, desiccated part of the Bargrave Collection in Canterbury Cathedral Archive. Western costume, millinery and even jewelry collections are full of animal pelts and parts: grebe skin stoles, whole birds decorating hats, a dress – and even a ceiling - encrusted with beetle wings, a necklace formed of hummingbird heads (Gere and Rudoe, 2010). Materials from vegetal sources are also common to both natural history and other collections. Ancient Egyptian floral garlands and the array of dried leaves and grasses used in so many ethnographic artifacts have close similarities with herbaria collection materials. Paper, card, glass, metals, textiles, resins, pigments and wax form integral parts of objects in both specialist fields. Dioramas for instance, are often now valued in their entirety as examples of a skilled taxidermist or preparator’s craft just as are the glass domes protecting and displaying Victorian ornaments in other collections.

The fact that these raw materials may be in different forms is another source of common ground. Many natural history specimens themselves have been taken apart and put back together in order to counteract the natural decay processes. A lion’s skin may be transformed into a realistic representation of a lion by being mounted onto a metal and fiber support, embellished with glass eyes and painted detail (Figure 2), or it might be kept as a specimen skin or stitched flat onto a fabric mount to create a lion skin rug, or made into a ceremonial cape, lined with red satin. All are complex, composite objects: the ways in which they are put together are as important as the materials themselves.

**Agents of deterioration**

The impact of insect pests, dust, inappropriate relative humidity (RH), light levels, poor handling and storage are responsible for much of the damage to objects made of materials common to natural history and other organic collections. Whether feathers are part of a mounted specimen, an elaborate headdress or a decorative interior, a moth infestation can be equally devastating and irreversible, destroying much of the research and visual value of objects. The three-dimensional and complex nature of materials effectively traps dust and high or fluctuating RH can lead to cementation (Lithgow et al., 2005) and formation of micro-climates, spoiling visual impact, accurate rendering for research and providing increased food sources for insect pests and molds. Stretched skins can split in response to low or fluctuating RH whether they are tensioned over a body form, a skeleton or a drum-head. Effective lighting remains a shared challenge to allow collections to be appreciated and studied without the risk of embrittlement or fading (Pearlstein et al., 2010). When objects are handled, studied or even used by researchers, students, members of the public or indigenous communities, the risks of damage are often multiplied, particularly as resources for invigilation are reduced.

Whilst techniques used to prepare skins, in natural history, ethnographic and historical collections may vary, the deterioration that can result from poor preparation often appears similar. The role of fats in object preparation and in degradation is one example. Preparation for taxidermy and, for instance, in Inuit methods of skin preparation, involves removing...
Figure 2: Group of mounted lions; Courtesy of Norfolk Museums and Archaeology Service.
fats. When this has been done inadequately fur or feathers may be stained, and at its worst, the deterioration of remaining fats may result in chemical degradation of skins. In natural history collections this is usually described as ‘fat-burn’ (van Grouw, 2010) and is amongst one of the most difficult problems to treat (Figure 3). In other collections a similar pattern of discoloration, embrittlement, cracking, breaking and fragmentation is seen although the decay mechanism may be different (Figure 4), over use of leather dressing on tanned leather artifacts, for instance (Wills et al., 1992). So-called ‘red rot’ (acidic decay of leather; see Hatchfield, this volume), particularly affecting vegetable tanned leathers, differs from ‘fat burn’ in its chemical process, but the challenges which need to be overcome – reducing acidity and surface friability and increasing physical strength – have much in common with the treatment of fat-burn.

**Pesticides and the hazards posed**

Proteinaceous materials are amongst the most susceptible to insect pests. From the earliest times, taxidermists, makers, collectors and museums have done all they can to protect them. This has often involved the use of wide ranging insecticides. Whilst in taxidermy arsenic compounds (Mate, 2006) or mercuric chlorides were frequently used as a specimen was prepared, the vast majority of collections housing skins, furs and feathers, including natural history, have been liberally treated over the years with toxic dusts, sprays, fogs and fumigants. There is an historic scarcity of information about what exactly was used in the past. Excellent work has been achieved in developing and using analytical techniques to identify residual insecticides on all types of objects (Ormsby et al., 2006; Bacon et al., 2011) and to develop protocols for handling affected collections (Odegaard et al., 2005; Cane and Gayle, 2012). The Integrated Pest Management (Pinniger, 2001) approach to pest monitoring and control alongside the development of freezing, heat and anoxia treatments have all led to greatly reduced use of chemicals. This is an area where curators and conservators in all fields have benefited greatly from each others experiences and where common resources, such as on-line sites and networks, have forged strong links.

**Historic under-valuimg of collections**

Value can have many meanings to different people - cultural, monetary, scientific, spiritual, historical. Western and indigenous values in particular can be widely divided. The under-valuing that natural history and ethnography collections, in particular, have shared in the past has had much to do with a Western perspective on the worth of things, and this has included monetary value. There are collections which, from the earliest times have been highly valued in this sense – paintings is an obvious field, which have for centuries commanded high prices that have helped to ensure they are well cared for. Natural history and ethnography have lagged behind. Thirty years ago the curatorial snobbery towards aspects of ethnographic collections was still palpable – they were second class collections in the eyes of some. Natural history specimens were frequently referred to as replaceable; museums were working hard to get their old ‘boring’ stuffed animals off display. This lack of appreciation contributed to the poor condition of many of these collections today. Recently there has been something of a renaissance in natural history and ethnography. Awareness of wildlife conservation, advances in scientific study of collection material and its relevance to contemporary issues, the less bigoted view of indigenous cultures and their ability to speak up for themselves, the role of modern artists in recognizing the value of both ethnographic material culture and increasingly taxidermy and the subsequent rise in monetary value have all contributed to a higher profile, reflected in the popularity of exhibitions with the public. And yet just as natural history collections are becoming more appreciated, those who know most about them, natural history curators, seem to be less valued. In Britain certainly, financial constraints in museums are leading to some serious losses of natural history posts.

**AREAS OF DIFFERENCE**

**Preparation techniques**

Whilst sharing many raw materials, the ways in which they are prepared to form objects are often very different. Wet collections, the use of protein denaturing agents and formalin used in relation to natural history collections are distinctive, posing their own challenges and characteristic forms of deterioration. And yet there is growing body of fluid preserved art works in galleries now, such as Damien Hirst’s ‘Mother and Child Divided’ at Tate – where there is surely scope for shared experience between their curators or conservators and those dealing with natural history material.
Rae, 2014: **EXPLORING THE COMMON GROUND**

Figure 3: Bird skin specimen from a study collection, showing skin degraded by 'fat burn'.

Figure 4: A small leather shoe (Chinese, c 19th century) showing fragility and disintegration similar to that caused by fat-burn, but in this case probably due to the effect of iron-based dyes.
Other processes undertaken by taxidermists to preserve skins (Pe’Quignot, 2006) may not be as different from techniques used to prepare skins as is often assumed; for instance the use of mineral tanning agents, such as alum (alum tawed leathers) and salt (natron desiccated tissue in Egyptian mummies). In general, however, the range of chemical agents, techniques and materials used by taxidermists are clearly different from the vegetable tannins, acid, alkali and smoke treatments used traditionally in western and many indigenous cultures to make leathers and cured skins. The aging and deterioration of all these treatments can pose specific challenges.

The mounting of skins onto an internal form to recreate the appearance of an animal in life appears to be a distinctive feature of natural history collections. Whilst this form of taxidermy is increasing in modern art, the skills remain the skills of the taxidermist working with, or as, an artist. Over time the selection of internal mount materials have changed and evolved, from natural materials, waddings and metal armatures to fiber-glass and other modern resin forms, all of which make their own contribution to the varied needs of a specimens’ care: long-term aging, pH, or responsiveness to RH fluctuations.

There has been little attempt to create the accurate appearance of life outside the traditions of Europe, setting aside mummification practices. Whilst animals and birds may have been case-skinned and retained as totems or symbolic objects there is no attempt to recreate the form as it was in life. Perhaps the closest approach to something like western mounted taxidermy specimens are the masks made traditionally by the EkoI people of Nigeria, in which hide is stretched and pegged over wooden formers (Julien, 2000).

Practitioners

Whilst the preventive steps taken to look after natural history specimens and artifacts from different types of collections often have much in common, approaches to their remedial care can take quite different paths. This often includes those who will be undertaking the repairs or treatments as well as the techniques and materials they use. This is the area where sensitivities are at their greatest; where offense and defense are most likely to be generated. Those conserving artifacts will usually have trained to degree and postgraduate degree level in the care of specific materials. They value a scientific approach to examination and treatment and often have experience of working in multidisciplinary teams, with scientists, curators and designers. The main focus of their role is conservation and they may be working in organizations in which they have no responsibilities for natural history collections, but are treating artifacts with very similar problems.

In many natural history collections it is more likely that specimens will be cared for by curators, usually trained to degree and postgraduate degree level in aspects of natural history. Preparators and taxidermists may also undertake repairs. Cleaning or repairing objects is often only a small part of their role and they have very limited time. They are most likely to have learned their approach to cleaning and repair from the craft skills and traditions of their colleagues. Increasingly, conservators trained through conservation degree and postgraduate training programs with specialist natural history modules are employed in natural history collections, sometimes working alongside craft-trained colleagues, technicians or preparators.

The divergence between craft traditions and an increasingly scientific approach to object conservation lies at the heart of the sensitivity between those working with similar object materials and treatment challenges. Many working in other fields, including bookbinding, horology and working machinery, share this uncomfortable union of craft and scientific traditions to treating objects.

A historical legacy of mistrust, secrecy, demarcation and insecurity has contributed to the distance between specialists in both natural history and artifacts. There are preconceptions to overcome, or at least to talk about. Some of these anxieties may be true: people do get set in their ways, judgmental, prickly and impatient. Professions rely on people and no one is perfect.

Treatments

Most conservators and carers will favor minimal intervention, using preventive measures wherever possible, but cleaning, stabilization or repair may be essential in order to preserve, understand or appreciate an object. Cleaning can take many forms depending on the object material and the reasons for cleaning. Those undertaking treatments on organic artifacts and natural history specimens will probably all consider gentle vacuum cleaning first, followed by an increasingly invasive range of cleaning methods (Mason and Graham 2005). Other dry cleaning techniques, such as molecular traps (e.g. Groomstick®), powdered rubber (e.g. Draft Clean®), solvent applications (Pack and
Torok 2012), water with or without detergents or products developed for taxidermy (Rogers, 1990a, 1990b) may be used. Some of them, selected in all good faith, can have very damaging consequences: they may be applied to objects which they may damage, for instance vacuuming away evidence of characteristic parasites from animal skins, or be difficult to remove, such as Draft Clean, or deteriorate over time. Practitioners can find they are unable to keep pace with research, especially when it is presented by specialists in other fields, and end up relying on out-dated, but familiar materials.

Relaxation to remove distortions or folds that limit the usability of skin or fiber objects is common. Controlled humidification is a method often selected by artifact conservators (Sully, 1992). More dynamic re-hydration or even commercial tannage (C. Collins, personal commun., 2013) is an option taken with some natural history specimens. These are very different solutions to very similar problems and the results achieved may not be well understood in the longer term or in relation to loss of evidence. Would a less aggressive method work just as well? Could more research data be retained by an alternative approach (Eklund, 2010)?

Repair of skins is another area with shared challenges - splits, tears, degraded surfaces, disintegration – to which natural history and artifacts specialists have also developed differing solutions. A wide range of adhesives, consolidants and support materials have been explored (Rae and Wills, 2002; Moore, 2006; van Grouw, 2010) and different combinations selected. Here too there is room for more skills sharing. Could the repair of splits and torn seams in mounted animal heads and those in fur clothing (White and Sully, 1992) benefit from similar treatments? Leather and book conservators have worked long and hard to develop effective treatments for acid-decayed leathers (‘red rot’). Could they help to address the problems posed by ‘fat-burn’?

The places or publications where information is shared

Accessing relevant work carried out by those working in other fields can be a real challenge. The majority is published, naturally, in places which fellow specialists use most. Those caring for natural history collections in particular have a very wide range of special interest publications which they can use and none of which might be conservation networks. Conversely, artifact conservators are most likely to publish in conservation focused journals, so missing sources more likely to be used by curators or preparators. Valuable work is so often not published or presented at all – it may seem too routine, not scientific enough or be too time-consuming to write up. This adds to the difficulties for specialists in both natural history and organic artifacts to understand each other’s challenges and to share resources and research.

PROMISING INITIATIVES

It would be wrong to suggest that those responsible for natural history and organic artifacts do not interact - the 1st International Symposium-Workshop of Natural History Collections is one example. International Council of Museums – Committee for Conservation, explicitly encourages its Ethnography and Natural History Working Groups to cooperate. Does this reach curators and preparators? Probably not – it is very strongly under the ‘conservation’ banner, which curators may not feel is relevant enough to them. The Natural Sciences Collections Association (NatSCA) and Society for the Preservation of Natural History Collections (SPNCH) have some members from both fields and foster sharing of knowledge. Preventive care has seen considerable cooperation and pooling of experience.

The role of individuals can make a big impact. A curator, conservator, preparator or taxidermist, who is interested in what their colleagues do, can start the ball of cooperation rolling. This is what has happened in some regional museums in the UK, for instance the Horniman Museum (London) where there has been an effort to work with taxidermists and to explore materials more usually used by natural history curators. The Natural History Museum (London) has involved artifact conservators as well as curators in starting to review and develop guiding standards for the care of natural history collections. These are exciting initiatives.

CONCLUSION

Those who care for natural history specimens and organic artifacts from other collections can learn much from each other. With the range of materials, technical and ethical challenges shared there is extensive common ground. Contact between people of differing roles, backgrounds and training can be uncomfortable at times and old prejudices take time to change. Actions do not need to be big,
dramatic or expensive: they just need to bring people together. Working more closely together, exploring techniques and materials, sharing resources to get materials tested and finding ways to share published resources more easily, will help to achieve common goals in keeping collections safe and accessible.

ACKNOWLEDGMENTS

Thanks and appreciation go to the organizing committee of the 1st International Conservation Symposium – Natural History Collections; staff in the Conservation and Natural History Departments at Norfolk Museums and Archaeology Service; Present and former conservation staff and curators at the Natural History Museum, London; conservation staff at the Horniman Museum, London; former colleagues in the Department of Conservation and Scientific Research at the British Museum, London and participants on ‘An Introduction to feather conservation workshops’ and the host organizations who made them possible over the last 5 years.

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Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/
THE COLLECTIONS OF VERTEBRATES OF THE ESTACIÓN BIOLÓGICA DE DOÑANA (CSIC): ORIGIN AND EVOLUTION

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ABSTRACT

The Collections of Vertebrates of the Estación Biológica de Doñana (EBD) are among the most important research collections in Spain. They were started by Prof. José Antonio Valverde in 1965 and boosted by Prof. Javier Castroviejo between 1976 and 1988. The collections are still actively growing and currently house over 100,000 cataloged specimens representing approximately 30,000 mammals, 26,400 birds, 23,600 reptiles, 11,000 amphibians, and 8,600 fishes. In total, more than 2,850 species are represented. The EBD collections contain several type specimens and a good representation of endangered and threatened species such as the Iberian lynx. Most of mammal and bird holdings are dried skins and skeletons, whereas amphibians, reptiles, and fishes are fluid-preserved. An emerging collection of tissue samples counts 5,500 vials. The EBD also houses an important collection of avian eggs. Most of the material belongs to the Iberian fauna, the North and West of Africa, and South and Central America.

Keywords: Scientific collections, biodiversity, natural history

RESUMO [in Portuguese]

As colecções de vertebrados da Estación Biológica de Doñana estão entre as mais importantes de Espanha. Elas foram iniciadas pelo Prof. José Antonio Valverde em 1965 e ampliadas pelo Prof. Javier Castroviejo entre 1976 e 1988. As colecções continuam a crescer e actualmente abrigam mais de 100000 espécimes catalogados, representando aproximadamente 30000 mamíferos, 26400 aves, 23600 répteis, 11000 anfíbios e 8600 peixes. No total estão representadas mais de 2850 espécies. As colecções EBD contêm vários espécimes tipo e uma boa representação de espécies ameaçadas ou em perigo de extinção como o lince ibérico. A maioria dos espécimes de aves e mamíferos são peles secas e esqueletos enquanto que os de anfíbios, répteis e peixes estão conservados em líquidos. Existe uma nova colecção de amostras de tecidos que conta com 5500 frascos. A EBD acolhe ainda uma colecção importante de ovos de aves. A maioria do material pretende à fauna ibérica, norte e oeste de África e América do Sul e Central.


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INTRODUCTION

The origin of the scientific collections of vertebrates of the Estación Biológica de Doñana (EBD) is linked to the origin of the Estación Biológica itself and to the life and work of its founder, J. A. Valverde. Valverde was a naturalist, zoologist and research professor of the Consejo Superior de Investigaciones Científicas (CSIC), who made important contributions to the knowledge of human evolution and ecology of vertebrate communities (Valverde, 2003a: 11). Between 1957 and 1963, Prof. Valverde started the scientific collections at the ‘Instituto de Aclimatación de Almería’, where he was working at that time. Some years later, those collections would become the core of the EBD vertebrate collections (Valverde, 2003b: 28). Later, he moved to Madrid to design the organizational structure of the future Doñana Biological Station, founded in 1964. He conceived a zoological center prioritizing ecology, with room for a library, laboratories and scientific collections linked to a taxidermy facility for the preparation of specimens. The first head office was in a small house in Seville in the neighborhood of Heliópolis (Figure 1).

Between 1955 and 1972, he carried out several expeditions to barely known regions of the Western Sahara. He also organized an expedition to Equatorial Guinea and Gabon and many others across the Iberian Peninsula and Morocco (Valverde, 2004). All field notes of Prof. Valverde were donated to the University of Salamanca and are nowadays available through internet (http://gredos.usal.es/ispui/handle/10366/3698). After his death in 2003, also his important personal collections under study were donated to the EBD by his widow.

Prof. Valverde directed the EBD until 1974, and was replaced by Prof. Javier Castroviejo in 1975. Prof. Castroviejo had spent some time in Germany, where he learned a classical approach to museums and collections. He began preparing specimens with Prof. Valverde at the Museo Nacional de Ciencias Naturales-CSIC. Together with other young naturalists and biologists, Castroviejo started a group in Madrid that was collecting and preparing vertebrates throughout the Iberian Peninsula and accumulated a collection of over 25,000 specimens within several years. When he started leading the EBD, he added part of these collections to the holdings gathered at the EBD by Prof. Valverde.

Figure 1: Prof. Valverde (first on the left) in front of the first head office of the EBD.
The collections of capercaillies (*Tetrao urogallus*), partridges (*Alectorix rufa*), as well as Iberian carnivores, such as wolves (*Canis lupus*), insectivores, and rodents from the north and center of the Iberian Peninsula were particularly important. The other part of the collection made by the group of students in Madrid went to the ‘Unidad de Zoología Aplicada’, and was finally incorporated in the collections of the Museo Nacional de Ciencias Naturales at Madrid. During Prof. Castroviejo’s leadership, the EBD collections were consolidated and reinforced. The EBD was moved to the ‘Pabellón del Perú’, a building originally part of the ‘Exposición Internacional Iberoamericana’ held in Seville in 1929, which counted with new facilities for the storage and preparation of the material, such as large storage rooms, compact cabinets, an appropriate preparation room and a large cold storing room. Prof. Castroviejo also provided the collections with staff for their management and maintenance, and taxidermists to prepare the specimens, promoted workshops for students to be introduced in taxidermy and created a first permanent position of a curator. During this period the first computerization process began and the first basic inventories were made (De la Riva & Mateo, 1991; Cabot, 1991). Prof. Castroviejo’s legacy includes an impressive growth of the EBD collections in the latest 70’s and 80’s. In this time, several important expeditions were organized to collect specimens for faunistic inventories in America and Africa associated to several PhD studies that contributed to the consolidation of an important generation of new Spanish zoologists. The collecting efforts led to a representation of international importance of specimens from these areas. Mammals, birds, reptiles, and amphibians from Mexico, Central America (Nicaragua, Panama), South America (mainly Venezuela and Bolivia, but also Ecuador, Paraguay, Argentina, and Chile), North Africa (Morocco, Algeria, Tunisia), and Equatorial Guinea in Central Africa, were incorporated to the EBD collections, which probably still represent the best collections in the world for some remote areas. Besides, important vertebrate material from the Iberian Peninsula (Cantabrian coast, Pyrenees, Andalusia, Castile and Leon, Canary Islands...) was continuously incorporated to the EBD collections.

Since 1988, after Prof. Castroviejo’s resignation, the general policy regarding the EBD collections have changed profoundly under the next directorships of the EBD from Professors Miguel Delibes, Miguel Ferrer, and Fernando Hiraldo to the present EBD director, Prof. Juan José Negro. In this modern conception of the EBD collections, growing was not assumed as a first priority, and consequently the massive entrance of specimens slowed down. In fact, focus was put on the registration, cataloging, and correcting computerization errors and to assure the correct preservation of the holdings of the collections.

Nowadays, new acquisitions come mainly from the Red de Centros de Recuperación de Especies Amenazadas (CREAs), belonging to the regional autonomic administration of the Junta de Andalucía, with which EBD has made an arrangement. Another important source of new material comprises the incorporation of stranded cetaceans along the Andalusian coasts. Finally, and to a lesser extent, some specimens come from donations of researchers or private collections, materials obtained from research studies, deprivations, etc. In 2008, the EBD headquarters moved again, together with all the collections, to a new building located in Isla de la Cartuja, in the outskirts of Seville. Again, this move presented new possibilities regarding better and more appropriate facilities such as new compact cabinets and larger spaces. In 2010, a new tissue collection was started, which currently contains 5,500 vials.

**RELEVANCE**

As a result of the work of collection, documentation and registration, the EBD owns a large scientific collection, which can be considered one of the most important in Spain. It is the second in Spain in number of vertebrate specimens, following the Museo Nacional de Ciencias Naturales at Madrid (González, 2012).

In the EBD collections, 52 orders, 300 families, 1,640 genera, and 2,831 species are represented (excluding fishes). They currently house over 100,000 cataloged specimens, representing approximately 30,000 mammals, 26,400 birds, 23,600 reptiles, 11,000 amphibians, and 8,600 fishes (Table 1). Most of the mammals and birds are preserved as dried preparations of skins and skeletons, whereas amphibians, reptiles, and fishes are fluid-preserved. It also includes eggs, nests, antlers, turtle shells, and tissue samples. Among the
most valuable holdings are the important representations of threatened species such as the Iberian lynx (*Lynx pardinus*), the Spanish imperial eagle (*Aquila adalberti*), the bearded vulture (*Gypaetus barbatus*) or species considered extinct in Andalusia like the European sea sturgeon (*Acipenser sturio*) or the Common buttonquail (*Turnix sylvaticus*). Most of the material contains associated information of locality, date of collection, sex, measurements, etc, which makes the EBD collections very valuable. Specimens come mainly from the Iberian Peninsula and from regions that are poorly represented in other collections in Spain, such as North and West Africa (Morocco, Algeria, Gabon, Equatorial Guinea, São Tomé and Príncipe, Angola), South and Central America (Venezuela, Ecuador, Bolivia, Paraguay, Chile, Argentina, Nicaragua, Panama, Mexico), and, to a lesser extent, Central and South East of Asia (Kazakhstan, Laos, Vietnam).

**Mammal collection**

These collections are of great scientific value due to the geographical areas represented, their high taxonomic diversity and the good temporal series preserved. The collections consist of specimens from the Palearctic (Spain, Portugal, Morocco, Western Sahara), Africa (Cameroon, Gulf of Guinea, Angola, Gabon and Ethiopia), the Neotropics (Argentina, Paraguay, Bolivia, Ecuador, Venezuela, Panama, Nicaragua, Mexico), and South East Asia (Laos, Thailand, Malaysia and Indonesia). They count 30,000 specimens of 20 different orders, Rodentia and Chiroptera being the best represented. The Chiroptera collection houses about 8,500 specimens of 271 species, belonging to 14 of the 18 families currently accepted. Within them, there is a great representation of the Gulf of Guinea (Bioko, São Tomé and Príncipe and Annobon Islands, and the Rio Muni region of Equatorial Guinea in the mainland), with 2,000 specimens belonging to 64 species. This Chiroptera collection is particularly interesting because the covered area is considered a hot spot of biodiversity, with 60% of endemic vertebrate fauna. These collections are the result of several years of study by researchers at the EBD, and include several type specimens of new taxa that were described based on this material.

The cetacean collection is remarkable as well. It is composed by specimens stranded in the Andalusian coasts, mainly in the Gulf of Cadiz. It is still a very active collection and one of the richest in Spain. Finally, one should mention the excellent series of the Iberian Lynx (*Lynx pardinus*), which is considered the most endangered cat in the world. There are more than 350 different specimens, which are of great scientific relevance, due to the risk of species extinction.

**Bird collection**

The bird collection currently counts 26,396 registered specimens belonging to 26 different orders. The best represented is Passeriformes with 10,288 specimens. These collections stand out for two main reasons: a) the complete information associated with the specimens, including geographical metadata, biometry, and collection date, and b) the quality of the taxidermy work, which has allowed their preservation in time. About 80% of the bird specimens are study skins, but there are also skeletons, eggs, and some fluid-preserved specimens. The Iberian Peninsula is well represented, especially the marshes of the Guadalquivir River. There are also good representations from the Western Sahara, Equatorial Guinea, São Tomé and Príncipe, Nicaragua, Central Andes and the Chaco region (Argentina, Bolivia, and Paraguay). The series of skins of partridges (*Alectoris rufa*) from the Iberian Peninsula collected before reintroduction of captivity-born specimens took place, are remarkable, as are the large number of Spanish imperial eagle (*Aquila adalberti*) skins and eggs. It is also worth to mention the scientific value of the important representation of eggs of different species from Doñana’s area collected after the accident of the Aznalcóllar Mine (1988), in which a spillover of waters polluted with dangerous levels of heavy metals reached Doñana National Park. Finally, the collection includes a large series of albatrosses and other sea birds from Namibia, as well as hummingbirds and other birds from the Andes and from tropical South America (Venezuela, Paraguay, Bolivia and Argentina).
Table 1: Number of specimens and species preserved in the EBD listed by order.

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<th>Class</th>
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<th>Nº specimens</th>
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<th>% collection</th>
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<td>0.24</td>
</tr>
<tr>
<td>Reptilia</td>
<td>(Others)</td>
<td>701</td>
<td>--</td>
<td>2.97</td>
</tr>
<tr>
<td>Amphibia</td>
<td>ANURA</td>
<td>6058</td>
<td>152</td>
<td>55.07</td>
</tr>
<tr>
<td>Amphibia</td>
<td>CAUDATA</td>
<td>4913</td>
<td>30</td>
<td>44.66</td>
</tr>
<tr>
<td>Amphibia</td>
<td>Gymnophiona</td>
<td>13</td>
<td>3</td>
<td>0.12</td>
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<tr>
<td>Amphibia</td>
<td>(Others)</td>
<td>16</td>
<td>--</td>
<td>0.15</td>
</tr>
<tr>
<td>Fishes</td>
<td></td>
<td>8666</td>
<td>(unknown)</td>
<td>--</td>
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</table>
Herpetological collection

The herpetological collection is formed by 23,616 reptiles and 11,000 amphibians, of which Squamata represent over 63.3%. Most of the specimens were fixed in formaldehyde and then kept in ethanol 70%. The Iberian herpetofauna is well represented, most importantly the regions Andalusia, the Cantabrian coast and the Canary Islands. The collection gathered in Morocco and Western Sahara is valuable both due to the number of specimens and the species diversity. The collections from Equatorial Guinea, Venezuela and Bolivia, Mexico, the Chaco region, Amazonia, Andes, and some other areas in Central and South America are also remarkable (Padial et al., 2003).

Fish collection

There are 8,666 fish specimens fixed in formaldehyde and kept in ethanol 70%. The fish collections houses basically fresh-water specimens that still need an in-depth study. As a consequence, the actual number of species represented is still unknown. From the holdings of the Iberian Peninsula, those from Doñana's marshes and the mouth of the Guadalquivir stand out in terms of their numerical representation. The holdings of some of the last specimens of the extinct Iberian population of sturgeons are particularly important. Also, the collection of the ichthyofauna of Equatorial Guinea is outstanding in terms of numbers of specimens and species represented, as well as the one from the Amazonian basin.

Tissue collection

A new collection of tissues was started in 2010, and currently counts 5,500 vials of 2,439 different specimens belonging to 400 species. As many as 3,300 samples are kept in 70-96% ethanol and other 2,200 are frozen in -20º freezers. The best represented groups are raptors and cetaceans, and they come mainly from Andalusia.

SERVICES

EBD collections were started to fill the almost empty space existing in relation to reference collections of vertebrates in Spain and to support the research carried out by the EBD researchers. Nowadays, the collections keep giving service and are opened to the whole scientific community. The main collection services are inquiries and loans. They are consulted by national and international researchers, attending about 100 requests per year, involving more than 1,000 specimens. There is an active entry of material coming mainly from donations and the incorporation of private material.

All information related to services as well as the catalog of specimens preserved in the EBD collections is available at the collections website (http://webext.ebd.csic.es/catalogocepciones). Currently, specific software (IT app.) is being developed and will allow a scientific and administrative management of the collections. A new website (http://www.ebd.csic.es/web/colecciones) will soon provide public access to information, loans, inquiries, etc.

The EBD has been involved with the GBIF Project (Global Biodiversity Information Facility), which has the goal of providing free and open access to world-wide biodiversity information. Between March 2006 and June 2008, 35,000 records from the EBD Collections were up-loaded to the GBIF network, and this information is available through the GBIF portal (www.gbif.org).

CONCLUSION

The vertebrate collections of the EBD arose 50 years ago as a consequence of the scarcity of this type of resource for the Spanish scientific community. In spite of their relative youth, these collections are of big interest particularly due to their wide geographical representation, their taxonomic diversity, and the conservation quality of the material, as well as the information associated with the specimens.

Facing the future, and in addition to continuing the tasks of management and preservation of the holdings and the incorporation of new material, the fundamental goal will be to highlight the importance of these collections by increasing their international visibility and by making their content easily available to the scientific community world-wide.

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REFERENCES CITED


Additional images and material can be downloaded at [http://www.jpaleontologicaltechniques.org/](http://www.jpaleontologicaltechniques.org/)