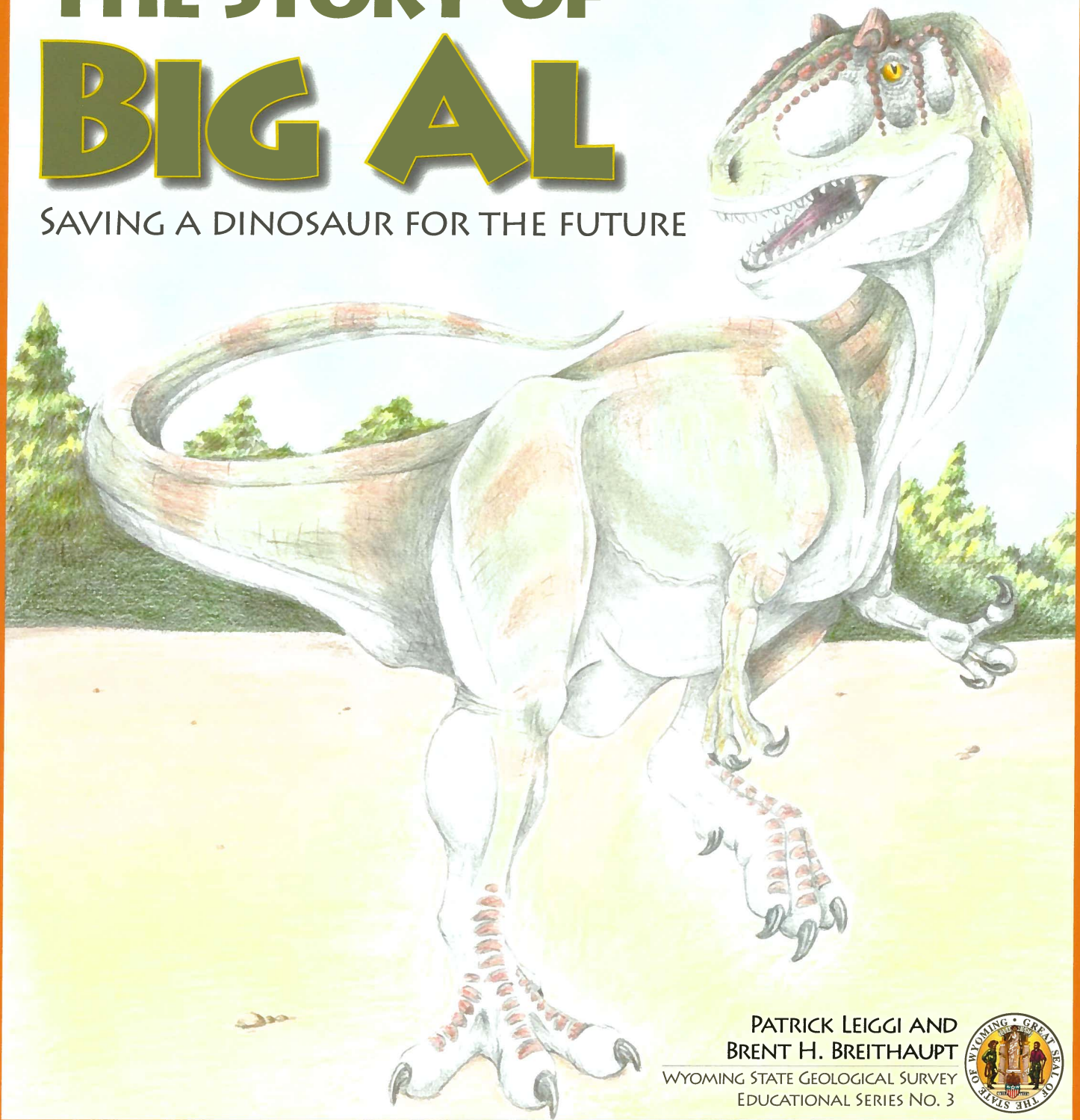
THE STORY OF BIG AL

SAVING A DINOSAUR FOR THE FUTURE



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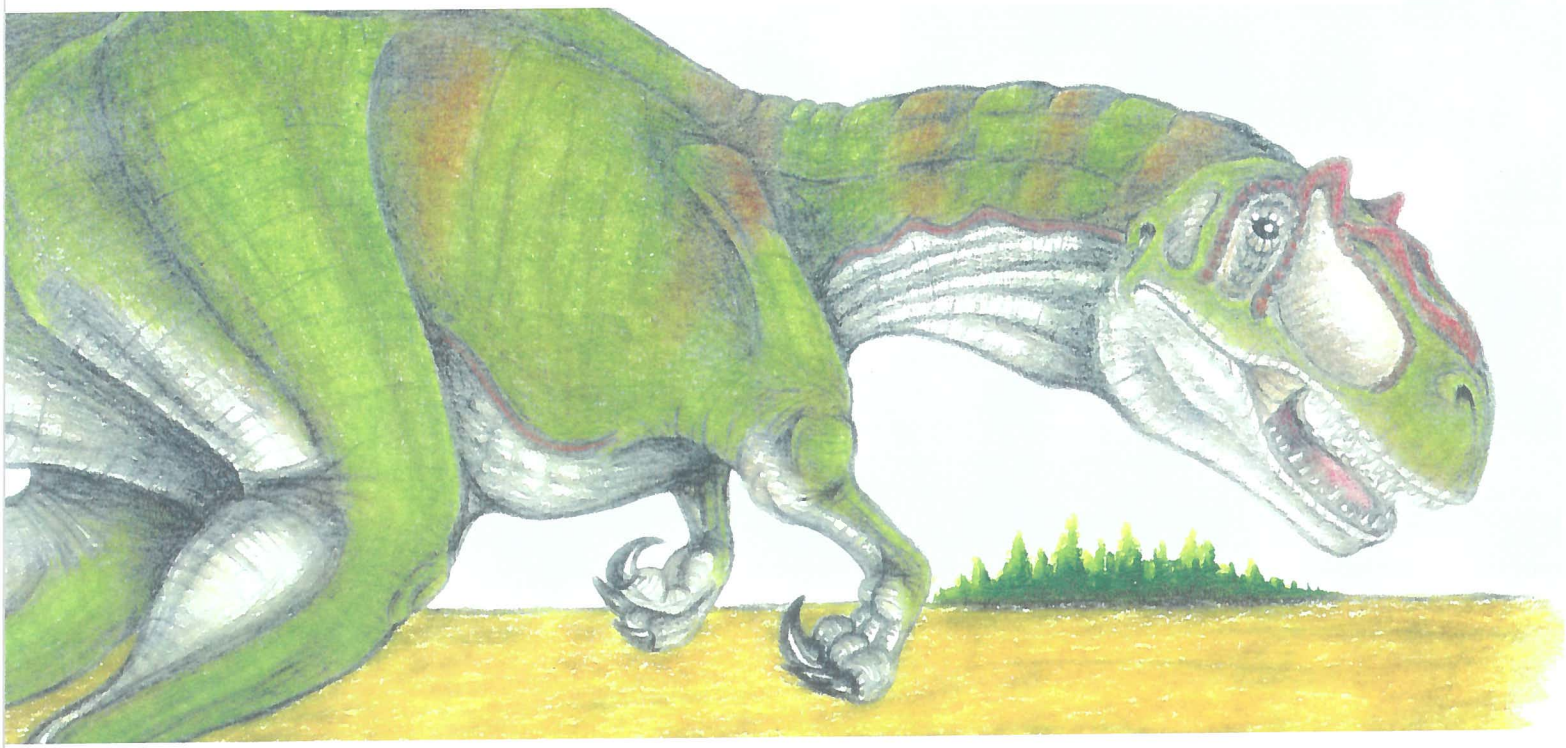
WYOMING STATE GEOLOGICAL SURVEY
EDUCATIONAL SERIES NO. 3

Wyoming State Geological Survey
Ronald C. Surdam, State Geologist



First printing of 1,000 copies by Vision Graphics, Loveland, Colorado, January 2009.

The Story of Big Al: Saving a dinosaur for the future, by Patrick Leiggi and Brent H. Breithaupt, illustrated by Thomas L. Adams.
Wyoming State Geological Survey Educational Series No. 3, 2009.
ISBN 1-884589-39-1

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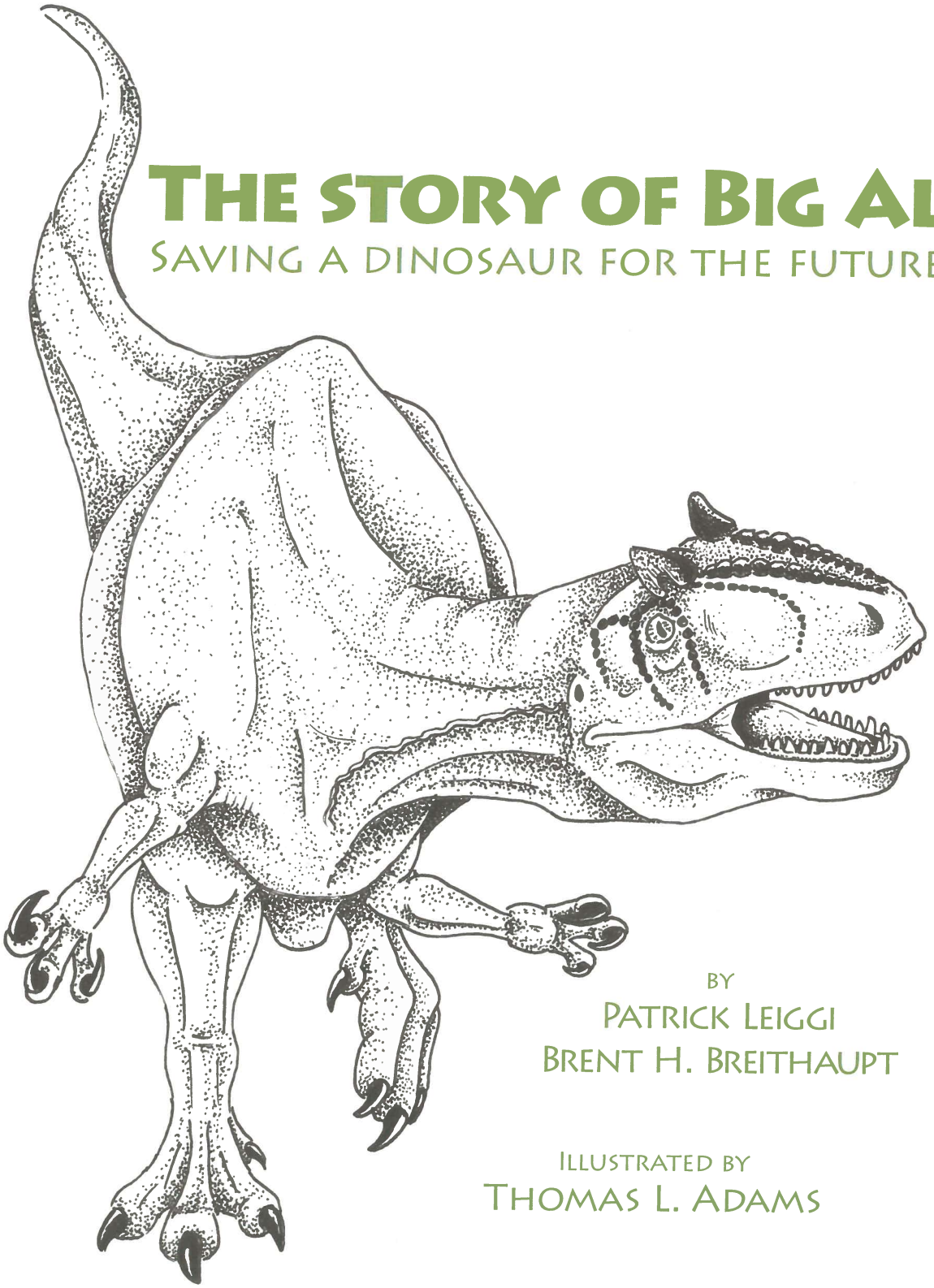

BY

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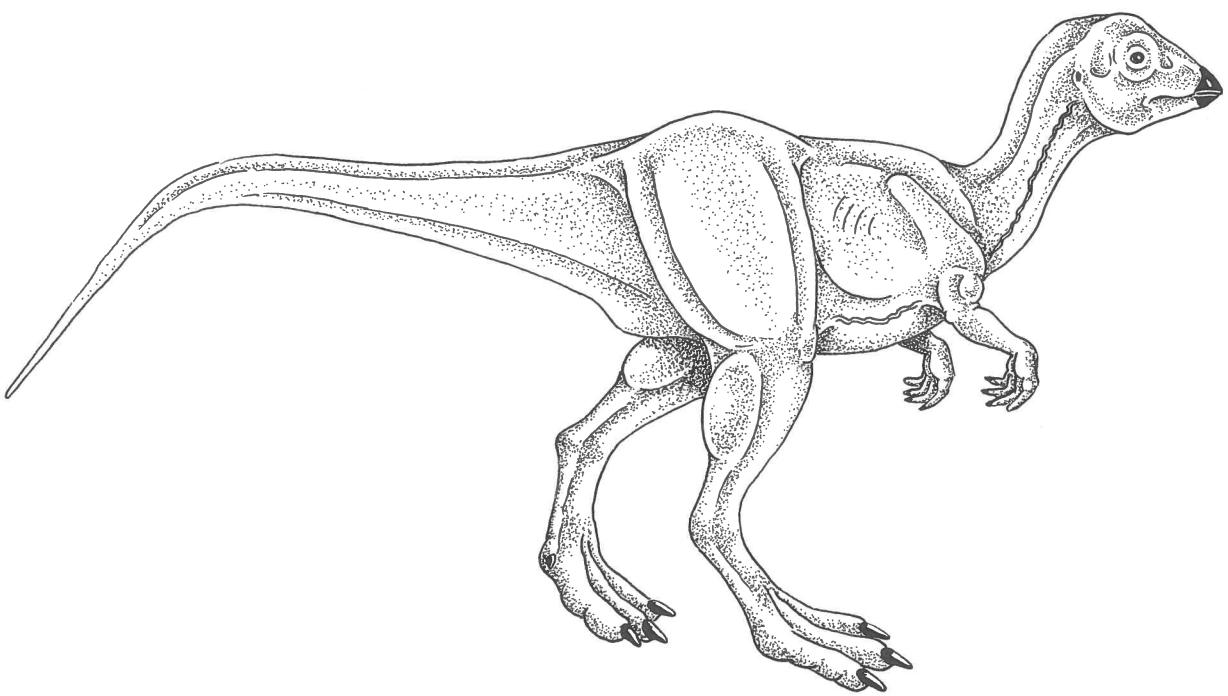
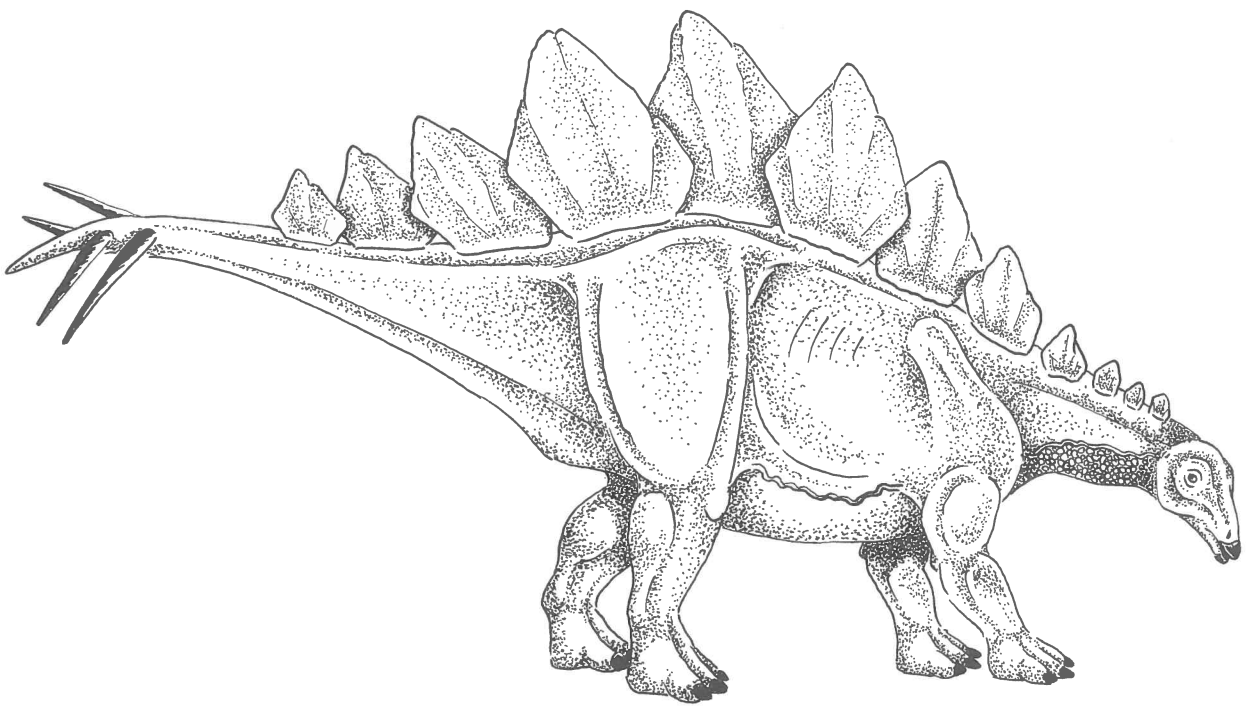


For

Cam, Cayley, Colby, Cooper J., Danielle,
Duncan, Eda, Gregory, Heidi, Innes, Jake, Jill,
Kelly, Maggie, Marshall, Michaela, Nate, Noah,
Olivia, Sally, Sarah, Spencer, Tatum, and William



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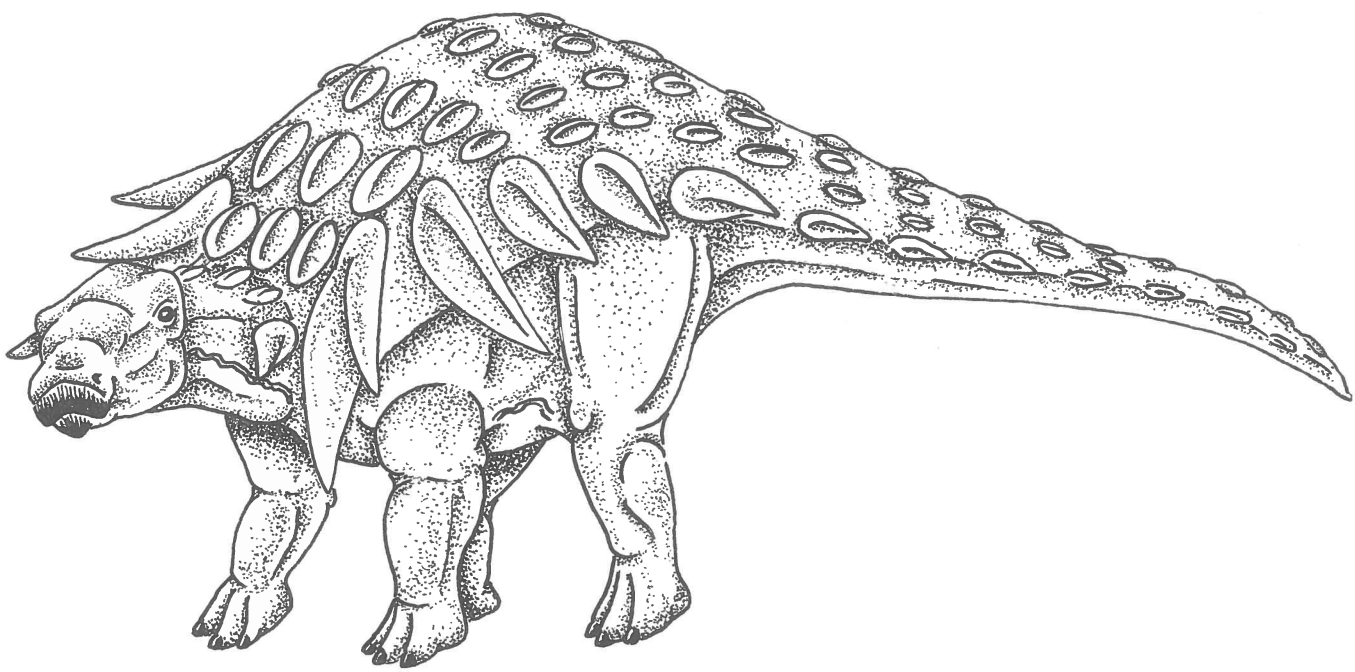


Foreword

Scientists have studied the Jurassic dinosaur *Allosaurus* for more than 100 years: Dr. Ferdinand Vandiveer Hayden first discovered a fragmented tail bone of *Allosaurus* in Colorado in 1869. Our knowledge of this species advanced tremendously with the 1991 discovery of Big Al, the most complete (95 percent) individual *Allosaurus* ever recovered. Found in the famous dinosaur-bearing Morrison Formation of northern Wyoming, this skeleton is the most well-preserved carnivorous dinosaur found in the fossil-rich state. Research on this specimen and the area where it was found is providing important information about Jurassic dinosaurs and the environment in which they lived.

Important paleontological discoveries continue to be made in the Rocky Mountain region. With a high potential for new discoveries in this region, cooperation between university scientists, museum scientists, and federal land management agencies is essential to the collection, study, interpretation, and exhibition of these specimens for future generations. Paleontological studies of fossils, such as this *Allosaurus*, are the basis for our understanding of past life – a fascinating topic for all of us.

Introduction

The Story of Big Al: Saving a Dinosaur for the Future is based on the actual events surrounding the collection and display of the most complete *Allosaurus* skeleton ever found, Big Al. The actual gender of this specimen is unknown, but the masculine form is used in this publication. This book is designed to present a picture of the life and times of an important dinosaur and to walk the young reader through all aspects of dinosaur discovery, collection, research, storage, and display. It also illustrates the views of paleontologists who believe that fossils on U.S. public lands are being threatened by a worldwide commercial fossil market, and that we need to better protect these important parts of our natural heritage for future generations, especially our future scientists and educators. We suggest that readers become familiar with the terms used in this book by reading the definitions provided in the glossary. The glossary will also help young readers understand the terms used in many other dinosaur books.

We hope this book will help all readers understand the importance of our fossil resources, their protection, and the scientific process, and that it will stimulate young readers to learn more about the fascinating world of dinosaurs.

150 Million Years Ago

Long ago during the Jurassic Period (**Figure 1**), Wyoming was a very different place. Instead of being thousands of feet above sea level divided by high mountains and valleys (as it is today), this area of the world was a lowland flood plain dotted with lakes and rivers. It was a place like the modern African plains, with vast open spaces, diverse vegetation, distinct subtropical wet and dry seasons, and a wide variety of animals.

The dominant animals of the time were the dinosaurs, a group that included the enormous *Apatosaurus* and *Diplodocus* and the ferocious *Allosaurus*. Allosaurs were the "tigers" of their age, some of the fiercest predators of the Jurassic Period. Their

powerful skulls were filled with serrated knife-like teeth, which allowed them to slice through meat quickly and easily. Their strong arms ended in sharp claws for grasping prey. Today, they are found preserved primarily in the Upper Jurassic Morrison Formation of western North America.

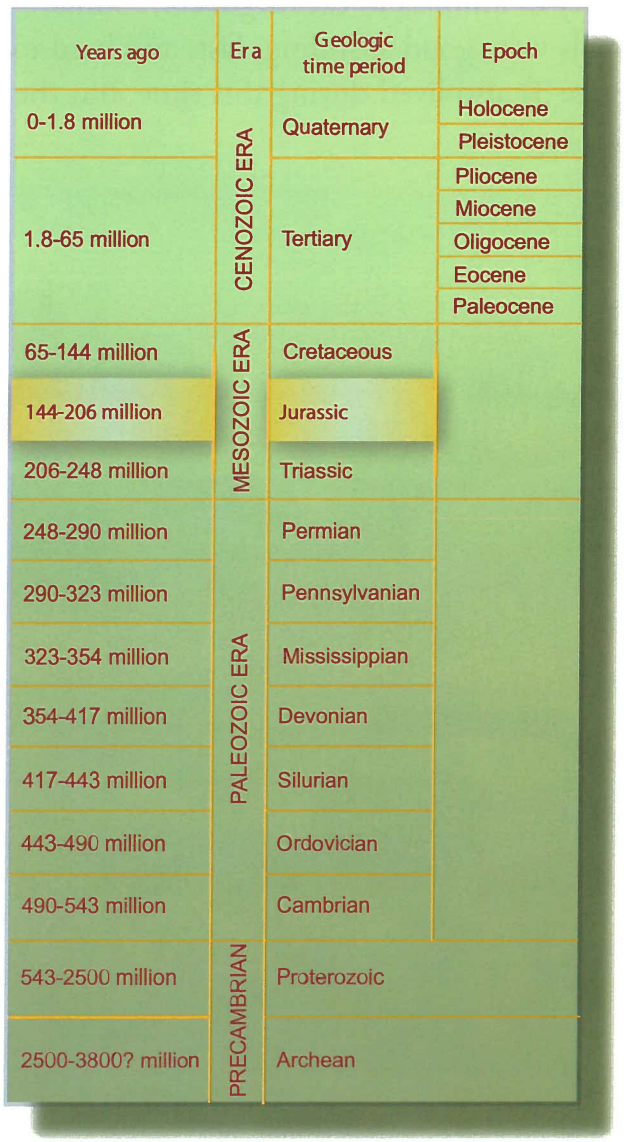


Figure 1. The Jurassic Period lasted about 62 million years. Modified from Geological Society of America's 1999 geologic time scale.

THE LIFE OF BIG AL

One *Allosaurus*, known as Big Al, was a young animal 25 feet long who weighed approximately 2,500 pounds (**Figure 2**). Adult relatives of Big Al were 35 to 40 feet long and weighed up to 4,000 pounds. Big Al, like many young adult animals today, spent most of his life simply trying to survive and eventually look for a mate. He spent most of each day looking for food. There were plenty of animals to eat (**Figure 3**). Some, like the little lizards and mouse-sized mammals were good at hiding, fast, and hard to catch. Flying reptiles like *Comodactylus* (**Figure 3**) also lived during this time, but they

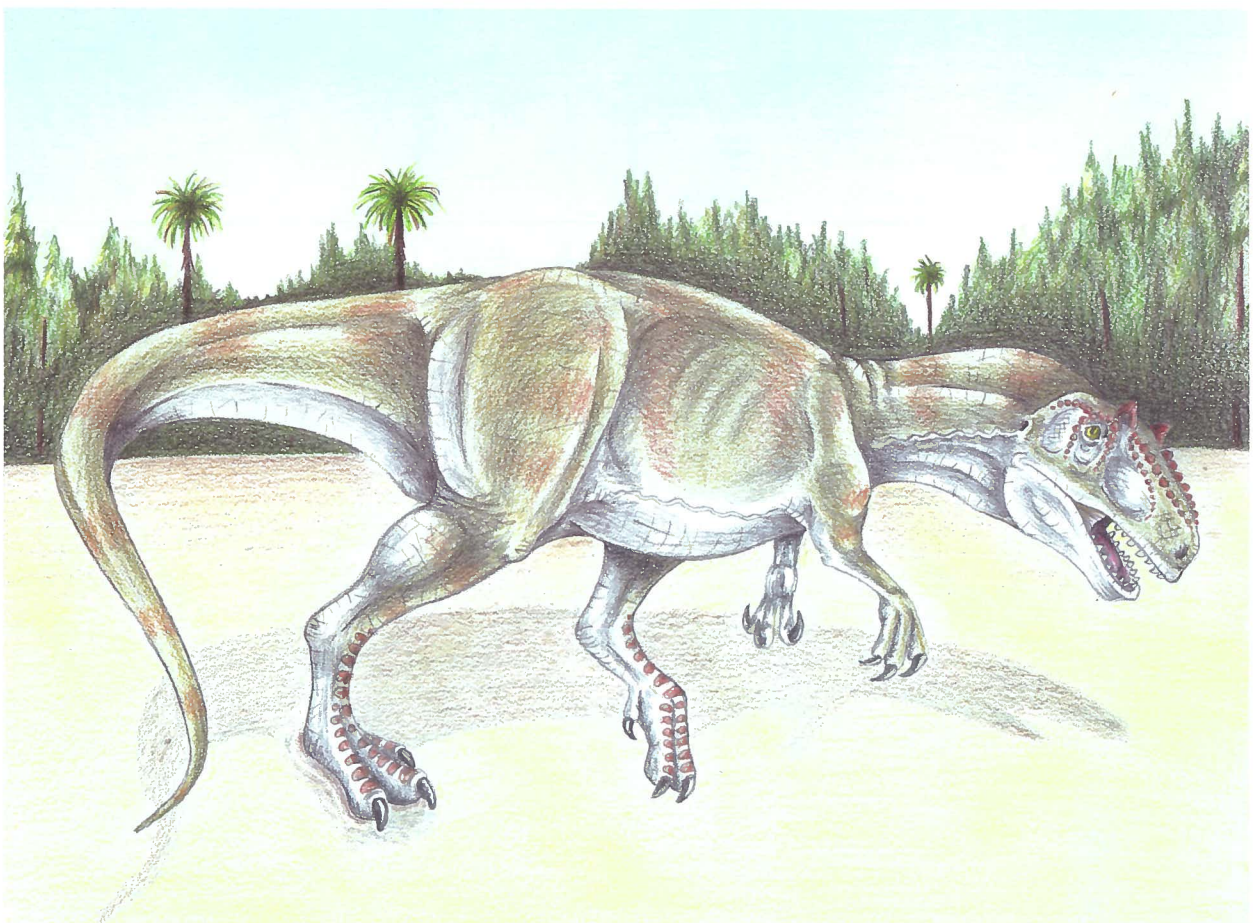


Figure 2. Big Al the *Allosaurus* exploring his Late Jurassic environment.

could fly away if they heard Big Al coming. Small plant-eating dinosaurs like *Dryosaurus*, *Othnielosaurus*, and young *Camptosaurus* were a good meal if they could be caught, but they were also swift.

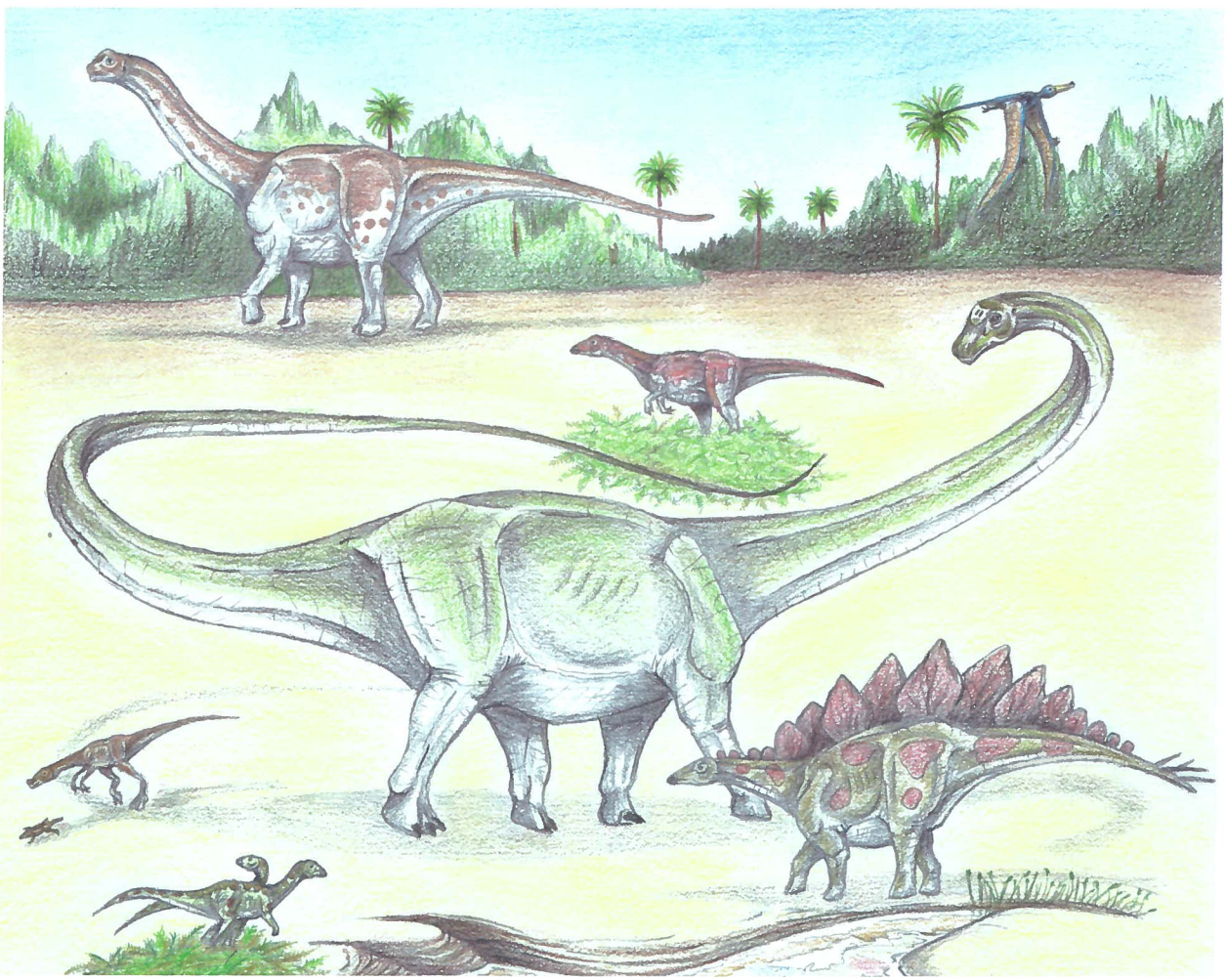


Figure 3. Animals of the Late Jurassic of Wyoming. Although not seen, Big Al could be lurking in the trees while a *Barosaurus* roams across an ancient floodplain in Wyoming. A pterosaur (*Comodactylus*) swoops from the skies, while two *Othnielosaurus* wade into the water. A small *Ornitholestes* chases a small mammal (*Ctenacodon*). A *Camarasaurus* walks away as a *Dryosaurus* stops eating and looks around, perhaps sensing Big Al's presence; an armored *Stegosaurus* ambles carefree across the plain. This drawing is titled "Eatables."

Young sauropods like *Apatosaurus*, *Diplodocus*, *Camarasaurus*, and *Barosaurus* were also vulnerable, but older and larger members of their group usually protected them. With their long necks and tails, some of these sauropods dwarfed Big Al: they measured more than 100 feet long and weighed well over 60,000 pounds. They had powerful limbs and tails. Big Al was no match for dinosaurs of this size. Likewise, young stegosaurs and ankylosaurs (like *Stegosaurus* and *Gargoyleosaurus*) were possible meals, but these juveniles traveled with adults. In addition, these dinosaurs were heavily armored. Some had protective plates on their backs and defensive spines on their tails. Prey was abundant – it was catching and killing these animals that caused problems for Big Al and other carnivores of the time. Occasionally, allosaurs may have hunted in small packs to catch a meal. Once an animal was caught, the battle was not over because other hungry allosaurs, ceratosaurs, megalosaurs, and the pesky *Ornitholestes* had to be chased away.

Dying Young

Just because Big Al was a fierce carnivorous dinosaur did not mean life was easy. He often fought with other animals for food. During some of these struggles, Big Al may have been injured. Just like modern animals, those of the past suffered from a variety of injuries and infections in their day-to-day lives. Because Big Al's bones were preserved so well and because we studied the bones in detail, we learned much about these injuries. Big Al had seriously broken bones and infections. He suffered major injuries to his feet, hands, hips, and ribs, which made breathing, running, and grasping prey difficult. Big Al was slower and weaker than other dinosaurs, and had a harder time killing prey.

Big Al's fossilized bones show us some of the hardships in the Late Jurassic. His injuries could have been caused by a number of factors. Perhaps another *Allosaurus* broke his bones as they struggled for food, or a sauropod defending its young stomped on and broke his ribs (**Figure 4**). Perhaps his toe became infected after he stepped on a

sharp rock, or on a broken bone while standing on a carcass. We do not know exactly how the injuries occurred, but we do know that they affected the way Big Al lived.

Another mystery is the exact cause of Big Al's death. With more than a dozen serious injuries, we do know that Big Al was not a healthy dinosaur. It was difficult for Big Al to survive. One day approximately 150 million years ago, while crossing a stream bed, Big Al collapsed because of weakness, injuries, or perhaps malnutrition, and died (**Figure 5**).

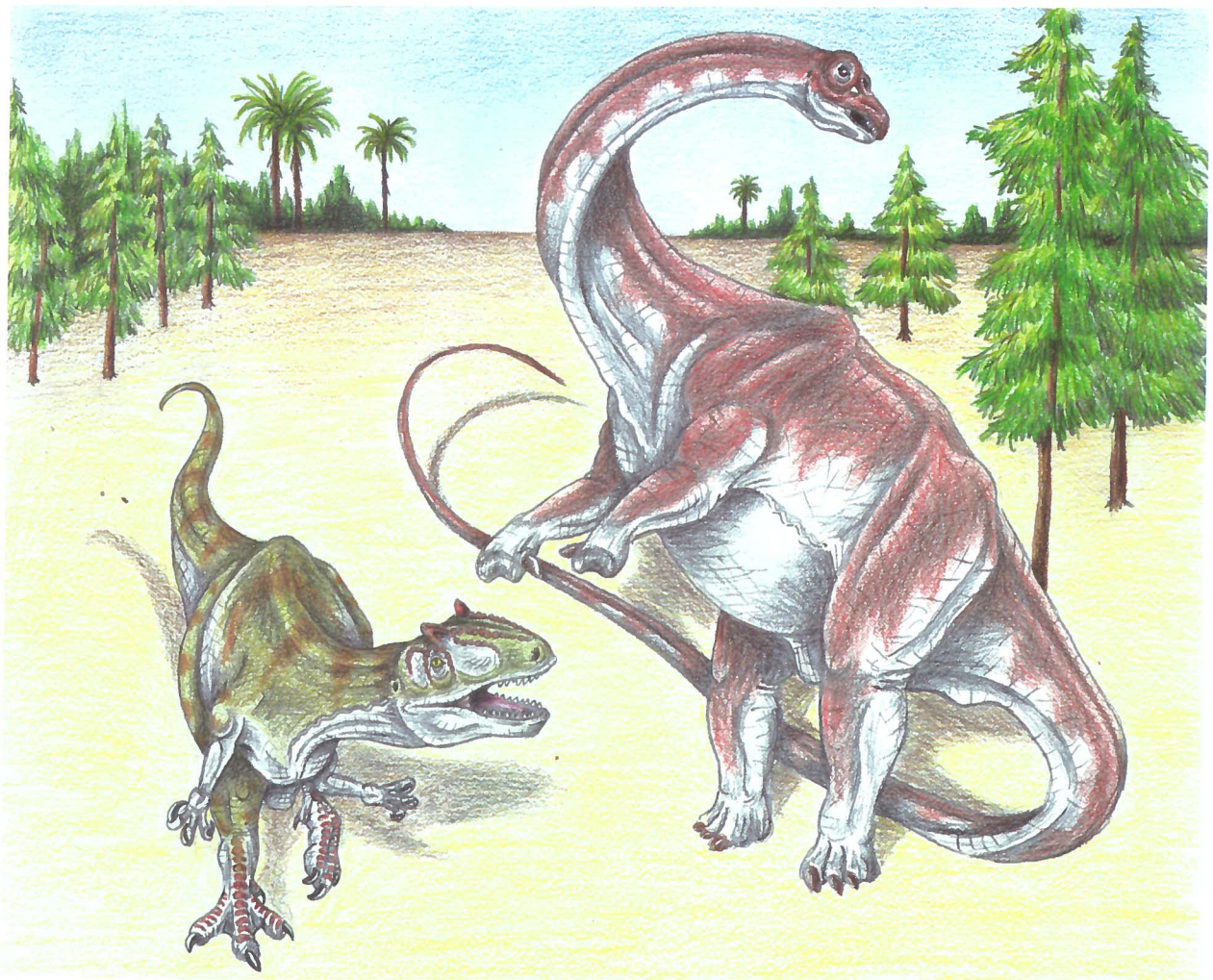


Figure 4. Big Al battling a huge *Apatosaurus*.

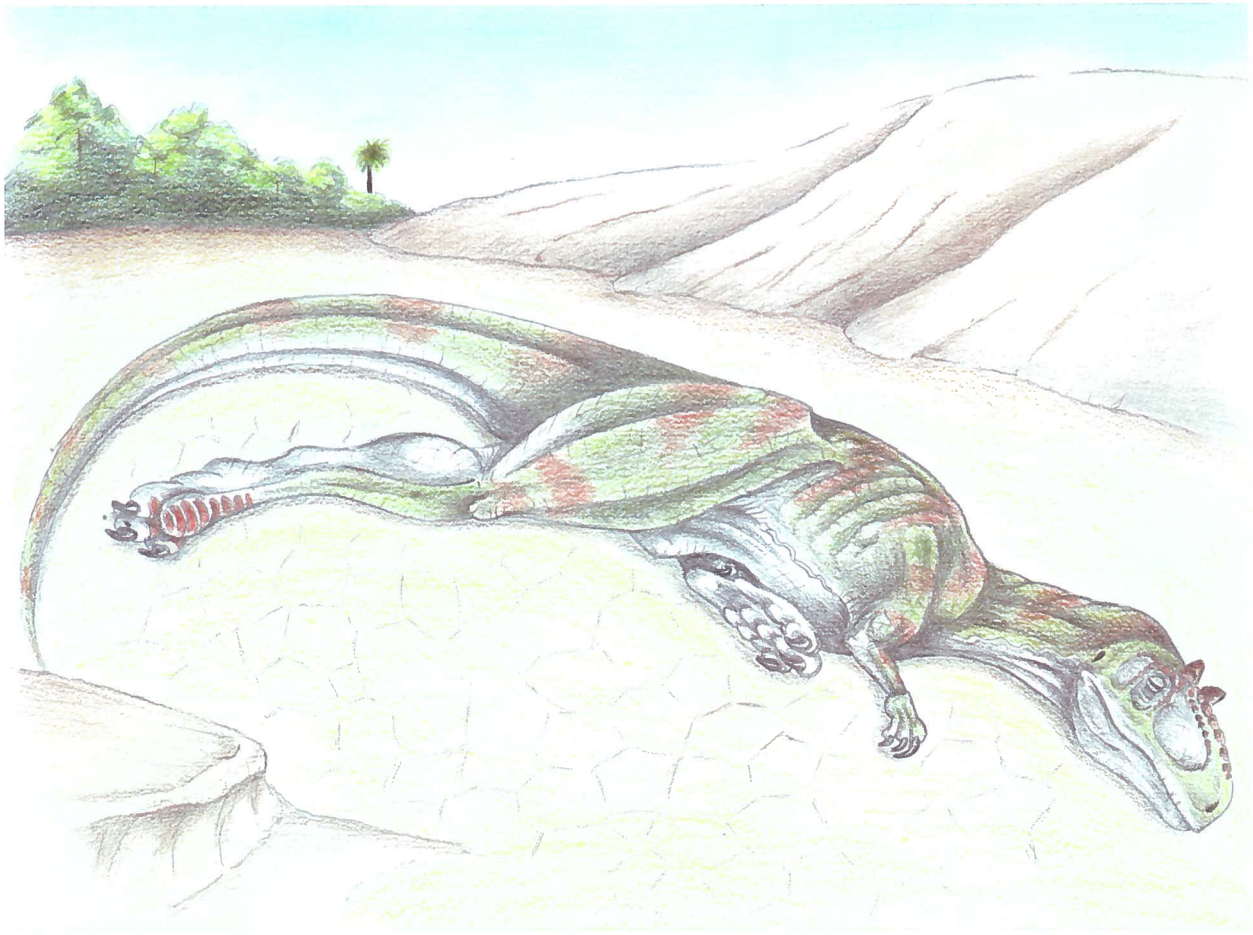


Figure 5. Big Al died along a stream after succumbing to injury and starvation.

Becoming a fossil

Big Al's carcass lay on the flood plain. His skin gradually rotted away and beetle larvae ate the soft tissue, while other animals may have pulled off pieces of flesh and scattered some of his bones. However, most of Big Al was not scavenged and remained articulated. As the carcass lay on the dry stream bed, the hot sun dried out the flesh. The soft tissues of the neck pulled Big Al's head over his back in a death pose typical of animals that died in an arid environment. Unlike most dinosaur skeletons, which are disarticu-

lated and scattered a long distance from where the animal died, the bones of Big Al remained at the spot where he expired. Some of the chest and bones of the right side, which were exposed the longest, had moved a few feet from the main part of his body. Big Al's skeleton was gradually buried by sand and mud as the rains of the wet season flooded the streams (**Figure 6**). In less than a year, Big Al's skeleton was completely buried, freezing his final position on earth in time.

Over the years, layer upon layer of sediment was deposited on the material that encased Big Al (**Figure 7**). In each of these layers, various plant and animal remains were also preserved. As time went by, the region changed, the oceans rose, and eventually the entire area was underwater. Ammonites and sea reptiles such as ichthyosaurs and plesiosaurs swam in the ocean over the buried Big Al. The earth continued to change during the remainder of the Mesozoic Era. The seas eventually retreated, and near the end of the Cretaceous Period Wyoming had become a swampy flood plain. Across the region, an enormous amount of vegetation grew, died, and eventually accumulated to form coal deposits. During the Cretaceous Period, various land animals walked over the buried Big Al. *Tyrannosaurus rex*, *Triceratops*, and *Ankylosaurus* were just a few of the dinosaurs present as the region continued to change. By the end of this period, dinosaurs had become extinct, but birds continued as their descendants.

Mountains rose and basins formed as the Cenozoic Era (**Figure 1**) began. *Hyracotherium* (also known as *Eohippus*, the dawn horse), titanotheres, rhinoceroses, and mammoths were just a few of the species that occupied this area of the world during the Cenozoic Era, the Age of Mammals.

Various prehistoric organisms were preserved in the thousands of feet of sediment laid down over Big Al; the sand and mud encasing him were compacted. Groundwater containing dissolved minerals filtered through the sediments around Big Al. Minerals crystallized out of the water and filled the pore spaces between the grains of sand and mud. These minerals became a cement to hold the loose sediment together. This process of compaction and cementation is how sedimentary rocks form. In addition, the groundwater filtered through Big Al's bones and filled in any available space with

Figure 6. Sediments in the stream during the wet season rapidly buried Big Al's bones where they lay in the streambed.

Figure 7. As time passed, more layers of sediment were deposited over the remains of Big Al, burying them deeper.

Figure 8. Eventually, the layers of sediment containing Big Al were compacted and cemented to form sedimentary rocks. Uplift tilted these rocks, and more sediment was deposited on top of them.

minerals, gradually mineralizing or petrifying the bones. Now Big Al lay petrified in a layer of rock thousands of feet beneath the surface of the earth (**Figure 8**). Most layers of rocks have been named by geologists for the regions or areas where they occur. Paleontologists use these names to help them identify the rocks that contain fossils. The rock layers that entombed Big Al are known as the Morrison Formation.

Millions of years after Big Al lived, died, and was buried, the entire area was uplifted thousands of feet above sea level and formed the Rocky Mountain region. These are the mountains and basins that exist in Wyoming today. Big Al (still encased in his rocky tomb) was elevated more than a mile above the oceans. At the same time, rain, wind, snow, and ice weathered and eroded away the uplifted rocks, creating more sediment and exposing the remains of various prehistoric plants and animals (**Figure 9**).

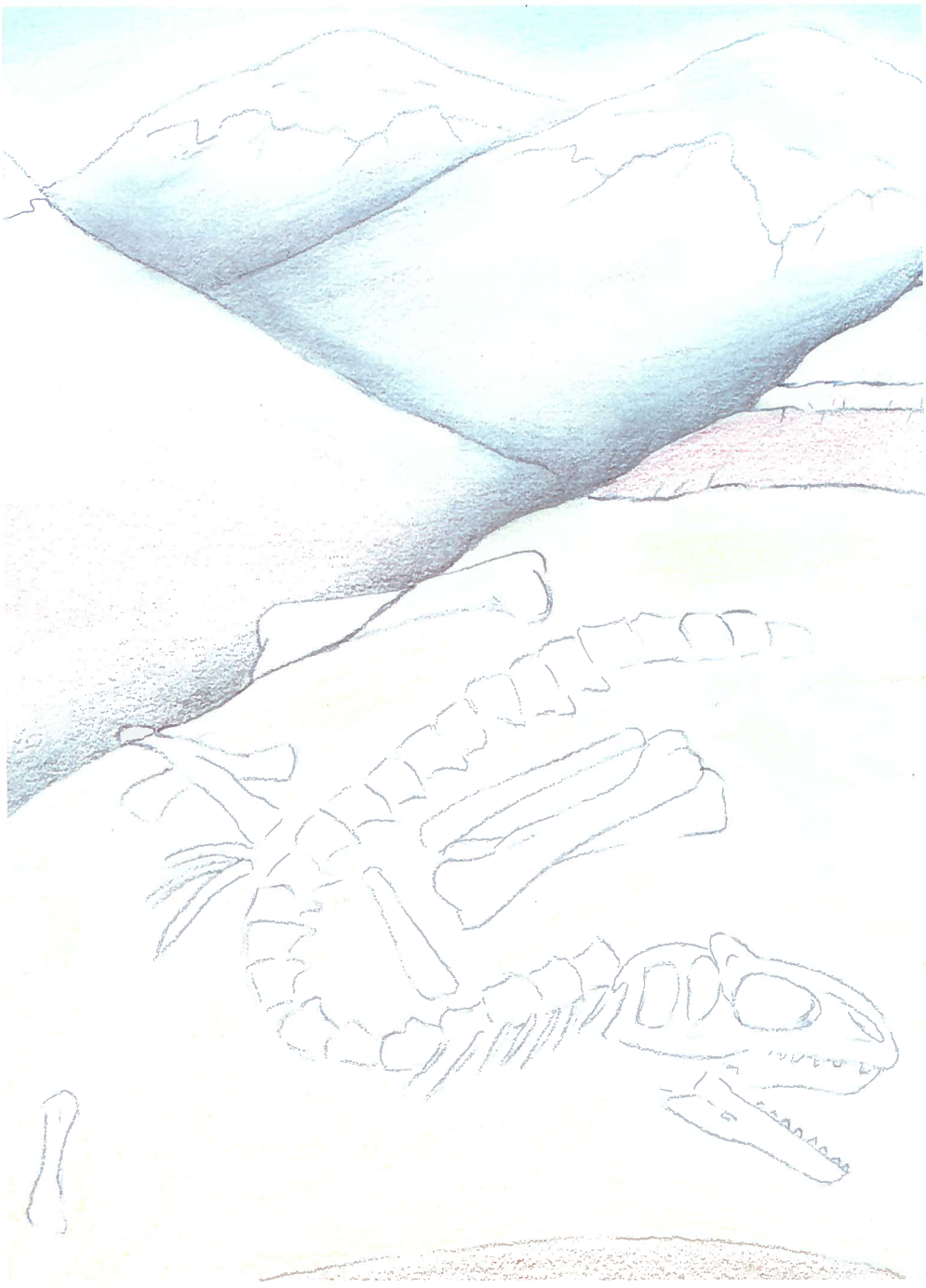


Figure 9. Erosion and uplift of the Rocky Mountains exposed the fossilized remains of Big Al buried 150 million years earlier.

The First Discoveries at Howe Quarry

In the 1930s, Barker Howe, a rancher who lived in Wyoming's Bighorn Basin (**Figure 10**), found some prehistoric remains that had weathered out of a hillside on his property. He contacted Barnum Brown, a well-known paleontologist from the American Museum of Natural History in New York (**Figure 11**). Brown recognized the remains as those of an enormous Jurassic dinosaur and brought a crew of fossil collectors to Howe's land in 1934 (**Figure 12**). Later that summer, a mass of bones from a group of sauropods was also discovered in the Morrison Formation (**Figure 13**). Skeletal remains were crisscrossed and interlocked in a confusing "pickup sticks" fashion. This jumble of bones was exposed, mapped (**Figure 14**), and photographed (**Figure 15**). After the quarry map was made to record the location of the bones (**Figure 14**), the specimens were painstakingly removed from the quarry (**Figure 16**).

The Howe Quarry produced an enormous amount of fossilized remains and contained one of the highest single concentrations of Jurassic dinosaur bones ever found. More than 4,000 dinosaur bones representing at least 20 animals were uncovered. The quarry was dominated by sauropods such as *Barosaurus*, *Diplodocus*, *Apatosaurus*, and *Camarasaurus*. In addition to these dinosaurs, remains of *Camptosaurus* and teeth of *Allosaurus* were also found. The remains in the Howe Quarry were generally disarticulated. Skin impressions and gastroliths were also found there.

The quarry was a popular attraction. Thousands of tourists from the U.S. and Europe visited the site while the museum was working in the quarry. By the time the work was finished, more than 60,000 pounds of fossil bones had been collected from the Howe Quarry. Approximately six months after the quarry opened, the last of 144 boxes of fossils was loaded on a train and shipped to New York.

In September 1991, fifty-seven years after Barnum Brown shipped his dinosaur bones to New York, a Swiss commercial fossil dealer and his crew were collecting bones from

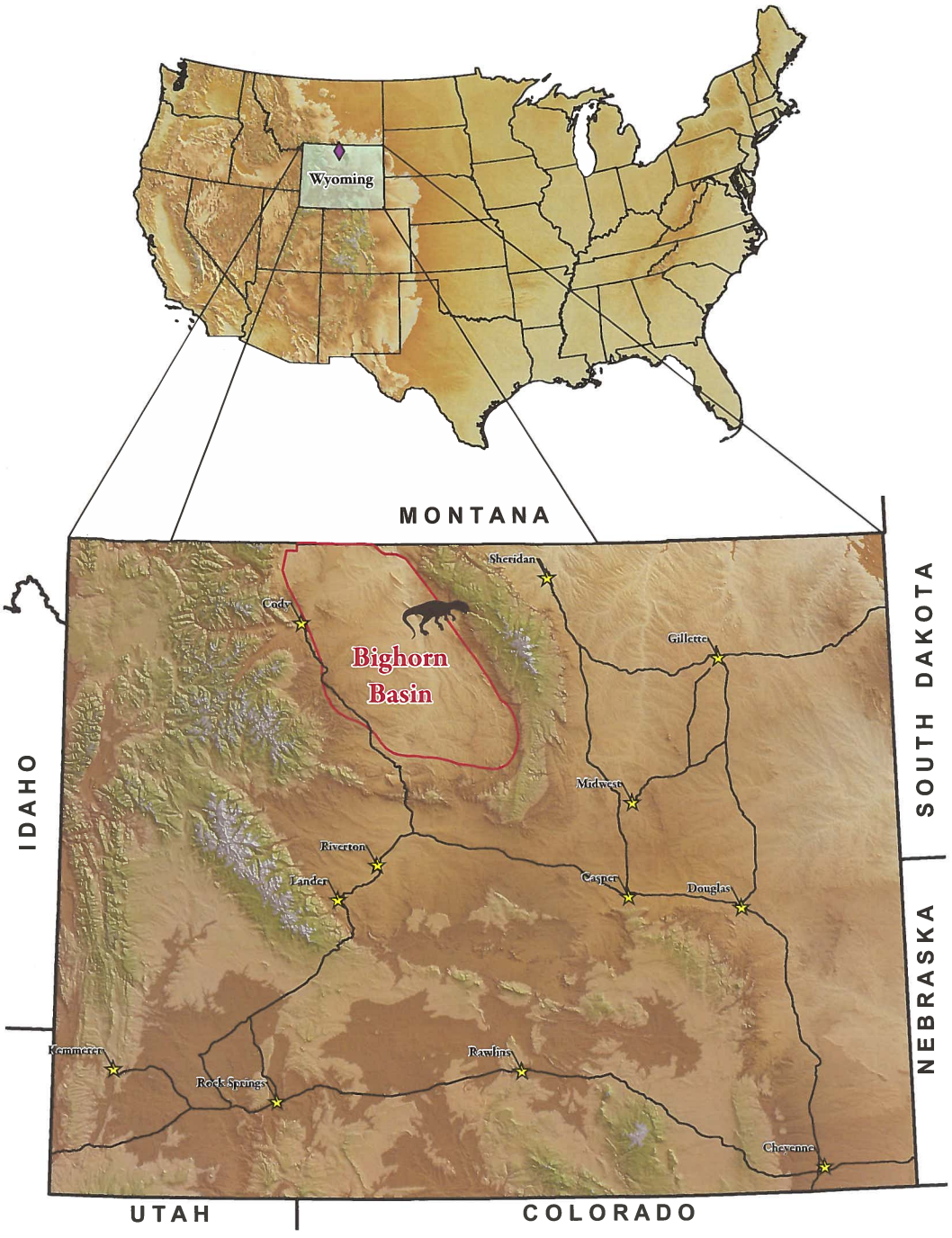


Figure 10. Map of Wyoming showing the location in the Bighorn Basin where Big Al was discovered.

Figure 11. Barnum Brown at the Howe Quarry in Wyoming, 1934. Photograph is negative number 132806 courtesy of the Department of Library Services, American Museum of Natural History.

Figure 12. Crews from the American Museum of Natural History discovered the remains of over 20 different dinosaurs from the Howe Quarry in the Morrison Formation of northern Wyoming. Photograph is Negative number 132805 courtesy of the Department of Library Services, American Museum of Natural History.

Figure 13. More than 4,000 bones were uncovered at the Howe Quarry in 1934. Photograph taken by Roland T. Bird (from the hay stacker), 30 feet above. Dr. Barnum Brown was in charge of the expedition. Photograph is negative number 132803 courtesy of the Department of Library Services, American Museum of Natural History.

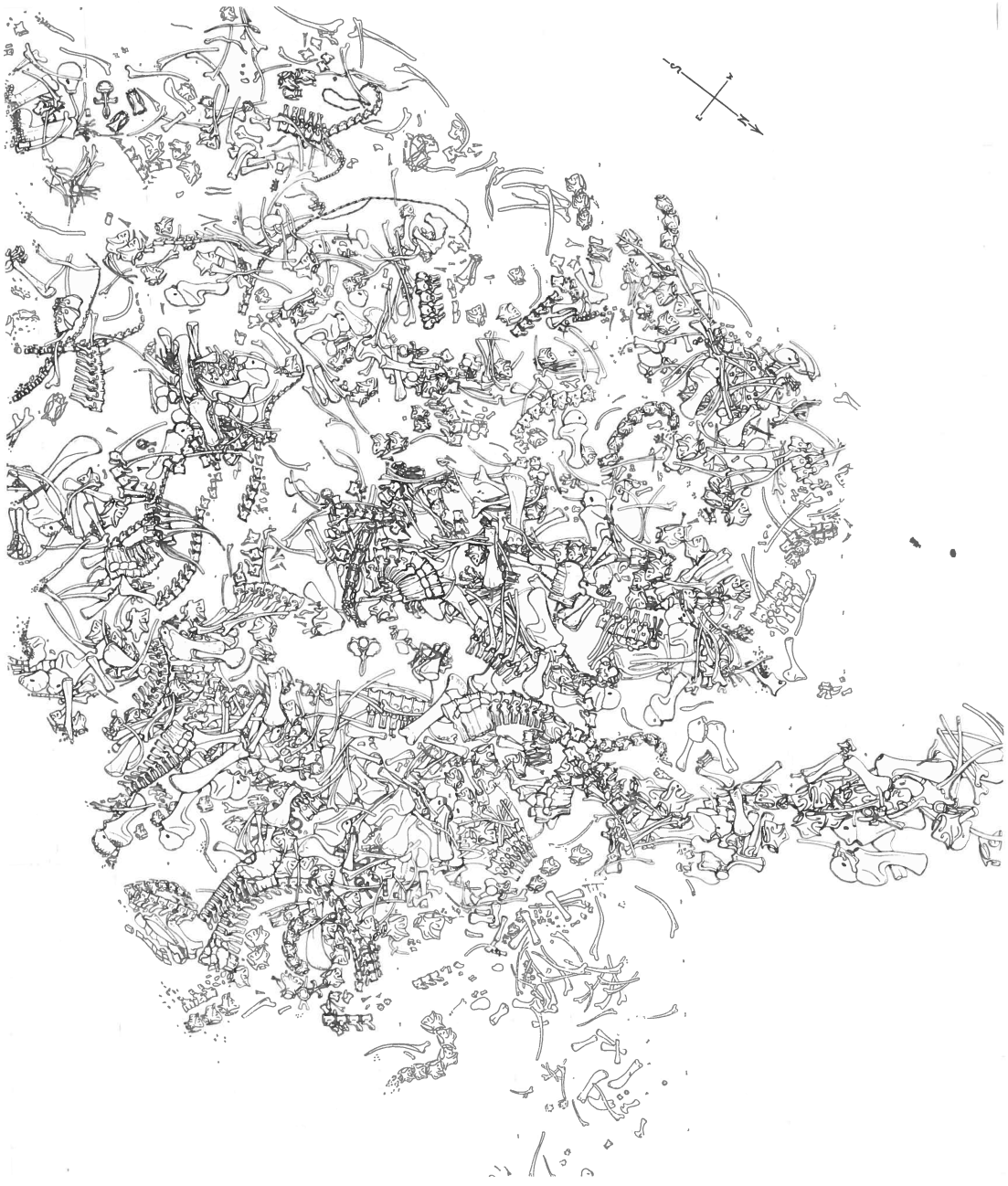


Figure 14. American Museum worker Roland T. Bird made a quarry map of the Howe Quarry. Photograph is Negative number 314524 courtesy of the Department of Library Services, American Museum of Natural History.

Figure 15. Roland T. Bird photographing from the hay stacker, Howe Quarry, Wyoming, 1934. Photograph is negative number 2A25670 courtesy of the Department of Library Services, American Museum of Natural History.

Figure 16. Lillian Brown, R.T. Bird, and C. Sorensen removing bones from the Howe Quarry, Wyoming, 1934. Photograph is negative number 2A25669 courtesy of the Department of Library Services, American Museum of Natural History.

the privately-owned Howe Quarry. The Swiss crew worked very hard, but they were not finding very many complete dinosaurs. One of the crew members started to look for dinosaur fossils in the hills nearby and found what appeared to be a nearly complete carnivorous dinosaur skeleton. It was Big Al! The Swiss crew worked quickly to uncover Big Al's bones. Big Al's story didn't end here. In fact, the excitement was just about to begin.

The Swiss fossil collector knew Big Al's skeleton could sell for a lot of money so he traveled to a big fossil show in Denver, Colorado to tell other fossil dealers about his discovery. Unfortunately, he didn't know that his crew had found Big Al on public instead of private land. According to the laws, vertebrate fossils found on federal public land belong to all U.S. citizens and cannot be sold commercially or permanently removed from the country. Weeks after the discovery, a surveillance crew from the U.S. Bureau of Land Management (BLM) flew over the area and spotted the Swiss crew's road leading to the Big Al site. They became suspicious of the work on public land and decided to investigate.

PUBLIC FOSSILS ARE FOR EVERYONE

The BLM is one of several federal land management agencies. Its job is to protect our public lands, which are owned by all U.S. citizens. Not only does the agency care for our public lands, it also looks after fossils and Native American artifacts because the ones found on public lands are owned in common by the American people. This means that no person can own a vertebrate fossil or artifact that was found on public land – sort of like a book in a public library. Since the Swiss crew found Big Al on public land, he could not be sold to an individual or leave the country. Instead, Big Al would need to go to a museum in the U.S. so he could be studied and enjoyed by all Americans. The BLM was worried that Big Al was going to be sold.

Fortunately, the BLM found the Swiss quarry before Big Al was removed from the ground and sold. Jim Chase (**Figure 17**), an archaeologist with the BLM in Cody, Wyoming, is familiar with publicly-owned fossils and artifacts and was contacted about Big Al. When he visited the site where Big Al was discovered, he informed the Swiss crew that they were on public land and that they could no longer dig up Big Al's remains because they did not have permission.

Jim was looking for advice on what to do with Big Al. After talking with other BLM staff members in Wyoming, he decided to call dinosaur experts at three museums. He called Brent Breithaupt at the University of Wyoming Geological Museum in Laramie, Pat Leiggi at the Museum of the Rockies at Montana State University in Bozeman, and Brooks Britt from the Royal Tyrrell Museum of Paleontology in Drumheller, Alberta, Canada.

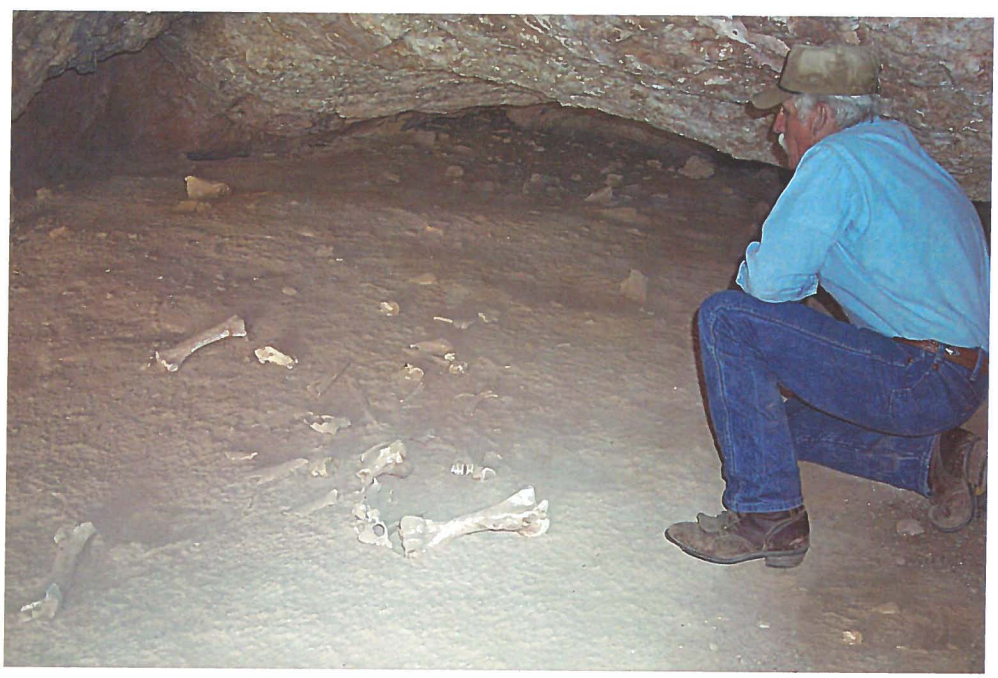


Figure 17. BLM archeologist Jim Chase from Cody, Wyoming.

Brent, Pat, and Brooks met with Jim at the Big Al site (**Figure 18**). When they saw Big Al (**Figure 19**), they couldn't believe their eyes. Big Al was the most complete *Allosaurus* they had ever seen! One question came up: who was going to carefully dig up Big Al's bones? Brooks worked at a museum in Canada, so his museum would not do the work. Brent did not have a staff at his museum to remove Big Al's skeleton. Pat's museum had a trained dinosaur team, so they decided that the Museum of the Rockies would excavate Big Al's bones and preserve them. Brent would map Big Al's bones and help the team when they arrived at the site.

Saving Big Al: the DiRT

It was now late September 1991 and the nights were getting cold. Pat knew that he had to get the dinosaur excavation team to the site as fast as possible. He made Bob Harmon (**Figure 20**) from the Museum of the Rockies the crew chief for the Big Al excavation. Bob is a very experienced dinosaur digger. He had helped Pat excavate a *Tyrannosaurus rex* in Montana the year before, and worked with Museum of the Rockies Curator of Paleontology Jack Horner for many years on many dinosaur sites. The discovery of Big Al became big news in the U.S. (**Figure 21**) and around the world. Pat asked Shelley McKamey (**Figure 22**) from the Museum of the Rockies to join the dinosaur team because she knew how to work with news reporters – many curious people and reporters wanted to visit the site. The BLM called in their rangers (law enforcement personnel) for security, and a camp was set up for the entire crew near the Big Al site (**Figure 23**).

The crew (Pat, Brent, Bob, Shelley, Carrie Ancell, Ellen Lamm, Karen Masta, and Allison Gentry) assembled at the Big Al site the next day, and Bob gave instructions to the team. Greg Erickson (**Figure 24**), a graduate student from Montana State University who visited the site, started calling the crew the Dinosaur Recovery Team or "DiRT" (**Figure 25**). The crew was known as DiRT throughout the entire Big Al excavation.

Figure 18. Brent Breithaupt, Brooks Britt, and others examining Big Al's bones.

Figure 19. Big Al was partially exposed when Pat and Brent first arrived at the site. Big Al's head is just above the large scale-bar on the right side of the photograph.

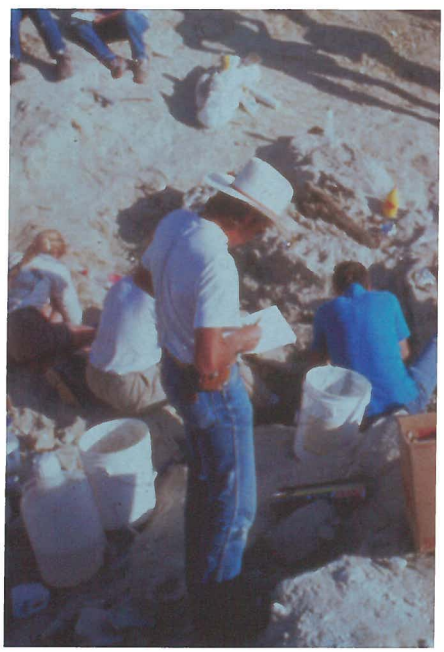


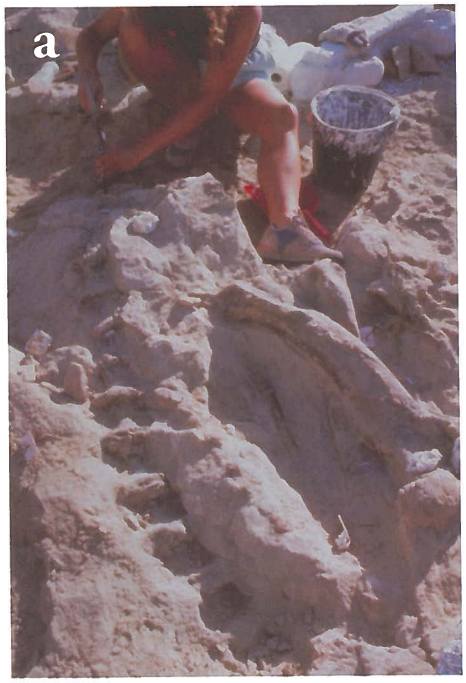
Figure 20. Bob Harmon has collected dinosaur bones for the Museum of the Rockies for many years.

Figure 21. Big Al became famous worldwide from the many newspaper stories written. This display, titled "Big Al in the news," is located at the University of Wyoming Geological Museum.

Figure 22. Shelley McKamey came from the Museum of the Rockies to help with public relations and media presentations about Big Al.

Figure 23. The Big Al site is located in northern Wyoming with the Big Horn Mountains just a few miles to the east.

Figure 24. Montana State University graduate student Greg Erickson excavating the vertebrae of a sauropod.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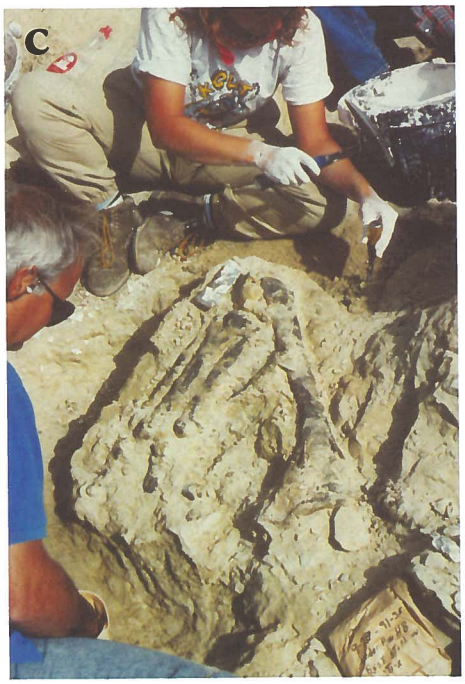
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Figure 25. Pages 34 and 35. (a) DiRT member Allison Gentry uncovering Big Al's skeleton. (b) Big Al being excavated by DiRT members (from right to left) Bob Harmon, Pat Leiggi, Greg Erickson, and Carrie Ancell. (c) As with this leg and foot, many of Big Al's Bones were still articulated. (d) The DiRT hard at work excavating Big Al. (e) The DiRT documenting and excavating Big Al. (f) Shelley McKamey and Pat Leiggi carefully exposing Big Al's bones.

Figure 26. Big Al was very well preserved in the sandstones and mudstones of the Morrison Formation. Compare with Figure 19.

The team started to carefully remove the sediment from around Big Al's bones (**Figure 26**) with hand tools such as awls, dental picks, ice picks, and chisels (**Figure 27**). Little by little the rock around Big Al's bones was loosened and swept away with small soft-bristled brushes. After 150 million years, the bones were very delicate. As soon as a small part of Big Al's fragile bone was exposed, the team drizzled a thinned plastic hardener or glue on it. The glue helped strengthen the bones so they would not break or fall apart. The team worked slowly and meticulously as they uncovered Big Al's bones. Every time a bone was uncovered, Brent mapped it on a grid (**Figure 28**) so scientists would have a record of how Big Al's remains were left in the ground 150 million years earlier.

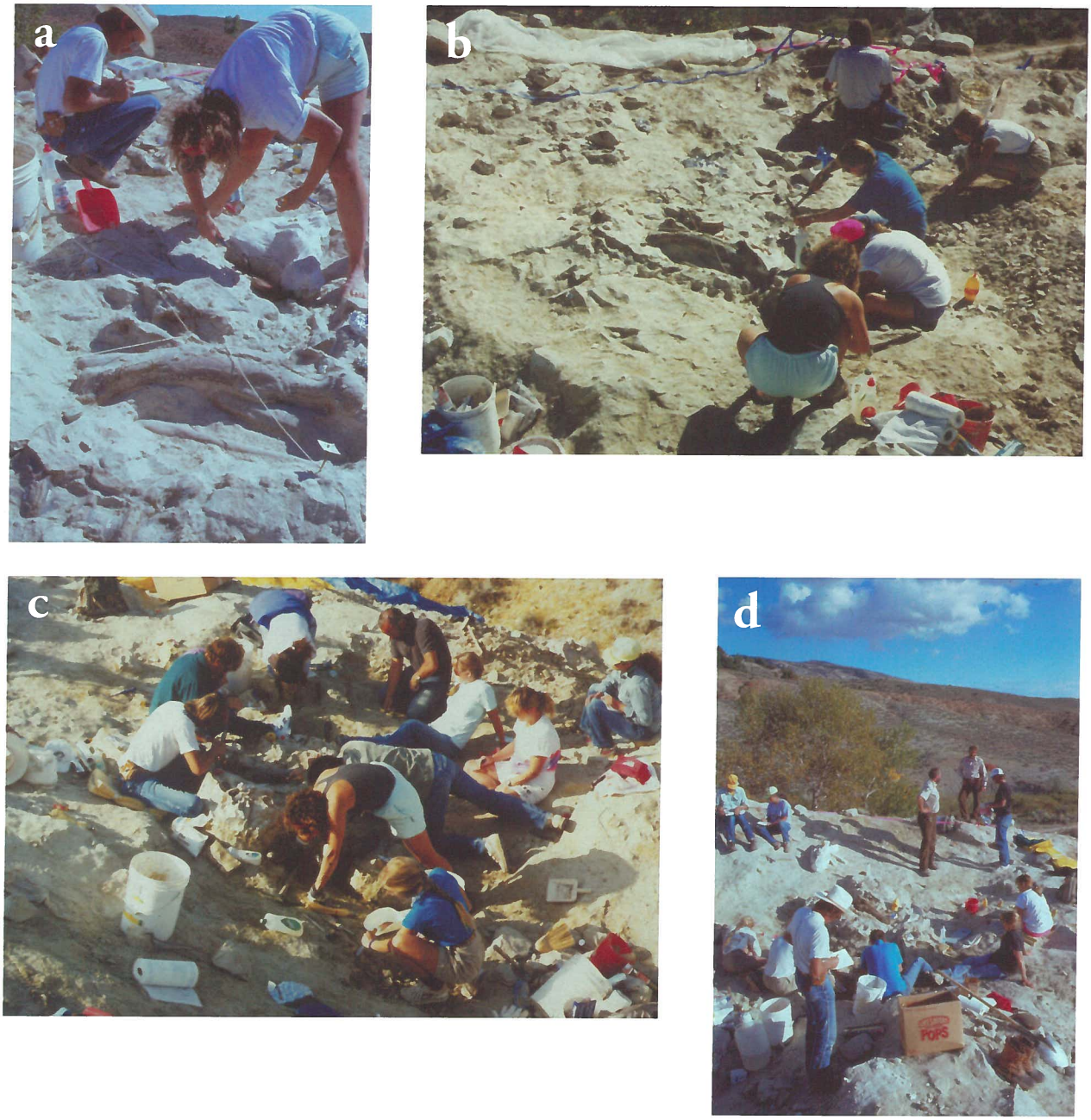


Figure 27. (a) Allison Gentry works on a bone while Bob Harmon documents its location. (b) DiRT members (top to bottom Bob Harmon, Ellen Lamm, Carrie Ancell, Karen Masta, and Allison Gentry) at work on Big Al. (c) All DiRT members had a role in the excavation of Big Al. (d) DiRT members with BLM Rangers (with brown pants and khaki shirts).

Figure 28. Brent mapped all of Big Al's bones. Here he discusses the location of the bones with Greg Erickson.

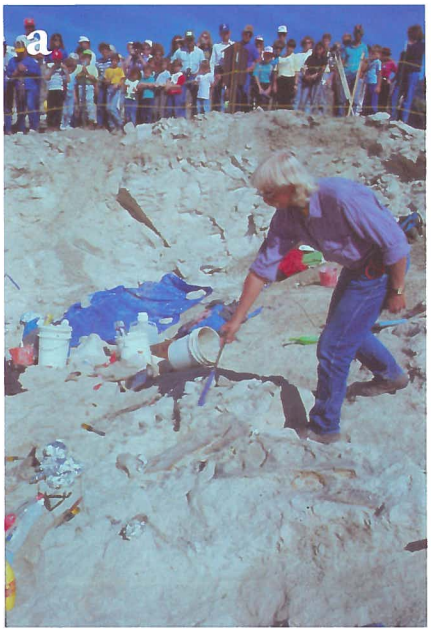
A FEW FRIENDS STOPPED BY

While the DiRT uncovered the bones of Big Al, excitement about his discovery had spread across the country. The BLM arranged for children from many schools around the Bighorn Basin to visit the site (**Figure 29**). More than 4,000 school children and adults visited the Big Al excavation in one week. Many people volunteered their time and assisted in the excavation (**Figure 30**). While the crew worked, Brent showed visitors something they had never seen before: Big Al – a virtually complete articulated dinosaur entombed in the rock (**Figure 31**).

Newspaper reporters (**Figure 32**) were curious about how Big Al was discovered and asked Pat and Brent questions about fossil collecting. They wondered why a Swiss commercial fossil dealer was looking for dinosaurs on U.S. public lands. The Swiss team had permission to search on the adjoining private lands but ventured 200 feet beyond the property line when they found Big Al. The authors explained that vertebrate fossils collected from public lands cannot be sold. They also said that current

Figure 29. Students from many schools in the Bighorn Basin visited the Big Al site.

Figure 30. Many volunteers traveled to the Big Al site to help the DiRT with the collection of this important specimen.



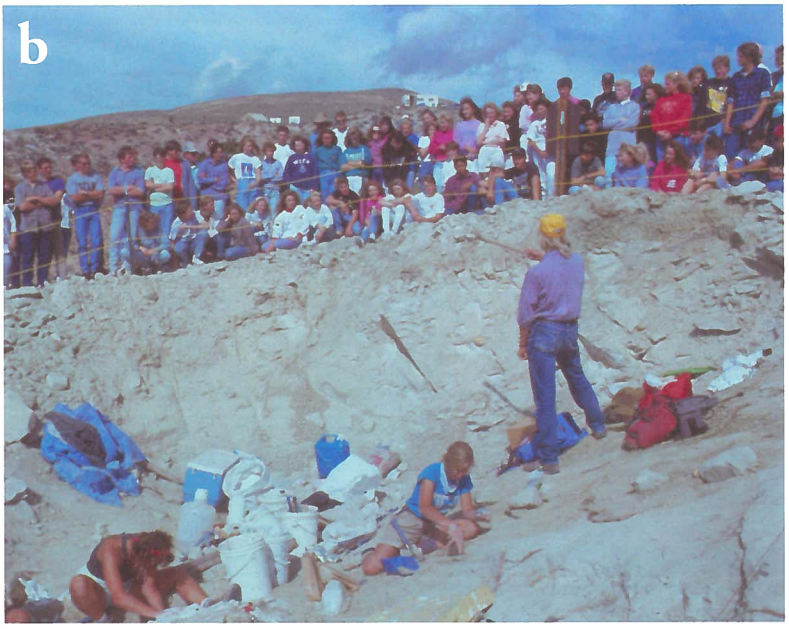


Figure 31. (a) Thousands of children saw Big Al as he was being excavated from the ground. Big Al's head is just below Brent's left foot. (b) Brent spoke to thousands of the visitors during the excavation.

Figure 32. Newspaper and television coverage of the Big Al excavation showed Big Al to the world. Note the two photographers at the top of the photograph.

laws were not effective enough to keep commercial dealers from collecting fossils from our public lands and that fossil poaching occurred regularly in the West. Pat and Brent believed that new laws were needed to keep important dinosaurs like Big Al from being illegally collected and sold.

Saving Big Al became so important that even the director of the BLM in Washington, D.C., Cyrus "Cy" Jameson, visited the site (**Figure 33**). Cy was very impressed with the work done by the BLM and the DiRT. He was also very happy to see school children visiting the site. Most of all, the BLM director was delighted that Big Al would go to a museum in the U.S. where his remains would be studied and enjoyed by the public for many years to come.

Figure 33. Cyrus Jameson, the director of the BLM in Washington D.C., traveled to Wyoming to visit Pat and Brent because of the significance of Big Al. Pictured from left to right are Brent Breithaupt, Museum of the Rockies Interim Provost Kay Chaffee, Pat Leiggi, and Cy Jameson.

BEFORE IT SNOWS

After several days, the team had uncovered most of Big Al's bones. They started to protect large blocks of Big Al's skeleton with a hard shell cast called a field jacket. It is made of plaster and burlap and is similar to a cast a doctor would use on a broken arm or leg. The burlap is cut into long strips about 6 to 8 inches wide and then soaked in wet gooey plaster. Paleontologists place damp paper towels over the bone and then wrap the bone and remaining sediment with the plaster-soaked burlap strips (**Figure 34**). When the plaster dries, it becomes very hard and sturdy. With heavier bone and sediment blocks, more plaster and burlap are applied. Sometimes wood is used to strengthen the field jacket. Once the jackets set, the fossils can be transported to the laboratory safely, just as they were in Barnum Brown's day.

On the eighth and final day of the excavation, the team worked hard and fast, making sure that every bone was encased safely in a field jacket. They had to finish before snow started to fall. Late in the afternoon, all of Big Al was covered (**Figure 35**). He was now ready for transport to the Museum of the Rockies. The BLM used heavy machinery (**Figure 36**) to lift the large blocks out of the quarry and placed them side by side on a trailer. The DiRT left the site with Big Al's bones that evening. An hour later, it snowed.

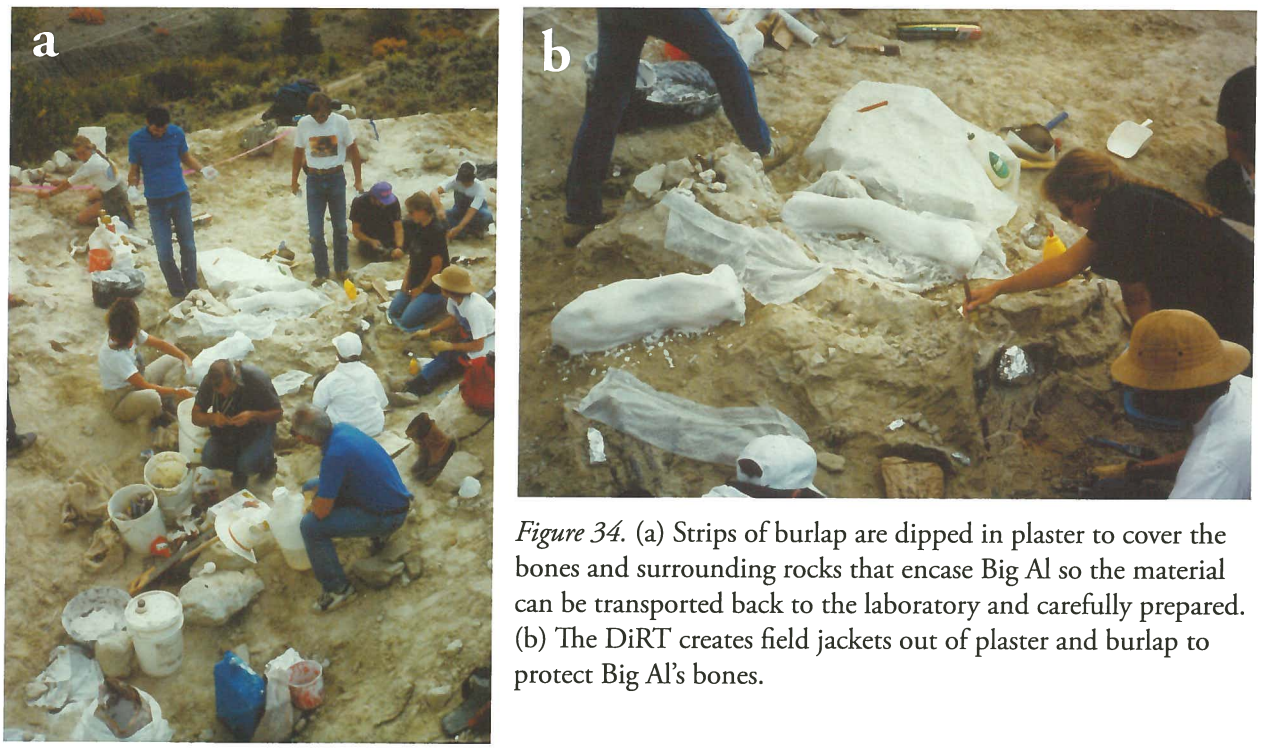


Figure 34. (a) Strips of burlap are dipped in plaster to cover the bones and surrounding rocks that encase Big Al so the material can be transported back to the laboratory and carefully prepared. (b) The DiRT creates field jackets out of plaster and burlap to protect Big Al's bones.

Figure 35. Big Al was bundled up in his plaster jackets, ready for transport to the Museum of the Rockies. Here Bob and Pat get ready to move the blocks.

Figure 36. A BLM backhoe carefully lifted the Big Al blocks out of the quarry.

Big Al's New Home

Big Al arrived at the Museum of the Rockies (**Figure 37**) the next day. The large field jackets that contained his bones were brought to the paleontology laboratory. Bob Harmon used tools such as dental picks and air scribes to clean and prepare the bones (**Figure 38**). He carefully removed any remaining rock and hardened the bones with a liquid plastic so they would be strong. He used special adhesives to glue any broken bones back together (**Figure 39**). Fossil preparation is a very tedious process (**Figure 40**): it took more than three years for Bob to completely clean and strengthen Big Al's bones. Bob and a small crew revisited the Big Al site in 1992 and 1993 to collect any remaining bones, especially ribs and arm bones, that had been scattered a few feet from the rest of the skeleton prior to burial.

Jack Horner, Curator of Paleontology at the Museum of the Rockies, assigned a catalog number to Big Al, MOR 693. When Bob finished preparing the bones (**Figure 41**),

Figure 37. From left to right, Ellen Lamm, Allison Gentry, Carrie Ancell, Bob Harmon, and Karren Masta transported the field jackets containing Big Al back to the Museum of the Rockies in Bozeman, Montana.

Figure 38. Bob carefully removed each of Big Al's bones from the encasing rock. Here, he is preparing the backbone, ribs, and left ilium.

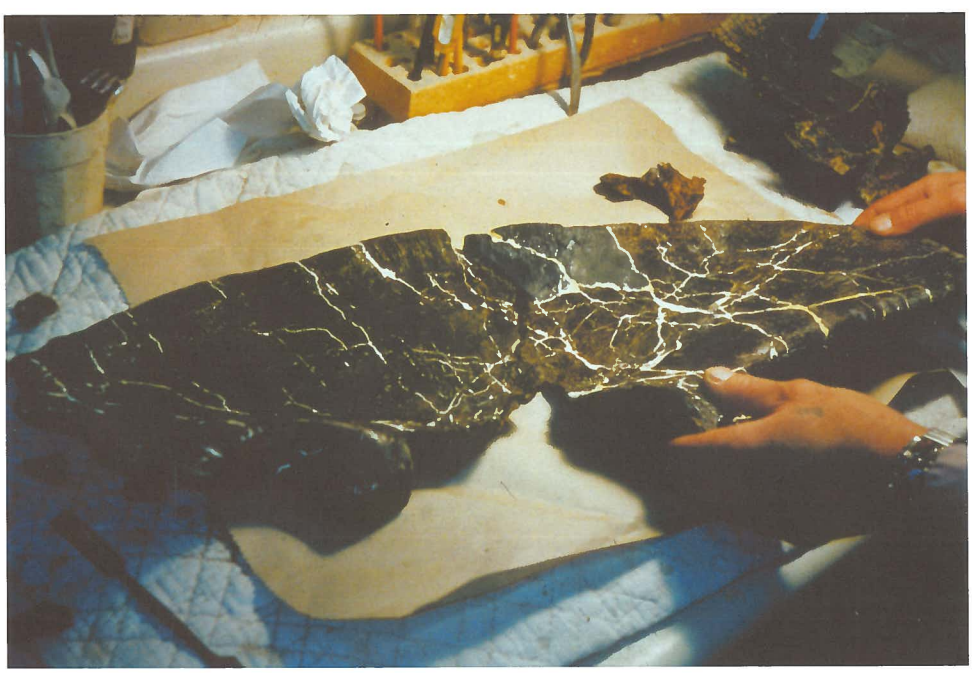


Figure 39. Bob and his crew pieced all of Big Al's broken bones back together like a life-sized puzzle. This bone is a broken ilium.

Figure 40. Bob prepared and repaired Big Al's bones over the course of three years. Here Bob works the block that contained Big Al's skull.

Figure 41. When it was exposed, Big Al's skull was one of the best-preserved *Allosaurus* skulls ever found.

he wrote this special museum catalog number on every one of them and placed them carefully on a padded storage shelf (**Figure 42**) in the collection room. But the work on Big Al was not finished.

Big Al was (and still is) a very popular dinosaur. Brent wanted a replica or cast of Big Al's skeleton to display at the University of Wyoming's Geological Museum. Bob started a process called *molding* (**Figure 43**). Molding is a method used by artists and paleontologists to make an exact replica of an original object. In this case the objects were Big Al's bones. Bob and Carrie coated each bone with a rubberized material called silicone. The silicone was then reinforced with plaster. When each mold was completed, they removed the molds from each bone and put the bones back in the collection room. They reassembled the molds and poured a liquid plastic resin inside each one. The plastic resin dried into perfect replicas of Big Al's bones. Bob took the plastic replicas of Big Al and made a skeletal mount for the University of Wyoming Geological Museum. Later, he made another mount for the Museum of the Rockies. But still the work on Big Al was not finished.

The day that Bob completed the first replica skeleton of Big Al, Brent arrived at the Museum of the Rockies to take it to the Geological Museum in Laramie (**Figure 44**). Bob went to Laramie with Brent and helped him place Big Al on exhibit (**Figure 45**). In January 1996, the Big Al replica was dedicated in the University of Wyoming Geological Museum by the BLM (**Figure 46**).

While the UW Geological Museum developed displays and educational programs around the cast of Big Al, the Museum of the Rockies made a second Big Al mount for their highly acclaimed traveling exhibit *T. rex on Trial.* As many presentations were given on this important specimen, media attention around the world focused on Big Al. The British Broadcasting Corporation (BBC) contacted Brent with plans to do an episode highlighting Big Al as part of their hugely successful *Walking with Dinosaurs* series. The BBC traveled to Laramie in 1999 and spent a number of days filming in the museum. They traveled around the world interviewing various scientists familiar with Big Al. BBC's *The Ballad of 'Big Al'* aired in Europe and Australia in December

Figure 42. Padded storage shelves in the collection room at the Museum of the Rockies hold the original fossilized bones of Big Al.

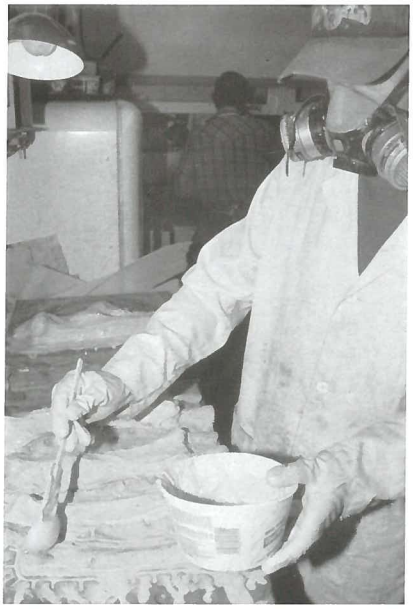


Figure 43. Bob carefully applies the molding rubber to make exact replicas of Big Al's bones for display.

Figure 44. The vertebrate paleontological staff of the Museum of the Rockies stands around the cast of Big Al.

Figure 45. Bob and Brent reassembled the display of Big Al in Laramie at the University of Wyoming Geological Museum.

Figure 46. The replica of Big Al installed at the University of Wyoming Geological Museum in Laramie.

2000 and in the U.S. in April 2001. Using state-of-the-art computer generated graphics, the episode told Big Al's story from hatching to death. Detailed discussions of the science behind the story of his life were also included. In 2002, photographers from *National Geographic* magazine traveled to Laramie and photographed Big Al. He was featured in a special issue on dinosaurs in March 2003. Because of this type of media attention, Big Al continues to be known worldwide and is one of the most well-known individual dinosaur skeletons ever found.

What Scientists Learned

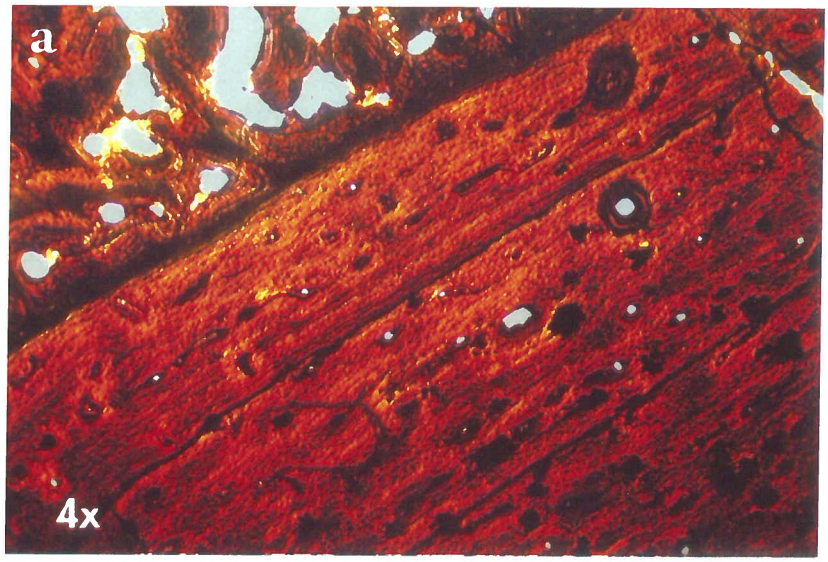
Big Al was a one-of-a-kind discovery. Although other allosaurs are preserved in museum collections, he was the most complete individual specimen ever discovered. Big Al was originally thought to represent the common species *Allosaurus fragilis*, which means "strange lizard which is easily broken." However, additional work on Big Al, as well as other discoveries, indicates that Big Al may represent a brand new species of dinosaur – *Allosaurus jimmadsenii* – named after renowned *Allosaurus* specialist, Jim Madsen. In addition to being 95 percent complete, the skeleton was partially articulated and in near perfect condition. This is very rare for a dinosaur skeleton.

Because of the completeness, we were able to see many of the problems that Big Al had when he was alive. We were able to piece together the story of the last years of Big Al's life based on the fossil record. Work accomplished by a graduate student at Montana State University, Rebecca "Becca" Hanna (**Figure 47**), showed that Big Al had 19 injured or diseased bones. His broken ribs (**Figure 48**) and infected toe bone (**Figure 49**) were just some of the more dramatic pathologies found. Rebecca looked closely at these bones and compared them with those of allosaurs in other museums. She even looked inside the bones (**Figure 50**) to better understand the injuries and how they healed. Although we have never seen a living *Allosaurus*, studies of injured bones help us understand that life was not easy for carnivorous dinosaurs like Big Al. The cause of Big Al's death is unknown, but the pathologies indicate that day-to-day activities like getting food and roaming around would have been a struggle.

Figure 47. Like an ancient medical examiner, Becca Hanna, a student at Montana State University, studies the fascinating injuries of Big Al.

Figure 48. Big Al had many severely injured bones. Here one of the right ribs has been seriously broken, displaced, and partially healed.

Figure 49. Big Al had a number of infected bones in his body. Here the center toe on his right foot displays a severely infected bone.



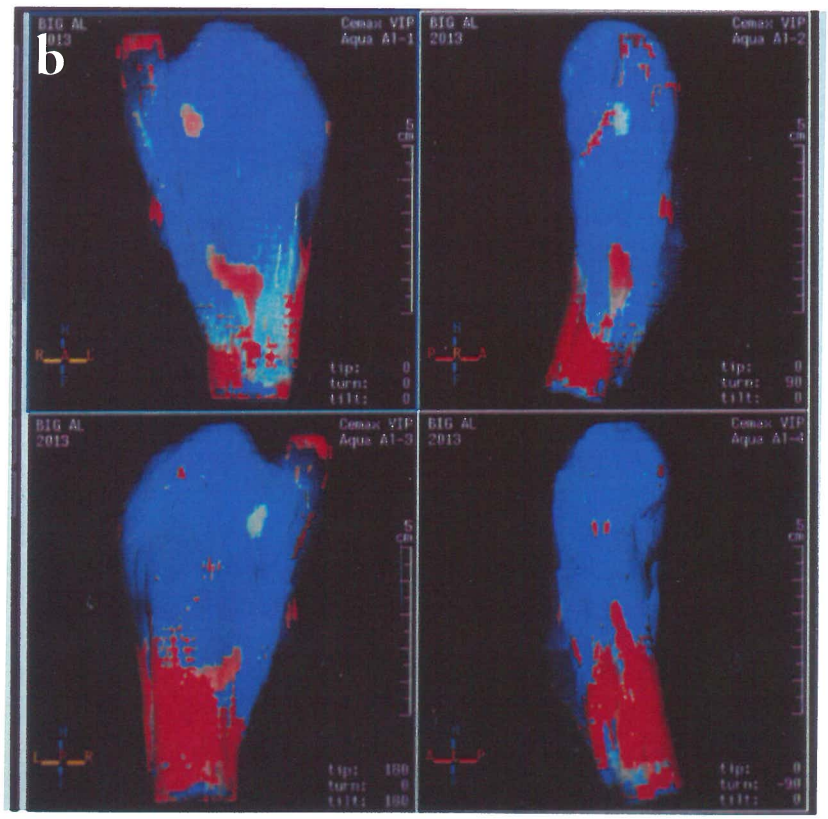


Figure 50. (a) Becca took microscopic thin sections of a few of the bones to see what the injured bones looked like and how they compared to normal bones. (b) Becca used CAT scan images to see how the injured bones (such as this rib) looked inside.

Brent's detailed quarry map (**Figure 51**) showed us how Big Al looked shortly after death. Since the bones had not been scattered far, we got a pretty good picture of Big Al's death. We know that he collapsed on his left side (**Figure 5**). His body lay on the ground exposed to the hot sun for a fairly short time before it was buried by sand and mud carried by a flooded stream (**Figure 6**). The soft tissue dried up like jerky, de-

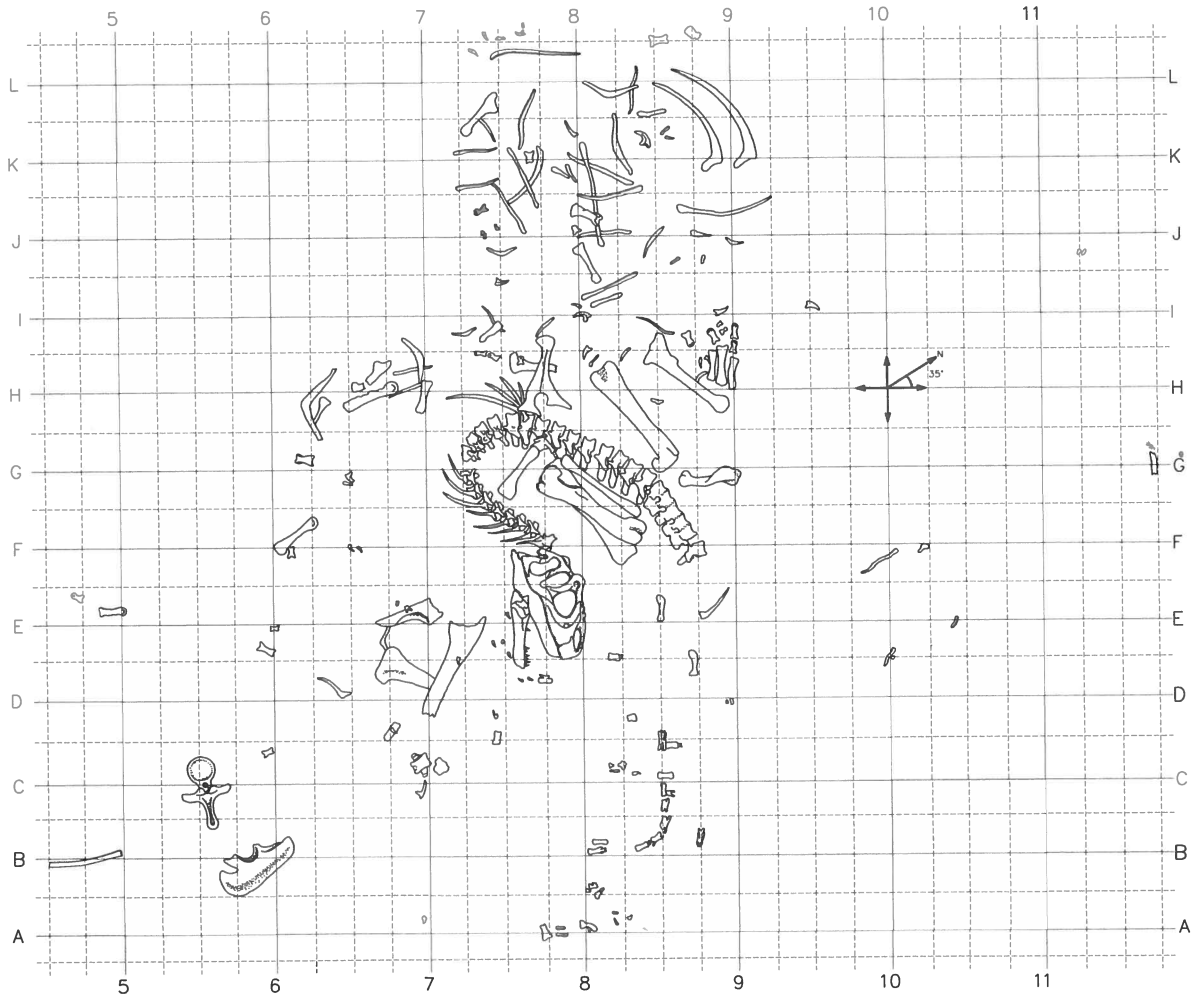


Figure 51. Brent's quarry map (redrafted by Scott Hartman) accurately documents how Big Al lay in the ground prior to burial, which helps us understand what happened to his skeleton after he died.

forming his skeleton into the position in which it was found. We see little scavenging of the skeleton, but do see many marks probably made by ancient beetles as they burrowed into some of the bones.

Cambridge paleontologist Emily Rayfield used computer and x-ray scans (CAT scans) of Big Al's skull to determine how his skull and jaws worked. By looking at these CAT scans (**Figure 52**) she was able to see the bite forces present when Big Al attacked. She determined that Big Al probably attacked prey with his mouth wide open, and used his powerful jaws like a hatchet. In 2001 and 2008, Brent arranged for the Big Al skeleton cast in Laramie to be laser-scanned for three-dimensional analysis. These images (**Figure 53**) will allow for unique computer studies of Big Al in the future.

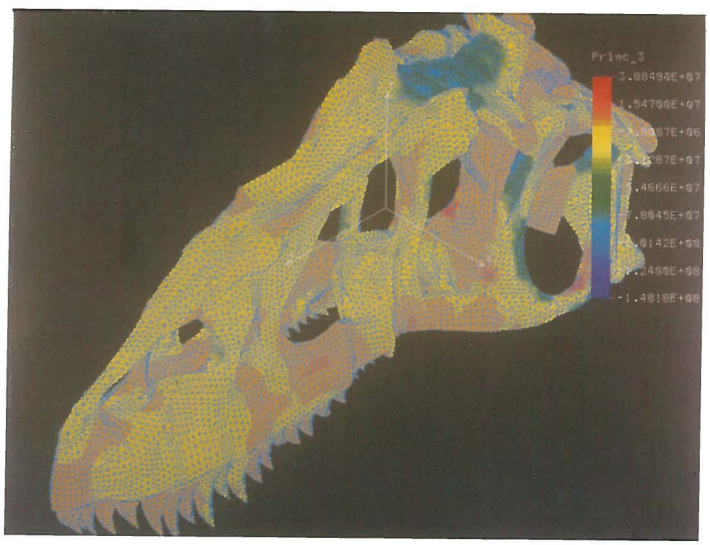


Figure 52. A CAT scan, like this one of Big Al's skull, was used to determine how his jaws worked when he attacked his prey.

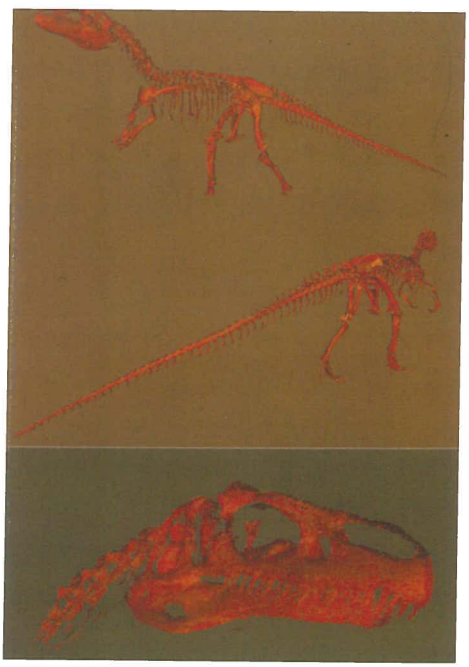


Figure 53. These laser scans will be very valuable in future computer studies of Big Al.

The research isn't finished. Lots of work is still ongoing with Big Al's skeleton, comparing him to other allosaurs, learning about dinosaur growth, and fossil preservation. Analyses of Big Al and other animals preserved in this area, as well as the rocks that contain these fossils, are providing an exciting glimpse into North America 150 million years ago – the real *Jurassic Park*! Big Al will be protected in a museum for years to come.

Why is Big Al Important?

Big Al lived 150 million years ago. His bones have told a story no one knew about until he was discovered, carefully collected, and sent to a museum where scientists study dinosaurs. If the BLM had not found the Swiss fossil collector's quarry in time, Big Al could have been sent out of the country and sold to a private collector. He may not have been available for paleontologists to study. Because dinosaur fossils bring commercial fossil dealers a lot of money, more and more dinosaurs are being collected and sold, sometimes without any concern for their educational and scientific value. Paleontologists are trying very hard to protect fossils on public lands so they will always be available for the public to learn about and see in museums, and for paleontologists to study.

Big Al's bones will always be available for scientists to study because they are preserved in a public museum. There is still much to learn about Big Al and other dinosaurs in museums around the world, and the research continues. Maybe someday you will be a scientist and will want to study Big Al. Since his skeleton was collected and protected with you in mind, you can!

The possible loss of Big Al to science and the American people helped paleontologists and federal land managers understand the importance of fossil protection and preservation. This is why paleontologists will continue to work with members of the U.S. Congress to improve laws that will protect fossils like Big Al.

If you and your classmates would like more information about Big Al, please visit the Museum of the Rockies paleontology website at http://www.museumoftherockies.org (remember, Big Al's special catalog number is MOR 693) and the University of Wyoming Geological Museum website http://www.uwyo.edu/geomuseum/.

Where to see Big Al and other allosaurs

Big Al was featured in a traveling exhibit called *T. rex on Trial* which appeared in many cities around the country. Permanent displays can be seen at the University of Wyoming Geological Museum in Laramie (**Figure 54**) and in the Museum of the Rockies Siebel Dinosaur Complex. Many other museums around the world also have *Allosaurus* skeletons on display. Many of them are listed below.

- American Museum of Natural History, New York, New York
- California Academy of Sciences, San Francisco, California
- Carnegie Museum of Natural History, Pittsburgh, Pennsylvania
- Cleveland – Lloyd Dinosaur Quarry Visitors Center, Utah
- Cleveland Museum of Natural History, Cleveland, Ohio
- Dakota Dinosaur Museum, Dickinson, North Dakota
- Denver Museum of Natural History, Denver, Colorado
- Dinosaur Journey, Museum of Western Colorado, Fruita, Colorado
- Dinosaur National Monument, northeastern Utah
- Emery County Museum, Castle Dale, Utah
- Fort Worth Museum, Fort Worth, Texas
- Houston Museum of Natural Science, Houston, Texas
- Los Angeles County Museum, Los Angeles, California
- Museum of Ancient Life, Lehi, Utah
- Museum of the Rockies, Montana State University, Bozeman, Montana
- Museum of the San Rafael, Castle Dale, Utah
- Museo Civico di Storia Naturale di Milano, Milan, Italy

- National Museum of Natural History, Washington, DC
- National Science Museum, Tokyo, Japan
- Natural History Museum, London, England
- Nebraska State Museum, Lincoln, Nebraska
- New Mexico Museum of Natural History, Albuquerque, New Mexico
- Oklahoma Museum of Natural History, Norman, Oklahoma
- Price Museum of Eastern Utah, Price, Utah
- Princeton University, Princeton, New Jersey
- Royal Ontario Museum, Toronto, Ontario, Canada
- San Diego Natural History Museum, San Diego, California
- Saurier Museum, Aathal, Switzerland
- Science Museum of Minnesota, St. Paul, Minnesota
- The Journey, Rapid City, South Dakota
- University of Wyoming Geological Museum, Laramie, Wyoming
- Utah Museum of Natural History, Salt Lake City, Utah
- West Texas Museum, Lubbock, Texas

Figure 54. Thousands of visitors every year continue to learn about Big Al at the University of Wyoming Geological Museum (shown) and the Museum of the Rockies.

Acknowledgements

The authors wish to thank the following people for their reviews, suggestions, information, and advice that contributed greatly to the story of Big Al: Thomas Adams, Vicki Burton, Mark Goodwin, Bob Harmon, Scott Hartman, Jack Horner, Rebecca L. Hanna, Mark Loewen, Neffra Matthews, Shelley McKamey, Roger Moore, Emily Rayfield, Bruce Selyem, Beth Southwell, Ted Vlamis, Janice Woodburne, and Mike Woodburne.

GLOSSARY

air scribe: A hand-held vibrating chisel tool powered by air compression.

Allosaurus: ("Strange Lizard") A carnivorous dinosaur that lived in the Late Jurassic.

ammonites: A large group of extinct sea mollusks related to octopus, squid, and the chambered nautilus.

ankylosaurs: A group of bone-armored, plant-eating dinosaurs that lived during the Jurassic (e.g. *Gargoyleosaurus*) and Cretaceous (e.g. *Ankylosaurus*) periods.

Ankylosaurus: ("Stiff Lizard") A bone-armored, plant-eating dinosaur with a club at the end of its tail that lived during the Late Cretaceous.

Apatosaurus: ("Deceptive Lizard") A large plant-eating sauropod dinosaur that lived in the Late Jurassic; formerly known as *Brontosaurus*.

archosaurs: A group of reptiles that includes dinosaurs, crocodiles, and pterosaurs.

arid: A climate in which rainfall cannot support abundant vegetation.

articulated skeleton; articulation: Bones that remain connected.

artifacts: Human objects of prehistoric age such as tools, weapons, and ornaments.

Barosaurus: ("Heavy Lizard") A large plant-eating sauropod dinosaur that lived during the Late Jurassic.

basin: A large depressed area that nearby or adjacent land drains into.

beetle larvae: A worm-like feeding form of newly hatched beetle, which at times burrows into bone.

bipedal: Walks on two legs.

burlap: A coarse heavy fabric used to make field jackets when soaked in plaster.

Camarasaurus: ("Chambered Lizard") A large plant-eating sauropod dinosaur that lived during the Late Jurassic.

Camptosaurus: ("Bent Lizard") A large plant-eating ornithopod dinosaur that lived during the Late Jurassic.

carcass: A dead body or corpse.

carnivorous: Eats animals.

casting: A process whereby plastic resins or plaster are used to replicate an object.

Cenozoic Era: The last of the four eras as recorded by the stratified rocks of the earth's crust. Period of time after the dinosaur extinction also known as the Age of Mammals. A geologic term that refers to the Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Recent epochs.

ceratosaurs: Large carnivorous dinosaurs that lived during the Jurassic Period.

Comodactylus: ("Como Finger") An extinct flying reptile that lived during the Late Jurassic.

Cretaceous: The last of three geologic periods during the Mesozoic Era.

crystallize: A natural process whereby dissolved minerals become solid.

curator: A person who takes care of collections, such as fossils, in a museum.

descendant: A person or animal that is descended from a specific ancestor; offspring.

desiccated: Dried out, dehydrated.

dinosaurs: A group of advanced small to large archosaurs, including the ancestors of birds that lived during the Mesozoic Era.

Diplodocus: ("Double Beam") A large plant-eating sauropod dinosaur that lived during the Late Jurassic.

disarticulated skeleton: Bones that have separated by natural causes such as water or scavenging by other animals.

Dryosaurus: ("Oak Lizard") A plant-eating ornithopod dinosaur that lived during the Late Jurassic.

earth: The planet third in order from the sun and/or the land surface of the planet.

environment: A combination of surrounding air, light, moisture, tempera-

ture, wind, and soil that creates living conditions for animals and plants.

excavate: The process of digging, uncovering, and removing fossils from the dirt and rock in the ground.

extinct: No longer in existence; died out.

federal: A form of government in which power is distributed between a central authority and a number of territorial units or states.

field jacket: The dried plaster and burlap shell that protects fossils during transportation from the field to the laboratory.

flood plain: A portion of a river valley that is next to a river channel, which is formed from the sediments carried by flood waters.

formation: The primary unit consisting of unique strata used for mapping or description.

fossil: Any naturally occurring evidence of past life.

Gargoyleosaurus: ("Gargoyle Lizard") An armored ankylosaur that lived in the Late Jurassic.

gastrolith: A highly polished, well-rounded stomach stone associated with some plant-eating dinosaur skeletons (gizzard stone).

grid: A precise pattern of points and lines forming a square used in mapping fossils.

Hyracotherium: A small primitive multitoed horse that lived during the early Cenozoic Era (formerly called *Eohippus*).

Jurassic Period: The second of three geologic periods during the Mesozoic Era.

lowland: An area of land that is low in relation to the surrounding geography.

malnutrition: Poor nutrition caused by an insufficient, oversufficient, or poorly balanced diet.

mammoth: An extinct elephant that lived during the Late Cenozoic Era.

map: a drawing or picture showing selected features of an area (such as the surface

of the earth, the moon, or a section of the brain) and usually drawn to a given scale.

megalosaurs: Large carnivorous dinosaurs that lived during the Jurassic Period.

Mesozoic Era: A geologic time that includes the Triassic, Jurassic, and Cretaceous periods. Also known as the *Age of Reptiles*.

minerals: Naturally occurring inorganic substances with a definite chemical composition.

molding: The process by which a liquid rubber compound is applied to a bone or object to create a cast or replica.

Morrison Formation: A widespread formation in the Rocky Mountain West consisting of various sedimentary rocks formed by Late Jurassic rivers and lakes.

organism: Any living thing.

Ornitholestes: ("Bird Robber") A small carnivorous dinosaur that lived during the Late Jurassic.

Othnielosaurus: ("Othniel's lizard") A small plant-eating ornithopod dinosaur that lived during the Jurassic Period; named after Othniel C. Marsh.

paleontologist: A scientist who studies organisms of past geologic ages based on fossils.

pathology: The study of disease and injury.

petrify: to convert into stone or a stony substance.

poaching fossils: To take fossils illegally.

prehistoric: A period of time before recorded history.

private land: Land owned by an individual or company.

pterosaurs: A group of flying reptiles that lived during the Mesozoic Era.

public land: Land that is collectively owned by a government or organization.

quadrupedal: Walks on four legs.

quarry: An open excavation site.

replica: A duplicate or cast of an original specimen or object.
research: To study something thoroughly.

resin: A substance used to replicate or cast a specimen or object.

sauropods: A group of large, long-necked, long-tailed, quadrupedal, plant-eating dinosaurs that lived during the Mesozoic Era.

scavenger: An animal that feeds on animal carcasses.

sediment: Solid fragments of inorganic or organic material that come from the weathering of rock and are carried and deposited by wind, water, or ice.

skin impressions: Imprints left in sediment by an animal's skin.

Stegosaurus: ("Roof Lizard") A quadrupedal plant-eating dinosaur with bony flat plates along its back and four spikes on the end of its tail that lived during the Late Jurassic.

strata: a single bed of sedimentary rock, generally consisting of one kind of matter representing continuous deposition.

subtropical: Climates with relatively warm winters that rarely get frost or snow. Plants such as palm, citrus, and many broadleaf evergreens flourish.

surveillance: The act of keeping a close watch over a person, group, or area.

titanothere: A large, rhinoceros-like, plant-eating mammal that lived during the Cenozoic Era.

Triceratops: ("Three-Horned Face") A large, three-horned, plant-eating dinosaur that lived during the Late Cretaceous Period.

Tyrannosaurus rex: ("Tyrant Lizard King") A large carnivorous dinosaur that lived during the Late Cretaceous.

vertebrates: Backboned animals such as fish, amphibians, reptiles, birds, and mammals.

INDEX

Suggested Reading

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Thomas L. Adams worked at the UW Geological Museum from 1999 until 2004 while earning two bachelors degrees (one in geology and one in zoology/physiology) from the University of Wyoming. Previously, he attended commercial art school and worked in the private sector for several years before deciding to return to college to be a vertebrate paleontologist. Thomas has conducted research in Alaska and Wyoming and has been involved with additional expeditions in Colorado, Utah, and Texas. He is currently a graduate student at Southern Methodist University in Dallas, Texas, were he earned his Masters degree and is working towards his Ph.D. His research interests involve paleo-ecology and Alaskan Triassic ichthyosaur paleobiogeography. He is an active member of the Society of Vertebrate Paleontology. Photo courtesy of *Uwyo Magazine*.

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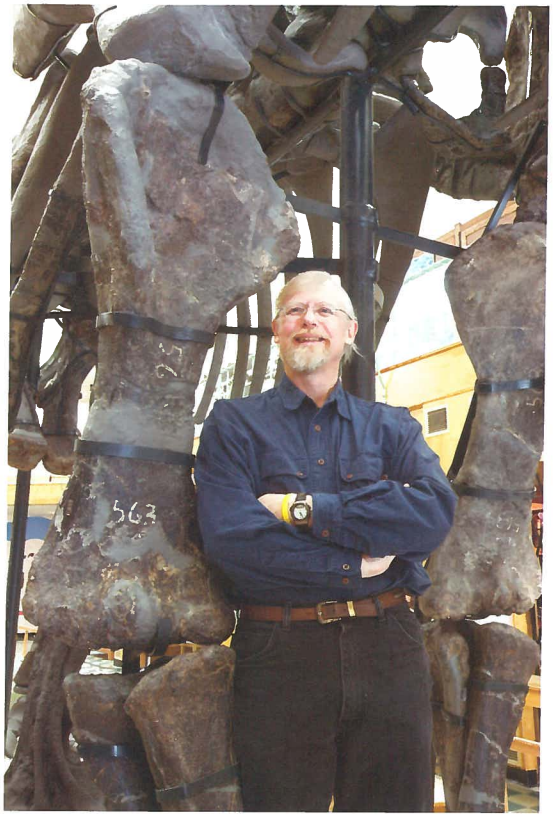
Patrick Leiggi is the Administrative Director of Paleontology and Exhibits at the Museum of the Rockies, Montana State University in Bozeman, Montana. He has worked there since 1985. Previously, Pat was the Chief Preparator of Paleontology for Jack Horner and Donald Baird at the Museum of Natural History, Princeton University from 1980 to 1984. From 1984 to 1985, he assisted in the development and construction of a dinosaur hall at the Academy of Natural Sciences in Philadelphia. In late 1985, Pat was named Chief Preparator of Paleontology at the Museum of the Rockies until he was promoted to his current position.

Pat's extensive knowledge of fossil collection and laboratory techniques has been passed on to many other technicians in the field of paleontology. In 1994, he published the collaborative volume, *Vertebrate Paleontological Techniques Volume 1*, Cambridge University Press, with Peter May. As a member of the Society of Vertebrate Paleontology's Government Affairs Committee for the past several years, Pat devotes much of his free time to fossil protection issues so that these resources will remain available for generations of American scientists and educators in the years to come.



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Brent specializes in terrestrial faunal analysis, taphonomy, and the history of fossil collecting in the American West. He has published dozens of articles and given numerous lectures on these subjects to groups around the country. He is also a former member of the Society of Vertebrate Paleontology's Government Liaison Committee and a current member of the Education/Outreach Committee. Brent has dealt with vertebrate fossil collecting issues on state and federal public lands in Wyoming for more than 25 years.

ISBN 1-884589-39-1