# Lesson 2: Death and Fossilization

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## Learning objective for lesson 2: Students will be able to describe how fossils form and interpret the taphonomy of skeletons and bonebeds

### Learning objective 2.1: Classify fossil occurrences

In Lesson 1, we learned how to interpret the anatomy of dinosaurs based on their fossil remains. Often, there is more to a fossil's story. The moments immediately after a dinosaur's death may have been an eventful period, and a great deal could happen in the more than 65 million year interval between a dinosaur's death and the discovery of its fossils. **Taphonomy** is the study of all natural processes that involve an organism after it dies -- this includes how it decays, is scavenged by other organisms, becomes fossilized, and erodes.

Although you might think that a dinosaur would naturally stay put after it dies, it is not uncommon for dinosaur carcasses to have been moved considerable distances from the original site of their deaths. Predators, and later scavengers, may carry a carcass to their dens or some other more secure feeding area. Shortly after death, decay may cause a body to swell with putrid gasses, and this may cause the carcasses of even large animals to float easily and to be transported by shallow and weakly flowing water. This phenomenon is known as **bloat-and-float**.

Finding complete dinosaur skeletons is rare. More commonly, only a single bone or a few isolated bones are found. There are many taphonomic factors that can contribute to the disarticulation of a skeleton. Partial consumption by carnivores is one such factor. Carcasses that have rotted for some time may be easily broken apart if swept away by rivers or flood waters. Water currents may also carry different portions of a skeleton to different locations, based on the weight and shape of the different bones. Prolonged exposure to sunlight gradually weakens and disintegrates bone. Skeletons that become only partially buried will eventually lose their exposed portions. Portions of skeletons may also be trampled by animals or have their mineral content leached away by the roots of plants. These are only a few examples, and there are a large number of other taphonomic factors that can contribute to both the transportation and the **disarticulation** of a skeleton.

**The skeleton of an Argali sheep (*Ovis ammon*) undergoing modern taphonomic processes in the Gobi Desert. More of the skeleton was located up the slope out of the frame of this picture. The skeleton has partially disarticulated, and most of the flesh has been stripped from the bones. Photo by V. Arbour.**

Even while buried, taphonomic factors may modify a skeleton. The weight of layers of rock and sediment above a bone may flatten it, and even bone that has already fossilized may be subjected to plastic deformation. **Plastic deformation** occurs when pressure causes the shape of a buried fossil to be changed such that, even when the pressure is later removed, the fossil does not return to its original shape. Plastic deformation is an important process to understand and to be mindful of. Otherwise, plastically deformed fossils may be incorrectly assumed to display their true original shapes.

### Learning objective 2.2: Suggest which environments are best for preserving fossils.

To become fossilized, a bone needs to be buried. Burial can occur if an animal dies in its own burrow, if it falls into a sinkhole, or if it, or one of its bones, is buried by a predator. But most often, burial occurs when water washes sand or mud over a carcass. Fossilization is, therefore, more common in wet environments than in dry environments, where there is no water to help bury carcasses. Fossilization is also more common at low elevations, where sand and mud carried in by water are able to build up, than at high elevations, where sand and mud are often carried away by erosion before they can build up and 'permanently' bury and protect a carcass. For this reason, we most often find dinosaur skeletons in ancient river, stream, and lake deposits. River and stream deposits are called **fluvial deposits**.

Animals that died and were preserved in lakes (**lacustrine deposits**) have the best chance of preserving soft tissues like hair or feathers in the fossil. This is because there is very little water movement in the lake to disrupt the skeleton, and the sediments laid down in lakes are very fine-grained – it's easier to preserve impressions of feathers in mud than in sand.

Even though there were no marine dinosaurs, we do sometimes find dinosaurs in ancient **coastal environments** (and, rarely, deeper-water environments), if the dinosaur was washed out to sea during a storm or tsunami.

We don't often find dinosaurs in sediments representing ancient deserts (usually represented by **aeolian, or wind-based, deposits**) , because there wasn't enough sediment being deposited to preserve the skeleton. However, one amazing exception are the ancient environments represented by the rocks in Mongolia. During the Cretaceous much of what is now Mongolia was a sand swept desert, but it was not all dry. A river also coursed through the desert and, like the modern Okavango River system of modern Africa, the river formed a large deltaic plain that created a huge oasis. In this deltaic plain, many desert animals, including large dinosaurs, had a chance to be buried by the sediments that were deposited by the river. Dinosaurs in the deserts of Mongolia could also be buried in another way: by sand dunes that suddenly collapsed onto the still living animal. This can happen when dunes suddenly become wet and saturated, like during a heavy rainstorm. As a result, the dinosaurs of Mongolia are often preserved in crouching positions, with their necks reaching up towards the air.

### Learning objective 2.3: Identify which kinds of rocks preserve dinosaur fossils.

With only a few rare exceptions, all fossils are found in sedimentary rocks. **Sedimentary rocks** are rocks that form when mineral and organic particles accumulate and become either cemented or compacted together. The two other basic rock types are **igneous rocks**, which form when magma or lava cools, and **metamorphic rocks**, which form deep underground when sedimentary or igneous rocks are changed by extreme heat and pressure.

**Sedimentology** is the science of how sedimentary rocks form. Different kinds of sedimentary rocks form in different environments. Understanding the environmental conditions that led to the formation of the particular sedimentary rocks that contain a fossil can give important clues about the habitat of the fossil organism. Sedimentary rocks that form from mud and silt are called **mudstone** and **shale**. Lakes are places where large amounts of mud and silt accumulate, and large deposits of mudstone and shale often indicate a former lake bottom environment. Sedimentary rocks that form from sand are called **sandstone**, and sandstone can indicate a former beach, river channel, or ocean floor environment. **Coal** is a special kind of sedimentary rock that forms from the compressed remains of plants, and coal indicates a former swampy environment. **Limestone** is formed from the accumulation of shells and exoskeletons of small marine invertebrates, and limestone always indicates a former shallow marine environment.

### Learning objective 2.4: Classify types of fossil preservation.

Fossils may form in a variety of ways. The different ways that fossils form are called **preservation styles**. Most dinosaur bone fossils form through either permineralization or replacement. **Permineralization** occurs when the empty internal spaces of a bone are filled with minerals. These minerals are first dissolved in water and are then deposited in the empty bone spaces as water soaks through the bone. **Replacement** occurs when the original bone gradually decays and minerals fill the space that the bone once occupied.

### Learning objective 2.5: Describe the techniques used to collect, prepare, and curate dinosaur fossils.

Simply because a dinosaur bone managed to beat the odds and become buried and fossilized, does not mean that the fossil will ever have a chance to be discovered by a paleontologist. Most of the dinosaur fossils that ever formed have either been destroyed (they have been melted or metamorphosed by geologic processes deep within the earth or have eroded away to dust on the earth's surface) or they remain buried too deep for current excavation technology to detect or to reach. Just as becoming a fossil requires a special set of circumstances, so does becoming a fossil that is discoverable.

To prevent a fossil from eroding away, it must remain buried. However, the burial process must be at least partially reversed in order for the fossil to be near enough to the surface to be found. Dinosaur fossils are, therefore, most commonly found in modern environments where there is considerable recent erosion. Modern environments that are covered with vegetation are bad places to hope to find fossils. Vegetation covers and holds together an environment's topsoil and prevents erosion. **Badlands**, such as those throughout the Canadian and American west, are arid environments where vegetation is sparse, where erosion rates are high, and where large expanses of ancient sedimentary rocks are exposed. Badlands are among the best places to hunt for fossils.

**The badlands of Dinosaur Provincial Park are good places to find fossils today, because lots of rocks of the right age and type are exposed at the surface. Photo by V. Arbour**

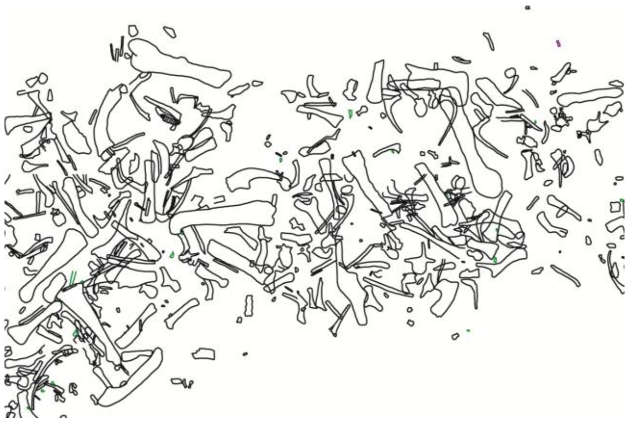
Using geologic maps, paleontologists can identify locations where there are exposures of sedimentary rocks that are the right age to contain the fossils of dinosaurs. Often, a paleontologist that is hunting for dinosaurs returns to a particular location where fossils have been found before. Whether hunting in a new location or returning to an old location that has previously yielded good specimens, a paleontologist does not simply grab a shovel and immediately commence to digging. First, a paleontologist, and usually an entire paleontological field crew, prospects for promising specimens. The ideal dinosaur skeleton is one that is freshly, and only just barely, exposed above ground. Fossils that are not exposed at all are simply not detectable, and fossils that are completely exposed, and have been for a long time, may be badly weathered.

**These are the remains of a hadrosaur jaw, in Dinosaur Provincial Park. Once above ground, exposure to rain, and freeze-thaw cycles in the winter damage the fossil and splinter it into many small shards. Photo by V. Arbour**

Once found, the first step in the excavation of a large fossil specimen is overburden removal. **Overburden** is the rock and earth that covers a fossil specimen and that must be removed before the full extent of the specimen can be judged. Overburden removal usually involves large indelicate tools like shovels, pickaxes, and occasionally even jackhammers and bulldozers. However, such tools are not used in close proximity to fossils. At close distance, the work of the final excavation switches to hand picks and brushes.

Large dinosaur skeletons or bonebeds (accumulations of the bones of many dinosaurs) cannot usually be excavated and removed all at one time. Instead, they must be excavated in parts and usually over the course of many field expeditions. Before any one bone is removed, it is important to map its location relative to the other bones. Mapping the relative positions of bones may help in putting a skeleton back together and may also give important taphonomic clues. For instance, if, in a bone bed, all the long limb bones share a similar orientation, this may indicate that the bones were carried and deposited by a strong river and that this river oriented the limb bones in line with its current.

**Dr. Currie uses a grid square to mark the location of hadrosaur bones on map sheets at the Danek Bonebed. Photo by V. Arbour.**



**The individual map sheets are combined and digitized to form a map of the entire dinosaur bonebed, a small segment of which is shown here. The map helps us to understand the distribution of different bones within the quarry: whether or not small bones are found together or mixed in with larger bones, if the long bones are aligned in the same direction, if any bones are articulated together still, etc. Map created by Katherine Bramble.**

Once a bone has been mapped, it is ready to be dug up. Although fossil bones are mineralized, they are usually brittle and unable to support their own weight. This makes them delicate to transport. To protect a fossil bone on its trip from the field to the laboratory, the bone is wrapped in a layer of protective material (this can be cloth, paper towel, or aluminum foil) and is then covered by strips of burlap that have been soaked in plaster. Once the plaster hardens, it forms a strong and rigid jacket around the fossil. These plaster jackets are not opened until they have reached the laboratory. Then, special glues are applied to the fossils to strengthen them. The final work on removing the rock that surrounds a fossil takes place in the laboratory, and this process often takes more time than the field excavation.

## Learning objective 2.6: Identify taphonomic features common to dinosaur bones.

There are many clues available to help a palaeontologist understand what happened to a dinosaur after it died, and sometimes even evidence for how the dinosaur might have died. **Disarticulation** of a skeleton may occur as carnivores eat the carcass, or because the specimen was transported by water. In a bonebed, the **orientation** of the fossils is important: long bones (like the femur or humerus) that are aligned in the same direction indicate that the bones were transported by water, and tell us the direction the water was flowing. The amount of **abrasion** on the bones can give a relative sense for how far the bones may have been transported by flowing water. Scratches on the bones can be **tooth marks**, which indicate that carnivores fed on the carcasses (but do not necessarily indicate that the dinosaur was killed by that carnivore).

## Learning objective 2.7: Evaluate the taphonomic history of a dinosaur fossil.

By the end of this lesson, you should be able to explain the conditions necessary for a bone to become fossilized. What kinds of environments are we most likely to find fossils in? What are the steps in the fossilization process? You should also be able to provide some suggestions for what kinds of taphonomic processes occurred if you are given an example to interpret.

**Stages in the final excavation of a large dinosaur bone. First, the top surface and sides of the fossil are fully unearthed. Then, a protective and cushioning layer of soft and tight-fitting material is added -- in this case, moist paper towels. Finally, the fossil is covered by strips of burlap saturated with plaster. Once hardened, the protective jacket is complete and the fossil may be safely lifted and carried away.**

Photos by W. Scott Persons

## Supplementary Resources

Geology Kitchen – The 3 Types of Rocks [Video]

Dinosaur Tracking - Ankylosaur reef. [Blog post]

National Geographic – Digging up a Dinosaur Graveyard [Video]

Dinosaur Tracking - A monumental murder mystery. [Blog post]

National Geographic – 10,000 Wildebeest Drown in Migration "Pileup" [News article]

Adventures in the Mara – 3,857 and Another Failed Crossing Today [blog posts about mass wildebeest drownings]

**Optional additional resources:** These include some examples of recent fieldwork in Canada, including work done by the University of Alberta crew.

News video shot during the University of Alberta PALEO 400 field school at the Danek *Edmontosaurus* bonebed in 2012. [Video]

More footage from the UofA fossil preparation lab in this interview with Christopher Harrisson, one of our volunteers. [Video]

Sewersaurus! A dinosaur discovered in sewer excavations in Edmonton. [Video]

Royal Ontario Museum - ROM Research: Dinosaurs in Alberta's Badlands [Video]

Royal Tyrrell Museum – Suncor Ankylosaur [Video]
Canadian Geographic – Searching Tumbler Ridge [Video]

Field update from a dinosaur locality in Nova Scotia [Video]

Royal Tyrrell Museum Speaker Series: The preservation and diversity of small dinosaurs. [Lecture]