



Texas Memorial Museum

Hall of Geology and Paleontology
Background Information

Geology, Paleontology and the Age of the Earth

Some Deep Time “Milestones”:

Earth formed 4.6 billion years ago from the spinning disk of gases and dust that was the origin of our solar system. Even though there are no longer any Earth rocks from the time of formation, we have evidence of Earth’s age from dates obtained from meteorites and moon rocks (the Moon formed at about the same time as Earth). Plate tectonics and other geological processes have recycled the earliest rocks, but there is still plenty of evidence that supports the age of our ancient Earth.

The oldest dated terrestrial (land) materials are 4.40 billion year old zircons (a very common mineral in many rocks) from Western Australia. The oldest rocks on Earth are part of the Canadian Shield and are dated at 4.0 – 3.96 billion years old. The Acasta Gneiss near Great Slave Lake in the Northwestern Territories, Canada, is thought to be the oldest known exposed rock unit, with 3.96 billion year old zircons from the gneiss providing the date. Rocks that are at least 3.5 billion years in age have been found in North America, Greenland, Australia, Africa, and Asia. In the United States, rocks from northern Minnesota are dated at 3.6 billion years, while the oldest rocks in Texas (Honey Creek gneiss in the Llano Uplift and pyroclastic rhyolites near Van Horn) are dated at about 1.37 billion years.

The oldest evidence of life on Earth is found in 3.85 billion year old banded iron formations (BIFs) in Greenland. BIFs are deep ocean deposits comprised of layers of iron-rich minerals (e.g. magnetite) alternating with layers of iron-poor minerals (e.g. chert). Common 2.8 – 2.0 billion years ago, BIFs do not form today, but are evidence of the presence of increasing amounts of free oxygen, a product of photosynthesis. There is also evidence of 3.5 billion year old microbes and stromatolites in Western Australia. Stromatolites are the fossils of cyanobacteria, primitive single-celled microorganisms that often formed mats or dome-like structures as they deposited calcium carbonate on the sea-floor. They were important reef-building organisms in the Precambrian seas.

(Be sure to see the BIF slab and the Precambrian and Cambrian stromatolite specimens on exhibit)

Fossils and Fossilization:

A fossil is any evidence of past life, be it the remains of an organism’s body, a track, or a trace. Scientists who study fossils are called paleontologists, for the study of ancient life is the science of paleontology. Paleontology should not be confused with archaeology, the study of the human past, which includes ancient cultures and associated artifacts.

Fossils are typically formed within sediment that becomes lithified (turns to rock), and are at least several thousand years old. However, not all fossils are *fossilized*, that is, have undergone some kind of change during preservation.

Types of Body Fossil Preservation

1. Essentially unaltered or “actual” preservation
 - A. Frozen intact (flesh included) – e.g. mammoths found in Siberian ice
 - B. Trapped within tree resin (amber)
 - C. Asphalt impregnation – saber-toothed cats from Rancho La Brea, CA
 - D. Unaltered (i.e., original skeleton unaltered) – e.g. calcite exoskeletons of corals,

bryozoans and oysters; phosphate exoskeletons of brachiopods; and chitin skeletons of arthropods

2. Desiccation – Remains of organisms may lose all water, becoming “mummies”.
3. Carbonization – As organic material decomposes under water, the volatile constituents (oxygen, hydrogen, and nitrogen) are slowly lost in a process called distillation. When this occurs, carbon concentrations are sometimes left behind as a thin film. Plants and soft-bodied organisms have been preserved this way.
4. Alteration by mineralizing solutions
 - A. Replacement – the original skeletal material is replaced by another mineral (silica, pyrite, limonite, and glauconite are common).
 - B. Permineralization – additional minerals fill pore spaces within bone and wood.
 - C. Recrystallization – the original mineral material is reorganized into other crystalline forms (most commonly aragonite to calcite).
 - D. Concretions and nodules – fossils may be preserved within spherical or elliptical rock bodies. The decomposing organism provides a localized chemical environment that favors mineral precipitation.

Trace fossils

1. Tracks, trails and borings – these fossils are evidence of behavior and can be used to interpret ancient environments and modes of life.
2. Gastroliths or “gizzard stones” – these are rounded and highly polished stones found in association with some reptile (sauropod dinosaurs and plesiosaurs) and bird remains. Several stones in a gizzard-like structure were used by these animals to help mechanically break down food before it is deposited in the stomach.
3. Coprolites – fossilized feces. Coprolites may contain identifiable remnants of undigested food.
4. Molds, casts and impressions – Entire plants or animals may be dissolved away following burial so that only cavities in the sediment are left. The walls of these cavities are considered natural molds of the fossil. Later, sediment or minerals may fill these cavities and form *natural casts* of the original organisms. Molds are external if the outline of the outer surface of a hard part of the fossil is apparent, or they are internal if the impression of the inner surface is preserved.

Life in Texas from the Past to the Present

For a downloadable copy of the geological time scale published by the Geological Society of America, visit:

<http://www.geosociety.org/science/timescale/>

Life on Earth before the Paleozoic not only included stromatolites, but also small shelly fossils from Siberia and the remains of strange soft-bodied animals from Australia. But in Texas, fossils from this time are extremely rare. In fact, the oldest fossils in Texas may be feeding traces of marine life from 1.25 billion year old rocks near the town of Van Horn.

Paleozoic Era, 541-252 million years ago

Life in the Sea (Cambrian Period through Permian Period 541-252 million years ago)

The Cambrian explosion includes many organisms recorded in Texas' history, especially invertebrate groups such as trilobites, brachiopods and echinoderms. There is significant fossil evidence for the appearance and rapid diversification of the major groups of animals during this time. Vertebrate evolution centered on the fishes during the Ordovician Period through Devonian Period (485-359 my). Strange jawless armored fish called ostracoderms were some of the earliest forms, to be followed by the first jawed fishes in the Silurian and a great diversity of placoderms (armored fish with sharp bony plates for teeth), chondrichthyans (sharks, rays and skates), lobe-finned fish (lungfish and coelacanths) and ray-finned fish in the Devonian.

Near the end of the Devonian, coral reef communities worldwide came close to a total collapse. Many organisms recovered from the mass extinction, but the reef systems changed to those dominated by algae, sponges and bryozoans. The Guadalupe Mountains in West Texas are part of a series of Permian (298-252 my) reef complexes that not only included these frame-builders, but were also home to a variety of cephalopods (squids, nautilus and ammonoids), brachiopods and horn corals.

Life on Land (Pennsylvanian Period through Permian Period, 323-252 million years ago) Paleozoic Terrestrial Plants

The evolution and diversification of the first land plants occurred during the mid-Ordovician and Silurian. Non-vascular plants such as the mosses and liverworts were the first to colonize land, but still required moist living conditions. Vascular plants appeared by the mid-Silurian (about 433 million years ago). During the Carboniferous (Mississippian and Pennsylvanian) scale trees, club mosses, horsetails and ferns were common. We do not see fossil evidence of these land plants in Texas until the Pennsylvanian, because for much of the Paleozoic, Texas was under the sea. During the Permian Period there was a worldwide radiation of cycads, ginkgos and conifers. Plant fossils from this time are well known from north-central Texas from environments that ranged from very wet (swampy) to those with well-drained soils.

Paleozoic Terrestrial Animals

The early tetrapods (four-footed vertebrates) appeared in the Devonian, making the transition from an aquatic lifestyle to that on land. One lineage led to the amphibians and extinct relatives and the other to the amniotes (mammals, birds and reptiles). Tetrapods faced some challenges to life on land – problems with drying out, temperature regulation, and changing food resources. Some forms remained quite aquatic, returning to water to reproduce or look for food, others adapted to feeding on terrestrial arthropods or plants. Amniotes laid shelled eggs that allowed for gas exchange and contained food and fluids for the developing embryo. This type of “land egg” is still produced by reptiles, birds, and a few mammals (platypus and echidnas) today.

Permian Extinctions

The end of the Permian Period (and thus, the Paleozoic Era) is marked by a mass extinction, far worse in terms of species lost than the event that resulted in the extinction of non-avian dinosaurs at the end of the Mesozoic. It has often been called the “Great Dying.” The marine invertebrates were hardest hit, for 95% of all known species became extinct. Trilobites and eurypterids (“sea scorpions”) were two major groups that disappeared. On land, 65% of all known amphibian and reptile species were

lost, and 33% of all known insect species became extinct. Climate change and increased volcanic activity appear to have been the causes, for there is evidence of increased carbon dioxide levels and global warming during the last 8 million years of the Permian Period. A combination of very warm and anoxic (without oxygen) ocean waters devastated marine ecosystems.

Mesozoic Era, 252-66 million years ago

Triassic Period 252-201 Million Years Ago

The rifting of the supercontinent Pangaea into Laurasia and Gondwana began in the Triassic and had lasting effects on oceanic circulation, climate and the distribution of plants and animals. In the Triassic seas, bivalves (clams, oysters and scallops), and echinoids (sea urchins) became more infaunal, living within sediments rather than solely on the surface of the sea floor. Modern corals appeared, evolving from an anemone-like ancestor, forming the first true coral reefs.

On land it was warm temperate to tropical in climate, with some regions experiencing alternating very wet to very dry conditions. By the Late Triassic, several groups of organisms diversified (evolved into a variety of species), including the archosaurs – a lineage of reptiles that includes the extinct aetosaurs, phytosaurs and pterosaurs as well as crocodiles and dinosaurs. The earliest archosaurs still retained the sprawling posture of other reptiles, but later archosaurs evolved a posture that brought the legs under the body and allowed increased stride length and agility.

Jurassic Period 201-145 million years ago

Life in the Jurassic Period flourished, but unfortunately, Texas does not have a fossil record to provide us with the details. There are practically no rocks of Jurassic age exposed on the surface in Texas, for most are buried beneath the thick limestone deposits of the Cretaceous. Isolated outcrops of Jurassic rocks containing marine fossils can be found in West Texas. At this time the Gulf of Mexico, which first formed in the Triassic, continued to open and much of the state was covered by a sea.

Cretaceous Period 145-66 million years ago

Life in the Sea

The Cretaceous sea that covered much of Texas during this time was home to several groups of reptiles adapted to a marine predatory lifestyle. Plesiosaurs were marine reptiles that used their long, oar-like front limbs to move through the water. Some forms had long sinuous necks, while others were shaped more like dolphins, but all fed on fish and cephalopods. Yet the top predators were the mosasaurs, extinct relatives of lizards and snakes, which also fed on small plesiosaurs and even smaller mosasaurs. Mosasaurs used their paddle-like forelimbs for steering while the long powerful tail pushed it through the water, moving in an undulating motion.

The invertebrate fauna was rich and included a variety of cephalopods, gastropods, bivalves, echinoderms (sea stars, sea urchins and sea lilies), crustaceans (crabs, lobsters and shrimp) and corals. Reef frameworks were built by strangely shaped and thick-shelled bivalves called rudists and oyster banks were common. Ammonoid cephalopods were extremely diverse and their fossils today still serve as “time markers” for rock layers of Cretaceous age.

Life on Land

The terrestrial record in Texas is dominated by dinosaurs, with representatives from all major groups including the bipedal, carnivorous theropods and the quadrupedal herbivores including ceratopsians,

hadrosaurs and sauropods. West Texas and places along the shores of the Cretaceous inland sea were home to dinosaurs, for we find not only bones and teeth, but trackways, which provide us with information about locomotion and other behaviors of dinosaurs. Overhead flew their archosaurian relatives, the pterosaurs, as well as birds, which are part of the theropod evolutionary lineage. Flowering plants exhibited an explosive radiation during the Late Cretaceous to become the widespread, diverse and abundant plant forms we see today.

Cretaceous Extinctions

A significant global extinction event marks the end of the Cretaceous Period and the close of the Mesozoic Era. Global climate change was taking place, and conditions were changing significantly from a warm and mild climate to one that was cooler and much more variable. Volcanic eruptions were increasing, especially in India, and millions of years of ash and other matter ejected into the atmosphere may have affected the climate by blocking sunlight. There was an extraterrestrial impact, as evidenced by the impact crater (Chicxulub) in the Yucatán, and the presence of an extremely rare element, iridium, in a clay layer deposited in several places globally, above the last layers containing non-avian dinosaurs. Extinctions took place in both terrestrial and marine ecosystems, and included ammonites, rudist bivalves, mosasaurs, plesiosaurs, and pterosaurs. The only dinosaurs to not become extinct were the birds. Thus the survivors of this extinction event became the ancestors of today's flora and fauna.

Cenozoic Era, 66 Million years ago-today

Life in the Sea, Paleocene-Pliocene epochs (66-2.6 million years ago)

Gulf Coast shoreline fluctuated across the region several times through the Cenozoic before receding to the level of today's Gulf of Mexico. Gastropods, crustaceans and cephalopod fossils found in areas of the Texas coastal plain indicate the extent of the sea at this time. Corals diversified after the extinction event at the end of the Mesozoic to again become the dominant reef building organisms.

Life on Land, Paleocene-Pliocene epochs (66-2.6 my)

The Paleocene through Pliocene epochs (formerly named the Tertiary Period) represent more than 60 million years of ecosystem change in Texas. Extinctions, originations, and immigrations of mammals and the diversification of ecosystems make this an exciting time in Texas' history. Paleocene through Oligocene (66-23 million years ago) communities included tropical-subtropical forests and even a mangrove community in South Texas. Arboreal fruit-eating mammals such as primates and rodents were quite common in Texas, especially in communities in south and west Texas. Large-bodied herbivores included the pig-like entelodonts and the rhinoceros-like brontotheres. Freshwater lakes and other wetland areas were home to a diversity of fish, amphibians and reptiles.

Miocene through Pliocene (23-2.6 million years ago) fossils document changes from closed forests to woodland, savannah, and grassland environments. Grasses expanded their range, and with the change in vegetation and open tracts of land, the mammals were changing too. Mammals became increasingly more cursorial (able to run) and fossorial (able to dig). The teeth of many herbivores such as equids (horses, asses, zebras) developed characteristics that allowed them to graze on tough plants (especially grasses, which are high in silica). The hoofed mammals were diverse in body size and shape, and horn patterns. Some camels were giraffe-like, browsing on vegetation at a level above that browsed by smaller herbivores. Many herbivores such as rhinoceroses and gomphotheres developed large body sizes, while others remained small. Carnivorous mammals such as cats, dogs and bears diversified,

having specializations in their morphology and behaviors that allowed them to successfully prey upon the herbivores in their communities.

Life in the Sea, Pleistocene Epoch (2.6 million–12,000 years ago)

Salt domes that formed in the Gulf of Mexico millions of years before the advance and retreat of the Pleistocene glaciers pushed up through the layers of sediments deposited by rivers flowing into the sea. Coral reef communities began growing on these salt domes at the end of the Pleistocene, about 15,000 – 10,000 years ago. These communities are thought to have originated by colonizing larvae of corals and other animals carried northward from Mexico by gulf currents. Now protected as the Flower Garden Banks National Marine Sanctuary, this unique ecosystem is home to over 23 species of corals and numerous species of reef-dwelling invertebrates, algae and fishes.

Life on Land, Pleistocene Epoch (2.6 million–12,000 years ago)

The Pleistocene (commonly called the “Ice Age”) was a time of climatic and faunal change in North America, even as far south as Texas. Although glaciers did not extend into Texas, the effects of their advance and retreat can be seen in the fossil record. Mammal communities included immigrants from Eurasia such as bison, mammoth, lion, gray wolf, and human beings as well as our native horses, camels, saber-toothed cats, and pronghorns. The diverse and unique xenarthrans (sloths, armadillos and glyptodonts), immigrants from South America, were also an important component to the fauna, as were smaller, more “every day” animals such as rodents and rabbits.

Ecosystems varied from temperate and dry to cool and moist, and from grasslands to woodlands in Texas. This environmental diversity is still apparent today in Texas. Small mammal distributions in Texas have been affected by changes in the environment. Some communities in Texas include mammals that no longer coexist today. The megafauna (large-bodied animals) have gained the most attention, for their extinction at the end of the Pleistocene Epoch cannot be attributed to a single cause. Mammoth and bison remains have been found at several Paleo-Indian kill sites in North America. Both hunting by humans and climate change appear to have played an important role in re-shaping the diversity of Texas mammal communities.