STABILIZING WITHOUT COMPROMISING: USING CASTING SAND TO STABILIZE FOSSIL BLOCKS

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In fossil preparation and conservation, there are trade-offs between specimen stabilization and specimen alteration. This is often an issue when dealing with poorly preserved fossils, friable matrix, or specimens and matrix that have degraded over time. Remediation of these conditions requires a thoughtful balance between active structural and chemical intervention and passive cautious monitoring. The current suite of applied methodologies in molecular paleontology makes the latter of these a crucial consideration, as such preparators must be more conscious of specimen alteration during preparation and conservation. Here we present on the application and efficacy of a metal foundry technique known as casting sand or greensand as an easy, inexpensive, reversible, and relatively chemically inert way of stabilizing large cavities, undercuts and cracks within large fossil jackets. Casting sand (i.e., greensand) is a mixture of sand, clay and either oil or water that is mixed to a ratio that produces the desired consistency for a given task. Experimenting with different ingredient ratios, we produced a satisfactory mixture that is malleable when moistened but rigid once dried, allowing for easy removal and reuse. Color differentiation between the casting sand mixture and surrounding matrix can be enhanced with the addition of naturally colored sand (e.g., aquarium sand). Through experimentation, we discovered that differences in clay types (e.g., smectite vs. bentonite) had a nominal difference in how the mixture cured, with the use of bentonite clay resulting in slight shrinkage of the infilling bolus. Our formula consisted of 50% play sand purchased at a local hardware store, sieved to 1.18mm grain size and 50% sodium bentonite claypurchased online and pulverized in a blender for consistency. Tap water was added slowly until the mixture would hold its shape when compressed (~30% volume of dry mixture). As the mixture consists of only sand, clay and water, it is almost completely chemically inert and as such can be applied directly to cracks or voids in fossil specimens with little worry of alteration of the fossils. Additionally, the constituent parts are readily available, inexpensive and can be mixed and stored in large batches for future use. This technique has the potential to also help stabilize jackets in the field.

ADVANCES IN 3D SURFACE SCANNING: MOBILE DEVICE APPLICATIONS SET A NEW STANDARD FOR THE DIGITIZATION OF FOSSILS AND MUSEUM ARTIFACTS

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Over the last decade, the utilization of 3D surface scanning in vertebrate paleontology has become an increasingly important method for data collection, visualization, and 3D printing. Although still in its infancy, the field of surface scanning has seen a proliferation of commercial and open-source software and devices. Here we report on a series of quantitative and qualitative comparisons between a variety of 3D scanning approaches that included the Artec Spider/Leo hand-held commercial scanners processed with Artec Studio software, the desktop photogrammetry software Agisoft Metashape, and mobile device applications using Object Capture API and/or LiDAR (Capture3, Hedges, Kiri Engine, Luma, Metascan, Polycam, Qlone, RealityScan, and ScandyPro). Each method was evaluated quantitatively and qualitatively across a wide set of metrics including processed 3D mesh scaling/measurement/resolution accuracy, texture/color mapping, scannable object size ranges, workflow ease/speed (capture, upload, and

processing), real-time scanning feedback, reprocessing availability, cloud vs. offline device processing capability, availability of exportable formats, raw data/picture export availability, object/background masking features, cost, accessory equipment needed, data security, and customer/community support.

We find that Metascan outperforms all tested approaches in nearly every category and is the only program that allows the export of original images taken within the application. However, it is only available on iOS devices from 2015 or later. The latest iPhones outperform the latest iPad Pros (main camera sensors with 48 MP vs 12 MP), and the smaller size of iPhones provides a wider range of navigation around small and complex specimens. When paired with a Bluetooth camera shutter remote, a 10 cm diameter ring light, and a clip-on 15x macro lens, texture and geometric mesh resolution in the millimeter to the submillimeter size range was achieved, allowing for the 3D digitization of vertebrate microfossils, oviraptorosaur eggshell ornamentation, ornithopod orbital rim scalloping, and pathological tyrannosaur bone surface texture. Using these parameters, full 360° scans were achieved in as little as five minutes, allowing for the bulk processing of multiple specimens in rapid succession. Finished and correctly auto-scaled models can be batch uploaded directly from the device to most cloud storage providers or downloaded directly from the Metascan web program.

BONES TO BYTES: COMPUTED TOMOGRAPHY DATA PREPARATION AND VISUALIZATION STRATEGIES FOR LARGE, COMPLEX FOSSIL DATASETS

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Paleontologists often encounter massive clusters of bone encased in logistically difficult matrix that prove challenging for traditional mechanical preparation methods. Imaging methods such as computed tomography (CT) scanning allow for visualization of elements through digital preparation of such large, jacketed, unprepared, complex fossils. Here, we scanned a 0.75m3, 550kg burlap-field jacket reinforced with wood 2X4's that contained an assortment of fossils. The specimen was scanned using a 6MeV system at the North Star Imaging facility in Aliso Viejo, California. The output data was provided as two datasets; 1) 350mm voxel size and 20.1GB file size; and 2) 244mm voxel size and 88.7GB file size. The lower-resolution dataset was useful for preliminary data review as a "scouting" dataset because it was less computationally demanding and contained sufficient detail for relating major and most minor skeletal remains in the fossil. The higher-resolution dataset provided more anatomical detail but required a unique, novel digitalpreparation approach due to the large file size. We faced several challenges with the higher-resolution dataset that required adjustments to our standard workflow; the most-limiting factor was computational resources that made working simultaneously on the dataset with a larger team difficult. The full 89GB fossil dataset could not be opened on all workstations. To address this, we cropped the full dataset into eight 11GB orthogonal blocks. The bulk of segmentation work took our team of 10 over 5000 hours. We imported each discovered fossil element as a segmented Region of Interest (ROI) back into the full, uncropped 89GB dataset for final cleanup and 3D visualization. Here, we encountered issues with global coordinate positioning, realignment, and merging of fossil ROIs. We eventually solved these issues by importing each fossil ROI into the full dataset, resetting the coordinates as needed, and resampling geometry of the fossil ROI into the full dataset. To assist with 3D rendering and visualization we created mesh proxies for the matrix block and jacket. This eased the computational requirements for visualizing the final segmentation results. Our findings demonstrate the challenges and solutions for managing large fossil CT-datasets collaboratively, offering insights into potential solutions for improving the efficiency and accuracy of segmentation, meshing, and postprocessing of large data sets.

Funding Sources National Science Foundation, National Geographic, Lyda Hill Philanthropies

FOSSILS IN FOCUS: ASSESSING THE POTENTIAL OF ACCELERATING DIGITAL PREPARATION WITH AI-ASSISTED SEGMENTATION ACROSS MULTIPLE FOSSIL TYPES

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Computed tomography (CT) scanning has revolutionized the study of vertebrate fossils, providing a non-destructive method to examine specimens through digital preparation and endocasting. However, generating accurate 3D models of fossil specimens from CT data remains a challenging and time-consuming task, especially for fossils that have not been mechanically prepared. Reducing the significant time commitment of studies that utilize scan data would tremendously increase the output of digital reconstructions and related research. Artificial intelligence (AI) is one potential tool that could be used to accomplish this. AI can learn from a small training dataset of segmentations created by an experienced technician or researcher and use the data to segment an entire scan. Here, we evaluate the ability of AI to segment CT data of fossils using scans of varying quality to identify optimal practices and novel applications of this approach across a wide range of fossil types. We trained regression models and convolutional neural networks (CNNs) created for clinical scan data to segment fossil and zoological specimens in various stages of preparation. We used Random Forest and U-Net model architectures because of their integration in the 3D visualization software, Dragonfly. Regression models were faster to train and more computationally efficient, while CNNs could recognize the more complex patterns in the CT data. Tissues of zoological specimens were easily separated using regression models, providing a baseline expectation for optimally segmented fossil data. Fossils show a range of success based on level of preparation and typically require using a CNN. Sutures of fully prepared fossils can be mapped, allowing for easier bone-by-bone segmentation. Compressed vertebrate fossils can be digitally separated from their matrix but require additional post-processing to separate adjacent elements. Remains encased in coprolites and concretions are challenging for AI and often require considerable manual corrections to create accurate 3D models; however, CNNs can locate elements in these specimens that might otherwise go unnoticed. Our study shows that AI can be highly effective in future efforts to digitally prepare a diverse array of vertebrate fossils. Future development of a neural network specifically designed for segmenting fossil CT data will strengthen the growing relevance of machine learning in paleontology and save researchers countless hours in the long run.

Funding Sources Denver Museum of Nature and Science, National Geographic Society, David B Jones Foundation, Lyda Hill Philanthropies

HYDROGEN PEROXIDE BREAKDOWN OF FOSSILIFEROUS SEDIMENTS FROM UPPER CRETACEOUS MICROVERTEBRATE SITES IN THE WILLIAMS FORK FORMATION, NORTHWESTERN COLORADO

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Vertebrate paleontologists identify the bulk of past diversity by collecting microvertebrate fossils. Screen washing is a technique commonly used by paleontologists to reveal microvertebrate fossils by some combination of soaking and sieving fossiliferous sediment. We collected sediment from two sites in the Upper Cretaceous (Edmontonian), Williams Fork Formation (WFF) in northwestern Colorado– Rebecca's

Hollow (RH) and Super Charger Heaven (SCH). Rebecca's Hollow yields osteichthyans (bony fish), amphibians, turtles, crocodiles, dinosaurs, and mammals. We have found similar fossils such as crocodilian teeth and gar scales from SCH and expect to find many more due to its close proximity to RH.

Traditional screen washing processes of WFF sediments began with weighing ~600 grams of sediment, placing them into sieves, and soaking in gently agitated water for 24 hours. Afterwards, the sieves were taken out to dry and weighed again to calculate the amount of sediment lost. This method showed an average of 56% sediment breakdown at RH and 80% at SCH. Anecdotal reports suggest that the addition of 3% hydrogen peroxide (H2O2) improves sediment breakdown, apparently by assisting in breaking bonds between clay particles. Greater breakdown results in a higher concentration of fossils relative to sediment, improving picking efficiency. After verifying that H2O2 did not degrade fossils it was added to the screen washing process. Thus, we placed the sediment in a separate bucket filling it with 3% H2O2 until the sieves were completely submerged; letting them soak for 5-30 minutes. During this we observed off gassing as the clays were breaking down, until the sieves were relocated to the screen washing station to replicate the traditional process. This method showed an increased average breakdown of 87% for RH and 95% for SCH. This addition has reduced the concentrate for picking by ~70% making this a more efficient method of screen washing for the recovery of microvertebrate fossils. Hydrogen peroxide (3%) is not an especially hazardous chemical and our tests have not shown any visible damage to the microfossils. Re-washing previously screen washed concentrate from RH with H2O2 resulted in 47% additional breakdown, and fossils were immediately recovered from this concentrate that were not seen previously, supporting the importance of H2O2 in retrieving microfossils from fossiliferous sediment.

Funding Sources We acknowledge support from our Office of Student Research for funding.

NO SAW SUPPORT JACKETS

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Many large or fragile specimens require jackets, cradles, clamshells or other plaster and fiberglass supports. The method most used is to layer plaster and fiberglass well over the edges of the specimen, wait until the plaster is dry, remove the specimen, and saw off the edges. This is a dusty process, requiring appropriate PPE to avoid breathing harmful flying plaster and fiberglass dust, as well as hearing and eye protection. It should be performed with a vacuum or dust collector. It can leave fiberglass splinters sticking out of the rough jacket edges, requiring either covering with an additional layer of plaster or even blowtorches. Fiberglass splinters in hands, and the annoyance and damage from plaster and fiberglass supports are the subject of many methods discussions among preparators and collections staff.

Here at the Yale Peabody Museum, we use a technique which eliminates the step of sawing the edges of our support jackets. We simply stop applying the fiberglass approximately one-half inch (or 1cm) inside of the planned edge of the jacket. We continue plastering that last ½ inch around the edge manually making a nice, rounded edge. This method works for any kind of jacket, cradle or clamshell. Either Hydrocal or Hydrocal FGR 95 work well with this method. As a barrier between the plaster and the specimen we have used felt, ethafoam, or a clay layer that is replaced with ethafoam. We primarily use continuous strand mat, but we have also used fiberglass veil, fiberglass fabrics and fiberglass scrim purchased from Fibre Glast. Once the plaster has set, but before it is fully dry, the jacket is lifted from the specimen and the edge is cleaned up quickly with a Sur-Form.

This method does require some understanding of the properties of plaster and how to work with them. For example, as the plaster sets and thickens it can be used to build up any thin sections around the edge. It can be smoothed with spatulas or hands with a bit of water. Tools used include silicone mixing bowls, spatulas - a variety of small and large metal and plastic tools, and Sur-Form tools (this tool consists of a steel strip with holes in a handle; one side of the hole is sharpened to make a cutting edge). The preparator should, of course, use appropriate PPE, such as N95 masks, gloves, and eye protection when working with plaster and fiberglass.

The edge is as sturdy as a cut edge, easier and cleaner to achieve, and much less aggravating.

ASSESSMENT OF JACKET TENSILE & FLEXURAL STRENGTH FOR SOME COMMON PLASTER JACKETING FABRICS

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Jacketing is a practice where, most commonly, a fossil and its surrounding matrix are encased with a plaster-soaked fabric and left to cure. While jackets play an important role in protecting fossils during transport and storage before reaching a laboratory setting, little published literature exists comparing the mechanical properties of jacketing materials. Burlap has been one of the most commonly used fabrics for making jackets, but recently, paleontologists have tried finding alternative fabrics; this study aimed to quantifiably compare some of the jacketing materials used in paleontology.

This study utilizes methods adapted from American Standards for Testing Materials to compare the maximum tensile and flexural strengths of plaster jackets made with veil fiberglass, polyester quilt batting, polyester fleece, 12-ounce burlap, and both parallel & diagonally orientated 10-ounce burlap. One-way ANOVA and follow-up pairwise comparisons showed that jackets made in similar dimensions and with the same number of layers but with different fabrics had maximum tensile values that were all significantly different. In the tests for flexural testing, the maximum flexural values for comparisons between diagonally orientated 10-ounce burlap and veil fiberglass, as well as polyester quilt batting and polyester fleece reporting as statistically similar in pairwise comparisons.

The mean peak tensile load values from testing samples were recorded in pounds of force and from highest to lowest were 12-ounce burlap (600.84 lbf), parallel orientated 10-ounce burlap (582.41 lbf), polyester fleece (460.95 lbf), diagonally orientated 10-ounce burlap (349.27 lbf), polyester quilt batting (220.69 lbf), and veil fiberglass (70.80 lbf). From highest to lowest, mean peak flexural load values were polyester fleece (31.91 lbf), polyester quilt batting (30.15 lbf), 12-ounce burlap (23.39 lbf), parallel orientated 10-ounce burlap (13.56 lbf), diagonally orientated 10-ounce burlap (6.60 lbf), and veil fiberglass (2.66 lbf). These results provide useful insights when deciding what materials to use to make plaster jackets. Materials that make jackets with higher flexural strengths should be more appropriate when making jackets for larger fossil specimens. Polyester fleece may be a new, useful field jacketing material as it provides the greatest flexural strength of the materials tested and provides greater tensile strength in any orientation than burlap provides in its diagonal orientation.

ENHANCED RESOLUTION AT THE MECHANICAL-DIGITAL INTERFACE: A METHODOLOGY TO ASSIST IN PREPARATION DECISION MAKING AND IMPROVED RESEARCH AND OUTREACH OUTCOMES

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Fossil preparation finds technical means to balance specimen preservation with the development of data to address research questions. This conservation development tension is most evident when in-matrix associations and data preserved at burial/collection are weighed against matrix-free, disassociated, and repaired fossils. Decisions rest at the interface of taphonomy, field collection, digital preparation, and mechanical preparation. Molding and casting, and more recently a host of scanning modalities, are typically employed to capture bone/matrix relationships that can then facilitate or obviate further mechanical preparation.

Methodological advancements presented here will provide mechanical and digital preparators with approaches to aid in this decision-making process, and in some cases, to pursue both in-situ and in-life outcomes. Capture of spatial relationships between fragments or elements (whether CT, surface scanning, or photogrammetry) is requisite, even if the resolution provided is inadequate for detailed morphological study. This may occur either at the field site or in the lab. For complex, multi-specimen or -element collections such as jackets from microvertebrate bone beds or associated skeletons, a coarse initial CT scan in which rough morphology is captured can serve as a volumetric scaffold. Mechanically-extracted fossils can be scanned at the desired resolution for morphological study or other purposes, and then mapped back into the coarselyresolved coordinate space created in the first step. Applications include explicit spatial re-association of specimens collected in multiple jackets, capture of fossil/matrix dynamics, and quarry mapping with basic morphology integrated into an accurate 3D representation of burial conditions across a large area/volume. This can simplify decision-making for mechanical development in circumstances where the research value of spatial relationships is currently ambiguous. The methodology also optimizes the use of “old” or “bad” scan data. Unification into a single, model frame space of multiple scanning events and derivative segmentation products allows for expedited digital preparation when better scan data or segmentations become available. Scan events can be treated as time series for potential 4D analysis of process, and a unified frame space of CT scan events allows complex queries and filtering possibilities for otherwise poorly resolved or radiographically dense materials.

Funding Sources Ohio University Heritage College of Osteopathic Medicine; NSF EAR_1525915

NEVER GIVE UP, NEVER SURRENDER: PLANNING AND CONSTRUCTING DUST EXTRACTION SYSTEMS IN TWO FOSSIL PREPARATION FACILITIES AT MUSEUM OF THE ROCKIES

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Respirable crystalline silica (RCS) is a common byproduct of fossil preparation. Long term, regular exposure to RCS is the leading global cause of occupational silicosis, an incurable chronic respiratory illness with a high mortality rate. Appropriate mitigation of RCS dust is therefore an immutable requirement for any facility where fossil preparation takes place. Exposure to hazardous levels of RCS (OSHA permissible exposure limit [PEL] = 50 ug/m3) is preventable through use of a dust extraction system outfitted with HEPA filtration. Museum of the Rockies (MOR) recently completed construction and installation of two independent dust collection systems in its main fossil preparation laboratory and its public-facing viewing laboratory. The project was executed in several phases over approximately two years, beginning in the spring of 2021. MOR contracted an independent industrial hygienist to perform

baseline (no filtration) air quality testing to verify and quantify that respirable dust and RCS dust were generated by fossil preparation. Resultant data revealed respirable dust levels 800% above OSHA PELs, and RCS levels 250% to 600% above OSHA PELs. Follow up testing in November 2021 and February 2022 was conducted with portable, HEPA filter-equipped dust extractors utilizing the same specimens. Extractors lowered respirable dust levels to less than 2% of OSHA PELs, and RCS levels to less than 25% of OSHA PELs. With this data MOR was able to move ahead with appropriate design parameters for permanent dust collection systems. Specifications included HEPA end filtration, articulated telescopic trunk arms with capture velocities of 500 cubic feet per minute, and sound dampening between machine rooms and lab spaces. Planning passed through several concept phases with system design and material sourcing contracted through an engineering consulting firm. The project went out for bid in the late spring of 2022, and construction began the following October. Several challenges were encountered throughout construction, including lab closure, manufacture lead time, material availability, pandemic-related global supply chain issues, contractor and engineer communication and coordination, and inventory delivery errors. The original completion date of December 2022 was delayed several months with significant completion by April 26, 2023.

Funding Sources WEM Foundation

NO TOUCH TRANSFER OF SKIN IMPRESSION TO RESIN PRINT: APPLICATION OF THE LINDOE TECHNIQUE

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Replicating fossils for research, exhibit, or educational purposes is a common endeavor in paleontology. Recent advances in surface scanning and 3D resin printing have made the process more accessible for specimens that cannot be handled or chemically altered by the application of molding materials. The end product is a highly accurate replica of the original specimen in a solid color. In some cases, reproduction of the original coloration is desirable to indicate soft tissue preservation that has no physical structure. The Lindoe Technique was developed in the 1970s to create realistic replicas of low-relief fossils such as leaves and insects. The replica is achieved by adhering paper-printed fossil images that have been transferred to a flexible layer of cured matte medium onto blank matrix slabs. Here we report on employing this method to produce a touchable, highly accurate reproduction of a well-preserved tyrannosaur skin impression that can be used for education and exhibition. The specimen was surface scanned in high resolution using the Object Capture API photogrammetry based Metascan Application and photographed in high resolution to produce a color print on standard copy paper. The surface scan was edited in Blender 3.4.1 for 3D printing and a photopolymer resin print was produced. The Lindoe Technique has traditionally been performed on porous stone/matrix blanks. Concern about matte medium's bonding ability to a non-porous resin was ameliorated after we successfully tested the method with a smaller fossil leaf specimen. Producing an image that, after transfer, reflected an accurate coloration and contrast to the original proved to be a challenge. We recommend enhancing the image in photo-editing software in preparation for the technique because some image contrast is lost through the transfer to matte medium. To compensate, the saturation, contrast, and brightness should be modified beyond what would appear to be acceptable digitally. The Lindoe method worked well applied to photopolymer resin and proved to be a useful tool to replicate the very delicate impression of skin we wish to make more accessible for museum visitors.

THE IMPACT OF ADHESIVES, CONSOLIDANTS, AND SOLVENTS ON GEOCHEMICAL DATA: AN EXAMPLE USING X-RAY FLUORESCENCE

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Adhesives are an integral part of the preparation process. They are necessary for the stabilization of fossils both in the field and in the laboratory and their use is ubiquitous in paleontology. However, the effect that applying these chemicals may have on future geochemical studies remains largely unstudied. To explore this question, we conducted a series of tests on commonly used adhesives using a Niton XL5 pXRF spectrometer. First, we scanned beads of Paraloid B72, Butvar B76, and Butvar B98 to determine if their actual elemental composition matched their published chemical formulae. Those adhesives were then mixed with acetone, allowed to dry in a circular disk at the bottom of plastic bottles (both LDPE and HDPE), and scanned to determine if any additional contaminants were introduced by either the solvent or the bottles. Additionally, the inner surfaces of the bottles were scanned before and after the above-mentioned adhesives and solvents were added and allowed to dry to determine if the elemental composition of the bottles was altered, which in turn would impact the composition of the adhesives stored in such bottles. The final test aimed to determine if and to what degree the presence of adhesives impacts the full spectrum of elemental data obtained from scans of matrix samples. For that test, five hand samples of non-fossil bearing sandstone were scanned before and after (in the same spot) the application of either Paraloid B72 or Butvar B76 (both in acetone) of various thicknesses. Briefly summarized, the results show that all three adhesives contain trace amounts of unreported elements (e.g., Si, Al, K, S) and that the solvents/adhesives do leach some elements from the plastic bottles (e.g., Si, K, Cl, S, Ti), changing the chemical composition of the dried adhesive. The matrix tests showed a clear decrease in most detectable elements that was proportional to the thickness of the adhesive applied. However, the effect was not uniform as some elements (e.g., Si, Al, Mg, and P) were more strongly affected than others. The only element that showed increasing values with glue thickness was Cl, which resulted from contamination from the bottles/solvents. Though limited in scope, this study demonstrates that adhesives can both interfere with the collection of data from a pXRF spectrometer and introduce contamination to those data. A broader study is planned to evaluate a wider range of modern and historical adhesives, consolidants, and solvents. Funding Sources This research was funded by the David B. Jones Foundation.

DESIGN AND SAFE JOURNEY TO A 21STCENTURY FOSSIL LAB

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The Walker Museum at the University of Chicago predated the Field Museum of Natural History but closed its doors in 1965. Paleontological research on campus arose anew into a thriving program, but now without a collection or preparation facility. Thus, some 25 years ago with the advent of large scale field operations, a Fossil Lab was created in temporary space in the Enrico Fermi Institute, a WWII era building slated for demolition in 2021. With no available campus space, the Fossil Lab turned to a warehouse of 6,000 sq. ft. in a neighborhood adjacent to campus. How best to design and move a fossil lab into a neighborhood?

Working with architects, we identified workspaces to facilitate both research and community engagement. That process began with the building's facade, where we added a framed mural space for rotating display of artwork and a new backlit logo. The entry corridor is lined with transparent glass looking into the prep lab. A large learning room combines collections and research areas with mobile tables and carts for class engagement activities. A kitchenette and large screen facilitate teaching at all levels, meetings, or movie

events. Engineers accommodated needs for large specimen transit between all rooms (garage door street access, level concrete floors, double doors eight feet wide, mobile gantry crane) and compressed air, dust collection and power for ten benchtop work areas plus heavy duty mobile tables.

Move-in required custom packing for small fragile specimens to multi-ton blocks. We injected quick setting platinum silicone to seal cracks in a large fossil block of soft sandstone containing the remains of a precious dinosaur mummy. Fiberglass-reinforced plaster support shells lined with polyethylene foam protected massive sauropod bones. Smaller fossils were protected in custom boxes made with corrugated plastic sheets and various thicknesses of polyethylene foam supports. Small specimens in collections cabinets were padded in polyethylene lined trays, and movers transported entire packed cabinets into the new lab. All arrived safely in ample time to arrange an open house for neighborhood schools and the general public. While not a public institution on the scale of a museum, a Fossil Lab in a neighborhood can have remarkable positive local impact.

WORKING WITH GIANTS: LOGISTICS AND SAFETY OF MOVING, ROTATING, AND PREPARING OVERSIZED, MULTI-TON FOSSIL BLOCKS

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Preparation and conservation of oversized fossil blocks (>1,000 kg) creates countless logistical, safety, and ergonomic challenges, and concerns for preparators, facilities infrastructure, and the specimens themselves. These challenges and concerns include, but are not limited to, preservation quality and stability of the fossils, infrastructure limitations (e.g., weight bearing capacities of floors), transport challenges of lifting, rotating, and moving massive fossil blocks, safety concerns for staff, visitors, and the fossils, and ergonomic concerns for preparation staff. To ameliorate many of these challenges and concerns, the North Carolina Museum of Natural Sciences (NCMNS) paleontology unit embarked on an ambitious project to design and build a world-class public fossil preparation space uniquely equipped and capable of safely and effectively moving, lifting, rotating, preparing, and exhibiting massive fossil specimens utilizing three dimensional space. The project started with increasing the overall floor capacity of the new lab from 9 lbs. per square foot to 400 lbs. per square foot to accommodate the combined weight of multi-ton blocks and the equipment needed to hold and manipulate them. In consideration of safely lifting these oversized blocks, NCMNS installed a 10-ton overhead bridge crane capable of smoothly hoisting and transporting blocks almost anywhere within the lab space. Additionally, proper preparation and conservation will require the massive fossil blocks to be tilted and rotated in small increments to access sides and bottoms. To accomplish this delicate maneuvering, paleontology staff worked with engineers to custom design and commission a modular incremental fossil rotator frame (a dinosaur “rotisserie”) which allows blocks of various sizes, up to 6-tons, to be relatively easily and safely tilted, rotated, or flipped. The rotisserie facilitates preparation by changing the relative position of fossil blocks and working surfaces into more ergonomic and easily accessible positions, all while maintaining a safe and stable working environment. Considered together, the features of the newly constructed public preparation space improve the safety, ergonomics, and feasibility of preparation and conservation of multi-ton fossil blocks.

Funding Sources NC State Employees Credit Union, Wake County, State of North Carolina, NCMNS Friends of the Museum

CHALLENGES AND SOLUTIONS FOR RECOVERING QUATERNARY SMALL FELINE FOSSILS FROM THE DUNGEON, A PIT ROOM DEEP WITHIN NATURAL BRIDGE CAVERNS, COMAL COUNTY, TEXAS.

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Caves and karst foster unique depositional settings capable of preserving exceptional samples of body and trace fossils, associated biomolecules such as collagen and aDNA, as well as abiotic evidence of paleoclimate. Accordingly, caves offer critical data for vertebrate paleontologists examining faunal and environmental change in the geologic past, particularly in the Quaternary. Yet, the physical settings of caves can be complex and dangerous, requiring technical skills and experience to navigate. Those challenges act to potentially limit our ability as paleontologists to access and interpret the fossil record.

Skeletal remains preserved deep (>1.2 km) within Natural Bridge Caverns in Comal County, Texas, offer insights into small feline diversity and distribution in the late Quaternary. The condition and location of those fossils, however, made recovery complex. The skeletal elements occurred in a pit room known as The Dungeon that is accessible only through a ~24 m vertical shaft. Skeletal elements were embedded in and protruded from two thin, brittle flowstone (i.e., calcite formation) slabs broken loose and moved, but not collected, during the initial exploration of the cave in the early 1960s. Transporting these specimens out of the cave required navigating other obstacles, including a tight squeeze crawl. In this presentation, I report on the methods and approach that a team of cavers and I utilized to collect this important sample as well as our results. We used standard SRT (single rope technique) ropework methods to rappel into The Dungeon. The slabs were encased in plaster jackets that were then padded with foam sheets, placed in hard plastic cases, and hoisted from the room. Once out of The Dungeon, those protective layers made it possible to safely maneuver the fossil bearing slabs through the tight squeeze and across other obstacles. Those methods to preserve the samples were successful with only minor, easily repairable damage to a small minority of skeletal elements.

Application of standard methods from paleontology and speleology allowed us to overcome physical barriers and collect these important specimens. Recovery of these specimens also allowed us to overcome a gap in knowledge, produced by a lack of field notes and loss of living memory, to clarify our understanding of other feline samples collected during the early exploration of Natural Bridge Caverns 60 years earlier.

Funding Sources This research was funded by Natural Bridge Caverns and Wuest Legacy Partners, Ltd.

LIMPING ALONG: CONSERVATION OF A PATHOLOGICAL *SMILODON FATALIS* PELVIS AND FEMUR FOR EXHIBITION FROM RANCHO LA BREA, CALIFORNIA

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Development for an exhibit required conserving fossils of a dysplastic *Smilodon fatalis* pelvis (LACMHC 131) and femur (LACMHC 6963) from Rancho La Brea, a late Pleistocene paleontological locality in Los Angeles, California. All fossils were excavated and prepared in 1913-1915. Lacking archived preparation data, observations and general knowledge of historical practices guided conservation.

Morphology was obscured by asphaltic matrix on LACMHC 131 and LACMHC 6963. Both fossils were brittle, with friable cortical diaphysis on LACMHC 6963. Test patches of 1 cm2 on LACMHC 131 and

LACMHC 6963 were treated with acetone, then with 80°C H_2O to identify adhesives based on interactions with these substances. Results revealed glyptal and white glue. A degreasing solvent, Novec 73DE, was applied to surface asphaltic matrix with foam tip applicators (FTAs) and nylon paint brushes. Surface glyptal was removed with acetone and FTAs, white glue with 80°C H_2O and cotton swabs. Paraloid B72 (B72) in acetone was used for consolidation and <1 mm crack repair. Cracks ≥1 mm wide were filled with B72 and 12 gsm Nasu Kozo paper (Kozo). Excess B72 was removed with acetone.

LACMHC 131 required additional conservation. A metal rod connecting and supporting the iliac wings had loosened from degraded adhesive. Two gaps in the ramus had been filled with white glue and plaster. These were covered with 30 gsm Kozo and B72 during initial conservation to prevent damage and separation. Kozo was removed in sections and fillers were treated with 80°C H_2O applied with nylon and boar bristle brushes. Fillers were removed in sections with dental tools and tweezers. After air drying, sections were filled by layering torn pieces of 12 gsm Kozo and B72. These pieces of Kozo were applied with tweezers and a nylon bristle brush with acetone. A layer of 15 gsm Kozo was placed over the 12 gsm Kozo for additional support. Excess B72 was removed with acetone.

Conservation data was recorded in written documentation and time-lapse videos, with weekly assessment photos. A Standard Operating Procedure was compiled with instructions for plaster and adhesive removal. This conservation was successful, but there was a degree of uncertainty that the use of quantitative methods for identifying adhesives would have alleviated. Such methods have not historically been used at RLB. This project demonstrates the utility of such methods to decrease uncertainties when drafting conservation plans for preparation.

Funding Sources Thanks to the Natural History Museum of Los Angeles, County, La Brea Tar Pits & Museum, M. Balisi, C. A. Clarke, A. Farrell, E. Lindsey, A. Novie & G. Takeuchi.

THE CHALLENGE OF HARD-TO-REACH SPACES IN MECHANICAL FOSSIL PREPARATION: DEVELOPMENT OF A NOVEL SHORT-BODIED AIR SCRIBE WITH A FLEXIBLE HEAD

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Pneumatic air scribes are the primary tools used for mechanical fossil preparation, especially in vertebrate fossils. However, their long and straight, pen-shaped shafts (generally 100–150 mm in length) and fixed heads limit the working angle in narrow and hard-to-reach spaces, such as the intricate surfaces of pneumatic bones and inside deep cavities (e.g., sauropod vertebrae). Moreover, when preparing microvertebrate fossils (e.g., frogs, lizards, and small mammals), the limited working space for long air scribes between the microscope's objective lens and the fossil specimen restricts effective preparation. To overcome these challenges, we developed a novel short-bodied air scribe (Wada-type air scribe) constructed from hardware readily available at home improvement stores. The new Wada-type air scribe has an extremely short body (35 mm) and the handle with a hinge can be attached to make the working angle adjustable, allowing users to hold it in an ergonomically natural hand position during preparation. Despite its short body, performance of the newly developed Wada-type air scribe is comparable to conventional air scribes with a similar stylus size. In addition, the Wada-type air scribe can upcycle used styli that are too short to continue using in the conventional air scribe. Together with its maneuverability in the limited space, the novel configuration of the Wada-type air scribe overcomes disadvantages of the conventional air scribes.

We described herein a detailed, step-by-step materials and methods to build the short-bodied Wada-type air scribe, so that fossil preparators across the world can reproduce and use it. While most of the knowledge on fossil preparation techniques and methods has been shared by most palaeontological communities, unique and highly specialized preparation methods and techniques independently developed by local palaeontological laboratories and museums are rarely shared. We believe that the active publication and demonstration of in-house paleontological tools and methods further enhances the development of fossil preparation techniques and strengthens paleontological research.