The History of Supersaurus and "Jimbo"

Supersaurus has had an interesting history, from its discovery at Dry Mesa Dinosaur Quarry in western Colorado, to its description based on material from the Jimbo Quarry in east-central Wyoming. The unusual depositional environments of both quarries have been a blessing and a curse. Dry Mesa Dinosaur Quarry is thought to be the result of an accumulation of skeletons near a dry watering hole during a decade long drought. When the drought ended, a flashflood brought a thick slurry of sediment down the drainage picking up skeletons from at least 13 genera of dinosaurs, as well as the remains of several turtles, crocodiles, lizards, and mammals. This rapid act of burial broke apart and scattered the skeletons, making it quite difficult to identify what bone belonged to what animal. This is one of the largest Jurassic dinosaur quarries in North America, however, and has provided a wealth of information on the diversity of the ecosystem from the Morrison Formation (Late Jurassic). It was in this quarry that the holotype (first diagnostic bones) of *Supersaurus* was described.

The name *Supersaurus* was first published informally in Reader's Digest in 1973 in an article discussing a newly found 2.4 meter long scapula (shoulder blade). "Dino" Jim Jensen formally coined the name *Supersaurus vivianae* when he published a diagnosis of the new genus in 1985. In the same paper Jensen diagnosed two other giant sauropods he thought to be new species. Unfortunately these two 'new' species were not really new. One, *Ultrasauros macintoshi*, was based on a large brachiosaur-like scapula, a huge neck bone (cervical), and a huge back bone (dorsal). Jensen himself reassigned the neck bone to *Supersaurus*; the back bone also belonged to *Supersaurus*, a fact noted by Brian Curtice and others nearly ten years later. They also formally assigned the scapula of *Ultrasauros* to *Brachiosaurus*, making *Ultrasauros* an invalid genus (nomen dubium). Five years after the demise of *Ultrasauros,* Curtice and Stadtman referred the only bone that belonged to the second of the 'new species', *Dystylosaurus* to *Supersaurus*. This effectively killed two of the three new species described by Jensen.

Jensen, and later Curtice, referred several new bones to the holotype specimen of *Supersaurus*. Some of these were correct, and others were not. Jensen incorrectly referred 12 articulated tail (caudal) vertebrae to the holotype in the original diagnosis. Several other tail bones were mistakenly assigned to the new genus. This has lead to many errors in ascertaining the family relationships of *Supersaurus* among the diplodocids (*Barosaurus, Apatosaurus,* and *Diplodocus*).

The only way these errors could be uncovered was with the discovery of a single skeleton that would show us which bones truly belonged to *Supersaurus*. This need was answered in 1996 when the associated skeleton of a huge sauropod was found near Douglas, Wyoming.

Similar to the Dry Mesa Dinosaur Quarry, the Jimbo Quarry was also the result of rapid burial after a long drought. The mechanism of burial, however, was very different. The remains of one sauropod (and two bones of a stegosaur) are the only vertebrate fossils found in the Jimbo Quarry. There are abundant plant fossils, seeds, and fern spores. Most of the plant remains are charcoalified, indicating a wildfire prior to burial of the *Supersaurus* skeleton known as "Jimbo". We think there was a drought induced-wildfire that burned the vegetation, destabilizing the soils on an elevated slope (likely a remnant river levee). Once destabilized, heavy rainfall saturated the slope with water, causing the soil to mobilize as a muddy-debris flow. This type of debris flow is a viscous fluid that behaves more like a plastic than a liquid. Because the debris flow buried only one sauropod at the Jimbo Quarry, we don't have the same identification problems that were associated with the Dry Mesa specimen.

The Jimbo specimen let us identify what bones from Dry Mesa actually belonged to *Supersaurus*. When the tail bones were compared, the errors in the original diagnosis of the species became quite apparent. Many of the tail bones assigned to *Supersaurus* clearly belonged to another sauropod, identifiable as either *Barosaurus* or *Diplodocus* (known as diplodocines). Diplodocines have an excavation on the bottom of their tail-bones (which makes them look like someone took an ice cream scooper and scooped out part of the bottom of the tail bone). After the correction, comparisons were made with other diplodocids (the diplodocines plus *Apatosaurus* and *Suuwassea*), and it was discovered that *Supersaurus* is more closely related to *Apatosaurus* than either is to diplodocines.

Both the BYU and the WDC *Supersaurus* specimens were found in the Morrison Formation, which is widely regarded as being a semiarid environment, with year-round vegetation along rivers, and lakes. Evidence of droughts, wildfire, and heavy rain-induced burial add further support to this well-established hypothesis.

The story of Jimbo: from discovery to display

In 1995 Bill Wahl was invited by landowner Howard Miessler to look at some Morrison Formation rock exposed on his land. While prospecting the gray-green and purple mudstones Bill found some of the bluish-grey chips typical of weathered bone in the Morrison. Carefully following the chips up the drainage, large bits of 'float' bone were found. Finally, with persistence and knowledge, Bill located the spot where the bone was weathering out. Initial excavation showed him and the landowner there was more bone in the hill. After this, with the lease donation of the site to the Wyoming Dinosaur Center, the quarry was officially opened and named after one of the landowner's sons "Jim."

During the first year of excavation a broken knife and some material used by paleontologists was found very near the quarry site indicating someone had come upon, and the possibility is that students from the University of Wyoming were there because the previous landowner had in the 50's given permission.

In Wyoming, summer is the only time excavation can be conducted. Although our falls can be mild, the quarry must be covered prior to the first hard frost. Water that permeates the dirt surrounding the bone will freeze and expand; causing many tiny fractures in the bone that can destroy them. This leaves only June through August for excavation. For nearly a decade Bill conducted the excavation with the help of federally funded 'Job Training Partnership Act' and 'Workforce Investment Association' field crews, composed of local students learning valuable skills in teamwork, work ethic, and responsibility. Many other workers volunteered their time over the last decade to help excavate and prepare this enormous animal. Without their help and the lease donation from the landowner this quarry could not have been excavated with the limited funding and manpower available to us.

Excavation was preformed using standard techniques and tools; tools range from old dentist picks to chisel and hammers from local pawnshops. Overburden (the rock above the layer with bones), sometimes two to three meters deep, was removed to get to the bone-bearing layer. Over the last ten years, it is estimated that over 200 tons of overburden and matrix (rock surrounding the bone) have been removed. Impressively, all of this was done by hand. Most of the major dirt removal was done with picks and shovels, though smaller tools such as screwdrivers, and oyster knifes were used to locate and excavate bone within the bone layer. Once a bone was found, smaller tools such as dental picks were used to remove the matrix. Glues such as vinac (used for binding books), acrylic (concrete sealer), and cyanoacrylate (super glue) were used to stabilize the delicate fossil bones. Each bone would then have a protective plaster jacket applied before it was flipped and carried down the hill. Bones were carried by hand from the field, sometimes with the assistance of a stretcher or a one-wheeled cart typically used by hunters for carrying game. The slope going up to the quarry is covered in huge sandstone blocks. This makes the removal of large jackets difficult; some jackets weighed nearly a ton have been carried by as many as eleven people to get it safely off the hill.

For every hour we spend in the field another 12 hours must be spent in the preparation lab, where the bones are taken out of their protective jackets and cleaned. In order to study, make replicas, and display the bones, all of the surrounding matrix must be removed. During the process of removing the matrix, the bones are further stabilized with glues and hardeners. Preparation of bone is a delicate and time-consuming task but for many of our volunteers and staff it is also very rewarding work.

Once a bone is prepared it is sent to our molding and casting facility to begin the molding process. The molds, once complete, are filled with liquid polyurethane plastic, which solidifies to form a perfect replica of the original bone. Foam polyurethane plastics can also be poured to produce a lighter version for study or mounting onto a complete skeleton.

To make a complete mount of Jimbo, a sculptor was hired to sculpt the missing pieces. About 40% of *Supersaurus* is known between the two specimens, which considering the size of the animal, is a lot. Replicas of all the original bones were used in the mount, and were also used as guides in the reconstruction of missing bones. Because

Supersaurus is most closely related to *Apatosaurus, Apatosaurus* was usually used as the model for building missing parts such as the upper and lower arm, and the upper leg bones. Modifications were made based on bone proportions to more closely resemble what *Supersaurus* really looked like. A metal armature was constructed so the mount could be broken down into 12 foot working sections when it was moved. The armature was placed inside the replica, to make the skeleton more natural looking.

Some bones were too delicate to mold, so they were scanned using a three-dimensional laser scanner. The scans were used to aid in sculpting, and can be used to make foam rapid prototypes of the bones. Also, using the three-dimensional data future studies can be preformed using physics simulation programs to analyze aspects of neck or body motion using perfect digital models. The digital data set is also a lot lighter than the real thing! For instance if a researcher in Australia wanted to look at the tail bones of *Supersaurus,* we could mail them a CD with the digital bones and they could study them on their computer without risking accidental damage to the bones during study. Of course the real bones will always be available to researchers that need to view the originals.

After the skeleton was made we had to do a test mount to make sure everything went together smoothly before Jimbo went to his world debut in Japan. It went together surprisingly smoothly and we all celebrated the completion of this phase of the project. During the assembly of the mount there was a film crew shooting us putting up the mount for an NHK (Japanese version of PBS) production that focused on the animals exhibited in the Giant Dinosaurs Expo 2006, with Jimbo as the main attraction! The mount was then crated up and sent overseas to Japan for four months. In Japan, over one million people viewed Jimbo in less than 60 days! It was a huge success and we were all proud of our accomplishment.

Upon the conclusion of the Giant Dinosaurs Expo 2006 we repacked Jimbo for the ocean ride back home to Thermopolis. Once it returned home we began to renovate the large Jurassic display in the museum. Jimbo is currently the WDC's star attraction, only to be rivaled by the display of the Archaeopteryx.

It is through this process of fieldwork, preparation, molding and casting, and mounting the replica in an anatomically accurate pose, that we brought one of the largest creatures the earth has ever seen to life. The *Supersaurus* mount is the largest scientifically accurate dinosaur mount the world has yet seen.

Taphonomy...

Just like Dr. Grissom in an episode of CSI (Crime Scene Investigation) we look for clues that indicate the environment, ecology, mode of burial, and even how much rainfall fell on average in a year. The story that was gleaned from the dirt at the Jimbo Quarry is amazing indeed.

The quarry site was found in the middle of the Morrison Formation, the unit of rock famous for the Late Jurassic dinosaurs such as Allosaurus, Camarasaurus, and Apatosaurus. The geological section (rock profile from the top to the bottom of the exposed rocks) around the Jimbo Quarry (JQ) was analyzed in great detail to try and figure out what circumstances lead to the burial of this huge creature. Sediment samples were collected along the section profile to see what the clay and mineral composition is in order to better understand the environmental conditions leading up to, and after, the burial of Jimbo. The composition can tell us information about very specific parts of the section.

For instance, a river system will show features characteristic of moving water such as cross-bedded sandstone or ripple marks; while a well drained (water seeps through quickly and is often dry) soil profile is often a deep maroon color because most of the iron is oxidized (rusted). These characteristics let us describe the changing environment through the sections profile.

At JQ we know that there was a river system that flooded periodically (we see the flood sands) and had many well drained levee deposits. The river appears to move farther away throughout the evolution of Late Jurassic landscape leaving soils to form. These soils have little rocks that form from the evaporation of water (so we know it is a relatively dry environment), and from these rocks we can derive the mean annual temperature and rainfall! So we know that during the time of Jimbo the area was quite dry with periodic heavy rainstorms (e.g. annually, or longer depending on drought conditions).

Within the clay rocks are dozens of different micro fossils, although these are not as impressive to see in a museum (often they are microscopic), they are crucial to figuring out what the ecology of the area was like. At JQ we have found different types of moss, ferns, drought tolerant conifers (pine trees), and a huge amount of burned wood called charcoalified wood (literally charcoal that got buried). Above the quarry we find abundant algae, fish vertebrae, crustacean shell fragments, turtle bits, croc teeth, and even a small dinosaur (but no pine or charcoal wood fragments).

The structure of the sediment also tells a story. At JQ we can clearly see the layer that contains the bones is about 1 meter thick and has a sharp irregular contact with the soil sediments below, and an obvious contact between the bone layer and lake sediments above. At the upper contact there is evidence of slight soil development based on preserved plant roots, and the change in minerals around the roots. This is because plants uptake minerals, or leach them from the soil, and changes the chemical profile around the roots themselves.

In the bone bearing layer the bones are found throughout the layer supported by the dirt or matrix, and not found on the bottom of the layer. This is odd. This is very odd. Normally we would see all of the bones at one level because they either start on a surface and get slowly buried, or they are transported by water and fall out of suspension due to gravity, at near the same time. These bones, however, are found willy-nilly throughout the layer! There are even bones that demonstrate that a great deal of force was applied to the bones during burial because of how they are broken up. One rib was even wedged between two other bones and had been split like a banana peel.

After many tests and analyses, we were able to determine that the only way this all could happen is if Jimbo was buried in a debris flow. A debris flow is a super thick mud slurry that flows down hill and suddenly stops when it looses enough energy. In this manner the bones of Jimbo were buried. This, as well as the abundant charcoalified wood, tells the truly amazing tale. Jimbo was buried because there was a forest fire that burned all the vegetation (which destabilizes soils) quickly followed by a torrential rain that loosed all the soil on an old levee causing a big mudslide. Jimbo's bones were entrained in this mudflow, or debris flow, and buried.

Soon plants began to colonize the new mud pile that entombed the supersaur bones within it. Shortly after the soil began to form the water table rose and a small lake formed preserving the remnants of the animals that lived in or near it, such as crocodiles, turtles, fish, algae, mosses, and ferns.

It is from all these different data that we were able to determine that the dry environment Jimbo lived in experienced periodic droughts and wildfires as well as heavy rains. This rough environment supported a relatively diverse flora and fauna ranging from small meat eating dinosaurs to giant plant eating sauropods, from drought tolerant pines to alkaline loving algae. It was in this environment that Jimbo lived and died. Cause of death? Still unknown. Perhaps the cause of death will yet be discovered!

With the undying gratitude of the Big Horn Basin Foundation, the Wyoming Dinosaur Center, and the science community in general, the landowners have ensured that Jimbo will remain in Wyoming for future generations to enjoy and study.