The Third Planet
360 Virtual Tour Script

Note: Black font is used to denote physical labels in the museum. Blue font is used to denote text from our virtual 360 tour.

Welcome to the Milwaukee Public Museum's *Third Planet* gallery! In this exhibit, you'll explore the formation and geology of Earth along with the evolution of life on the planet. During this self-led tour, you'll hear from MPM scientists, get close-up looks at behind-the-scenes artifacts, and unlock the secrets of Earth's 4.5-billion-year history.

Watch Dino/Di-No Episode 1

Watch Dino/Di-No Episode 2

Watch Dino/Di-No Episode 3

Torosaur

Exploring Life on Earth

The exhibits displayed throughout the Geology Hall depict the continuing evolution of the landscape and of life on earth. As the continents changed their geographical positions through time, due to the continuous motion of the earth's plates, physical and biological changes occurred on Earth. The changing continents and oceans affected the evolution of life.

Paleontologists study the history of life on earth. They study fossils. Fossils are the preserved remains of animals, plants and other organisms that lived on Earth long ago. Paleontologists also study how these organisms interacted with each other and their environment.

When you walk into the *Rainforest* exhibit, which follows the Geology Hall, you can learn more about the diverse ways in which life on Earth has met the challenge for existence.

The Torosaurus

Age of the Dinosaurs

Scientists divide the 4.5-billion-year history of the Earth into blocks of time called eras and periods. Dinosaurs lived during the Mesozoic era. The Mesozoic era is divided into three periods shown above. Dinosaurs became extinct at the end of the Cretaceous Period.

Torosaurus, the "Perforated Lizard"

The Torosaur skeleton on display in this exhibit was discovered in eastern Montana in 1981 by a Milwaukee Public Museum expedition which combined staff and volunteers. The bones came from the Hell Creek Formation, the last rock unit of the Late Cretaceous, at the very end of the dinosaur era. Exposed at the surface in Montana and the Dakotas, the Hell Creek is composed of sandstones, siltstones, and mudstones that were deposited by meandering rivers from 67 to 65 million years ago.

This specimen was important for several reasons. Torosaurs are far less common than the related dinosaur *Triceratops*, and this was the first ever found in Montana. More importantly, this was the only specimen with significant post-cranial (behind-the-skull) remains; most Torosaurs are represented by skulls only. This skull, nearly nine feet long and eight feet wide, is one of the largest dinosaur skulls ever found.

Lifestyles of the Big and Dangerous

Gigantic Plant-Eaters

Torosaurs were herbivores (plant-eaters) whose specialized teeth were arranged like the blades on a pair of scissors. This allowed Torosaurus to chop up vegetation before it was swallowed. Their robust jawbones indicate powerful chewing muscles for tearing plants apart. In addition to their likely diet of low-growing plants, Torosaurs might have eaten fallen fruits and leaves. The parrot-like beak would be useful for picking up and manipulating such food.

Magnolia were present as early as 100 million years ago and today can still be found in your backyard.

Loners or Herd Animals?

Torosaurus, when fully grown. weighed between five and seven tons and was 25 to 30 feet long. Like most of the large ceratopsians, Torosaurs were specialized for walking and likely running on four legs. Notice they have hoof-like nails on their toes. Some ceratopsians have been found fossilized in large numbers, suggesting they traveled in herds, at least part of the year, as many large modem grazers do. However, Torosaur finds thus far have been isolated individuals.

Rebuilding a Torosaur

From Fossil to Skeleton

The dark brown areas in our specimen are the actual fossilized bones found in 1981. The lighter areas are replicas of the missing parts.

Due to the various actions of decay of dead animals, their preservation as fossils, and the erosion that exposes them for excavation, dinosaur skeletons are very rarely complete. Remains from several individuals are usually required to understand what the whole skeletal structure was like. We had enough shoulder, leg, and rib remains to realize the body was much like a *Triceratops*, so a fossil of that dinosaur was used to cast the other bones.

The dark brown areas are the actual fossilized bones, while lighter areas are replicas.

Shown is a record of how the Milwaukee Torosaur was found, to compare with the reconstructed skeleton.

Some museums have mounted ceratopsians with the legs straight beneath the body, but based on this skeleton we believe that *Torosaurus* had flexed forelimb position and have mounted our skeleton to suggest this.

Beyond the Bones

Markings, ridges and grooves called "muscle scars" are often preserved on the surface of fossilized bones where muscles were attached. Such details help us determine how the animal may have moved the different parts of its body such as its head, jaws, or limbs.

After careful study of the forelimb bones of the Milwaukee *Torosaurus*, we have mounted our front legs in a flexed stance. This position makes the most scientific sense, based on the morphology (shape) of the bones, how they articulate (fit together), and how the muscles attach to the bones to allow the front limbs to move.

Horns and Hypotheses

Horned dinosaurs are often depicted using their horns as defense against predators. Recent studies of skull structures and areas of damage suggest that they were also significant in fights among members of the same species, as is found in many living animals with horns or antlers.

Horn core from *Triceratops* skull, Hell Creek Formation, northeastern Montana is on display.

The horns of ceratopsian dinosaurs were probably covered by a sheath as are the horns of modern animals. This sheath was probably composed of the protein keratin.

Look in the mirror behind the Torosaur’s head. You will see a small, jagged hole in the side of its skull. This hole is a puncture wound that was probably inflicted by another *Torosaurus* during a battle to defend territory or to establish rank in the herd.

Questions in the Science

Science is a continuous process of making observations, developing possible explanations (hypotheses) to explain these observations, and formulating experiments with new observations to test the hypotheses. Science does not attempt to prove a hypothesis is true. If tests falsify the hypothesis, it may be rejected altogether or possibly revised and retested.

Paleontology is the science concerned with ancient life - plants, animals, and environments that no longer exist except as rocks and fossils. In developing and testing hypotheses about events that are long past, observations are derived from the geological and fossil record as well as the study of living organisms and earth processes.

Did the puncture wound cause death?

We have already observed the puncture wound in the *Torosaurus* skull. A head wound of this size is quite serious, but was it the cause of death for this individual?

Hypothesis Testing

Hypothesis: The puncture causing the wound was the immediate cause of death.

Test: Examination of the wound shows a callus or thickening of the bone around its edges. This is normal as damaged bone heals. Also, the punctured left side of the skull is shorter than the right side, indicating significant growth following the puncture.

Conclusion: The hypothesis is rejected as the animal did not die immediately after receiving the wound.

Earth's Interior

The deepest holes drilled into Earth have but scratched its surface. Only sensitive instruments can tell us about Earth's interior.

From laboratory experiments, scientists have learned that earthquake shock waves change as they encounter fluids and solids of different densities inside the Earth. Analysis of earthquake shock waves using a worldwide network of seismographs have revealed that Earth is a concentrically layered planet, containing a solid inner core, a molten outer core, a partially molten mantel, and a solid crust.

Earth became a layered planet early in its history. Then it was largely molten because radioactive heat generated more rapidly than it could flow away. Iron and nickel melted and sank to form a central core; lighter materials floated upward and cooled to become the mantle and crust.

Scientific probes of the interior expose a vital partnership between Earth's crust and upper mantle.

The lithosphere, from *lithos* for "stone," is Earth's outermost layer of rigid rock. It includes the continents, ocean floors, and the uppermost mantle. It has fractured into a mosaic of gigantic plates that slowly move -- separating, shearing, compressing, and underthrusting one another.

The asthenosphere, from *asthenes* for "weak," underlies the lithosphere. Heat and extreme pressure make it deformable and perhaps partially molten. It can flow to relieve stress. As it moves, the overlying plates of the lithosphere move with it, setting continents, oceans and life in motion.

Change: A permanent condition of the third planet

Earth's face changes its expressions through time. These surface changes are caused by movements among crustal plates driven by internal radioactive heat.

When Earth's crustal plates collide, separate, or slide by one another, the planet's surface changes. Continents drift, oceans are created and destroyed, molten rocks rise from the interior, volcanoes erupt, mountains are folded and buckled. The study of these dynamic processes is called plate tectonics.

Most changes occur in imperceptibly slow motion

Consider the Himalaya Mountains and the Atlantic Ocean. The Himalayas have been in the making for 40 million years; the Atlantic has been growing for about 200 million years.

Where plates separate…

Molten rock from the mantle rises to fill the fractures, or rifts, at their parting boundaries. It solidifies and welds itself to the plates, causing them to grow. Earthquakes and volcanic action accompany the separation.

The mid-Atlantic ridge, stretching for thousands of kilometers along the ocean floor, is an awesome example of plate separation. It marks the continuing separation of the American from the Eurasian and African Plates -- and, hence, the continuing expansion of the Atlantic Ocean by an average of a few centimeters each year.

Where a continent and an ocean meet...

At the leading edges of colliding plates, the lighter continental plate overrides the heavier oceanic plate which descends, or subducts, into the mantle and is consumed. A deep seafloor trench often marks its descent. The average downward movement of descending plates is estimated at about eight centimeters (less than four inches) per year.

The leading edge of a continental plate meets an oceanic plate with tremendous compression and is crumpled and uplifted into mountains. Volcanoes and earthquakes occur, for as the oceanic plate descends, a heat-generating zone is created.

Where two continents collide...

At the leading edges of continental plates, neither plate descends into the mantle, for both are buoyant. Instead, there is a head-on encounter with a great and complex piling up of material. The material includes the sediments and rocks from the floor of the ocean that once separated the two continents. A mountain range is born!

Where plates slide past one another...

Friction builds up along the edges of both plates and in the area of slippage great transform fault zones with intense earthquakes develop. One of the most notorious of such zones is the San Andreas Fault in California.

Building Blocks of Earth's Crust

Elements are the stuff of which the Earth is made.

All matter is made of one or more elements. The smallest part of an element that can exist by itself is the atom.

One could start hoarding the element gold by acquiring a single atom, but its diameter would be little more than a hundred-millionth of a centimeter! In turn, that atom could be split in a nuclear reactor, but the resulting fragments no longer would be gold.

Some elements, such as gold, silver, and copper, are found uncombined in nature. These are the native elements. Other elements combine to form distinctive inorganic crystalline solids called minerals.

Minerals

Elements in combination create the many-splendored mineral kingdom.

Scientists have devised many systems of classification for Earth's more-than 2,000 minerals. In essence, all strive to categorize minerals by the shapes of the crystals they form and by their chemistry.

About 95 percent of Earth's crust is composed of a large complex group of rock-forming minerals called silicates. Silicates are compounds of oxygen, silicon, and one or more other elements. They top the inventory of abundant mineral groups in the crust, followed by phosphates, sulfides, carbonates, oxides, and halides.

Lead

This is an example of galena, a lead sulfide. It was the first metal ore mined in Wisconsin and is the official state mineral of Wisconsin. Lead miners who moved to the southwest part of Wisconsin in the 1820s and 1830s burrowed holes into hillsides for quick homes, earning the miners the nickname "badgers," hence Wisconsin becoming "the Badger State."

Meteorites...

Colby Meteorite

Stony chondrite consisting of olivine and hypersthene

Fell in Colb, Clark County, Wisconsin on July 4, 1917 at 6:20 p.m. Weight of this sample is 417.9 grams. 3D model of this specimen photographed by Dr. Ralph L. Kugler.

Rocks are mixtures of minerals

Rocks usually reflect the forces that made them -- sedimentation, heat, pressure. Some rocks form from mineral grains eroded by water and air from pre-existing rocks; some solidify from molten materials, others have been changed physically and chemically by intensive heating and squeezing underground.

Some rocks formed from molten materials. Granite and basalt, which may have been derived from peridotite in the mantle, play a prominent role in shaping the continents and ocean floors.

Granite

Principle rock of the continents, consisting chiefly of the minerals quartz and feldspar. Continental rocks are Earth's oldest. The Isua granite of Greenland is 3.8 billion years old.

Basalt

Basalt rock is the lower continental crust and, except for a thick covering of sediments, of all ocean floors. Oceanic crust is thinner but more dense than continental crust and is nowhere older than about 200 million years.

Have you wondered what's beneath the surface of the Earth?

If you guessed rock, you're right! Magma from the center of the Earth is pushed up into the surface and cooled, making rocks like this that create the crust of the Earth, separating it from the molten core.

There is one place in Wisconsin where you can walk on basaltic lava rock that makes up Earth's crust – Interstate State Park near St. Croix Falls in NW Wisconsin. There, the volcanic basalt has been raised up and exposed to the erosive actions of glaciers and glacial meltwater.

Peridotite

Major component of the upper mantle, composed mostly of the mineral olivine, but sometimes containing pyroxenes and probably garnet. Mantle rocks are even more dense than those of the ocean floors.

Insight about Earth's interior often falls from outer space.

Meteorites, the unburned remains of shooting stars, are probably fragments left over from the formation of the solar system. Some rain down as fine dust particles; others arrive as chunks of all sizes, including huge bodies that gouge out enormous craters upon impact. Meteor Crater in Arizona, for example, was formed by a meteorite weighing hundreds of thousands of tons.

Almost all meteorites were formed about 4.6 billion years ago. Scientists use this date to fix the time of the solar system's formation. They also use the composition of meteorites to interpret Earth's interior.

Stony Meteorites

Composed mostly of olivine and pyroxene. The same minerals are prominent in Earth's mantle.

Iron Meteorites

Composed of an iron-nickel alloy which is regarded as similar to the ingredients of Earth's core.

Crystals

Fluorite Crystals

3D photogrammetry by Dr. Ralph L. Kugler

Crystals are not alive, but they grow. And their growth, like the growth of plants and animals, is modified by their environment.

Crystals grow when minerals solidify from gaseous or liquid states. Some solidify from briny water, some from escaping volcanic vapors, but most crystallize from molten materials. They grow by accretion — the orderly adding of layers of material around a nucleus. Thus the crystal shows continuous symmetry as it enlarges.

Crystals range from microscopic to gigantic. The giants have the same internal arrangement of atoms as their smaller counterparts but the larger the crystal is the less chance it will be perfect.

Mountains: Towering upheavals of rock

Earth’s folded linear mountain systems are the products of plates engaged in encounters that severely compress their colliding boundaries.

The slow but powerful impact of continental plate exerts immense pressures that fold and thrust rocks up into towering peaks. The geologically young and growing Alps and Himalayas were born of such upheavals: the Alps from the repeated collisions of the African and Eurasian Plates, and the Himalayas from the northward advance of India against central Asia. The Himalayan uplift continues as India grinds northward a few centimeters each year.

The Andes Mountains on the rumpled west coast of South America formed when the ocean-carrying Nazca Plate was overridden by the continental South American Plate. The continuing descent of the Nazca Plate creates extensive zones of compression, volcanoes, and earthquakes.

Of sutures made in stone..

When two continents collide, compression forms complex mountain systems and severe deformities of the crust result. These complicated attachment zones are called sutures.

The Rock Mountains have a long and complex history. The so-called Ancestral Rockies formed from continental collision hundred of millions of years ago. After a lengthy period of erosion, a second period of uplift and deformation began about one hundred million years ago. The present mountains result from the second episode of mountain-building activity.

Volcanoes: The Rock Makers

From a human point-of-view, volcanoes can be devastating. From a geologic point-of-view, they are stunning, surface-building processes.

For thousands of years, people have dwelt in clusters around volcanoes, for there they have found rich soils. Indeed, volcanoes and life on Earth are inextricably interwoven.

When Earth was young, volcanoes riddled its surface, venting vast quantities of water vapor and carbon dioxide into the atmosphere. Condensing as rain, the water vapor supplied the oceans with water, the medium that cradled life. The carbon dioxide nurtured green plants.

The varied shapes of volcanoes are caused by the kind of lava they erupt. Some are gentle, others explosive.

Shield Volcanoes

Shield volcanoes, such as Mauna Loa of Hawaii, resemble inverted saucers. They are built from thousands of thin flows of basaltic lava. If the magma moves upward slowly, gas bubbles escape freely and gradually, resulting in relatively gentle non-explosive eruptions.

Composite Volcanoes

Composite volcanoes, such as Mount St. Helens in Washington state, are conical piles of andesitic and rhyolitic lavas. Both are pasty, or viscous. Viscous lavas resist flow and inhibit gas separation and escape. They erupt explosively and eject fragmented materials, or pyroclasts, ranging in size from fine ash to large chunks of lava called bombs or blocks. Composite volcanoes are typically constructed of layers of pyroclasts interbedded with lava flows.

Fissure Volcanoes

Fissure volcanoes occur over long cracks, or fissures, in the crust. Commonly, the lava is a runny basalt which floods extensive areas and sometimes piles up into lava plateaus. To build the Columbia Plateau of the northwestern United States, lava flow piled upon lava flow to bury some 350,000 square kilometers (9,000 square miles) of mountainous terrain under 2,000 meters (5,500 feet) of basalt.

Earthquakes…

Why does the Earth shudder? The elastic rebound theory is one explanation.

Earthquakes are associated with large fractures or faults in the crust. For example, at the west coast of North America, the North Pacific Plate moves alongside the North American Plate, creating a system of faults. The main boundary between the two plates is called the San Andreas Fault. Earthquake conditions develop along this fault when the plates become jammed against one another. A frictional zone is created.

Stress builds up, and the rocks deform and bend as elastic energy is stored in them, much like the energy stored in a wound-up clock spring. This energy may accumulate for tens or hundreds of years.

Energy builds until the locked fault can no longer hold, and it breaks at its weakest point. This point at which the rocks suddenly slip or offset is the focus of the earthquake. Stress is relieved, and the rocks spring back, generating the intense vibrations we call earthquakes.

Seismograph

The land that is today Wisconsin wasn't always located "up north." This is because beneath the ocean and continents, the Earth's crust is made up of tectonic plates. The hot magma inside the Earth moves these plates, like water moving a sheet of ice floating on it. Tectonic plates move about as quickly as your fingernails grow. That doesn't sound like much, but over billions of years, they can move thousands and thousands of miles.

The edges of tectonic plates push or slide against each other, which can create mountains, volcanoes, and earthquakes, like the one recorded in this seismograph.

Rocks Born of Fire…

The slow but relentless and powerful encounters among plates provide a heat-generating environment for the production of igneous rocks.

Igneous rocks are formed from the cooling and hardening of molten materials, or magmas, which intrude near or extrude upon Earth's surface from the interior. Surface-erupting magmas are called lavas and form volcanoes. Magmas cooling as massive underground structures are called plutons; granites are examples of plutonic rocks.

The texture of an igneous rock is a complex mosaic of intergrown mineral crystals. A rock cooling slowly underground is coarse-grained, For its crystals have had time to grow. Rocks solidifying from surface lavas are fine-grained or even glassy, for their crystal growth is stunted by rapid cooling.

New Rocks from Old...

Deep underground where the crust is heated and compressed, existing rocks are changed into new products: metamorphic rocks.

Regional metamorphism occurs over thousands of square kilometers. It happens where great linear belts of crust are folded and uplifted into mountain chains. Shale is a frequent participant in such processes. It changes into slate as folds in the crust sharpen, pressures increase, and temperatures rise.

Contact metamorphism is restricted in area. It happens where an intrusion of magma heats and may partially melt the surrounding rock. This metamorphism under high temperatures but low pressures produces rocks with an even granular texture. In this way, marble is formed from limestone, quartzite from sandstone, and hornfels from shale.

Sometimes the two kinds of metamorphism produce the same rock. For example, limestone becomes marble by both regional and contact metamorphism. What kind of metamorphism do the fold patterns in this marble suggest?

Earth’s Crustal Plates making their presence known

Most of Earth's volcanoes, earthquakes, and great linear mountain systems occur in narrow zones that girdle the planet. These zones map the geologically active boundaries of the plates that pave Earth's surface.

The "ring of fire," rimming the Pacific Ocean, is the most important of these zones. Its seafloor trenches, active and dormant volcanoes, and destructive earthquakes trace areas where plates are descending into Earth's interior.

Volcanic Fury… Rock turned to stone

Continental Positions through Time

For all of recorded geologic time, crustal plates have been in motion. Over the last 300 million years, they have moved from a consolidated supercontinent called Pangaea to their present independent positions. This movement has been substantiated by evidence from physical geology, fossils, and paleomagnetics.

Key Pieces of a Continental Puzzle

Crustal Evidence

Phyllite and granulite rocks in eastern South America are virtually identical to the rocks found in western Africa. These distinctive bands of rock were once continuous, but when the supercontinent Pangaea rifted apart, these bands were separated by an ever-widening ocean, and are now found on opposite sides of the Atlantic

Fossil Evidence

The land plant *Glossopteris* and the fresh water reptile *Mesosaurus* once ranged across the southern realm of the supercontinent Pangaea. These plants and animals, which could not have crossed ocean barriers, are now found as fossils on widely dispersed continents such as South America and Africa.

Glossopteris: A seed-bearing plant which lived in South America, Africa, India, Antarctica, and Australia, when the continents were part of a single land mass.

Mesosaurus: A 200 million year old fresh water reptile found in South American and Africa.

Moving toward Earth's surface ...

Cave

Water, Water Everywhere.

Abundant water unique to the Third Planet.

As a gas, liquid or solid, it participates in all geologic and biologic processes. Water also often serves as the architect of caverns, underground palaces dissolved out of stone. Water becomes a dilute carbonic acid, as it absorbs carbon dioxide from the atmosphere and from decayed organic matter in the ground. The acidic water reacts with limestone, converting it to calcium bicarbonate which readily dissolves in water. Slowly the groundwater dissolves massive deposits of limestone, enlarging tiny cracks into large chambers and intricate passageways.

Stalactites grow down... Stalagmites grow up.

But both grow by the same process.

When a drop of water carrying dissolved limestone hangs from a cavern roof, it loses some of its carbon dioxide through evaporation. This causes the dissolved limestone to resolidify as minute particles sticking to the roof. Repeated again and again, this evaporation and dripping process eventually leaves a hanging deposit of limestone called a stalactite.

If water from falling drops lingers on the cavern floor, further evaporation builds another deposit upward as a stalagmite.

Stalagmites and Stalactites

Rocks and magma aren't solely responsible for how the Earth looks. Water has and continues to shape the landscape every day. Below the ground, water carves out caves like this one. As water drips into the cave, it deposits calcite minerals it picked up traveling through the ground on the same spot over and over again, slowly creating these formations over hundreds of years.

These formations are known as stalactites (which stick tight to the ceiling) and stalagmites (which stand mightily on the ground). When a stalactite and a stalagmite grow large enough to merge, they are known as a column, also shown here.

Geodes: Dull on the outside, dazzling on the inside

Geodes are formed by processes very much like those which make caverns. Groundwater passing through porous rock, usually limestone, will often leave behind some of the mineral matter it is carrying. If large enough cavities are present, crystals will grow on their inner surfaces. Geodes are most often formed of varieties of quartz. Geodes are, in fact, little caverns.

Two Earthscapes

What makes them different?

Water is responsible, in numerous ways, for the familiar face of Earth. The blue color of the sky, reddish oxidized rocks, deep river-carved gorges, snow atop a mountain, life -- all rely upon the presence on Earth of water.

How extensive is the importance of water?

Earth's Surface

The Continents under Siege

Earth's surface is shaped by opposing forces … those that build and those that destroy.

Plate encounters, attended by mountain-building and by rock-producing volcanism, perpetually renew Earth's surface. But it is water and air, powered by the sun's heat, that wear down mountains, decompose rocks, and intricately sculpt the planet's surface.

Neither process has gained the dominance. They have attained a grand equilibrium that keeps Earth's surface hospitable to life.

The Surface Rocks...

"...have slowly yielded to the silent and unseen powers of the air, and crumbled into dust, and been washed away by the rains, and carried into the seas by the rivers." - Major John Wesley Powell, Geologist

This observation, written in 1875, eloquently describes the work of weathering and erosion in fashioning America's most awesome natural wonder, the Grand Canyon.

Weathering and erosion encompass all the processes that decompose, disintegrate, and transport surface rocks. Weathering causes the breakdown of rocks. The fragmented or dissolved materials are then transported by landslides, rockfalls, water, wind, and glaciers.

The background of this window represents the Grand Canyon, which was formed through the process of erosion. Beginning 5-6 million years ago, water from the Colorado River eroded, or wore away, through layers of rock, slowly creating the natural wonder we see today.

Diplichnites

Wisconsin has sandstone like this throughout the state, which holds clues to its past. In MPM's Geology research collection, a 2,600-pound piece of sandstone discovered in Marathon County, WI shows footprints of an arthropod creature (related to modern-day insects, crustaceans, and spiders) that lived approximately 500 million years ago. Learn more here.

Weathering: An Assault on Earth's Surface

Chemical Weathering...

...weakens rocks by altering their minerals. The mineral feldspar partially dissolves after reacting with water, leaving a clay residue. When feldspar in a granite rock weathers into loosely adhering clay, the granite crumbles, because its strength, derived from interlocking mineral crystals, has been weakened.

Other minerals, such as calcite, dissolve completely during chemical weathering. Iron, reacting with water and oxygen, converts to rust.

Clays and soils, the salt content of oceans, and the minerals used by sea organisms to build shells and skeletons are products of the chemical weathering of the continents.

Physical Weathering...

...is the mechanical breakdown of rocks. An example is the breaking down of rock by water that seeps into cracks and crevices and then expands upon freezing, cracking, and splintering the rock. Salt crystals deposited by evaporating water achieve the same effect by growing in crevices and expanding until the rock shatters.

Erosion's Mighty Excavators and Landscapers

Rivers...

...are masterful erosive forces. Their turbulent currents excavate valleys by eroding channels and transporting dissolved or fragmented rock debris downstream. There, it is finally deposited, usually in lakes, seas, and oceans.

The smallest and lightest particles are carried in suspension. Larger sand particles move in an intermittent jumping action called saltation. They are lifted into the current, travel awhile, and then fall back to the bottom. The largest and heaviest particles are rolled and pushed in a process called traction.

A stream's erosive effectiveness is determined by the volume of water carried, the swiftness of its current, and the downhill slope of its channel.

Waves...

...catapulting sand and gravel against Earth's shores and coasts shape the margins of the continents. Their pounding power is enhanced by the weathering action of the sea water that they force into cracks of shoreline rocks. Thus, oceans, the reservoirs into which rivers empty their burdens of rock debris, are themselves competent but limited agents of erosion. Materials brought to them by rivers or taken by waves from the shorelines of the world are deposited as beaches or transported by currents to continental shelves and deeper regions of the ocean floors.

Glaciers...

...are creeping tongues of ice filling mountain valleys, or are thick continental-sized ice caps flowing out in all directions from high central areas. They form from the accumulation, burial, and compression of snow and moisture from the air. Snow gradually changes from loosely packed flakes to a more dense granular form, and finally into intergrown crystals of ice that form the glaciers.

Glaciers work like gigantic scrapers that pluck, grind, and tear rock materials, sometimes house-sized boulders, from the surface.

Wind...

...erodes most effectively where there is little water to bind particles together. As dust and silt are blown away, ground surfaces are gradually lowered, or deflated. Deflation can occur on plains and deserts and on dried-up floodplains and lake beds. Where deflation has removed the finer particles of rock, it leaves behind a pavement of pebbles too large for transport. Armed with sand, wind can shape rocks into distinctive forms called ventifacts.

Sedimentary Rocks...

The veneer of continents, the tombs of ancient life.

Where water currents and wind quiet, dust and sand settle. Where glaciers melt, mud plains and moraines are left behind. Wherever erosion is interrupted, sedimentation begins.

Sediments, the rock materials eroded from the continents, are usually deposited in layers. The most important accumulation sites are oceans, seas, lakes, river bottoms, and floodplains.

Solid rock particles or mineral grains are dumped directly by water, air, or ice. But dissolved minerals must be precipitated from water. The formation of rock salt or gypsum by evaporating seawater are examples of precipitation. Yet another process of rock formation is the extraction of minerals from sea water by organisms which use them to build shells or skeletons.

Sedimentary Rocks

When sediments are cemented and compacted, they become sedimentary rock.

Sandstone is a typical clastic sedimentary rock composed of rock fragments or mineral grains that have been cemented together.

Limestone is a typical non-clastic sedimentary rock: The lime, carried in solution, either precipitated directly from water or was first extracted by sea organisms and then secreted as hard body parts. Coal, formed of compacted plant remains, is another non-clastic rock.

Because any sediment may become rock, endless variety is possible. Only some of the most important sedimentary rocks are exhibited here.

A Gallery of Fossils

From bones in stone to carbon copies.

Because sedimentary rocks are surface materials and formed under less pressure and heat than other kinds of rock, the remains of organisms may be preserved in them.

Fossils are the preserved remains or traces of ancient life. Generally, preservation requires that the organism possess some hard body part. Teeth, bones, shells, and the leaves and woody parts of plants are most frequently fossilized.

Rapid burial in a sediment or other protective medium is essential, for it limits destruction by decay bacteria, scavengers, and weathering and erosion.

Fossilization… How Ancient Life is Preserved in Stone

Carbonization occurs when plants and animal remains, consisting largely of carbon-based materials, are deeply buried. The pressure and heat created by overlying rocks force the oxygen, hydrogen, and nitrogen out of the organism, leaving only a black carbon film or residue.

Permineralization occurs when porous cavities in hard body parts are filled with minerals gradually deposited by seeping groundwater. Vertebrate bones and invertebrate shells are often preserved in this way.

Replacement occurs when original substances are dissolved and replaced by mineral matter of a different sort. When wood is preserved in this way, the change is so gradual and delicate that cell walls and other microscopic structures may be preserved. But replacement may also result in the loss of all internal structures while preserving only the external form of the original object, as when a shell is replaced by quartz.

Molds form when sediments press around fossils and record the outside shape.

Casts result when fossils dissolve within molds, and the molds are then filled with new materials that record the details set in the molds.

Trace fossils (tracks, trails, burrows, and coprolites) are left by organisms as they move through the environment. From them, scientists can reconstruct what the organisms were like by looking at the things they did. Coprolites, the preserved excrement of ancient animals, offer evidence about anatomies and diets.

Preservation in amber happens when insects, spiders, and other delicate organisms are trapped in the sticky resin of conifer trees, which later hardens. The resin seals off the organism from air and water and forms a pressure-resistant case as it hardens. Some fossils preserved in amber are from

10 to 50 million years old.

How long is Geologic Time? A long, long time, indeed!

The history of Earth is measured in billions and millions of years, numbers far too large to be meaningful.

Here that history has been scaled down to a familiar unit of time -- the 30-day month. This Earth calendar allows you to appreciate when and how slowly or quickly events unfolded.

Each calendar day represents 150 million years.

- On what day did life first appear? (Day 4)
- On what day did complex cells develop? (Day 18)
- On what day did shelled animals become abundant? (Day 27)
- On what day did life colonize land? (Day 28)
- On what day did dinosaurs dominate? (Day 30)
- On what day did the earliest humankind beings appear? (Day 30)

The Precambrian Era

The birth of the third planet from a cloud of cosmic particles and the emergence of its continents, oceans, and earliest life happened 4.6 billion to 600 million years ago.

Earth, according to the most accepted scientific theory, condensed from a cloud of cold solid particles.

As it grew, the weight of the outer layers compressed the center. This gravitational energy together with energy from radioactive decay heated the interior, reducing the infant planet to a partially molten sphere. The heaviest matter sank to the center. Around this core à compact mantle of lighter materials formed. Floating rafts of basalt and granite crust finally encased the hot interior.

Earth's Oldest Rocks

This 3.8-billion-year-old rock was collected in southeastern Greenland from the Isua Formation, the oldest known body of rock on Earth.

On every continent, there are places called "shields."

Here, Precambrian rocks, billions of years old, are exposed at Earth's surface over broad low areas.

Most of the oldest rocks are granites which cooled near the surface when the infant Earth was much hotter than at present. This produced the early continental crust.

Precambrian land masses were shaped differently and occupied different positions. Scientists are still unravelling Precambrian patterns of shifting plates and drifting continents.

When did Earth acquire its oxygen-filled atmosphere? Some Precambrian rocks hold the answer.

In early Precambrian time, Earth's atmosphere contained no oxygen, although photosynthetic algae were releasing some oxygen into the seas. The sea water also carried vast quantities of dissolved iron, which readily combined with the oxygen to form iron oxides. This explains the marine origin of rich iron deposits in some Precambrian rocks.

Banded iron formations, consisting of alternating bands of fossil-bearing chert and iron oxides, occur only in the Precambrian and most are more than two billion years old. Earth's oxygen-rich atmosphere cannot be much older, because there was no free oxygen to accumulate in the atmosphere until all the ferrous or dissolved iron in the seas was oxidized.

The Earth didn't change to an oxygen atmosphere all at once. In fact, the amount of oxygen varied over time, and is evident in this banded iron formation. The conventional concept is that the reddish layers are made of iron and were formed in sea water as the result of oxygen released by primitive photosynthetic bacteria (blue-green algae). Iron combined with oxygen to form iron oxides, which formed a thin, red layer alternating with shale and chert. The alterations are thought to be due to cyclic or seasonal variations in available oxygen.

Not long ago, Precambrian life was thought to be scant and unimpressive.

But today, scientists are finding this life surprisingly rich and diverse.

Few Precambrian fossils are visible to the unaided eye. For billions of years, Earth's only lifeforms were one-celled aquatic organisms.

Fossils of the Gunflint Cherts: 2 billion years ago

The Gunflint Cherts of the Canadian Shield contain unusual and varied fossils, including unmistakable blue green algae, and bacteria together with organisms that have no modern parallels. Their variety is significant for it suggests a very early tendency toward increased diversity that intensified in the eras that followed.

The oceans and the atmosphere formed from searing gases escaping the young planet's hot interior.

This toxic atmosphere was composed mostly of water vapor, carbon dioxide, ammonia, and methane. As it cooled, the water vapor condensed into persistent rains that gradually flooded crustal depressions and formed the first seas.

Stromatolites: Massive fossils built by tiny life

Here, we have a trace fossil called stromatolite. It is evidence of one of the earliest forms of life on Earth – cyanobacteria. About 3.5 billion years ago, cyanobacteria developed the machinery to turn carbon dioxide and water into sugar using sunlight as an energy source. In the process, they released oxygen as a waste product, just like plants. Over time, this transformed the Earth into an oxygen-rich atmosphere, allowing for the emergence of complex lifeforms, including us.

Stromatolites formed when fine-grained sediments were trapped on the interwoven sticky surfaces of bacteria and blue-green algae. The algae grew around and upward through the sediments, incorporating them in layered structures. Some Precambrian stromatolites were 15 meters (50 feet) high and nine meters (30 feet) wide at their base.

The knobby surfaces of Gunflint Cherts represent the tops of stromatolites; the vertical cross sections show their layered structures.

The first multicellular animals lived some 700 million years ago...

...near the end of the Precambrian Era. They left a fine array of fossils in the Ediacara Hills of South Australia.

These first complex animals were all soft-bodied and aquatic. Some swam, others floated free, and still others crawled or were stationary on the bottom of the shallow sea.

Paleozoic Era

The Early Paleozoic Era

Barren continents, bountiful seas, 600 to 400 million years ago

When the Paleozoic Era dawned, large areas of the continents were low-lying, barren land masses repeatedly flooded by warm shallow seas that extended from the oceans. The continental seas swarmed with an amazing variety and abundance of life.

The fossils gathered here represent the first 200 million years of the Paleozoic Era -- the Cambrian, Ordovician, and Silurian Periods. Most of the inhabitants of the marine communities were invertebrates, many with hard shells or skeletons. But the fossil record also includes evidence of the first vertebrates, jawless fish represented today only by hagfish and lampreys, and the first primitive land plants, scorpions, and insects.

A Tropical Reef of Southeastern Wisconsin 410 Million Years Ago

By Silurian time, North America was positioned on the equator.

When shallow, tropical seas invaded the continent, extensive reefs grew in Wisconsin.

This reef, constructed by massive colonial corals, sponges, and bryozoans, was populated by animals that colonized specific zones. Stalked, flower-like animals, crinoids and blastoids, attached themselves to the reef surface. Thriving solitary corals, fan-shaped bryozoans, brachiopods, and trilobites were preyed upon by large predators like the cone-shaped nautiloids swimming above the reef.

Sponsor Edward U. Demmer Foundation

If you were in this exact spot 410 million years ago, you'd probably need some scuba gear!

There are surprisingly no plants in this window. While plants did exist during the Silurian period, they looked very little like any plant today and did not inhabit a reef like the one here. We'll learn more about them later in the exhibit. Learn about MPM's Silurian Reef collections here. You can explore the Silurian Sea in detail at the Virtual Silurian Reef site, which was made in partnership with Chicago's Field Museum.

Calymene Niagarensis-Triolobite

- Hawthorne, Illinois USA
- Collected by Thomase Greene-3 April 1909
- Trilobite is 20 mm long
- MPM collections No. (723
- MPM Locality No. 30039
- 3D Photogrammetry by Dr. Ralph L. Kugler
- 648 photographs used to make this model.

The Late Paleozoic Era

An emerging supercontinent, diversifications and extinctions in the seas, 400 to 225 million years ago

The Devonian, Mississippian, Pennsylvanian, and Permian periods span about 175 million years.

In the seas, the rapid evolution of predatory fish, particularly in the Devonian Period, bore enormous consequences for marine communities.

Mass extinctions of certain marine animals, especially invertebrates living in shallow continental seas and coastal areas, marked the era's end. The formation of the supercontinent Pangea contributed to these extinctions, for as landmasses merged, continental seas withdrew, and shallow water marine habitats diminished.

Successfully invading land, plants evolved and diversified into numerous habitats, accompanied by insects, snails, and amphibians. But as the era waned, reptiles were conquering the land.

Mesozoic Plants

Colonization of the Land

For billions of years, from the early stromatolites through each window you have already passed, life on Earth has been going through the process of evolution. Evolution is when organisms develop and diversify, eventually creating new species.

This window displays the evolution of plants on land. Although plants evolved after animals, they actually made it to land first. They began as small, leafless structures and eventually evolved into towering trees. Like the cyanobacteria, they would have a major impact on Earth's atmosphere.

Some animals, drawn to this new food source, eventually evolved to live on land, leading the way for the diversity of life above water. Learn more about the scientist who first theorized evolution, Charles Darwin.

Silurian seas were crowded with life, but the land was lifeless.

The uninhabited terrain offered new space in which to grow and multiply but exploitation of this region presented problems for sea life. The bodies of plants and animals adapted to a life under water required changes in order to colonize the land.

The fossil record suggests that there may have been a sudden flourishing of land plants toward the end of the Silurian Period. By the Devonian Period a wide variety of land plants existed, among them relatives of the clubmosses, horsetails, and ferns.

The earliest land plants were simple in form, consisting essentially of naked stems which lacked leaves, roots, and flowers.

Some Fine Points of Going Ashore

For the earliest land-colonizers, going ashore did not mean abandoning water; it meant developing water-conserving anatomies that allowed them to maintain wet environments within themselves.

To live out of water, plants and animals evolved water-conserving body coverings and developed plumbing systems for obtaining and transporting water. They also developed land-based methods of reproduction and ways to support their bodies without the buoyancy of water. And, animals evolved systems for extracting oxygen directly from air, and suitable appendages for moving about on land.

Eusthenopteron, an ancient lobe-finned fish of the Devonian period some 370 million years ago, had lungs and carried bones in its fleshy fins, making movement in shallow water possible.

Ichthyostega, the first recognized amphibian, lived in the late Devonian period some 375 million years ago. It possessed lungs and legs, indispensable adaptations for terrestrial vertebrates. Nevertheless, both Eusthenop teron and Ichthyostega were aquatic animals.

Seymouria... Was it an amphibian or a reptile?

Forms like Seymouria are hard to classify because they blend reptilian and amphibian characteristics. Seymouria lived during the Permian Period, some 280 million years ago. Most researchers place Seymouria within the reptiles and classify it as a cotylosaur, or "stem" reptile. Stem reptiles were the ancestors of all the later reptiles.

Carboniferous Coal Forests

345 to 280 million years ago

The Carboniferous includes the Mississippian and Pennsylvanian periods.

Primitive plants, the raw material for coal beds, were abundant and diverse in warm lowland swampy environments.

The plants were accompanied by numerous insects and vertebrates, including both amphibians and reptiles, while primitive fishes swam in the rivers and oceans.

The coal forests gradually disappeared in the later Pennsylvanian period. The formation of the great supercontinent Pangaea caused Earth's climate to become arid, drying up the coal forest swamps.

This case shows fossils from the Carboniferous period. Eventually, these rainforests began to fragment into smaller pieces and were devastated by the drying climate. This led to what is called the Carboniferous rainforest collapse (CRC), a mass-extinction event involving the lycopods. Microscopic analysis suggests that lycophytes make up 70% of the organic matter that formed Carboniferous coal. Coal miners have found the outlines of these trees in their mines.

A Primeval Forest of Northern Illinois, 310 million years ago

In the Carboniferous time, dense tropical forests were concentrated along the equator. Decaying vegetation, compressed by overlying deposits of sand and mud, was gradually converted into coal. Coal deposits of Illinois, the Appalachians, Wales, England, and Germany were originally found in a continuous band which was dispersed when the continents drifted apart.

Curious plants and animals, now long extinct, were found in these forests: giant tree-sized plants with distinctive leaf scar impressions on their trunks; horsetail-like plants with jointed stems; and tree ferns provided cover for an active animal community. Insects and fish attracted predatory reptiles and amphibians such as the alligator-sized Anthracosaurus. Some insects were giants. The wingspan of Meganeura, a dragonfly-like creature, reached 30 inches.

During the Carboniferous period, oxygen in the atmosphere rose to as high as 35%, compared to 20% today. This contributed to a period of insect and amphibian gigantism, whose sizes are constrained by their ability to diffuse oxygen.

In the Early Carboniferous period, approximately 350 million years ago, the climate was uniform, tropical, and humid. The great tropical rainforests were dominated by the towering lycopsids. These huge trees had trunks 100 feet high and more than four feet across.

Stegosaurus

Most geologists believe dinosaurs did live in what is now Wisconsin, but unfortunately there is no evidence. In fact, that entire layer of our state's history is missing. During this time period, Wisconsin was probably above sea level, and little was preserved in the rock record. In addition, whatever might have been deposited was ultimately lost due to erosion.

Although popular media tend to show a wide variety of dinosaur species living together, "the age of the dinosaurs" actually spanned 135 million years, which included many extinctions. In fact, *Tyrannosaurus rex*, which we'll see in the next exhibit, lived closer in geologic history to humans (which existed 65 million years apart) than it did to this *Stegosaurus* (which existed 80 million years prior to the *T. rex*).

The Mammal-Like Reptiles of Pangaea

Some 250 million years ago, all the continents except China were welded together into the supercontinent Pangaea.

In North America, the equator passed through a wet tropical region that is now the American Southwest. During the Permian period, the tropics supported flourishing communities of large amphibians and the earliest mammal-like reptiles, the pelycosaurs. Later, during the early part of the Triassic period, more advanced mammal-like reptiles, the therapsids, dominated cool environments of southern Africa.

In general appearances, the mammal-like reptiles had not departed far from their "stem" reptile ancestors.

The earliest mammal-like reptiles of the Permian period were cold-blooded.

Confined to the tropical northern realm of Pangaea, they relied on external heat to raise their body temperatures above the air temperature.

Finback reptiles like Dimetrodon and Edaphosaurus may have routinely basked in the sun. Their enormous "fins," supported by long spines on the vertebrae, probably helped regulate their body temperatures by absorbing and dissipating the sun's heat.

The bulky body, small head, and battery of blunt teeth suggest that Edaphosaurus was an herbivore, well-suited to grinding up leaves of seed ferns and other vegetation. The stabbing and shearing teeth of Dimetrodon establish it as an effective carnivore.

Another carnivorous early mammal-like reptile was Sphenacodon.

Later mammal-like reptiles of the Triassic period lived in colder climates.

They probably were able to generate some body heat internally and were insulated by hair.

Mammals descended from carnivorous mammal-like reptiles, such as South African Cynognathus. Other Triassic mammal-like reptiles were herbivores and grew to considerable size.

The Mesozoic Era

The breakup of the late Paleozoic world...

A flowering of plants... and a radiation of reptiles until the great dying, 225 to 65 million years ago.

Reptiles dominated the Mesozoic world. By the Jurassic and Cretaceous periods, they had invaded almost every habitat Earth had to offer.

Giant dinosaurs and their smaller kin dominated the land, while gliding reptiles, some sparrow-sized and some with wingspans of up to 50 feet, rode on offshore air currents in search of surfacing fish. Some reptiles (ichthyosaurs, plesiosaurs, and mosasaurs) moved into open oceans and evolved fish-eating ways of life.

And of the commonplace reptiles (commonplace only because they survived the trials of time and change, and are with us still), there were the crocodiles, tortoises and turtles, and lizards and snakes in that ancient world.

Coelophysis

Coelophysis was one of the earliest saurischian dinosaurs. It was a cannibal, and the remains of a young Coelophysis are in the stomach region. This is a reproduction of a fossil collected in New Mexico.

From Little Thecodonts, Mighty Dinosaurs Evolved.

A diverse group of small Triassic reptiles, the thecodonts, gave rise to the first dinosaurs and gradually displaced the mammal-like reptiles.

Some particularly agile, fine-boned thecodonts achieved a two-legged stance that permitted them to maneuver with a swift, ostrich-like running gait. While hind legs increased in length and power, the front legs became shorter and weaker, and a large mouth with pointed teeth developed for grasping prey. These thecodonts were the forerunners of the two great orders of dinosaurs, of gliding reptiles, of crocodiles, and of birds, surviving descendants of dinosaurs.

The Hip-Bone Connection

A handy key to identifying the two orders of dinosaurs:

The pelvis of both the lizard-hipped (saurischian) and bird-hipped (ornithischian) dinosaurs were composed of three bones. Above the hip joint, the ilium attached the pelvis to the backbone. Below this joint, in the saurischian, the pubis was in front, and the ischium faced back. Some dinosaurs of this order were gigantic two-footed meat-eaters like *Allosaurus*. Others were four-footed plant-eaters, some of which, like *Brachiosaurus*, were among the largest animals ever to have lived on land.

The bird-hipped or ornithischian dinosaurs were virtually all plant-eaters. In their pelvis, the pubis was parallel to the ischium. An additional bony appendage from the pubis supported the dinosaur's belly muscles. Many ornithischian dinosaurs were four-footed with hind legs conspicuously larger than front legs, as in *Stegosaurus*.This characteristic presumably was retained from their ancestors, most of which walked erect on powerful hind legs.

Stegosaurus

Name: Stegosaurus (Plated Lizard)
When it lived: Late Jurassic (135 million years ago)
Where it lived : Western United States
What it weighted: 7,000 kilograms (15,000 pounds)
What it ate: Plants

Interesting facts: The purpose of the large, bony plates running down its back is uncertain. It is possible that the animal raised and lowered them at will.

A. Perhaps raised plates discouraged attackers.
B. Perhaps lowered plates protected its sides.
C. Perhaps plates acted like a radiator, helping the animal control its body temperature.

Stegosaurus was the most under-brained of the land animals. Its brain weighed 2.4 ounces, about the size of a walnut. Its hindquarters were controlled by a bulbous enlargement of the spinal cord, once thought by scientists to be a “second brain.”

Sponsor: Northwestern Mutual Life Insurance Company

The Triassic Period

Land and sea patterns 225 to 190 million years ago

At the beginning of the Triassic period, all the continents of Earth still formed one supercontinent. Laurasia, the northern realm, consisted of modern North America and Eurasia; Gondwanaland, the southern realm, eventually split up into modern South America, Africa, Australia, Antarctica, and the Indian Peninsula.

Similar types of Triassic reptile fossils are found in regions that are now separate continents. The long-established amphibians and reptiles of earlier times dominated until they were displaced by vigorous newcomers that rose from their ranks.

In addition, the oldest known mammals are from the late Triassic.

Some Triassic landscapes were graced by luxuriant forests on floodplains and in coastal areas.

Giant conifers dominated early Mesozoic forests, while new groups of plants with pineapple-like trunks, the cycads, joined the long-established tree ferns as middle story plants. All of these plants were part of the gymnosperm (naked seed) flora which dominated during most of the Mesozoic Era.

In the Petrified Forest National Park of Arizona, Triassic deposits have yielded fossils of primitive araucarian pines that attained heights of over 200 feet. Today, these conifers are restricted to small areas in the southern continent and India. The araucarian pines shaded the lower-growing tree ferns, cycads and "true" ferns, which served as ground cover.

The Jurassic Period

Land and sea patterns 190 to 130 million years ago

In the Jurassic period, plate movements continued breaking the old supercontinent apart. Its northern and southern realms became partly separated. Nevertheless, the similarity between North American and East African dinosaurs is strong evidence that the two continents were still united.

Tropical seas advanced once again over the lowered continents, bringing with them abundant marine life. The spreading seas brought milder climates to most of the world -- warm, moist climates that suited terrestrial plants and reptiles. Both increased in variety and abundance, extending their domains as far north as modern Alaska and Siberia. The giants among dinosaurs lived in Jurassic time.

Cephalopods, such as the ammonites here, were aggressive predators in Mesozoic seas. They

ranged from one inch to seven feet in diameter.

By the end of the Mesozoic, when ammonite populations began to decline, some remarkable types evolved, including some partially uncoiled forms. The Late Cretaceous demise of ammonites paralleled that of the great marine reptiles and the dinosaurs.

The Cretaceous Period

Land and sea patterns 130 to 65 million years ago

During the Cretaceous period, the Atlantic Ocean widened and the southern realm of the supercontinent separated into South America, Africa, Australia-Antarctica, and India.

Shallow seas, bisecting North America and Eurasia from north to south, created two isolated landmasses -- a western landmass, consisting of western North America and Asia, and an eastern landmass, consisting of eastern North America and Europe. Dinosaurs evolving in the North American west did not spread to Europe where "old-fashioned" types persisted.

Coccoliths: The cliff builders

Coccoliths are delicate, microscopic marine organisms and an important source of food for larger organisms in modern oceans. In the warm seas of the Cretaceous period, their populations increased greatly, and their skeletons collected in tremendous numbers on the ocean floors, giving rise to the great chalk beds for which the period is named. The Latin word "creta" means chalk. There are many Cretaceous chalk formations, but none so famous as the White Cliffs of Dover, England.

The Great Dinosaur Debate

What Were the Real Dinosaurs?

Dim-witted, plodding, cold-blooded curiosities, or successful, active, warm blooded animals still living among us as birds -- or something in between?

Many scientists are comparing the physical structure, behavior, and distribution of modern reptiles and mammals with that of dinosaurs.

This research has convinced some that dinosaurs were a unique group of warm-blooded animals, even insulated with fur and feathers in some instances, and that they require special classification in the Animal Kingdom apart from the reptiles. Some of their arguments are summarized here.

Evidence suggesting that dinosaurs had heat-retaining insulation...

...comes from Archaeopteryx, a Late Jurassic fossil clearly showing feathers. Archaeopteryx, classified as the earliest bird, was closely related to small carnivorous dinosaurs. Its shoulder joints, identical with those of carnivorous dinosaurs, indicate that its forearms were possibly adapted for grasping prey, not for wing-flapping movements. Also, it lacked well-developed wing muscles. Thus, Archaeopteryx was apparently a glider rather than an active flyer like most modern birds. Many scientists are convinced that its immediate ancestor was a small carnivorous dinosaur, and some scientists even think that ancestor was feathered.

Among populations of present-day mammals...

...only about five percent are predators, while almost half of the living reptiles are predators. The predator-prey ratio among dinosaurs is much closer to that of modern warm-blooded mammals than that of modern cold-blooded reptiles. In other words, plant-eating dinosaurs far outnumbered the meat-eaters, just as plant-eating mammals far outnumber meat-eating mammals today.

The legs of dinosaurs...

...were situated under the body, so that the animal was positioned over them in mammal fashion, rather than slung between them in the typical sprawl of reptiles. Some scientists point out that erect stance, and the sustained locomotion it allows, are not possible without a consistent flow of energy from an internal "warm-blooded" system.

In warm-blooded mammals and birds...

...blood vessels within the limb bones are numerous and densely packed. But in the bones of the more passive, cold-blooded reptiles, they are sparse. Likewise, the Haversian Canals, those sites which supervise the exchange of calcium between the blood and skeleton, are more numerous in mammal bones than reptile bones. In these internal bone structures, dinosaurs are more similar to mammals than to reptiles.

This is a replica of the Archaeopteryx fossil, believed to be one of the first birds.

Did you know that birds are dinosaurs? Dinosaurs did not “turn into” birds, but rather birds evolved from avian dinosaurs. To think of it another way, compare an extinct mammal, such as a mammoth, and a living mammal, such as an elephant. Both are mammals and look similar, but they are very different and lived at different times. Mammoths, even though extinct, did not turn into elephants, even though both are mammals. Likewise, birds and dinosaurs evolved from the same group.

Hell Creek

This exhibit shows a variety of herbivores (plant-eaters) and carnivores (meat-eaters). Download the Herbivore and Carnivore Printable Game to help you identify which is which.

Hell Creek of Eastern Montana

66 million years ago

In this lifesize recreation of a lowland forest floodplain, *Tyrannosaurus* feeds upon a dead three-horned *Triceratops*. The *Dromaeosaurus* dinosaurs wait patiently nearby to scavenge their share, while the speedy ostrich-like dinosaur, *Struthiomimus*, watches from a sand island in the stream. The scene is early spring, with occasional sunshine breaking through dark thunderclouds. In the distance, mournful cries of loon-like birds are accompanied by the racket of insects.

For more information about this *Hell Creek* habitat, see the exhibits directly behind you.

The Dinosaurs

Tyrannosaurus rex, "King Tyrant Lizard"

The largest land-dwelling predator of all time, *Tyrannosaurus* depended on its powerful hind legs and massive jaws to kill and devour prey. Its forelegs appeared too small for weapons, too short to bring food to its mouth. The purpose they served is still unknown.

Dromaeosaurus, "Swift Lizard"

Both scavengers and speedy predators that may have hunted in packs, *Dromaeosurus* had an inner toe equipped with a three-inch, razor-like talon probably used to rip open the stomachs of prey. Recent evidence suggests these and other theropods had fathers, much like their living bird relatives. Compare both models based on earlier versus recent scientific discoveries.

While there is strong evidence for many species of dinosaurs having feathers, it does not mean that every dinosaur had them. Scientists are still uncovering clues about the evolution of dinosaurs and birds and are making incredible discoveries every year. Watch our *Dromaeosaurus* video here.

Triceratops, "Three-horned Face"

This ponderous plant-eater lived in herds and had three sharp horns adapted for defending against predators. *Triceratops* was one of the most numerous of the dinosaurs during this time period.

The *Triceratops* is one of many species of ceratopsians. To learn more about ceratopsians, visit the Torosaur at the beginning of the *Third Planet* gallery.

Struthiomimus, "Ostrich Mimic"

One of the fastest creatures that ever lived, this bird-like dinosaur had a small head and horny beak. *Struthiomimus* may have eaten both plants and animals, using its claws to pluck fruit and leaves from trees, and to dig for eggs in the sand.

Pachycephalosaur Skull

This specimen was recovered in 1985 as part of a former MPM citizen science program called Dig-A-Dino. This program was focused on dinosaur abundance and diversity at the end of the Cretaceous period, with a particular focus on the Hell Creek Formation. The specimen here, VP 7111, is assigned as Stygimoloch spinifer and is one of two pachycephalus skulls housed within our collections. Both of these specimens have been studied to understand the anatomy and physiology of these dome-skulled dinosaurs. Studying these specimens, paleontologists have refined their understanding of the behaviors from these dinosaurs, and that their skulls were most likely used for display behaviors (think brightly colored feathers of birds) rather than for headbutting and territorial behaviors.

3D Photogrammetry by Dr. Ralph L. Kugler

More than just Dinosaurs

The ancient ecology of the Hell Creek Formation

The great dinosaurs of the Late Cretaceous shared their environment with numerous species of animals and plants. All these organisms were parts of biological communities. Each community was related to a major part of the environment; similar communities are present in the modern world.

The animals and plants of the Late Cretaceous Hell Creek Formation lived under subtropical conditions. There were slowly moving rivers with low banks and broad floodplains between the rivers. The coast of the shallow midcontinental sea was less than 160 km (100 miles) away to the east, and the low Rocky Mountains were rising the same distance to the west. Cenozoic uplift of all the western part of North America elevated the Hell Creek country and began the cycle of erosion which has revealed its fossils.

The Stream Community

Numerous fishes, including primitive bowfins and garpike, swam in the Hell Creek Rivers. Aquatic turtles (trionychids), advanced bony fishes, and larval insects also moved through the lotus and scouring rushes in shallow water

The Stream-Bank Community

Along the banks lived those animals, like the amphibians, which required much water as well as pond turtles, alligators, crocodiles, and champosaurs, and probably some mammals that fed on fish. It is likely that small carnivorous dinosaurs also used this food source and that herbivorous dinosaurs and mammals fed on the soft stream-bank vegetation which included small herbaceous plants and young shoots of willow and sycamore.

The Flood-Plain Community

Here in the expanse of open forest ranged the terrestrial dinosaurs as well as a diversity of snakes and lizards, birds, and the various mammals. Some mammals, such as the multituberculates, were largely tree-dwellers; others, including the condylarths and some insectivores, moved about on the forest floor.

The forest vegetation was dominated by dawn redwood *(Metasequoia glyptostroboides*) trees which were smaller understory trees such as the katsura tree (*Cercidiphyllum japonicum*) and ginkgo (*Ginkgo biloba*). Willows and sycamores could be found on the less permanent land near the stream.

Groundcover included small ferns, pachysandra, sphagnum moss, and small fan palms.

Tyrannosaurus rex (reproduction) Hell Creek, Montana

Tyrannosaurus rex was the largest, most-ferocious land-dwelling animal and the most-advanced of the carnivorous reptilian types. The powerful jaws and teeth were highly specialized for flesh-eating. This cast was made from one of the rarest and most highly prized fossils, found in 1908 by Barnum Brown of the American Museum of Natural History.

Recreating the Past

Want to know how MPM scientists remove fossils from the ground for research? Click on this video to learn all about what's in a Paleontologist's Toolkit.

What's the evidence for our dinosaur scene?

Our large dinosaur diorama portrays a particular place (eastern Montana) at a particular geologic instant (Late Cretaceous period, about 66 million years ago).

We know that the combination of plants and animals is authentic because of documentation provided by several Milwaukee Public Museum expeditions to eastern Montana.

The rocks which produced the fossils are called the Hell Creek Formation. Composed mostly of sandstone and shale, the Hell Creek Formation was laid down by meandering rivers which periodically flooded. During the floods, large amounts of debris were carried down from the mountainous areas upstream to the west. As the flood waters lost their strength, sediments were deposited, covering bones and skeletons which had been lying on the floodplain, plus those carried along by the flood waters.

Fossil-Collecting

Fossil collectors now search the eroding remnants of the rivers and floodplains, seeking fragments of ancient animals and plants. Mineralized bone and wood is usually harder than the surrounding sedimentary rock, so it is left behind as the rock weathers away.

Most often, only small fragments of fossils are found. But occasionally a complete bone or tooth, or even more rarely, a skeleton, is found. The more complete fossils are valuable because of the amount of information they provide about life of the past. They are collected by carefully enclosing them in protective plaster coverings.

Very small fossils are collected by underwater sieving. Fossil-rich rock is gathered in large quantities and placed in boxes with screen bottoms. When allowed to soak in water, the rock disintegrates, smaller particles pass through the screen, and a gravel containing small fossils remains on the screen. This gravel is sorted underneath a low-power microscope, and a collection of tiny teeth, bones and fish scales results.

Scientific Data

Detailed data is kept as specimens are excavated. This helps with reconstruction in the Museum laboratory and allows the fossil to be studied in conjunction with other specimens from other localities.

Preparation and restoration of the specimen is done under carefully controlled laboratory conditions. In this way, damaged and delicate materials are readied for scientific study and exhibit.

And Then There Were None

Within a few million years, at the end of the Cretaceous period, the dinosaurs disappeared after dominating Earth for 160 million years.

The gliding reptiles, the great marine reptiles, and the ubiquitous ammonites (almost all marine and terrestrial animals of any size) also became extinct.

Why did this great extinction occur?

Many extinction theories have been proposed and are modified as new data become available. For instance, the once-attractive egg-eating mammal theory has been virtually abandoned. The asteroid theory, on the other hand, now receives much support. But scientists are still unsure which, if any, of the theories is correct, and continue to search for answers.

Some theories explaining this massive, relatively rapid extinction are Earth-centered, based on competition between mammals and reptiles and/or climatic changes resulting from continental movements. Other theories are extraterrestrially based and suggest that supernovae, comets, or asteroids may have affected Earth's surface and its inhabitants.

Perhaps small mammals with insatiable appetites...

...halted dinosaur evolution by eating their eggs.

Perhaps eggs of Late Cretaceous dinosaurs lost their viability...

...that is, they failed to hatch. Clutches of unhatched eggs have been found in deposits in southern France.

Perhaps a reversal in the Earth's magnetic field....

...a recurring phenomenon throughout Earth's history, caused a temporary breach in the ozone shield that protects life from harmful cosmic rays. The radiation leak killed large land and marine animals, including the mosasaurs.

Perhaps a chemical imbalance in the oceans...

...the result of an overflow of fresh water or brine from landlocked seas, killed some vital species of plankton. Since these tiny organisms at the base of the foodchain provided food for predators like the ammonites, their decline set off a disastrous chain reaction throughout marine communities.

Perhaps intense volcanic activity, associated with plate movement...

...filled the air with ash, preventing sunlight from reaching the Earth's surface, and suffocating animals, or belched out so much carbon dioxide that it created a "greenhouse effect," trapping heat in the atmosphere and causing fatal temperature increases.

Perhaps it was a "normal" event...

...because over the course of geologic time, all species gradually disappear. Natural selection, competition, and nonspecific chance events are likely causes for extinction.

Perhaps the impact of a small asteroid...

...eight to 16 kilometers (five to 10 miles) in diameter, hurled dust and debris into the stratosphere, blocking out sunlight for months or even years. The long interval of darkness halted plant growth, killing off the large grazing dinosaurs and then the meat-eaters that preyed upon them.

Perhaps a meteorite…

...striking the moon threw out debris which became caught in the Earth’s gravitational field and formed a ring around the Earth. Its shadow altered the climate enough to cause extinction.

Throughout this exhibit’s timeline, millions of species have evolved and gone extinct due to changes in resources, landscape, and climate. The Mesozoic Era came to an abrupt end 66 million years ago and with it the extinction of many animals and plants on land and sea. Non-avian dinosaurs also disappeared from the fossil record after this time. Today, there is agreement that the primary cause of this extinction event was the asteroid that struck Earth and set off a series of catastrophic events.

Evidence of this asteroid is found in stones that have a white band, known as the KT Boundary. Below this band, dinosaur fossils are found; above it, no dinosaur fossils are found. MPM has a wonderful example of this in our collections. You can see a recreation of this boundary in our *Exploring Life on Earth* exhibit.

Who Survived the Great Extinction

To inherit an underpopulated earth?

A rather unimpressive gathering of mammals, birds, and smaller reptiles survived the great extinction to inherit a new age and dominance of the Earth.

While the dinosaurs and many of the larger reptiles were disappearing from the scene, the tiny mammals were becoming more diverse. Both of major modern mammals -- marsupials (pouched mammals) and placentals (higher mammals) -- increased in numbers and diversity through the Late Cretaceous extinction.

Although their fossil record is not nearly as complete as that of the mammals, the birds also diversified during the extinction. Included in this radiation were modern types such as loops, avocets, flamingoes, and sandpipers.

Smaller reptiles, especially snakes and lizards, flourished while their large cousins became extinct.

The elimination of the dinosaurs and many of the larger reptiles apparently left important ecological boids. Within a few million years after the extinction, mammals radiated very rapidly to fill many of these openings. Mammals increased in size, though no terrestrial mammal ever became as immense as the large dinosaurs.

The Bird Pedigree

The oldest known bird, *Archaeopteryx*, lived in the middle of the Jurassic Period, some 140 million years ago.

It is classified as a bird because it possessed feathers , but skeletally it was virtually identical to the small carnivorous dinosaurs. It provides excellent evidence of the evolution of birds from a reptilian ancestry.

Birds fossilize poorly, both because they do not tend to live in areas where sediments are rapidly deposited and because their thin, light bones, so well adapted to flight, are readily destroyed. Thus, the fossil record of birds is not nearly as complete as that of land-dwelling vertebrates.

During the Cretaceous period, a number of specialized marine birds developed, some of which possessed teeth and, like modern penguins, could not fly. By the end of the Cretaceous period, at the time of the extinction of the dinosaurs, essentially modern birds were present.

The Mammal Pedigree

The first vertebrates to be classified as mammals lived during the Triassic period and were very similar to their mammal-like reptile ancestors.

Like advanced mammal-like reptiles, they were warm-blooded, but are considered mammals primarily because of the structure of their ear and jaw bones. Nonetheless, these mouse-sized creatures might still have laid eggs.

By Middle Mesozoic time, at the height of dinosaur diversity, several distinct groups of mammals had evolved. The largest were only the size of house cats. and most were much smaller than that. All the Jurassic types except one ultimately became extinct. though the modern Australian egg-laying platypus and spiny anteater may be descended from them.

In the Cretaceous period, small shrew-like mammals gave rise to nearly all the modern types. Two separate lines evolved from them: the marsupials and the placentals.

The Lowland Forest Floodplain

A home for more than dinosaurs

In this lifesize recreation of a lowland forest 66 million years ago, the vegetation is dominated by dawn redwood trees, with smaller trees such as the katsura and gingko occupying the understory. Sycamores and willows are found on the less permanent land near the rivers. Beneath the understory trees are small fan palms and tree ferns which overshadow a ground cover of sphagnum moss, pachysandra, and small ferns.

A great diversity of animals lived alongside the dinosaurs: insects, lizards, birds, and small mammals. Within the next million years, the dinosaurs would disappear forever, victims of a great extinction. Yet many of the plants and small animals survived. For more information about this extinction and its survivors, see the exhibits directly behind you.

The Cenozoic Era

A golden age of mammals and mountain building, a breath of cold and a time of ice, 65 million years ago to present

In this era, the last 65 million years, the continents arrived in their present locations and assumed their familiar shapes as seas withdrew from their margins. Restless plates collided, raising the Rockies, Cascades, Andes, Alps, and Himalayas.

A geologic instant ago, glaciers advanced southward over partos the northern continents.

Mammals diversified in this changing world, filling ecological spaces abandoned by the extinct reptile. Movements and dispersal of terrestrial and marine life were affected by the physical changes of Earth's surface.

About 50 million years ago, Europe and North America were still in contact across the north Atlantic. An island continent, India, was about to join Asia and close the Tethys Sea. Antarctica and Australia were separating, and South America was another island continent. Seas separated Africa from Europe.

Repopulating the Earth

The Paleocene Epoch, 65 to 53 million years ago

During the Paleocene Epoch, mammals diversified and took over many ecological niches emptied during the Late Cretaceous extinction. Paleocene mammals were generally small in size, and it was not until the end of the epoch that pony-sized creatures appeared. Paleocene animals are best known from the northern hemisphere (Asia, North America, and Europe), but clearly distinctive South American forms already existed, and marsupial colonists had probably arrived in Australia and Antarctica.

Many species of flowering plants were not affected by the Late Cretaceous extinction and provided the setting for the Cenozoic mammal radiation with a spectacular array of trees, vines, shrubs, and ground cover.

Mammals Mature

The Eocene Epoch, 53 to 37 million years ago

With the continental plates in this fragmented condition, many distinctive suites of organisms evolved. The northern continents saw the appearance of some modern mammal groups (horses, rabbits, bats, camels, and lemuroid primates) and the rise and disappearance of archaic types. The oldest known whales, sea cows, and proboscideans are found along the shores of ancient Tethys in Egypt and south Asia. Isolated in South America were primitive sloths and specialized hoofed mammals.

The later Eocene Epoch saw the odd-towed ungulates, including horses and rhinoceroses, gradually outnumbered by the even-toed ungulates, including deer, camels, and pigs, as the dominant browsing mammals.

The Green River Basin

In a vast, shallow freshwater lake in western Wyoming, thousands of meters of thinly bedded shale accumulated. The shale preserved, in remarkable detail, aquatic and near shore life of the Eocene.

While the Green River Formation accumulated in the lake, stream and floodplain sediments called the Bridger Formation were deposited along the shores. Here is preserved the diverse land life of the middle Eocene.

Giants in the Earth Again

The Oligocene Epoch, 37 to 24 million years ago

The Oligocene Epoch was a time of transition in the northern continents. Archaic mammals of the Early Cenozoic gradually disappeared and more progressive forms took over. Perhaps the competition for ecological niches had grown so immense that only the most efficient mammal types persisted. In any event, the extinction of mammalian families outpaced the origin of new ones for the first time in the Cenozoic Era.

The Brule Plain

The younger sediments of the Brule plain contain a vast array of fossils, but the giant titanotheres were gone.

Brule mammals included giant piglike entelodonts, small camels, three-toed horses, a variety of carnivores, such as early saber-toothed cats, and large swamp-dwelling rhinos as well as smaller, swift-running diat lived on dry uplands.

But the most conspicuous mammals were the oreodonts. Oreodonts were cud-chewing ruminants distantly related to camels, even though their exteriors were somewhat piglike with long bodies and short legs.

The White River Badlands

Fossils of early mammals of North America are entombed in beds of sedimentary rock that form vast badlands over parts of the Dakotas, Nebraska, Colorado, and Wyoming. The fossil beds, called the White River Group, are divided into two formations: the lower, older beds are the Chadron; the upper, younger beds are the Brule.

Swift-Running Rhinoceros

Although it still had four toes on the front feet, *Trigonias* is one of the earliest representatives of the true rhinoceros. *Trigonias* had no horn and seldom exceeded three-and-one-half feet in height. It lived on the Brule Plain with oreodonts and many other grassing and browsing animals.

Grasslands and Grazers

A new environment exploited

The Rocky Mountains rose between 100 and 50 million years ago. This dramatic uplift altered the climate of central North America. The combination of marked seasonality and aridity produced an environment which favored the development of grasslands.

At the end of the Oligocene, the grassland environment expanded. The vast savannahs of the Great Plains developed into a major continental ecosystem. Mammals quickly exploited this opportunity. The appearance of large herbivores with high-crowned teeth and long legs can be related directly to the expansion of grasses.

High-crowned teeth allowed herbivorous mammals ao feed on abrasive grasses without suffering extensive tooth wear. Long legs were an obvious adaptation to rapid movement on treeless plains.

The Chadron Plain

The Chadron Plain was a hospitable environment. Ample waterways, fringed with groves of trees and shrubs, supported its largest inhabitants, the titanotheres. The giants among them, such as *Brontops*, commonly grew to a length of 4.5 meters (14 feet) and a height of 2.5 meters (eight feet) and weighed up to 10,0000 kilograms (22,000 pounds). With massive bodies, concave heads, the V- or Y-shaped bony protuberances on the nose, they resemble modern rhinos. They were browsers, pulling leaves from shrubs and trees with their lips.

The Golden Age of Mammals

The Miocene and Pliocene Epochs, 24 to 2.5 million years ago

During the Late Cenozoic, a grand cast of quite familiar mammals appeared. Immense herds of herbivores prospered, as did the carnivores that stalked them.

Although the various continents were periodically joined, some mammals could not, or did not, move far from their ancient lands. Thus, the mammal assemblages acquired distinct regional flavors. Apes, giraffes, hippos, pigs, cattle and assorted antelope were present in Eurasia and Africa. Certain horses and camels distinguished North America. Giant sloths, marsupial sabre-toothed carnivores, and specialized hoofed animals were in South America; many of these disappeared in the Pliocene when the Isthmus of Panamajoined South America to America and a torrent of placentals poured southward. The isolated marsupials (kangaroos, wallabies, koalas, and relatives) left an abundance of fossil remains in Australia.

Of the mammals that did move freely, the mastodons and horses were marvelous success stories Mastodons emigrated from Africa and ultimately traveled throughout Eurasia and North America and, briefly, into South America. Horses developed in North America and spread throughout the northern world and Africa in the Miocene.

The Grasslands of Western Nebraska

10 million years ago

The Great Plains hosted crowds of nearly modern animals reminiscent of the grand spectacle of wild game on African savannas today.

In Late Miocene times, streams meandering from the Rocky Mountains onto the Great Plains nourished trees and shrubs as well as grass. On these savannahs, grazing and browsing animals coexisted. Shovel-tusked mastodons, aquatic rhinoceroses, and pig-like oreodonts fed upon the soft, moist vegetation. Elaborately horned herbivores, such as Synthetoceras with a Y-shaped, fused pair of horns growing above its nostrils, and the sloth-like Moropus, remarkable for its clawed feet, roamed among herds of horses.

An Ice-Age Bestiary, 10,000 years ago

During the Pleistocene Ice Age, advancing glaciers brought cooler, humid climates. Grasslands were replaced by forests and as winter intensified, the forests shrank and the tundra replaced them. When glaciers retreated, the process was reversed. In those uncertain times, many animals, including those shown here, became extinct. What caused the extinction is still a puzzle. One theory suggests changes in climate and vegetation triggered a succession of extinctions. Another theory suggests that the creatures' demise may be linked to the arrival of human hunters.

Irish Elk *Megaloceros giganteus*

Common throughout Northern Europe during the Ice Age, *Megaloceros* had the largest antlers of any known deer. Up to 14 feet across and weighing as much as 72 pounds, these antlers were shed on a yearly basis. Its modern relatives, the red deer, have similar antlers but of more manageable size. The specimen is on loan from the Smithsonian Institution.

This item is on loan from The Smithsonian Institution, National Museum of Natural History, Department Paleobiology, USNM V7052. You can learn more about this specimen by clicking here.

Peccary (wild pig) *Platygonus compressus*

This skeleton, exhibited in the position in which it was found, is one of a herd of five peccaries discovered in 1967 in Kentucky. The crouching position of all five animals indicates that they died quietly and were buried rapidly, perhaps overwhelmed in a dust storm. The specimen is on loan from the Smithsonian Institution.

This item is on loan from The Smithsonian Institution, National Museum of Natural History, Department Paleobiology. USNM V26098. You can learn more about this specimen by clicking here.

Moa (flightless bird) *Dinornis giganteus*

Collected in the 1930s in New Zealand, this skeleton stands nine and a half feet tall. Moas belong to a group of flightless birds that includes the ostriches, and are the only birds to have lost all the bones of their wings. Moas flourished throughout the Ice Age and became extinct only 400 years ago. It is thought that human activity (both hunting and burning of forest habitats) led to the moas' demise.

Mastodon *Mammut americanum*

This skeleton of a young-adult, male mastodon was discovered in 1903 by a farmer draining a bog in Indiana. Mastodons are common fossils in peat bog deposits in the East. The last mastodons died about 10,00 years ago. Their closest living relatives are elephants.

Mammoth or Mastodon?

Mammoths and mastodons are two extinct species that once roamed Wisconsin. Although they look similar, they are actually part of two different families. Mammoths belong to the same family as modern-day elephants, whereas the mastodons were part of their own family that is now extinct.

How can you tell the difference?

Mastodons were smaller, with flatter heads. Mammoths had a rounder head as well as humps on their backs.

But the biggest difference between these animals is in their teeth and jaws. Mammoths and mastodons were both herbivores, but differences in diets required different teeth.

Mastodon jaws were longer with three molars on each side on both the top and bottom. Their teeth had cone-shaped cusps on their molars that allowed them to crush hard twigs and branches, which made up a large portion of their diet.

Mammoths were grazers and had flatter teeth that allowed them to grind coarse vegetation such as grass and shrubs. A fun fact about mammoth teeth: They would wear down and be replaced five times in a mammoth's life, which means they were born with six sets of teeth.

A mammoth fossil known as the Hebior Mammoth, found in Kenosha, WI, shows cut marks, confirming the existence of humans in Wisconsin as early as 14,500 years ago

Bison *Bison antiquus*

One of the many bison recovered from Interstate Bog in northwestern Wisconsin, this composite skeleton was assembled from the bones of more than one specimen. The modern bison evolved from *Bison antiquus*, which dominated the North American plains during the end of the Ice Age, about 7,000 years ago. After near extinction due to overhunting, modern bison are making a comeback.

Saber-toothed cat *Smilodon floridanus*

The specimen shown here is reproduction of one of 2,000 skeletons recovered from La Brea tar pits in southern California. These animals became trapped and later buried in pools of tar about 11,000 years ago. The saber-toothed cat's most striking feature is two dagger-like fangs, nine inches long, used to stab its victims.

The Glacier's Edge Wisconsin, 12,000 years ago

In Pleistocene time prolonged, heavy snowfall was compacted by its own weight into ice layers that built the continental glaciers. The weight of snow and ice caused the glacier's lower layers to move forward. The advancing ice sheets plucked up debris and pushed it along. In warmer periods when the glaciers retreated, meltwater released the finer debris as dust which was blown across the continents. The coarser debris was left behind as Ice-age land formations, which are typical in Wisconsin. The glaciers, more than a mile thick, covered 30% of Earth's surface, which sagged under the stupendous weight.

Sponsor: Patrick and Anna Cudahy Foundation, Inc.

Between 20,000 and 10,000 years ago, glaciers known as the Laurentide Ice Sheet moved across much of Wisconsin, changing the entire landscape. Scientists believe some glaciers may have been more than one mile thick and so heavy that the continental plates beneath them sagged under the mass/weight of the ice. When they melted and retreated back north, the Great Lakes were formed. Other features include landscape formations like moraines, drumlins, and kames. Wisconsin's bedrock is still to this day rebounding from the weight of the glaciers.

The Ice Chronicles of Earth

About one million years ago, in the Pleistocene Epoch, the first in a series of great continental glaciers flowed south over parts of the northern continents.

After many thousands of years, the glacier retreated, and the barren lands it left reverted to forests and grasslands. And then the ice came once again.

It is customary in North America and Europe to divide the Ice Age into four major glaciations, each of which is subdivided into lesser phases. Each major glaciation was followed by a warm interval or interglacial period. The advances and retreats of these glaciations are recorded on Earth's surface.

Glacial Movement

The abrasive debris carried by glaciers ground and polished the bedrock to remarkable smoothness, but sometimes it etched scratches or striations in the rock. The striations followed the directional flow of the ice and have been used to map the paths of specific glaciers.

Glacial Deposits

Evidence for a series of four major glaciations followed by interludes of warmer climates include multiple layers of "cold" and "warm" deposits in many areas of the northern continents.

The "cold" deposits are glacial till or unsorted materials ranging in size from boulders to flecks of clay. These cold deposits are separated by "warm" deposits or layers of deeply weathered soils, windblown dust or loess, and other sediments bearing fossils of plants and animals adapted to warmer climates.

Erratics

Like massive bulldozers, glaciers scraped up and transported rock hundreds of miles away to foreign localities. These are called glacial erratics and are typified by huge boulders deposited by glacial melting in some parts of North America.

Sometimes, distinctive and geologically rare objects were carried southward. In Wisconsin, erratics include fragments of native copper, some weighing many hundreds of pounds, and occasional diamonds. In the late 19th century, approximately 20 such diamonds were found in Wisconsin, but none have been discovered recently. The copper and diamonds probably originated in Ontario in Upper Michigan.

In the Ice-Age

Mammoths and mastodons browsed in Wisconsin forests, while seals and walrus splashed about in the Great Lakes.

An intensive phase of the Wisconsinan glaciation occurred from 22,000 to 12,500 years ago. During the warming that followed, forests moved northward. In the Two Creeks area of eastern Wisconsin, a forest of spruce, hemlock, and other trees typical of northern or boreal forests has been exposed along Lake Michigan.

Sturdy mammals moved north with the forests, including mammoth, bison, muskox, caribou, moose, giant beaver, and peccary. Along the shorelines of the Great Lakes, seal, whale, and walrus left evidence of their presence.

Some 12,000 years ago, the forest at Two Creeks died under the onslaught of the final surge of the Wisconsinan glaciation. Some of the wildlife remained near the ice margin, and those species that survived eventually migrated north to the tundra.

Landforms and Lakes

Made in Wisconsin by glaciers

Each of the four major continental glaciers in North America is named for the state in which its maximal development occurred.

They are, in order from the oldest to the youngest: the Nebraskan, Kansan, Illinoian, and Wisconsinan. As it retreated northward, the most recent glacier left deposits 50,000 to years old in Illinois, and up to 30,000 years old in Wisconsin.

Part of southwestern Wisconsin apparently was not covered during the most recent glacial advance. This, the "Driftless Area," remains poorly understood in the reconstruction of Wisconsin's geologic history. Glacial debris was applied to the land in a variety of forms under differing conditions. Nowhere are Ice-Age landforms more faithfully preserved than here in Wisconsin.