THE CONSERVATION OF A 19TH CENTURY GIANT DEER DISPLAY SKELETON FOR PUBLIC EXHIBITION

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Following a mishap, a 19th Century mounted giant deer was subjected to a detailed osteological assessment and conservation treatment which required both structural repair and the extensive modeling of broken and missing skeletal components. The historic mounting system and plinth were largely intact and structurally safe for the skeleton and so these could be retained along with any historic restorations deemed sound and non-damaging. The original skull suffered irreparable damage and both antlers were detached from the specimen. A replacement skull was acquired but it was necessary to attach the original antlers to the new skull in a manner both structurally sound and aesthetically accurate enough for the deer to be placed back on open display. After testing commonly used conservation-grade filler materials suitable for fabricating missing skeletal components, losses to the vertebra and the ribcage were re-built using epoxy resin bulked to putty consistency with phenolic microballoons and applied over barrier layers of Paraloid B72 and Japanese tissue. All losses were in-painted with earth pigments in Paraloid B72 before re-articulation. The unique role of this specimen determined the conservation approaches adopted and included a balanced consideration of conservation ethical concerns, client expectations, future structural stability, aesthetic impact and the limitations of the future display location.

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Introduction

The extinct giant deer (*Megaloceros giganteus* Blumenbach, 1803) is classified as an Old World deer within the Family Cervidae and is genetically and morphologically the most similar to the extant European fallow deer (*Dama dama dama*) (Lister *et al.* 2005; Hughes *et al.* 2006). The giant deer had a geological history spanning from the Middle/Upper Pleistocene to Early Holocene periods and its subfossils have been found in hundreds of deposits across Europe, Russia, northern Africa and southwestern Asia (Gould 1974, 1977; Lister 1994; Geist 1999). Giant deer were locally extirpated in Ireland towards the end of the Younger Dryas (Woodman *et al.* 1997).

The first remains of giant deer subfossils in Ireland were discovered in County Meath in 1588 (Mitchell and Parkes 1949). The Late Glacial lakebeds of Ireland and Britain have yielded a preponderance of giant deer remains since the 17th century to recent times, while some remains date back to before the last Ice Age (Woodman *et al.* 1997). The distinctive characteristic palmate antlers, borne only by the males and spanning up to 4m tip to tip, are rarely found fully intact. From the mid-late 1800s, giant deer skeletal remains were prepared as full skeletal mounted specimens for exhibition displays, usually with unnatural straight necks to enhance the overall large 'body' size, within numerous museums worldwide including: the National Museum of Ireland, The Field Museum (Chicago), Ulster Museum (Northern Ireland) and the Natural History Museum (London). However, many of these mounted exhibited skeletal specimens are composite skeletons, i.e. bones from many individuals were utilised to produce a single mounted skeleton. Both male and female bones have been identified within the same exhibited skeleton in several museum/other collections, along with absences of some individual bones (e.g. the full complement of the ribs and smaller leg bones) (Carden 2006).

In the 19th Century, preparators of fully mounted skeletal display specimens of large mammals were typically articulated around a wrought iron frame with holes drilled through the long bones and the vertebrae enabling them to be threaded onto iron bars, which could then be bolted together to form a rigid frame. Lighter skeletal elements such as the ribs and the metatarsals were then wired onto the mounted skeleton. It was necessary to forge the structural iron rods into a more life-like approximation of legs and spinal column before articulation; therefore the holes drilled into bones had to be large enough to accommodate any such kinks and curves in the iron bars. Such preparations frequently meant that large amounts of bone material were lost during the articulation process thereby further weakening the already compromised bone structure.

The term sub-fossil bone refers to osseous material that has been exposed to the elements for a period of time before burial whereupon a proportion of the organic and inorganic content of the bone becomes degraded (Andrew 1996). Through the partial loss of the collagen framework (vital for flexibility and strength) and lack of any secondary mineralisation, sub-fossil bone has a propensity for mechanical weakness (Shelton and Johnson 1995).

The mounted giant deer skeletal specimen

This particular giant deer specimen was mounted in the mid-19th Century and acquired around this period by the original owners. In 1971, the deer was donated to a university collection where it was exhibited on open display in a public location for a number of years until a mishap occurred in the late 2000s. The insufficient support of the antlers had allowed them to come crashing down during the aforementioned incident, shattering the original skull into three main sections and hundreds of fragments. Upon impact with the ground a number of antler tines had also become damaged or detached. The client had sourced a replacement skull, however the antlers of that skull had been sawn off and thus any treatment would necessitate the marrying of the original antlers to the new skull.

The incident provided an opportunity to conserve the skeleton as a whole and address wider issues such as the failing previous repairs and the broken or detached skeletal elements. Extensive conservation works were required to re-assemble the specimen and identify and monitor any environmental conditions which may have contributed to its deteriorating condition.

Conservation objectives

The unique role of this object determined the conservation approach adopted. This individual is the only fully articulated specimen in a private collection in Ireland and would be returned to open display within a university library. This meant that it must be structurally sound, so as not to present a hazard to any library visitors, be anatomically correct as befits an object in a centre for learning, and also be of a high aesthetic standard to justify its prominent display position within a newly developed building whilst still retaining much of its original features as a historical skeletal exhibition-style mounted specimen.

Pre-conservation state

Initial condition assessments of the whole specimen revealed that extensive restoration had occurred in the past as well as a number of *ad-hoc* repairs. The plaster-based fillers used for both gap-filling and the larger areas of re-modelling were crumbling and a very dark brown paint-layer on the bone surfaces further emphasised this state of disrepair (Figure 1). Other fillers and stabilising materials included wood, various metal rods and nails, cable ties and even a plastic syringe cap used to dowel two sections of rib together (Figure 2).

Figure 1. The pre-conservation condition of the giant deer specimen ribcage whilst still in situ. The light brown painted surface of the old repair works is clearly visible against the real bone.

Figure 2. A selection of materials applied during previous restoration treatments found and removed from the specimen.

The specimen was entirely coated in a shellac-like substance soluble in both alcohol and acetone. As mentioned previously the skull was in an extremely fragmented state and was therefore detached from the mounted specimen, as were the antlers, after falling approximately 1.5m onto the ground.

In order to limit the movement of the bones once they were mounted, cavities around the iron rods were routinely filled with plaster or linseed putty and packed with soft materials such as newspaper (Buttler 1994; Andrew 2009). In the case of this specimen, a fracture to the left distal femoral condyle region revealed the plaster-fill along with a tantalising scrap of newspaper containing articles which could be dated to 1864, giving an approximate date for the original mounting (Figure 3).

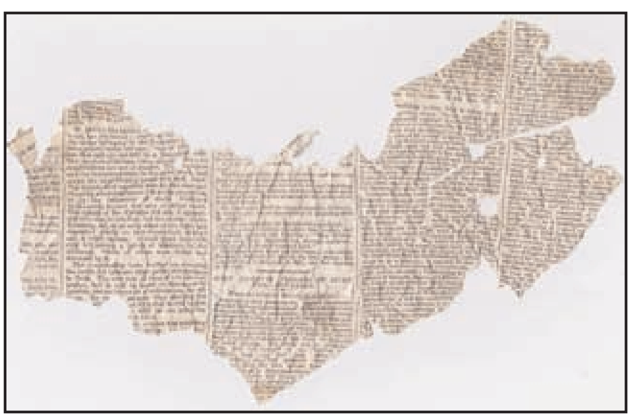

Figure 3. Newspaper fragment found within the left femur dated to 1864.

Pre-conservation assessment of the skeleton

The majority of the skeleton was disarticulated to allow a thorough series of anatomical and conditional assessments. The long bones comprising the fore- and hind limbs however, they were well anchored to their mounting rods and were relatively structurally sound. For this reason, the limbs were unbolted from the spinal rod and left assembled as four distinct articulated units. It had always been the intention to retain as much of the historic mount as possible and so unnecessary articulation was avoided to minimise any further damage to the specimen.

A detailed anatomical assessment was performed on the various disarticulated and articulated parts of the specimen. All of the bones were examined in detail to ascertain (i) their anatomical and taxonomical identifications, (ii) to provide the correct sequence of the elements (e.g. order of left/right ribs), (iii) to determine what, if any, skeletal elements were absent and (iv) to record the overall preservation state of each element. All of the examined bones were identified as adult giant deer. There were numerous duplicate ribs, not necessarily from the same individual adult (all epiphyseal sutures were fully fused) giant deer (composite skeleton). Of the eight left ribs, two 4th ribs were present and originated from different individual adult giant deer. There were a number of missing skeletal elements which included the hyoid apparatus, some teeth, 12 ribs and all of the false ribs, all of the caudal (tail) vertebra and some of the smaller cuboid leg bones. Many fractures and evidence of breakages were immediately visible in numerous parts of the skeletal remains, along with historical repair works (for further specific details see Carden 2015).

It was decided not to attempt to remove the shellac-like coating from the surface of the specimen as it appeared stable and possessed a sufficiently high enough glass transition temperature not to become tacky and adhering dirt in the future. Any surface dirt present was removed with a soft brush and vacuum. The areas of visible plaster and dark brown paint on external surfaces were removed with acetone on cotton swabs while dental tools and tweezers were used to carefully extract fragments of plaster from the interstices of fractured areas. Any areas of plaster that were stable and not visually disruptive were left in situ as it was deemed too damaging to attempt to remove it all. In the case of the articulated limbs, the plaster was providing an anchor between bone and iron rod and so it was particularly important to leave this intact as both a structural element and evidence of this historic mounting method.

One concern when assessing the condition and potential stability of the specimen in the future, were the large splits running longitudinally though the centre of each of the long bones within the four legs. Without disarticulating the legs and risking significant damage, it was not possible to see whether one iron rod passed through the long bones continuously or if shorter sections of iron secured the joints leaving the bones themselves to bear the weight of the rest of the specimen. The latter scenario had obvious structural limitations and would need to be addressed. The least invasive way to investigate whether there was a single continuous iron rod or not, was by radiological (X-ray) imagery of one of each of the fore- and hind limbs.

The X-rays revealed that the iron rods did indeed run continuously through each leg (Figure 4) and that rather than being stress fractures caused by compression, the longitudinal splits were likely the result of the expansion and contraction of the bones during environmental fluctuation.

Ethical Considerations

A balanced consideration of conservation ethical concerns, client expectations, future structural stability and the limitations of the future display location was necessary before treatment and was re-assessed as work progressed. The main conservation principles of reversibility/re-treatability must be adhered to, which embodies that any treatments

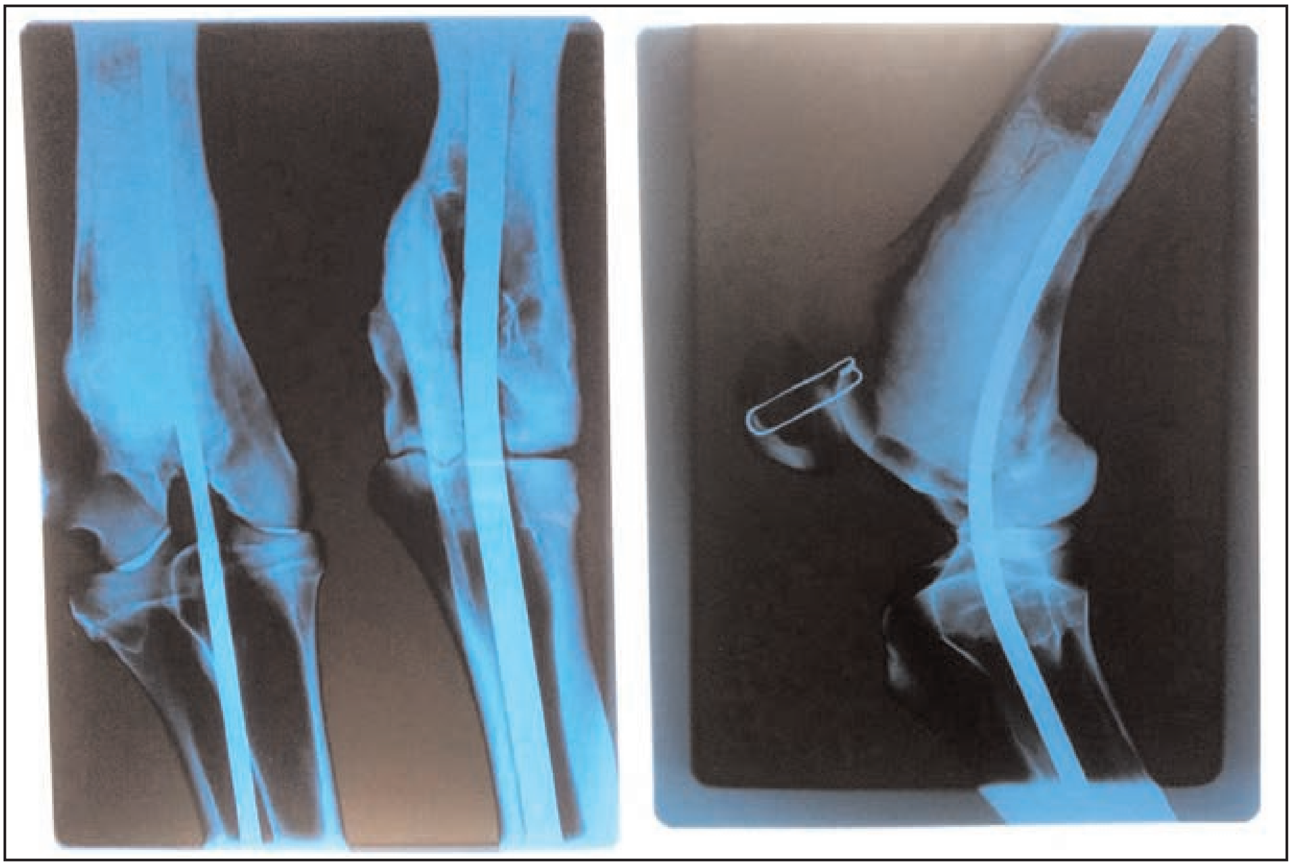

Figure 4. Radiological (X-ray) imagery of the (A) right femur-tibia junction anterior, (B) right humerus-radius/ulna junction posterior aspect and (C) right humerus-radius/ulna junction, medial aspect. X-ray images courtesy of Jens Werner MRCVS of Western Veterinary Surgery, Clifden, Co. Galway, Ireland.

applied to the object should be able to be reversed in so far as is practicably possible. The materials introduced in the course of those treatments should also meet conservation standards for long-term stability. It was also important to consider that any adhesives or consolidants penetrating the specimen could severely compromise the retrieval of genetic material in the future. The historic mounting system and plinth were largely intact and structurally safe for the skeleton and so these could be retained along with any historic restorations deemed sound and non-damaging.

Materials

When considering which materials may be suitable for reinstating missing skeletal components and re-modelling missing sections a number of fillers, commonly used in conservation, were tested. A range of proprietary fillers and bulked adhesives were assessed for their handling properties, level of adhesion and the ease with which they could be shaped. The introduction of compressively weak fillers such as microballoon spheres have been found to lower the compression modulus of a polymer based adhesive whilst heavy levels of bulking reduce adhesion through a lowering of contact surface area (Barclay and Mathias 1989). For these reasons, microballoons became the primary bulking agents tested. The phenolic microballoons chosen had a particle size ranging between 0.005-0.127 mm. Paraloid B72, a solvent evaporation adhesive widely used in a variety of conservation applications, offers desirable properties such as long-term stability and ease of removal (Horie 2003). However, when subjected to a high degree of bulking and applied in large quantities solvent retention can occur resulting in a fill that fails to cure fully (Larkin and Makridou 1999).

Building up multiple layers of bulked Paraloid B72 filler over a period of time was impractical for reinstating the large areas of bone related loss in this specimen but could have provided effective lightweight fills for the smaller areas of bone loss. Utilising a single material for both gap filling and structural remodelling limited the number of different substances introduced to the specimen and enabled treatment to be identified as a single phase of conservation in the future. Grattan and Barclay's (1988) research has demonstrated that an epoxy resin and phenolic microballoon mixture performed well in compression tests, resisting fluctuations in relative humidity, without damaging weakened surrounding timber.

Epoxy resin, when bulked with phenolic microballoons, could be easily carved and was capable of holding crisp detail, which is an essential property in accurately modelling large areas of bone (Barclay and Matthias 1989). A low viscosity two-part epoxy resin was chosen (UKH-137 Resin, UKH-136 Hardener: Material safety datasheet outlining chemical composition available upon request at online at www.epoxy-resins.co.uk). As a commercial product, it is possible that impurities may contribute to slow oxidation causing yellowing over time (Horie 2003; Down 1984). Given that the epoxy filler would be heavily bulked with brown phenolic microballoons and in-painted, potential yellowing was not considered problematic. The cohesive strength of the bulked epoxy filler also meant that it required very limited internal support and in many cases could be built up in just one application. Concern has been expressed over the heat generated by the exothermic reaction, which occurs during the curing of epoxy, and this should be taken into account in the application of fills deeper than 20mm (Barclay and Mathias 1989). In the course of this treatment however, the gaps filled were not sufficiently deep to create any perceptible heat build-up. When applied in large quantities, the epoxy fill material was exposed to the air on all sides, with the exception of the interface between bone and fill, and so heat could quickly dissipate.

In order to address issues of reversibility around the use of epoxy resin, the epoxy / microballoon filler was applied over a barrier layer of Japanese tissue adhered with 40 % solution Paraloid B72 in acetone (w/w). The high viscosity of this Paraloid B72 solution was selected in order to maintain a reasonably homogenous layer at the joint between bone and fill, without excessive absorption into deeper levels (Ellis and Heginbotham 2004). The bond between Paraloid B72 and a bulked epoxy fill applied to wood is reversible, if required, through exposure to a solvent vapour with acetone exposure which requires nine hours to fully reverse bonding (Podany *et al.* 2001). In the planning of the treatment of the giant deer specimen, the experiment conducted by Podany *et al.* (2001) was replicated using samples of new and weathered bone and the results were found to be comparable. A layer of 12gsm Japanese tissue was included in the barrier layer system to limit the mechanical adhesion of the fill material by minimising any interstices in the uneven bone surfaces. As with any solvents or epoxy-based adhesives, care was taken to ensure appropriate extraction and personal protection was utilised at all times.

Conservation methods

Fractured bone surfaces

Prior to the application of the bulked epoxy filler, all the fractured surfaces were consolidated with a viscous layer of Paraloid B72. This was applied with a No.10 synthetic hair brush and whilst tacky, a single layer of Japanese tissue was applied to the Paraloid B72 with care taken to ensure that the tissue conformed to the uneven surfaces. A second layer of the Paraloid B72 solution was then applied on top of the Japanese tissue. The barrier layer was left to cure for twenty-eight hours to allow full solvent evaporation before the epoxy / microballoon mixture was applied (Ellis and Heginbotham 2004). The majority of bone surfaces were relatively stable with very few friable or flaking areas so deeper penetration of a consolidant was not required.

Remodelling of the bone

Larger areas, for example the scapula, required re-modelling and 1.5mm copper plated mild steel welding rods were used to provide an internal armature (Figure 5). The welding rods were chosen as they offered a high degree of stiffness and malleability allowing small gauge rods to be used. Since they would be entirely enclosed within the filler the likelihood of oxidation of the copper plating was limited. A stainless steel wire could also have been used as an alternative but would likely have required a higher gauge size for comparable stiffness. Where possible, the holes left by previous doweling attempts were reused but where there were no existing holes, the wire was pushed approximately 20mm into the cancellous bone interior and secured with a highly viscous solution of B72. The bulked epoxy filler could then be applied and left to cure for twenty-four hours before shaping.

Consultation Process

After the skeleton had been fully disarticulated and anatomically assessed a consultation process between the conservators and the anatomist commenced. The condition of the various skeletal elements was discussed and decisions were made about the extent to which missing or damaged components should be remodelled. The anatomical features of the skeletal elements of the exhibited giant deer skeletal mounts, fallow deer and red deer skeletal material held within the Zoological Collections of the National Museum of Ireland - Natural History Division were examined and detailed observations were recorded in terms of anatomy and articulation. Other published material on deer skeletal morphology proved useful (for example, Post 2014).

In order for the viewer to fully understand the overall scale and shape of the specimen, it was decided that certain anatomically correct areas of a proportion of the skeletal elements should be reinstated namely, the distinctive vertically protruding dorsal processes of the thoracic vertebra and the posterior ribs within the ribcage. The caudal (or tail) vertebrae were not included within the restoration since these bones have been rarely found with giant deer subfossil remains, either due to lack of preservation or poor retrieval excavation techniques. The number of caudal vertebrae found within deer species can vary in total number and we do not know the full number of these bones found within giant deer tails.

Repair and re-modelling of skeletal elements

Skeletal components that required remodelling in their entirety were created in a similar way to the

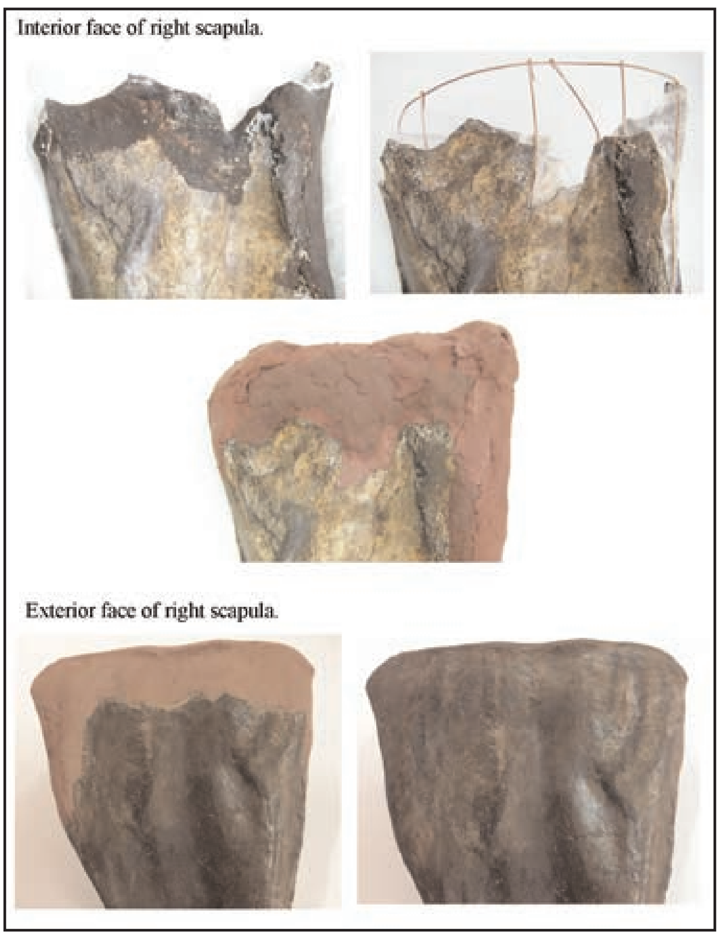

Figure 5. Stages in the modelling of damaged skeletal components (see text for stage explanations).

aforementioned missing localised larger areas. In the case of the ribcage, the vertebrae and ribs were anatomically arranged to establish where the new ribs should be located and to ensure they followed the contour of those already present. Reference photographs and an average set of dimensions were recorded from three similarly mounted specimens within the National Museum of Ireland - Natural History Museum and these measurements were used as a guideline for approximating the anatomically correct rib lengths and shapes. A series of 1.5mm copper plated steel welding rods and existing ribs were temporarily secured to a flexible external armature made from 5mm diameter fiberglass rods with low tack masking tape. The bulked epoxy filler could then be shaped around the welding rod supports and refined once cured (Figure 6). All modelled components were constructed in this way using photographs of mounted giant deer specimens for reference in-conjunction with anatomical diagrams of morphologically similar deer species.

Colouring

Once shaped with riflers, files and wood carving chisels, the fills and modelled sections were in-painted with earth pigments in a 10% solution of Paraloid B72 in 50:50 IMS and acetone. The earth

Figure 6. (Top) The ribcage of the giant deer specimen during construction. (Middle) The remodelling and fabricated ribs are those areas that display a lighter brown relative to the remaining darker brown coloured real bone. (Bottom) The fabricated ribs post 24-hour curing and shaping, and subsequently in-painted with earth pigmentation.

Figure 7. The giant deer (right) humerus bone before and after colouring with earth pigmentation.

Figure 8. Giant deer lumbar vertebrae with newly remodelled bone infilled areas clearly visible in ultraviolet light (bluish colour), after in-painting with earth pigments.

pigments had the advantage of closely matching the brown earth tones of the specimen, providing a convincing aesthetic match and could be easily and quickly removed if swabbed with acetone. The reddish brown hue of the phenolic microballoons was also advantageous in achieving a close match (Figure 7). As a binding agent, the Paraloid B72 added a slight sheen that accurately represented the sheen of the shellac-covered bones. An additional benefit to this system is that the in-painted areas can be quickly identified as matt dark areas in contrast to the shellac coated bone surfaces when exposed to ultraviolet light (Figure 8).

Treatment of skull and antlers

By far the most challenging aspect of remounting the giant deer, was establishing a viable way to integrate the newly obtained skull with the antlers belonging to the specimen. Aesthetically, introducing external brackets was undesirable and while the antlers could be partially supported from above, attaching load bearing supports from the ceiling in the proposed display location was not possible. This meant that however the antlers were attached they would need to be largely self-supporting. The left antler had suffered two serious breaks across the main beam in the past and been repaired with several heavy duty brackets. The large number of holes in this area and the presence of weak historic fillers made finding a location to securely attach a new external bracket problematic. For these reasons, the difficult decision was taken to permanently attach the antlers to the new skull without the reversibility measures usually associated with the use of epoxy resin adhesives. An un-bulked structural two-part epoxy (UKH-136 and UKH-137) offered high levels of adhesive strength and the high glass transition temperature necessary in a very warm display location. It has been suggested that on a porous substrate, the bond strength of epoxy based adhesives applied over a barrier layer of Paraloid B72 is comparable to the bonds yielded by epoxy alone (Ellis and Heginbotham 2004; Podany *et al.* 2001).

The post-treatment internal access to either the skull or antlers however, was deemed too limited to allow such a barrier layer to be reversed in any practical way and so this was ruled out. An alternative to this somewhat drastic measure could have been to cast replica antlers in a light-weight, conservation grade material and instead mount these on the new skull and store the original antlers. The time and materials required to cast high quality replicas was outside of the budgetary constraints and so the decision was made to use 15mm high tension CFRP carbon fibre rods to effectively dowel the antlers onto the replacement skull. This was done by drilling two diagonal holes down through the pedicles at such an angle that the carbon fibre dowels passed through the thickest structures within the skull with the crossed ends meeting at the nasal cavity. Corresponding holes were drilled into the cancellous interior of the antlers and adhered with several applications of the liquid epoxy. Milliput® modeling epoxy was then used to extend the lower edges of the antler coronets to hide the join and in-painted to match. Upon reinstallation, heavy duty fishing line was looped around both antler beams and secured to ceiling trusses for additional support.

The broken antler tines were adhered with a lightly bulked solution of epoxy resin and phenolic microballoons applied over the Paraloid B72 and Japanese tissue barrier system. Any missing tines were recreated in soft lightweight pine, shaped using a rasp and coated with a thin skin of the epoxy and microballoon filler before in-painting. Although aesthetically effective, this method was greatly improved upon in the treatment of another antler set through the use of an expanded metal mesh armature coated in the same epoxy based filler.

Skull and anterior spinal rod and the vertebra

Within the original mounted specimen, the anterior portion of the spinal iron rod had been inserted into the skull through the foramen magnum with a bar that passed through a hole in the rod creating a T-shaped support. Both ends of the T-bar exited through the orbits and were secured simply by bending the bar ends around the edge of each orbits. As an aesthetic improvement to this system, the new skull was secured to the spinal rod with two heavy duty stainless steel nuts and bolts from the ventral aspect.

A layer of 2mm Plastazote® was adhered to the spinal rod to minimise unwanted movement of the vertebrae which were subsequently threaded onto the rod in the same original manner. The addition of Plastazote® discs between each vertebra provided further cushioning that similarly mimicked the functions of the *pre-mortem* intervertebral discs or fibrocartilage in these locations. The ribcage was attached by reusing the previous mounting holes; however, these were first consolidated with several applications of Paraloid B72 to impart greater strength. Soft copper wire was utilised for its malleability and in-painted with acrylic paints.

Historical use of metal fixtures

As well as the intrinsic structural mounting rods, a number of metal brackets, nails and metal bars had been used externally to secure weakened components. One such example was the pelvis, which bore a high degree of structural stress and strain as the only point of contact between the rods protruding from the proximal areas of the hind limbs, and the rod supporting the spinal column. A large internal section had been historically incised from the sacrum to allow it to be threaded onto the end of the spinal column and this was then adhered to the pelvis with an animal glue and cotton filler. Subsequently, the pelvis was attached to the femoral articular heads with M6 mild steel threaded bars, screwed into a tapped hole in the top of the leg rod, which protruded through holes drilled in the both of the femoral articular heads and passed on through the centre of the acetabular fossa of the pelvis (acetabular-femoral articular head joints) where they were secured with nuts and washers. The holes in the articular heads of each femur had become enlarged through wear and allowed the threaded rods to be upgraded to heavier duty M8 stainless steel replacements. It was clear that the stress placed on the pelvis in this way must be transferred to a supportive bracket and so a new stainless steel bracket was designed and cold forged in 1.2mm stainless steel sheet to run in a continuous loop, conforming to the interior facets of the pelvis and sacrum with 2mm Plastazote® providing a cushion between bone and bracket (Figure 9). The original holes securing the leg rods to the pelvis were then re-used with new stainless steel rods, nuts and Plastazote® washers.

Figure 9. The pelvic bracket in situ after the completion of the treatment.

Future care and recommendations

In fluctuating environments, damage to sub-fossil bone typically takes the form of surface de-lamination, longitudinal splits or cracks along lines of weakness such as growth plate/epiphyseal sutural boundaries (Doyle 1986). The longitudinal splits and localised fractures observed in this specimen required ongoing observation and thus a monitoring programme was instigated which involved visual inspections by staff of Conservation | Letterfrack of the mounted specimen every few months to examine the bone surfaces in detail for any signs of new cracks or the widening of those already treated. An Easy Log USB data logger was also tucked inside the eye socket (orbit) to gain an overall picture of the day-to-day conditions experienced by the specimen. In long-term storage, ideal conditions for sub-fossil bone range between 50-60% relative humidity whereas on display, around 40-50% is recommended with fluctuation of 10% or more per day likely to cause damage (Andrew 1996).

The proposed display location for the completed specimen was always likely to be problematic as the position, directly in front of a large expanse of windows, was subject to high levels of temperature and relative humidity fluctuation. As well as diurnal temperature fluctuation caused by central heating and the greenhouse effect of largely glass surroundings, varying occupancy within the room influenced less predictable relative humidity levels. The opening and closing of doors and windows inside the space further compounds this issue.

The readings obtained from the data logger (Figure 10), taking hourly readings across a four-month period, recorded a minimum temperature of 12.5°C with the highest temperatures reaching 34°C. The average relative humidity recorded across this span was 37.7% but alarmingly, on particularly unstable days the specimen was subject to diurnal relative humidity fluctuations of around 20%. These values fall well outside of recommended levels and so a maximum exhibition period of six months was advised for this specific location with regular monitoring in place to flag up potential issues before they became damaging to the conserved skeleton. Presently, the specimen has been removed to a climatically stable storage location while research is underway to source a suitable display case with incorporated climate control.

Conclusions

From our examination of this historically prepared full skeletal mounted giant deer specimen, we outlined procedures, in line with best practice conservation guidelines, with regards to use of fillers and adhesives that will ensure an accurate reconstruction and aesthetically pleasing remodelling while still retaining historical features of the original mount. The highly interventive and largely irreversible adhesion of the original specimen antlers to the newly obtained skull was decided upon after an exhaustive exploration of reversible options. The conservation treatment imparted structural strength to an otherwise unsteady display specimen

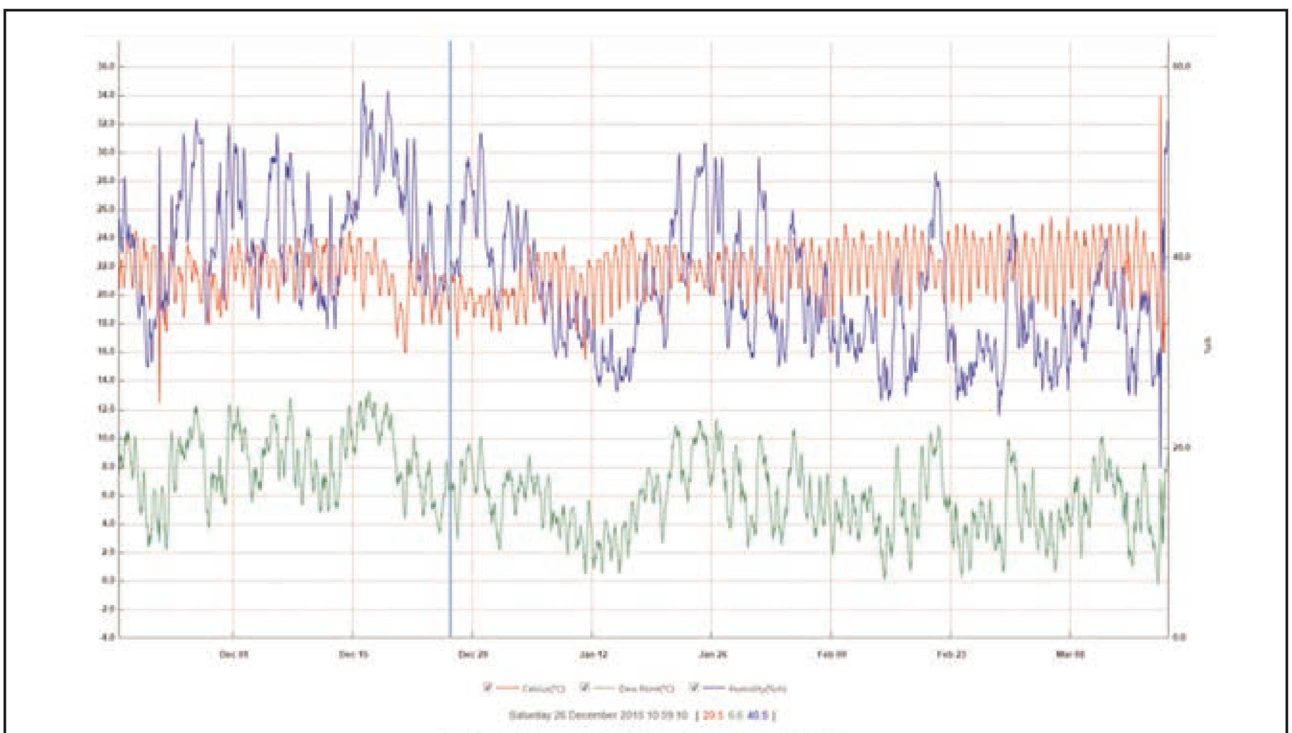

Figure 10. Data logger hourly readings across a four-month period, illustrating fluctuations in recorded minimum temperatures (red), average relative humidity (blue) and the dew point (green).

and aimed to improve the viewers understanding of the scale and shape of the specimen by reinstating missing or broken skeletal components. The use of an epoxy resin bulked with phenolic microballons for modeling purposes was largely informed by the sucessful use of such materials in the conservation of degraded wood. A comparison of the compressive and tensile strengths of this material with subfossil bone is an area for future research. Due to fluctuating environmental factors occurring within the display area, a maximum exhibition period of six months was recommended with an ongoing monitoring programme in place to safeguard the future of the specimen. A climate controlled display case and alternative future display location are currently being investigated (Figure 11).

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