

NYMPHAEA Folia naturae Bihariae	L	231-243	Oradea, 2023
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Restoration of a woolly mammoth skeleton and its conservation in the permanent exhibition of the Țării Crișurilor Museum, Oradea

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Abstract. The Țării Crișurilor Museum owns the most complete woolly mammoth skeleton from Romania, 1/3 of the bones of a single individual, which were discovered in Oradea. After in situ conservation in 1972 and ex situ restoration, the *Mammuthus primigenius* skeleton was displayed in the permanent exhibition for almost four decades. Due to the ageing of the old adhesives, the tusks and ribs needed restoration several times. In 2006 the exhibition was closed, the skeleton was packed and relocated to the new museum building in 2018. The repeated moving of the packed skeleton, until it was displayed in the new permanent exhibition, resulted in the fracturing of the bones along the areas of former restorations. The skeleton was restored again and displayed in the new permanent exhibition in 2020. The heating system with air convectors of the new location led to a severe decrease in relative humidity (RH). Therefore, a humidifier is operating, and the microclimate values are permanently monitored.

Keywords: restoration, conservation, *Mammuthus primigenius*, relative humidity, temperature

Abbreviation: MTCO – Țării Crișurilor Museum Oradea.

Introduction

Proboscideans are well represented in the Țării Crişurilor Museum's paleontological collection. The following species are present: *Deinotherium giganteum* (Derna), *D. proavum* (Derşida), *Tetralophodon longirostris* (Dijir, Derşida), *Anancus arvernensis* (Huta, Oradea – Viilor Hill), *Mammuth praetypicum* (Păgaia), *Mammuthus meridionalis* (Subpiatră, Oradea – Viilor Hill, Brusturi, Drăgeşti, Balc, Groşi), *Mammuthus trogontherii* (Betfia) and *Mammuthus primigenius* (Oradea, Galošpetreu, Râpa, Sălard, Sîntion, Batăr, Şicula), which cover a timeframe from Late Miocene to Late Pleistocene (Jurcsák 1983, Jurcsák & Moisi 1983, Codrea et al. 2005). The most outstanding specimen of proboscideans in our museum is an almost complete skeleton of *Mammuthus primigenius*, discovered in Oradea in February 1972, during construction work at the former Beer Factory. This location is well known today as the Lotus Center.

The fieldwork at the Beer Factory, conducted by Tiberiu Jurcsák, was extremely well documented for 1972, all taphonomical information being recorded. The skeletal remains were found dispersed but in recognizable association, at 5 m depth in an area measuring 19.5 m x 16 m. The bone bearing sediment consisted of loess, laid on gravel, deposited within the former terraces of the Criş River. Anatomically adjacent elements articulated when brought together were consistent in size and ontogenetic age (Jurcsák & Moisi 1983). It was therefore evident that all these bones pertained to a single young wholly mammoth individual, which is the best-preserved specimen in Romania. A total number of 136 skeletal elements and bone fragments were initially recovered and marked on the field map, comprising 31 skull fragments, 16 vertebrae and fragments of neural spines and arches, 36 ribs and rib fragments, 10 bones of the right forelimb, 11 bones of the left forelimb, 10 bones of the right hindlimb and 7 bones of the left hindlimb (Jurcsák & Moisi 1983). Due to weathering and subsequent compaction of the sediment, the bones were mechanically weak and vulnerable once excavated due to the low temperature in February. The

excavated skeletal remains were very friable and wet, saturated in water, and the large bones were deformed due to the weight of the overlaying sediments (Jurcsák & Moisi 1983).

According to Jurcsák & Moisi (1983), the bone surfaces were cleaned by brushing and covered with wet sheets of cellophane to block the rapid evaporation of the water. The cellophane sheets were covered with wet cheesecloth and the bones were plastered to protect them from freezing. The jackets of larger bones, such as the tusks, pelvic bones, femora, and humeri, were strengthened with iron bars, bolted around the plastered specimens. The plaster jackets also maintained the mechanical integrity of the bones (Fig. 1) during lifting and transportation and allowed the bones physical protection until they could be opened in the museum's building under a more controlled microclimate. A four-week period followed, to offer stability to the enclosed bones to dry up and acclimatize to the new conditions before the jackets were removed and restoration begun (Jurcsák & Moisi 1983).

The plastered bones were deposited up-side down at floor level (14-16°C) and left to dry up for four weeks. After drying up all exposed bone surfaces were impregnated with a weak solution of nitrocellulose lacquer dissolved in acetone (4-10%). To consolidate the porous interior of large bones, their surfaces were perforated and consolidant was poured through the holes in the interior of the bones. The plaster jackets were gradually removed, and the bones were gradually impregnated with 4-10% solution of nitrocellulose lacquer dissolved in acetone. The corresponding bone fragments were glued together with undiluted nitrocellulose lacquer (Jurcsák & Moisi 1983).

Only 74 determinable bones out of 136 fragments could be restored, representing 1/3 of the skeleton of a single individual. The missing bones, such as tibia, bones of the pes and manus, were completed as artificial copies. The *Mammuthus primigenius* skeleton was reconstructed and displayed for almost four decades in the permanent exhibition of the Natural Sciences Department hosted in the Baroque Palace. In 2006 the exhibition was closed, the skeleton was packed and prepared for relocation to the new museum building. The

repeated moving of the packed skeleton, until it was finally moved to the new museum building in 2018, resulted in the fracturing of the bones along the areas of former restorations, due to the ageing of the consolidant.



Figure 1. In-situ conservation of the wholly mammoth skeleton at the Beer Factory in 1972 (MTCO archive).

Material and method

As information about preparation and conservation of paleontological specimens is extremely important (Fitzgerald 1988), the examination of formerly used consolidant started with the information regarding preparation techniques and adhesives used after the discovery of the *Mammuthus primigenius* partial skeleton and during its restoration (Jurcsak & Moisi 1983). In the first restoration process, solution of nitrocellulose lacquer dissolved in acetone (4-10%) was used.

All the subsequent restorations were performed by Elisabeta Popa, who recorded all the processes in the Restoration Data sheet and the Preparation Register. E. Popa used a solution of 3-10% of nitrocellulose dissolved in acetone, to consolidate the exfoliated bone surfaces.

To avoid ageing, two types of consolidants are recently used in the Paleontology Lab, respectively Paraloid B72, supplied as solid pellets, and Mowillith, supplied as powder. Paraloid B-72 is an extremely stable methyl-acrylate copolymer, has a long shelf life, is soluble, removable, and re-workable over time, is resistant to degradation under normal conditions of exposure, and is soluble in acetone, ethyl alcohol, or a combination of those two solvents, as well as in toluene (Davison & Brown 2012). Polyvinyl-acetate copolymer Mowillith has a moderate reversibility, is soluble in acetone and ethanol (Elder et al. 1997), it is less glossy than Paraloid B72 and is easier to dissolve, given its powdery appearance.

Given the large surfaces of the mammoth bones and the short period of time for the restoration process, Mowillith was used as consolidant, dissolved in acetone.

The microclimate of the Paleontology Lab and the Exhibition Room was monitored by measuring and recording the temperature and relative humidity (RH) by spot checks, using an electronic thermohydrometer.

The ageing of the old consolidant

Due to the ageing process of the nitrocellulose lacquer used in restoration of the wholly mammoth skeleton, the joints became brittle and cracked, resulting

in the splitting of joins along the former restoration areas. The most affected skeletal parts were the most fragile ones, especially the tusks, ribs, and pelvic bones, which were subjected to stress due to their weight and position on the display and in the wooden boxes, where the bones were packed and stored.

The ageing of consolidants used in paleontological collections, especially in the preparation and restoration of Quaternary vertebrates or sub-fossil bones, caused problems all over the world. Although nitrocellulose was easy to use, easily reversible and offered good joins, was not very stable and became brittle with age (Keene 1987). Elder et al. (1997) provided a Wall Chart for the Society for the Preservation of Natural History Collections on Adhesives and Consolidants in Geological and Paleontological Conservation, including chemical composition, glass-transition temperature T_g , reversibility and solvents. According to this Wall Chart, cellulose nitrates, such as the nitrocellulose lacquer, tends to yellow and deteriorate, and migration or volatilization of plasticizers results in severe shrinkage, potentially damaging the objects (Elder et al. 1997).

The skeleton was constantly restored over time by Elisabeta Popa, and the last restoration of the tusks, ribs, and pelvis dates to 2002. According to the restoration documentation, E. Popa impregnated the bones with a solution of 3 g of nitrocellulose lacquer dissolved in 100 ml of acetone and the fractures were joined with undiluted nitrocellulose lacquer. The join areas and deeper cracks were filled with gypsum. Over time, nitrocellulose used as consolidant showed considerable ageing.

Restoration of the skeleton

In 2007 the skeleton was packed and prepared to be moved to the new location of the museum. The relocation of the collections and the opening of the museum itself were delayed for almost a decade. The packed large mammoth bones were repeatedly moved from time to time, which implied fluctuations in the microclimate and caused damage to the bones. In 2018 the relocation was finalized, but due to the lack of space in the Paleontology Lab, the effective restoration of the skeleton began only in 2020.

The examination of the conservational state of the bones showed that the following elements were the most affected skeletal parts: left tusk (MTCO 10975/3), right tusk (MTCO 10975/11), parietal fragment (MTCO 10975/62), ribs (MTCO 10975/27, 37, 41, 46, 61, 73, 85, 94, 95, 104, 122), left fibula (MTCO 10975/109), dorsal vertebra (MTCO 10975/124), fragment of the left pelvis (MTCO 10975/124) and the left scapula (MTCO 10975/80), being fractured along the formerly restored areas. This was due mainly to the ageing of the formerly used consolidant, nitrocellulose (Fig. 2), which yellowed, became brittle and showed evident signs of cracking and flaking (Fig. 3). The type of formerly used consolidant was examined, and all the needed information was available in the preparation register and Restoration data Sheet, as well as in the description given by Jurcsak and Moisi (1983).

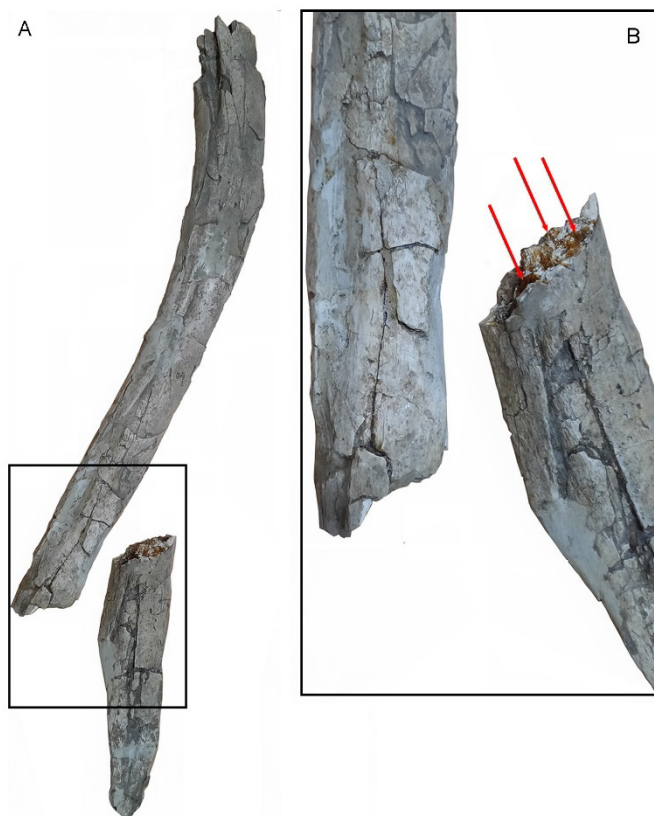


Figure 2. (A) The right dorsal rib (MTCO 10975/122) fractured along the formerly restored area. (B) Detail of the fractured area, arrows indicate the aged consolidant.



Figure 3. (A) Flaking of the left tusk (MTCO 10975/3) due to the ageing of the nitrocellulose. (B) Detail of the fractured area of the left rib (MTCO 10975/37), arrows indicate the brittle consolidant.

After evaluation, the first step was to remove the aged nitrocellulose from the surface of the bones and from the glued fractures. When repairing old fractures, it is important to ensure that all old glues are removed from the joined areas, as they may alter the setting of modern adhesives. Thus, the old nitrocellulose was removed by dissolving it with acetone. This process was time-consuming, nitrocellulose had to be removed from the bone surfaces as well as the fractured areas by gently swabbing with cotton swabs soaked in acetone.

The second step of the restoration was to consolidate the cleaned bone surfaces and the fractured areas, using a solution of Mowilith 3-10% dissolved in acetone. Next, the restorer cemented together the fractured parts by using a

highly viscous mixture of Mowilith and acetone (17-50%), in accordance with the weight of the specimen.

The gaps were filled with gypsum, using the same material as the one formerly used in the restoration process (Fig. 4). At the end of restoration, a final consolidation was performed by impregnating the bone and filled surfaces with weak Mowilith (3%) solution dissolved in acetone (Fig. 4).

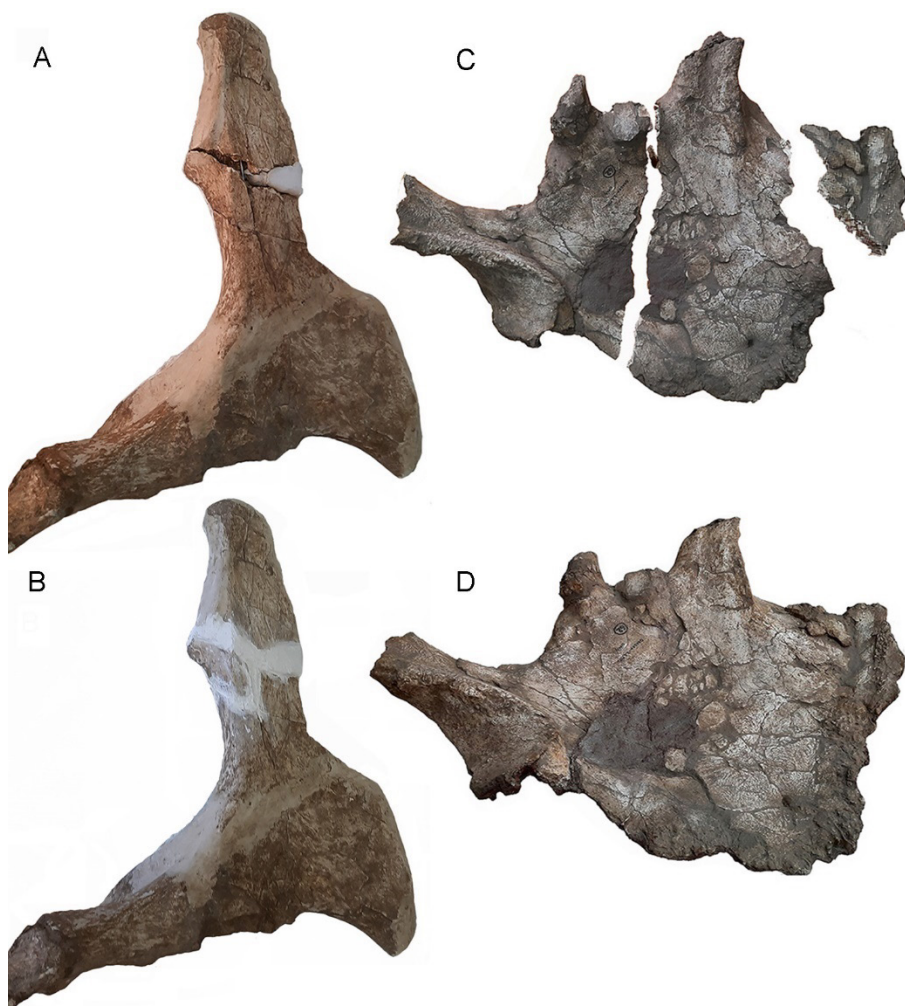


Figure 4. (A-B) Fragment of the left pelvic bone (MTCO 10975/54), before and during restoration. (C-D) Parietal fragment (MTCO 10975/62) before and after restoration.

After restoration, the woolly mammoth skeleton was displayed in the permanent exhibition of the Natural Sciences department of the museum (Fig. 5).

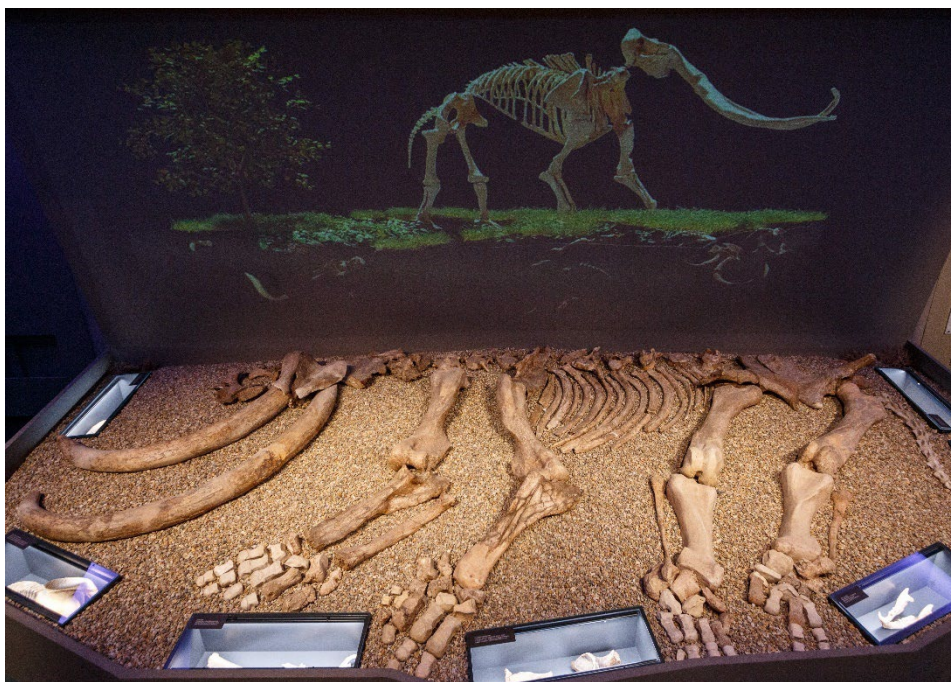


Figure 5: *Mammuthus primigenius* skeleton in the permanent exhibition

Conservation measures in the Quaternary Hall of the Natural Sciences permanent exhibition

Fossils that retain original organic constituents, particularly those from Pleistocene, may be sensitive to ultraviolet lights and high or low relative humidity values. The general rules for curatorial care for geological and paleontological collections recommend humidity levels at 45-55% and the elimination of ultraviolet lights (Cato 1994, Stainley 2004, NPS 2005).

The mammoth skeleton was displayed in the new exhibition, where the microclimate was permanently monitored, knowing that Pleistocene vertebrate fossils

are very sensitive to low RH values. The RH values were monitored in the exhibition by daily spot-checks with a hand electronic thermohydrometer. The exhibition room was designed without any source of natural light, to limit UV damage.

The heating system, consisting of air convectors, started to operate in November and reached its maximum capacity in January 2021, leading to a severe drop of the relative humidity (23-28%). Material shrinks and stiffens at low RH, which may be accompanied by fracture sensitivity and embrittlement (Erhardt & Mecklenburg 1994, Erhardt et al. 2007). Low RH values in the exhibition room might affect the old consolidant, namely nitrocellulose, which was used in the former restoration of the mammoth partial skeleton. Long term low RH values might even affect the more stable new consolidant as well, respectively Mowillith, which we recently used in the restoration of bones affected by breakage and exfoliation.

To avoid the consolidant's ageing and to obtain the relative humidity close to 45-55%, a humidifier was installed at the beginning of February 2021. According to the Standard in the Museum Care of Geological Collection, revised by Stanley (2004), controlling humidity by installing humidifiers is efficient and cost-effective, because if relative humidity is held at the required levels, the temperature can be allowed to fluctuate. Our RH controlling system consists of a simple, portable humidifier, which needs maintenance by the museum staff (i.e. filling the empty reservoirs).

The museum uses a central heating system with air-convective heaters and humidifiers, a situation defined by Martens (2012) as Control of Level No. 3: Temperature and simple RH control.

During the operation of the central heating system, the mean RH values without humidifiers was between 23-28%. The conservator monitored the temperature and RH values and the daily operation of the humidifiers for three years. There is a significant improvement of the mean RH values when the heating system is operating. Mean values of RH varies between 38-43% during the winter months, which is closer to the optimal values of 45-55% for paleontological collections (Cato 1994, Stanley 2004). Although the microclimate is not the best in the exhibition, since the operation of the humidifiers there were no severe RH value drops like those recorded before.

Conclusions

Pleistocene vertebrates might show a high degree of degradation in time, due to their porous structure and weak fossilization, as well as the ageing of the consolidants used in their preparation. Any restoration work must start with the identification of the formerly used consolidant, its removal and restoration with more stable consolidants.

The most affected bones of the wholly mammoth skeleton were the ribs, tusks, shoulder blade and pelvis bones.

Microclimate monitoring is very important in any museum collection. Low RH values and fluctuation of the temperature can affect the specimens in the paleontological collections, leading to an accelerated ageing process of the consolidants. The continuous operation of the humidifiers significantly improved the microenvironment of the exhibition room and the conservational status of the wholly mammoth skeleton in the permanent exhibition of the Țării Crișurilor Museum.

Acknowledgements

We would like to express our deepest appreciation to Elisabeta Popa, former restorer at the Natural Sciences Department, who closely supervised the restoration process, even after she retired.

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Landing, E. (ed.): *Studies in Stratigraphy and paleontology*. New York State Museum, Bulletin 481: 149-160, New York.

Taylor, T. N. 1981 - *Palaeobotany: An introduction to fossil plant biology*. McGraw-Hill Book Co., New York, 589 pp.

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