A PRACTICAL GUIDE TO START A NEW VERTEBRATE FOSSIL PREPARATION LAB

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After field collections and acquisition of specimens, fossil preparation is the crucial next step in the conservation of fossil dedicated to research, collection, exhibition, and education. Proper and safe fossil preparation requires a wellequipped laboratory that is supplied with a variety of mechanical equipment, hand tools, and chemical supplies. Starting a new fossil preparation lab is a challenging task, especially for institutions in which space is limited, and in developing countries with limited budget and without an experienced preparator. In order to facilitate the difficulties associated with planning to start a new lab, we have developed a practical guide with a categorized list of items.

A list containing about 50 basic items was made with the purpose to start a preparation lab for a museum in China in 2011. Over the years, preparation labs were built at three museums, more items were added as projects in the labs expanded and the list became extensive after several revisions. The current list contains over 180 categorized items. Categories include a general lab environment, tools for work stations, safety equipment, matrix removal, acid preparation, molding/casting, and conservation. This list serves as a useful guide to aide in selecting items to start a new lab based on the type of preparation and conservation work performed according to institutional needs. It is important for an institution to identify the techniques and materials required to prepare different types of fossil specimens and various modes of preservation so that the lab can be equipped accordingly for the tasks at hand. Different tasks require different supplies. For example, if the majority of lab work focuses on manual and mechanical preparation, then the lab should be equipped with items from the 'lab environment', 'work station', 'safety equipment', and 'matrix removal' categories but leave out items from the 'molding/casting' or 'acid preparation' sections. Subcategories are also useful to guide selecting specialized materials and equipment suited for a particular project, such as macro preparation involving large sauropod elements in coarse sandstone which requires air scribes and a high capacity compressor. Micro preparation of small and delicate specimens require a high-powered binocular stereo microscope and a pin vise fitted with a carbide rod. As a different task is assigned, lab personnel can plan a budget to purchase items from the appropriate category. This guide is a practical reference for starting and expanding a vertebrate fossil preparation lab.

CHALLENGES IN THE FIELD: COLLECTING WET VERTEBRATE FOSSILS WITH THE APPLICATION OF ACRYSOL WS24, ACRYLOID B72, AND CYANOACRYLATE CONSOLIDANTS

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Recent field excavations of wet vertebrate fossils (dinosaur, turtle, fish) in groundwater saturated, clay-rich sediments from the Chronister Dinosaur Site in southeastern Missouri, U.S.A. , presented unique excavation challenges, but provided great opportunities to apply various consolidation methods in wet sediment conditions. Originally discovered in 1942, the

first fossils recorded from this site belong to the iguanodontian *Hypsibema missouriense*. Since its initial discovery, the site was purchased for science by Bruce Stinchcombe and has been periodically excavated with efforts led by Guy and Doris Darrough. A large greenhouse currently protects the site from collecting rainwater and against vandalism. Over the past three years, field crews from the Field Museum of Natural History have carried out systematic paleontological excavations with assistance from the Darroughs and other local volunteers.

The fossil elements are preserved in various states, ranging from almost pristine to dorso-ventrally crushed and plastically deformed. Due to the near permanently wet conditions of unlithified sediments, much of the in-situ fossil material is soft and porous, making excavation and collection of the fossils challenging. Separation of matrix from bone in the field was difficult and frequently resulted in the 'peeling off' of cortical bone, exposing trabecular bone or the medullary cavity and damaging internal structures. Air drying the fossiliferous clays prior to excavation proved impractical and potentially harmful to the fossils due to formation of large desiccation cracks, necessitating excavation in wet sediments. Applying a variety of consolidants was necessary to protect fragile specimens. The application of 10% Acrysol WS24 (WS24) was preferred over 10% Acryloid B72 (B72) on matrix at the Chronister Site. WS24 penetrated deeper into the matrix and the adjacent bone and solidified harder, providing better stabilization for the fossils. B72 dried quicker, but penetrated poorly, and left a white film on glued surfaces. B72 proved effective in filling porous bones. The use of 50% B72 solutions, typically used as a temporary glue in 'dry' field sites and in the lab, was ineffective for wet specimens. Instead, cyanoacrylate worked well on moist surfaces and nearly disintegrated fossils. When applied one at a time, no negative interaction between the three consolidants was observed. Applying a combination of these types of consolidants has proved to be effective and is necessary when collecting specimens from water saturated sediments.

SIEVING WITHOUT TEARS. THE FIRST 40 YEARS OF AUTOMATED SEDIMENT SCREENING FOR MICROVERTEBRATES

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When collecting microvertebrates, a major challenge is to extract the fossil from the sediment with a minimum of physical effort and damage to the specimens. The traditional method with poorly consolidated sediment involves drying the sample, then soaking it in water to disaggregate it, then hand sieving the sludge in water. A refinement of this technique is to soak the sample in a sieve box, generally a high-sided tray with a mesh base, prior to sieving.

Neither of these methods, however, solve the basic problem of being labourintensive and destructive. This was partially solved by European mammal workers in the 1960's who used bulky static sieves and a power pump to bulk process large volumes of sediment in the field. This method can be very effective but is labour intensive. The disadvantages include the weight of the equipment and problems of transporting the pump, sieves, hoses et al. to the site. However, an advantage is that the residue is prepared in the field and available for immediate sorting.

It was a small step to encase the static sieve in a 330-litre polythene tank and replace the hand held hose with lawn sprinklers. The sieve, with an area of about 0.5 square metres is fitted with 500µ stainless steel mesh on its sides and base. A syphon allows the tank to partially fill and empty. Sprinklers wash the disaggregated sediment off the surface of the sample, through the sieve and into the tank. The fluctuating water level in the tank gently removes any further sediment and keeps the mesh clean. Specimens detached from their sediment drop to the bottom of the sieve and congregate in an area not washed by the sprinklers. They are not damaged by prolonged abrasion against the mesh nor clasts within the sediment.

Originally this machine was developed to wash dried sediments. However, it coped quite adequately with wet clay but at a much slower rate. Dried clay can be processed at a rate of 10-15kg/hour, compared with about 50kg/ hour with a hand sieve. Wet clay is processed at about 1-2kg/hour. The slowness of the wet process is more than offset by the energy saved by not having to dry the clay and that plant material may be recovered intact. Functioning 24/7, it is feasible to wash large amounts of poorly fossiliferous sediments. The water can be recycled after passing through settling tanks. This machine can be used in the field, with a gasoline water pump or in the laboratory using a domestic water supply. Whether the sediment is processed wet or dry, there are considerably fewer breakages compared to hand sieving. Our machine is 40 years old this year and still functions.

REMOVING ASBESTOS FROM RECONSTRUCTED AREAS OF SPECIMENS AT THE SMITHSONIAN MUSEUM OF NATURAL HISTORY SAFELY AND WITH THE LEAST IMPACT TO THE SPECIMEN.

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During the recent renovation of the fossil halls at the Smithsonian Institution's National Museum of Natural History, the process of testing for asbestos was done prior to disarticulation of the existing skeletal mounts. Three mounts tested positive for asbestos containing building material (ACBM): two *Eremotherium rusconi* skeletons and a *Mammut americanum* skeleton. These specimens contained a substance with 20 to 25% Chrysotile asbestos fiber. The ACBM was within a sculpting material ("guk") made of plaster, papiermâché, and Alvar (polyvinyl acetal), with asbestos fibers added to strengthen it. Guk was used in the NMNH prep lab in the 1960's and '70's to reconstruct and repair fossils, and in some cases to fill the gap where individual bones articulated. We quickly made ourselves familiar with OSHA asbestos regulations, followed by multiple certification courses for asbestos removal and supervision. It was determined that the project would involve two separate setups for asbestos removal. A temporary enclosure was built at the museum to disarticulate the skeletons, and a permanent enclosure was built at RCI's facility where the fossils could have the asbestos remediated. The permanent facility included a decontamination shower for staff to clean the tools and themselves.

Throughout this process, several methods and procedures for isolating areas of the individual fossil elements that contained ACBM were developed. All of the procedures were done using the proper personal protective equipment (PPE). Glove bags were used for the majority of the work to further prevent and control the release of asbestos fibers. This involved inserting the fossil into a plastic and rubber bag and working on the area with the ACBM. The other parts of the fossil remained outside of the bag, removing them from the wetting process used to prevent the asbestos fibers from becoming airborne. Larger pieces were remediated in the open in the permanent enclosure. In these cases, the areas of the fossils that did not require ACBM removal were isolated with plastic sheeting. The material was removed using a combination of hand tools, such as knives, and hammers and chisels. These tools were used so no dust was generated during the remediation process. Power tools and air scribes generate airborne particulates, and are not to be used according to the OSHA guidelines. The successful goal of these methods was to reduce the amount of impact the remediation had on the fossils, while still maintaining a safe work environment.

UNEARTHING A GIANT: THE MAKING OF ZUUL

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In June of 2014 a huge sandstone block containing a large armoured dinosaur was excavated in Hill County, Montana U.S.A. Parts of the skeleton had been exposed while quarrying for a medium sized theropod that was lying on top of this skeleton.

A skull, tail club, articulated vertebrae and partial ribs were exposed in the field, small patches of skin impression, preserved armour plates and keratin indicated that there was something special to be uncovered. In January of 2018 preparation of the Zuul body block got underway and exposed the skeleton from the hip to the base of the neck in articulation, a mold was taken, the block jacketed and a steel frame built. The block was then drilled through and cut in half with a diamond rope saw, lifted and flipped so the reverse side could be prepared, once prepped a fantastic representation of soft tissue in articulation with the skeleton was exposed.

The skeleton was then reconstructed using the information uncovered, this is the first time armour was placed in correct association and pattern on a mounted skeleton.

ACID PREPARATION OF CARBONACEOUS FOSSIL MATERIAL USING A MEDICAL INTRAVENOUS KIT FOR TARGETED DELIVERY OF 7% ACETIC ACID SOLUTION.

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The chemical techniques used to remove acid-soluble matrix from fossil bone are effective because the matrix, calcium carbonate (CaCO3), is susceptible to attack by diluted acetic acid (CH3COOH) whereas fossil bone, made up mostly of calcium phosphates (Ca5 (PO4)3(OH, F, Cl), is not.

In 1992, acid preparation began of a near complete ankylosaur (QMF18101) found near Richmond, Queensland, Australia. Now named *Kunbarrasaurus ieversi*, the specimen was preserved in a calcareous nodule broken into 41 interlocking blocks.

The acid preparation process involved coating all exposed bone with a protective polymer (Paraloid B72), submerging each block in a 7% solution of acetic acid, and then washing thoroughly with water. This process was repeated many times until the desired level of preparation was achieved. During preparation, however, bone deterioration and loss of detail threatened to become a problem. *Kunbarrasaurus* has a layer of small dermal ossicles, about 3 -

5mm in diameter, that we aimed to keep intact wherever possible. Areas containing these small elements were coated with extra layers of Paraloid B72, however after continual exposure to acid small 'pinprick' holes appeared, even when additional coats were applied between acid treatments. This resulted in undesired dissolution of the matrix and loss of some of the ossicles.

It was best practice to keep high-risk areas out of acid altogether by propping the specimen but often these areas had to be submerged to allow the acid level to reach unprepared matrix. Mechanical preparation was too risky because the ossicles were so small and embedded randomly in matrix where microfracturing would threaten them.

In 1994, a new technique was adopted which involved targeted application by dripping acid from an intravenous drip kit mounted above the specimen. The apparatus was set up to deliver continuous drops of acid directly to the matrix where preparation was required; most commonly along the side of a bone. Advantages of this new technique included keeping high-risk areas away from acid altogether and increased control of acid delivery. Disadvantages included small amounts of acetate crystals appearing on the edge of the acid flow and slower preparation time.

After using the technique in conjunction with standard immersion methods for a period of 12 months, the results showed that we could prepare quite selectively along the edge of fossil bone without effecting the rest of the block. Over the past 20 years, this technique has been used for other specimens with similarly beneficial results.

PHOTOGRAPHS AND FOSSIL FILLINGS: A REVERSIBLE POLYESTER FILL AND UTILIZING NATIVE IPHONE APPS FOR COMPREHENSIVE PHOTO DOCUMENTATION

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When working with fragile fossils, it's normal to encounter missing pieces that endanger the stability of the section or fossil as a whole. To combat this, it's common to fill these sections to provide support, stabilize and to allow for further preparation of the specimen. In working on a small notoungulate jaw, I needed to fill a missing chip of tooth on the inner edge of a crown. Bulked adhesives commonly used offer reversibility but overall were much too soft for my purpose. Epoxy putty would also be too soft on such a small scale. Polyester bulked with talc had the desired rigidity but isn't easily reversible. The solution to this dilemma was the utilization a Paraloid B-72 coating as a separator for the polyester, enabling removal if desired.

In addition, the iPhone's native Camera and Photos apps has proven very useful in reassembling fragmentary teeth. In the iOS 10 update, the "Markup" feature was added to allow the user to draw on images with their finger or a stylus. When reassembling complex projects with multiple fragments, it can be difficult to remember where each individual piece exactly fits over the course of multiple prep sessions. With this tool, it's easy to trace, write notes, number, label and otherwise organize reference images. I utilized this method to photograph in situ pieces of a shattered brontothere tooth through a microscope and number the fragments for easier reattachment after prep. The Markup feature could be helpful with other types of extended projects. For example, it would allow for multiple people working on the same project to easily pick up where another person left off without having to relocate the fits.

THE USE OF TRADITIONAL MORTARS AND HIDROFUGANTS IN RESTORATION AND PRESERVATION OF PALEOICHNOLOGIAL SITES

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La Rioja (Spain) is one of the richest areas of the world in terms of paleoichnological record, with almost 10000 dinosaur footprints and around 1000 trackways, in a surface of just around 5000 km2. This work presents the analysis and both corrective and preventive actions carried out in "La Virgen del Campo", one of the best-known sites of this area, found in the Enciso locality (La Rioja, Spain). Many pathologies were identified in this site, that could be causing its deterioration.

First, superficial pathologies such as cracks and fractures were analyzed. They are especially important in this site conservation because of the high temperature and humidity variation, in addition to rainfall erosion and other factors that could be damaging the rock and the footprints in it. The materials and methods used in paleoichnological sites had varied in space and time due to the lack of a uniform action protocol. Considering the advances in conservation and preservation of stone monument heritage, a new protocol for La Rioja paleoichnological sites is being developed.

With this information, we performed laboratory tests on samples taken from the same geological layers of the site to verify the proper functioning of the material before the restoration work in the site. As we know the pathologies and the harm of the site, we can choose the proper materials doing the appropriated tests. There are many researches about the durability and reversibility of lime mortars. We studied different kind of mortars made of hydraulic lime and different types of aggregates, such us sand, silica and calcium carbonate. Depending on the wanted or needed result, we may choose one kind or another.

In addition, there is a problem of accumulation of water in the footprints and cracks. Moreover, sometimes the water leaks under the geological layer. This leaking is problematic because it could erode or dissolve the layer or even induce mineral precipitation that could result in fractures and cracks to the site. For this reason, we decided to test and use a hydrofugant product. After all the laboratory tests, we performed the same analysis near the site but in the rock itself, not in samples. We applied the different mortars depending on the needs. For the correct application of the mortars by the work team, we designed a diagram with instructions for every possibility. Nowadays we are monitoring the environmental conditions and results of our work, so we can determine the efficiency and durability of this restoration in the future and add some changes if the site needs it.

MANAGEMENT OF COLLECTIONS CARE PROJECTS: REFINING THE APPROACH TO CURATION WORKFLOWS AND PERSONNEL TRAINING

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The international community of specimen and data stewards is beset with a sheer volume and vast breadth of work to tackle at their respective institutions. Inventorying collection needs can open up the discussion of project priorities between staff (technicians, collections managers, curators, and administrators), but can also pave the way for potential funding sources that augment efforts to preserve and increase access to collections for posterity. Identifying and prioritizing specific projects is essential for optimizing use of personnel, time, space, and available resources.

Quality management of collections care projects requires an understanding of the processes to be performed and their sequence of execution, documentation and refinement of established workflows, and an astute sense of how to train staff and volunteers to implement best practices accurately and efficiently. Prior to evaluating the management of collections care projects, existing staff and volunteers were assigned projects and given guidance and resources on an as needed basis, resulting in sporadic achievements of varying qualities and quantities. Upon closer critique, the sequence of decisions was flipped to first prioritize feasible projects, document workflows, acquire needed resources, and then select personnel to execute the defined project within an allotted time frame. Prioritizing projects can be assessed on the basis of administrative, research, and physical needs. At the core of usable workflows are a succinct recording of the sequence of tasks to be performed, definitions of specimen and data standards, and descriptions of preventive conservation practices.

Training personnel to execute workflows involves imparting a philosophy of collections care stewardship that equips them to make independent decisions in light of best practices. Exemplary workflow topics include: specimen handling, condition assessments, collections organization, taxonomic and element identification, writing locality descriptions, cataloging specimens, specimen labeling and archival housing, and digital imaging of specimens and accessory data. Useful workflows will address essential skill sets that can be adopted and amended by the user through time. Assessing and refining the management approach to collections care projects will shed light on established methods, elucidate priorities, and make strides toward standardizing the knowledge base of personnel who make decisions affecting the quality of primary and secondary scientific data held in public trust.

COMPARATIVE ANALYSIS OF PARALOID B-72 AND BUTVAR B76 DISSOLVED IN ACETONE SOLUTIONS

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Despite the incredible importance of solution adhesives and consolidants in the preparation and conservation of fossil material, very little empirical work has been done to compare the effectiveness of one brand of polymer over the other. It is currently unknown if there is an advantage to using Paraloid B-72 or Butvar B-76 polymers dissolved in acetone in any given situation. Current anecdotal knowledge holds that low viscosity, low concentration consolidants will have better penetrative and consolidative capabilities than a high concentration, high viscosity consolidant, and Paraloid has superseded the use of Butvar B-76 in many institutions. The results of this experiment should help preparators and fossil conservators choose which polymer-based solution adhesive/consolidant to use in a given situation.

In order to compare the penetrative and consolidative capabilities of these two solution adhesives/consolidants, 20ml treatments of each adhesive/consolidant prepared in varying concentrations using the weight by volume method and were applied to 200ml well sorted sand samples in varying concentrations, and the effectiveness of each consolidant was determined by directly comparing the results of volumetric, resistivity, and diffusion measurements. After the experimental data was collected, it was analyzed using the statistical program PAST.

Qualitative analysis of the data confirmed the expected results that of Paraloid B-72 in low concentrations (5, 10, and 15%) showed greater penetration and mass consolidated than Paraloid B-72 in high concentrations (40, 45, and 50%) and Butvar B76 (in 5%, 10%, and 15% solutions). Statistical analysis using Kruskal-Wallis and Dunn's Post Hoc tests confirmed the initial analysis, but also showed that high concentration Paraloid B72 showed no significant difference from the Butvar B-76 test group.

HIGH RESOLUTION REMOTE SENSING APPLIED TO FOSSIL DISCOVERY: OVERVIEW AND PROSPECTS

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We have analyzed the physical properties of fossils in museum collections and compared them to the regional-scale information recorded by optical sensors (RGB and multispectral cameras) gathered from satellites, drones, weather balloons, and kites.

Such an approach allows researchers to record visual details of fossils in the original context of deposition in the field and, more importantly, to determine the position of uncollected specimens still exposed at the ground surface in areas that are difficult to access.

When a fossil exposed on the ground is captured by a camera, it records information related to the color and physical properties of the specimen in accordance with the sensitivity of the used sensor. Therefore, the possibility of discerning it from the depositional matrix is related to the other information transmitted by the rest of the image.

Keeping in mind these limitations, we introduce the principal concepts of Remote Sensing applied to paleontology with insights of the methodologies and spatial algorithms we have used. In particular, we discuss the spectral signatures of fossils, their recalibration for multispectral and visible bands, and their application to imagery of specific paleontological collecting areas including the Pisco Basin and the John Day Fossil Beds.

We have statistically evaluated spatial maps of probabilities to assess whether the spectral signature of specific fossils analyzed in the lab match with the information in the pixels of the remote sensing images.

This method is applicable to any kind of fossils, from large tetrapods to vegetation, allows researchers to exactly locate fossils in advance of fieldwork, so we expect it to become a significant step forward in the approach to fieldwork, for monitoring paleontological resources, and to increase the fossil record available for future paleontological studies.

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MILLIONS OF YEARS, DOZENS OF SAMPLES, ONE SINGLE SCAN: NEW METHODS TO RAPIDLY INCREASE THE NUMBER OF SPECIMENS CAPTURED IN A SINGLE HIGH-QUALITY SCAN.

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High-resolution microcomputed tomography, or microCT, has become an increasingly valuable tool for the non-invasive visualization of small objects. MicroCT is particularly beneficial for the study of museum collections, which often contain millions of small, delicate, and unique objects not amenable to traditional preparation. Despite the increasing use of microCT in systematic biology, a major challenge remains in the practical imaging of high numbers of small specimens within a project scope, for example in the context of largescale analyses of community change over time. This has proven difficult because of the need for specimens to remain motionless during scan time and because each individual must be digitally labelled to match the original specimen's identity. Here we outline steps developed for the high throughput microCT scanning of micro-fossils (~ 2mm), meant to facilitate advanced exploration of museum collections, and allow researchers with limited access to microCT facilities the opportunity to maximize their investments. We based our studies on micro-fossils from Capricorn Caves in Queensland, Australia, to study changes in morphology, ecology and distribution of reptiles, amphibians and mammals. We succeed in maximizing the quantity of samples per scan in order to obtain high quality 3D models and compare them to their modern counterparts. These steps should also be applicable to any small, dry objects of similar properties and size.

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