REMOVAL OF A COLUMBIAN MAMMOTH SKULL FROM AN IN-SITU BONEBED

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In July 2016, a Columbian mammoth skull with one intact tusk was removed from the in-situ bonebed at the Mammoth Site of Hot Springs, SD. The decision to remove the skull, which was located in a high density area of the bonebed, was based on largely health and safety concerns. The skull sat atop a tall pedestal of sediment with slanted bedding planes, consisting of layers of dense clay-rich sediment interspersed with thin layers of sand. Potential failure of the pedestal could have caused irreparable damage to the skull and upwards of two dozen surrounding specimens, including several tusks and a second skull. The safety of staff and volunteers working in the area was also a concern. The entire removal process took over three weeks. Surrounding specimens needed to be protected from numerous hazards including heavy foot traffic during the project, tool damage, damage from falling tools or sediment, and damage from support ropes attached to the skull. Those specimens deemed at greatest risk of damage were protected by temporary plaster jackets, others were covered in padding. A metal support frame was installed around the skull, part of which was welded in place inside the bonebed. The metal frame was incorporated into the plaster jacket surrounding to the skull. The skull was successfully removed using a built-in overhead crane with a one ton lift capacity.

A COMPARISON OF FOUR DRYING TECHNIQUES FOR THE CONSERVATION OF WATER-SATURATED BONE REMAINS FROM COLD LAKE, ALBERTA, CANADA

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Over the past four years, the Quaternary Palaeontology program at the Royal Alberta Museum has been accessioning vertebrate remains collected from three underwater areas of Cold Lake, on the Alberta-Saskatchewan border. Initial remains from the lake were allowed to air dry at ambient temperature and humidity. Those specimens proved highly sensitive to damage caused by water loss. The most common types of damage were delamination, twisting, and cracking. To address those issues, we initiated a series of conservation tests for additional vertebrate remains collected from Cold Lake.

We tested four drying methods on ungulate vertebrae of comparable size: vacuum freeze-drying, controlled air-drying, solvent-drying, and vacuum freeze-drying with Acrysol™ WS-94, an acrylic dispersion. Specimen weight was monitored and drying was deemed completed when weight stabilized for 5 consecutive measurements, except in the case of solvent-drying where specific gravity was monitored and drying was deemed completed when specific gravity stabilized. We evaluated the methods in terms of the damage observed on the specimens after the treatment and time it took for them to dry. In addition, the vertebrae were measured in multiple dimensions prior and post treatment to evaluate size change related to water loss. We predicted that damage and size change would be positively correlated. Damage was judged by the amount and severity of delamination, twisting, and

cracking. Surprisingly, size change due to water loss was not correlated with the amount of damage observed.

Solvent-drying and controlled air-drying produced the best results. The specimens treated with these two methods did not show appreciable damage. Vacuum freeze-drying was associated with substantial delamination and cracking, whereas vacuum freezedrying with Acrysol™ WS-94 showed minor delamination and cracking. Controlled airdrying took over three months to complete while the other treatments took between one and two weeks. Although controlled air-drying took a considerable amount of time to complete, it has some advantages over solvent-drying that need to be considered when selecting a drying method. Controlled air-drying is considerably cheaper and does not require the addition of chemicals to dry the bone, which may interfere with certain analytic techniques.

PALEONTOLOGY LABORATORY EQUIPMENT, MATERIAL, AND METHODS FOR UTILIZING ULTRAVIOLET LIGHT IN FOSSIL PREPARATION

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In an effort to facilitate and broaden the use of ultraviolet (UV) lighting techniques in preparation of fossils, several experiments were conducted utilizing various lighting methods and wavelengths from both visible and non-visible light. This research was primarily performed on a nearly complete Stylemys nebrascensis tortoise recovered in 1994 and donated to the Heard Natural Science Museum in 2013 for preparation and display. The specimen was collected from the White River Group bentonite sediments of the Brule Formation.

The bentonite matrix was a uniform gray color and the fossils contained within were of a similar neutral gray coloration; any contrast between bone and matrix was difficult to discern under visible light. Ultraviolet (UV) light in the high range (UVA, 395 nanometers [nm]) was found to be most effective and would greatly enhance the quality of fossil preparation. The source of the light was critical when using UV as light emitting diodes (LEDs) produced a focused beam on the specimen that excited the electrons of the matrix and bone in different ways. Incandescent or fluorescent light sources had a minimal effect and were inferior compared to LED illumination. When viewed through amber UV filter glasses, the matrix absorbed the UV light turning the uniform gray color to a dark brown while the bone reflected the light resulting in a pale blue, nearly white shade. The remarkable contrast in hues gave the laboratory volunteers a valuable resource to use and provided the confidence needed to remove deposits without incurring damage to the fossil. In addition to the initial research on the White River specimens, further experiments have concluded that the benefits of UV light during preparation also extends to other specimens within clay composition deposits. During the experiments, specific safety protocols were developed and utilized by the volunteers. Any exposure to additional UV light can be harmful and although the work is completed with UVA at very low wattage (3 watts) and a limit of four hours for UV sessions is established, each preparator is required to wear gloves and UV filter glasses to protect the skin and eyes from potentially harmful radiation. A typical lab station would include a desk lamp equipped with a three watt, 395 nm UV LED bulb(s), and UV filter glasses.

REPAIRING THE TITANS: CHALLENGES AND CONSIDERATIONS FOR DEALING WITH SAUROPOD BONES

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A new exhibit featuring the largest known titanosaur was unveiled at the American Museum of Natural History in January of 2016. Along with a complete mounted skeletal cast, five original fossil elements of an as-yet unnamed Argentine titanosaur are showcased. Stresses on two elements (a scapula and a 500 kg femur) during the extended air and ground transport from Argentina resulted in significant damage. Transverse fissures along the femur yielded broken elements, each piece weighing between 100–250 kg. A team consisting of Preparation, Exhibit, and Conservation staff arranged logistics for repair during a two-week time frame. Due to the outstanding dimensions and masses of these specimens, critical decisions were made in the choice of treatment, specifically in the selection of adhesive, and in the mechanical handling of broken elements (particularly for the femur). Paraloid B-72 (in acetone 1:1 w/v) and Devcon 2-ton epoxy (an irreversible structural adhesive) were each considered. Working qualities and setting times of these materials were assessed within the context of the very limited time frame. Most importantly, physical qualities including shear, tensile, and compression strengths were compared with the aid of limited but impactful conservation literature on this subject. Despite its irreversibility (and sometimes controversial use) in fossil conservation, epoxy adhesive was employed for the repairs. Shear and compression load calculations on the two femoral breaks as estimated by basic mechanical stress formulae, were pivotal in making this choice. Unlike the majority of fossil repairs wherein the strength of Paraloid B-72 suffices or exceeds the demand, specimen repairs of titanosaurian size leave room to question this adhesive's suitability. I will describe the practical and physical quality comparisons of both adhesive options which resulted in the final treatment plan, and handling logistics for the femoral repair. Details on the utility of stress load calculations for large specimen repairs will be coupled with a summary of important published data on tensile/shear strengths of some of the most widely-used adhesives in fossil preparation and conservation.

POLYESTER OR EPOXY: ASSESSING PRODUCT EFFICACY IN PALEOHISTOLOGICAL METHODS

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Histological examination of bone microstructure provides insight into the physiology of modern and extinct vertebrates. The field of paleohistology has grown immensely because of the wealth of data contained in the microstructure of fossil bone and sampling of modern bone allows for direct comparisons along evolutionary lineages of fossil taxa. Specimens sampled for histological examination are first embedded in a plastic resin which is then cut into thin sections, mounted on slides, and polished for viewing. Standard embedding procedure of fossil material involves embedding specimens in relatively inexpensive polyester resin. Conversely, small fossil material and modern tissue is embedded in a higher priced epoxy resin. Modern tissue and small fossil material often require thin sections near or below 100 micro meter causes increased likelihood of sample peeling, material loss, and is unsuitable for modern tissue and small fossil material embedding. To test this assumption, three fossil bones and two modern bones were embedded in Epothin™, an epoxy resin, while five fossil bones and four modern bones were embedded in Silmar S-41, a polyester resin. Embedded specimens were sectioned

and mounted following standard protocol. A total of 35 slides (26 from Silmar S-41 embedding and nine from Epothin™) were produced, then ground on a lapidary wheel using decreasing grit sizes until bone microstructure was completely discernable. Additionally, two slides, one with a polyester resin embedded specimen and one with an epoxy resin embedded specimen, were continuously ground on 600 grit paper until peeling occurred. Slide thickness at the point of peeling was measured for direct comparison of resin types and timing of specimen loss. Finished slide thickness ranged from 23–230 micrometers. We found no appreciable difference in bone microstructure visibility between Silmar S-41 embedded material and Epothin™ embedded material, and none of the 35 finished slides exhibited signs of peeling. There also was no observable difference in the timing of the occurrence of peeling. The specimen that was embedded in epoxy resin began peeling at 77 microns while the specimen in polyester resin peeled at 55 microns. Counter to previous assumptions, our results suggest that expensive epoxy resins can be replaced by polyester resins in histological preparation of modern bone tissue and small fossil material.

CUTTING BONE—A CREATIVE USE OF CYCLODODECANE (CDD) IN HISTOLOGIC SECTIONING OF FOSSIL SPECIMENS

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Histology is a growing field in vertebrate paleontology and it is being incorporated into many fossil preparation labs. Since the kind of sectioning equipment varies among institutions, there is often a period of trial and error in establishing in-house protocols for histology practices, especially for the first step of removing a sample of fossil bone. The portion of the bone must be removed from the rest of the specimen and embedded in a resin block that is subsequently cut, sectioned, and polished. This first step was one of the largest hurdles faced in the lab at Petrified Forest National Park (PEFO). Breaking the bone along preexisting fractures is easily carried out by weakening the fracture with acetone, water, or other means. If a fracture was not already present, the best option is to use a precision saw. The goal is to minimize damage to the remaining fossil and to maximize the number of viable sections to be taken from the resin block.

As a solution, PEFO developed a technique for sawing through fragile Triassic specimens while maintaining their integrity without cracking or splintering unstable or oddly-shaped fossil bones. After consolidation with Acryloid B-72, a specimen was coated in a layer of Carbowax™ 4000 polyethylene glycol (PEG) to stabilize the bone. The resulting globular shape did not fit the saw at PEFO, which lacks a chuck for holding the specimen. Instead, placing the coated fossil in a square block of plaster allowed the swing arm of the saw to hold the specimen and maintain a rigid base to stabilize the specimen during the cut. Liquid plaster contains water, therefore hydrophobic CDD was utilized as the coating instead of hydrophilic PEG. Major cuts for histological sectioning are typically made perpendicular to the length of a long bone. Although the stabilizing technique of CDD and plaster proved to be an effective way to safely cut the specimen, error in the angle of the cut was introduced because a thick layer of CDD prevents the preparator from seeing the actual fossil; it was difficult to judge the exact angle when placing the specimen in the plaster. The result is that by using a thinner layer of CDD (no more than 1.5 mm thick), observing anatomical features not embedded in the plaster, and photos of the entire bone, preparators are now able to consistently orient and cut fossils at the proper angle for histologic analysis while introducing a minimum of incompatible chemicals to the fossil itself.

PRECISION, ACCURACY, AND REPRODUCIBILITY OF RESEARCHQUALITY PHOTOGRAMMETRIC MODELS OF VERTEBRATE MICROFOSSILS IN THE 0.5–2 MM SIZE RANGE

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I have refined my protocol to produce 3D photogrammetric models of vertebrate microfossils using inexpensive equipment and readily available software to the point where it is now possible to build research-quality digital models. Here I present a method to confirm that sufficient photographs have been taken to produce a good model and test the ability of my protocol to yield 3D models that are precise, accurate, and reproducible. My test object for this study was an upper second molar of a shrew (Sorex sp.) with an occlusal area of approximately 1 mm2. I used three series of 220 focus-stacked images to build the initial specimen models. I randomly subsampled each of the image sets three times by increments of 10% and built new models for each subsample (84 models total). Fitting a mechanistic growth model to a plot of the number of photographs used versus the calculated Dirichlet normal energy (DNE) of each model yields a curve that approaches an asymptotic value for each series and indicates when sufficient photographs have been used. For two of these series the DNE curves leveled out at approximately 50% of the initial number of photographs. One series failed to approximate the asymptote. I then performed a 3D geometric morphometric analysis to assess the precision and accuracy of each of these models relative to a series of models in which I exaggerated the length and width by increments of 5%. On scale, each of these steps represents a difference of approximately 50 microns. A plot of PC1 vs PC2 of the Procrustes transformed data reveals that all models generated from subsamples of 50% and higher, including those from the series that failed to reach the asymptote of the DNE curve, form a single tight cluster that lies far from the nearest exaggerated model. These data suggest this method can yield precise models with an error rate of less than +/- 2%. While the method remains labor intensive, the fact that research-quality digital models of sand grain sized specimens can be produced with equipment costing less than $1500 has the potential to significantly lower the bar of entry to working with these types of 3D data.

PHOTOGRAMMETRY OF MICROFOSSIL VERTEBRATE TEETH FROM THE LOWER JURASSIC KAYENTA FORMATION OF SOUTHWESTERN UTAH

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A macrophotography technique coupled with focus stacking was developed and successfully used to produce source images for subsequent photogrammetry of two isolated microvertebrate teeth from the Lower Jurassic Kayenta Formation of southwestern Utah. Macrophotography was conducted using a sensor format digital camera and a 65 mm macro lens. A focusing rail coupled to a rotation stage was used to manipulate specimens for photography. Focus stacking software was used to produce completely focused images for input into Agisoft® Photoscan photogrammetry software. The digital models created by the photogrammetry software were exported as both pdfformatted files and stereo

lithography files. These three-dimensional PDF files are then available for other purposes, such as examination, sharing, and storing information about specimens outside of the photogrammetry software. Photogrammetry of microvertebrate fossils, especially for type and figured specimens, would prove extremely important for research, collections management, and exhibition purposes. It would allow for the study of tiny, delicate, and unique specimens without actually having to risk handling and/or transporting fossils. The use of a stereo lithography files to produce a 3D-printed rapid prototype model of one tooth was also demonstrated.

"LIBERATION FROM THE BONE CELLAR"—LOW TECH, HIGH QUALITY—HOW TO CHEAPLY 3D DIGITIZE A COLLECTION OF VERTEBRATE MACROFOSSILS

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The Museum für Naturkunde Berlin's Bone Cellar holds a vast collection of fossils from the German Tendaguru Expedition. In our project "Liberation from the Bone Cellar—online access to the Tendaguru dinosaurs of the Museum für Naturkunde" we used photogrammetry to 3D digitize all longbones, all girdle elements, some vertebrae and some manus and pes bones, ranging in size from several centimeters to 2+ meters, at high accuracy (< 0.5% error compared to total bone size) and high resolution (better than 0.1 mm). The workflows we developed are applicable not only to dinosaur bone collections, but also to all other kinds of skeletal remains, and even on non-vertebrate specimens in the same size range.

Data capture was performed in the Bone Cellar with equipment costing less than $2000. The data capture time per specimen on average was three to eight minutes for photography, and two to six minutes for other tasks, e.g., moving the bones and placing scale bars. Model creation was immediately successful in more than 80% of cases. Manual addition of masks on the images and other post-capture improvements resulted in half of the remaining models giving good results, for a total success rate of over 90%.

For this project we developed a number of workflows that may be of high interest for the paleontological community, as they allow high-resolution data capture at a high success rate and comparatively low cost. These include details of how the specimens were placed on various backgrounds for data capture, how scale bars were used during data capture and model creation, how the specimens were lit, how the camera equipment was handled and how the individual images were best and most speedily acquired. Our methods are versatile and also suited for data capture on research visits. Our project can thus serve as a best-practice guide and as a model for calculating digitizing time and monetary costs, both for in-house digitizing initiatives and research visits.

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DIGITAL RECONSTRUCTION OF A HEAVILY TAPHONOMICALLY ALTERED PLESIOSAURIAN SKULL UTILIZING LASER SCAN DATA AND NOVEL 3D MODELLING TECHNIQUES

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A recently discovered new taxon of elasmosaurid plesiosaurian from Montana, U.S.A., was laser scanned for research and archiving purposes. The skull was obliquely deformed, being flattened on the left-right axis and skewed ventrodorsally and anteroposteriorly, which preserved most of the palatal view and the left lateral without deformation. This resulted in a state of preservation not conducive to standard analog reconstruction methods. We digitally reconstructed the skull of this elasmosaurid using a combination of techniques and software. 3D sculpting software, ZBrush, was used to cut and separate the mandible from the cranium and the individual cranial plates along distinct suture lines. The pieces were then retrodeformed, using photo references and CT scans of sister taxa as guides, and the pieces of the cranium that could not be salvaged were discarded and replaced by mirroring more complete components from the left side of the specimen. The mandible was dissected along the symphysis and corrected as distinct pieces and later merged into a solid structure. The cranial pieces were further retrodeformed and digitally merged to match natural sutures. Using morphometric data supplied by ongoing research of the plesiosaur the cranium was returned to life proportions and cleaned of taphonomic alterations such as fractures and pitting. The teeth were replaced with digitally sculpted analogs that were individually scaled and shaped on a tooth by tooth basis, matching the original teeth as closely as possible. The mandible was fitted to the cranium and the teeth were adjusted to allow for proper range of motion without occlusion. The reconstructed skull was 3D printed at full scale and used as a skeletal template for the manual addition of soft tissues in order to create a new life-like reconstruction of an elasmosaurid head for display at the University of Alaska Museum of the North. A full-body, digital model of the plesiosaur will also be used for research purposes and serve education and outreach roles.

WHEN THE SMOKE CLEARS: A DISCUSSION ON FOSSIL WHITENING AND AN EVALUATION OF CLEANING METHODS FOR SPECIMENS SMOKED WITH AMMONIUM CHLORIDE

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Smoking describes a family of techniques wherein chemical powder is sublimed and deposited onto specimens. Smoking has long been employed for enhancing the relief of fossils and other natural history objects during photography. Several different chemicals can be used for smoking, but the most common is ammonium chloride. Though there are many documented methods for coating specimens in ammonium chloride, there are few published explanations on how best to remove this coating after application. Ammonium chloride is acidic and dissolves in the presence of moisture, potentially etching specimens and posing a risk to museum collections. To test the efficacy of several cleaning techniques for the removal of an ammonium chloride coating, we smoked a series of calcitic invertebrate fossil specimens and cleaned those using eight commonly used or suggested cleaning techniques. The experiment was split into two experimental groups. In Group 1, we tested the following cleaning techniques: brushing with a dry brush, puffing with a camera lens puffer, breathing on the specimens, and rinsing in deionized (di) water. In Group 2, we tested the following cleaning techniques: blowing with a compressed air gun, brushing with di water, brushing with 95% ethanol, and rinsing in 95% ethanol. We performed six trials per experimental group using six specimens per trial: two control specimens and four experimental specimens upon which the cleaning methods were performed. After performing the appropriate cleaning method, we thoroughly rinsed each specimen in di water. We then tested the rinse water by mixing it with a silver nitrate solution. Chloride ions react with silver nitrate to produce a white precipitant, turning the solution an opaque, milky color. Using their relative opacities as a guide, we visually compared each silver nitrate solution in order to create a qualitative scale to measure the efficacy of each method. Using this procedure, we found the di water rinse to be the most effective cleaning method. Every brushing method was moderately effective. Every other cleaning method was either ineffective, or potentially dangerous to the specimen. Breathing on the specimen, a commonly used method, was ineffective at removing the ammonium chloride coating, and likely exacerbates the problem of etching by dissolving remaining residue. Smoking procedures and methods of smoke removal should always be carefully planned out in advance and recorded in the collections database, with specimen safety being taken into consideration before smoking.

EMESOZOIC: BRITISH FOSSILS IN THE DIGITAL AGE

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Museums are under pressure to digitise and share collection information. Consequently, many institutions are investing in large-scale digitisation programmes. The Natural History Museum, London (NHM) has embraced this and is investigating how best to digitise its large, diverse, and internationally significant collections; thereby making our collections openly available.

eMesozoic was an NHM pilot digitisation project focusing on British Mesozoic vertebrate collections. These collections were selected as they are subject to intense research activity and have wide public appeal. They also present many challenges to digitisation such as the wide variation in specimen size from microscopic teeth and scales to large articulated specimens.

Consultation with collection users established the need for clean, high quality data as essential for effective use of the collections, particularly for research along with an image of the specimen. To achieve this, we trialed the use of Master records covering sites, stratigraphy, and taxonomy to aid with transcription. Using this methodology, only clean, verified metadata is available to append to specimen records, significantly reducing the need for post-digitisation validation. An outcome of this is a wealth of clean metadata which could be exchanged with other institutions to assist with digitisation projects, therefore reducing the burden on individual projects to clean and verify data and ensure that collection data from multiple sources could be more easily integrated into large-scale datasets.

Issues arising when dealing with a historic collection have included many legacy issues, the critical importance of pre-digitisation collection preparation, multiple work flows encompassing the wide range of specimen sizes and the relatively slow speed of digitising diverse palaeontological collections.

The project has been successful and we have digitised 20,000 specimens and gathered valuable data on estimating the time, effort and resources required to digitise large historical palaeontological collections. The specimen data available via our data portal is proving fruitful, with researchers from across the globe approaching the NHM to discuss new research projects based on the eMesozoic specimens and data. This data will be beneficial to other institutions considering embarking on similar projects, particularly ensuring its utility to researchers, exhibitions, outreach facilities, and curation.

PROJECT AIRLESS: A LARGE-SCALE CROSS-DISCIPLINE PROJECT TO PROTECT FOSSILS FROM PYRITE DECAY THROUGH THE USE OF ANOXIC MICROENVIRONMENTS

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Airless is a three year project currently being undertaken by a small dedicated team at the Natural History Museum (NHM) in London, UK. The aim of the project is to ascertain how much of the museum's historic fossil and mineral collections are at risk of pyrite decay, and to take measures to conserve and protect these specimens. This involves conducting surveys of the collections to identify the location of all pyritic specimens, and assessing the severity of oxidation. The specimens are then allocated a unique barcode, photographed, and condition assessed. Following any necessary remedial treatment, the specimens are then placed in specially constructed anoxic microenvironments. In collaboration with data managers, conservators, curators, and other staff from across the museum, the project merges large-scale preventative conservation with collection management and digitisation.

Pyrite, commonly known as 'fool's gold', is an iron sulphide mineral that can often be involved in fossilisation, or present in the surrounding matrix. In its microcrystalline form, the mineral can be prone to oxidation (often referred to as pyrite 'decay'). This chemical process is greatly affected by relative humidity, and can produce harmful byproducts such as ferrous sulphates, sulphur dioxide and sulphuric acid. These can have destructive effects on specimens, labels, and storage media, and also pose health risks.

The initial remedial conservation treatments involve removing oxidation products by dry brushing and airbrasive techniques. For more severe pyrite oxidation, ammonia gas and ethanolamine thioglycollate treatments can neutralise the by-products. Following remedial treatments, specimens are re-boxed in conservation-grade materials before being sealed in anoxic microenvironments. The latter are constructed from gas barrier film which prevents oxygen ingress from the surrounding environment. Oxygen scavengers are placed inside the enclosure to remove any oxygen already present. Bespoke webbased applications are utilised to combine the high-quality condition photographs with the registration number, specimen and location barcodes, to create digital surrogates on the museum's collection management system. The barcoding system allows more efficient tracking of a specimen's location, and rapid association of condition and treatment data. To date, the team have processed over one thousand specimens using this method, including pterosaurs, ichthyosaurs, and fossil fish. Thousands more fossils will be processed by project completion.

PREPARATION AS INTERPRETATION IN THE STUDY OF FOSSIL VERTEBRATES

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Natural history specimens experience a transformative path from the field to the collection, and these changes continue through the museum life of the object. Fossils specimens are typically mechanically or chemically prepared from the rock in which they are preserved prior to study. These techniques shape our interpretation of the morphology of extinct life, yet the basic methods are infrequently documented in the laboratory or collections and rarely reported in the scientific literature. A case study of one specimen from Petrified Forest National Park illustrates the impact that paleontological methods bear on identification of fossil materials.

PEFO 31205 represents a partial skull of a pseudopalatine phytosaur collected from the Sonsela Member of the Upper Triassic Chinle Formation. Originally described as the first occurrence of the genus Nicrosaurus from Arizona, and the second from North America, this taxonomic identification was based on the condition of the skull upon discovery, partly weathered out of a large block of coarse sandstone exposing a portion of the left lateral view of the posterior skull. The original research team and park resource managers determined that it was not feasible to collect the skull in this remote area of the park, thus it was described in situ. The interpretation was therefore based on unprepared material, in which much of the anatomy present was obscured by matrix.

Subsequent collection and preparation of the skull revealed that much of the skull roof, and posterior skull, including the upper part of the braincase, were preserved. As a result of this preparation, a phylogenetic analysis including the newly exposed morphological characters, particularly the projection of the external nares above the skull roof and the width of the posterior squamosal process in lateral view, recovers the specimen as the sister taxon to *Machaeroprosopus buceros* and therefore distinct from the predominantly European genus *Nicrosaurus*. As a result, biostratigraphic correlations of *Nicrosaurus*-bearing rocks to the Chinle Formation are no longer supported by this specimen. This case study illustrates the effect that paleontological methods can have on scientific interpretation affecting taxonomic, biostratigraphic, and biogeographic hypotheses by demonstrating the transformative effect that preparation has on available data. It likewise reinforces essential preparation competencies such as understanding of fossils as geological and biological data, as well as recording and reporting of methods applied to specimens.

FOSSIL PREPARATION IN A SMALL LAB: A CASE STUDY OF PREPARATOR TRAINING AT THE STERNBERG MUSEUM OF NATURAL HISTORY IN HAYS, KANSAS

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The process of fossil preservation is exhaustive and meticulous, and demands knowledgeable specialists. In small museums, the preparation staff can often be limited by the need for tools, funds, and experience. Although online resources are available, it can be difficult for novice preparators to find current information in a single location and evaluate the resource's legitimacy. This case study highlights the development and fieldtesting of preparatory resources to train novice students at the Sternberg Museum of Natural History. The Sternberg Museum has a backlog of fossils requiring preparation and a need for volunteers trained in fossil preparation, making it an ideal location.

At the start of training, student volunteers were provided with a workbook containing guidelines, common mistakes, and tips on preparatory techniques. A teaching manual was also compiled, detailing lesson plans to guide the trainer through a series of workshops and pedagogical techniques for training different types of volunteers. Over the course of four two-hour sessions, students learned techniques for assessing fossils and their matrix, determining the appropriate tools to use for any given sample, proper use of materials and tools (including hand and pneumatic), and molding and casting. The students were also given a list of resources if they had questions and the lab manager was not available. Qualitative skill assessments were based on final prepared specimens, knowledge of methods, and a self-assessment at the end of the fourth session.

Upon completion of all sessions, students were able to satisfactorily prepare a variety of specimens. The course material successfully trained the beginnings of a preparation corps of volunteers for the Sternberg Museum and allowed for greater engagement with the public by more consistently populating the preparation laboratory. The simple and methodical nature of the materials produced educated students that were permitted ample time for practice, assessment, and improvement. Upon refinement, the versatility and scope of the materials will provide an easily downloadable and free resource for museums of any size to train and educate new preparators in proper fossil preparation techniques.

PALEONTOLOGICAL EXHIBITS AT THE NATURAL HISTORY MUSEUM OF UTAH: AN OUTSTANDING EXAMPLE OF COLLABORATION WITH MUSEUM STAFF, VOLUNTEERS, GRADUATE STUDENTS, AND EXTERNAL INSTITUTIONS

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The Utah Museum of Natural History (NHMU) features a large number of unique paleontological exhibits which were primarily developed in house as the result of an outstanding collaboration amongst museum staff, volunteers, graduate students, and external contractors. This collaboration began several years in advance of the museum's public opening in 2011, during the earliest planning stages. Specimens were selected by the paleontology staff to support story lines which were developed by museum paleontologists, graduate students and exhibit designers. Original specimens were prepared by staff and volunteers of several governmental and educational organizations. Molds and casts were produced by several external contractors who worked closely with NHMU paleontologists to reproduce and recreate skeletons. These skeletons were used by exhibit designers and curators to weave a story about the Past Worlds of Utah, illustrated through original material and supplemented with cast mounts derived from NHMU paleontology collections. NHMU volunteer preparators were critical in providing exhibit ready material for mounting and molding and casting. Original elements were carefully mounted by in-house exhibition staff, external contractors, and rigging specialists with some assistance from NHMU paleontology volunteers. University of Utah paleontology graduate students provided critical input in scientific content in the exhibits which often highlighted their research specimens. The exhibit features many specimens which were collected, prepared and described in the decade leading up to the opening of the museum. These include many specimens from the Early and Late Cretaceous deposits of Utah including the Cedar Mountain, Wahweap, Kaiparowits and North Horn formations, as well as Jurassic specimens from the Navajo and Morrison formations. The most outstanding specimens from the exhibit that illustrate this collaboration include *Seitaad*, *Nothronychous*, *Falcarious*, *Gryopsaurus*, *Utahceratops*, several tyrannosaur specimens, and the wall of ceratopsians.