2013 Preparator's session abstracts

THE YUKA WOOLLY MAMMOTH (MAMMUTHUS PRIMIGENIUS BLUM) BRAIN EXTRACTION AND PRESERVATION: THE METHODS AND RESULTS

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The Yuka Woolly Mammoth was found in 2009 on the coast of the Dmitry Laptev Strait (Siberia, northern Yakutia). The radiocarbon dating of the of the 6 to 9 year old mammoth yielded results of 39,440 - 38,850 cal BP (GrA-53289). The carcass was transported to Yakutsk for studies in January 2012, and since then it has been stored below freezing temperature in stable conditions. The first CT scan of the cranium was performed at the Sakha (Yakutia) Republic Academy of Sciences, Yakutsk in May 2012 to access morphology of the unerupted molars. It unexpectedly revealed the preserved brain with well-defined major gross anatomy features, including frontal, temporal, and parietal lobes with gyri, and cerebellum with internal structures, which yielded the first chance to examine Woolly mammoth brain morphology. Brain extraction was performed based on our own experience combined with the generally used treatment for large mammals, including modern elephants. In February 2013 the brain was preserved by the method of flowing fixation developed by Prof. Saveliev (Research Institute of Human Morphology, Russian Academy of Medical Sciences (RIHM RAMS), Moscow, Russia), which included three weeks of continuously on-going preservation of the braincase content only using formalin (performed by I. Pavlov, Museum of History and Culture of People of the North). Skull trepanation was performed on February 25th in Yakutsk. An angle grinder was used for the initial cut and a dental drill for the sphenoid, frontal, and nasal areas. The inner mantle of the neurocranium was opened by chisels. The cutting line went through the lower part of occipital bones, the lateral parts of parietal bones, and across the temporal and cranial parts of frontal bones. After removal of the fornix cranii, the dura mater was dissected along three lines near the cerebral falx and cerebellar temtorium. The brain, which appeared to be dehydrated and very brittle, was lifted off the cranial base and removed manually, together with the dura mater. After the extraction the brain was wrapped with fabric for support and placed into formalin solution overnight before being flown to Moscow. It is currently stored in formalin solution at the RIHM RAMS, Moscow, Russia. The results of the Yuka brain's conservation proved the methods of preservation and extraction were very successful and could be applied to mummified carcasses of paleontological objects found in permafrost.

UNDER THE HEADWALL: FIELD LOGISTICS OF EXCAVATING FOSSILS FROM LARGE VERTICAL EXPOSURES

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Field collection techniques for recovering vertebrate fossils have remained relatively unchanged since the late 19th Century. Traditional methods include: (1) removal of overburden using picks and shovels; (2) careful excavation of fossils with hand tools; and (3) removal of specimens within protective plaster jackets. Occasionally, specific locality characteristics require the development of alternative field collection techniques. Here we describe field logistics associated with excavating and collecting fossils from large, vertical exposures. Quarries situated at the base of large vertical headwalls (e.g., cut-banks, erosional cliffs) can result in insurmountable overburden, producing vertical excavation surfaces necessitating unique collecting approaches. To complicate matters, matrix can vary from poorly consolidated to highly indurated sedimentary facies. Fossil horizons can also extend deep into the vertical surfaces causing precarious destabilization of overburden as quarry faces are expanded into the headwalls. Moreover, fossil horizons can lie near water seeps or the water table, resulting in damp to waterlogged matrix that severely limits the types of consolidants (e.g., Paraloid B-72, Rhoplex B60A) and jacketing techniques that may be applied. Effective approaches include: (1) careful mining of fossil specimens from the quarry face; (2) block removal of larger and more complex materials; and (3) hours to days of block desiccation prior to conventional methods of stabilization and protection. The friable condition of waterlogged specimens can be transformed to a highly durable state once the surrounding matrix has dried; subsequent laboratory preparation of specimens can reveal exquisitely preserved details. The geological and paleontological importance of some localities warrants a multi-phase collecting effort, and insights gathered over the past several years of field excavations are documented for use in other locales with similarly challenging collecting conditions.

TARPOLOGY 501 - ADVANCED SHADE TARP TECHNIQUES FOR PALEONTOLOGICAL FIELD EXCAVATIONS; STRATEGIES FOR FIELD PALEONTOLOGY ON A WARMING PLANET

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The Utah Geological Survey has been conducting summer field excavations in Cretaceous strata throughout southern and eastern Utah for over a decade. During these excavations, air temperatures often exceed 110°F(43°C), with substantially higher ground-surface temperatures. The use of shade structures over our excavation areas has allowed us to work in these harsh conditions. For our excavation areas (quarries) we have refined a shade tarp system that is easy to transport and simple to assemble. Providing comfort and safety are the obvious advantages of using shade tarps. Heatrelated medical conditions, such as heat stroke and heat exhaustion can be quite serious, particularly in remote areas. Even minor heat-induced conditions (e.g., dehydration) can greatly limit the amount of work a field crew member can accomplish. Long-term sun exposure can lead to serious skin damage, including skin cancers. Another important benefit provided by shade tarps is more even lighting, which helps to discern fossils from matrix. For enhancing visibility it is critical that only neutral color tarps, such as white, be used because other colors will adversely alter the spectrum of light, making it difficult to see. The use of colored tarps, especially the common blue tarp, is one of the reasons that some workers have shunned the use of shade tarps. We use ¾ inch shelter corner connectors and ¾ inch electrical conduits to construct 8 foot x 10 foot frames, with legs of various lengths for suspending the tarps over the work area. We have had success with two types of tarps: a heavy mesh material that we have custom made, that withstands windy conditions, and store-bought solid polyethylene tarps that provide deeper shade but do not work as well in windy conditions. For securing the tarps to the frames we use small toggle balls (bungee balls) that can be quickly wrapped around the conduit and through the tarp grommets during set-up. These also allow for easy tarp removal in the event of wind gusts. We have found it necessary to take down the tarps each night so that storms do not move the poles around damaging fossils exposed in the quarry. The solid polyethylene tarps can then be used to cover the quarry to protect it in the event of rain. For securing the tarp frames, we use ropes tied around rebar and/or 12 inch spikes pounded into the ground. Two knots that are useful are the bowline and the trucker's hitch. Once the square frames are set in place, additional tarps can be strung off the sides to enlarge the shaded area.

CUTTING OUT THE MIDDLE MAN: ARCHIVAL SUPPORT CRADLE DESIGN FOR USE DURING PREPARATION

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In 2008 the Yale Peabody Museum (YPM) began annual excavations at Petrified Forest National Park (PEFO). One of their finds was a partial Typothorax skeleton YPM 58121. During preparation at YPM it was found that the skeleton included a well preserved skull. The skull was in soft, weathered claystone matrix and was very fractured and unstable. The left side of the skull was exposed and damaged on the erosional surface. Preparators at the YPM consequently exposed the right side of the skull and decided to curate the specimen in its field jacket.

Subsequently the skull was temporarily returned to the park for study. To stabilize it during shipping the right side of the skull was coated with a layer of cyclododecane and it arrived undamaged at PEFO during the summer of 2012. It was decided that the fragile specimen should be prepared with both sides visible to facilitate research. This presented the problem of how to remove the field jacket and stabilize the specimen during preparation. In lieu of removing the cyclododecane and building a tight fitting, disposable support cradle we constructed an archival support cradle whose padding material was firm enough to support the specimen during preparation and could also expand slightly to support the specimen as the cyclododecane sublimated away. Deep undercuts were filled partly with damp tissue paper. A layer of mechanically softened Tyvek was placed over the specimen, followed by a layer of polyester fiber padding. Rigid polyethylene foam blocks were added to further fill shallow undercuts and uneven surfaces. Finally a layer of 1/8 inch polyethylene sheeting roughened with sandpaper was added to adhere the padding to the outer shell made of FGR-95 plaster and fiberglass. While the plaster cured the shell was weighted with sand to compress the padding. The ensemble was then wrapped with a tinfoil separator and strapped tight with rubber bands while a temporary plaster jacket was applied to keep compression on the assemblage during preparation. Starting in the center small sections of the original field jacket were then removed and the weathered left side of the specimen was consolidated and prepared until the entire field jacket was removed. During preparation the right side of the skull prepared by YPM remained in firm contact with the padding preventing breaks due to collapse while the cyclododecane sublimated away. This cradle technique allowed us to skip temporary support jackets and therefore avoid potential damage due to transferring the specimen multiple times.

FIELD JACKET CONTAINING MULTIPLE ACIPENCERIFORMES

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Sturgeons and their relatives, the paddlefish, belong to the order of primitive rayfinned fishes known as Acipenceriformes. True sturgeons and paddlefish first appeared in the Upper Cretaceous fossil record about 200 million years ago. They have changed little since then; and they are notable for being primarily cartilaginous, lacking a vertebral column, lacking teeth, and being partially covered with ornate bony scutes, rather than scales. These very characteristics make preparation of a single specimen a delicate, difficult and time-consuming effort.

When a quite large field jacket from the Hell Creek Formation of South Dakota was brought to the Field Museum and opened, it contained at least eight exposed complete specimens of Late Cretaceous sturgeons and paddlefish, as well as fragments and scutes. There were more fish fossils underneath the top layer, as well. The matrix was a very unconsolidated, friable and crumbly mudstone. Some of the top layer specimens had already been exposed and over-prepared before arrival to our Collections. Once it was determined how many individuals might be in the jacket, the first step was to figure out how to consolidate such a copious amount of material, both fossil and matrix, to keep all from collapsing. The challenge would then be to remove the extensive consolidation without damaging fossil material. Preparation of these ephemeral specimens could then proceed.

A low-tech strategy was determined to be the best way to go. Continuous application of various consolidants was necessary to keep specimens and matrix intact throughout preparation. Consolidant reversal and delicate mechanical means (pin vises, art brushes, etc.) were used to make the surfaces workable to clean and define the fossil fish.

A gentle, but time-consuming approach ensured that specimens were successfully prepared with little sustained damage. A team of skilled volunteer preparators were also key in making continuous progress towards completion of this difficult project.

DAMAGE CONTROL, SAFETY, AND PREPARATION ON A VOLUNTEERBASED EXCAVATION OF AN IN SITU BONEBED AT THE MAMMOTH SITE OF HOT SPRINGS, SD, INC.

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The Mammoth Site of Hot Springs, SD, Inc., a 501 (C) 3 non-profit organization located in the Black Hills of South Dakota, houses a 26,000 year old in situ bonebed containing non-permineralized fossils of over 60 mammoths. The bonebed was deposited inside a sinkhole fed by a hot spring, which acted as a natural trap for mammoths and other Pleistocene fauna. For six weeks each year, volunteer dig crews organized through two outside non-profit organizations come to the Mammoth Site to excavate. The typical volunteer excavator is usually retired, with a long held interest in paleontology or archaeology, but little to no experience in excavation. Many participants also have mobility or balance concerns. Because excavations occur amongst approximately 1,500 in situ mammoth bones in a high relief bonebed, having a limited mobility dig crew creates serious challenges for excavator safety, specimen safety and enforcing proper excavation methods. At the close of the 2012 dig season, an excavation-related damage and preparation report was compiled recording causes of damage to in situ specimens. Of the 67 specimens requiring treatment, 65% sustained preventable damage, caused primarily by foot traffic, bumping and poor digging habits. Results of the report prompted a reevaluation of excavation and safety training for volunteers.

Instructional methods were refocused with heavy emphasis on preventative safety and proper excavation. The new training program is designed to mitigate difficulties caused by limited mobility without alienating volunteers, some of whom come to the Mammoth Site with unrealistic expectations, but end up as donors or off-season volunteers. The approach will first be implemented during the July 2013 excavation, with new measures including an expanded introductory lecture covering safety and the goals of in situ preservation, more individualized hands-on instruction, and restrictions on unnecessary movement of volunteers throughout the bonebed. Additionally, each excavator will be required to devote a set amount of time to pathway maintenance and overburden removal in order to improve safety and create more excavation space, respectively. Excavation and damage reports from the 2012 and 2013 field seasons are presented and contrasted.

PREPARATION OF A CROCODYLIFORM AND SAUROPOD DINOSAUR FROM MONTANA: SOLUTIONS TO COMPLEX MOLDING PROBLEMS

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An articulated marine crocodyliform and a partially articulated sauropod skull and cervical series were collected from Montana and prepared at the Museum of the Rockies. Both specimens posed unique problems for molding. The 2.2m long crocodyliform (~50% complete) specimen is to remain in articulation for display, but a cast of the skull and cervical series needed to be available for researchers. Therefore it was necessary to mold these elements while still in articulation because they likely could not be replaced if they were removed. This was a challenge because of the size and fragility of the specimen. A silicone rubber mold (Smooth-On Mold Max 20) and plaster mother mold (Hydrocal FGR 95 with fiberglass filter media) was applied to the dorsal surface, with the posterior most cervical vertebrae acting as the pour spout. A partial plaster cradle to cover the unmolded dorsal areas of the specimen was then added. This allowed the specimen to be rolled so the ventral side of the mold could be completed using the same procedure without damaging the specimen. After removing the ventral side of the mold, the full ventral cradle was replaced so the specimen could be rolled and the dorsal side of the mold removed.

The partially articulated sauropod skull and cervical series presented molding challenges as well. Prior to removing each element it was necessary to mold the entire specimen within the matrix to preserve a record of the taphonomy. Photogrammetry was attempted, but did not provide adequate detail. The left lateral side of the skull and neck were exposed, and as much matrix was removed as possible while still leaving the neck in articulation. Molding was complicated by the fact that the specimen is quite large (2.1m long), and the right lateral side of the specimen still needed to be prepared. The left lateral side was molded using the same procedure as the crocodyliform. Loops of plastic mesh were incorporated into the silicone and passed through slots made in the plaster. During casting rods were placed in the loops to hold the silicone tight against the plaster to prevent loss of shape. The plaster mother mold was created in two parts enabling easier removal later. Rebar was also added along the length of the mother mold for additional support as it also functioned as a cradle when the specimen was rolled to prepare the other side. Once the specimen was rolled, much of the remaining matrix was removed and the molding process was repeated.

The molding of both of these specimens helped develop new techniques, as well as improving old ones, and will help in future molding procedures.

NEW TECHNIQUE TO REMOVE ASPHALT FROM MICROFOSSIL-RICH MATRIX FROM RANCHO LA BREA

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Rancho La Brea is one of the richest terrestrial late Pleistocene fossil localities. Typical Rancho La Brea fossils are composed of unaltered organic material—bone, plant remains, shells, insect exoskeletons. Extraordinary preservation of Rancho La Brea fossils is due principally to asphalt impregnation which helps protect the material from diagenetic changes. Vertebrate fossils from Rancho La Brea rarely display permineralization.

Asphalt-preserved fossils present specific cleaning and preparation challenges not encountered with permineralized fossils. Historically, heated kerosene was used to remove the asphalt but is flammable and occasionally caught fire. Solvents used since include 1, 1, 1-trichloroethane and perchloroethylene but these come with a variety of drawbacks including environmental hazards, regulatory restrictions, adverse health effects, and expense. Biodiesel is a safe, economical, and efficient alternative.

Pure biodiesel, or B100, is a diesel fuel consisting of methyl esters of fatty acids produced by refining vegetable oil triglycerides. While biodiesel is not an effective asphalt solvent at room temperature, it becomes very effective when heated to temperatures between 60°C and 80°C. Biodiesel can subsequently be removed from the treated fossil materials by soaking them in an n Propyl Bromide. Our current excavation, Project 23, has yielded large quantities of microfossil-rich asphaltic sand. We have found heated biodiesel to be an effective and efficient solvent for processing these asphaltic samples.

PRACTICAL METHODS FOR THE USE OF CYCLODECANE IN VERTEBRATE MICROFOSSIL PREPARATION

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Since 1995, cyclododecane (CDD), a waxy cyclic alkane hydrocarbon that sublimes at room temperature, has found increasing use by conservators as a temporary binder, facing, barrier coat, consolidant or mounting medium in the conservation of a range of fragile objects from ceramics and textiles to ancient paintings and frescoes. Over the past decade, CDD's unique and advantageous properties have led to its adoption by vertebrate paleontology preparators for a variety of uses, including temporary fills during molding or reinforcing support during transportation, but its primary use is as a temporary mount or "work-holder" for delicate microfossils during preparation. The basic concepts of the latter use have been presented before: the specimen or its containing block of matrix is partially imbedded in a small container of melted CDD which is then secured to a work platform that can be easily held and manipulated under the microscope. However, the details and nuances of carrying out this procedure safely (for both the specimen and the preparator) have not been presented adequately. In addition to its support function, CDD can be used during micro-preparation to provide protection for fragile elements previously exposed and as a "warning-cushion" for edges of access while working inside enclosed cavities (such as endocrania). CDD is also useful as a temporary consolidant of non-cohesive matrix in cases where removal of matrix would otherwise result in collapse of the enclosed specimen. Since CDD is hydrophobic and insoluble in strong polar solvents, consolidation of otherwise porous matrix and specimen also allows use of the "water-bead" technique to enhance visual differentiation of matrix and bone. The proper use of special tools and the selective warming (or not) of specimens is key to the successful application and removal of CDD in these and other micro-prep procedures. Although the MSDS indicates that CDD has low toxicity, thorough safety studies have not been conducted. CDD is known to be a bioaccumulant with primary routes of entry through respiration and skin absorption. It is strongly recommended that heating, melting and application of CDD be done under a fume hood and gloves and safety glasses be worn during use.

ROCK, PAPER, ADHESIVE: DEVELOPING VARIOUS METHODS FOR THE USE OF PAPER IN ARCHIVAL FOSSIL REPAIR

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The previous use of fibrous and granulated cellulose as adhesive thickeners is well documented. These techniques were elaborated upon using pulped and intact sheets of archival paper impregnated with Paraloid B-72 ethyl methacrylate copolymer in 20 to 50% ethanol or acetone solutions. The first technique is the use of adhesive-impregnated pulped paper to fill and structurally support gaps ranging from small cracks to areas of major loss where there is limited or no contact between joins. A second technique is the use of adhesive-impregnated paper to build a structurally supportive armature to which a paste of adhesive mixed with pulped paper or pulverized matrix can then be applied. A third technique involves using such a paper armature to maintain association of elements of a fossil in a field jacket during preparation. As a thermoplastic resin, Paraloid B-72 can be manipulated after setting with the application of directed low heat, a characteristic which allows the impregnated paper armature to be adjusted and re-shaped after the fossil is removed from the jacket. A fourth technique is analogous to the external "bandages" of adhesive-impregnated fiberglass that have been presented previously for use in fossil preparation. Adhesive-impregnated archival paper has been used in the same way, providing similar benefits. These techniques are simple, archival, cost-effective, and are beneficial in diverse scenarios faced by fossil preparators.

LASER CLEANING OF MACROVERTEBRATE FOSSILS FROM THE UPPER CRETACEOUS SITE OF "LO HUECO" (CUENCA, SPAIN)

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The site of "Lo Hueco" (Fuentes, Cuenca Province, Spain) has yielded an abundant collection of vertebrate fossils representing fishes and reptiles (turtles, squamates, crocodiles and dinosaurs) from Campanian-Maastrichtian levels. One of the most immediate objectives for action on the collection of skeletal remains is the proper conservation of all its elements and, as a priority, the choice of the specific preparation techniques that allow its analysis and documentation.

The vertebrates from "Lo Hueco" present diverse modes of preservation. Usually, a phosphatic matrix, covered by the clays that are the predominant lithology, constitutes the skeletal remains at the site. Often, the periosteal surface is covered with a ferruginous crust that may have variable thickness, and may differently affect the surface of the fossil. Some bones also show radial microcracks in secondary osteons and ferruginous rings in Haversian channels.

Usually, these crusts hinder access to the specimen, making difficult, for example, proper consolidation, and in many cases, can impede the assessment of morphological features. However, removing these crusts is not simple. So far, tests with various wellknown preparation techniques, both mechanical and chemical, to remove ferruginous crusts from the bone surfaces indicate that safe limits of preparation are not so evident, and that is difficult to avoid damaging the surface of the samples.

In order to select alternative methodologies for the preparation of the fossils with fewer side effects on their surfaces, several laser cleaning techniques and evaluation protocols have been tested. These techniques were previously applied to remove layers and surface deposits of lithic materials in the field of cultural heritage. However, their application in paleontological preparation is not yet widespread and their effectiveness is not well delimited. Different pulsed Nd:YAG laser devices have been used. They emit in the fundamental wavelength 1064nm (infrared) and one of them is able to also emit in the second (532nm, green) and third harmonics (355nm, ultraviolet). The pulse duration is in the range of nanoseconds (6-8ns) or microseconds (60-120μs) and the energy ranges from 50mJ to 2J, depending on the device used.

Results are not absolutely conclusive, but tests indicate that, under certain conditions that can be identified by previous analysis, the ferruginous crusts on the "Lo Hueco" fossils can be removed using laser-cleaning techniques.

MOVING MARSH'S DINOSAURS INTO THE 21ST CENTURY

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In 1926, the Peabody Museum constructed what was then a state-of-the-art storage facility to house the dinosaur collections of Othniel Charles Marsh, including type specimens of such iconic taxa as Apatosaurus, Stegosaurus, Camarasaurus, and Triceratops. The hand-made metal storage featured an innovative design of adjustable, wire mesh pullout shelves. Though advanced for its time, this storage system was far from ideal, being subject to corrosion and exposing specimens to mechanical damage through vibration. The storeroom itself was dungeon dark and had no climate control; fluctuations in temperature and humidity added stress to already failing 1870's hide glue joints. In 2000 the Museum was able to deal with specimen-level issues, but the larger problem of the storage area itself remained. In 2011, the Museum made a successful application to the Save America’s Treasures program, based on the significance of Marsh and his discoveries to the history of the United States. Recently the Peabody Museum has been able to move these important specimens into new compactorized storage, in a newly renovated, climate-controlled space in an adjacent building, with access controlled by a new security system. The renovation of this space called for complete removal of the existing floor and installation of a new floor that would withstand the weight of the bones and the compactors. The new well-lit, white Delta Designs compactors feature pullout shelving that extends to its full depth, smoothly, with the touch of a finger, making it easy for researchers to study any specimen on the shelf. This move has enabled us to reorganize the collection, reuniting elements from specimens that were formerly dispersed around the original room. Specimens are now arranged taxonomically and within taxon by catalog number. As the specimens are moved into the new storage facility their condition is checked, any needed repairs made, specimens are digitally imaged, and both the original location and the new location are databased. This presentation describes the long process through which, step-by-step, we have been able to improve the accessibility and stability of these specimens.

MOVING COLLECTIONS INTO THE NEW NATURAL HISTORY MUSEUM OF UTAH

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In November 2011, the new Natural History Museum of Utah opened to the public in our new facility at the Rio Tinto Center. For those of us in the paleontology collections, however, the job of moving into the building had just begun. From October 2011 through April 2012, we transferred all of the NHMU paleontology collections, including approximately 26,000 vertebrate, 6,000 invertebrate, and 4000 paleobotanical specimens into our new collections facility. This proved to be a very intense process which required repairing, rehousing and stabilizing a large diversity of specimens, including significant Mesozoic and Cenozoic faunas from Utah and the surrounding area. Most vertebrate specimens were rehoused into new drawers and fully stabilized with ethafoam prior to being moved into the new building, where they were sorted into cabinets mounted on compactable carriages. Oversized specimens were palletized and stabilized prior to moving. All of the large broken material was repaired and many of the largest and most delicate specimens were rehoused into large open faced or clam-shell styled support jackets, constructed of fiberglass and gypsum cement and lined with felt or ethafoam. Throughout the move specimens were organized into hierarchical order based on a combination of stratigraphic, systematic and anatomical properties. A small crew of three full time staff, three part time interns and 10–15 volunteers worked six days a week for six months to complete the move. Four days per week were spent rehousing and stabilizing specimens in the old building, which were moved into the new facility on two move days per week with the assistance of professional movers. The movers also provided assistance and expertise on moving large specimens out from difficult places in the old collections as well as moving select furniture and cabinets which were transferred from the old building into the new museum. While the move was complete by April 2012, reorganization and inventory of the collections in the new facility will continue for at least another year.

FOSSIL SPECIMENS AS THEORETICAL MODELS

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The study of fossil vertebrates is based on anatomical remains preserved in the geological record. These remains are excavated, prepared in the laboratory, and housed in museum collections, at which point they are defined most broadly as natural history specimens. Of those three transformative steps, the act of preparation is often the most time consuming and requires the most extensive human interaction with the fossil. For the purposes of research, museum specimens are generally assumed to a) represent a natural organism, and b) to remain static through their life in the collections. However, fossils are a result of a complex interaction between biological and geological processes subject to physical and chemical alteration both prior to discovery and continuing through their museum life.

Often mischaracterized as a purely technical activity centered on accurate exposure of anatomy, fossil preparation is in fact a process of scientific interpretation. Reducing error is certainly a focus of preparation, but in practice, decision-making is based on the judgment of a worker in the laboratory. For example, identification of a "natural" margin between cancellous tissue and matrix near the epiphysis of a limb bone is often impossible because this boundary results from an interface between multiple types of materials. Therefore, an artificial determination of "bone surface" is produced through interpretation of physical evidence. The end result of the process is a physical representation of a theoretical model created by an individual combining knowledge of anatomy, geology, and chemistry with skilled manipulation of materials.

Furthermore, alteration of specimens continues throughout their museum lifetime. Agents of deterioration are constantly acting upon specimens, and specimens are periodically re-prepared or conserved. Museum specimens change four-dimensionally; their physical properties can vary through time. Thus, observations that inform scientific theories may not be reproducible at any given point on the continuum. Consideration of specimens as ever-shifting theoretical models allows a unique opportunity for study of philosophical concepts regarding scientific practice.

A TALE OF TWO EXHIBITS: THE FOSSIL PREPARATOR AS AN INTEGRAL PART OF MUSEUM OUTREACH

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Within the last decade, Petrified Forest National Park (PEFO) has constructed two separate exhibits in its Rainbow Forest Museum. Initially, a division of park staff whose major responsibility was to conceptualize and write the exhibits lacked the requisite knowledge needed to synthesize and relate the complex topic of geology, deep time, and paleontology to the public. Also, both of these exhibits began with casework and other design elements being constructed by contractors which, whereas they were certainly of high quality, used most of the budget set aside for the project and added layers of complexity that sometimes slowed and confused progress. In both cases, as deadlines passed, professional exhibits were ultimately designed, written, constructed, and installed by a very small crew of in-house staff led by fossil preparators and other paleontologists, who possessed the broad skill sets necessary to successfully complete the exhibits. Ultimately, by utilizing the in-house talent of its preparators to complete all aspects of the exhibit, PEFO minimized costs of materials and labor. For example, by modifying preexisting furniture, constructing armatures, writing text, casting specimens, and creating fossil reconstructions, all of which minimized personnel and time involved and reduced the need for most contracting. If further contracting was required, the preparators possessed the expertise to provide the necessary quality control, ensure accuracy, and continuity between exhibits. In times of financial crisis, preparators and other museum support staff are either hired on a short term basis or are potentially cut because of a perceived narrow breadth of expertise associated with the job title "preparator". Contrary to that perception, this case study concludes that because it is necessary for the professional preparator to be conversant with every aspect of the museum experience from conservation and research to public outreach, preparators are central to a functional paleontology outreach program. This is especially true for smaller institutions where there are a limited number of positions and available funds.

IMPARTING OUR KNOWLEDGE: EDUCATING THE NEXT GENERATION OF FOSSIL PREPARATORS AND COLLECTIONS PERSONNEL

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As working professionals in supportive roles to curators, researchers, and educators, we maintain an underlying commitment to the advancement of science. While our immediate responsibilities are often constrained to the laboratory and collection areas, our contributions to the scientific community have widespread and lasting effects. Cultivating a pedagogy of learning, that is, a philosophy of education, among preparators and collections personnel will not only better equip ourselves for the tasks at hand, but also make an impact on the future development of our profession. Unlike our academic colleagues, there are limited avenues of education available to those interested in learning how to prepare fossils and care for fossil collections. How might we as a community of working professionals better equip the next generation of staff, students, and volunteers? In order to better equip others, we must first be intentional about broadening our current understanding of fossil preparation and curation. A holistic approach to professional development involves understanding what we do and for what end or purpose. Imparting our knowledge to the next generation involves laying a foundation of thought regarding the "best practices" of our day. Increasingly larger numbers of professionals are urging us to standardize our terms, build our knowledge base, and disseminate this knowledge to others. Advances in technology are allowing us the opportunity to gather together our ideas, pause, reflect, and think critically about the future development of our profession.