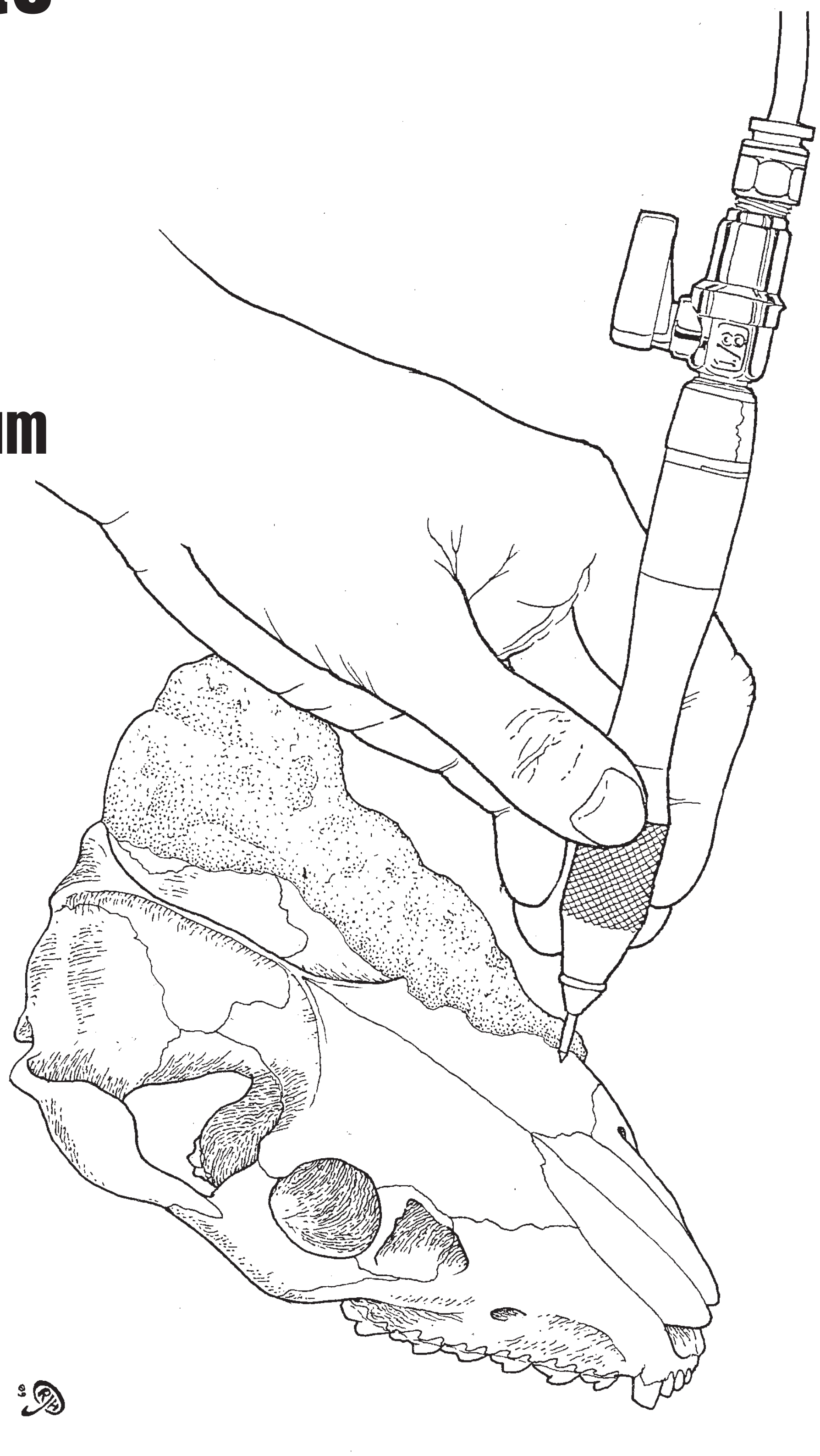
Tate 2009

15th Annual Tate Conference

The Annual Fossil Preparation and Collections Symposium

June 5-7



Introduction

Last Spring, the First Annual Fossil Preparation and Collections Symposium was held at Petrified Forest National Park (PEFO). I think all who attended agreed it was a resounding success. Matt Brown was the chief organizer for that event. Early during the symposium he brought to our attention that he had taken the liberty of calling it the “First Annual” with the caveat that the hopeful Second Annual be held somewhere other than Holbrook, Ariz. The Tate Geological Museum decided to take this ball and roll with it, and here we are at the Second Annual Fossil Preparation and Collections Symposium. I look forward to attending the Third Annual at a different venue in 2010.

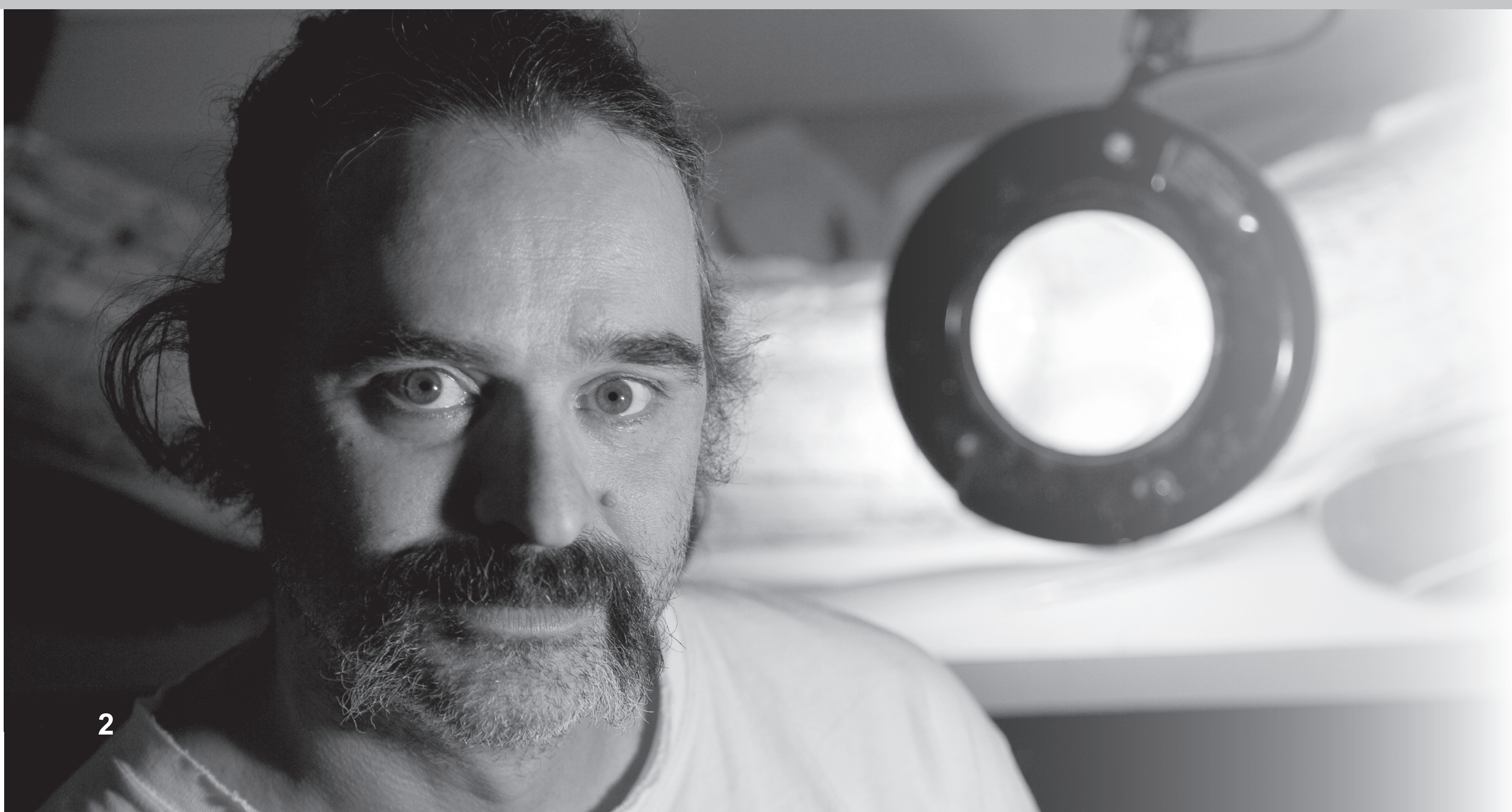
Meanwhile, this is the 15th annual Tate Conference, subtitled “Annual Symposium in Geology and Paleontology.” The first Tate Conference was held in 1994 in conjunction with the Wyoming Geological Association’s annual meeting which had a dinosaur theme that year. The Tate Conference has been almost annual since then; 2000 was a rough year, and the conference did not take place that year. The original idea was to get a group of speakers together for a weekend and attract like-minded professionals as well as members of the public, and to incorporate a field trip or two to local fossil producing areas. Educational and fun is the plan. The original idea is still alive and well in the 2009 Tate Conference. The conference has a different theme every year usually a time-related or taxonomic theme. This year’s is a technical theme… fossil prep and collections management. The two subjects are closely related. In many smaller museums one person is responsible for both duties. This year, since the theme is technical, the second day of field trips is being replaced by a day of workshops.

In previous years the Tate Conference guidebook has featured drawings relevant to the subject by our resident artist and educator, Russell Hawley. Since drawings of fossil preparation and cataloging are not Russell’s forte, this book features a collection of Russell’s drawings that are somehow connected to each author’s paper or previous work.

And this just in from an Internet search… there is apparently also a Tate Conference every now and again at another similarly named museum in an English city called London. The Australian Literacy Educators’ Association in co-ordination with the Tasmanian Association of Teaching English held a TATE Conference in 2006.

We welcome you all to Casper and to Casper College for Tate 2009, the Second Annual Fossil Preparation and Collections Symposium.

JP Cavigelli, Wearer of Many Hats
Tate Geological Museum, Casper College



Acknowledgements

Melissa Connely, Interim Director of the Tate Museum, for organizing much of Tate 2009

Russell Hawley for his wonderful drawings and accompanying text, of course

Arnold Woods for proofreading almost all the papers

Theri Reel and **Kent Sundell** for additional proofing

The **College Relations Office** at Casper College for putting this book together

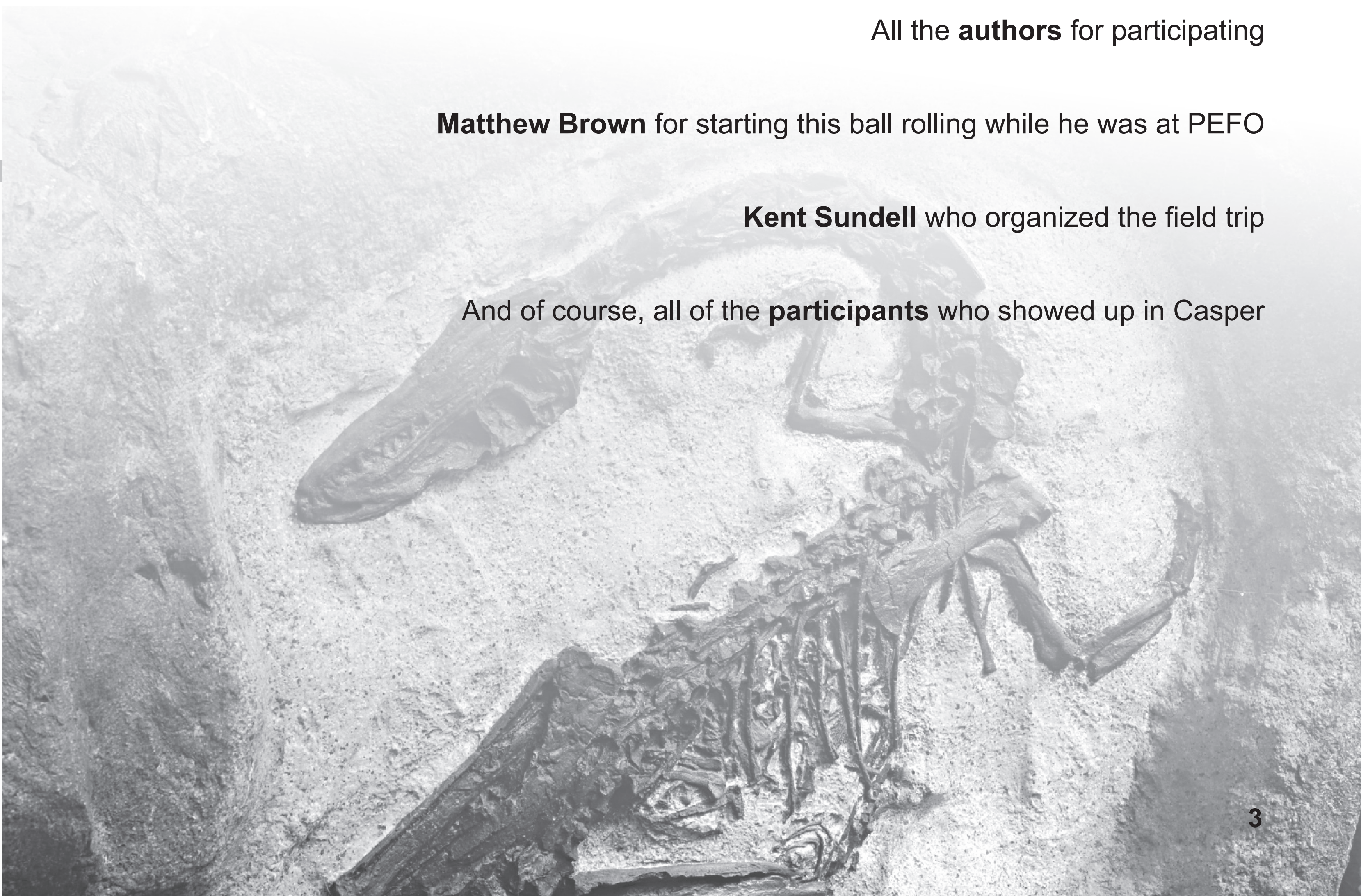
Rachel Wright, Physical Science Academic Assistant for assisting in many ways

All the **authors** for participating

Matthew Brown for starting this ball rolling while he was at PEFO

Kent Sundell who organized the field trip

And of course, all of the **participants** who showed up in Casper



Thursday, June 4

Early check-in all day 9 am to 6 pm-Tate Geological Museum, Casper College

Informal gathering: TBA

Friday, June 5

Workshops at Tate Museum

7:30-8 a.m.	Check-in at Tate Geological Museum
8-10 a.m.	Making a two-part silicone mold, session one
10 a.m.-Noon	Carbowax workshop
Noon-1:30 p.m.	Lunch (on your own)
1:30-2:30 p.m.	Making a two-part silicone mold, session two
2:30-3:30 p.m.	Lab ideas roundtable discussions
3:30-5 p.m.	Air abrasives workshop
5-5:30 p.m.	Making a two-part silicone mold, session three
6:30-9 p.m.	Icebreaker and Keynote Speaker at the Casper Petroleum Club: Mike Getty, Utah Museum of Natural History, University of Utah, Salt Lake City, Utah. ***10 Years Paleontological Exploration of the Kaiparowits Plateau of Grand Staircase Escalante National Monument*** (Hors d'oeuvres and cash bar)

Saturday, June 6

Speakers at Sharon D. Nichols Auditorium, Casper College

7:30-8:30 a.m.	Registration and refreshments
8:30-9 a.m.	Opening remarks Melissa Connely, Interim Director, Tate Geological Museum JP Cavigelli, Prep Lab Manager, Tate Geological Museum
9-9:30 a.m.	Kelli Trujillo ***The Making of a Preparator*** or ***How I Went From Finding Dinosaurs to Gluing my Fingers to Them***
9:30-10 a.m	J-P Cavigelli ***A Primer to Polyethylene Glycol Use in Paleontological Preparation*** or ***How I Learned to Stop Worrying and Love Prepping Thin and Delicate Bones***
10-10:30 a.m.	Pete Reser ***Maximizing Situational Conservation and Minimizing Visual Ambiguity To Reveal Toothmarks on an Osteoderm of*** **Typothorax Coccinarum*****, in Typical Late Triassic Chinle Formation Preservation, Using Cyanoacrylate and Ground Matrix Exclusively***

10:30-10:45 a.m.	Break
10:45-11:15 a.m.	Matthew Brown ***Preliminary Report on Professional Development in Vertebrate Fossil Preparation***
11: 15-11:45 a.m.	Kathy Hollis ***Collection Registration Issues in the University of Colorado Museum of Natural History Paleobotany/Invertebrate Paleontology Collection*** or **Why is this Fossil Sitting in my Office and Not in its Cabine*t Where it Should Be?***
11:45 a.m.-1:15 p.m.	Lunch on the Tate Lawn
1:15-1:45 p.m.	Andrew Bland ***Preparing Fossils in Concretions***
1:45-2:15 p.m.	Kenneth Bader ***Recognition and Preservation of Insect Traces on Fossil Bones***
2:15-2:30 p.m.	Break
2:30-3 p.m.	Eric Lund ***Working With Nonmineralized Vertebrate Soft-Tissues: The Delicate Side of Fossil Preparation***
3-3:30 p.m.	Melissa Connely ***Using Wax Casts to Reshape Distorted Fossils***
3:30-4 p.m.	Anthony Maltese ***The Remounting of*** **Apatosaurus excelsus** ***UW 15556*** or ***All for a Little Tail***

Sunday, June 7

Field trip to White River Formation near Douglas, Wyo. (lunch provided)

7 a.m.	Meet at Tate Geological Museum for Field Trip
7:30 a.m.	Depart
6 p.m.	Return to Tate Geological Museum

Table of Contents

Kenneth Bader

Kenneth Bader received his B.S. and M.S. degrees in geology at the University of Kansas. The focus of his research is the application of forensic entomology using insect traces on bone to determine the timing of the death and burial of sauropods in the Late Jurassic. During graduate school he worked as a preparator specializing in molding and casting. He is currently working as a preparator at the Petrified Forest National Park.

Andrew Bland

Andrew Bland, an amateur paleontologist, is a software engineer from the Pacific Northwest. Andrew, and his brother Steve, started by collecting crab concretions and soon Andrew developed his fossil preparation skills. His work became noticed and he was contracted by others to do prep work in his spare time.

Andrew and a few friends started the North American Research Group (NARG), an organization to promote scientific and responsible fossil collecting. During field explorations, Andrew discovered a Jurassic Asian crocodile in the Blue Mountains of eastern Oregon, about 5,000 miles from the place it most likely died, in an exotic terrane that joined Oregon, via plate tectonics. The National Geographic Society named this the number two dinosaur and fossil find for the year 2007.

Matthew Brown

Matthew Brown is currently the chief preparator at the Vertebrate Paleontology Laboratory, University of Texas at Austin. Previously Matthew has worked as a preparator for the National Park Service, Field Museum of Natural History, and University of Chicago, as well as performing contract work and consulting for researchers at the Smithsonian Institution, American Museum of Natural History, Burpee Museum of Natural History, and the University of California, Berkeley. Nonpreparation projects include exploring avenues for professional development within fossil preparation and examining methods for training and evaluation of fossil preparators. Matthew has served as the chair of the Society of Vertebrate Paleontology Preparators Sub-committee on Professional Development since 2006, and in 2008 organized and hosted the First Annual Fossil Preparation and Collections Symposium at Petrified Forest National Park.

Jean-Pierre Cavigelli

JP Cavigelli was born back east in the summertime, of Swiss immigrant parents (from the type Jurassic area). He is prep lab manager, field trip organizer and Collections Manager at the Tate Geological Museum. As a biology major at the University of Chicago, JP also became interested in paleontology, although way too late to get a degree in it. This led him to a summer spent in Wyoming (mostly in the Big Horn Basin) in 1983 doing field work in search of small Cretaceous mammal teeth with a University of Wyoming team. JP fell in love with Wyoming but left for a five-year adventure in fun and poverty as a ski bum and whitewater rafting guide in Colorado and Australia. JP came back to Wyoming in 1990 to be part of a paleo field crew at the UW again. He stayed in Laramie working off and on in paleontology for 14 years, doing field work as well as a two-year post as the collections manager for the UW's Dept. of Geology and Geophysics. He also was a fossil outfitter, running Western Paleo Safaris for six years. For the past 15 years, JP has been doing freelance fossil preparation in his basement. He has had the good fortune of having been invited to join international paleontological expeditions to Mongolia, Niger, Tanzania and North Dakota. He has lived in Casper for four and a half years since he started working at the Tate Geological Museum.

Melissa V. Connely

Melissa is originally from Washington state where she spent her early years in the apple orchards of the Yakima Valley. She spent her early educational years in Morrison Colorado where she developed her love for dinosaurs. Living in Wyoming since 1975, Melissa developed a larger appreciation for geology and earth science. She has pursued that interest by obtaining an A.S. degree in elementary education from Casper College, a B.S. degree in geology from the University of Wyoming, and a master's degree in geology from Utah State University. Melissa has been active in various research projects as an undergraduate and after graduation. Her main interest is in the paleoecology of Mesozoic. Melissa has worked in fossil quarries since 1994, 10 years of which were at Como Bluff, Wyo. where she discovered and prepared the most complete *Apatosaurus* skull known at the time. She has been involved with the Tate Geological Museum as a volunteer, lab manager, and now interim director. She has her own company and provides paleontological surveys for the petroleum industry as well as geological consulting and outfitting. She has participated in many field expeditions in the Rocky Mountain Region and abroad. Melissa is married to Brian Connely, a biologist for the county. Together they have three knuckleheaded children and one very spoiled little dog.

Mike Getty

Mike Getty's hometown is Calgary Alberta, Canada, where he was born and raised. He had an early interest in dinosaur paleontology, and hung out as much as possible in the Alberta badlands while growing up.He started volunteering with field crews from the Tyrrell Museum in 1988. He did a B.S. degree with majors in biology and geography at the University of Calgary followed by a M.S. degree, also from the University of Calgary, with graduate research on the paleoecology of frozen peat bogs in the Yukon Territory. Mike began working full time for the Royal Tyrrell Museum of Paleontology in 1995, first as a field assistant, then as camp manager for the museums "field experience program" and ultimately site manager for the museum's field station at Dinosaur Provincial Park. He moved to Salt Lake City, Utah, in 1999 to become the collections manager of paleontology at the Utah Museum of Natural History, where he's been ever since. His job as collections manager includes fossil preparation. He has been very fortunate to spend a great deal of time conducting fieldwork in North America and abroad. He has been on numerous field expeditions to Alberta, Montana, Wyoming, Colorado and Utah, as well as Mexico, Patagonia, Madagascar, Venezuela, Kenya, and Tanzania.

Kathy Hollis

Kathy Hollis currently works as the invertebrate paleontology collection manager at the University of Colorado Museum of Natural History. She received an M.S. in geology from Ohio State University in 2005 and an M.S. in museum studies from the University of Colorado at Boulder in 2008.

Kathy's research interests in paleontology and collections management combine understanding taphonomic and collecting biases. Her mind often wanders to these questions:

- Is the fossil record a good representation of what used to be alive?
- Are museum collections a good representation of the fossil record?
- How does the representational quality of museum collections vary from museum to museum?

She believes that well-organized and databased collections are imperative to answering these questions. As such, she strives for improving the quality of collection data and tries to do her part to help make collection data available to researchers worldwide.

Eric Lund

Eric was born and raised in Salt Lake City, Utah. He received his B.S. in geology from the University of Utah in 2004 and he is currently working on a master's degree at the University of Utah. He has been fascinated with dinosaurs from the age of 5 when he got his first glimpse of the wall at Dinosaur National Monument; from then on he knew what he wanted to be when he grew up. Eric started volunteering at the Utah Museum of Natural History for the paleontology department in 2000. He continued to volunteer until fall 2004 when he became the supervisor of the paleontology lab at the museum. He has had the opportunity to prepare several type specimens including *Gryposaurus monumentensis*, and a new centrosaurine from southern Utah. For Eric this is a dream come true. As paleontology lab supervisor, he oversees the many volunteers who devote countless numbers of hours working on specimens. In his spare time he loves to mountain bike, hike, fish, camp, cook, and scuba dive. He has been lucky enough to have opportunities to work on numerous paleontological field expeditions both in Utah and around the world including Mexico and Tanzania. His research interests include taphonomy, particularly soft-tissue preservation, ceratopsians (horned dinosaurs), and paleoecology.

Anthony Maltese

Anthony Maltese works as the curator and field collection manager for the Rocky Mountain Dinosaur Resource Center and Triebold Paleontology Inc. in Woodland Park, Colo. This has kept him busy for the past five-years, however he got his start in the University of Kansas Vertebrate Paleontology Lab in 1997. As a student he learned techniques from Larry Martin and David Burnham, trained volunteers and worked on ridiculously large sauropod bones. This was a continuation of a love of dinosaurs from his youth in Detroit, seeing exhibits at the University of Michigan and Cranbrook Institute, with the occasional visit to the Field Museum while with relatives in Chicago. After graduating in 2003 with a degree in geology, he also did freelance preparation on other sauropods until the move to Colorado in 2004. Since then, Anthony has spent nearly nine months in the field in places such as Texas, Colorado, Kansas, Montana and the Dakotas. His current research interests are of the biodiversity and biostratigraphy of the Niobrara Chalk, and repressing a latent sauropod foot fetish.

Pete Reser

Pete was introduced to fossil preparation in 1977 as a member of the survey team that searched the San Juan Basin in New Mexico for fossil localities prior to the BLM granting coal leases. That resulted in a large voucher collection housed at the University of New Mexico (UNM) at the time, which became the nucleus for the collection at the New Mexico Museum of Natural History (NMMNH). He made it his business to learn the treatment and care for that collection and never looked back. Pete started doing preparation for UNM sporadically then, went to work for NMMNH half time in 1987 and quit his day job to become their chief preparator in 1989. He then became the first staff preparator at Petrified Forest National Park in ‘04 and retired in ‘06. Quite a ride, all in all. He’s done extensive fieldwork in New Mexico and the surrounding states and has the good fortune to have worked in Mexico, Kazakhstan, and China. The most surreal were the saguaro forests of Mexico. The most remote was the far eastern reaches of Kazakhstan soon after the collapse of the Soviet Union. It’s one way to achieve existential satisfaction.

Kelli Trujillo

Kelli Trujillo grew up in Colorado and attended CU-Boulder, Colorado Mountain College, and Western State College of Colorado. She taught middle school science and college science and math before deciding to go to graduate school. She received her M.S. in 1999 and her Ph.D. in 2003 from the University of Wyoming, both in geology with emphasis in vertebrate paleontology. Her master’s work focused on microvertebrates of the upper Jurassic Morrison Formation, and she described three new localities near Medicine Bow, Wyo. Her Ph.D. research grew from this work and focused on the stratigraphy and correlation of the Morrison Formation. She currently works for Uinta Paleontological Associates, Inc. of Vernal, Utah, and oversees their Laramie office. She is continuing her research on the age of the Morrison and Cloverly Formations, using U/Pb dating to put better age constraints on these terrestrial rock units. In her spare time she plays music, works on her house and garden, and drinks an occasional beer with friends.

Mike Getty - Utah Museum of Natural History - Keynote Speaker

Mike Getty, keynote speaker for Tate 2009, coated with dust from using a rock saw in the field.

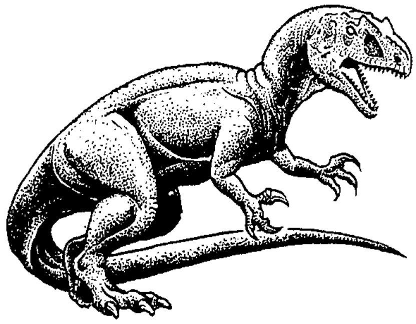
Ten Years of Paleontological Exploration of the Kaiparowits Plateau in Grand Staircase Escalante National Monument

Mike Getty, Utah Museum of Natural History, University of Utah, Salt Lake City, Utah

Since 2000, the Utah Museum of Natural History (UMNH) has been conducting paleontological research in the Kaiparowits Plateau region in Grand Staircase-Escalante National Monument (GSENM). This area is one of the largest and most remote wilderness areas in the lower 48 states and, as such, has been a very challenging and exciting area for vertebrate paleontology. During the last nine years UMNH crews have discovered and collected a number of significant new dinosaur specimens from the Late Cretaceous sediments within the GSENM, including ceratopsians, hadrosaurs, hypsilophodonts, ankylosaurs, and a variety of small and large theropods. The excavation of many of these specimens has been particularly difficult due to the geographic challenges of working in remote wilderness, further exacerbated by the specimens frequently being preserved in very hard rock. To date, UMNH crews have managed to collect more than 20 significant skeletons from the back country of the Kaiparowits Plateau, which is now proving to be a new and unique vertebrate fauna. Having conducted most of the significant excavations ourselves, we have also been able accumulate an excellent taphonomic record of nearly every associated vertebrate specimen known from the formation. I will present the highlights of nearly a decade of working in the Kaiparowits, particularly from the perspective of the field crews and the challenges of collecting dinosaurs from the backcountry of this remote wilderness.

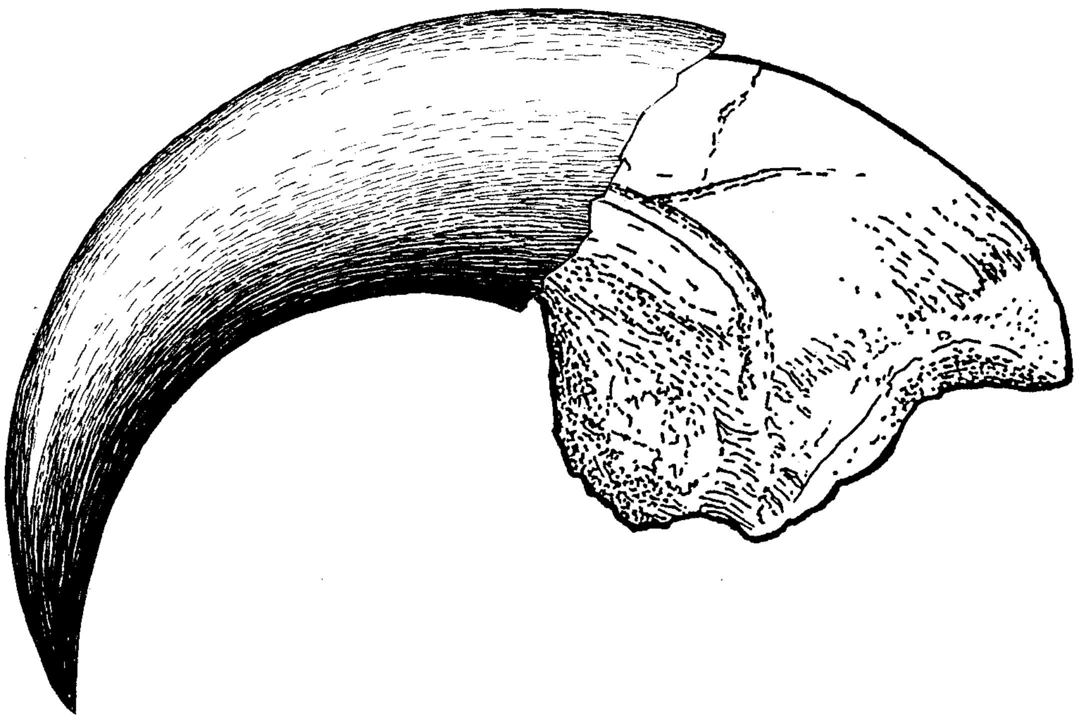
Above: Two proud dinosaur hunters, (Josh Smith and Ryan King), with their catch, (a partially articulated *Gryposaurus* monumentenis skelton), in GSENM.

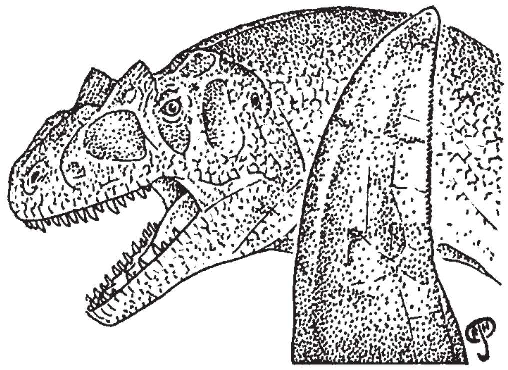
Right: Using a gasoline-powered rock saw to free jackets containing a large *Gryposaurus* skelton in the GSENM.

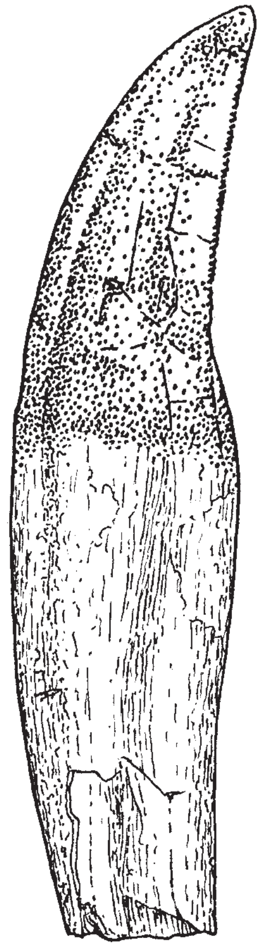


***Allosaurus*:** This was the most common predatory dinosaur of the Late Jurassic Morrison Formation. Its bones have been found throughout the western United States. Most were between 6 and 8 meters long.

***Allosaurus* claw:** It's important to remember that when you're looking at the claw on a dinosaur skeleton, you aren't actually looking at the claw – you're looking at the bone that went *inside* of the claw. In life the bone would have had a keratin sheath that would have made the claw about 30% longer and quite a bit sharper.

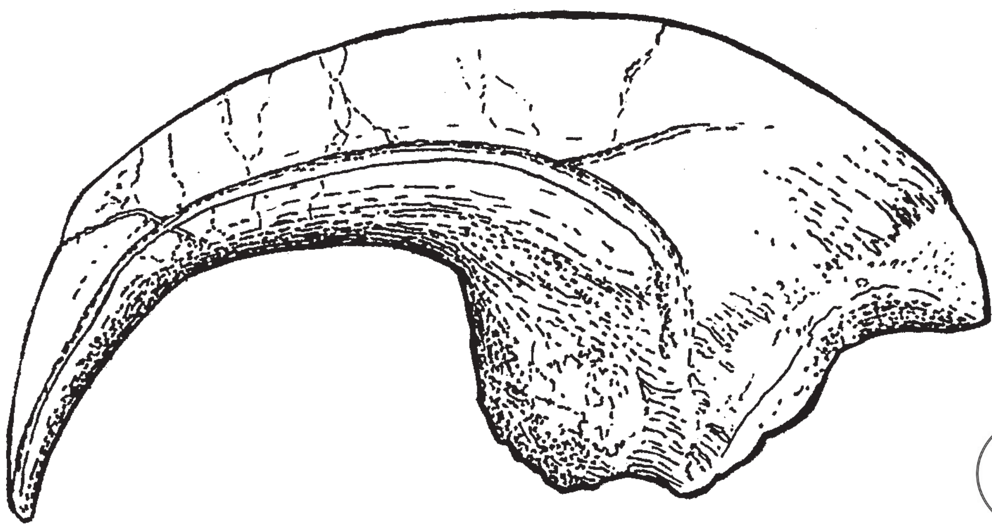






***Allosaurus* tooth:** *Allosaurus* had laterally flattened, serrated, blade-like teeth that would have been we suited for cutting into flesh. For a theropod, the teeth were unusually uniform in size and shape.

***Allosaurus* ungual:** This is the terminal bone of an *Allosaurus* thumb. It's hooked, curved shape would have been well-suited for grabbing and holding prey animals. The large flexor tubercle at the base of the claw would have attached to a tendon that ran under the wrist to the flexor digitorum muscle on the underside of the arm.



Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

The dinosaur site on the REX Pipeline shortly after its discovery.

The Making of a Preparator

or

How I Went from Finding Dinosaurs to Gluing My Fingers to Them

Kelli C. Trujillo, Ph.D., Paleontologist-Geologist, Uinta Paleontological Associates, Inc., Laramie, Wyo.

How is a preparator made? Are preparators hatched fully formed, with all the knowledge to properly deal with every type of fossil and problem? Well, not in my case.

I am currently in charge of a project to prepare dinosaur fossils found in a natural gas pipeline trench south of Laramie, Wyo. in September of 2006. I supervise three other preparators, and together we have prepared over 250 specimens to date. We have been learning as we go; everything from the best way to move very large jackets, to what type of bottle to put the adhesive remover in after it ate through its metal container (it now comes in a plastic container). We have a cooperative agreement with the University of Wyoming do our prep work as a working exhibit in the UW Geological Museum.

When we began this project, I had the most preparation experience of any of my crew (which was not very much). My prep experience had been mainly on a community dinosaur project in Gunnison, Colo., the reconstruction of "Morris the 'Saurus.'" I spent a lot of time with an airscribe in my hand, and I thought I knew a lot about preparing fossils. Boy, was I wrong! Lucky for me, there are many great references for information on preparation tools and techniques, and many helpful people willing to share their experience.

pre·par·a·tor n. One who prepares specimens or exhibits for scientific study or display, as in a museum.

information provided by www.thefreedictionary.com

So how does one go from being an everyday field paleontologist to the most valuable part of the paleo team, a preparator? In my case it was by necessity, and it started with the discovery and excavation of the Laramie pipeline dinosaurs.

On September 20, 2006, I was checking the Rockies Express-Entrega Pipeline trench on the McKinsey Ranch south of Laramie, Wyo. when I noticed what appeared to be fragments of large dinosaur bones in the sidewall of the trench (Fig. 1) and in the debris pile (Fig. 2). I notified Uinta Paleo and REX-Entrega Pipeline personnel, and we roped off and signed a 200-ft.-wide area centered on the initial discovery in the trench.

Uinta Paleo crews were called to the site, and we immediately started to work through the debris pile by hand. We found many bone fragments in the debris,

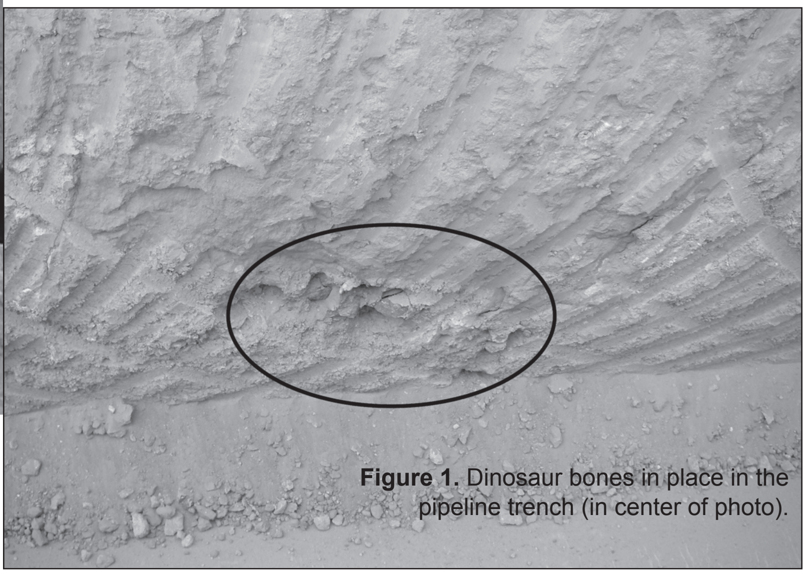


Figure 1. Dinosaur bones in place in the pipeline trench (in center of photo).

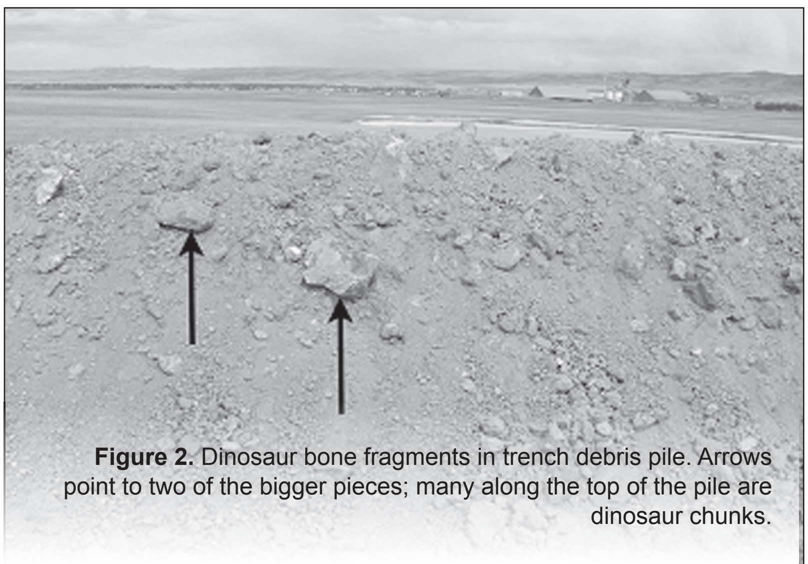


Figure 2. Dinosaur bone fragments in trench debris pile. Arrows point to two of the bigger pieces; many along the top of the pile are dinosaur chunks.

which we collected for potential later reassembly. After a few days a backhoe and operator were brought in (courtesy of Associated Pipeline, Inc.), and buckets-full of material from the debris pile were placed into a screen by the backhoe and sorted in a much quicker manner (Fig. 3).

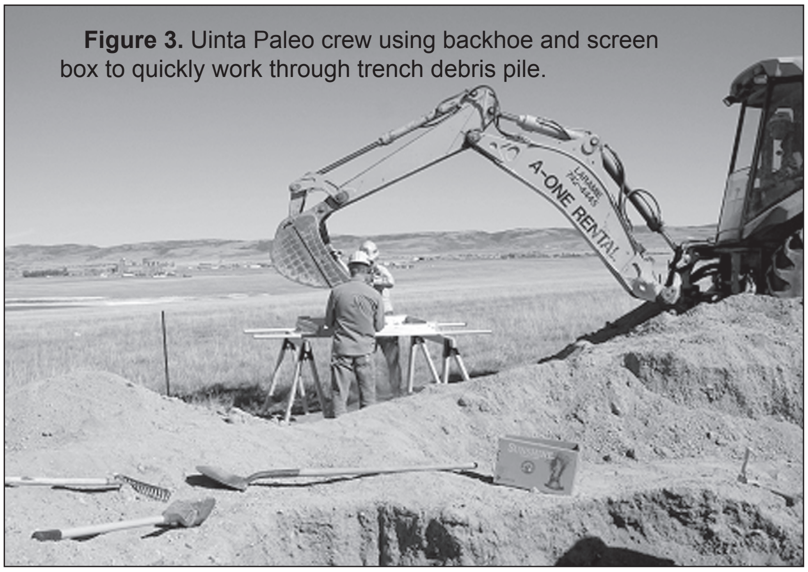


Figure 3. Uinta Paleo crew using backhoe and screen box to quickly work through trench debris pile.

Once the debris pile was screened, the backhoe then moved to the south side of the trench and created a ramp to allow us safe access into the trench. During this process the backhoe operator found a large bone with the backhoe bucket. This bone was temporarily stabilized and marked for later work. It later was identified as the right femur of the large plant-eating dinosaur *Camarasaurus*.

The backhoe removed the thick layer of Quaternary sediment that covered the Upper Jurassic Morrison Formation to a depth of up to four feet. This allowed us to access the bone-bearing horizon much quicker than if we had to remove this overburden by hand. We began working with hand tools just above the bone that I had initially spotted in the trench (Fig 4).

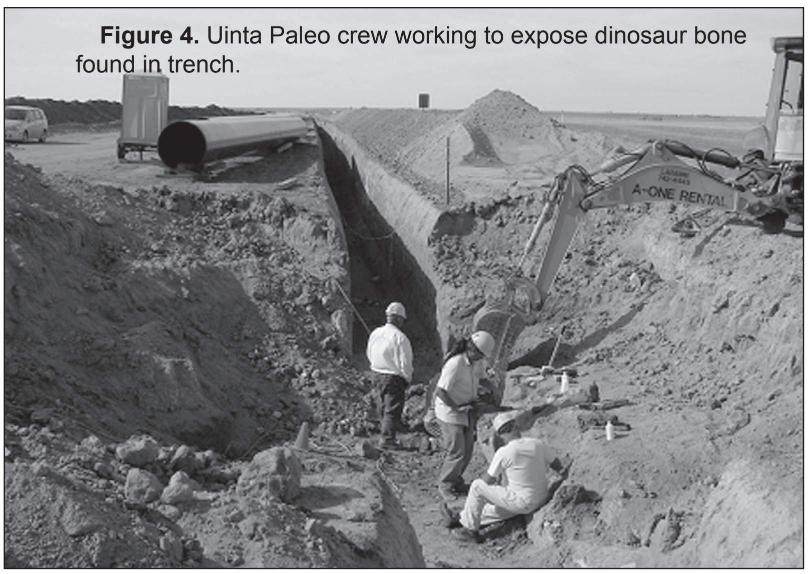


Figure 4. Uinta Paleo crew working to expose dinosaur bone found in trench.

Over the next four weeks, the Uinta Paleo crew, with the assistance of two different backhoe operators from Associated Pipeline, Inc., exposed, tentatively identified when possible, mapped, photographed, plastered, and removed an estimated 10 tons of material. To expedite the excavation process, we removed many bones together in very large packages rather than taking the time to isolate each bone as is often done (Fig. 5). At the time, bones from *Camarasaurus* and *Allosaurus* were identified.

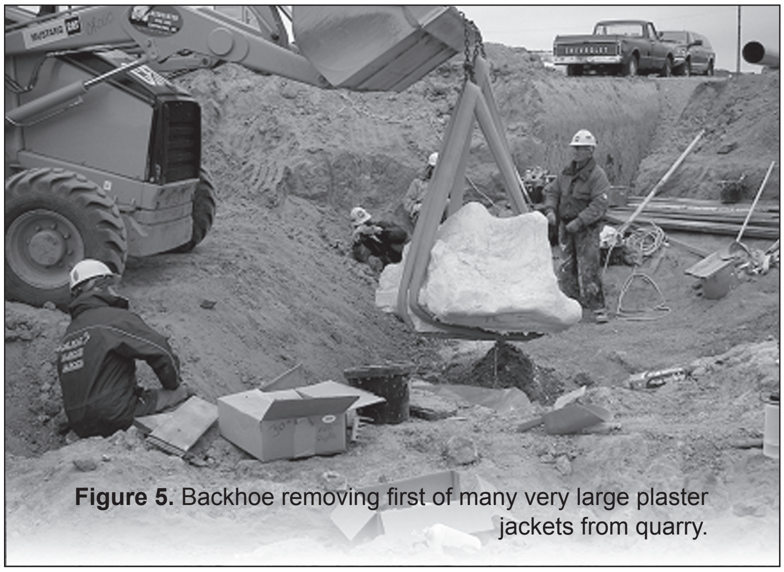


Figure 5. Backhoe removing first of many very large plaster jackets from quarry.

Because of time constraints we left many bones in the ground, including several at the contact between the Upper Jurassic Morrison Formation and the overlying Quaternary sediments, while many more were barely exposed in the wall 10 feet from the north side of the trench wall. All of these bones were photographed, and mapped using GPS, and it is our hope to excavate them sometime in the future.

An agreement was reached between the landowners, REX Pipeline, and Uinta Paleo for the removal of the bones from the property and the temporary storage and preparation of the fossils. The preparation and curation of the fossils was to be paid for by Kinder Morgan, Inc., the main company behind the construction of the natural gas pipeline.

During the excavation, I had assumed that someone other than myself would be preparing the fossils. I had no desire to delve into the complexities of prepping the squished dorsal vertebrae we were excavating, and hoped that someone already skilled in preparation would want to prep the fossils, and be available. Unfortunately, no one was up for it, and we concocted a plan to prepare the bones in Laramie, with me in charge of the project.

As I mentioned, Uinta Paleo entered into a cooperative agreement with the University of Wyoming Geological Museum and the University of Wyoming to prepare the bones as a public exhibit in the museum. The Geological Museum allowed Uinta Paleo to take over an existing preparation station and also moved exhibits out of a neighboring alcove (Fig. 6). This gave us adequate space to begin the preparation of many of the dinosaur bones. In exchange for the space, we talk to the museum visitors, including school children and college students, about the excavation and preparation.

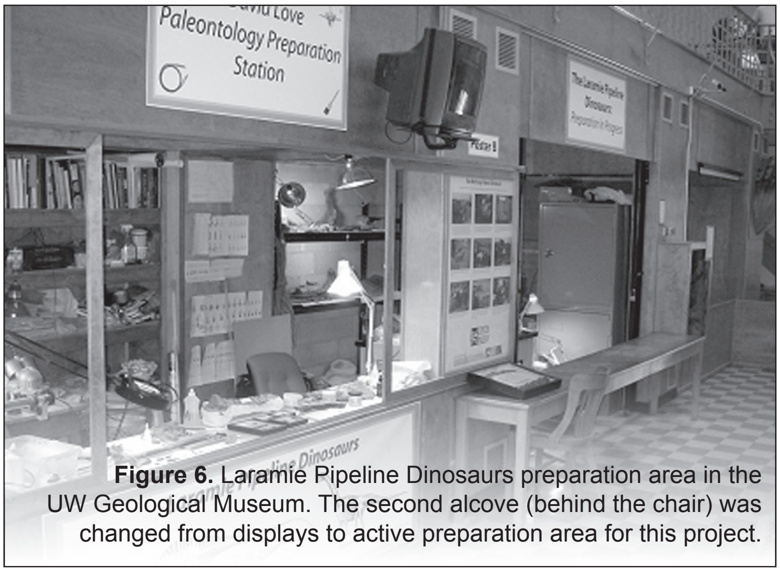


Figure 6. Laramie Pipeline Dinosaurs preparation area in the UW Geological Museum. The second alcove (behind the chair) was changed from displays to active preparation area for this project.

Preparation began in earnest in early January of 2007. We have been very lucky in that the fossils are enclosed in a mudstone that is easily flaked with hand-held blades, and so we have only needed to use air tools to remove occasional calcite and silica deposits on the bones. The Monitoring and Mitigation agreement we have with Kinder Morgan, Inc. requires us to “stabilize and identify” the fossils, and we have used standard techniques and equipment including vinac, acetone, PaleoBond glues and penetrant

Figure 7. Caudal vertebrae of *Camarasaurus,* examples of bone from MRX Quarry in good condition.

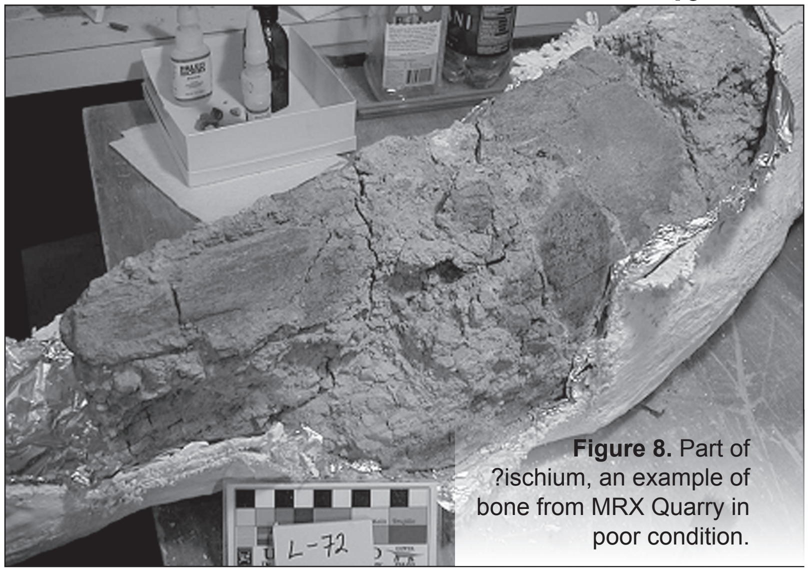


Figure 8. Part of ?ischium, an example of bone from MRX Quarry in poor condition.

stabilizer, and EpoxySculpt epoxy putty to do this. Although much of the material is in good shape (Fig. 7), some specimens are very fragmented and fragile (Fig. 8). As of March of 2007 we had completed preparation on 60 specimens. These specimens included parts of neck and tail vertebrae, ribs, and fragments of the pelvic girdle of the sauropod dinosaurs *Apatosaurus* and *Camarasaurus*; tail vertebrae and a toe claw from a juvenile Allosaurus; shed teeth of both meat- and plant-eating dinosaurs; shed teeth of crocodiles, crocodile scutes, and turtle shell fragments.

By July of 2007, the preparation had progressed to the point of having completely cleaned and stabilized 125 specimens. During that time we moved several mid-sized jackets into the preparation space with the help of the UW moving crew, and sometimes using a rented engine hoist. including two that contained many articulated cervical vertebrae of *Camarasaurus* and one with much of a scapula of *Camarasaurus*. Each of these jackets was estimated to weigh at least 1000 pounds. The crew also completed the recovery and stabilization of the bone from many of the smaller jackets and packages removed from the site.

By mid-November, we had completely cleaned and assembled 171 specimens, and were in the process of preparing several more including a femur, scapula, and several delicate cervical vertebrae (Figs. 9, 10, 11). We also began to open the very large jackets in the storage unit, with the idea of removing bones for detailed cleaning and stabilization in the museum (Fig. 12).

By March of 2008, the number of completely prepared and stabilized specimens had risen to 208. Work continued on the sauropod bones. In

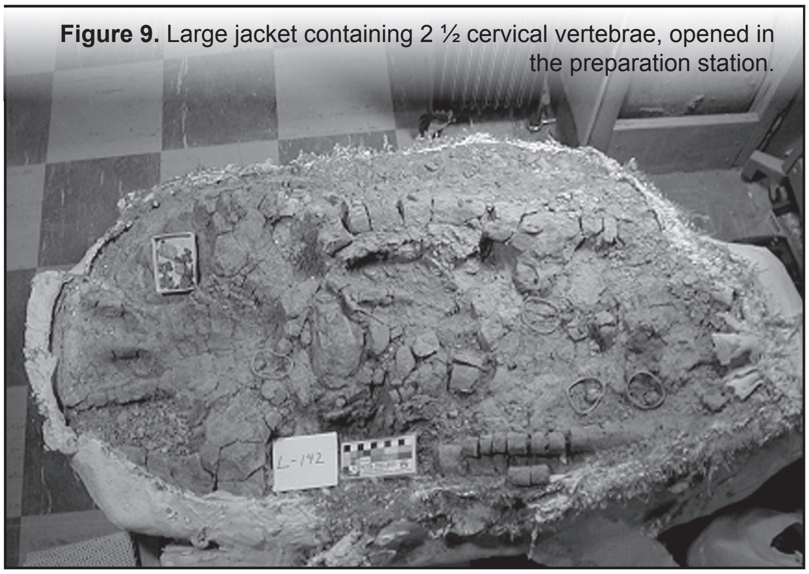


Figure 9. Large jacket containing 2 ½ cervical vertebrae, opened in the preparation station.

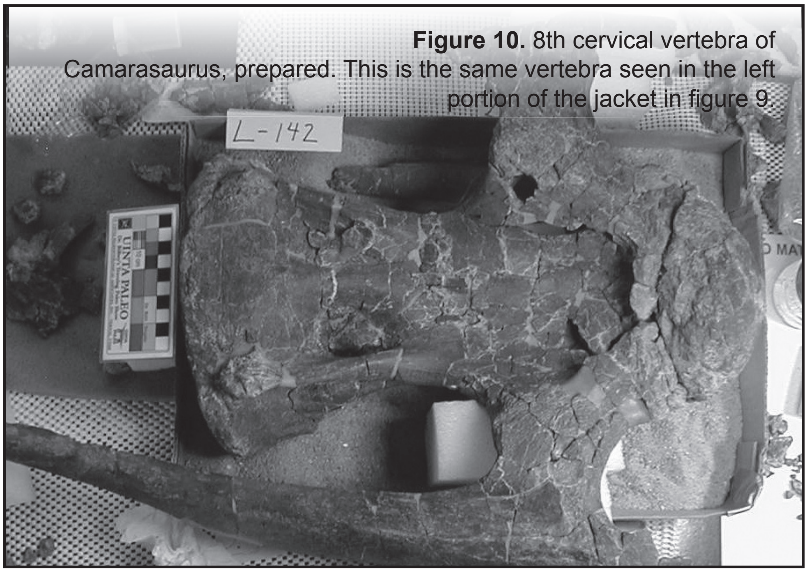


Figure 10. 8th cervical vertebra of Camarasaurus, prepared. This is the same vertebra seen in the left portion of the jacket in figure 9.

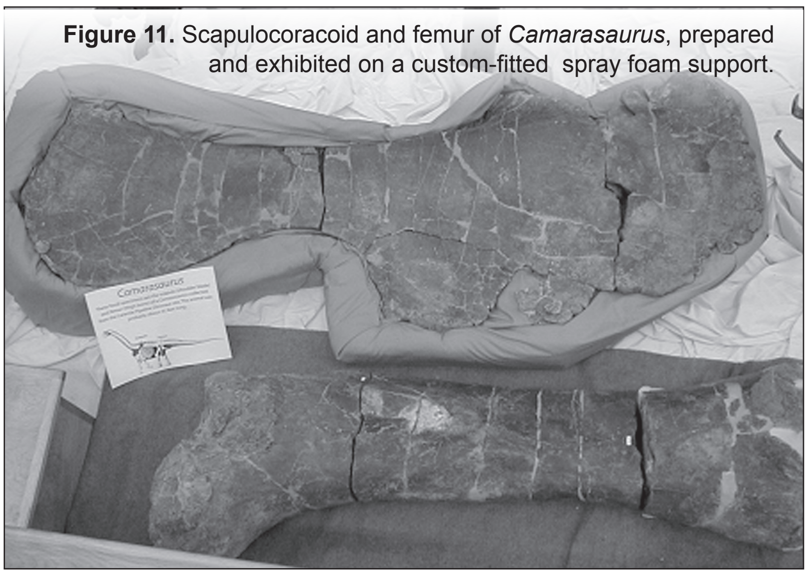


Figure 11. Scapulocoracoid and femur of *Camarasaurus*, prepared and exhibited on a custom-fitted spray foam support.

addition to the juvenile *Allosaurus* tail bones and claw, which had been previously prepared, we also recovered two ribs from an adult *Allosaurus* from the bonebed. There are also many shed teeth from this meat-eating dinosaur, as well as many bones with deep gashes that were likely caused by scavenging allosaurs. The microvertebrate faunal list was expanded to include fish (very small teeth), and a small crocodile (a vertebra). We also made excellent progress in piecing together the fragments of bone that were directly impacted by the trenching machine. From these pieces (which were collected by screening through the trench debris) we constructed 13 almost-complete vertebrae (Fig. 13). These vertebrae have been identified as anterior tail vertebrae from the sauropod dinosaur *Apatosaurus*. Based on the size of these vertebrae we believe they came from a sub-adult animal.

By September of 2008, we had completely prepared and stabilized 248 specimens. Because of the warm late summer weather and the temporary closure of the geological museum for construction, much time was spent working in the storage unit on two of the large jackets. The bones in these jackets, mainly articulated dorsal, sacral, and caudal vertebrae of *Apatosaurus*, are very fragile and complex, and they required considerable time to properly stabilize (Fig. 14). Although there are numerous bones in these jackets, due to their fragility the bones will remain together in a plaster cradle after preparation.

As of mid-March of 2009, we have prepared, stabilized, and identified more than three-quarters of the fossil material removed from the REX pipeline right-of-way on the McKinsey Ranch. We have two very large jackets left as well as two smaller but still pretty big jackets. We will continue the preparation until May 8, when our funding from Kinder Morgan will be exhausted.

This narrative glosses over the messy parts of the preparation, where we learned to breathe on our glues to make them set faster and learned to get smeared epoxy putty off the bones before it hardens. We learned how to make cradles for fragile bones out of spray foam and cardboard, and to ask for help from the UW movers when we needed to get the larger jackets into the museum. And we learned the hard truth that sometimes there is no way to save a fossil.

The saving grace of this project – what made it doable for a novice preparator like me – was the invaluable advice from others, most notably our dear hairy friend JP Cavigelli. All the information on the Internet has been great, too, but nothing beats being able to call someone up and say, “Hey, how would you do this?” or, “Does what I’m thinking of doing make sense?” The community of preparators is very willing to share their stories of both triumphs and mistakes, both of which have helped me and my crew tremendously. I’ve learned that becoming a preparator is a long process that I hope to keep working at for a very long time.

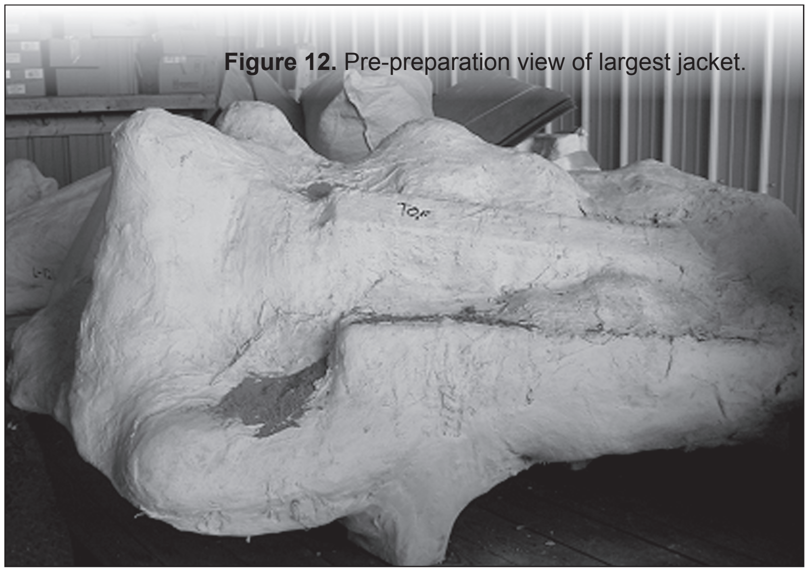


Figure 12. Pre-preparation view of largest jacket.

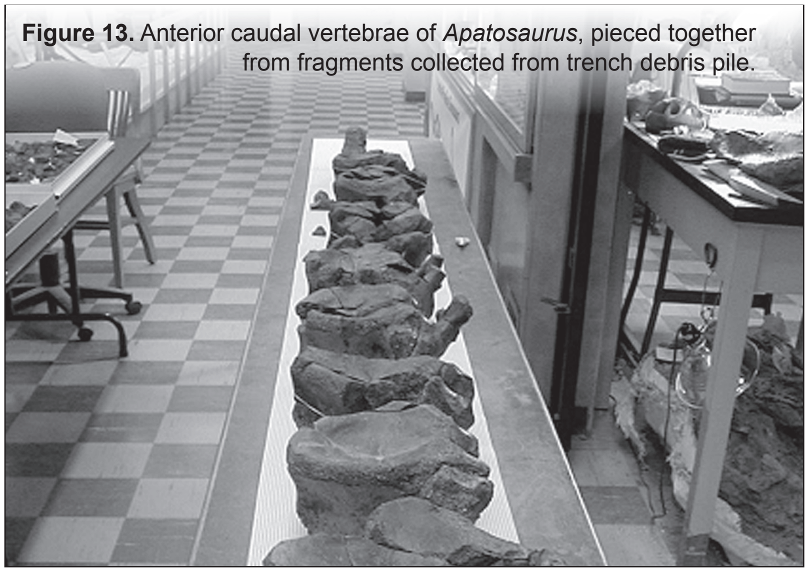


Figure 13. Anterior caudal vertebrae of *Apatosaurus*, pieced together from fragments collected from trench debris pile.

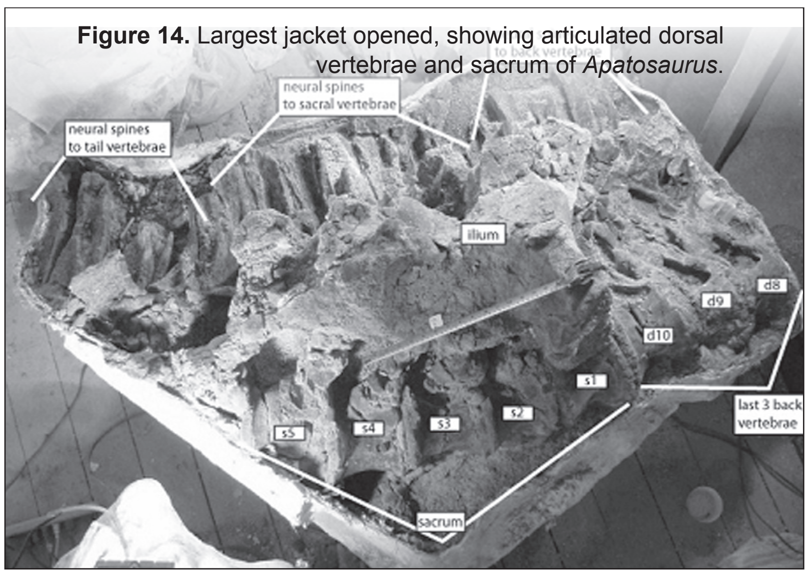
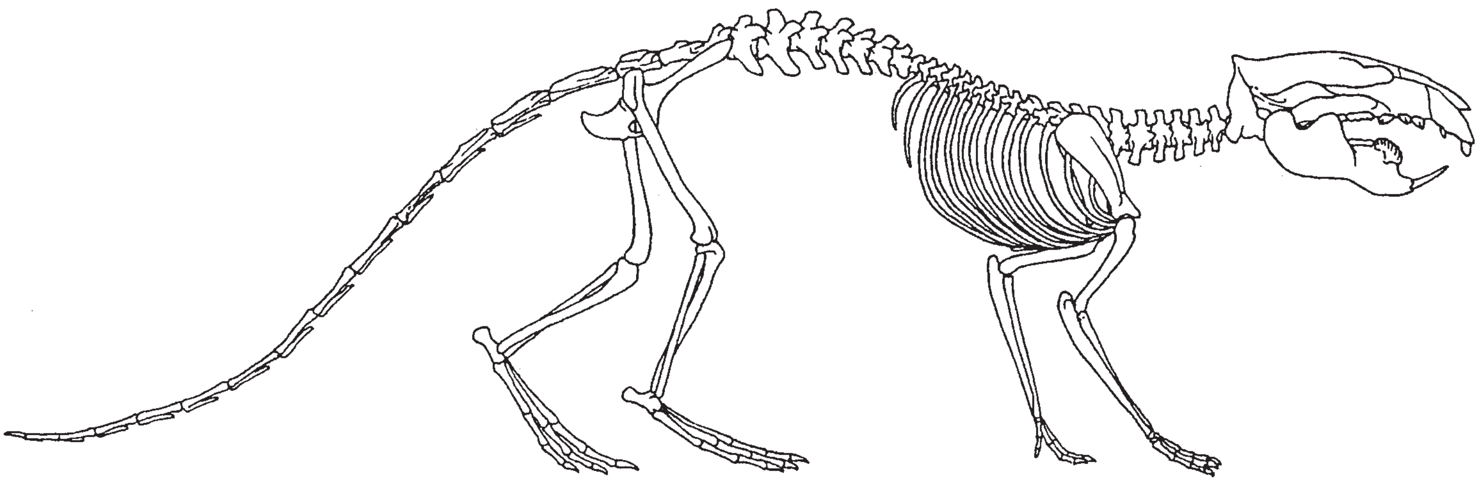


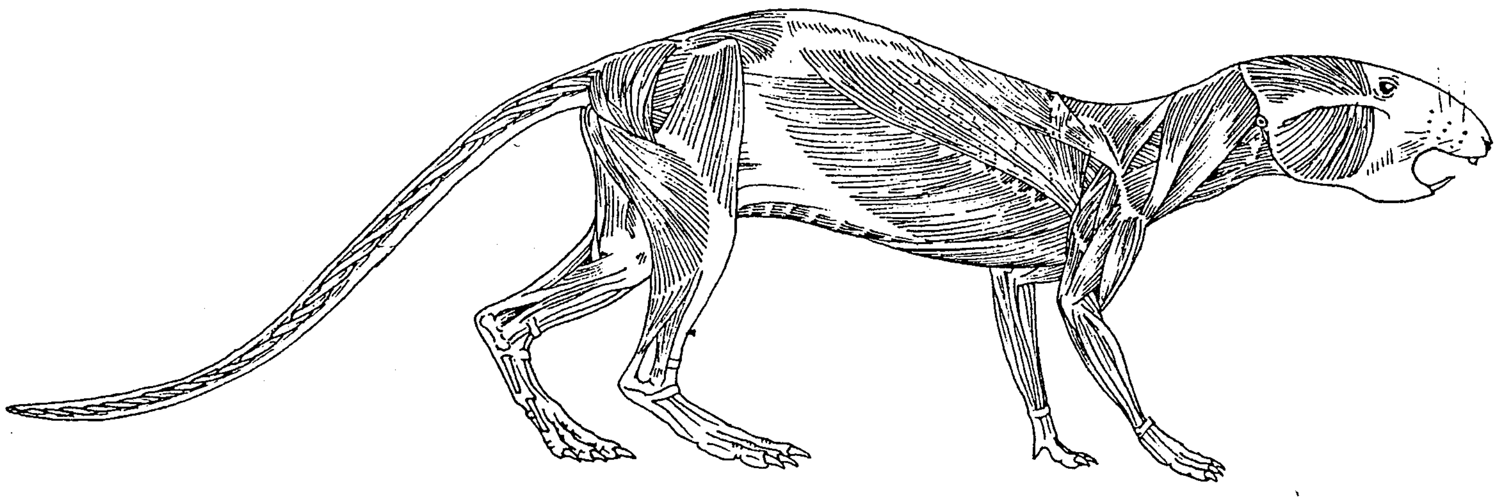
Figure 14. Largest jacket opened, showing articulated dorsal vertebrae and sacrum of *Apatosaurus*.

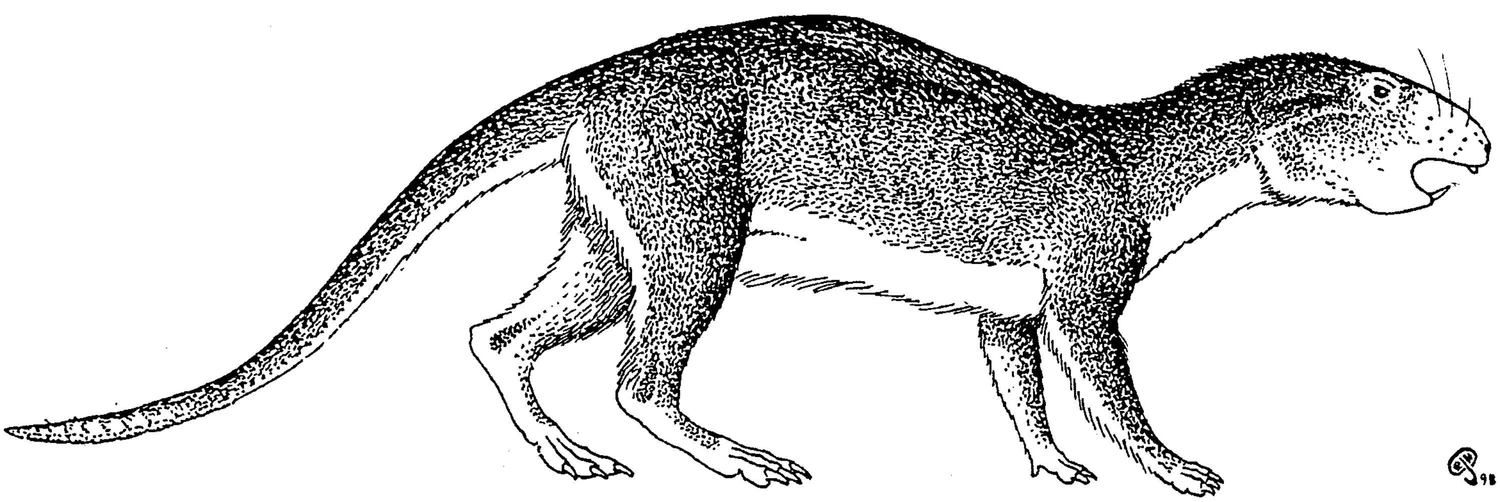
Multituberculate (*Mesodma formosa*)

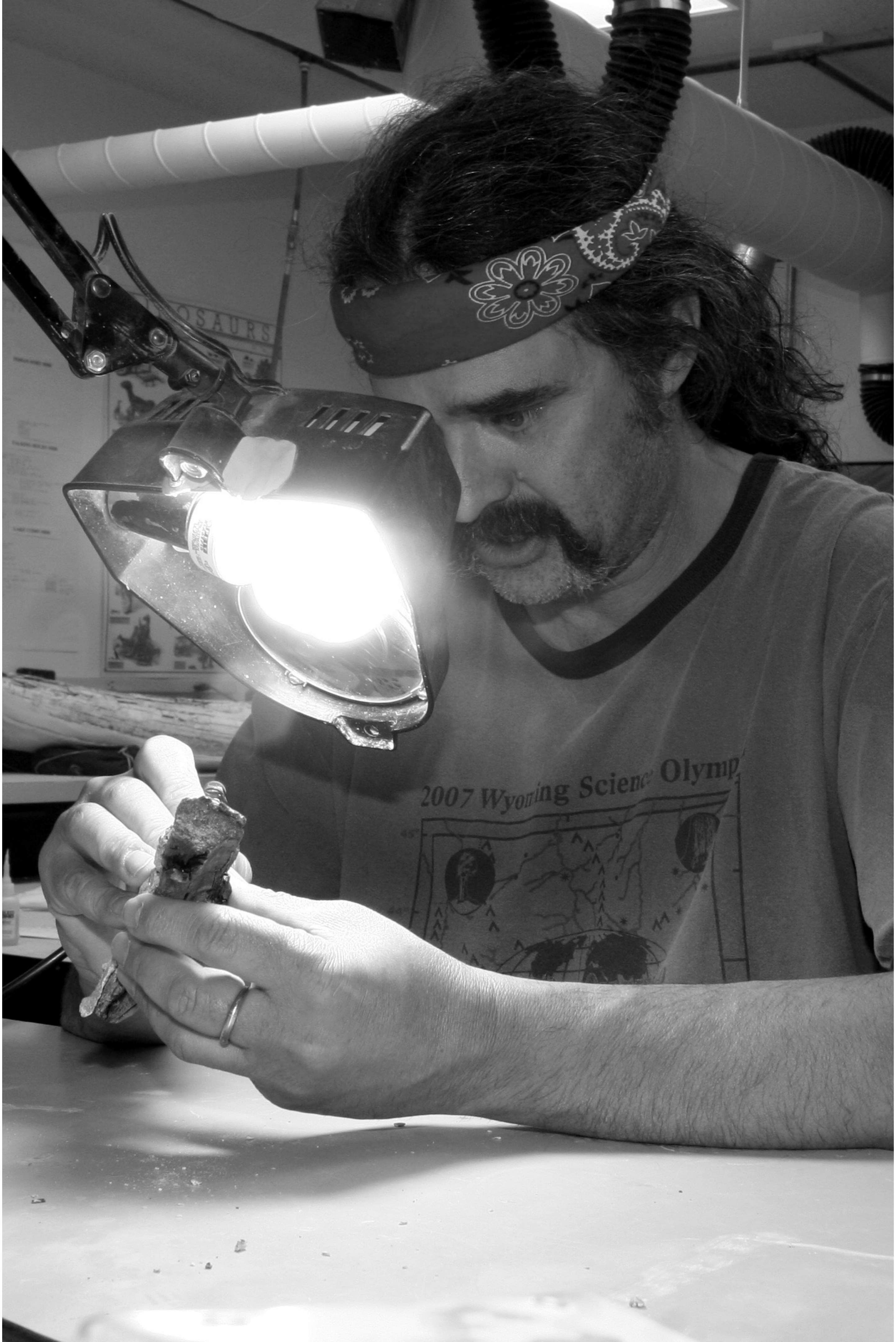
Multituberculates are one of evolution's greatest success stories. They first appeared near the end of the Triassic period and continued to persist until the Oligocene -- a run of over 170 million years! The skeleton shown here is a speculative composite restoration.



Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist







Jean-Pierre Cavigelli - Tate Geological Museum, Casper College

A Primer to Polyethylene Glycol Use in Paleontological Preparation

or

How I Learned to Stop Worrying and Love Prepping Thin and Delicate Bones

Jean-Pierre Cavigelli, Tate Geological Museum, Casper College, Casper, Wyo.

Introduction

What do make-up, toothpaste, suppositories, organic insecticides, soldering flux have in common? Carbowax™. Carbowax™ is a trade name for polyethylene glycols (PEG) and methoxy-polyethylene glycols manufactured by Dow Chemicals. The name is a registered trademark of Union Carbide, which was bought by Dow Chemical Company after the Bhopal incident in 1984. Carbowax™ is available in food grades, including kosher varieties. Its uses in industry are multitudinous. It is in many different products (the list above is just the beginning) and its properties make it useful in the manufacturing of thousands of others. Some of these properties include its low melting point, its nonreactiveness, its lack of odor, its safety and its water-solubility. (Carbowax™ web site)

And what does this have to do with fossils?

Carbowax™ is a water-soluble wax, often referred to as PEG, used to make temporary supports for delicate fossils. Fossils are embedded in the wax, providing added strength and rigidity, so that they can be prepared while minimizing risk to the fossil. The idea is fairly simple. A preparator can prepare one side of a fossil, set the fossil in Carbowax™ with the prepared side down, prepare the other side and finally remove the wax by immersing the whole thing in water. The following is a how-to based on my experience as well as that of others. Its use in paleontology was first described by Rixon (1965).

The Procedure

Figures 1-13 show steps in using Carbowax™ to support a fossil for preparation.

Figure 1. A collection of tools used to mount a fossil in a temporary Carbowax™ mount, and remove it. Front row: a hot surface, two spoons, X-acto® knife, dental pick (sharpened to a chisel point), ½ inch paintbrush, scissors, a Carbowax™ frame, cardboard. Back row: glass baking dish and plastic container, recycled Carbowax™ in container, cyanoacrylate glue, Carbowax™ and pot. Missing from photo: tweezers and razor blade.

The first step is to prepare the fossil on one side and prepare the necessary tools (Figs. 1 and 2). Be sure to stabilize this side of the fossil as necessary. If cracks need to be filled with either glue or epoxy putty, do so. A fossil that will be set in Carbowax™ should not be stabilized with water soluble glue. With a thin or delicate fossil, it is imperative that the fossil be able to support its own weight after it is fully prepared. If there is any doubt about this, it may be more important to leave some matrix on the fossil than to completely remove it from the matrix.

After preparing and stabilizing one side of the fossil, the preparator should make or find a frame for the fossil and Carbowax™. The requirements of a Carbowax™ frame are fairly simple; the base needs

Figure 2. The specimen used in this set of photos is a piece of dinosaur bone from the Morrison Formation. As we were collecting it, it popped off the matrix with only a little bit of matrix stuck to it. In contrast to the procedure described in main text, this specimen has not been prepared on one side first. The specimen was embedded in Carbowax™ to prepare the first side, removed from Carbowax™, then re-embedded to prepare the second side. The piece on the left in this photo is the piece featured in Figures 3 to 13.

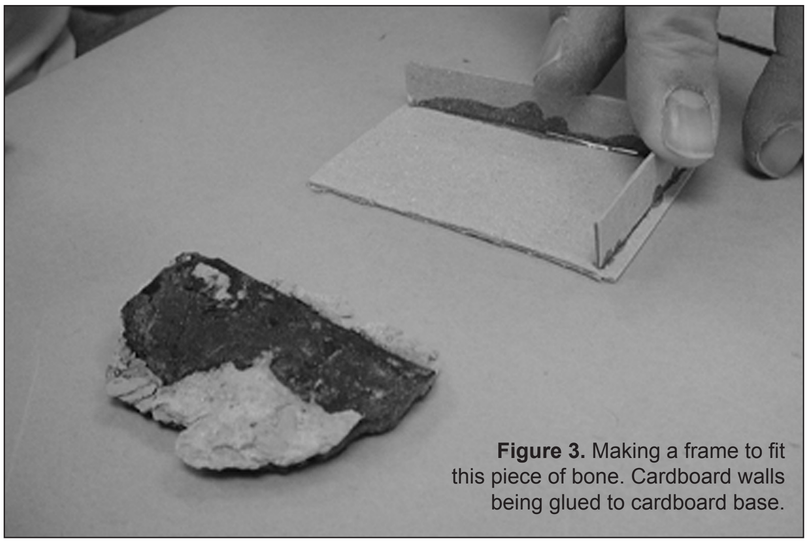


Figure 3. Making a frame to fit this piece of bone. Cardboard walls being glued to cardboard base.

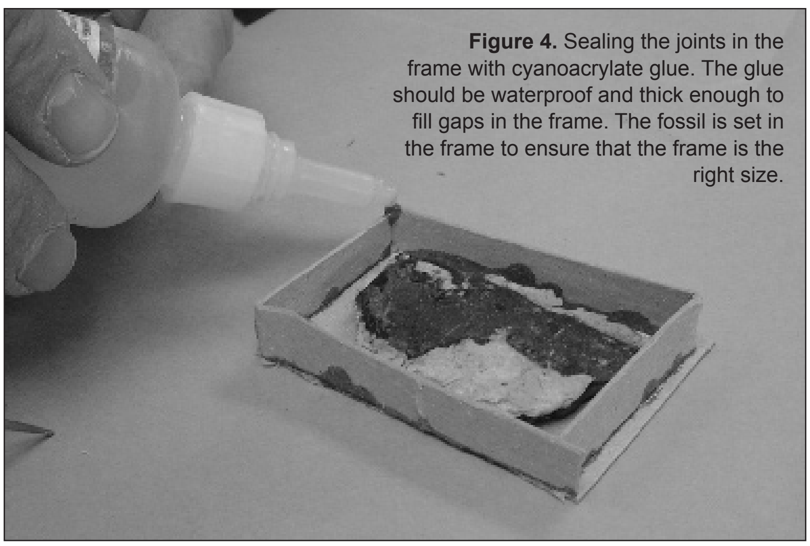


Figure 4. Sealing the joints in the frame with cyanoacrylate glue. The glue should be waterproof and thick enough to fill gaps in the frame. The fossil is set in the frame to ensure that the frame is the right size.

to be fairly rigid and the walls need to be high enough to contain enough Carbowax™ to hold the specimen. A custom sized frame can be made in a matter of minutes from thin (noncorrugated) cardboard or paperboard and glue (Figs. 3 and 4). The cardboard that backs a pad of paper is a good example, or the paperboard used for cereal boxes. Medium thickness cyanoacrylate glue is useful, as it is somewhat gap-filling and dries quickly. First, a base is cut that is a little bigger than the fossil. Then walls are cut that will be erected on the base. The walls should be placed vertically to outline an area into which the fossil will fit. Glue these in place in a form that will contain the bone. Voila… a custom frame.

Lego™ building bricks can also be used to make custom containers. Experience has shown that a Lego™ base should not be a thin Lego™ sheet, but rather a plate that is the same thickness as a regular Lego™ brick. When it comes time to take the frame apart, a thinner sheet will tend to bend and possibly break the fossil. Be aware, also, that very hot Carbowax™ can bend thin Lego™ pieces. It is best to let the Carbowax™ cool for a minute before filling the frame.

Carbowax™ can be melted on a heater in a pot or a pan. It is best to allocate a single pot to the Carbowax™ and not contaminate it with other chemicals. When melting Carbowax™ it is best to stick around and patiently watch it melt. Avoid the temptation to work on something else. Burning Carbowax™ will create a smoky, stinky mess. It apparently loses its effectiveness when overheated (unnamed Dow™ sales representative, pers. comm.), but I have not noticed this to be the case for paleontological concerns. Once the Carbowax™ has melted, it takes several minutes (up to a half hour) to recrystallize as it cools. The fossil can be placed into the frame and Carbowax™ poured around it to the correct level. Alternatively, the Carbowax™ can be poured into the frame and the fossil placed upon in it (Figs. 5 and 6). A spoon can be used to transfer some liquid Carbowax™ from the pot into the frame. Pour enough Carbowax™ into the frame to support the bottom (prepared) side of the fossil. Leave the unprepared side and matrix sitting above the wax. The Carbowax™ can also be poured directly from the pot, but his will invariably leave some Carbowax™ dripping down the outside of the pot. This excess will burn off unpleasantly next time the pot is heated. The prepared side of the specimen can also be painted with a layer of Carbowax™ before embedding it in the

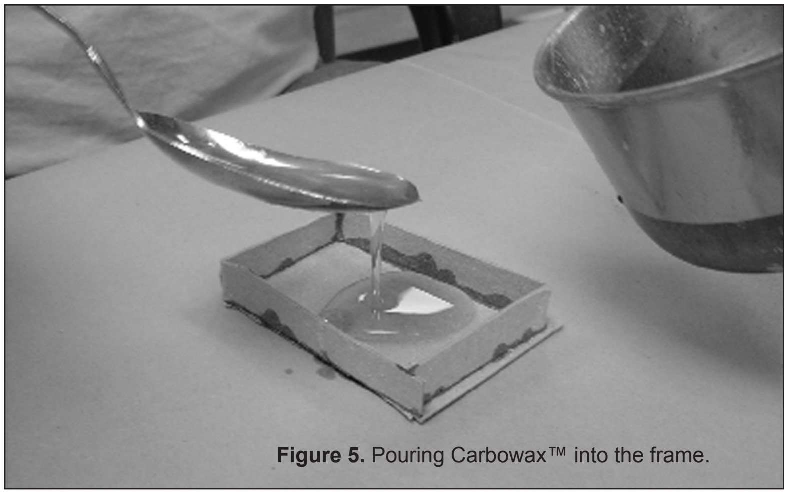


Figure 5. Pouring Carbowax™ into the frame.

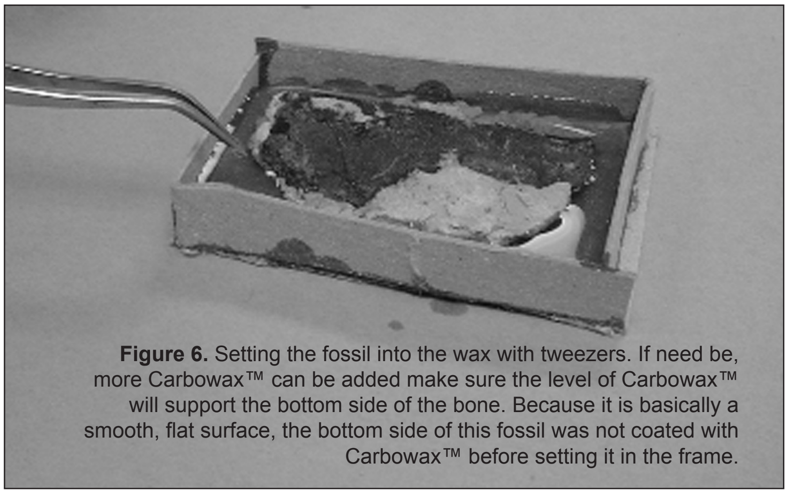


Figure 6. Setting the fossil into the wax with tweezers. If need be, more Carbowax™ can be added make sure the level of Carbowax™ will support the bottom side of the bone. Because it is basically a smooth, flat surface, the bottom side of this fossil was not coated with Carbowax™ before setting it in the frame.

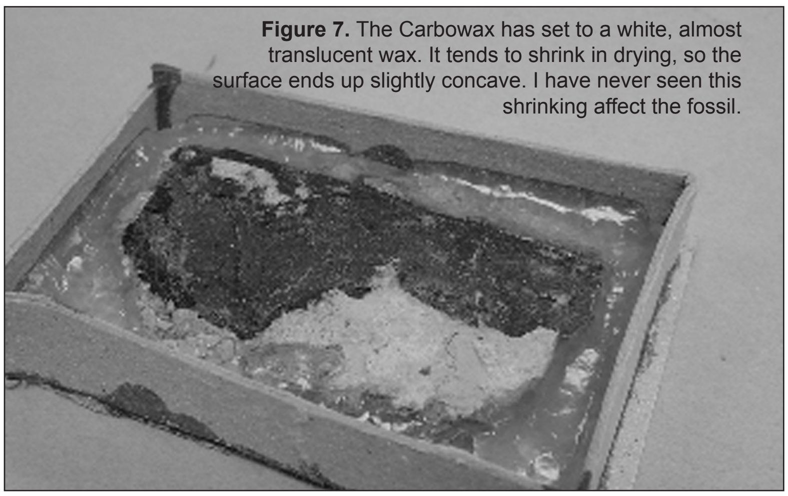


Figure 7. The Carbowax has set to a white, almost translucent wax. It tends to shrink in drying, so the surface ends up slightly concave. I have never seen this shrinking affect the fossil.

frame. This is especially useful if the specimen has hollow areas on the prepared side. If the specimen is simply placed into the molten Carbowax™, these hollows may trap air and therefore not benefit from the Carbowax™ support. On larger specimens, painting the Carbowax™ on can also be an alternative to the Carbowax™ frame.

A frame two inches square containing Carbowax™ a quarter inch deep and a specimen will set up in approximately a half hour. In a frame like this, the Carbowax™ will often shrink as it dries. Generally the areas that congeal first do not shrink, but the last areas to congeal will have holes in them due to shrinking. Areas contacting the frame and the specimen tend to congeal first, so the shrinking does not directly affect the specimen. Such hollows are visible in the front edge (next to the matrix) of the frame in Figure 7. I have never noticed this behavior to be a problem.

Something to consider before placing the specimen in Carbowax™ is “Will I be able to easily find the fossil within the matrix?” Often, a specimen placed in Carbowax™ appears as a lump of matrix in Carbowax™, with no fossil visible. If the shape of the fossil allows, it is helpful to first prepare around an edge of the fossil, exposing some of the fossil on the matrix side. When the whole thing is set in Carbowax™, with the matrix side up, the preparator will be able to see this edge of the fossil, giving him/her a good place to start preparing. This is better than preparing semi-blindly through matrix and hoping not to leave a tool mark of discovery. For example, if the fossil is a small mammal jaw, while preparing the first side, a little bit of the base of the jaw on the second side may be prepared (around the ventral edge of the bone). This edge will be exposed above the Carbowax™ when the prepared side is embedded in Carbowax™.

After the wax has cooled, the side of the fossil not in Carbowax™ can be prepared by the usual means. Excess Carbowax™ can also be prepared off with the same techniques. The Carbowax™ frame becomes a convenient way to hold the fossil. The frame can also be carved to allow access to different parts of the specimen from different angles (Fig. 8). Once the fossil is prepared it should be stabilized as needed. Now we are ready to remove it from the Carbowax™.

In order to speed up the dissolving of the Carbowax™, one can remove some of the base in the frame. A chisel-shaped dental pick works well for this, as does a scalpel or X-acto® blade (Fig. 9). A pointed tip will simply stab the Carbowax™ base, removing only a small quantity. Do not remove all of the Carbowax™, as soaking in water will do this with much less risk of breaking the specimen. The preparator can choose to remove the frame, leaving the fossil and its Carbowax™ support by separating the Carbowax™ from the bottom of the frame. This should only be done manually if one can actually carve out enough Carbowax™ from under the fossil to allow good frame/Carbowax™ separation. If there is

Figure 8. Here the fossil has been mostly prepared on this side using air scribes and air abrasive. The frame does not allow access to the left edge of the fossil, so an X-acto® knife is used to carve a notch in the frame making it easier to prepare this edge. One can go further and cut down into the level of the Carbowax™ and physically remove it to effectively access the fossil from different angles.

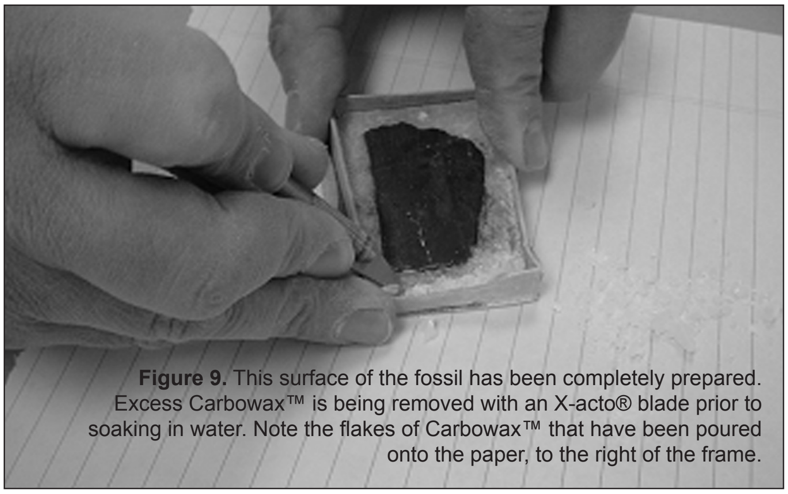


Figure 9. This surface of the fossil has been completely prepared. Excess Carbowax™ is being removed with an X-acto® blade prior to soaking in water. Note the flakes of Carbowax™ that have been poured onto the paper, to the right of the frame.

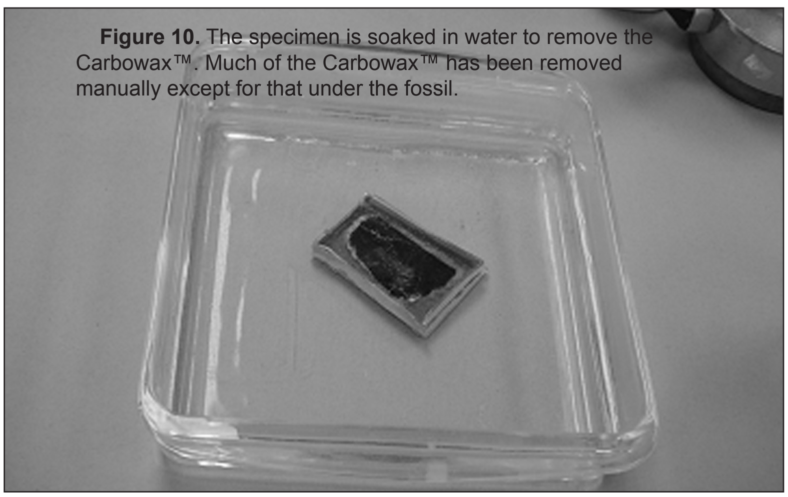


Figure 10. The specimen is soaked in water to remove the Carbowax™. Much of the Carbowax™ has been removed manually except for that under the fossil.

any doubt, the whole set-up should be allowed to soak in water; fossil, wax and frame. For large flat fossils, this is certainly the only safe technique. Even for less flat fossils, separating the Carbowax™ from the base of the frame brings the risk of breaking the fossil. If the fossil sits on a layer of Carbowax™ (rather than the base of the frame), there is better chance of separating the Carbowax™ from the frame. The advantage to separating is only that it will reduce soaking time. Again, if there is any doubt, soak the whole thing.

For dissolving Carbowax™, any water-tight container will work (Fig. 10). Warm water will speed up the process. Specimens I have prepared under the microscope, where the amount of Carbowax™ is very small, say the size of a pea, have dissolved the Carbowax™ in a matter of a few minutes. The more Carbowax™, the longer the time needed to dissolve it. As a rough guide, with specimens the size of a small rodent jaw, I have immersed the specimen, wax and frame in water, the dissolving takes about an hour (see also section on "Different Molecular Weights"). As the water cools, replacing the warm water will speed up the process.

When removing a specimen from water, either fingers or tweezers are often sufficient (Fig. 11). The fossil should be rinsed in a different container of warm water to minimize Carbowax™ residue (Fig. 12). Smaller or more delicate specimens may be too delicate to risk handling with fingers or tweezers, especially when wet. For these, most of the water may be decanted off, leaving the fossil at the bottom of the container in a small quantity of water. Decant the water into a separate container; if the small fossil accidently gets decanted, it is not lost. Use a natural bristle paintbrush to pick up these delicate fossils, (roughly size 1 or 2), by sliding the bristles under the fossil and picking it up from underneath such that the fossil rests on the sides of the bristles.

After rinsing, the fossil should be set to dry on a piece of absorbent yet tough paper. Tissue is inappropriate; when the fossil dries, it tends to stick to the tissue. (Whether this is due to dried minerals in the water causing adhesion, or fibers in the tissue physically holding onto the specimen, or to some other force is unclear). Paper towel is better suited to this, as is blotting paper. The frame can also be removed from the original water bath, rinsed and set aside to dry for re-use (Fig. 13).

Sometimes when stabilizing the fossil as it sits in the Carbowax™, excess preservative or glue will seep out onto the Carbowax™ surface. After the fossil has dried thoroughly, these may show up as a white plastic-looking film flapping about on the edge of the fossil. These can be either removed manually or bonded to the fossil by applying an appropriate quantity of the same preservative or the solvent used. Make sure the fossil is thoroughly dry before applying solvent-based products.

Carbowax™ can be recycled and used over and over again. The Carbowax™-rich water can be allowed to evaporate leaving behind the Carbowax™, which can then be harvested. A glass baking dish is useful because its allows for a large surface area of water, speeding up its evaporation. A razor blade can easily be used to scrape the dried Carbowax™ off the glass after the water has evaporated, (Fig. 14). This material can then be stored to be used again. The recycled Carbowax™ is kept in a separate container than the virgin stuff. If Carbowax™-rich water is to be thrown out, contact the local landfill to find out what to do with it; is it permissible, in your area, to dispose of small quantities down the sink? If Carbowax™-rich gets contaminated with small pieces of matrix, it can be filtered through a coffee filter before evaporating it.

If a specimen is very small it may sink in the Carbowax™ and may be difficult to find again without first dissolving the Carbowax™ off and starting all over. To avoid this, very small specimens should be floated on top of the Carbowax™ after it has started to crystallize. Use tweezers under the microscope to lay such small fossils on top of the Carbowax™ after small, round white crystals of Carbowax™ start to form. If a fossil is to be set in Carbowax™ and prepared under the microscope, it should be mounted on Carbowax™ under the microscope as well (Figs 17 and 18). Additional quantities of Carbowax™ can be built up along vertically protruding parts of the fossil if needed (Fig 19). A paintbrush dipped into the molten Carbowax™ can be useful for detailed Carbowax™ placement.

Different molecular weights

Carbowax™ comes in a variety of different molecular weights and properties. The ones useful to paleontology labs are those that are solids at room temperature. These include molecular weights of 1450, 3350, 4000, and 8000. A sample of each was used for a simple usability study. As a disclaimer, this

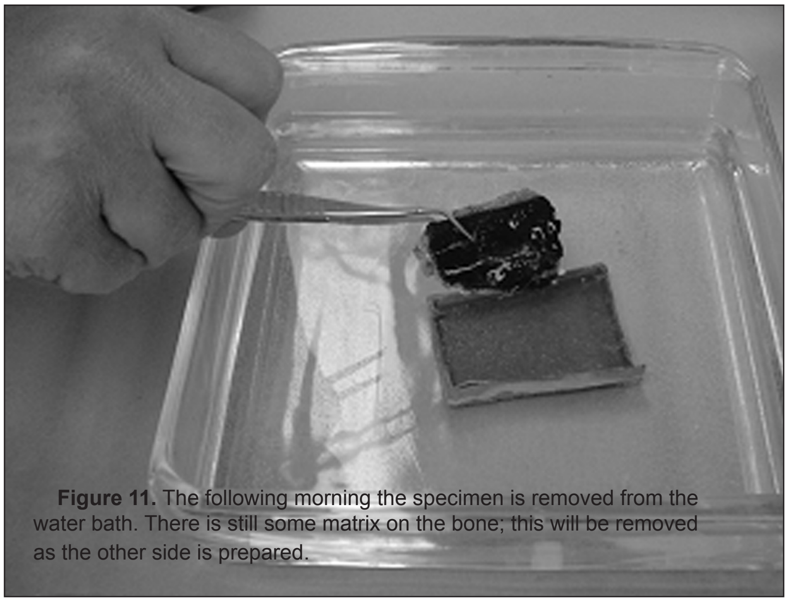


Figure 11. The following morning the specimen is removed from the water bath. There is still some matrix on the bone; this will be removed as the other side is prepared.

Figure 12. The specimen is rinsed in clean water not that does not have Carbowax™ in it, to remove Carbowax™ residues.

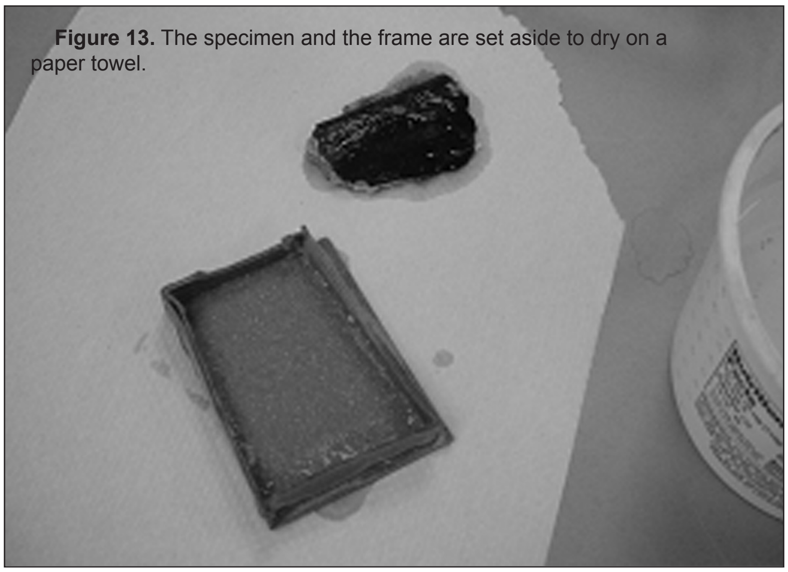


Figure 13. The specimen and the frame are set aside to dry on a paper towel.

Figure 14. Using a razor blade to scrape dried Carbowax™ from glass baking dish for recycling.

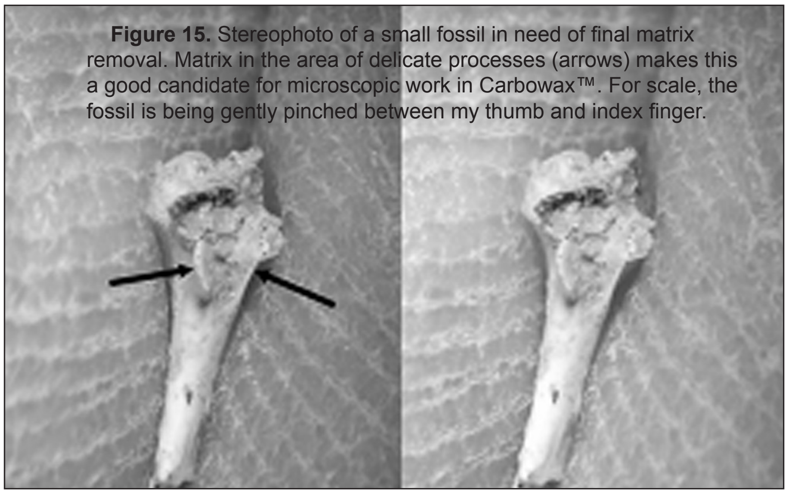


Figure 15. Stereophoto of a small fossil in need of final matrix removal. Matrix in the area of delicate processes (arrows) makes this a good candidate for microscopic work in Carbowax™. For scale, the fossil is being gently pinched between my thumb and index finger.

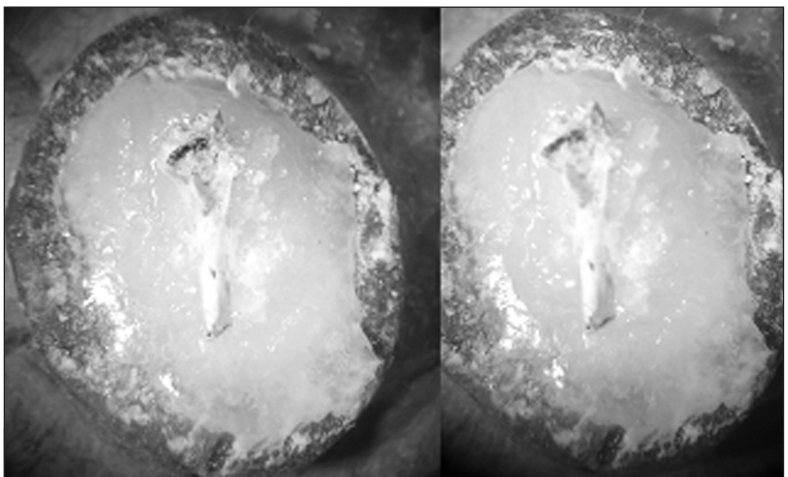


Figure 16. Stereophoto of the same specimen lying on a small bed of Carbowax™. Note the process coming toward the viewer just below the dark crystal in the matrix. As it stands, it is not protected from stresses that will be incurred in removing the matrix. The process on the right has a Carbowax™ backing. The fossil was set in Carbowax™ after the wax started to crystallize. Figure 17. A small drop of molten Carbowax™ has been added to the left of the process with a number 0 paintbrush to give it support. In this photo it has cooled and the specimen is ready for further preparation.

was not a rigorously controlled experiment, but rather a test to get some basic comparisons. In a clean pot, three heaping spoonfuls of each were melted and poured into a 1 3/8 x 1 7/8 inch specimen box. Each was timed to see how long it took to set up solidly. Each sample was also tested to see how easily it is carved and to see which dissolves the fastest.

The lower the molecular weight, the longer it took to set, but the results are not different enough to be a concern in the prep lab. (8000 took 24 minutes; 1450 took 29 minutes). In solidifying, the three smaller weights first developed a skin on top of the pool of wax. The 8000 seemed to solidify by crystallizing throughout the sample. The 8000 solidified with many small gaps in between crystals. The other three weights solidified with a few large gaps of empty space in the final solid. These gaps do not seem to affect the solidity of the whole mass, at least not in terms of simply stabilizing a fossil. My experience with Carbowax™ in the past suggests that Carbowax™ drying in layers (as when it is painted on a specimen) is not likely to create these empty spaces when solidifying. Painting Carbowax™ onto the back of a fossil before embedding is useful. A thin layer of Carbowax™ painted onto the back of a fossil tends to set up quickly.

Before immersing a Carbowax™ and fossil frame into warm water to remove the Carbowax™, physically removing a large amount from the frame will help speed up the dissolving process. The four samples were attacked with a dental pick sharpened to a chisel end. A subjective comparison of the four waxes was made. The 1450 is very plastic; pieces of the wax simply were pushed aside to allow the chisel in. The two middle weights were easily scraped (rather than carved) with the chisel. The 8000 was stronger yet more brittle than the others. When the chisel broke through, pieces of the hardened 8000 were sent flying and the chisel jerked forward into the mass of wax. Removing Carbowax™ 8000 from a frame is not easily controlled, making it the less useful for the prep lab. The plasticity of the Carbowax™ 1450 makes it less useful in this regard than the two middle weights. A fifth sample of Carbowax™ was melted and solidified to further test this property: an equal mix of 1450 and 3350. This material chiseled very satisfactorily and was easily carved. In terms of ease of physical removal, this mixed batch performed the best. For ease of physical removal, either the 3350 or the 4000 is the best pure molecular weight. Carbowax™ 8000 and 1450 should be completely immersed in warm water to remove them.

The same five samples were dissolved in warm water to see which dissolved fastest. They were all put into a glass baking pan which was filled with warm tap water. The pan was set on an electric griddle set at “warm” to keep the water from cooling. They were checked every ten minutes. The Carbowax™ 1450 melted in two and a half hours, while the Carbowax™ 8000 melted in four hours and 10 minutes; not quite twice as long. Melting times followed molecular weight except for one sample. The 4000 melted faster than the 3350. At one point the wax in this sample was seen floating in the water column, while all other samples remained on the floor. This is likely why it melted faster, as water would be acting on the bottom as well as the top side of the wax block, speeding up dissolving time.

As a note, the specimen boxes used had black paper on them. This paper bled into the melted Carbowax™ samples as well as into the water used to dissolve them.

In conclusion, Carbowax™ 3350 and 4000 are the best weights of Carbowax™ to use for fossil preparation.

Where to get Carbowax™

Carbowax™ is available from Dow Chemicals. Small quantities of some molecular weights are available for free. These include (as of this writing) Carbowax™ 8000, Carbowax™ 4000, and Carbowax™ 3350. The smallest available quantity is a quart, which should be enough to last a paleontology lab for a long time if it is recycled. Other useful grades (e.g. 1450) cost roughly $60 for a quart.

Safety Concerns

When ordering Carbowax™, make sure to ask for the accompanying MSDS. Without going into too much detail, Carbowax™ is a fairly safe product to use, (Carbowax MSDS, 2008). When melting Carbowax™, as well as chipping it out of the frame, it is best to wear protective eyewear. Overheating or burning Carbowax™ makes a smelly, smoky mess that may be a cause for changing the air. Regular safety concerns should be heeded, such as using sharp tools and heating units.

When to use Carbowax™

Or, when not to use Carbowax™. Any fossils that are sensitive to water should not be treated with Carbowax™. If the matrix is water sensitive and the fossil is to be left in matrix, Carbowax™ should not be used. If the matrix is to be completely removed, it may be okay to use Carbowax™. This should be considered carefully, as there may be enough matrix filling cracks in the fossil that the results may be less than ideal.

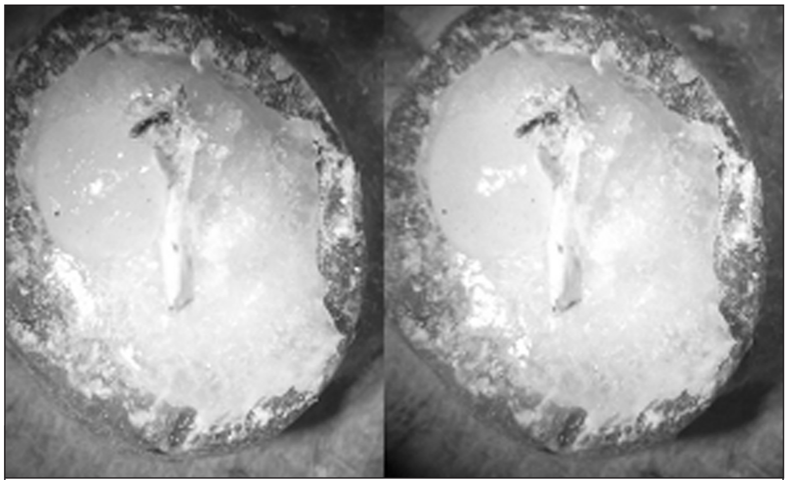


Figure 17. A small drop of molten Carbowax™ has been added to the left of the process with a number 0 paintbrush to give it support. In this photo it has cooled and the specimen is ready for further preparation.

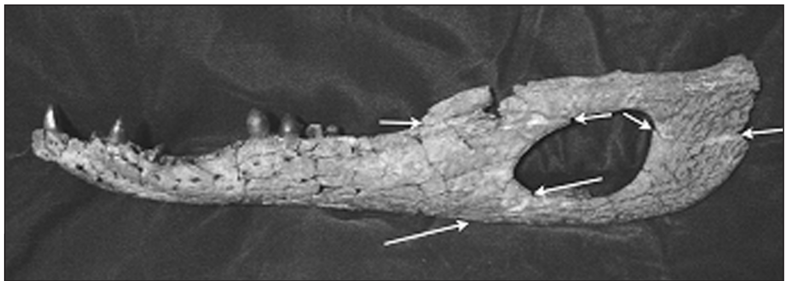


Figure 18. The multitudinous fragments in this Eocene alligator jaw are all held together with cyanoacrylate. The arrows show where the separate bones (dentary, angular, and surangular) are held together with Carbowax™ (barely visible as white fill somewhat connecting arrow pairs). Specimen is 16 inches (40 cm) long.

Many thin bones can put up with the force of an air-abrasive machine, but air scribes are generally more powerful. A thin bone that is to be worked on with an air scribe is an ideal candidate for a Carbowax™ support. Small bones that are difficult to handle are also good candidates for temporary Carbowax™ supports.

When water is an issue, the preparator may want to consider using cyclododecane as a temporary support (Brown, 2004). Cyclododecane is a similar wax product that sublimates at room temperature, thereby eliminating the need to immerse the specimen in water. Cyclododecane sublimation is considerably slower than Carbowax™ dissolving; measured in weeks, not hours. Cyclododecane’s safety factors are not yet clear (Cyclododecane MSDS, 2006).

Other paleontological uses for Carbowax™

Carbowax™ can be used to form joints between fossil bones. Often broken bones are glued together using glues that do not dissolve in water. Carbowax™ can be used to at least temporarily glue these bones together. When needed, the bones can be soaked in water without the risk of ungluing the previously broken parts. Carbowax™ joints such as this may not be strong enough to support free standing skeletal mounts of fossil animals (this was not tested). Carbowax™'s slow set time makes it useful for articulating bones with several points of contact, such as the alligator jaw in Figure 18. The dentary was joined to the angular with a layer of Carbowax™. While this first joint was setting, the third bone (surangular) was joined to each of these previous bones. Since the Carbowax™ was still pliable in each joint, the correct alignment between the three bones was attained before the Carbowax™ set up. The specimen can be soaked in water to disarticulate the bones without risking the cyanoacrylate bonds holding all the little pieces together.

Delicate fossils that need to be shipped can also be coated in Carbowax™ to protect them from the rigors of the shipping industry. The recipient can then soak the fossils in water to release them.

Carbowax™ could be used as a temporary filler in bones that are to be molded, either for reconstruction or to keep silicone out of cracks. I have not tried this, but my guess is that it would form a very smooth surface that will be inordinately smooth on a cast. A little texturing of the waxy surface may be appropriate.

Carbowax™ has also been used recently to mount small fossils on pinheads. Rixon (1965) also mentions a Carbowax™-based paste that can be used for this purpose. The advantage to the paste is that one does not need to repeatedly melt a supply of Carbowax™.

Naturally, all these applications should only be done with fossils that can withstand immersion in water.

A Cautionary Tale

Recently I have been preparing a small crocodile skeleton (skull is three inches or eight cm long). It is in somewhat soft sandstone. Some parts needed temporary supports and Carbowax™ was my first choice. I placed a piece of matrix in water to see if it disaggregated. It did, but only slightly. A second piece of matrix was covered with vinac (polyvinyl acetate in acetone) and let dry. This was then immersed in water to see if the vinac kept the water out, which it did. I also tested a scrap of bone from the specimen in similar ways. The bone stood up to water, with and without a vinac coating. I set a small piece of matrix into a Carbowax™ frame and prepared it. When it was time to soak off the Carbowax™, I did so. After soaking up some water, the rock broke in half and became rather soft. I gently… ever so gently… took it out of the water and let it dry overnight before reapplying more vinac to the two pieces of rock. A near disaster, but in the end, the two halves fit together nicely and very little bone was lost. Was there a weaker spot in the rock? In the vinac coating?

Unfortunately, there was still some Carbowax™ on the specimen, but I didn't want to expose it to more water. I removed as much Carbowax™ as possible by hand under the microscope. Several tenacious pieces of Carbowax™ still clung to a few areas on the rock. I prepared a hot water bath big enough to hold a smaller container that held hot water, like a double boiler. Since Carbowax™ dissolves faster in hotter water; the hotter the water, the less time the specimen would have to be wet, and hopefully the less additional damage would ensue. The inner container held only enough hot water to dip one end of the specimen that had remnant Carbowax™. The specimen would be dipped, not immersed. I held the specimen in water for a very short time, watching the water soak up into the matrix. Before too much rock became wet, I removed it from the water. Then I let it dry overnight. More vinac was applied to the newly exposed matrix. This process was repeated until all of the Carbowax™ was gone. As most of the Carbowax™ was removed manually, the last thin layers actually dissolved away quite quickly, and no additional damage was done to the specimen.

Looking back, I think I should have done more tests on this matrix. I have been using Carbowax™ for years and on many specimens. This is the first instance where it failed me. I used cyclododecane for other parts of this specimen.

You have been warned.

Acknowledgements

I wish to thank Bill Simpson at the Field Museum of Natural History in Chicago who first introduced me to Carbowax™ and how to use it. Thanks also to Dow Chemicals who make small quantities of some grades of Carbowax™ available for free. Thanks to the Tate Geological Museum staff and to Casper College for supporting research and professional development of their staff. Thanks to those who helped take some of the photos in this report: Steve Pfaff, Melissa Conelly, Tim Fox and Lisa Fujita. Thanks also to the vertebrate paleontology preparator's community for all sorts of help along the way.

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Brown, G. 2004. Cyclododecane: Vanishing support for the preparation laboratory. Journal of Vertebrate Paleontology. Abstracts. Vol. 24, No. 3 p.42A.

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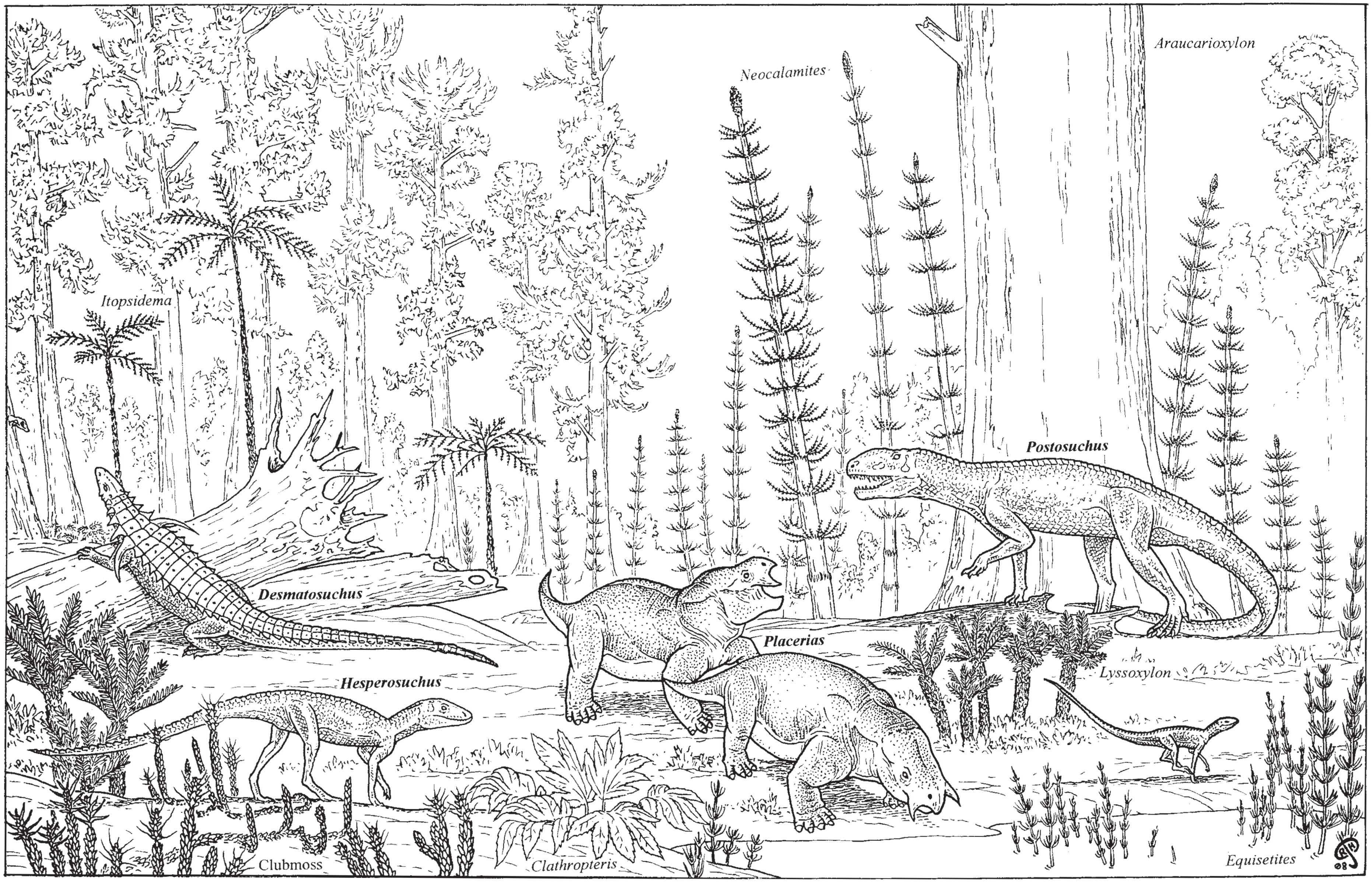
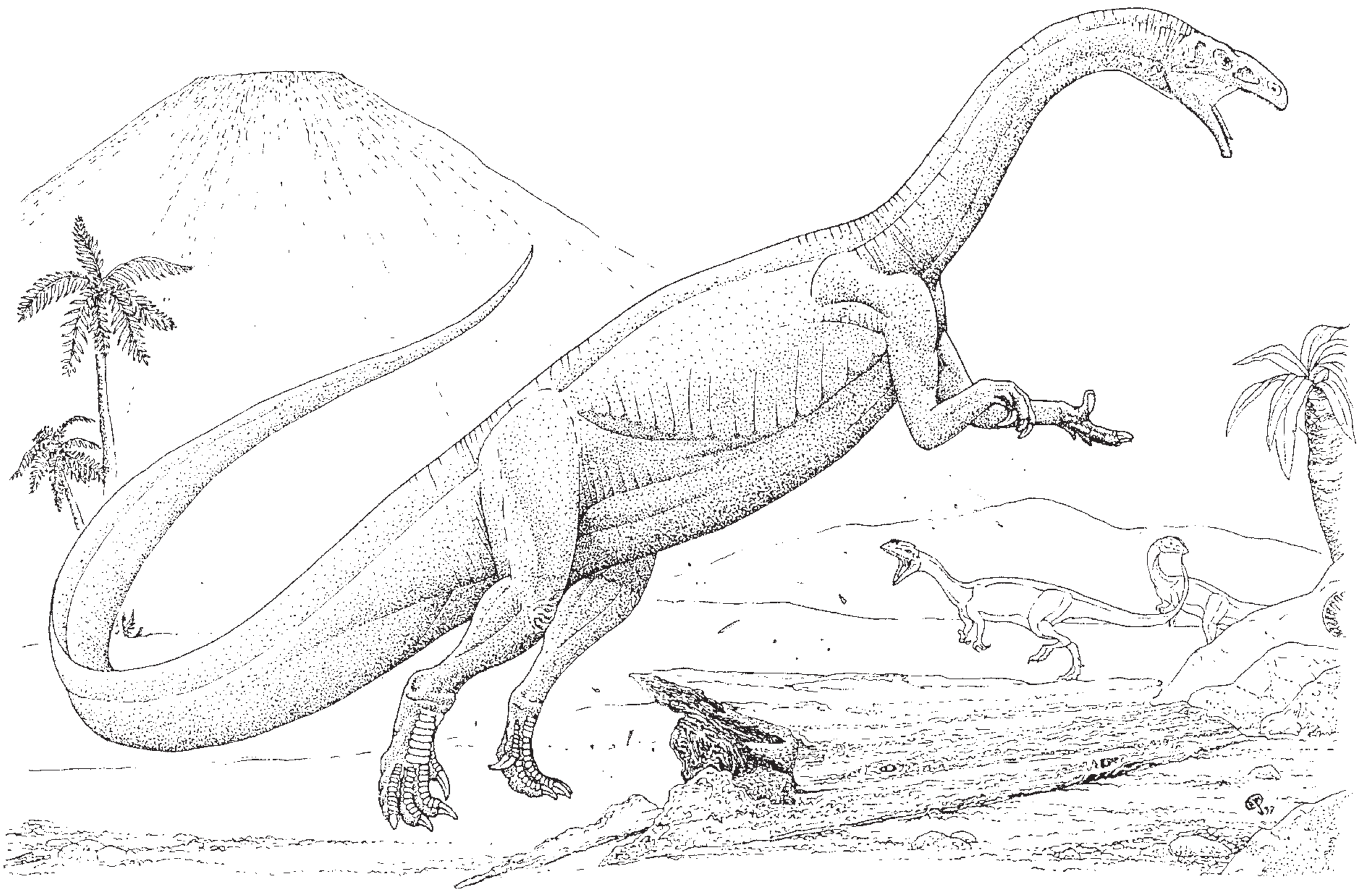
Arizona, 225 million years ago: The Petrified Forest is an outcrop of the Late Triassic Chinle formation, in which thousands of specimens of petrified wood have been found. Most of these are of *Araucarioxylon,* an extinct tree with wood that is similar to that of the modern monkeypuzzle tree. Among these were calamitales, relatives of the modern horsetail, but growing to a height of over 6 metres.

Many of the animals in the Petrified forest were archosaurs, reptiles with a pair of openings in the skull in front of the eyes. Triassic archosaurs included both armoured plant eaters and big predators. There were also slender little running crocodiles called sphenosuchians. The big, plant-eating therapsids were making their last stand at this time, but other therapsids had evolved into rat-sized beasts covered with fur – the first mammals.





Broad-footed Prosauropod (*Plateosaurus engleharti*)

Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Maximizing Situational Conservation and Minimizing Visual Ambiguity to Reveal Toothmarks on an Osteoderm of *Typothorax coccinarum*, in Typical Late Triassic Chinle Formation Preservation, Using Cyanoacrylate and Ground Matrix Exclusively

Peter K. Reser, Paleo-Tech, Albuquerque, N.M. • Scott Williams, Petrified Forest, Ariz.

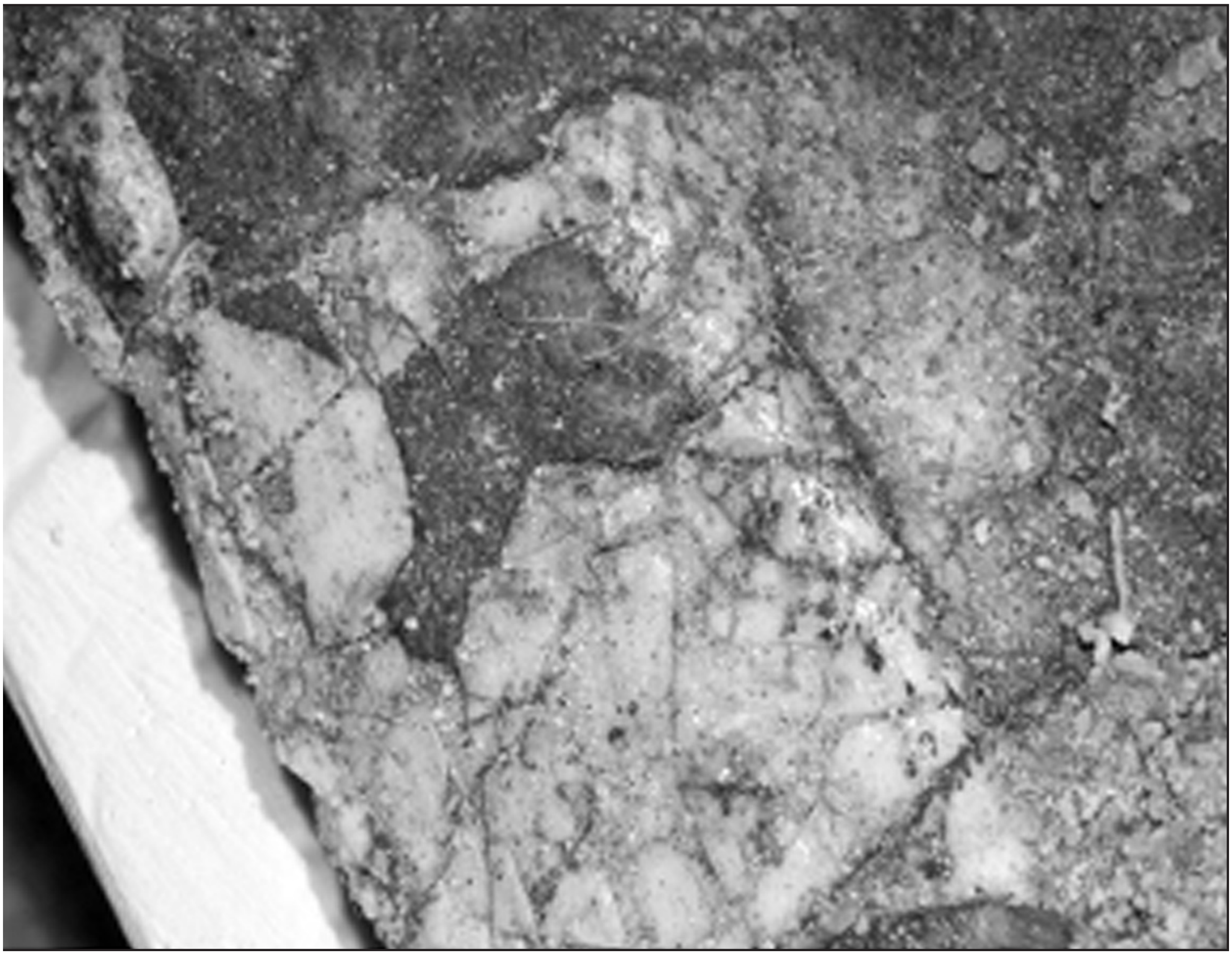


Figure 1. This is the dorsal surface of the scute before preparation. You can see roots and debris glued to it by the field consolidant as well as islands of matrix standing up above the bone surface and bound to it. Not visible in this view, are the microscopic calcite crystals that have grown into the bone, penetrating and slightly distorting the cortex. These crystals can't be removed with an airscribe because too much cortical bone gets blown away. They have to be sheared off flush with the bone surface by hand with a very small chisel that will be described presently. They also proved to be beyond our capacity to effectively photograph. All the images in this presentation were taken with a conventional camera with a macro lens.

Abstract

Vertebrate material from the Chinle Formation is usually collected in mudstone or siltstone that infiltrates the many cracks and fissures. Dissolution and recementation occur in these joints with some movement of the fragments. The goal of preparation is to provide structural integrity by gluing weak joints while correcting deformation, to the extent possible, by realigning drifted fragments during this process. A parallel goal is to reduce the amount of possible chemical interactions by introducing the smallest number of new materials into the finished specimen. Here, since the matrix in the lattice of fractures is already a significant and irreducible component, only cyanoacrylate is introduced to join fragments and as a binder in the ground matrix used to fill gaps and restored areas. The fill, produced and placed in this procedure, is planed to contour producing a crisp line of demarcation between actual bone and restored sections. It also provides mechanical security since the mixture of resin and matrix is stronger than either isolated material. This then allows detailed analysis of morphology and surface features to proceed. There is also an aesthetic benefit since the color of the fill is natural to the specimen while being distinctly defined.

This is a case study and we do not wish to advocate relevance beyond it.

The procedure and choice of materials described here developed from specific circumstances at Petrified Forest National Park, Arizona and involved a specific specimen which is a paramedian scute, or osteoderm, of *Typothorax coccinarum* (No. PVF70, 23388, Prep. # 014). These circumstances included the nature of the fossil material itself, such as degree and type of mineral replacement. Fossil wood found in and around the park is world famous for the hard and durable silica mineral replacement, but this is not the case with vertebrate fossils from the local Chinle Formation. The bone, with few exceptions, is not well mineralized. It is frangible and mechanically weak in that it easily fractures under extension or torque, and crumbles under moderate compression. It is the same type of preservation found in material from the Ghost Ranch *Coelophysis* quarry.

The institutional environment after preparation is another consideration. From a scientific collections standpoint, Petrified Forest National Park can be considered remote. Electrical service is lost several times a year in our experience. This could lead to very high ambient temperatures in summer due to lost air conditioning. Various other facility maintenance problems arise with enough regularity to confidently predict that untrained personnel would handle the specimen in any given future decade. Added to these predictable hazards was the fact that the specimen would be on exhibit in a park building several miles away from the collections facility. The strategy was to prepare this thin, flat, and delicate element to survive rough handling, temperatures in excess of 100 º F, and being supported on a steel exhibit armature with only a few weight-bearing points of contact.

Vertebrate material from the Chinle Formation is usually collected in mudstone or siltstone which contain a network of fractures infiltrated by matrix that cements these fractures – tightly in some places and loosely in others. It is typical for dissolution and recementation to occur in these joints, with some dislocation of the fragments. One of the purposes of this preparation is to provide structural integrity by gluing the loose joints while correcting fragment misalignment to the extent possible.

The original applications of butvar and vinac consolidant first had to be removed because they:

- glued excess matrix and detritus to the specimen.
- perpetuated correctable missalignment.
- did not reliably bond to the substrate.
- were mechanically weak in and of themselves.
- covered the entire surface creating a problematic microclimate underneath it.
- prevented a bond from a stronger adhesive.
- could melt during projected temperature spikes.
- interfered with the conservational goal of reducing the number of applied substances to reduce the complexity of long-term interactions between materials.

It is virtually impossible to remove all of a previously applied material. It this case the consolidant lifted off the substrate under the microscope on all the external surfaces and in almost all of the joint faces.

Cyanoacrylate was then used as the adhesive because of its inherent cured strength, strong bonding characteristics, and relative resistance to high temperatures. This resin acted as a binder, cementing tiny clasts of ground matrix into a durable composite stronger than its components. This formed an internal armature, supporting the weak bone fragments by surrounding them in the connected lattice of filled cracks. Note though, that the bone is stable and best preserved without a coating. So the external surfaces are uncoated and only the joint faces are in contact with the resin.

Since matrix was already an irreducible part of the fossil bone, introducing cyanoacrylate added only one substance to the finished object. Admittedly this is a proprietary commercial product possibly containing some unknown material(s). But it comes from a long established supplier (PaleoBond) and the long-term behavior is partially known and under observation. It is also widely used on fossil material in collections around the world, hence the documentation of this use.

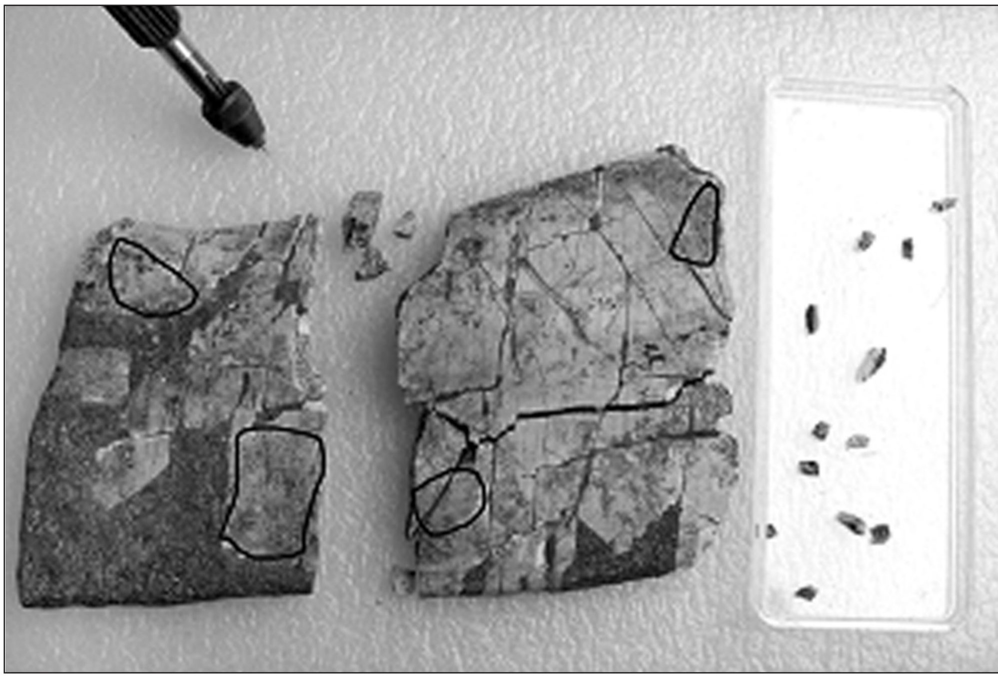


Figure 2. The two halves of the scute were prepared to an advanced stage before joining them together. Half a scute is easier to handle than a whole one during most phases of preparation. This half fell from the bench to the concrete floor shattering into the pieces you see before you. The larger pieces are placed together in their relative positions and the smaller ones in the box were all reincorporated. It landed on the restored corner seen on the left but it broke through the un-restored bone. This demonstrates that, when complete, the system imparts the maximum strength possible. The areas in black outlines are places where field consolidant has not yet been removed although it has been removed from the glue joints. Eventual removal is much easier after enough fragments have been joined together to make it large enough to handle. Carving the glue joints and restorations to contour is so similar to removing the old consolidant that it is more efficient to do both at the same time.

Figure 3. Matrix, processed to make aggregate for the system, was pounded with a hammer on a steel plate and the crushed rubble swept onto the newspaper underneath it.

Figure 4. The rubble is then put through a 14-mesh (14 openings to the inch) kitchen strainer. This produces the large grain fraction of the aggregate we will use. It is what you see in the bowl under the strainer.

Figure 5. Some of the large grain fraction is then put through a 30-mesh strainer producing the fine grain fraction. What we are producing is something like the sand and gravel used as aggregate to mix with Portland cement and water to make concrete. They make it stronger. Another similarity here is that by using only the fine grain fraction a sort of superglue mortar is produced for filling and adhesion in very small gaps.

Figure 6. This is how the “mortar” is mixed on top of a dental mixing pad of treated paper. After each batch the top sheet is torn off exposing a new clean sheet. A large drop of cyanoacrylate (PaleoBond number 750) resin is placed next to a pile of the ground matrix that’s about 30 percent large grain and 70 percent small grain. This will allow two or three sub batches but the aggregate greatly accelerates the curing time. Once the two are mixed, there are only seconds available to place it. Some of the resin is mixed with the matrix and held as a drop in the bend of the dental pick. It will flow off when touched to the work.

Figure 7. Everything must be done in a quick but fluid motion under the microscope. This is a dry run to visually locate everything so there will be no searching to bring the pick into the field of view during the real thing. The object, in this instance, is to fill the void seen at the sharp end of the pick. But the same method is used in filling cracks. The specimen rests on a sandbag made of denim.

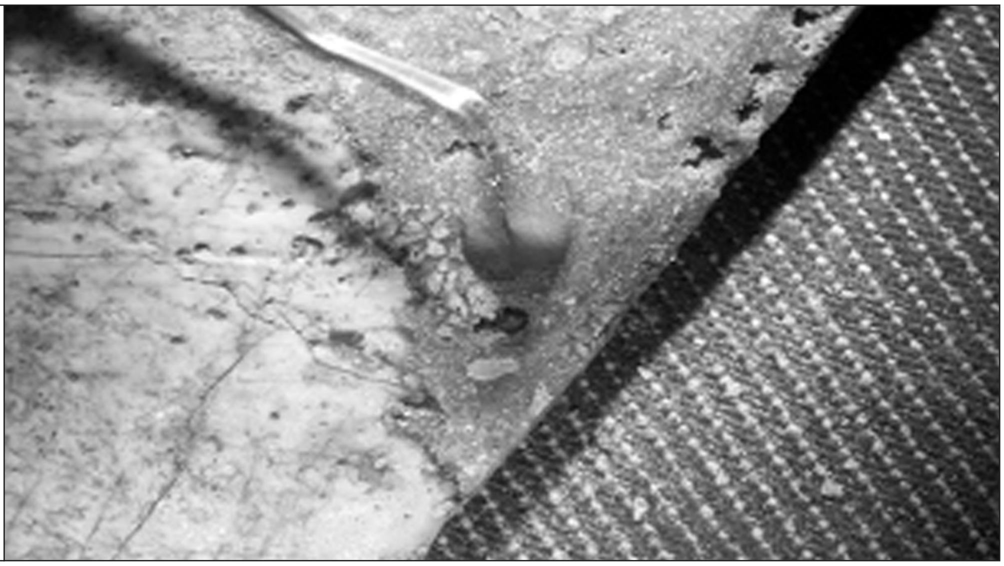


Figure 8. The placement sequence begins and runs through plate number 15. For the observer seeing this as it happens, understanding of the procedure is intuitive. It is a little harder to convey in words and pictures. Here, the pick is brought over the target area with the drop of mixed resin and matrix hanging below it but not touching the work. On contact, surface tension takes over and drains the drop off the pick at the point of contact. So the batch is wasted if it touches down at the wrong spot.

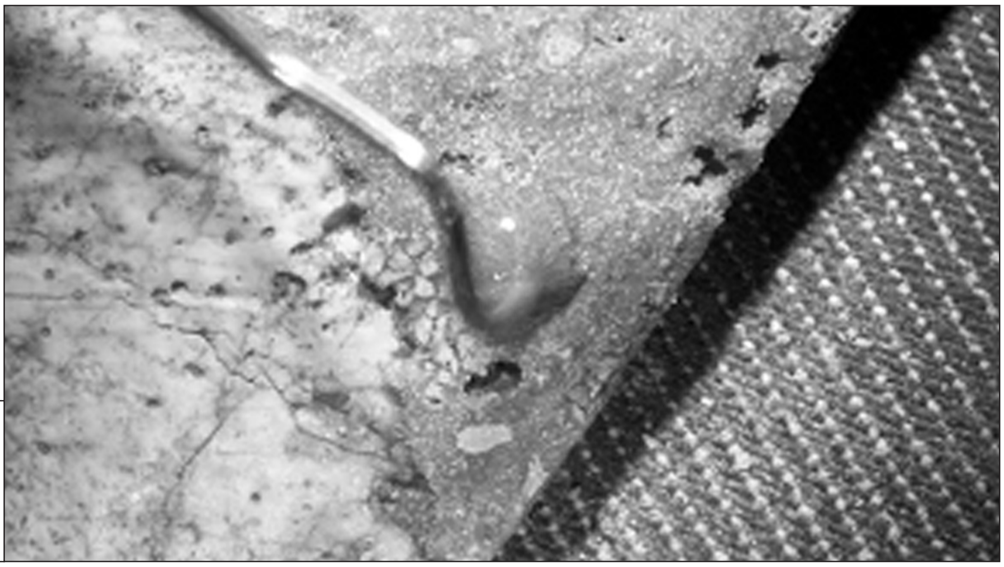


Figure 9. Homing in with the drop of mix on the pick.

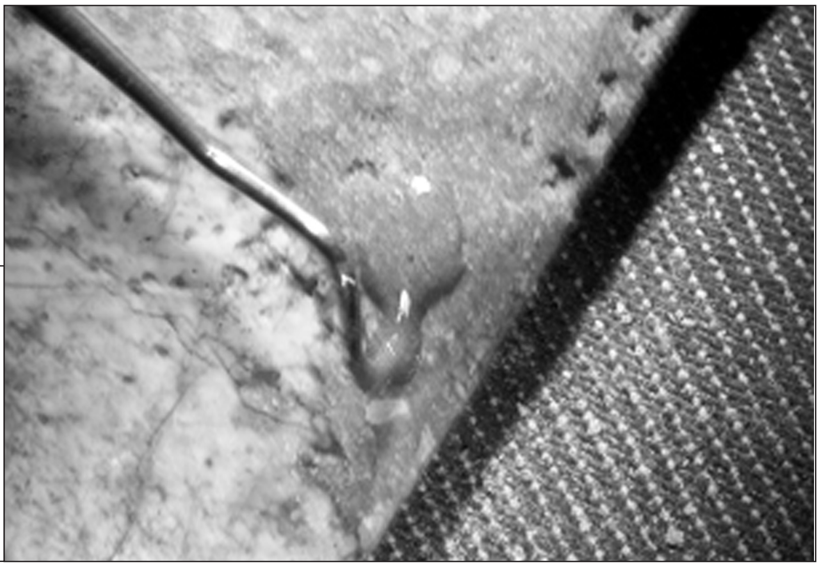


Figure 10. Contact is made and in the same motion the pick is moved towards the void so, in the second or two remaining, the fluid will fill it from the bottom up as it flows in, and avoid trapping air.

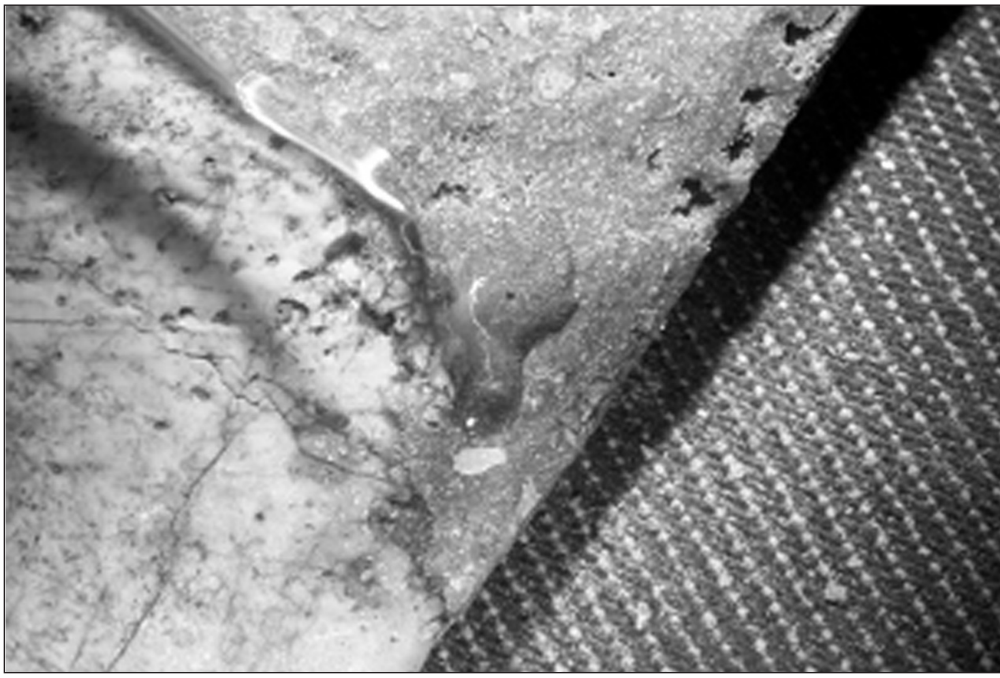


Figure 11. The pick slides along in contact with the work so the maximum amount of fluid will transfer from it.

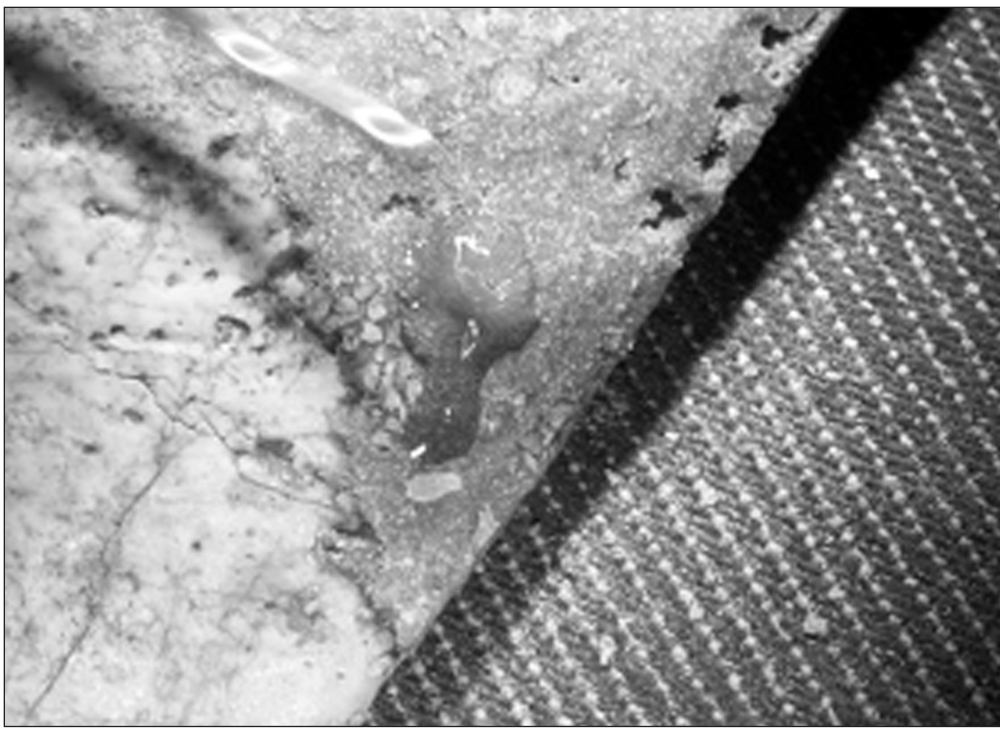


Figure 12. The pick lifts out of the fluid.

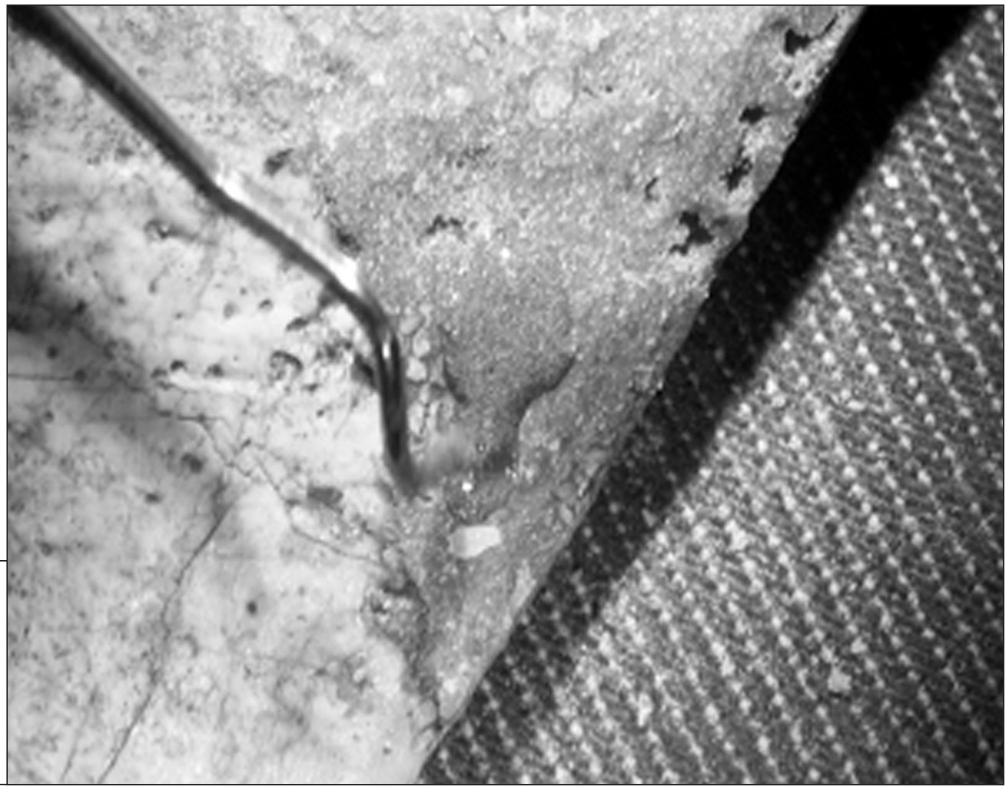


Figure 13. The pick recontacts the fluid meniscus to pull it a little into a better position while it is still flexible.

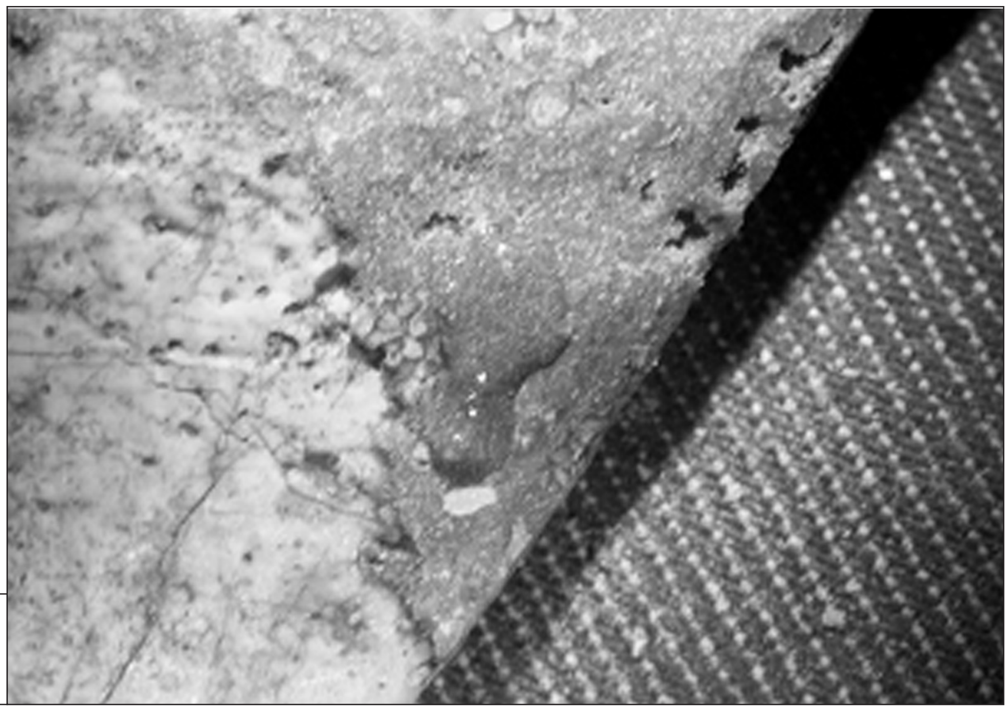


Figure 14. The fluid goes into the gel stage.

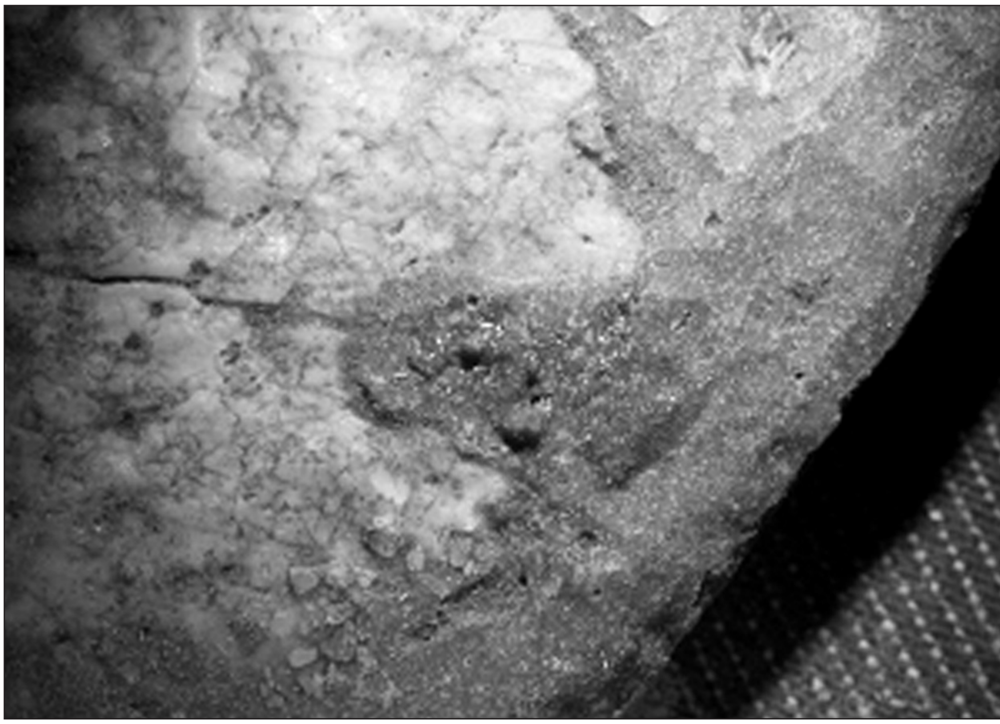


Figure 15. The resin has fired and the mixture now fills the hole and has shrunk in volume. This happens in an instant as the reaction reaches a critical point and you can see the mixture harden, shrink, and bond all at the same time. It will appear that nothing further happens, but, as with all resins, the real full cure takes a week or so. After that it is very stable and will be noticeably easier to machine.

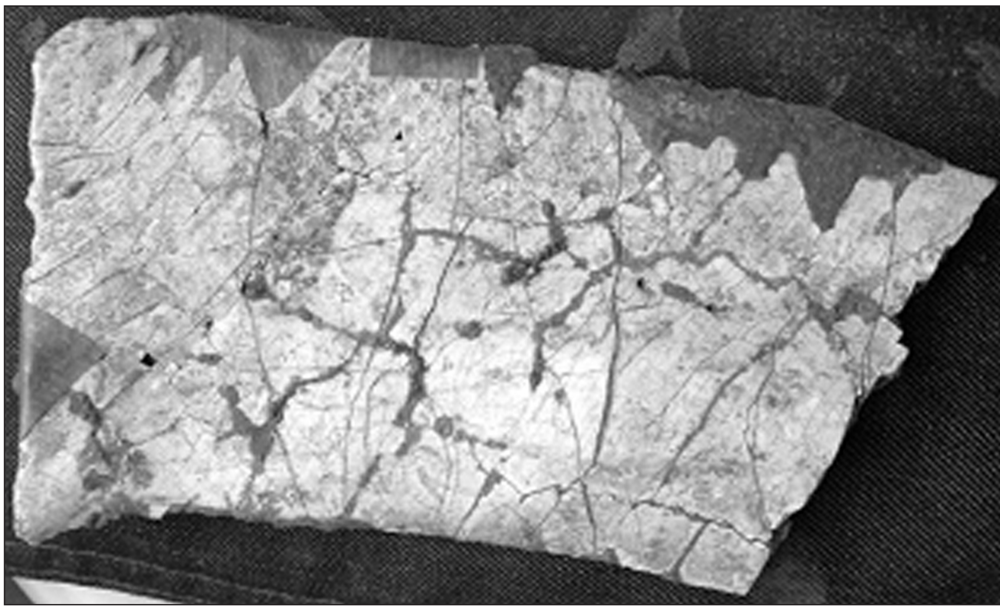


Figure 16. Ventral scute showing masking tape (on left edge and left half of top edge) used to contain the filler during multiple applications on the edges of the piece. There is a slight drawback in that the mastic residue from the tape has to be scraped off under the microscope. But that is far less time consuming than trying to do it without the tape.

Figure 17. The dorsal surface of the same half-scute showing the uneven surface of the filler from multiple applications. (bottom edge)

Figure 18. The excess filler must now be carved away. The blur in this picture is a spinning, 1/8 inch shank, single cut, oval head, carbide burr chucked in a pneumatic pencil grinder. This is used for roughing-out or bulk removal. If you always keep it moving in a circular pattern and start doing this in the air before touching down, you can produce a nice even surface like that in the right hand third of the image. But if you ever stop it will dig a divot like the one under the burr. This takes practice that should not be done on real specimens.

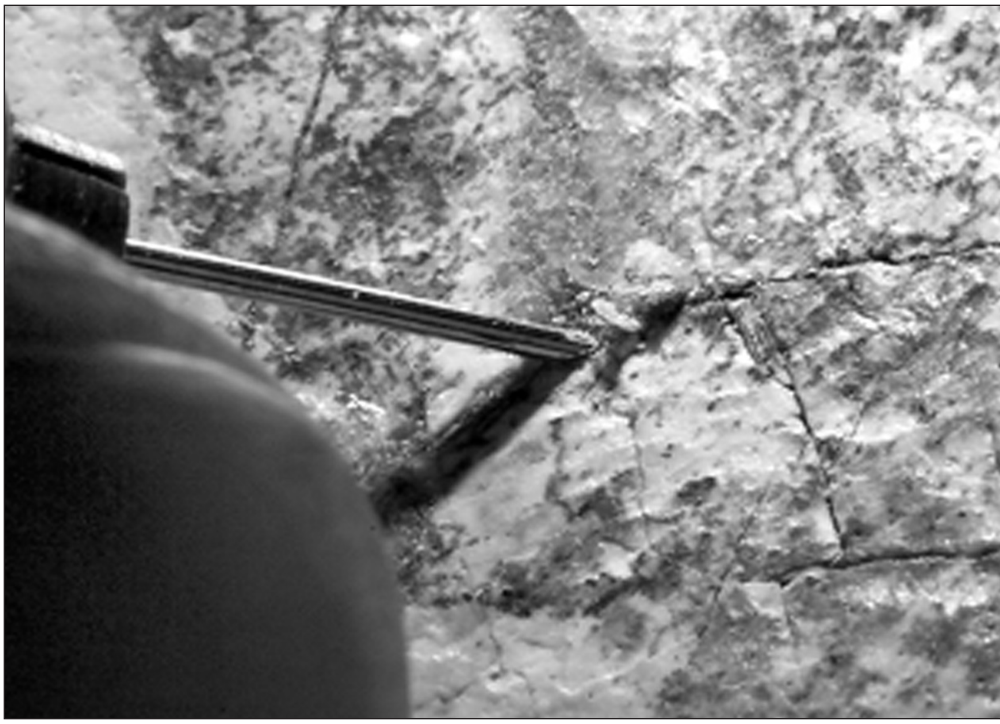


Figure 19. The final carving is done by hand with sewing needle ground to a chisel edge and chucked in a pin vise. We use at least four because you need to have a selection ground to various angles to accommodate carving in high-relief areas of the bone like the ornamentation. The chisel is floated across the surface and carves away anything, not bone, above it. Here it is pulled back slightly from trimming the excess filler in a crack.

Figure 20. The needles are sharpened on this diamond impregnated rubber wheel that is mounted on a miniature Foredom bench grinder. The wheel rotates away from the acute edge and final touch-up is done on silicon carbide wet or dry sandpaper 1000 grit or higher.

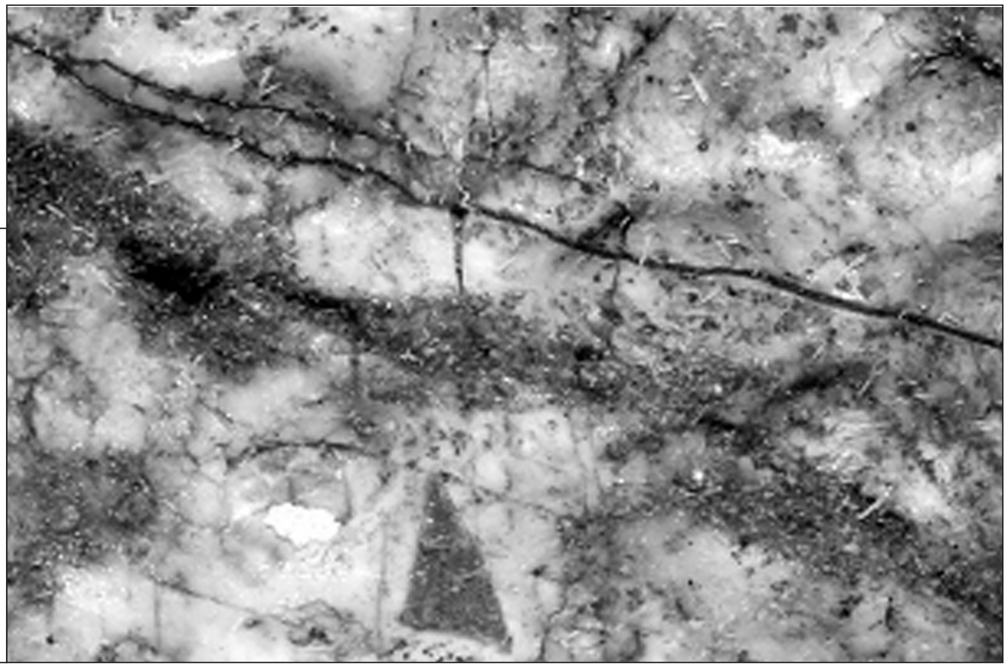


Figure 21. Pieces are glued together with straight cyanoacrylate (PaleoBond 1500) and all the gaps in the joint are then bridged with the filler. This shot shows a glued and filled joint not yet carved down. It's just above the triangle of masking tape and just under a naturally filled crack running parallel to it. You also see the "sawdust" from using the grinder for bulk removal.

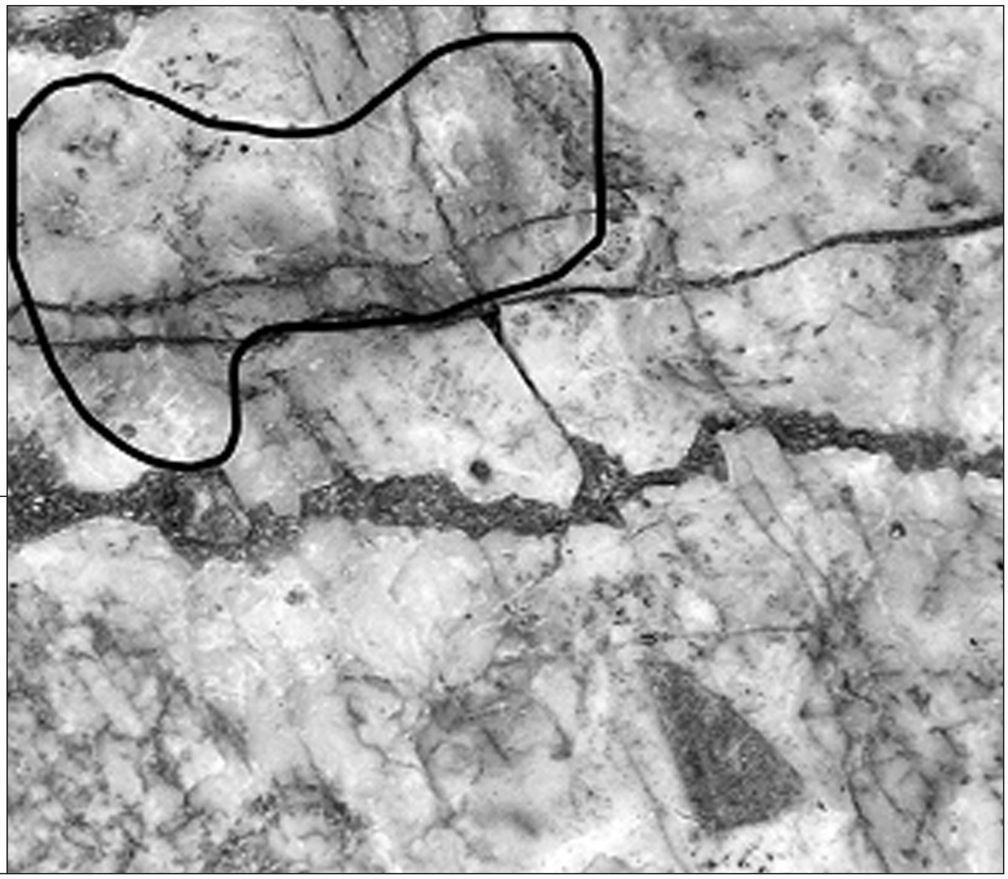


Figure 22. The same shot after the filler has been carved to surface contour. The area in the black line has old consolidant that will be removed the same way. The triangle of masking tape seen in Fig. 21 is also seen here near the bottom of the photo.

Figure 23. The complete scute in dorsal view. There is a sharp, definite line of demarcation between bone and filler. All voids that are not part of the original morphology are filled and there is nothing above the bone surface. The filler is also very close to the color of the natural matrix-filled cracks while still being distinct from them. This removes as much visual ambiguity as possible, making the piece easy to read.

Figure 24. Plaster cradle to support the specimen in collections. The cut-out allows thumb and forefinger to grasp the piece for easy removal and replacement.

Figure 25. The specimen in its cradle.

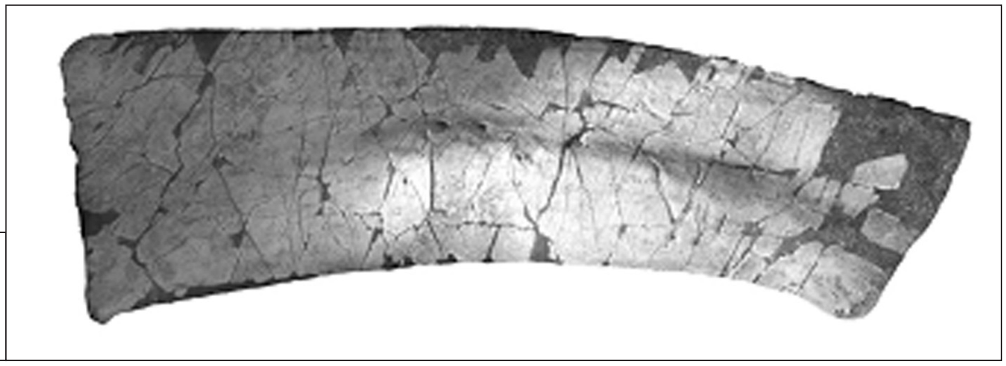


Figure 26. Ventral view of the complete scute.

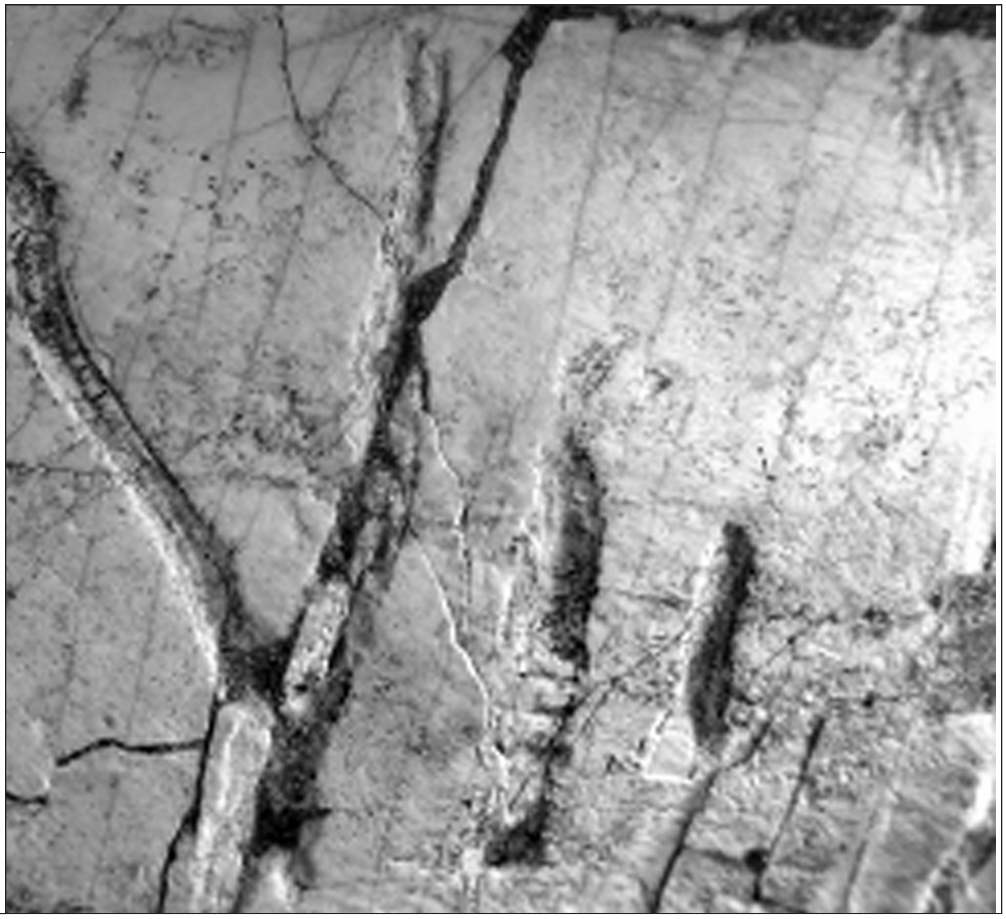
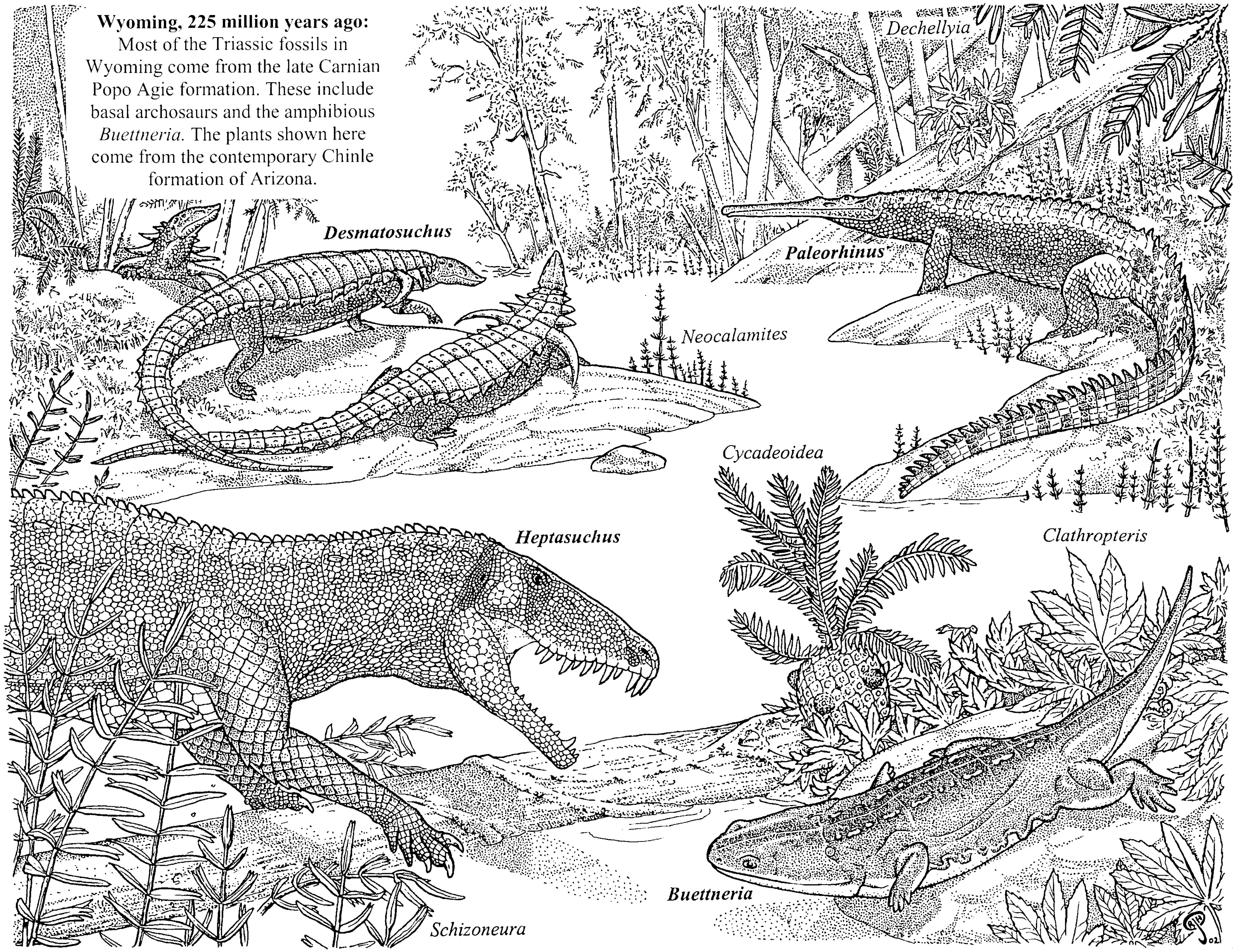
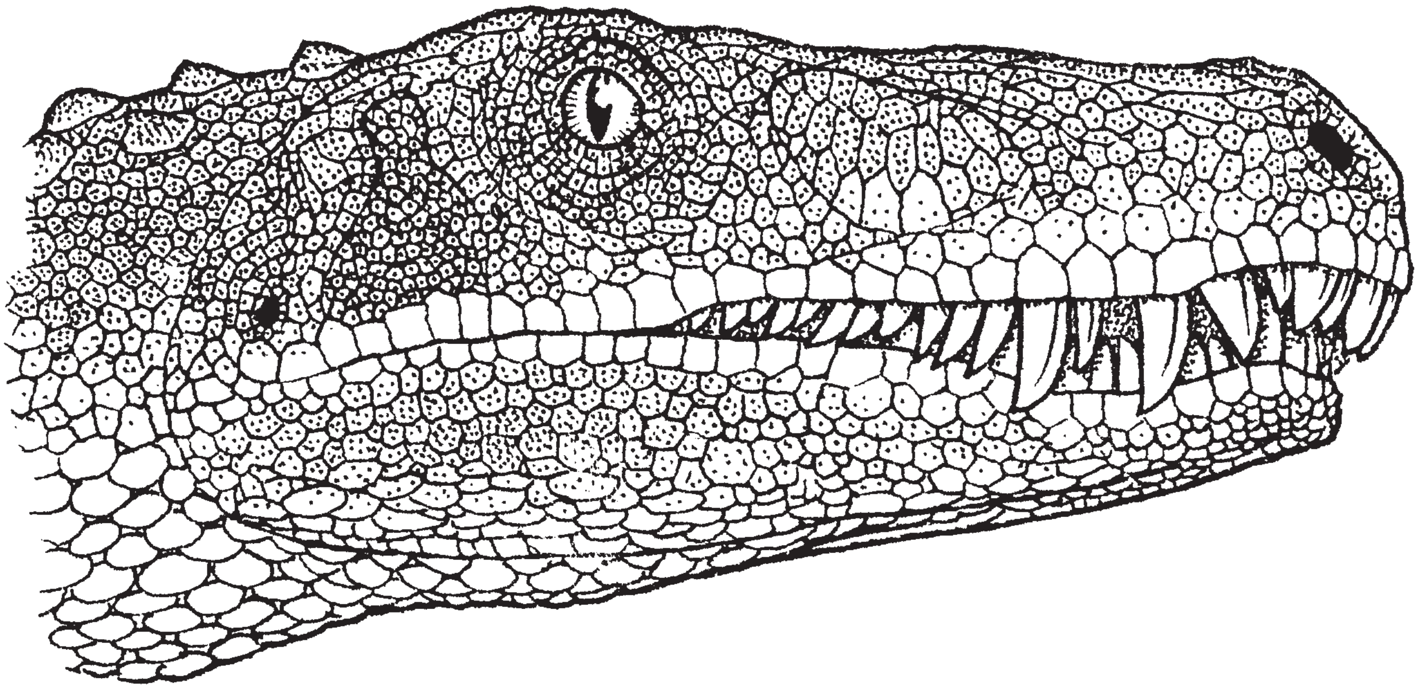


Figure 27. These grooves were gouged into the bone on that same ventral surface. The clean rounded edges with no fracturing and the compression rather than cutting of the cortex suggest that they were made when the bone was fresh, before fossilzation. We've interpreted them as tooth-marks. Removing as much visual ambiguity as possible in this preparation process greatly simplifies examination and interpretation. You can see that some of the post-depositional cracks go right across these grooves and have been filled and carefully carved to contour so they can be distinguished from them. Any consolidant covering the surface would have obscured the difference to some extent. And, in fact, the grooves were not recognized until after this treatment



Wyoming, 225 million years ago: Most of the Triassic fossils in Wyoming come from the late Carnian Popo Agie formation. These include basal archosaurs and the amphibious *Buettneria*. The plants shown here come from the contemporary Chinle formation of Arizona.



Herrerasaur (*Herrerasaurus ischigualastensis*)

Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Matthew Brown – Division of Resource Management, Petrified Forest National Park

Preliminary Report on Professional Development in Vertebrate Fossil Preparation

Matthew Brown, Division of Resource Management, Petrified Forest National Park*

Introduction

Common complaints by workers in the field of fossil preparation include lack of appropriate pay, lack of acknowledgement, lack of safety controls, and lack of respect from the greater paleontological community (sometimes represented by the phrase "just a preparator"). Some of these issues have persisted since the early days of paleontology (Brinkman, 2009). Many of these complaints can be addressed through the process of further professionalization of the field and continuing professional development of the individual.

In addition to promoting the individual worker, another aspect of professionalization is guaranteeing the quality of work produced. According to Horner (1994), "Vertebrate paleontology… is a field of study where the accuracy of collection and preparation of specimens and data is the foundation that determines the ultimate quality of the science."

This perspective highlights the fact that on the frontlines of data collection, the role of the fossil preparator is critical, fundamental to the quality of the science of paleontology. Therefore we must hold ourselves to the highest standards that we can create. Most preparators do that individually, but how do we ensure that goal as a profession?

Bodies responsible for the care of fossils call for skilled preparation, for instance, the Society of Vertebrate Paleontology Bylaws Article 12 Section 3 (SVP, 2002) states "Fossil vertebrate specimens should be prepared by, or under the supervision of, trained personnel." The National Park Service (NPS, 1991) goes one step further, Directive 77-Paleontological Resource Management Policy states that, "Fossil preparation is a specialized subdiscipline of paleontology and preparation should only be performed by professionals with suitable training."

These statements lead some to ask, who qualifies as trained? What does that "suitable training" even mean? As a group of content specialists, it is up to our community to define "suitable training." This report will briefly outline some methods used in this field to date, present an overview of professional development in selected similar fields, and suggest one model for continuing development within vertebrate fossil preparation.

Existing Strategies

Currently there is no overarching plan to professionalize the field that is well accepted or enacted by a majority of fossil preparators (Brown and Kane, 2008). Attempts to individually control quality and professionalism are widespread, and include management or institutional training, workshops and sessions at professional meetings, and publishing.

Preparators are responsible not only for exposing information about fossils, but also for minimizing loss of data. In most labs, a chief preparator or volunteer coordinator typically controls quality, in addition to the research staff for whose work the quality of data is ultimately dependent.

Some institutions have a formal training program, like the Denver Museum of Nature and Science, and a number of institutions have modeled programs on the DMNS. Typically these programs are geared toward volunteers, and weeding out early those without the long-term interest or ability to succeed in the lab (Carpenter, K. pers comm. 2008). For the most part, the skills required to prepare fossils can only be gained by doing; making an 'apprenticeship' of sorts the primary factor in learning. Theoretical knowledge is typically passed on by word of mouth.

The Field Museum of Natural History issues a skills test to volunteers and new employees before they can work in the laboratory (Bergwall, 2008). Called "the prep test," this examination was instituted to evaluate initial skill level and potential for new workers. Some lab supervisors, including this author, issue a similar skills examination before accepting new volunteer positions.

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While there is a large body of information available regarding preparation methods, it can be difficult for a novice preparator to locate, and more importantly, to evaluate. It may take many years to build a suitable reference library.

Preparators currently share information through conduits like the Society of Vertebrate Paleontology (SVP) Preparators Pages at the vertpaleo.org website, and Society for Preservation of Natural History Collections publication series. For example, a number of recent SVP platform and poster presentations are available on the SVP website in pdf format, in addition to an FAQ section and Short Papers.

The existence of the SVP prep committee itself is due to the hard work of many people who cared deeply about the importance of fossil preparation. The resulting website, preparators demonstration table, grant money, and promotion of the prep symposium to a regular session at SVP meetings are great advances professionally.

In April of 2008 Petrified Forest National Park hosted the first of an annual series of preparation-specific conferences, with locations already set for 2009 and tentative for 2010. There is also a rapidly growing internet presence in vertebrate paleontology preparation, through websites, mailing lists and discussion forums, including the SVP Preparators Resources page, www.fossilprep.org, and the vertebrate preparation discussion "preplist."

Professional Development in other Fields

Looking at other professions as models, steps can be identified to institute further professionalization of fossil preparation. Though there are many relevant organizations, two professional organizations from similar fields have been selected to elaborate upon as models for development; the American Institute for Conservation (AIC), and the Association of Medical Illustrators (AMI). The work of the objects conservator closely mirrors the duties and responsibilities of fossil preparators. The AMI represents a highly specialized group of artists whose work is similarly critical to the medical profession, in both research publication and visual explanation to the layman.

AIC—The AIC has developed a system of standards and code of ethics (AIC, 1994) to ensure and enhance professionalism in their field. For example, in order to define the Conservator, the AIC created a task force to consider "an individual at the very inception of his or her professional career… to identify the competencies that… can be regarded as fundamental to the definition of the conservator." (AIC, 2003:4).

This task force defined 12 essential competencies, and emphasized that "possessing each competency is not in itself sufficient, but that to be a qualified conservator one must utilize these competencies synergistically to maintain the standards of practice required by the profession." (AIC, 2003:5). Beyond having a basic knowledge in these areas, it is critical that the worker posses a proficiency in them.

The AIC also publishes the Journal of the American Institute for Conservation (JAIC), and hosts conferences and workshops for the benefit of conservators. Membership in the AIC takes place at several levels, as a way to offer additional credential to the individual conservator.

AMI—The Association of Medical Illustrators follows a similar model, existing to promote the field of medical illustration, encourage the individual illustrator, and offer increased quality control to the field as a whole. The AMI also supports a Board of Certification that offers evaluation and qualification of practicing illustrators. This board "is an independent body that administers this voluntary certification program designed to provide the practicing medical illustrator with the recognizable and valuable CMI (Certified Medical Illustrator) credential." (AMI, 2008).

Through these methods, the professional bodies are acting to help ensure the level of quality and professionalism available to those who employ or utilize the services of working professionals, as well as increase the benefits available to the professional in compensation for their skills and knowledge. These groups can provide guidelines for minimum safety controls for employers, to ensure the best interest of the institution, employees, students, volunteers, and possible customers.

Graduate programs also exist at numerous trade schools and universities for both of these professions. The professions define what a 'trained' or competent practitioner is, aid in the creation of training programs, and evaluate professionals practicing in the field.

Proposed Model for Vertebrate Fossil Preparation

Support of an Organization—Essential to the success and development of other professions is the existence of a professional organization. The professional body (or bodies) is the primary vehicle through which development and regulation takes place. Through organization of conferences, continuing education programs, development of a code of ethics, and enforcement of those standards and ethics, the organization thus raises the visibility and esteem of the profession. Due to increased educational opportunities, both the number of professionals and the quality of work then increases, making the individual more attractive and competitive in their institution and the field.

To date, the SVP preparators committee has played a vital role in professional development of preparators, and has the mission to “coordinate activities relevant to preparation of fossils at the annual meeting and during the year through a listserv. These activities include a preparation symposium or session and staffing of a preparation demonstration table at the annual meeting and coordinating the information about preparation on this web page of the SVP website” (www.vertpaleo.org). A separate body would not presume to replace the efforts of the preparators committee, but to support them and reinforce them. While it is incredibly important to have a group working within the society to represent preparators, it is equally crucial to have an outside advocacy group as well, that can promote both the individual and the community.

This report follows others (e.g. Brown and Kane, 2008; Madsen 2008) in advocating the creation of a professional association. This “Association of Fossil Preparators” (AFP) would work parallel to the SVP preparators committee with the goals of increasing the visibility and esteem of the fossil preparator, organize preparation specific conferences, facilitate training and continuing education, provide standards and recommendations to employers, endorse certification programs, and advocate standards of professionalism and competency.

Training—Informal training options should be supported, continuing programs similar to those at DMNH and many other labs. Advances in formal training programs should be pursued as well. The author has recently participated in two such programs, one in partnership with Petrified Forest National Park (PEFO) and California State University, San Bernardino (Brown et. al, 2008), and another as a contractor for the FossiLab Volunteer Training program at the National Museum of Natural History (Brown et. al, in prep). Both of these programs developed a semi-formal curriculum, and sought to impart both theoretical knowledge and training in mechanical techniques. Participation in the NMNH training program is necessary for new volunteers, while interns in the PEFO/Cal State program received both internship and science independent study credit.

Future work with higher education institutions is encouraged to develop accredited degree programs and apprenticeship opportunities.

Professional Certification Program—One avenue for raising the profile and esteem of the individual professional is through the establishment of a professional certification (Kane and Brown, 2008). Using the standards established by the professional society, a certification board is appointed or elected, who develop requirements for eligibility, and create a method for testing those requirements. While there is much theoretical knowledge to master in preparation, proficient mechanical skills are most important to success at the workbench. Receiving an AMI certificate requires a review of the candidate’s professional portfolio by a panel of expert referees. This review process can easily be adapted to fossil preparation.

According to the National Organization for Competency Assurance (NOCA), a body originally created by the U.S. Congress to develop standards and certification for Health and Human Services, certification of professionals promises (NOCA, 2009):

- Higher wages for employees in the form of bonuses, education assistance or higher salary.
- A more productive and highly-trained workforce for employers.
- Prestige for the individual and a competitive advantage over noncertified individuals in the same field.
- Enhanced employment opportunities.
- Assisting employers in making more informed hiring decisions.
- Assisting consumers in making informed decisions about qualified providers.
- Protection of the general public from incompetent and unfit practitioners.
- Establishment of a professional standard for individuals in a particular field.

This process is especially relevant for fossil preparators, since the field currently lacks any type of credentialing that reflects the skills and knowledge required for competency. A model for certification of preparators based on relevant similar professions would begin when qualified members of the preparation community create a board of certification, develop eligibility requirements, and write and update an examination of skills. Then a professional, who has reached a certain level of work and educational experience (e.g. two-seven years), would submit to a standardized written examination of knowledge, and assemble a portfolio of specimens (two or three), which would include photo documentation of the preparation process, along with a written rationale for methods applied. The applicant would describe chemicals and methods used in the process; whether they adhere to professional standards; and, if they deviate from accepted standards, provide a justification for the use of nonstandard methods. Upon successful scoring of the exam and portfolio, the applicant would be designated as a board certified fossil preparator. For example, a certified fossil preparator should be able to demonstrate knowledge of basic geology and biology concepts, knowledge of vertebrate anatomy, (ed.'s note: and invertebrate anatomy?), understanding of conservation principles, familiarity with chemical properties, and the ability to properly document specimen history.

Certification would be renewed periodically (e.g. three-five years), conditional upon completion of a specified number of continuing education or professional service credits. For example, presentation at a professional meeting, publication of a technical paper, attending or teaching workshops, field work, x number of hours of professional employment, college level classes, teaching experience, public outreach, etc., would all qualify for credits. Renewal ensures that the preparator is maintaining a professional skill level, keeping up with current preparation theory, and contributing meaningfully to the development of other preparators.

Conclusion

While it is important to note that many institutions already address issues of training and quality control individually, advances for workers will develop most quickly if a body exists to codify such solutions, to evaluate them regularly, and to work to make them universal. The experience of other occupations readily demonstrates the benefits to this process. Not only would there be eventual increases in salary and professional esteem, but quality of care of fossil specimens, our primary duty, would also improve.

An ideal simplified model for the preparation community includes a professional organization operated solely to represent the interests of the profession; standardized formal and informal training opportunities for professionals, students, and volunteers; and field-wide methods for evaluating and certifying competent preparators. Details of these elements will be greatly expanded upon in future work, and are subject to the input of the community as a whole. The author strongly encourages input from the community.

The steps outlined in this document are not intended to take place immediately, and concrete results would be expected over a period of years. Additionally, all aspects of the process are not required to be in place or polished at inception, professional development is very much an evolutionary program, the most important factor being that it has a beginning.

Acknowledgements

Thanks to Amy Davidson for comments on early versions of this draft, and to JP Cavigelli for editing this volume. Extensive conversations with William Parker and John Kane led to many of the ideas presented here, and discussions with many preparators and professionals in other fields have helped to refine them.

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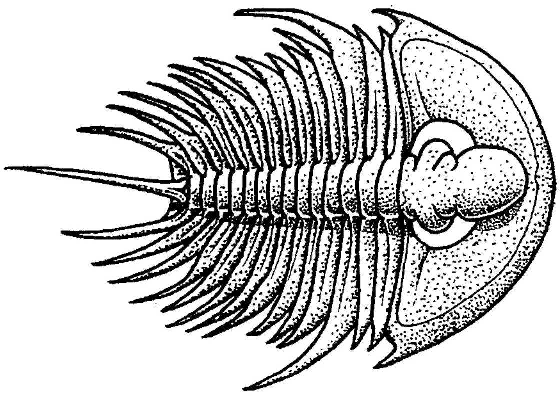
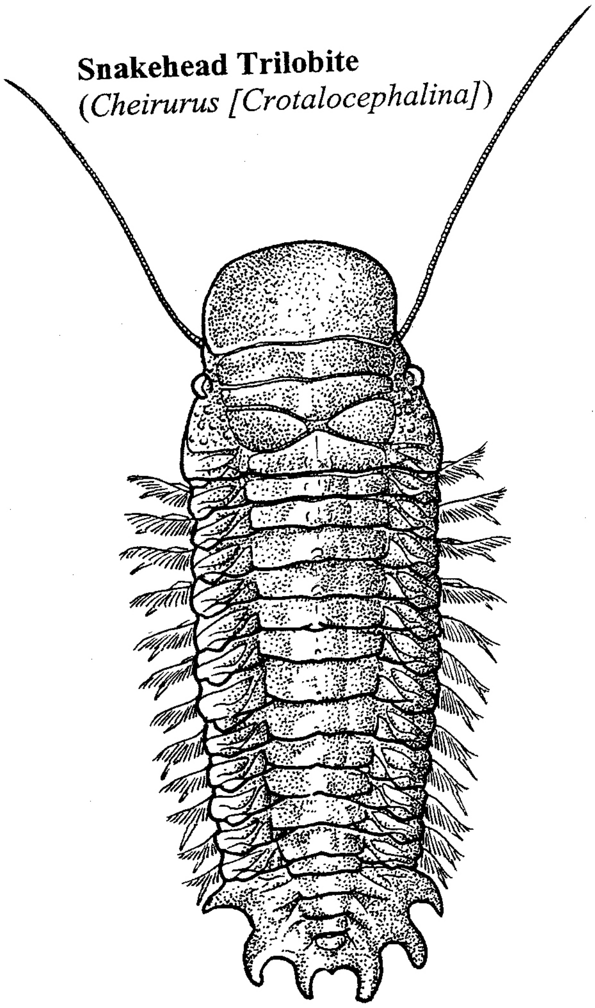
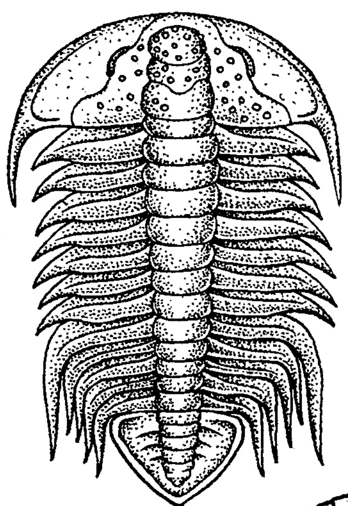
Trilobite Gallery



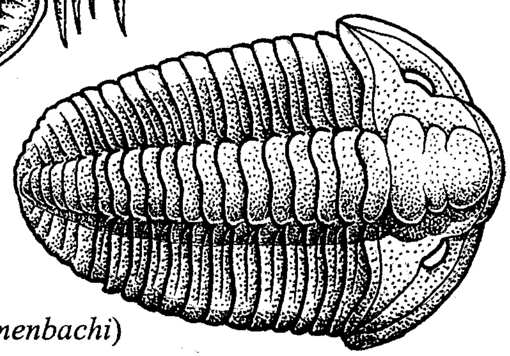
Pioche Trilobite
(*Olenellus gilberti*)



Snakehead Trilobite
(*Cheirurus [Crotalocephalina]*)

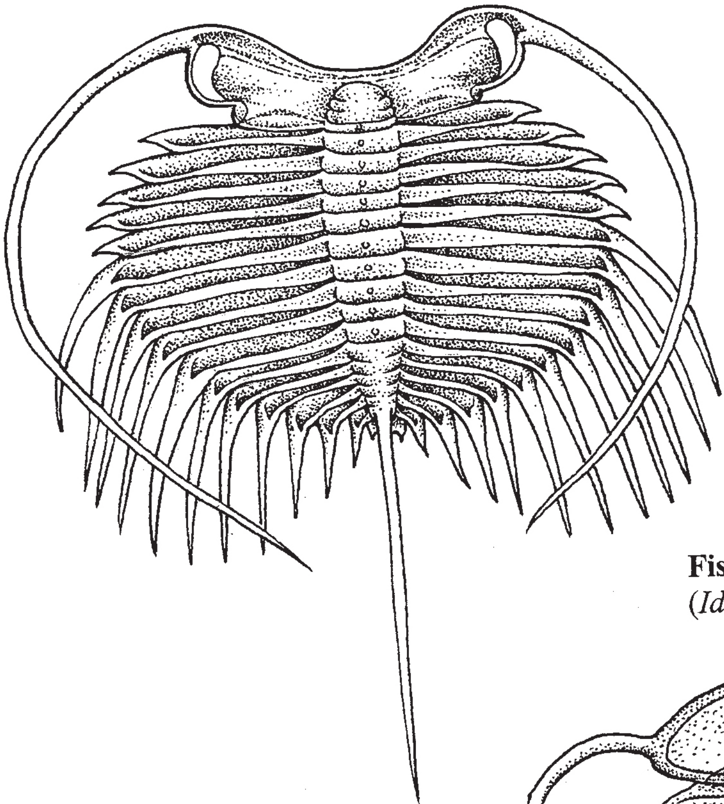


Idaho Trilobite
(*Idahoia*)

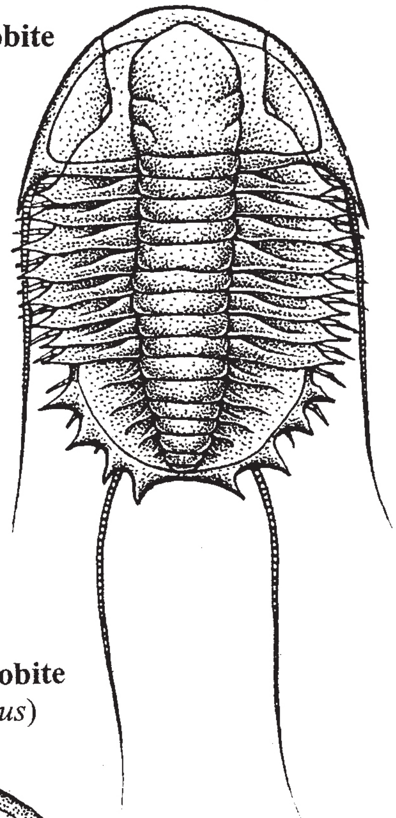


Dudley Locust
(*Calymene blumenbachi*)

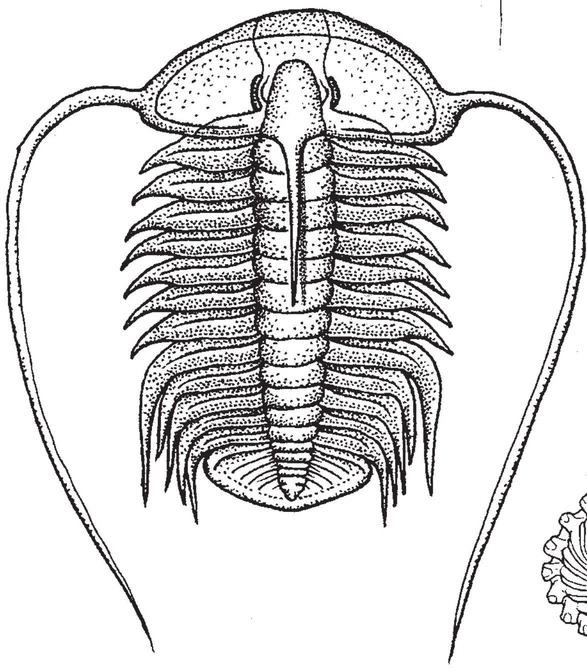
Comb-tail Trilobite
(*Ctenopyge*)

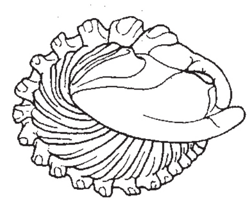


Burgess Shale Trilobite
(*Olenoides serratus*)



Fish-hook Trilobite
(*Idahoia hamulus*)





Roly-poly Trilobite
(*Flexicalymene meeki*)

Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Kathy Hollis - University of Colorado Museum of Natural History

Collection Registration Issues in the University of Colorado Museum of Natural History Paleobotany/ Invertebrate Paleontology Collection

or

Why is this Fossil Sitting in my Office and Not in its Cabinet Where it Should Be?

Kathy Hollis, University of Colorado Museum of Natural History, University of Colorado, Boulder, Colo.

Every collection should be managed based on best practices and should have policies and procedures in place to keep the collection neat and tidy. These policies and procedures are easy to implement when registering new material, but most likely there are rogue specimens in the collections that break some or even all of the rules of a collection's scrupulous registration procedures.

At the very least, specimens should have the following documentation:

- Records concerning the acquisition of specimens: This includes who brought them to the collection, when they were brought, what type of material was brought, and which staff member accepted the material. Acquisition records should also include who collected the specimens and where they came from geographically and temporally. If a permit was required for the collection of the specimens, there should be a record of the collecting permit. Information relating to acquisitions (e.g. donor records, copies of collection permits, etc.) should be kept in the acquisition files.
- All metadata relating to the individual specimens: Metadata are data associated with data. In the case of collections, an individual specimen is considered to be the datum, and the information related to that specimen – catalog number, scientific name, specimen description, collector, etc. – is the metadata. Specimen metadata about should be recorded in three places: (1) a hard copy of the catalog (ledger or catalog book); (2) a digital copy of the catalog (an electronic collection database); and (3) with the specimen on specimen labels. Specimen labels should be the only paper kept with the specimens, and all labels relating to that specimen should be kept. Labels make great paper trails. Handwriting and changes in specimen identification may help to untangle registration issues with that specimen that may arise in the future. Deletions of metadata on the specimen label or in the hardcopy of the catalog should be made as a one-line strikethrough so the old information can still be legible. Also, specimen numbers should be written on the specimen with a letter designation (e.g. UCM 1234) in case your specimen should ever get separated from your collection. If a specimen is removed from its cabinet, a check out label should be kept with the specimen and another label should be kept in the specimen's place in the drawer until the specimen is returned. Field notes, photos, and other papers should be kept with the material's accession file and not in specimen cabinets.
- Additional records: Records such as loan/borrow records, preparation records, deaccession records, repository agreements, correspondences and any publications concerning the collection, which should be kept under their own filing system.

Documenting specimen data and activities that related to acquisitions and specimens is vital to understanding what should happen if problems arise such as missing specimens, illegally donated specimens, or misplaced specimens.

The registration problems I commonly encounter are misnumbered specimens, incorrectly documented loans and deaccessions, material considered orphaned or "found in collections," as well as specimens with no number or documentation. Correcting some of these problems has been relatively straightforward. Some problems, however, have taken several weeks of sleuthing through paperwork and contacting former museum curators long since retired.

Misnumbered specimens are probably the most common and easiest issue to resolve. These specimens include two different specimens assigned the same number, one specimen from a specimen lot is figured but is not assigned a separate or new number, and specimens that contain a part and counterpart are assigned two separate numbers. Misnumbering problems are resolved by verifying the correct number on the label, in the database, and in the hardcopy catalog. For figured or type specimens, any publications that reference the specimen in question should be checked as well. When it is decided that a specimen needs a new number, the correction should be made on the specimen, on the specimen label, in the catalog book, and in the database. If a specimen was published and the number written on the specimen was incorrect, the specimen records should make note of the error and should cross-reference the correct records.

Orphaned collections, or specimens "found in collection," refers to uncataloged material that may or may not belong in the collection. Often, this kind of material was part of a personal research collection of a former researcher or curator and will have some documentation. Determining whether orphaned collections should be kept and cataloged first requires determining who has legal title to the specimens. It may be the case that some of the material was borrowed from other institutions and not returned. Sometimes the collection has legal title to the specimens, but the material is out of the scope of the collection. In this case, the material should be transferred to another collection or museum where the material is more relevant.

The most tragic registration issue is specimens with no number and no documentation. Without documentation, these specimens have little or no context within the collection and are little more than aesthetic objects. One may be able to identify a fossil's scientific name and guess about a specimen's age and locality, but not to the precision that is required for scientific research. Additionally, there is no proof that the museum actually owns the specimen. Did someone lend the specimen to the museum? Was it illegally collected and then donated to the museum? The only hope for documenting these specimens is stumbling across lost paperwork or files, therefore these specimens should not be transferred or disposed of. These specimens are best used for education and outreach, and should be housed separately from research specimens.

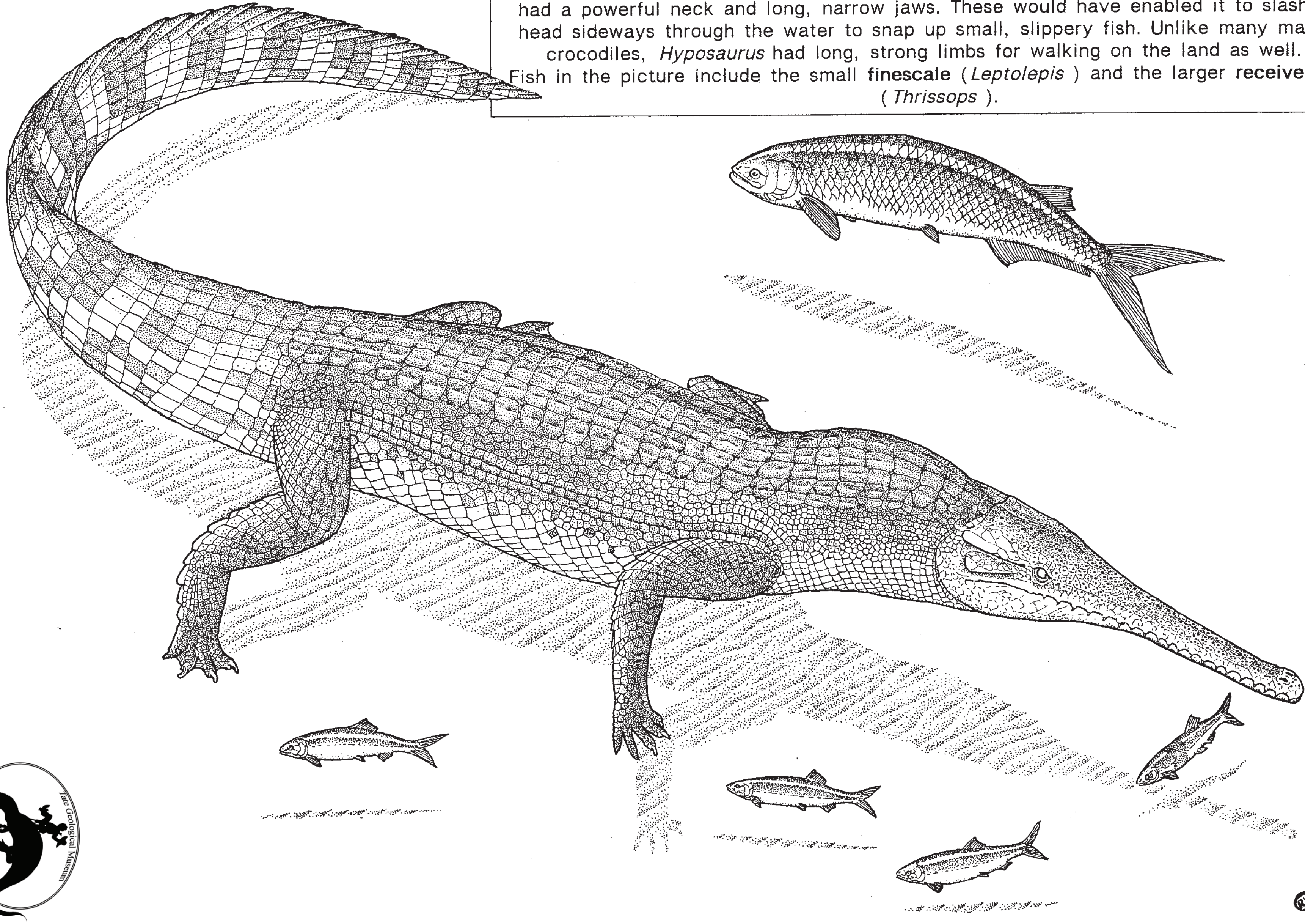
When fixing specimen data issues, I have the following recommendations that may help keep problem specimens from getting worse:

- Catalog and put away newly acquired specimens as soon as possible.
- Do not store problem specimens in office space. Keep one or two cabinets in your collection free to store registration projects.
- Post-its are easily lost, removed and confused. They should be used sparingly and temporarily (no more than a week).
- If you have registration projects that will take more than one week to complete, write out a plan of attack and keep it with specimens.

For the most part, specimen issues require case-by-case solutions depending on the issues. There should be no guesswork when it comes to making decisions about specimens. Thorough and organized documentation should guide collection managers' decisions on how to resolve specimen problems. Missing or poorly organized records may result in lost or misplaced specimens. Finally, care should be taken that, when specimens are removed from cabinets to be corrected or modified, they are corrected in an organized, well-documented, timely manner.

Tethyan Seacroc (*Hyposaurus* sp.)

During the upper Cretaceous and lower Tertiary, much of North Africa was covered by a vast, shallow sea, the **Tethys.** This was the home of *Hyposaurus*, a crocodile with several adaptations to marine life. The tail was deep and flattened for swimming, and the bony armour was reduced to help improve the flexibility of the body. *Hyposaurus* had a powerful neck and long, narrow jaws. These would have enabled it to slash its head sideways through the water to snap up small, slippery fish. Unlike many marine crocodiles, *Hyposaurus* had long, strong limbs for walking on the land as well. Fish in the picture include the small **finescale** (*Leptolepis*) and the larger **receiverfish** (*Thrissops*).



Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Andrew Bland - North American Research Group, Vancouver, Washington

Preparing Fossils in Concretions

Andrew Bland, North American Research Group, Vancouver, Wash.

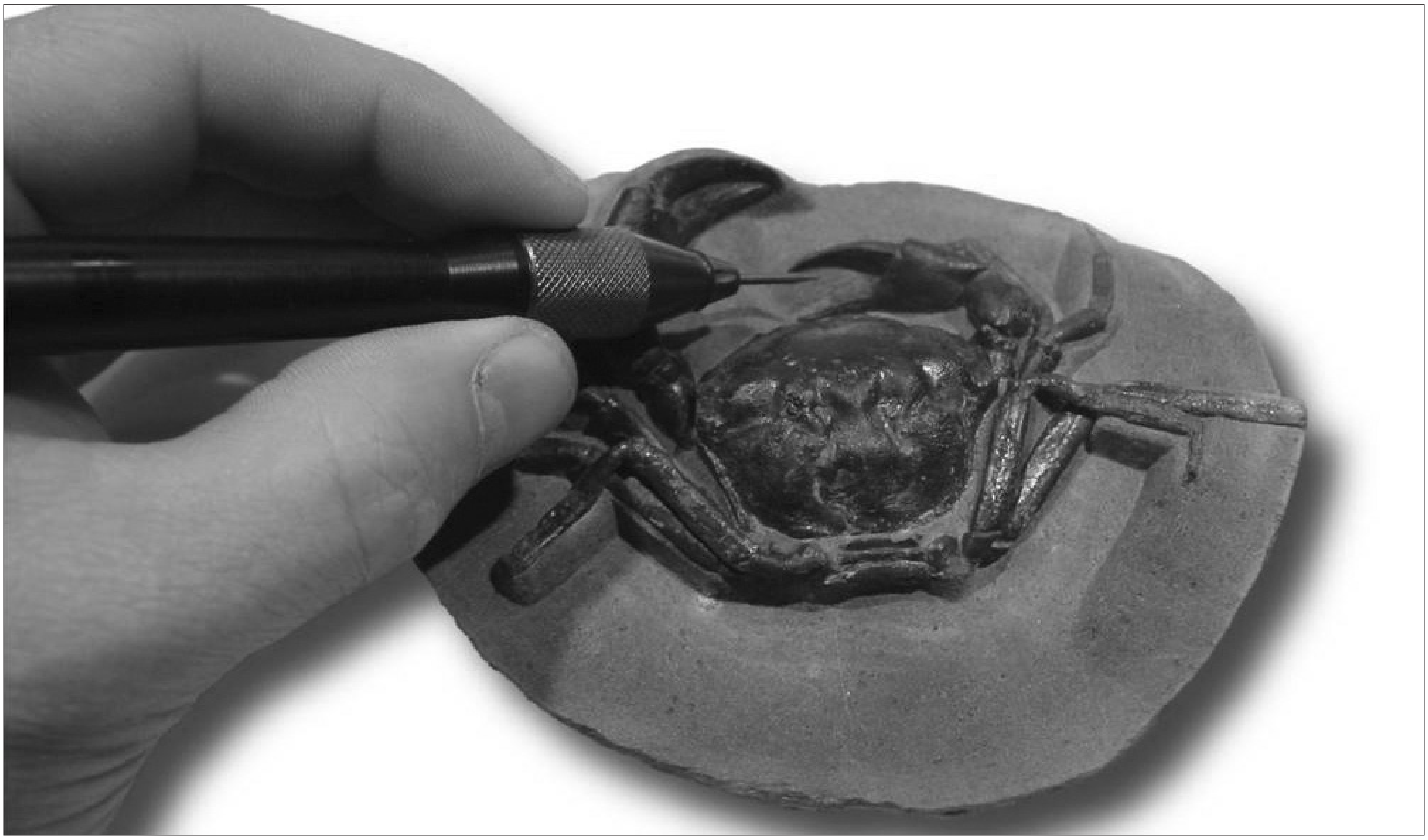


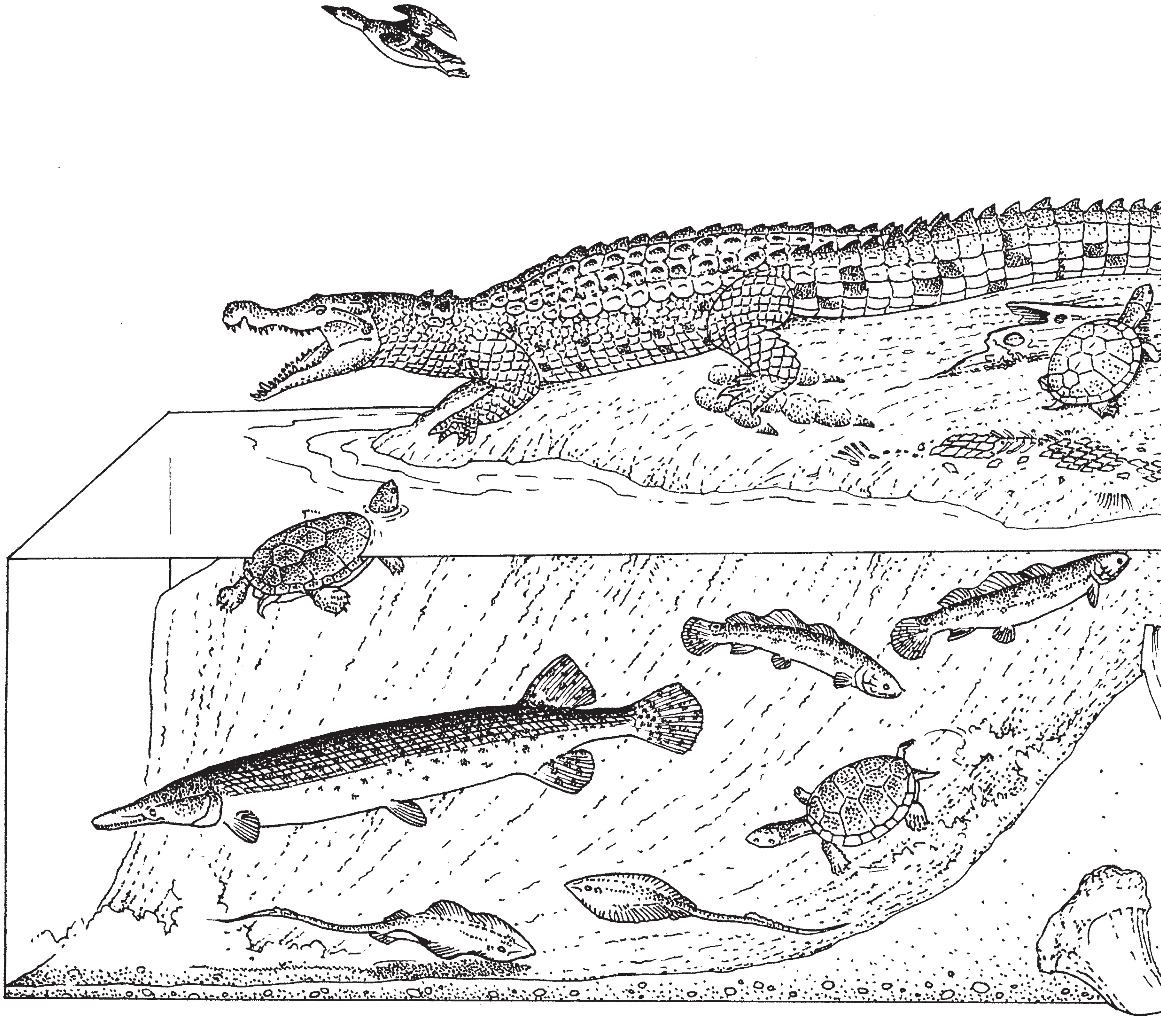
Figure 1. Adding final touches to a fossil crab (*Pulalius*) from the Pacific Northwest.

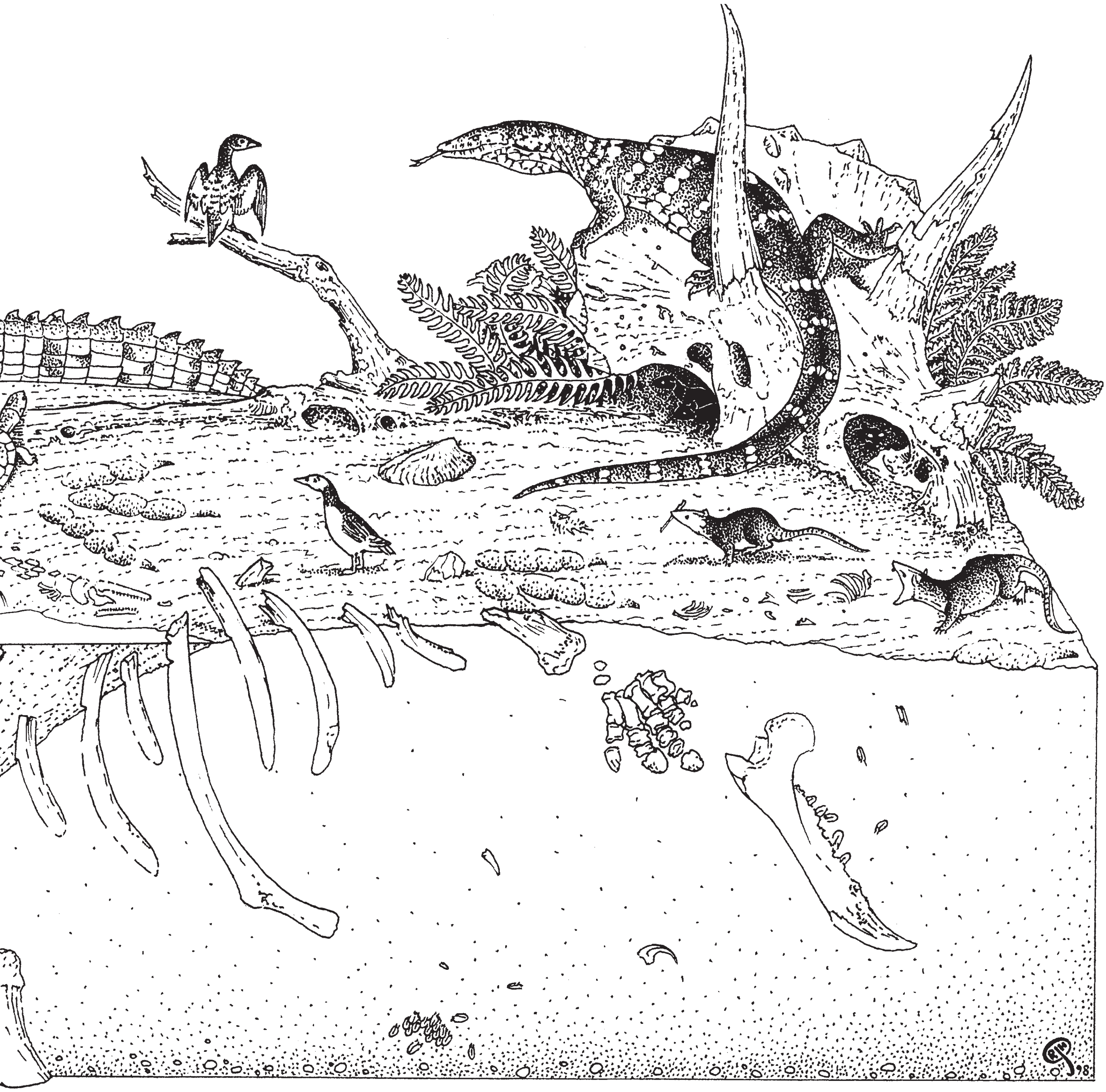
A concretion is a hard nodule of rock set in generally softer sediments. Some concretions are created during the decay of an animal, plant or other organism(s) in a marine environment. This occurs when a animal or plant is buried in sediment or trapped in a burrow on the ocean bottom where there is little oxygen.

As the organism decays, one byproduct, ammonia, is released into the sediment creating a halo around the organism. The ocean is rich in calcium carbonate. The ammonia and calcium carbonate react with each other and precipitate calcite. Precipitation is the formation of an insoluble solid from two solutions. Calcite is an insoluble crystal that locks in the sediment surrounding the organism creating the concretion.

Concretions are highly desired by paleontologists. The fossils that have been locked inside have been safely preserved for millions of years and have some of the finest detail that can be found, generally with three-dimensional preservation. Because of the hardness of the nodule it takes many hours of preparation to expose the hidden treasures they contain.

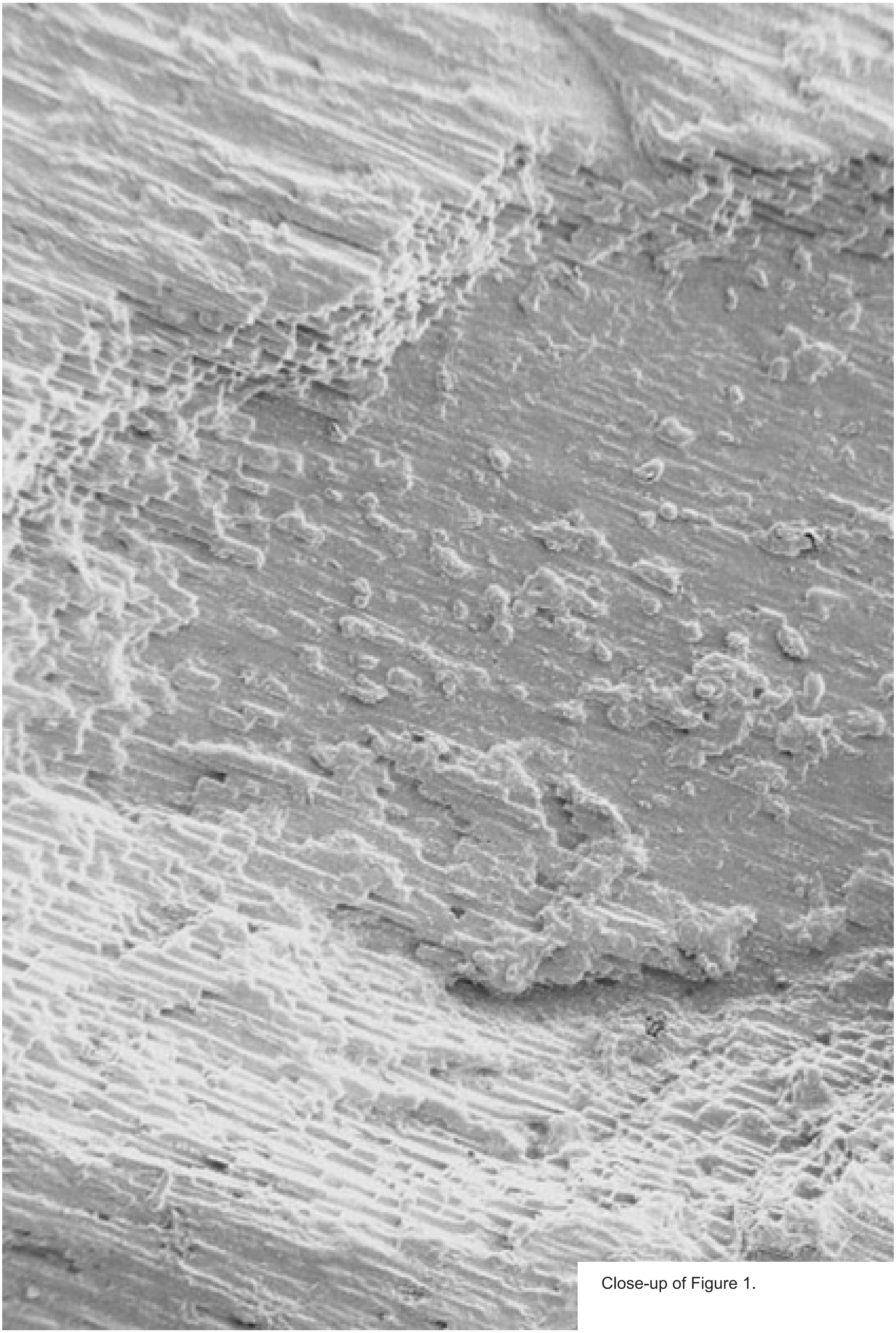
In the Pacific Northwest finding a crab bearing concretions is the easy part. Once found, the task of preparing begins. There is no single technique or process that can be used for the preparation and cleaning of fossils. Generally every fossil requires a different method in order to accomplish this properly, which can include the use of mechanical, chemical, and ultrasonic cleaning methods.





Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Kenneth Bader – Petrified Forest National Park, Ariz. and Natural History Museum and Biodiversity Research Center, University of Kansas, Lawrence, Kan.



Close-up of Figure 1.

Recognition and Preservation of Insect Traces on Fossil Bones

Kenneth Bader, Petrified Forest National Park, Ariz. and Natural History Museum and Biodiversity Research Center, University of Kansas, Lawrence, Kan.

Abstract

Desiccated soft tissues on vertebrate carcasses attract a special group of necrophagous insects that feed on dry flesh and can modify bone. This paper provides a review of modern and fossil insect traces on bone, compares insect traces to other traces on bones, and suggests techniques for preserving trace fossils on bone. Modern bone-modifying insects include dermestid beetles, tineid moth larvae, and termites. Each insect produces a unique type of trace that can be compared to fossil traces on bone. Five types of insect traces are recognized: pupation chambers, tunnels, shallow grooves, feeding traces, and galleries. Dermestid pupation chambers on sauropods bones from the Upper Jurassic Morrison Formation were preserved by applying a thin coat of B-72 or Vinac. GI-1000 silicone was poured over the trace and the resulting peel was used to create a high-resolution plastic cast for use under a scanning electron microscope.

Introduction

The principal scavengers on subaerially exposed and shallowly buried carcasses are insects. Most necrophagous insects feed on soft tissues and the larvae of other insects that inhabit carrion (Payne, 1965; Payne and King, 1970). A few species of modern insects with heavily sclerotized mandibles, including dermestid beetles (Coleoptera: Dermestidae), tineid moths (Lepidoptera: Tineidae), and termites (Isoptera), feed on dried soft tissues and can damage bone. Insect traces have been documented on bones from the Late Jurassic of North America (Britt et al, 2008; Bader et al, 2009); Late Cretaceous of Madagascar, Mongolia, and Utah (Roberts et al., 2007; Kirkland and Bader, 2009); and the Neogene of North America, Europe, and Africa (e.g. Kitching, 1980; Martin and West, 1995; Fejfar and Kaiser, 2005). The purpose of this paper is to provide a set of criteria for identifying insect traces on bone, suggestions on preserving these traces, and a literature review of documented insect traces on modern and fossil bone.

Morphology of Insect Traces on Bone

There are at least five distinct types of insect traces on bones, including pupation chambers, tunnels and notches, shallow U-shaped grooves, feeding traces, and galleries.

Paired mandible marks left by the chewing insects (Watson and Abbey, 1986; Kaiser and Katterwee, 2001) are only present in feeding traces and incompletely constructed traces (Kaiser, 2000; Fejfar and Kaiser, 2005). Movement of the insect within a completed trace is believed to wear down the internal surface and obscure the mandible marks. Fossil traces on bones may be produced by species related to modern bone-modifying insects or by an unknown insect with a similar behavior. The primary modern bone-modifying insects are dermestid beetles, tineid moths, and termites (Bader et al., 2009). Other possible modern bone-modifying insects include beetles from the families Scarabaeidae (Haglund, 1976) and Tenebrionidae.

Pupation chambers – The most common traces found in fossil bones are pupation chambers. These traces are circular to elliptical in plan view and have a flask-shaped or U-shaped cross section. The diameter of pupation chambers ranges from ~0.5–9 mm and the depth ranges from 0.5–2 mm. Pupation chambers in bones from the Morrison Formation (Upper Jurassic) have vertical walls and flat, horizontal floors (Bader et al., 2009). Some Morrison pupation chambers have a central pedestal of unmodified bone that probably represents an early stage in the excavation of the chamber. Pupation chambers are produced when the larva of a holometabolous insect with four stages in its life history (eggs, larva, pupa, and adult) bores a hole into a hard substrate to protect itself from predation during the vulnerable pupation stage. Modern dermestid beetle larvae pupate within dried flesh (Gabel, 1955), bone (Timm, 1982), and wood (Fig. 1). African tineid moths feed on keratin and pupate in the horn cores and astragali of bovid carcasses (i.e. Behrensmeyer, 1978; Hill, 1987). Pupation chambers attributed to dermestid beetles

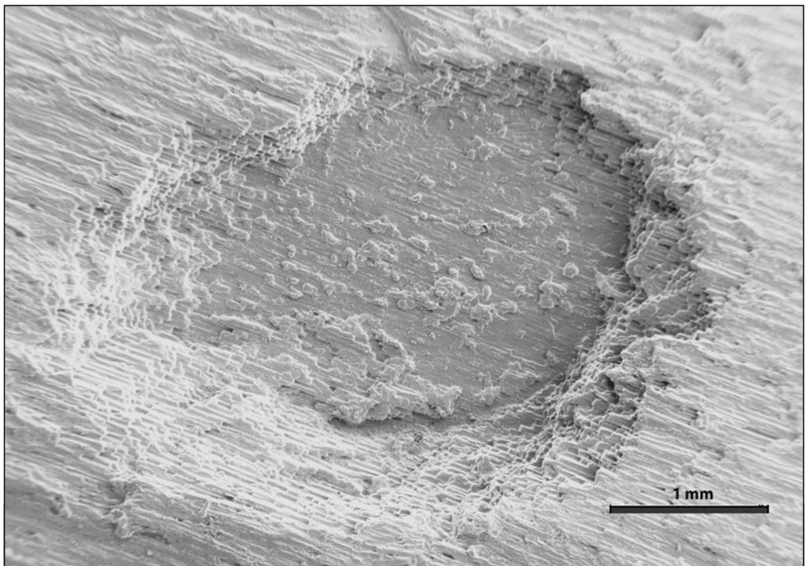


Figure 1. SEM of a typical dermestid beetle pupation chamber in wood. The floor of this trace is horizontal and the walls are vertical, similar to traces found in bones from the Morrison Formation.

have been record in bones from the Late Jurassic (Hasiotis et al., 1999; Britt et al., 2008; Bader et al., 2009) and Neogene (Kitching, 1980; Martin and West, 1995; West and Hasiotis, 2007). Fossil examples of pupation chambers excavated by tineid moths have not been reported.

Tunnels and notches – Circular or elliptical tunnels through bone result from the burrowing activities of fossorial insects that bore through bone that is buried above the water table within a paleosol (Rogers, 1992; Paik, 2001; West and Hasiotis, 2007; Kirkland and Bader, 2009). U-shaped notches are burrows that are constructed partially within the sediment and partially through the edge of a buried bone. In *situ* tunnels and notches are often connected with a burrow in the surrounding matrix. A trail of bone chips in the burrow on one side of the bone can provide the direction that the insect was traveling. Additional research needs to be conducted to determine if tunnels and notches are produced by necrophagous insects or fossorial insects not associated with carrion. These traces are commonly found on bones from Upper Cretaceous sediments in the Gobi Desert (Kirkland and Bader, 2009).

Shallow grooves – Shallow U-shaped grooves are similar to notches but are found in clusters on bones that were covered by a thick layer of keratin. Larvae of the tineid moth *Tinea deperdella etch* ~2 mm wide grooves into the horn cores of African bovids while feeding on the overlying keratin sheath (Behrensmeyer, 1978). The internal surface of the trace is typically worn smooth. Tobien (1965) illustrated a Pliocene or Pleistocene gazelle horn core that was likely bored by tineid larvae.

Feeding traces – There are two types of feeding traces: the focal destruction of a large section of bone, and the removal of the surface bone along a shallow linear trail. Paired mandible marks may be present in both types of feeding trace. Focal destruction occurs when an insect chews a hole into the bone and enlarges the hole in all directions. This type of damage is usually found in the softer cancellous bone at the epiphysis of limb bones. The destruction of the epiphyses of long bones is common on skeletons from the Upper Cretaceous of the Gobi Desert (Kirkland and Bader, 2009).

Trails occur when an insect feeds along the bone surface and the mandibles penetrate the periosteum and etch the outer layer of cortical bone. The mandible marks record the direction that the insect was traveling. Trails have been documented on Late Cretaceous bones from Utah (Roberts et al., 2007) and the Pleistocene of Texas (West and Hasiotis, 2007). Figure 2 is an example of a trail of mandible marks produced in plaster by the dermestid beetle, *Dermestes maculatus*. The purpose of the trail was to open a tunnel along the underside of the plaster block. When the larva reached the center, it bored a pupation chamber into the plaster.

Galleries – The bone-modifying activities of modern termites produce branching tunnels that run along the surface of a bone and penetrate into the marrow cavity. Termites first cover the bone with stercoral, a mixture of soil and feces. Excavation underneath the stercoral starts with the removal of small pits along a linear trail (Tappen, 1994). The pits are expanded and merge into a network of branching tunnels called a

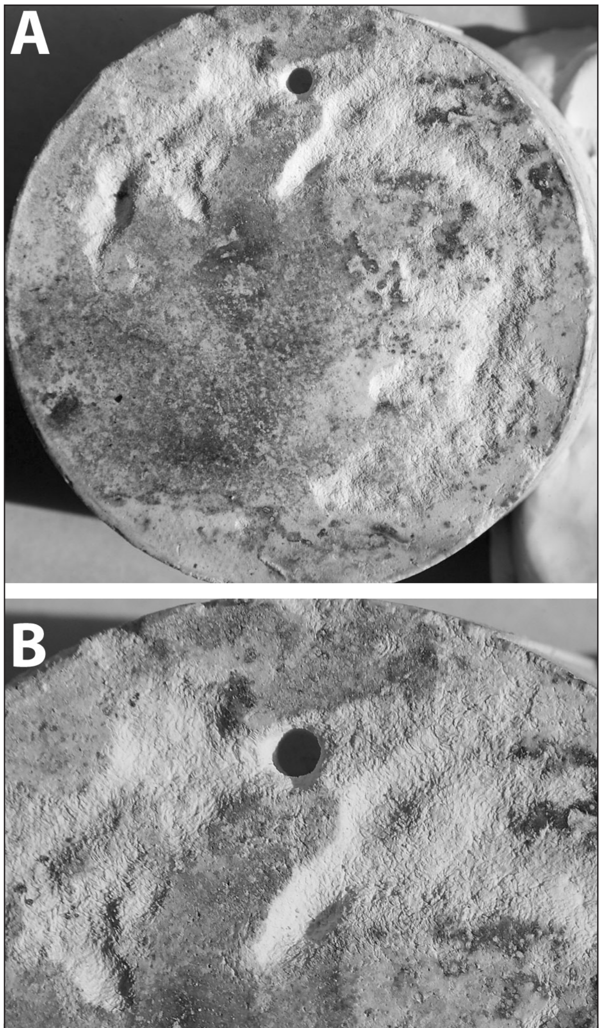


Figure 2. A. Underside of a plaster block with a flask-shaped dermestid pupation chamber and associated trail of mandible marks. B. Detail of the trail with paired arcuate mandible marks.

gallery. The surfaces of completed galleries are coated in stercoral. Long-term occupation of the bones will result in the complete destruction of the bone. Bones that are not covered in stercoral are not damaged by the termites (Thorne and Kimsey, 1983). It is unknown whether the termites are mining the bone for nutrients or shelter.

Other insect traces – Some fossil insect traces combine characteristics of two or more types of modern insect traces, making an interpretation of the recorded behavior difficult or impossible. Roberts and others (2007) described *Cubiculum ornatus*, an ovoid hollow chamber bored into cortical or cancellous bone with paired mandible marks on the internal surface of the trace. This trace can be found on both the external surface of the bone and on the walls of the marrow cavity. *Cubiculum* has only been reported from the Upper Cretaceous Maevarano Formation in Madagascar and has no modern analogs.

Other Types of Traces on Bone

Traces on bones can be produced by the feeding habits of carnivorous animals (Njau and Blumenschine, 2006), root etching (Binford, 1981), abrasion during transport prior to deposition, and preparation marks (West and Hasiotis, 2007). Each type of trace has a distinct set of characteristics. Bite marks from carnivorous reptiles can include a linear arrangement of puncture marks or parallel scratches. The scratches are U- to V-shaped in cross section and can have ragged or smooth edges. Njau and Blumenschine (2006) reported that crocodiles use a head-shaking technique to remove limb bones, resulting in parallel bite marks with a J-shaped morphology. Mammalian predators and scavengers chew on the bone surface (Hill, 1980). The results can range from a roughened bone surface to the total loss of the epiphyses. Rodents gnaw on the edges of bones, leaving paired incisor marks.

Root traces on bones are rarely greater than a few millimeters in diameter and have a sinuous or dendritic pattern (Binford, 1981). A halo of discolored, nutrient-depleted bone surrounds modern root etchings in fossilized bone (Bader et al., 2009). Fungal hyphae leave similar etchings but at a smaller scale of 1–100 µm (Davis, 1997).

Bones that have been transported in a fluvial environment are rounded with processes broken off and the bone surface abraded or polished. Large bones may be dragged along the river bottom; sediment leaves fine parallel grooves on the underside of the bone.

Marks produced during mechanical preparation with pin vices or pneumatic tools are linear and often occur in a repeating pattern. The internal surfaces have a fresh, polished appearance and matrix is not trapped within the trace. Air abrasion pits the bone surface, leaving an elliptical pattern that rarely penetrates to a depth greater than 1 mm.

Preservation of Insect Traces on Bone

Identified insect traces should be prepared underneath a microscope to reduce the chance of mechanical damage to the trace. Air abrasion and acid preparation can damage the surface of traces and should be avoided. The matrix immediately surrounding the traces should be examined closely for evidence of insect burrows or a stercoral layer covering the bones. Evidence for burrows and stercoral includes localized discoloration of the matrix or a sudden change in the lithology of the matrix immediately surrounding the trace.

Traces on small bones can be preserved by applying a thin coat of a reversible consolidant such as Vinac or B-72. Traces on large bones (e.g. sauropod limb bones) cannot be placed underneath a microscope and should instead be preserved by making silicone peels and plastic casts. Before molding, thin B-72 should be added to the traces to prevent the silicone from adhering to the surface of the trace. Trials were conducted using a variety of different brands of silicone, including: Knead-a-Mold® silicone, Whaledent Coltene President Plus®, GI-1000®, and thixotropic GI-1000®. Both Knead-a-Mold® and President Plus® can be peeled off the trace within a few minutes and can produce detailed casts with few or no bubbles. The thixotropic GI-1000® trapped air bubbles at the surface of the trace, preserving little or no detail. Figured traces on dinosaur bones from KU-WY-121 (Bader et al., 2009) were molded using GI-1000® silicone. GI-1000® was chosen because of its long working time (>10 minutes) and the cure time of 24 hours, which allows trapped air additional time to escape. Select traces were surrounded by walls of clay, and the silicone was poured over the trace to a depth of ~1 cm. The silicone was allowed to cure overnight and peeled off the next day.

Copies of the traces were cast using a variety of plastic resins, including: Dynacast®, ProCast®, and Smooth-on®. Dynacast® produced rigid casts with the greatest detail. Casts of the traces were produced by brushing a thin layer of plastic onto the molds and then placing the molds to 70 psi into a pressure pot at 70 psi to remove bubbles. Smooth-on® casts retained bubbles after pressurizing. Additional layers of plastic were added until the resulting casts were >2 mm thick. These high-resolution casts were used to designate the type ichnospecies for traces on Morrison Formation dinosaur bones by Bader and Hasiotis (in review). Dynacast® and ProCast® casts were examined and photographed under a scanning electron microscope, revealing perfect detail and an absence of air bubbles (Figure 3).

Conclusion

The study of insect traces on bone provides useful information about the timing of taphonomic processes (Bader et al., 2009). Insect traces on vertebrate skeletons indicate that the carcass was subaerially exposed or shallowly buried long enough for the soft tissue to desiccate. For large animals (i.e. sauropods) a dry season is necessary for the desiccation of the carcass. The dry flesh attracted necrophagous insects with mandibles capable of damaging bone. Comparison of fossil insect traces to those produced by modern insects can reveal the presence of species that are not preserved as body fossils.

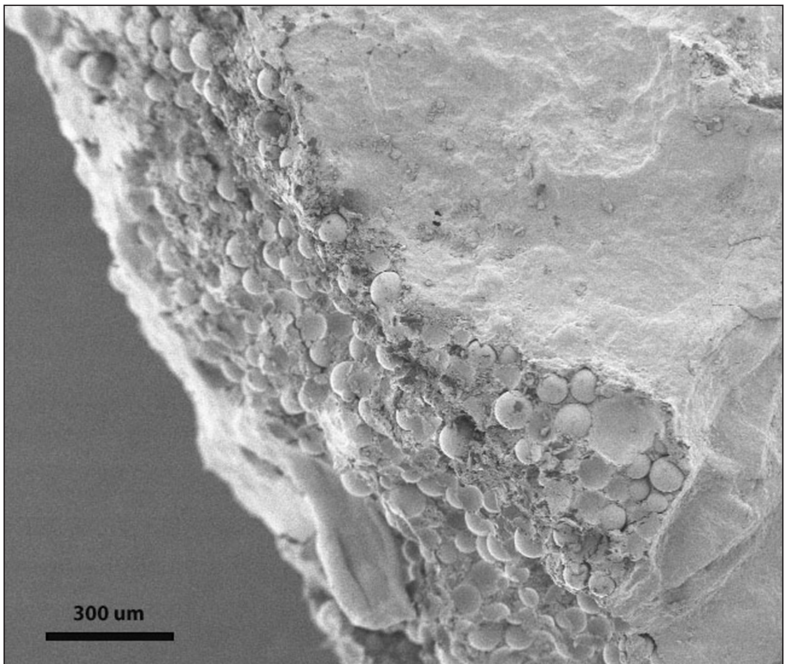


Figure 3. SEM of a broken edge of a cast made with ProCast® plastic. The presence of filler (spherical structures) did not impact the details of the trace.

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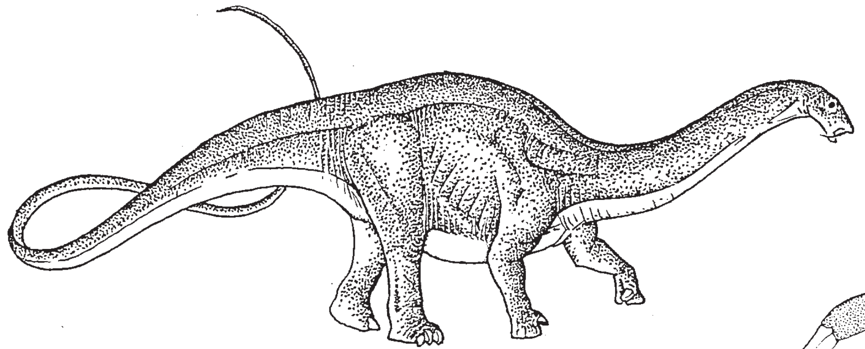
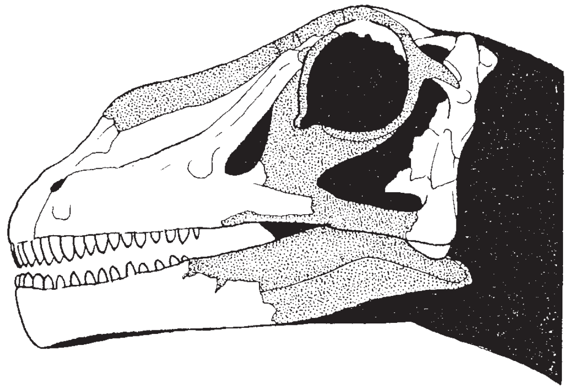




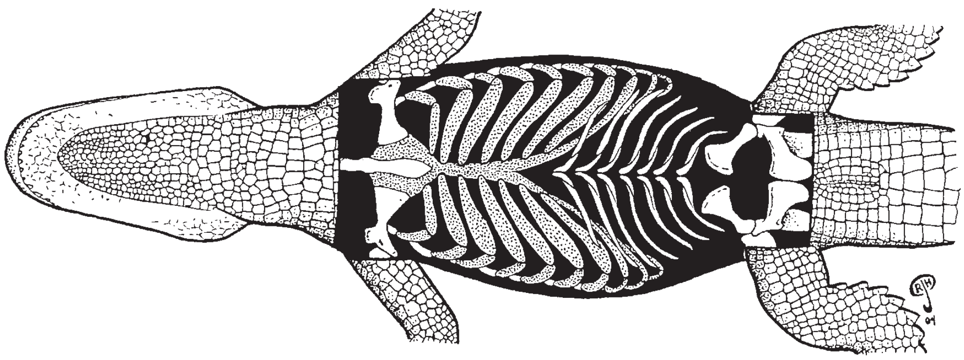
Brontosaur

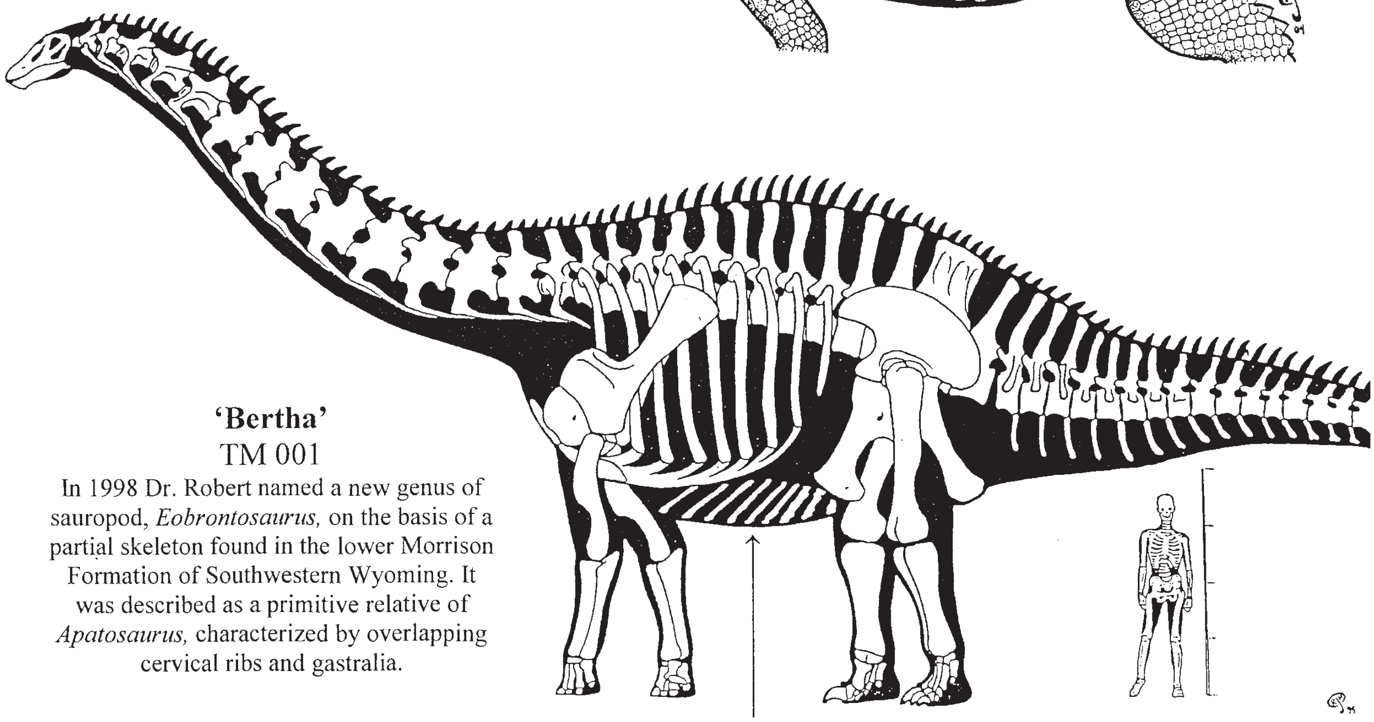
(*Apatosaurus excelsus*)

Apatosaurus lived in the front range during the Kimmeridgian and Tithonian stages of the Late Jurassic period.

Right: O. C. Marsh attempted a reconstruction of a brontosaur skull in 1879. Unfortunately, the bones that he used turned out to belong to another dinosaur, *Haplocanthosaurus.*

Below: The ventral elements of a modern alligator. Gastralia are drawn in white, the cartilaginous sternal ribs are stippled grey. Are Bertha's ventral elements really gastralia, or are they just ossified sternal ribs?





'Bertha'

TM 001

In 1998 Dr. Robert named a new genus of sauropod, *Eobrontosaurus,* on the basis of a partial skeleton found in the lower Morrison Formation of Southwestern Wyoming. It was described as a primitive relative of *Apatosaurus,* characterized by overlapping cervical ribs and gastralia.

Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Melissa Connely - Tate Geological Museum, Casper College

Using Wax Casts to Reshape Distorted Fossils

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Abstract

Fossil bones are often distorted by pressure from overlying strata and diagenesis. After a fossil skeleton has been collected and prepared, distortions often make it very difficult to articulate the skeletal elements for study or display. By making casts of the original material out of wax, the bones can be manipulated back to their original shape. The reconstructed wax casts then can be molded to form resin casts for distribution and display.

Introduction

Several years ago, a delicate, disarticulated *Apatosaurus* skull was discovered. At the time, it was the second (Ostrom and McIntosh, 2000) and the only complete *Apatosaurus* skull known (Connely and Hawley, 1998). It was important to assemble the various elements so that comparisons between the *Apatosaurus* skull and those of other sauropods could be made. However, many of the skull bones had become disarticulated, flattened, and in some cases crushed (Figure 1). These bone elements are very thin and the distortions made it impossible to articulate them. In order to fully look at the morphology of *Apatosaurus*, it was necessary to devise a way to bring these elements together. Using techniques similar to what is used by sculptors; a method was devised to reconstruct the skull for study and display.

Method

After the skull was prepared, silicon molds were made of each individual bone. It is important that the bones be completely sealed so that the silicon cannot penetrate the bones and thus break them when they are removed from the mold. Every single fracture and pore must be filled. Permanent filling can be done with epoxy putty. Temporary filling can be done with a sulfur-free sculptor's clay. Molding can be done as block molds or with rigid overmolds. Small molds can be done successfully with block molds (Figure 2).

Once the molds are complete, casts can be made using a microcrystalline sculptor's wax. There are many varieties of wax to choose from. Some are soft and sticky, while others are hard and brittle. Wax in between these two extremes is the best. However, you may wish to try a variety to get what works best for you. Sculptor's wax is available from most art supply companies.

The wax needs to be heated but the temperature varies depending on the type of wax you use. Start at 140°F and adjust as needed. A meat thermometer is good for this. Wax can be heated in an old enameled coffee pot or a coffee can with a bent pouring spout (Figure 3). It is important to find the right

Figure 1. Top: photograph of the premaxilla (anterior view) cast from the *Apatosaurus* skull. The lower piece was broken and pushed up into the upper piece. Below: same cast alongside a second version that has been repaired and teeth added.

temperature. If it is too hot, it will smoke or burn, if it is too cool, it will give your cast a ropey texture. For very thin pieces, you may also wish to heat up the molds by placing them in the oven. Silicon can handle higher temperatures so heating molds up to 200°F won't hurt them.

After pouring the wax into the mold, gently vibrate the mold to remove any air bubbles. Tapping may be sufficient. Then the molds can be set aside or immersed in water to cool. It is important that the wax be cooled down and solid before removing it from the mold. If the cast is flawed, simply re-melt the wax and try again.

Warning: do not add water to the hot wax pot as it can pop and cause burns. It is ok to add melted wax to cold water.

Reconstruction

The wax casts can be easily reshaped and/or reconstructed to the bone's original form. To alter the shape of a wax cast, immerse the cast in a tub or sink filled with warm water. 110°F is a good starting temperature. The shape can be manipulated by hand. When the desired shape has been made, cool the cast in cool water. Keeping them in water is also a great way to handle and store wax casts so that they don't get distorted by gravity or hard surfaces.

If a cast needs major repair, wax can be cut, carved and shaped easily. Knives can be heated on a portable electric burner (on a low to medium setting) and used for carving wax (Figure 4). Figure 5 shows the wax cast of the broken and misshapen *Apatosaurus* lacrimal bone, and the same bone after re-shaping the wax cast. Two casts were made and individual pieces were cut apart from each cast. The two desired pieces were then welded back together. Welding can be done by putting the two wax pieces in place, then inserting a hot knife into the seam to weld the wax pieces. The newly welded pieces will need to be cooled before moving them. Cooling can be done by spraying the wax with water or by immersing the two pieces into a cool water bath. If you spend a lot of time on a wax piece, it may soften and your welds won't hold. If this happens, just set the wax in cool water and take a break or work on another piece.

If additional reconstruction is necessary, sulfur-free clay or additional wax can be used to repair or replace missing or badly damaged parts. Clay does not permanently stick to the wax and seams are likely. This works great if you wish to show what was reconstructed and what is from the original material. However, if you wish for a better blend, reconstruction with wax is best.

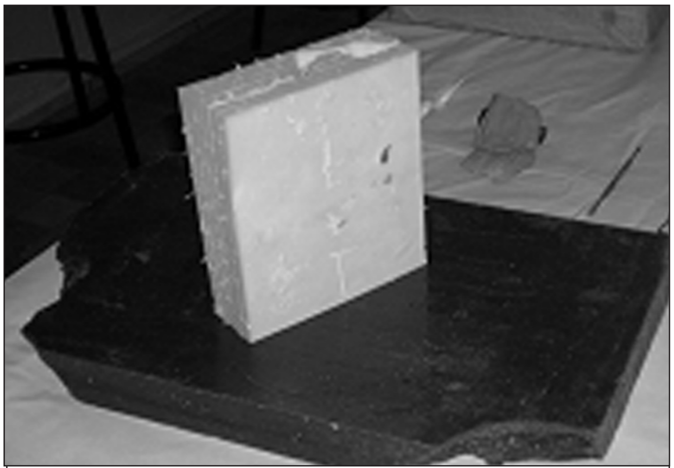

Figure 2. Typical silicon block mold sitting on a block of microcrystalline sculptor's wax.

Figure 3. Coffee can used to heat wax. The rim has been bent to form a pour spout.

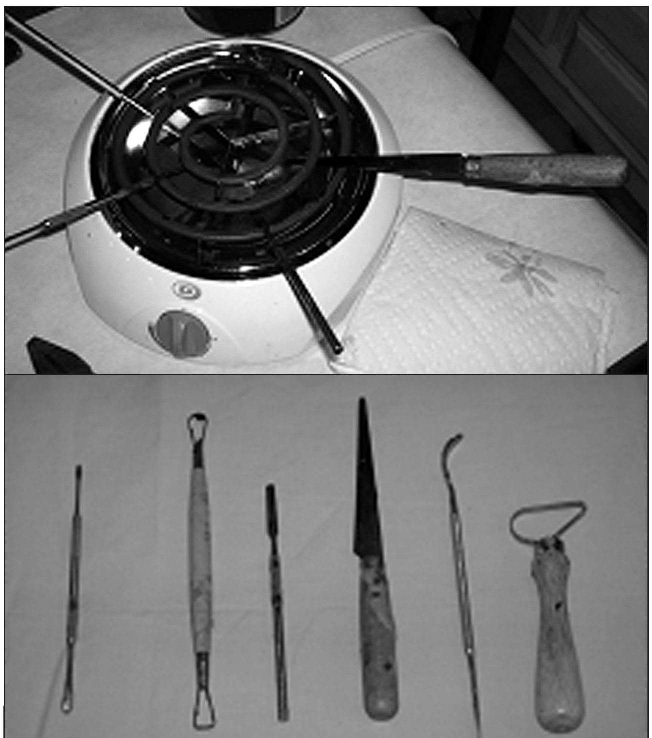

Figure 4. Electric burner heating knives and other wax carving tools.

Final Process

Once the wax casts are in the required shape, they can themselves be molded in silicone. In the case of the *Apatosaurus* skull, the bones were molded both individually for study, and as an articulated skull for display (Figure 6). As an articulated skull, the wax casts were lightly welded together. This process helped define the actual shape of the skull. The individual bones must articulate at precise suture locations. With wax casts, it was easy to 'tweak' each bone to fit. Once in place, they were welded using a hot knife. Temporary tacking of the casts was done using straight pins to hold each element in place. When satisfied with the placement of the cast, permanent attachments were made. Because the skull was delicate during this process, it was allowed to float freely in a large tub of water as each element was attached. Surprisingly, when all of the elements were attached, the skull was structurally sound and could be handled outside of the water bath.

The wax skull no longer exists. It was melted down for the next project, but the Apatosaurus skull lives on as a resin cast.

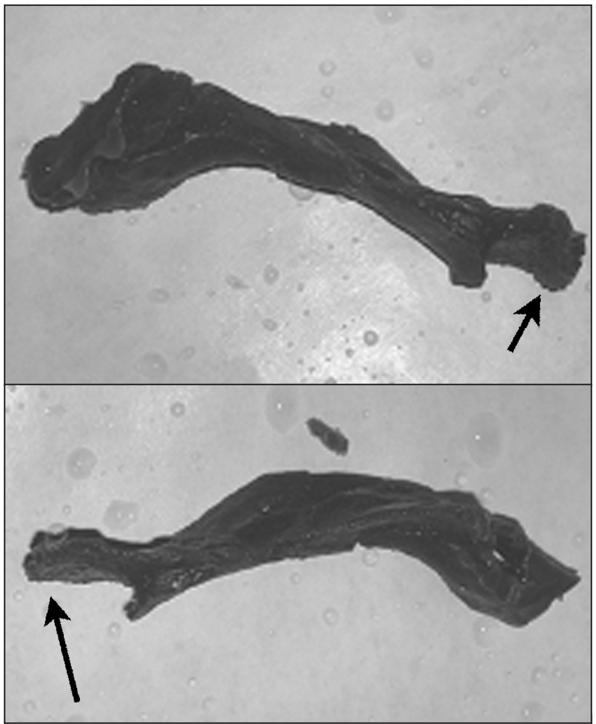

Figure 5. Wax casts of the lacrimal from *Apatosaurus*. The distal end was curved or bent (top) and was straitened (botto,).

Conclusion

Using wax casts is an easy and fairly inexpensive way to reconstruct small bones. There is very little shrinkage with the microcrystalline wax. Wax is reusable and mistakes are easily repaired. It is easy to carve, bend, manipulate, repair, and mold. By handling it carefully, it duplicates the delicate surface texture of the original bone; preserving detailed information and providing a more natural cast for display.

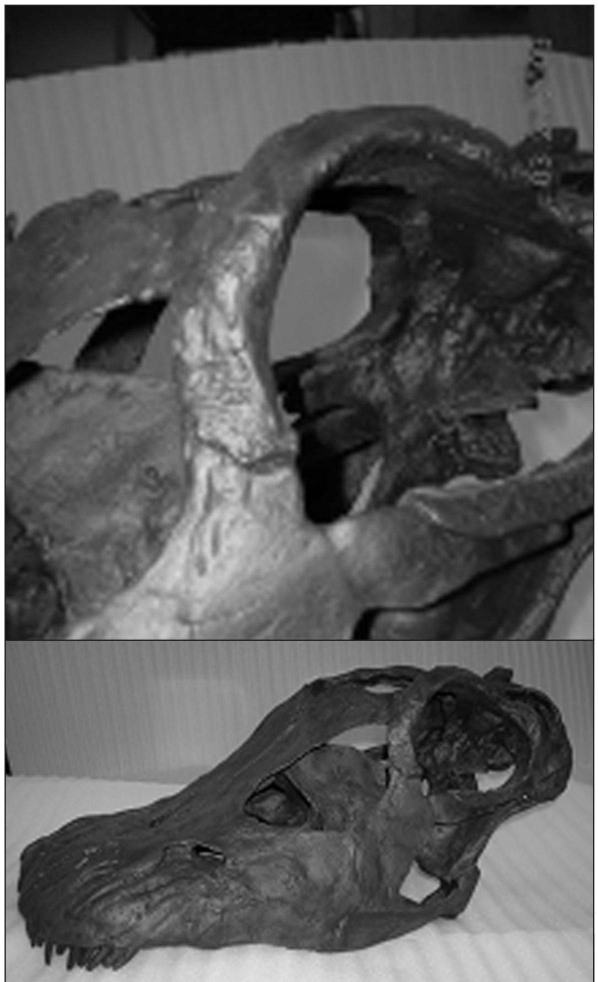

Figure 6. Left, final cast of the *Apatosaurus* skull with the repaired elements. Right, close up of the new lacrimal showing a tight fit with the jugal, which was not possible before re-shaping the bone.

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A New Look for *Triceratops*?

(*Triceratops horridus*)

Composite restoration based on the 'Lane' and 'Kelsey' specimens

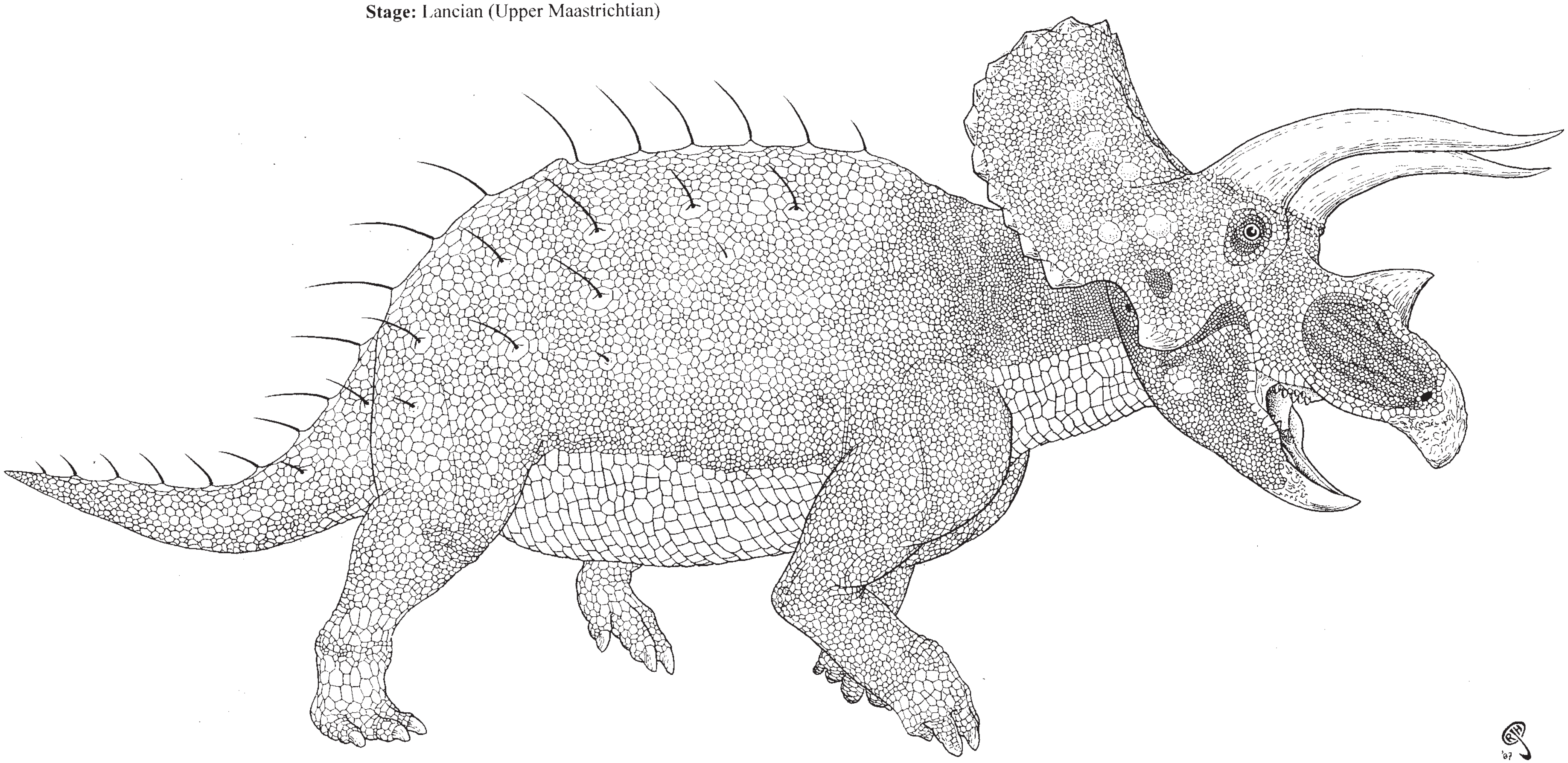
Fossilized *Triceratops* skin discovered by the Black Hills Institute of Geological research in South Dakota shows that this animal had large, rhomboidal scales the underside of its neck and smaller, more rounded scales on the sides and back. Most intriguing are large, polygonal plates scattered across the flanks and hips, each with a volcano-shaped protrusion in the center. These might have been the bases of long quills such as have been found in the related dinosaur *Psittacosaurus*.

Age: 66 million years

Locality: Lance Formation of Wyoming, Hell Creek Formation of South Dakota, North Dakota and Montana, Laramie Formation of Colorado, Scollard Formation of Alberta and the Frenchman Formation of Saskatchewan.

Period: Late Cretaceous.

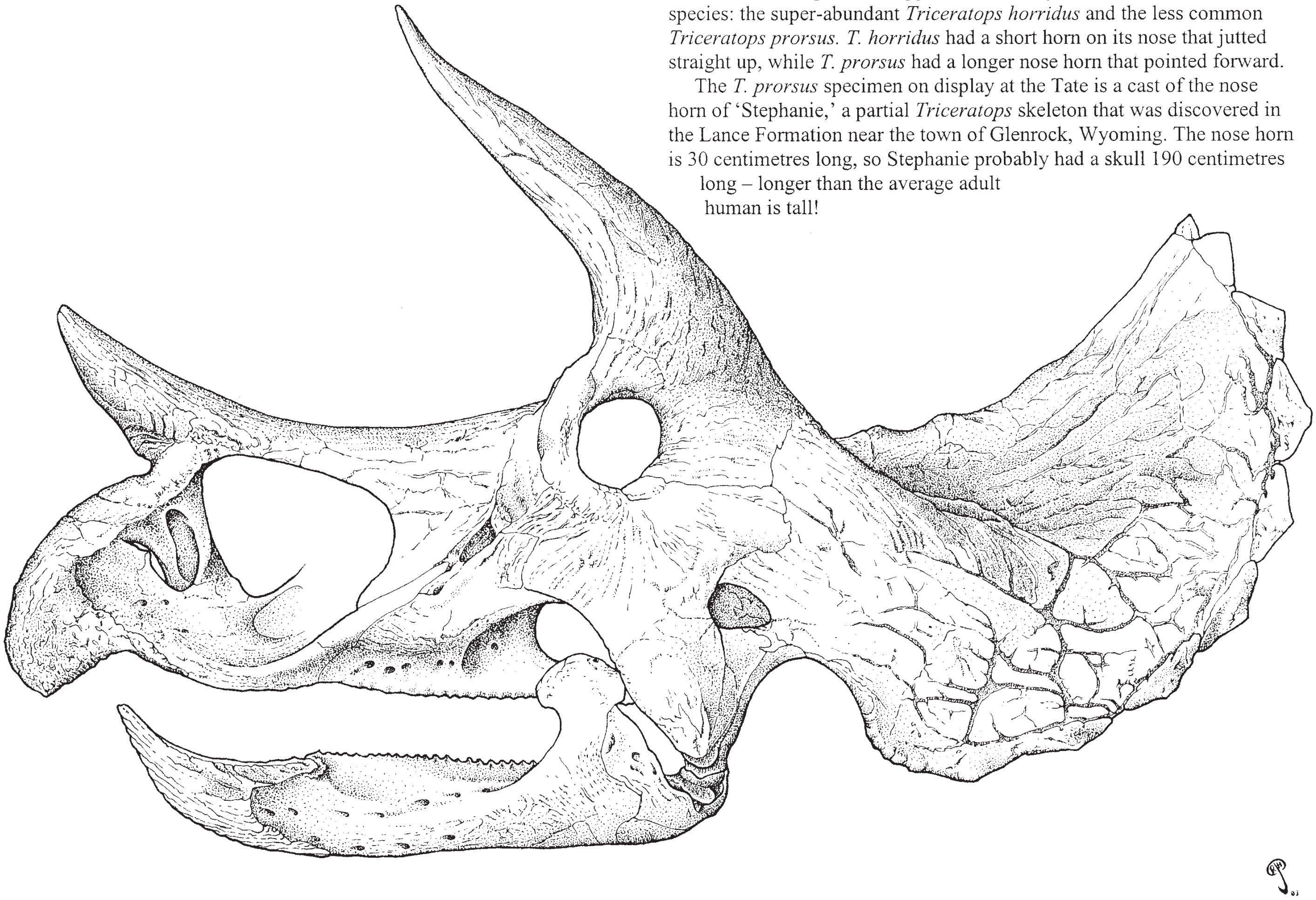
Stage: Lancian (Upper Maastrichtian)



Triceratops prorsus skull

Triceratops, the last and largest ceratopsid, lived during the late Maastrichtian stage of the Upper Cretaceous period. There were two species: the super-abundant *Triceratops horridus* and the less common *Triceratops prorsus. T. horridus* had a short horn on its nose that jutted straight up, while *T. prorsus* had a longer nose horn that pointed forward.

The *T. prorsus* specimen on display at the Tate is a cast of the nose horn of 'Stephanie,' a partial *Triceratops* skeleton that was discovered in the Lance Formation near the town of Glenrock, Wyoming. The nose horn is 30 centimetres long, so Stephanie probably had a skull 190 centimetres long – longer than the average adult human is tall!



Tate Geological Museum
Casper College

Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

Eric Lund - Utah Museum of Natural History, University of Utah, Salt Lake City, Utah

Working With Nonmineralized Vertebrate Soft-Tissues: The Delicate Side of Fossil Preparation

Eric Lund, Utah Museum of Natural History, University of Utah, Salt Lake City, Utah

Abstract

Vertebrate soft-tissues do not readily fossilize, and as such, they are relatively rare occurrences in the fossil record. The process of fossilization most often destroys or alters nonmineralized soft-tissues. Moreover, soft-tissues are a rich source of nutrients for predators, scavengers, and microbes thus decreasing the probability of preservation. However, a variety of nonmineralized soft-tissues have been preserved in the fossil record, including (but not limited to) skin, muscle, gut contents, blood vessels, and keratinous sheaths. Recent work in Grand Staircase-Escalante National Monument conducted by the University of Utah has yielded over 15 fossil vertebrate localities preserving soft-tissue structures. The majority of these sites are associated with dinosaur specimens, six of which are worth noting: 1) a juvenile ornithopod skeleton; 2) a 60 percent complete, partially articulated hadrosaur skeleton; 3) a nearly complete disarticulated hadrosaur skeleton; 4) a nearly complete, articulated hadrosaur skull; 5) the left manus of an oviraptor; and 6) a ceratopsian forearm. Excavation and ensuing preparation of these specimens has provided insights concerning the handling of fossilized vertebrate soft-tissues both in the field and in the preparation laboratory.

Field excavation and lab preparation of preserved soft-tissues is typically problematic, since these remains – like vertebrate hard tissues – vary greatly in quality and preservational durability. A primary concern in dealing with preserved soft-tissues is deciding to what degree preservation or destruction of a specimen is warranted in order to properly carry out collection or preparation. Generally, it is best to postpone such decisions until the specimen is in the controlled environment of the lab. Field collection of smaller specimens is usually conducted by wrapping specimens in tissue or cloth, but specimens that are too large to safely transport in this manner, or are associated with vertebrate material, should be encased with a plaster field jacket. Occasionally, a consolidant may be applied in the field to temporarily hold a specimen together, but the use of adhesives should be minimal. Ample photographs should be taken both in the field and in the lab, especially before the removal or destruction of any soft-tissues. If possible, a mold should be created with latex or silicone in order to preserve maximal information and enable placement of hard and soft tissues relative to one another at a future date.

Introduction

Occurrences of fossilized soft-tissues was once thought to be relatively rare in the Mesozoic fossil record, however, nonmineralized vertebrate soft-tissues of nonavian dinosaurs have been known in the fossil record since 1852, when S. H. Beckles described a patch of sauropod integumentary impression from the Wealden Shales of Atherfield (Isle of Wight, UK). Since then, both the mechanisms of preservation and the method for dealing with such fossils have remained relatively enigmatic. More recent discoveries of nonmineralized soft-tissues, predominantly skin and feather impressions, have been reported, along with some controversial claims concerning preserved blood vessels, blood cells, and various internal organs (Dal Sasso and Signore 1998; Chin et al., 1998; Fisher et al., 2000; Martill et al., 2000; Chin et al., 2003; Schweitzer et al., 2007). Methods for dealing with nonmineralized soft-tissues both in the field and in the lab are numerous and vastly different. There have been very few studies outlining the various techniques that have been employed in the past to deal with preserved soft-tissues (Cifelli, 1996). Past techniques include (but are not limited to), complete destruction, complete collection, and partial collection of vertebrate soft-tissues when identified.

Understanding how to deal with such delicate fossils both in the field and in the lab has been a mildly controversial topic within paleontology, both from a field collection and lab preparation standpoint, as well as from a research standpoint. Many field paleontologists, as well as preparators, see the need for consolidants and various adhesives to help with collection and preparation. Soft-tissue researchers, however, do not, as the consolidants and adhesives will alter the isotopic signatures of the specimens which they are trying to analyze. The simple answer is there is not one correct answer that solves every problem that will arise during collection and preparation of nonmineralized soft-tissues. And the ultimate decision falls to the collector or preparatory.

Materials and Methods

Field collection and laboratory preparation methods used during this study are standard for vertebrate paleontology. Collecting fossils in the field requires prospecting geologic formations of the correct age for the fossils that are desired (e.g., vertebrates, nonmineralized soft-tissues, plants, etc.). Field collection also requires evaluating the usefulness of the fossils to science and/or the collection plan of the paleontology program, because not all fossils that are found are worth collecting. For instance, poorly preserved and predepositionally damaged fragments that are isolated or that cannot be reconstructed typically are not collected.

Figure 1. Example of nonmineralized soft-tissue (keratinous sheath) preserved as an impression and an organic film. Scale bar is 2 cm. Photo by author.

Identification of nonmineralized soft-tissues in the field or in the preparation lab can be problematic, especially if the conformation of the soft-tissue is a simple organic film (Figure 1). Typically, organic films manifest as a discoloration of the matrix preserving a simple outline of the soft-tissue (e.g., feathers, hair, and keratinous sheaths). Preserved organic films tend to be less common in the fossil record and are generally extremely fragile and can be easily overlooked during collection or preparation. Integumentary impressions tend to be the most common nonmineralized soft-tissue preserved and their identification is typically easier, as they are generally preserved in 3-dimensional relief (Dodson et al., 1980; Anderson et al., 1998; Renesto and Avansini, 2002; Lingham-Soliar et al., 2003; Rainforth, 2003; Carpenter, 2007; Lund et al., 2008). However, integumentary impressions can still be relatively enigmatic to identify both in the field and in the preparation lab. Integumentary impressions are typically more robust and durable than other nonmineralized soft-tissues, often being preserved in well-cemented fluviatile sandstones (Dodson et al., 1980; Anderson et al., 1998; Renesto and Avansini, 2002; Lingham-Soliar et al., 2003; Rainforth, 2003; Carpenter, 2007; Lund et al., 2008).

Generally, nonmineralized soft-tissues discovered in the field or in the lab are preserved as impressions or organic films requiring immediate consolidation and conservation. Nonmineralized soft-tissues discovered in the field need to be treated as delicately as possible, being protected from subsequent collection techniques. Initial treatments should encompass gentle brushing of the exposed surface to remove any surficial debris and consolidation with vinac or a similar penetrating consolidant. However, if isotopic work is to be a primary or secondary focus of the collection, multiple samples of both the nonmineralized soft-tissue and the preserving matrix should be procured before the application of any chemical consolidant. If the procedure for collection of the specimen dictates that soft-tissues be left in place to allow for proper collection, they should be covered with a protective layer of tissue or even a proper field jacket after being consolidated. Generally, it is best to limit the impact of collection and handling on soft-tissues in the field, delaying all but basic preservation and consolidation treatments until the controlled environment of the preparation lab. It is also very important to take ample photographs and field notes for the locality. Nonmineralized soft-tissues discovered in the lab should initially be treated in the same manner as initial discovery in the field (see above). However, after initial treatments, soft-tissues can be cleaned with water or other solvents to remove any surface dirt, reconsolidated with Vinac or other preferred consolidant, or molded in latex or silicone. Similar to field collection, it is important to take ample photographs and any pertinent notes regarding the soft-tissues. Due to the delicate nature of nonmineralized soft-tissues it is best to avoid any collection or preparation methods involving mechanical techniques (i.e., air-scribes, air-abrasion, Dremel tool, wire brush, etc.).

Although a multitude of field collection methods exist, there are two relatively fundamental methods that are occasionally employed simultaneously: surface collecting and quarrying (excavating). Surface collection refers to collecting all fossil fragments that occur on or near the surface of the ground, called float. Typically, surface collected material can easily be picked up and wrapped in protective material (e.g., paper towel, or tissue paper) and placed in a sample bag along with proper documentation, completing the field collection of the material. When surface collecting fossils, every attempt should be made to locate the producing horizon to establish whether subsequent materials of the same specimen or other specimens are present, especially if the surface material contains preserved soft-tissues. Frequently the specimen has either completely weathered out of the substrate, or the producing horizon cannot be located. Surface collected fragments that are associated or found to fit together should be wrapped and documented accordingly. Quarrying refers to the collection of fossils through excavation. Occasionally, an association of well preserved *in-situ* material located subsequent to or during a surface collection may be discovered. This material needs to be properly quarried to recover the material intact or nearly intact, which is accomplished through careful excavation and encasing the fossils in a protective field jacket. It is important to refrain from field preparing fossils, as all preparation needs to be performed in the controlled environment of the preparation lab.

Excavating fossil material begins with the documentation of the locality, which is perhaps the most neglected aspect of fossil collecting (Cifelli, 1996). Without detailed field notes outlining sedimentologic and stratigraphic provenance, the scientific importance of any given specimen can be severely decreased. Proper field documentation should include all relevant information about the fossil locality (geographic location, geologic formation, lithology, stratigraphy, taxonomy, etc.). Geographic location should be accurately recorded by use of a Global Positioning System (GPS), and afterward plotted on a USGS topographic map. Specimens collected from a single locality should be properly mapped *in-situ* and given a site locality number so that they can be easily linked to field notes.

Prior to excavation of a particular locality, the float associated with the site must be collected and documented. Following surface collection of the float, careful digging reveals the extent of both the hard parts (i.e., bone, teeth) as well as any preserved nonmineralized soft-tissues. Before extraction of any material, a complete photo documentation of the entire locality, including nonmineralized soft-tissues and hard-tissues, should be undertaken. Application of a minimal amount of consolidant over the surface of the nonmineralized soft-tissues can help accentuate the surface features of soft-tissues. However, the use of adhesives is not recommended. If isotopic analysis of any soft-tissues is to be undertaken, multiple samples of soft-tissue should be carefully collected and documented for this purpose before the application of any consolidant. Subsequent to photo documentation, an initial decision of what to preserve *in situ*, what to remove but keep, and what to destroy in order to carry out collection of the locality must be made. Additionally, *in situ* nonmineralized soft-tissues should be properly mapped along with their relationship to any hard-tissues that may be associated with the material. Once critical logistics of the locality have been determined, excavation can commence. Excavation of both soft-tissues and hard-tissues is done following traditional field collecting techniques (i.e., uncovered, pedestaled, covered with a separator layer, wrapped in a proper field jacket, labeled). Once a sufficient jacket thickness is achieved, determined by the overall size and weight of the specimen, the field jacket is broken free from the supporting pedestal and rolled over, exposing the underside of the field jacket. With the field jacket flipped over, some of the matrix from the now exposed side can be removed; this step is mainly to decrease the overall weight of the jacket, but serves also to allow for the condition of the bone and or soft-tissues from underneath to be observed. Any soft-tissue or bone that was uncovered during matrix removal from the underside of the field jacket needs to be covered with a separator layer of dampened paper towel before completely enclosing the field jacket. After the field jacket is allowed to dry sufficiently, it should be properly identified with a label. Then the fossils can be safely transported from the field to the lab.

Back in the preparation lab, further decisions regarding the preservation or destruction of soft-tissues can be made. For soft-tissues slated for destruction or removal, it is advised that ample photographs be taken and if possible a latex or silicone mold be created preserving any relationship between hard and soft-tissues. Additionally, a mother mold will be needed to support any silicone or latex mold that is created. In the controlled setting of the preparation lab, application of adhesives can be used to reunite broken and separated segments of soft-tissues previously separated during field collection or during lab preparation. However, use of adhesives should be kept to a minimum. Additionally, during preparation of specimens

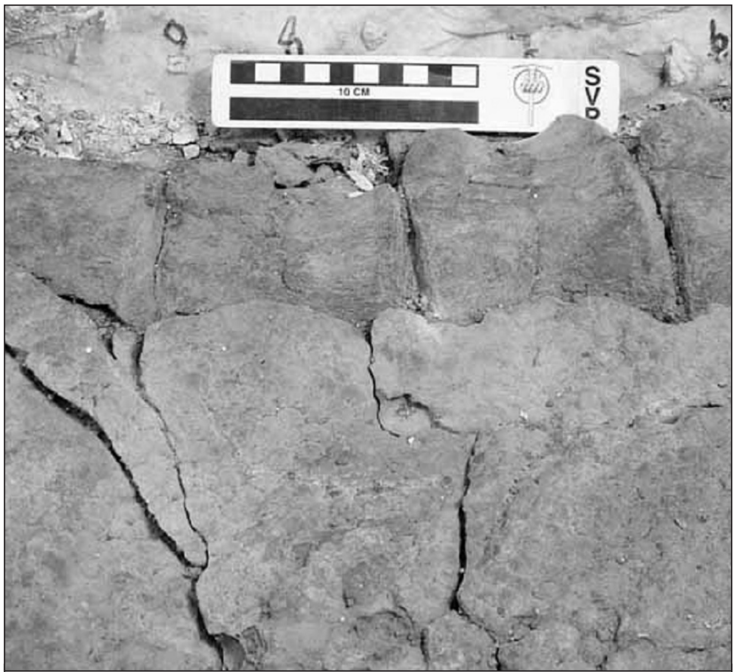


Figure 2. Soft tissues (in foreground) and hard tissues prepared in unison in the lab preserving the close association. Photo by Liz Gauthier

preserving both hard and soft tissues, it might be advisable to prepare the specimen in such a way as to preserve the relationship between the two (Figure 2).

Discussion

The majority of nonmineralized soft-tissues that have been recognized are integumentary impressions attributable to nearly every major group of dinosaur, and from every continent (Dodson et al., 1980; Anderson et al., 1998; Renesto and Avansini, 2002; Lingham-Soliar et al., 2003; Rainforth, 2003; Carpenter, 2007; Lund et al., 2008). This pattern holds true for the Upper Cretaceous (Campanian) Kaiparowits Formation of Grand Staircase-Escalante National Monument in southern Utah, the focus locality for this study. To date, over a dozen fossil localities preserving integumentary impressions have been identified from the Kaiparowits. In the majority of localities, integumentary impressions are associated with articulated to semi-articulated partial skeletons of single ornithschian dinosaurs, particularly hadrosaurs, in indurated, fine-grained fluvatile sandstone (Lund et al., 2008). The high durability of the encasing matrix has preserved the integumentary impressions extremely well. However, it also greatly hinders field collection. Often collection requires the use of gas-powered rock saws to mechanically 'slice' around the soft and hard tissues. Occasionally and unfortunately, hard and soft tissues are inadvertently cut through or touched by the saw blade, resulting in a slight loss of information. If this occurs during field collection, proper documentation is crucial for keeping track of both halves and eventually reconstructing the specimen.

As mentioned above, there have been six specimens recovered from the Kaiparowits Formation worth noting: 1) a juvenile ornithopod skeleton; 2) a 60 percent complete, partially articulated hadrosaur skeleton; 3) a 80 percent complete, disarticulated hadrosaur skeleton; 4) a nearly complete, articulated hadrosaur skull; 5) the left manus of an oviraptor; 6) a ceratopsian forearm.

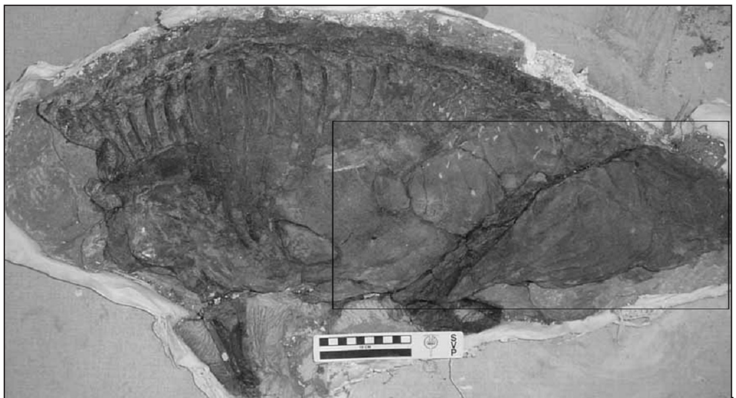


Figure 3. Juvenile ornithopod (UMNH VP 16677), box outlines location of preserved soft-tissues. Photo by author.

The unidentifiable juvenile ornithopod (UMNH VP 16677) is nearly complete, preserving much of the post-cranial skeleton, but lacking any skull or tail (Figure 3). The specimen preserves soft-tissue impressions along much of the left ventral hindquarters, in the form of relatively smooth undulations along the midsection transitioning into parallel striations along the proximal end of the tail (Figure 3). The integumentary impressions were noted on the bottom side in the field preserved in both positive and negative relief, (i.e., cast and mold), and processed according to the methods described above (see materials and methods). Both cast and mold are retained when they are present. The identification of these soft-tissues are unclear, but are thought to be related to the soft skin surrounding the groin, and muscle fibers surrounding the proximal tail.

The 60 percent complete, partially articulated hadrosaur skeleton (UMNH VP 12265), tentatively identified to the genus *Gryposaurus* based on multiple cranial elements, preserves portions of the skull and much of the postcrania including a nearly complete caudal series (Figure 4). The specimen preserves integumentary impressions along much of the caudal series, exhibiting texture noted for other hadrosaurs (Anderson et al., 1998). The integumentary

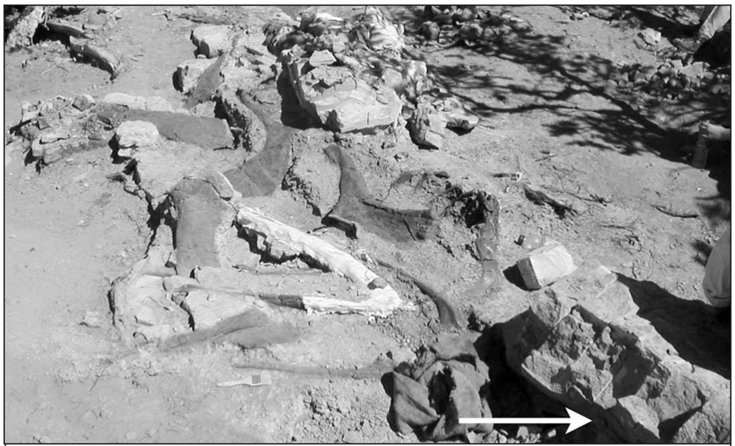


Figure 4. Hadrosaur skeleton (UMNH VP 12265) in the field preserving integumentary impressions along much of the caudal series. The arrow is pointing to the interface where the integumentary impressions are, under the thick sandstone block. Paint brush in lower center is approximately 15 cm long. Photo by author.

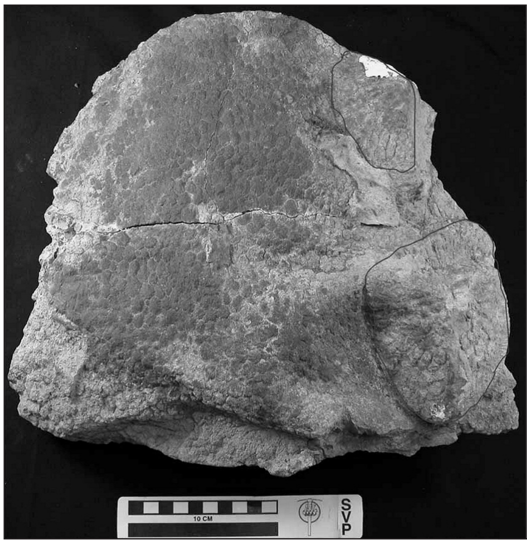


Figure 5. Hadrosaur integumentary impression associated with UMNH VP 12265, showing larger scute-like tubercles (outlined in black). Photo by Liz Gauthier.

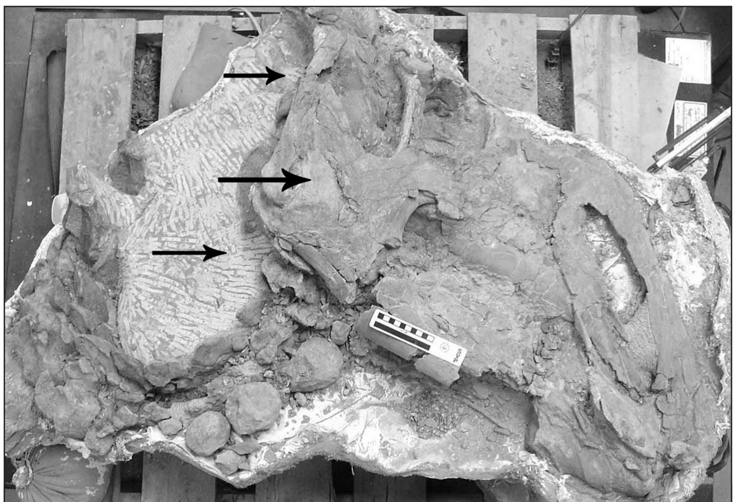


Figure 6. *Gryposaurus* skull (UMNH VP 16669) with preserved integumentary impressions surrounding much of the caudal portion of the skull. The arrows are pointing to where integumentary impressions were, before being removed. Photo by author.

impressions were noted on the top and bottom sides in the field preserved as both cast and mold of the impression. Additionally, larger scute-like impressions were noted in the field positioned atop every neural spin along the dorsal and caudal series (Figure 5).

The nearly complete hadrosaur skull (UMNH VP16669), also identified to the genus *Gryposaurus*, was preserved with integumentary impressions covering much of the caudal portion of the skull as well as much of the partially articulated neck (Figure 6). The locality was first discovered by finding large blocks of sandstone with integumentary impressions lying at the foot of a steep hill. The integumentary impressions are preserved as both casts and molds. The integumentary impression covering much of the skull also exhibits texture described for other hadrosaurs (Anderson et al., 1998).

The oviraptor specimen (UMNH VP 12765; Zanno and Sampson, 2005) preserves a complete left manus along with a fragmentary foot, and also preserves the two-dimensional outline of the keratinous sheath that would have covered one of the large unguals on the manus (Figure 7). The conformation of the sheath is only visible in the matrix that surrounded the specimen. The keratinous sheath impression was not noted until preparation began in the preparation lab.

Collected during the 2008 field season, the nearly complete, disarticulated skeleton of a very large *Gryposaurus* (UMNH VP 19468) is preserved with integumentary impressions covering much of the legs and pelvic region (Figure 8). The integumentary impressions exhibit texture described for other hadrosaurs and was preserved on the top side of many of the elements (Anderson et al., 1998). The nearly complete ceratopsian forearm is complete from the scapula-coracoid to the ulna and radius and is identified as a new genus and species of centrosaurine ceratopsid (Figure 9). The forearm preserves multiple patches of integumentary impressions associated with scapula and humerus, exhibiting texture unlike that described for hadrosaurs (Anderson et al., 1998). The integumentary impression was discovered during field excavation of the associated skull. Unfortunately the impressions were inadvertently cut through with a gas-powered rock saw (Figure 9).

Proper field documentation including mapping and note taking along with photographs is critical for documenting every aspect of the operation, and is better than relying on memory. Photographs should be a part of every paleontological research program; photos can highlight information that was missed during collection or preparation. During field

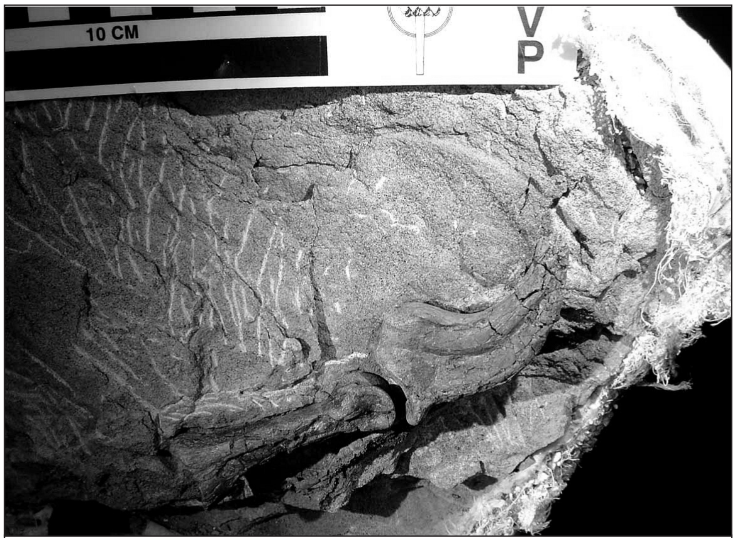


Figure 7. Left manus of the oviraptor *Hagryphus* (UMNH VP 12765) with preserved keratinous sheath impression. Photo by author.

Figure 8. Hadrosur skeleton (UMNH VP 19468) in the field preserving integumentary impressions. Skeleton is nearly complete, but disarticulated. Photo by author.

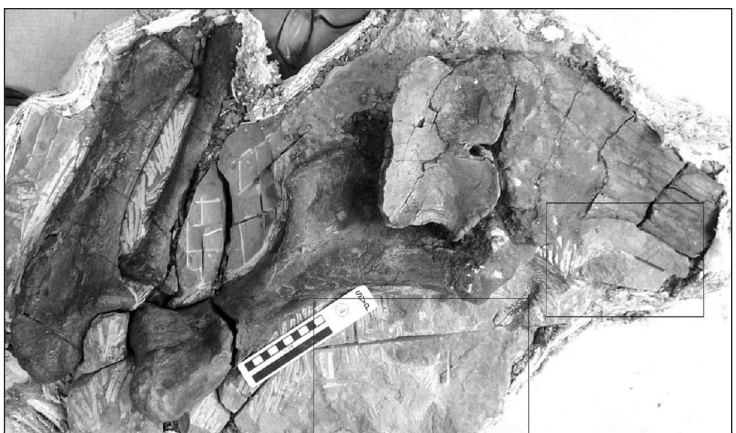


Figure 9. Articulated left forearm of a new ceratopsid dinosaur with preserved integumentary impressions associated with the scapula and humerus. Boxes outline location of integumentary impressions. Photo by author.

collection it is important to use consolidants to decrease the probability of the nonmineralized soft-tissues from degrading once exposed, it is also important to refrain from using any adhesives in the field due to the permanency of many adhesives (Howie, 1984; Madsen, 1996; Elder et al., 1997; Down and Kaminska, 2006). When soft-tissues are preserved as both cast and mold, both halves should be separated with a layer of tissue to prevent incidental damage that can occur during transport of such specimens. The separating layer can prevent or lessen the two halves from grinding or shifting against one another. The use of proper field jackets for preserving and transporting larger specimens is critical to prevent accidental loss or damage. Field jackets are also important for properly transporting specimens that preserve both hard and soft tissues. In the lab, the creation of a latex or silicone mold is important for preserving maximal information when soft-tissues are slated for removal or destruction. If a mold is taken it is also important to create a mother mold to help support the mold of the soft-tissues.

Conclusion

Generally, there will not be one single solution when dealing with nonmineralized vertebrate soft-tissue collection and preparation; solutions are fundamentally up to the collector or preparator. However, as outlined above (see materials and methods), there are several techniques that will greatly add to the success of the operation including; 1) postponing decisions regarding what to keep, what to destroy, or what to keep but remove from the specimen during either field collection or lab preparation until the specimen is in the controlled environment of the preparation lab; 2) photo-documentation of every aspect of collection and preparation; 3) proper field documentation of the locality, including location of soft-tissues with respect to vertebrate hard tissues, and type of preserved soft-tissues; 4) wrapping small specimens in tissue or cloth and placing them in a sample bag with proper documentation for transport; 5) encasing larger specimens in a proper field jacket for transport; 6) specimens preserving both positive and negative relief of the nonmineralized soft-tissues should be kept together, but separated by a layer of cushioning (i.e., tissue or paper towel) to prevent damage during transport; 7) if possible, soft-tissues removed in the lab should first be molded in latex or silicone to preserve maximal information, and to preserve the relationship between any hard and soft-tissues. Proper preservation of nonmineralized soft-tissues in the field and in the lab is pivotal in reconstructing evidence of past life, and for understanding the paleobiology and paleoecology of that life on earth.

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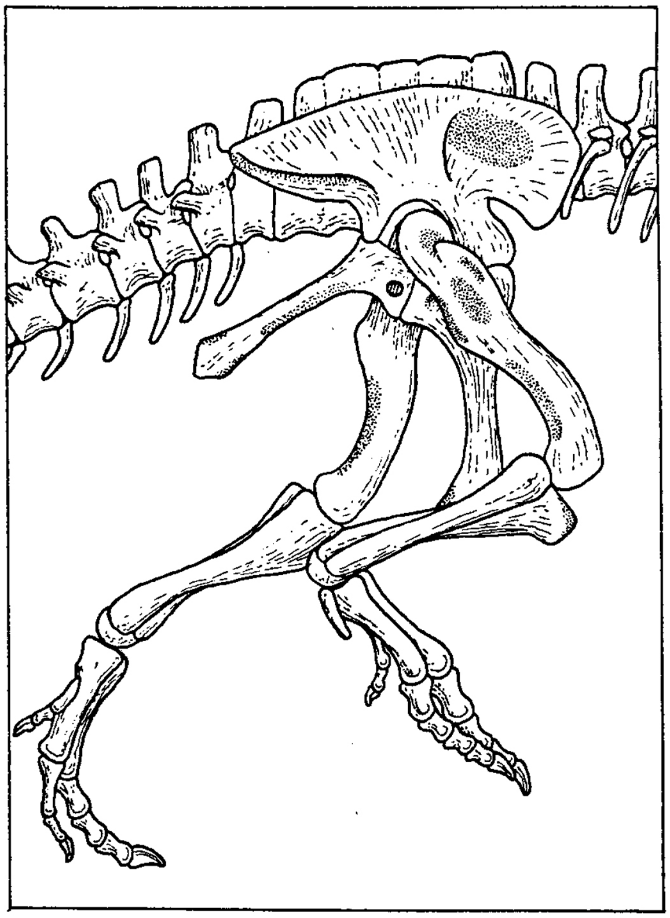
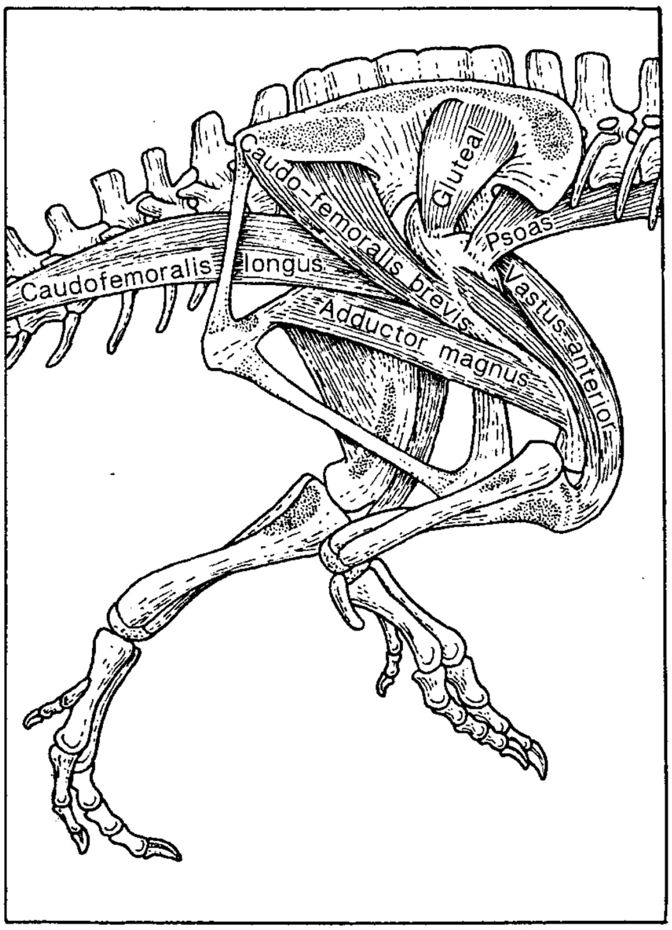


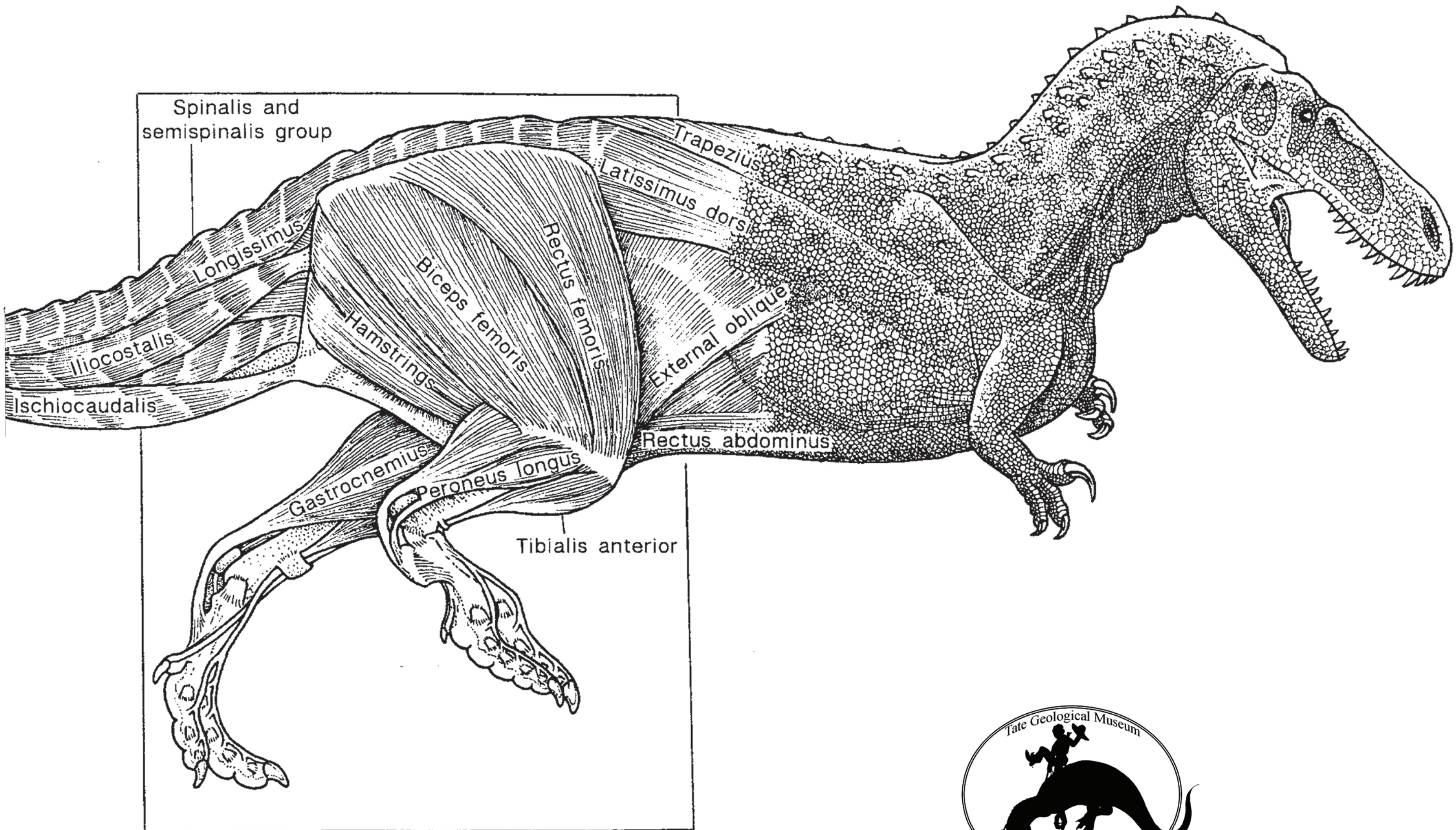

Caudo-femoralis brevis
Gluteal
Psoas
Caudofemoralis longus
Vastus anterior
Adductor magnus

Sequential muscle reconstruction of the

Giant Megalosaur (*Edmarka rex*)

Megalosaurs were a group of 'mid-grade' theropods -- more advanced than the archaic ceratosaurs but more primitive than the allosaurs. Most lived during the middle Jurassic and weighed about a tonne. For years it was generally assumed that by Morrison times they were extinct. But in recent years Dr. Robert Bakker discovered the bones of a new species of theropod, *Edmarks rex.* Although known from very incomplete remains, this animal seems to have been the last and largest of the megalosaurs. At almost 12 metres long and with a live weight of over 5 tonnes, *Edmarka* would have rivalled *Tyrannosaurus rex* in size.

The skeleton of *Edmarka*'s hindquarters is illustrated at upper left; bones of other megalosaurs were scaled up to fill in the missing portions. Shaded areas represent the attachment points for the muscles in the next stage of the reconstruction at lower left; on the actual bones these areas are often marked by muscle scars. Similarly, the shaded areas in that stage show the attachment points for the final stage below. Generally, *Edmarka*'s bones are much thicker and stronger in proportion to their length than the corresponding bones in *Allosaurus*. The size of the attachment points shows that the muscles were more robust as well. Perhaps *Allosaurus* was a fast running distance hunter, and *Edmarka* more of a jumping ambush predator.



Drawings courtesy of Russell Hawley, Tate Geological Museum Education Specialist

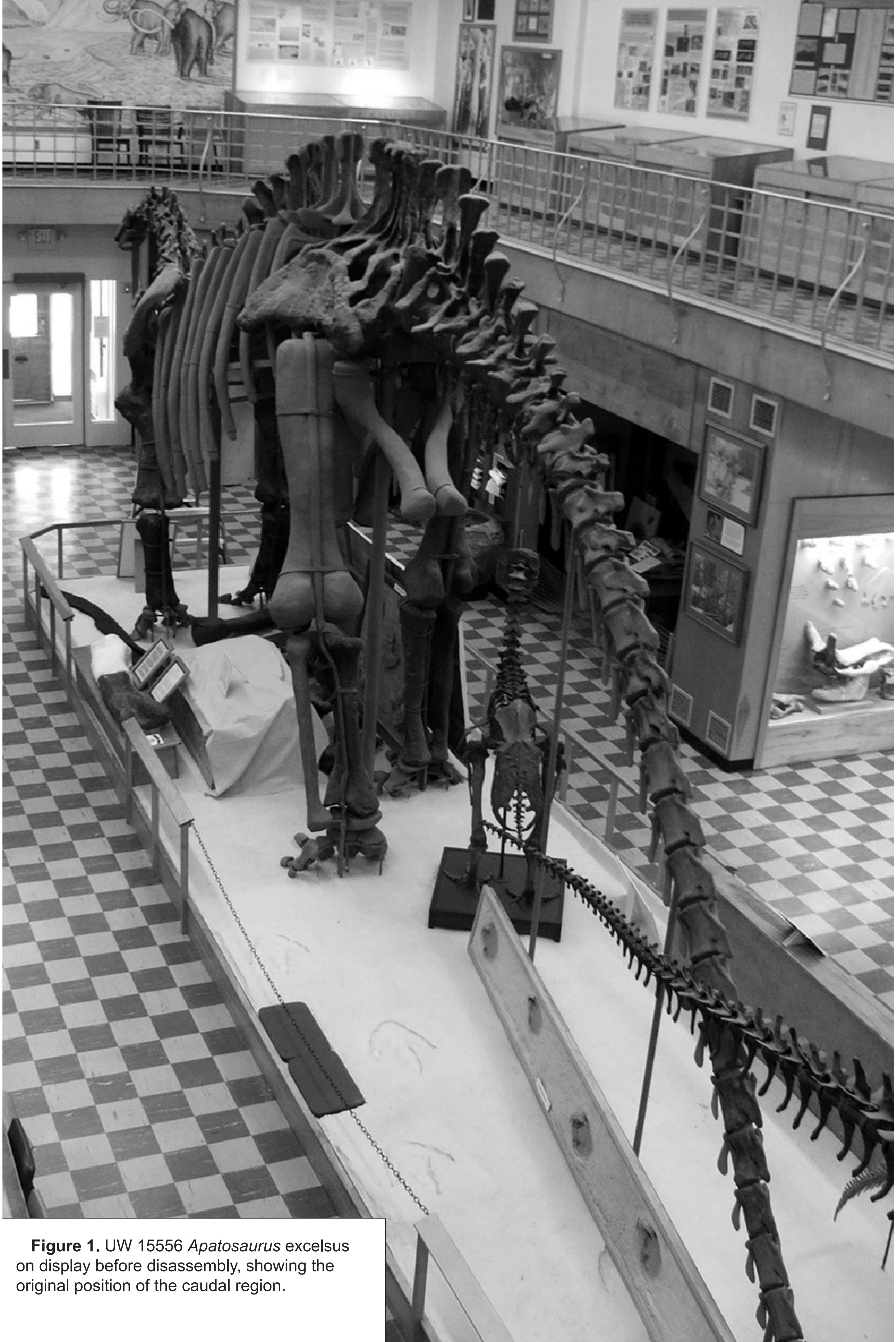


Figure 1. UW 15556 *Apatosaurus* excelsus on display before disassembly, showing the original position of the caudal region.

The Remounting of *Apatosaurus excelsus* UW 15556

or

All for a Little Tail

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Abstract

Like many museum displays, the University of Wyoming's *Apatosaurus excelsus* exhibit required renovation to keep pace with a half century of new discoveries and scientific research. In 2006, Triebold Paleontology Inc. (TPI) was chosen to disassemble, stabilize, re-prepare, mold, cast and remount this 24-meter-long skeleton. Working with legacy armatures and preservation techniques presented special challenges. Additional goals were to update the posture of the mount, correct previous anatomical errors, and incorporate pelvic elements not included in the original mount.

Introduction

UW 15556 (formerly CM 563) was discovered and excavated from the late Jurassic Morrison Formation along Sheep Creek, Albany County, Wyo. in 1902 by a field crew from the Carnegie Museum of Natural History (Hatcher 1902). It was quickly prepared and readied for mounting, however this specimen was never put on display. Another *Apatosaurus* specimen, (CM 3018) was mounted instead. CM 563 remained in storage until 1956 (McIntosh 1981). That year, Dr. Samuel Knight approached the Carnegie Museum about returning CM 563 for display to the University of Wyoming's Geological Museum. An agreement was reached, missing elements were fabricated and the skeleton was erected from 1959 to 1961. There it stood for nearly 50 years (Figure 1) with students, volunteers and museum staff providing necessary maintenance. In March 2007, staff from TPI arrived in Laramie to disassemble the skeleton and transport it to Woodland Park, Colo. for renovation and molding. The skeleton was made accessible to researchers to take detailed measurements and photographs during this phase. Additionally, staff from the Wyoming Dinosaur Center (WDC) used a laser-scanning device to digitally record the original bones.

Abbreviations

- **CM** Carnegie Museum of Natural History, Pittsburgh, Pa.;
- **KUVP** University of Kansas Natural History Museum, Lawrence Kan.;
- **UW** University of Wyoming Geological Museum, Laramie, Wyo.

Materials and Methods

Disassembly of the skeleton was fairly straightforward, however the size of the animal added difficulty to the project. A small amount of scaffolding was erected around the specimen. Cutting torches were used to remove metal supports, although in many cases the supports could simply be snapped free by hand. Bones were then lowered using ratchet-type nylon straps and manpower. The original mount was in a tail-dragging posture, and all elements that touched the ground were cemented into the base of the exhibit. At least two layers of paint covered all of the bones, and the individual vertebrae were bonded with plaster rings. The original bone material was weakly consolidated and had become brittle over time. The fossilized remains were prepared for shipment to Woodland Park with pallets, lumber and bubble wrap padding. For safety of workers and the specimen, the sacral bones and ilia (weighing an estimated one ton) were left mounted on the armature in Laramie.

In the lab, the bones were inspected for damage. A log sheet was created for each bone to track the extent of the previous two generations of restoration, and also used to record labor and materials. An engraving of "May 1902" was noted and preserved on the left tibia. Cracks were filled with Paleobond PB 002 penetrant stabilizer, and gaps filled with either Paleobond PB 750, PB 1500 or Aves Apoxie sculpt, depending on their size. Broken limb bones were

Figure 2. Caudal vertebrae of UW 15556 showing condition before (left) and after (right) air abrasion and consolidation.

Figure 3. Right Metatarsal II of UW 15556 with markings "L" and "563" exposed by removing outer layers of paint.

Figure 4. Right fibula of UW 15556 showing plaster restoration with wire mesh, as well as steel splints before removal.

consolidated using Paleobond PB 002 along the break surfaces to harden the interior of the bone. A 5/8 inch masonry drill bit was used to drill a 10cm deep hole on each side of the break, and the break itself was mended with ½ inch diameter threaded steel rod and either Paleobond PB 4540 Jurassic Gel or marine epoxy while the bone was held vertically in a sandbox. Broken transverse processes and neural spines on vertebrae were repaired in a similar method, without internal pins. The right humerus, which was mounted on the left side, had its distal end originally restored backwards. This bone was intentionally re-broken in the lab and correctly repositioned.

The layers of paint over the bones were removed using Armex Maintenance Formula XL sodium bicarbonate blasting media under low pressure from a high volume sandblasting unit normally used in automotive restoration. The pressure could be precisely controlled to remove only the unwanted layers of paint, revealing specimen and field numbers from its initial preparation (Figure 2, 3). Excess plaster restoration was removed using both air abrasion and pneumatic scribes. In many cases, broken bones were previously repaired by simply wrapping the bone in 1/4 inch galvanized wire mesh with a coating of plaster. Small half-round steel splints were also discovered in grooves carved into the exterior of the bone, joining two sides of a break (Figure 4). All of this older repair work was removed and the bones cleaned before rejoining the pieces in the method described above. Once cleaned, all bones were given a penetrating application of PaleoBond Vinac B15 to harden and seal the surface.

Molding was accomplished using a variety of methods, depending on the bone. Simple smaller bones were replicated using two-part RTV silicone block molds. Larger and more complex bones required multiple piece RTV thixotropic silicone or latex molds with Aquaresin mother molds. Clay lines were removed using naphtha. A thixotropic silicone peel with plaster and burlap mother molds was made of the sacral assembly on site (Figure 5). These molds were used to make a lightweight plastic and foam replica of the pelvis in Woodland Park, where it was then re-molded.

In order to save time, some bones such as the humeri, ischia and pubes, were shipped to Laramie with supporting metalwork already installed. Two-part urethane foam cradles were constructed for transport of most large bones. The metalwork cradling individual bones from the original mount was very thin. After restoration of the bones it did not precisely fit, so much of it was replaced. Thicker steel strap was contour-fitted to the bones and welded in place, similar to the method used to mount *Camarasaurus supremus* KUVP 129716 (Martin et al., 2001) (Figure 6). The shape of the main structural armature was left unchanged, however supports were modified to bring the tail up in a more modern pose. All joints were reinforced by welding where necessary, particularly where the pelvis support pole met the mount. This was done to ensure the joint could support the additional weight and torque of the original pubis and ischium. New mounting brackets were fabricated to attach all vertebrae. All steel supports for bones were welded directly to the armature. The old restored missing caudal elements and left femur had been made of plywood, wire mesh and plaster. These were not reused due to weight concerns. Instead, urethane foam casts made from molding the original restored elements were substituted. Additional chevrons were fabricated to complete the tail, as they were not present in the original tail-dragging mount. The tail was then raised by adding extensions to existing mounting points, as well as being supported by horizontal steel cable strung between the walls of the exhibit space (Figure 7). Remounting was completed in October, 2008.

Figure 5. TPI employee Raymond Vodden applying a mother mold over cured silicone on the pelvic assembly. Work is being done on an approximately 2m tall platform.

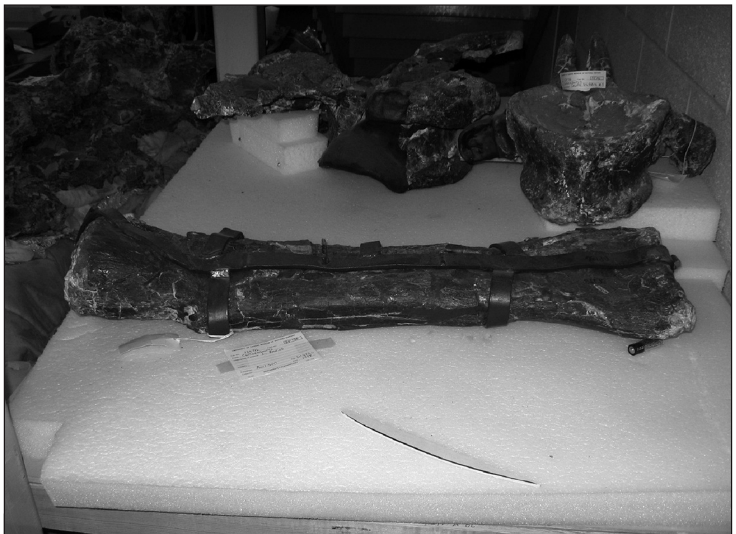

Figure 6. Left radius of *Camarasaurus supremus* KUVP 129716 showing steel strap contour fitted and welded. This is how some bones were prepared prior to shipping and final mounting.

Figure 7. Mount of UW 15556 nearing completion, with caudal region in its new position.

Conclusions

The entire project was extremely labor and materials intensive, taking over 18 months to complete. Special care must be taken with older mounts due to the nature and methods of consolidation and restoration, especially when records are sparse or missing. With special care, historical markings and details can be exposed and preserved. Documentation should be provided to the institution whenever possible. Communication and coordination between the home institution and the assembly team is critical at all levels, from deciding the final pose to which consolidants should be used.

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