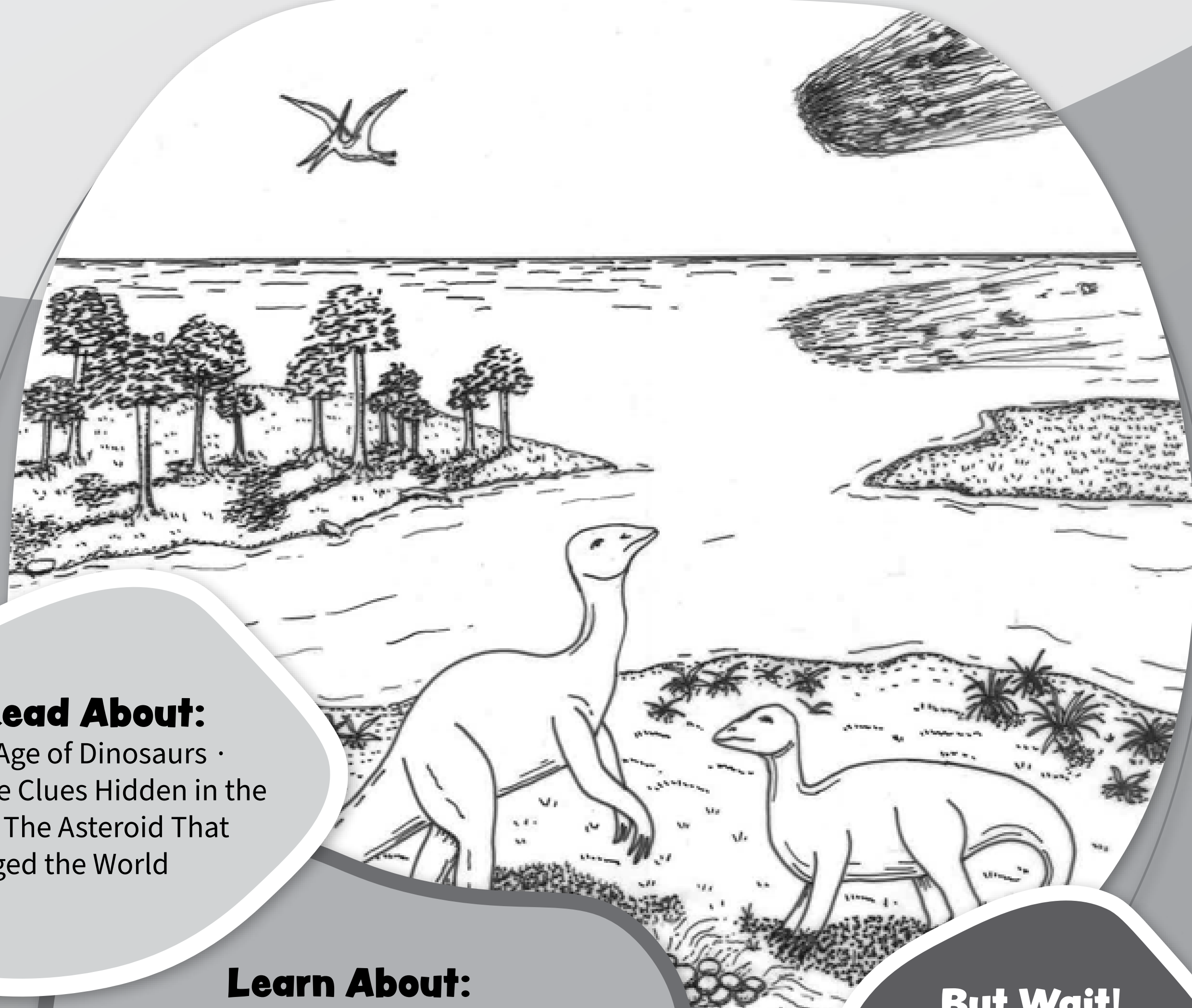
USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

FS-1224 | July 2023

LAST OF THE DINOSAURS

The Hell Creek Rocks of the Dakotas, Montana, and Wyoming



Read About:
The Age of Dinosaurs · Valuable Clues Hidden in the Rocks · The Asteroid That Changed the World

Learn About:
The Ocean That Once Split North America in Two · What Life Was Like When Dinosaurs Lived · What a Dinosaur Excavation Is Really Like

But Wait! There's More:
Puzzles · Coloring Pages · Activities

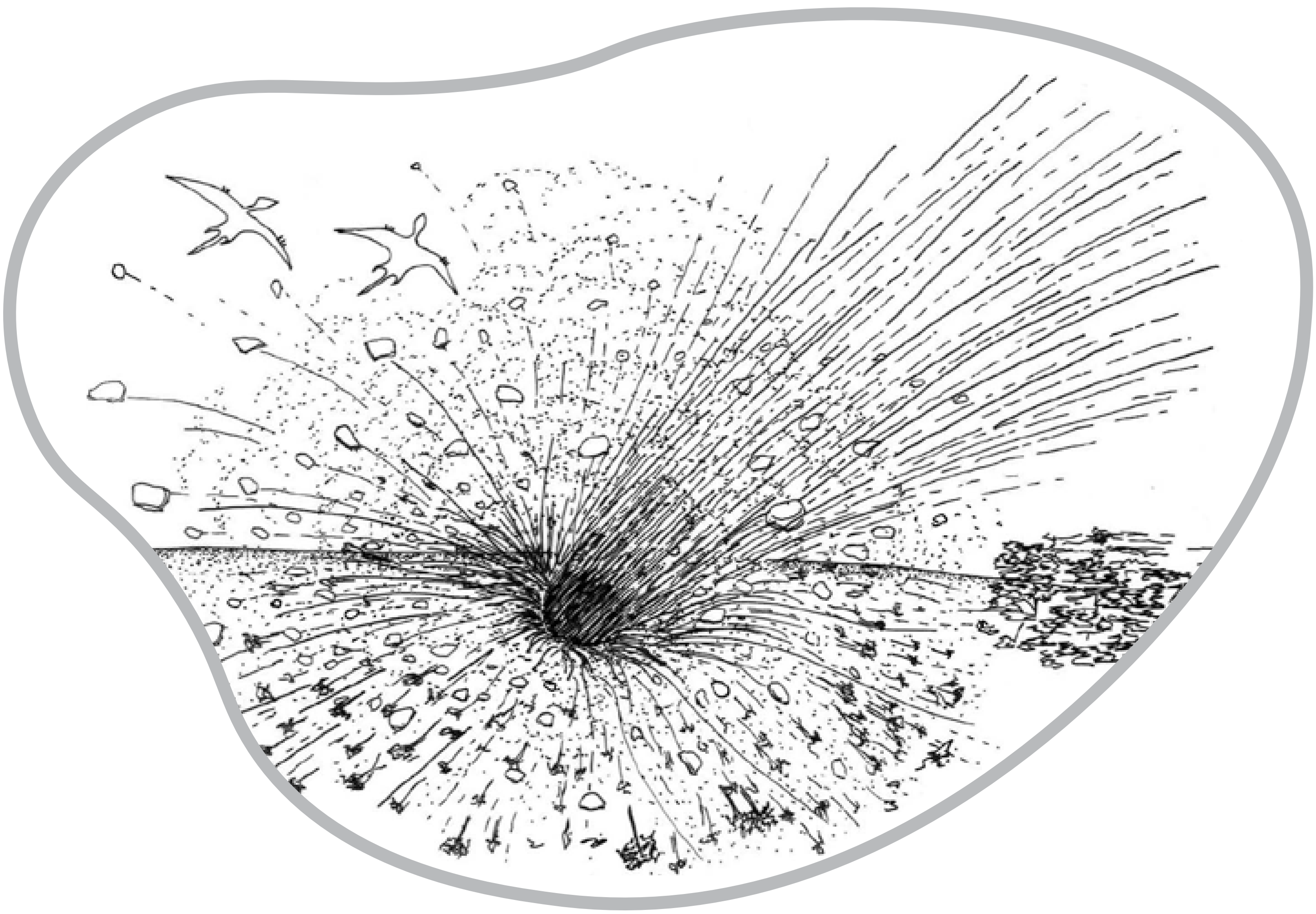
The Hell Creek Formation and the End of the Age of Dinosaurs

Imagine a peaceful low-lying plain near a vast inland ocean. A pair of duck-billed hadrosaurs are tending to their nests as a lazy river meanders by. The climate is warm and humid. The vegetation is tropical and lush. Suddenly and without warning the bright flash of an immense meteor streaks across the sky!

The meteor is a giant asteroid that survives its fiery journey through the Earth's atmosphere and slams into the Caribbean Sea. The massive impact creates a mushroom cloud of dust and debris that spreads through the atmosphere and covers the Earth. The dust cloud darkens the sky for years, blocking sunlight and creating winter-like conditions. Plants die from the cold and lack of sunlight. Herbivores that rely on plants for food begin to starve in great numbers, followed by carnivores that rely on eating herbivores. The food chain collapses, and 75 percent of life on Earth goes extinct.

Some birds and small mammals are among the lucky survivors, but gone are the giant dinosaurs. These events changed the world forever, and the rocks of the Hell Creek Formation record this catastrophe.

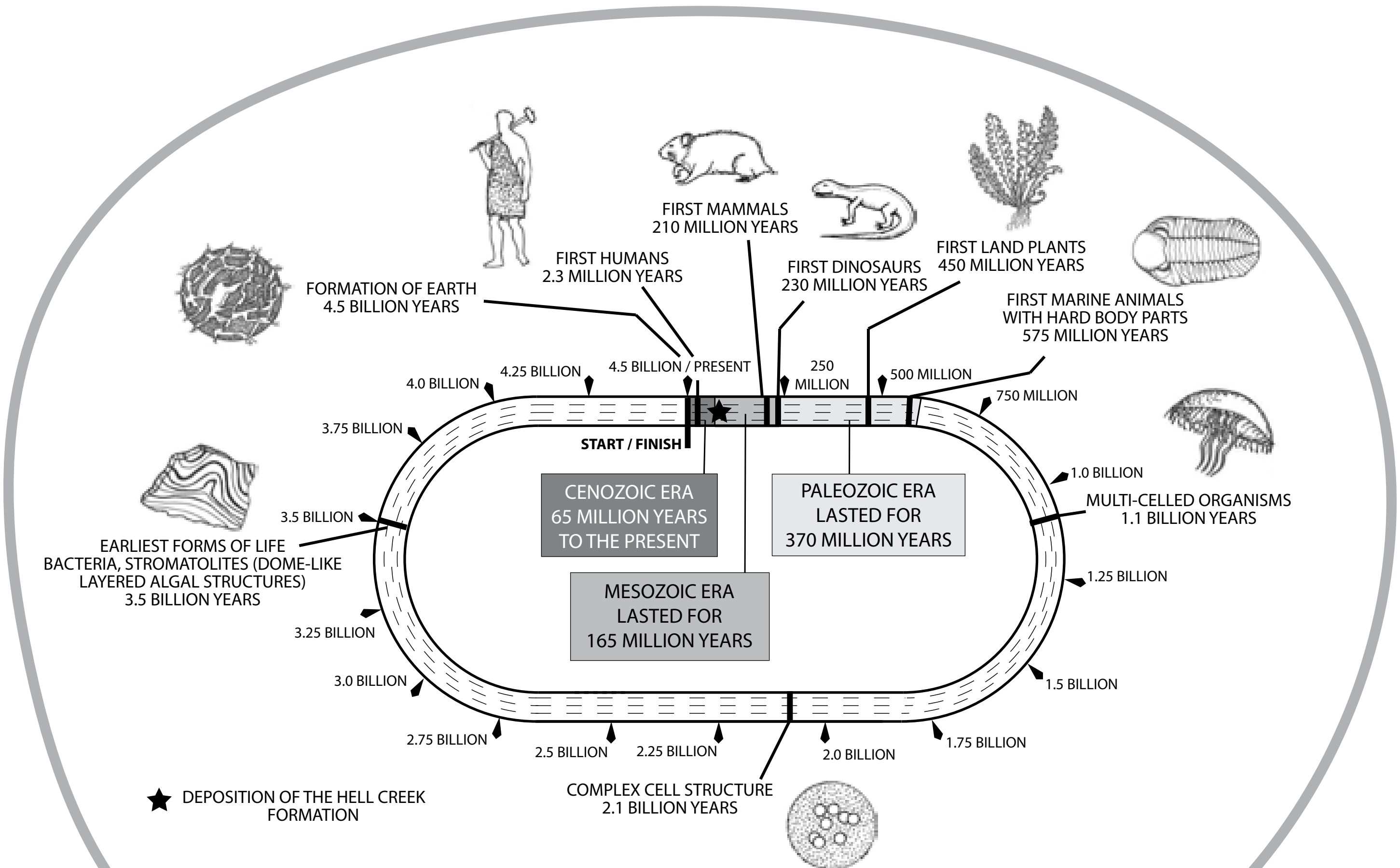
As you read this activity book and work the puzzles, you will learn about the Hell Creek Formation, the incredible fossils in its rocks, and the story they tell about the end of the Mesozoic Era: The Age of Dinosaurs.



The Age of the Earth as the Distance Around a Track

Think of the age of the Earth as the distance around a stadium track with the outside lane approximately 450 meters long (1,476 feet). The age of the Earth is 4.5 billion years. The start/finish line marks the beginning of the track as you run counterclockwise around the entire distance of the track, starting at the origin of the Earth 4.5 billion years ago and ending at the present day. Every marker (⧫) represents 250 million years (250,000,000 years). Major events in the history of the Earth and the development of life are shown as you proceed around the track.

The ages of the geologic eras (Paleozoic, Mesozoic, and Cenozoic) are shown as shaded portions near the end of the race. The Hell Creek Formation contains remarkably diverse fossilized life forms at the close of the Mesozoic Era, the Age of Dinosaurs. The Mesozoic Era lasted for 165 million years, from 230 million years ago to 65 million years ago when the dinosaurs became extinct and the Cenozoic Era, the Age of Mammals, began. Humans appeared on this track just inches from the finish line.



Number Crunch

If a 450-meter-long track represents the 4.5-billion-year-old Earth, how many years does 1 meter of the track represent? How many years is 1 centimeter? Or 1 millimeter? (Hint: There are 100 centimeters in a meter and 1,000 millimeters in a meter.)

The Phanerozoic Eon: Fossils Reveal the History of Life

ERA	PERIOD	EPOCH	SYMBOL	APPROXIMATE AGE	GEOLOGIC EVENTS IN THE DAKOTA PRAIRIES
CENOZOIC (MEANS NEW LIFE) AGE OF MAMMALS	QUATERNARY	HOLOCENE		PRESENT TO 10,000	THE "RECENT;" HUMANS ARRIVE IN N. AMERICA
		PLEISTOCENE		10,000 TO 2 M.Y.	THE ICE AGE, GLACIERS CROSS NORTH AMERICA AND DEPOSIT SEDIMENTS ON THE PLAINS
					VOLCANIC ERUPTIONS TO THE WEST
	NEOGENE	PLIOCENE		2 M.Y. TO 6 M.Y.	EXTENSIVE DEPOSITION ON DAKOTA PRAIRIES FROM VOLCANIC ACTIVITY AND EROSION OF MOUNTAINS TO THE WEST
		MIOCENE		6 M.Y. TO 22.5 M.Y.	REGIONAL UPLIFT, MOUNTAIN BUILDING TO THE WEST, DEPOSITION TO THE EAST
	PALEOGENE	OLIGOCENE		22.5 M.Y. TO 36 M.Y.	VOLCANIC ACTIVITY TO THE WEST, DEPOSITION OF ASH ACROSS THE PLAINS
		EOCENE		36 M.Y. TO 58 M.Y.	
		PALEOCENE		58 M.Y. TO 65 M.Y.	LARAMIDE OROGENY: EPISODE OF MOUNTAIN BUILDING THAT CREATED THE PRESENT-DAY STRUCTURE OF THE ROCKY MOUNTAINS
MESOZOIC (MEANS MIDDLE LIFE) AGE OF DINOSAURS	CRETACEOUS		K	65 M.Y. TO 141 M.Y.	COASTAL AND MARINE DEPOSITION FROM A SHALLOW INLAND SEA AND DEPOSITION OF THE HELL CREEK FORMATION
	JURASSIC		J	141 M.Y. TO 195 M.Y.	ERODED LAND SURFACE
	TRIASSIC		₮	195 M.Y. TO 230 M.Y.	MOUNTAIN BUILDING TO THE WEST, UPLIFTED AND ERODED LAND SURFACE TO THE EAST
PALEOZOIC (MEANS ANCIENT LIFE) TERRESTRIAL LIFE	PERMIAN		P	230 M.Y. TO 280 M.Y.	EROSION OF LAND SURFACE TO THE WEST WITH DRY ARID CONDITIONS IN THE DAKOTAS
	PENNSYLVANIAN		IP	280 M.Y. TO 310 M.Y.	SHALLOW SEA, SWAMPS, AND SHORELINE OUACHITA OROGENY: EPISODE OF MOUNTAIN BUILDING TO THE SOUTH
	MISSISSIPPIAN		M	310 M.Y. TO 345 M.Y.	
FISH	DEVONIAN		D	345 M.Y. TO 395 M.Y.	LOW ELEVATION LAND THEN SHALLOW SEA
LIFE EXPLODES IN THE SEAS	SILURIAN		S	395 M.Y. TO 435 M.Y.	LOW LAND SURFACE AND EROSION
	ORDOVICIAN		O	435 M.Y. TO 500 M.Y.	MARINE DEPOSITION IN A SHALLOW SEA
	CAMBRIAN		€	500 M.Y. TO 600 M.Y.	ERODED LAND SURFACE THEN MARINE DEPOSITION
PRECAMBRIAN			p €		GRANITE "BASEMENT" ROCK

M.Y. = million years

The Phanerozoic Eon is represented by the last 60 meters (200 feet) of the 450-meter (1,475-foot) track. **Geologists** divide it into three eras which are further divided into periods as shown in the table below. We know more about the Phanerozoic Eon than any other time in Earth's history. Why? Because of fossils.

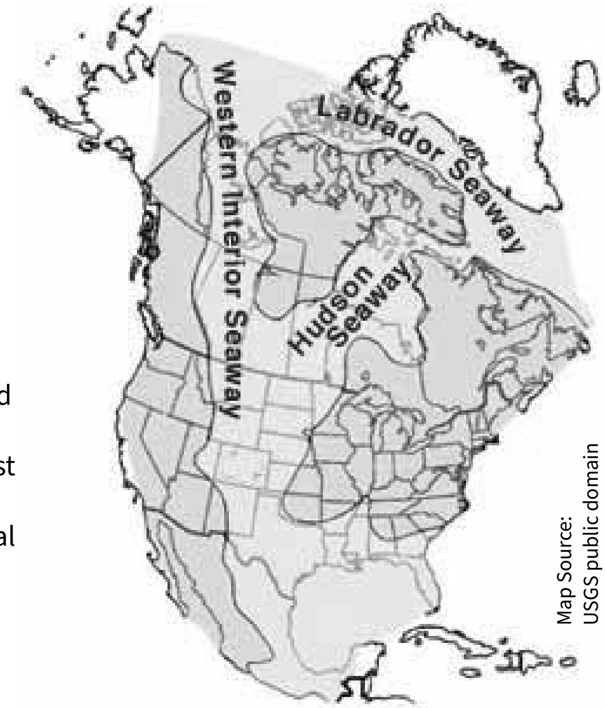
Life with hard parts—in the form of shells or outer skeletons—first appears at the beginning of the Phanerozoic. The hard parts of animals are most likely to be preserved as fossils in rock layers. Geologists study the rock layers and the fossils in them to learn about the history of the Earth.

Geologists know that limestone is deposited on an ocean floor, sand collects on a beach or desert, coal is formed in swamps, and ash and lava are ejected from volcanoes. Younger **sediments** are deposited on top of older sediment layers and if they are undisturbed, they stay this way as they harden into rock layers.

Geologists interpret the history of the Earth from this and other information. Let's now go on an adventure to learn the geologic and fossil history of the areas that are present-day national forests and grasslands in North Dakota, South Dakota, Montana, and Wyoming.

Bold words are defined in the glossary on page 15.

The Cretaceous Period: When Dinosaurs Lived Next to an Inland Sea!



Map Source: USGS public domain

Welcome to the Cretaceous! The environments of Montana, North Dakota, South Dakota, and Wyoming were like present-day Florida during this time. The climate was humid and subtropical forests, swamps, and rivers covered the land. The landscape teemed with crocodiles, insects, fish, flowering plants, small mammals, and dinosaurs! Dinosaurs dominated land habitats at the end of the Cretaceous, like the large mammals of today.

An ocean known as the Western Interior Sea covered what is now the central United States. Throughout the Cretaceous Period the sea spread and shrank in cycles, depositing **marine** mud layers as the seas spread over areas that were formerly dry land. These marine mud layers buried and preserved the remains of marine animals as well as the remains of **terrestrial** plants and animals that lived near the coast when the sea rose and spread over the land. Rivers snaked across the landscape leading to the shore, building up thick deposits of terrestrial mud and sand over areas inland of the sea deposits.

Distant volcanoes would sometimes erupt and winds would blanket the land and the sea with volcanic ash. Animals that breathed or swallowed the volcanic ash floating in the air and water suffered damage to lungs and gills resulting in periodic deaths of entire animal communities. Plant and animal communities would recover following volcanic ash-falls, and this cycle repeated itself many times during the Cretaceous Period.

The combination of river and floodplain sediments, nearshore sea sediments, and volcanic ashfalls are grouped together by geologists in a rock unit named the Hell Creek Formation in North and South Dakota, Wyoming, and Montana. Remains of plants and animals that were buried quickly by river or marine sediments became fossilized and left behind a record of past life in the Hell Creek Formation. Volcanic ash layers are important because radioactive minerals in the ash can be dated by lab tests, which allow scientists to determine the age of the rocks and fossils in the Hell Creek Formation.

Cretaceous Critter Puzzle

Draw a line from the name to the drawing of the Cretaceous fossils found in the Hell Creek Formation. Read page 5 for hints.

Ankylosaurus

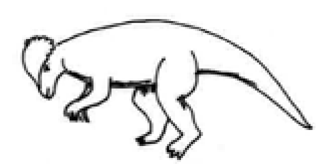
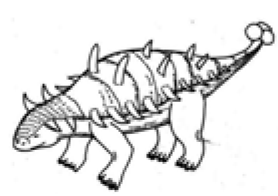
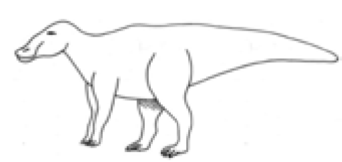
Edmontosaurus

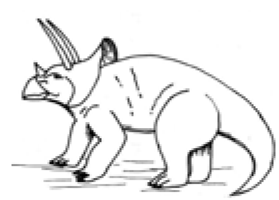
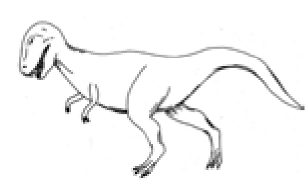
Pachycephalosaurus

Pteranodon

Triceratops

Tyrannosaurus

Answers on back page.

Dinosaurs of the Hell Creek Formation

The Hell Creek Formation contains fossils of many of the most famous dinosaurs known. Duck-billed hadrosaurs such as *Edmontosaurus* roamed in great herds. Hundreds of hadrosaur nest sites clustered together with abundant eggshell fragments tell us that hadrosaurs were social creatures that nested together like some modern birds.

Many kinds of horned and frilled ceratopsian dinosaurs are also present, including the well-known *Triceratops.* Horns served as highly effective defensive weapons against large predators. Horns and frills may also have played important roles in recognizing herd members as well as competition among rivals, like horns and antlers do in many living large mammals.

Pachycephalosaurs (meaning "thick-headed reptile") are unique among dinosaurs because of their thickened, dome-like skulls that are often surrounded by large bumps or spikes. Pachycephalosaurs are relatively small (2–3 meters long) herbivorous or omnivorous dinosaurs with short, thick necks on thick bodies that walked on their hind legs. Did pachycephalosaurs use their thick skull roof domes in head-butting behavior like modern bighorn sheep? Many **paleontologists** think so, and studies of fossilized injuries to pachycephalosaur skull bones support this theory.

Armored dinosaurs like *Ankylosaurus* are among the most ominous looking creatures from the Hell Creek Formation. *Ankylosaurus* was a fearsome adversary for any would-be predator, with a head and torso armored with bony plates beneath the skin, massive spikes along its sides, and a large bony club on the end of its tail. The small, flat teeth of these dinosaurs indicate an herbivorous diet.

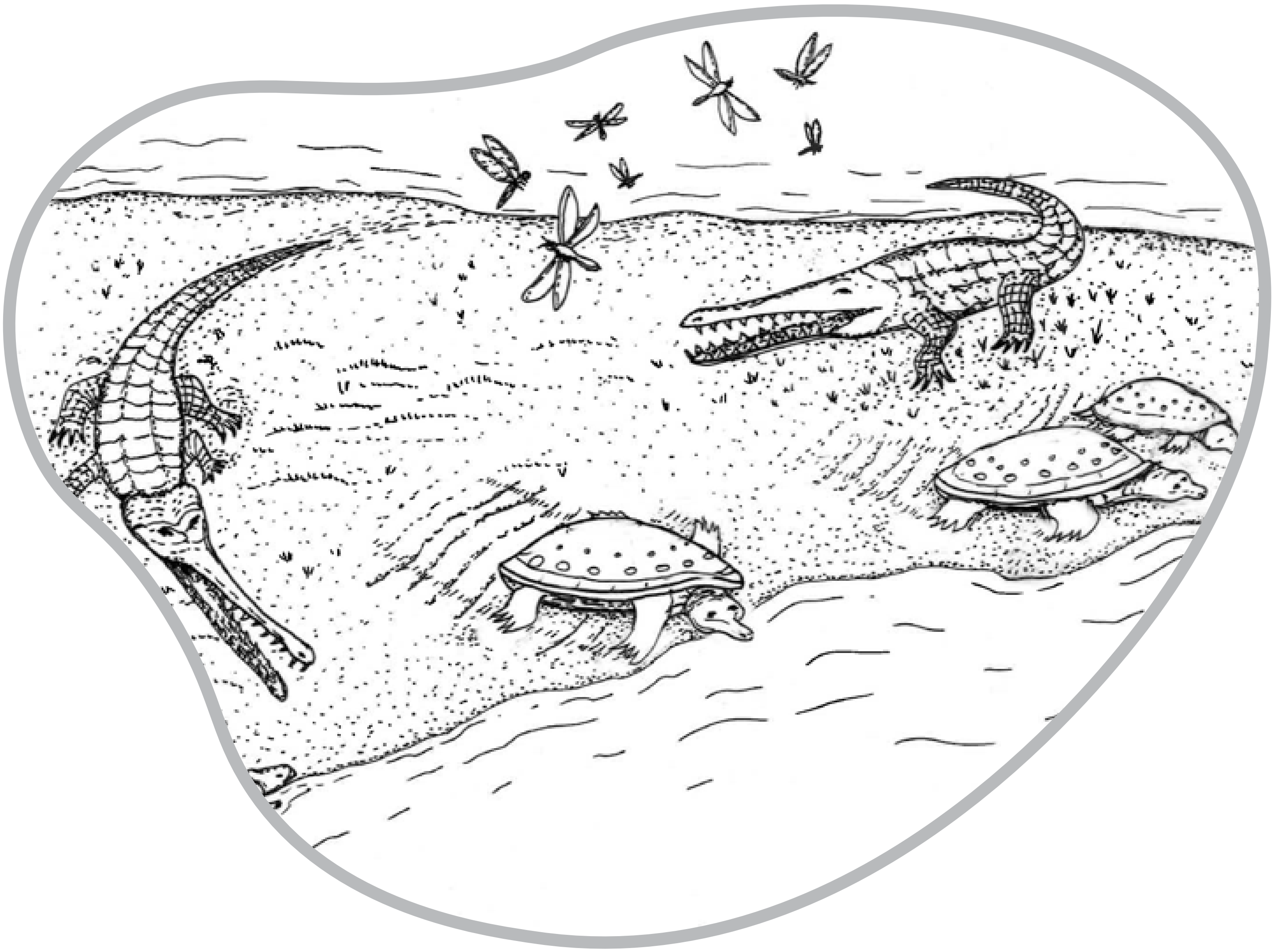
Did You Know?

Scientists sometimes use a special type of name for plants and animals, called a binomial. These names have two terms (notice the "bi" prefix) and are always written in *italic* (slanted) font. The first name is the genus and the second is the species, which are used to group organisms by their common traits. How many genera (plural of "genus") are mentioned on this page?

Look up a binomial for a common plant or animal that you know!

The Hell Creek Formation is also the burial place of the most famous dinosaur ever: *Tyrannosaurus rex! Tyrannosaurus* was the top carnivore on the Cretaceous landscape, and some scientists think females were larger than males like many of their living relatives, the birds. Big and mean, with the fiercest being the tyrant queens! *Tyrannosaurus* had a huge skull with massive 6-inch-long teeth and an immense bone-crunching bite force of 8,000–12,000 pounds per square inch!

Remarkably small forelimbs, along with other curious features, wrapped into a 6-ton, 40-foot-long package raise many unanswered questions about *Tyrannosaurus.* Was *T. rex* the only large predator in the late Cretaceous? Were they social animals that hunted in packs? Were they hunters at all, or were they just scavengers? Could *T. rex* truly run, or was the animal so heavy that it was limited to fast walking? Much of the dinosaur research by paleontologists today tries to answer these and other questions about fossils buried in the Hell Creek Formation.



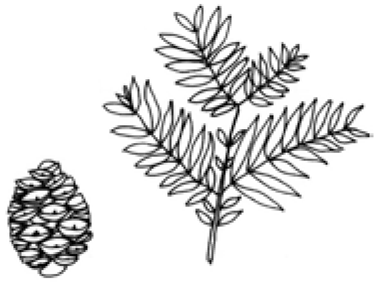
Not Just Dinosaurs: Reptiles, Amphibians, Fish, and Insects Lived There, Too!

Some very remarkable animals lived alongside and beneath the feet of dinosaurs during the late Cretaceous, including the ancestors of living alligators. The Hell Creek Formation is famous for skeletons of large dinosaurs, but it is also rich with deposits that have tiny bones, teeth, and scales. These deposits are called **vertebrate** microsites, and are places where rivers concentrated very small fossils on sand bars.

Microsites may have fossil bones of lizards, snakes, turtles, frogs, and salamanders, as well as early birds and small dinosaurs. Fish fossils are very common in microsites, especially the thick, shiny scales of gar fish. Bony plates from turtle shells are also common, and scientists have found small teeth of early mammals. Most mammals in the late Cretaceous were smaller than rabbits but were abundant in the Hell Creek landscape. Different species lived in many habitats and adapted to many different lifestyles, from ground-burrowing to tree-dwelling.

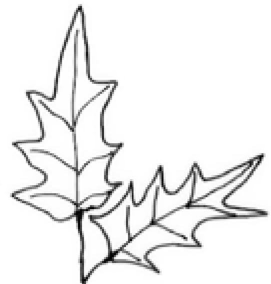
Rare amber (fossilized tree sap) in the Hell Creek Formation may contain insects, including flies, mosquitos, dragonflies, and early bees and butterflies. Tree-living animals such as baby birds and small lizards have been discovered in amber deposits from other locations.

Plants of the Cretaceous

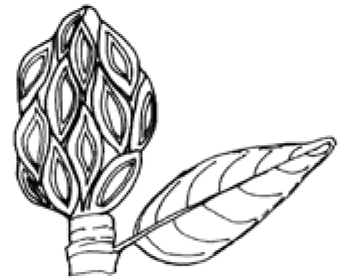


Sequoia

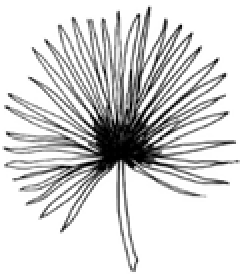
Ficus



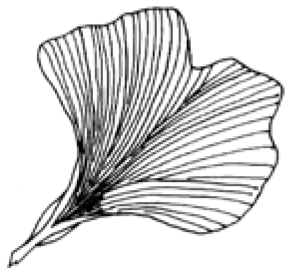
Barberry



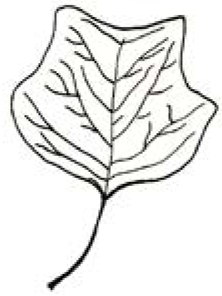
Magnolia



Palm



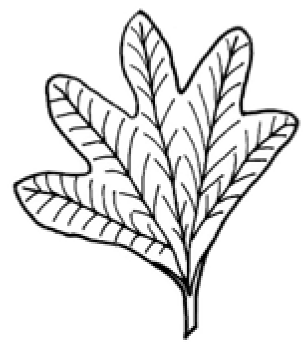
Ginkgo



Tulip Tree

Buckthorn

A rule that paleontologists use is that “the present is the key to the past.” Paleontologists use present-day examples of geological and biological processes to interpret the fossil evidence they study. Today, much of the world depends on flowering plants. So, the appearance of the first flowering plants (angiosperms) in the fossil record was a very important event in the Cretaceous Period.



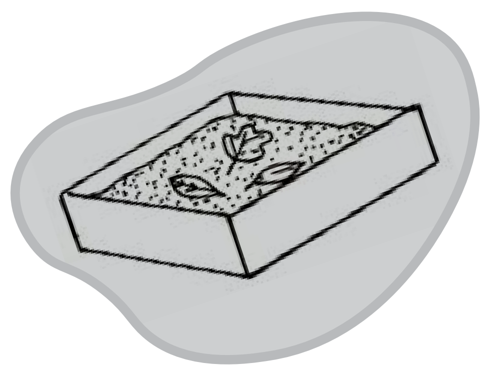
Plane Tree

The repeated flooding and volcanic events preserved a detailed fossil record of plant fossils and their spread in the Hell Creek environment. Fruits, cones, pollen, amber, and seeds from plants are known from fossils in the Hell Creek Formation. Because plants are rooted and were fossilized where they grew, plant fossils are excellent indicators of local habitat and climate. Some fossil leaves are so well preserved that insect chew marks can be used to identify the ancient creatures that fed on them.

Fossil plants show that the climate from 100 to 65 million years ago in the late Cretaceous world was much warmer and wetter than it is today. Tropical plants and ferns are found in Cretaceous sediments all over the globe, even in places that today are much colder and frozen year-round (permafrost).

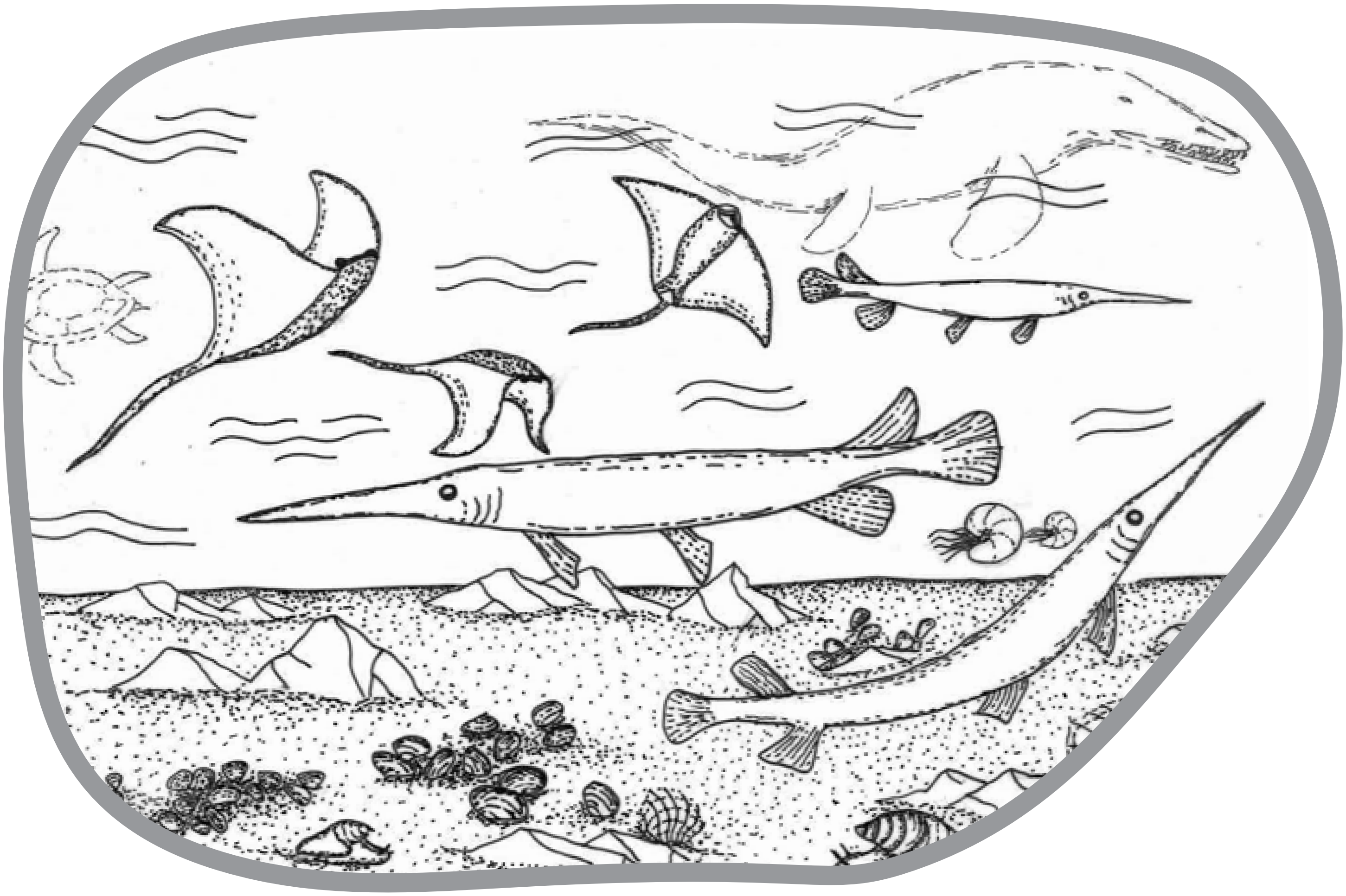
Activity: Make your own fossil!

A fossil is evidence of past life preserved in sediments and rocks. You can make a fossil by taking some mud, rolling it flat, and laying a leaf on top. Carefully press the leaf into the soft mud. Allow the mud and leaf to dry (mud will dry within days, and then the leaf can be peeled away). If you leave the leaf on the dried mud, it will decay and disintegrate after a while, but the leaf impression will remain. You now have a fossil leaf impression!



Try the same process in sand or sandy gravel. Can you make a leaf impression? It doesn’t work as well because the sediment grains in sand and gravel are too large for a leaf impression to be made. The very fine-grained sediments of the Hell Creek Formation were perfect for preserving details of plant leaves and other fossils.

The Western Interior Sea Swarmed With Life!

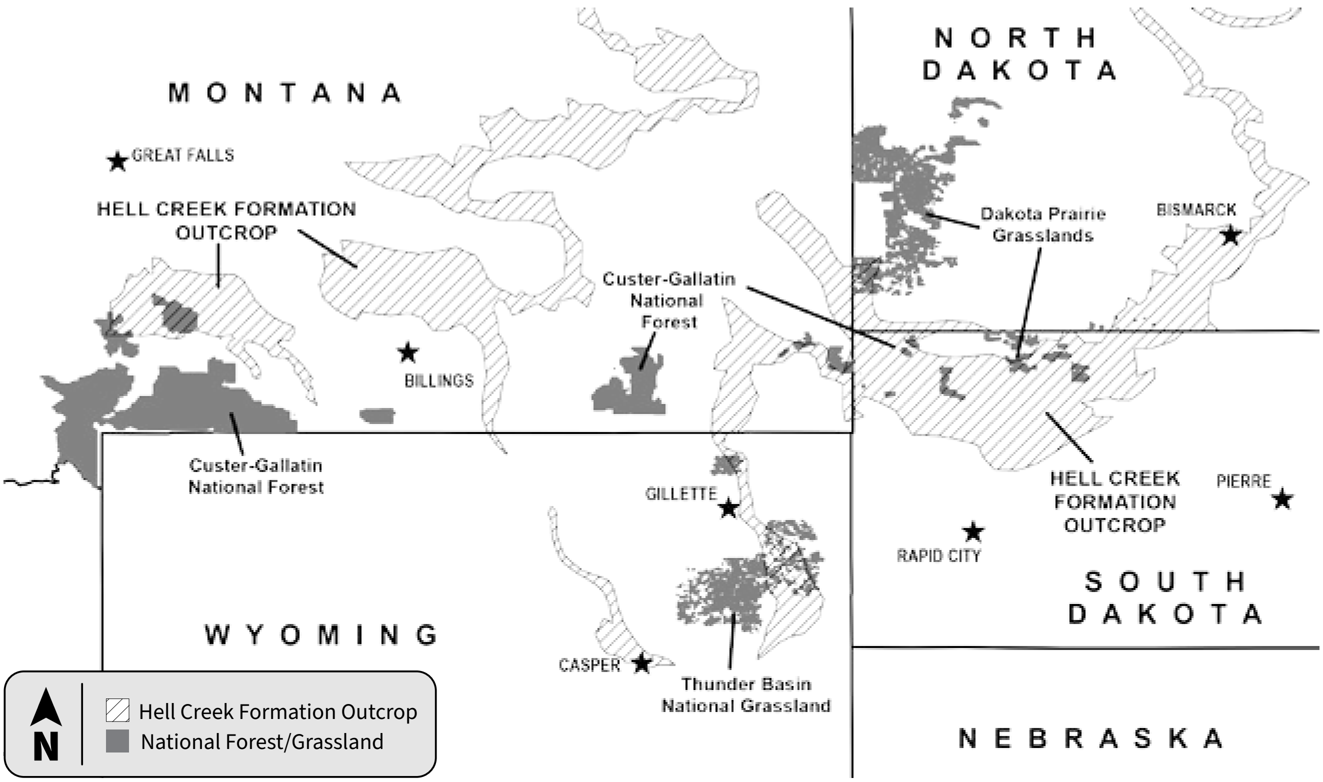


The Pierre Shale is a marine rock unit. It formed at the same time as the Hell Creek Formation, but the Pierre Shale was in a shallow sea. Pierre Shale fossils show that marine life during the Cretaceous compared to marine life today was as different as the terrestrial lifeforms of then and now. Some sharks, rays, and bony fish were like their living relatives, but the ocean also swarmed with ammonites, which were octopus-like animals living inside coiled shells. Giant sea turtles like the car-sized *Archelon* cruised the depths.

Scientists have not yet discovered any dinosaurs that lived in oceans, so the dominant predators of the sea were not dinosaurs. The largest and fiercest predators in Cretaceous oceans were the mosasaurs. Mosasaurs were huge (up to 30 feet long) ocean-dwelling lizards. Mosasaurs developed long, powerful tails to propel them through the water, and their limbs had evolved into flippers to quickly change direction while swimming.

Other remarkable reptiles found unexpectedly in sea deposits are the giant-winged pterosaurs (meaning “winged reptile”) like *Pteranodon*. Some pterosaurs had wingspans up to 24 feet or more. They glided over the ocean waves feeding on schools of fish or other marine animals, like modern pelicans. They lived along the shorelines, and sometimes after death their bodies were swept out to sea and sank to the bottom where they were buried and preserved.

The Big Extinction: Ending the Cretaceous With a Bang!



Iridium is a very hard, brittle, silver-white metallic **element.** It is one of the rarest elements in the Earth's crust, but it is common in rocks from space (asteroids). It is usually found on the Earth in **meteorites.** In 1980, scientists discovered a rock layer rich in iridium that formed at the end of the Cretaceous. They suggested that the layer was created by a large asteroid crash on Earth (scientists call this crash an "impact").

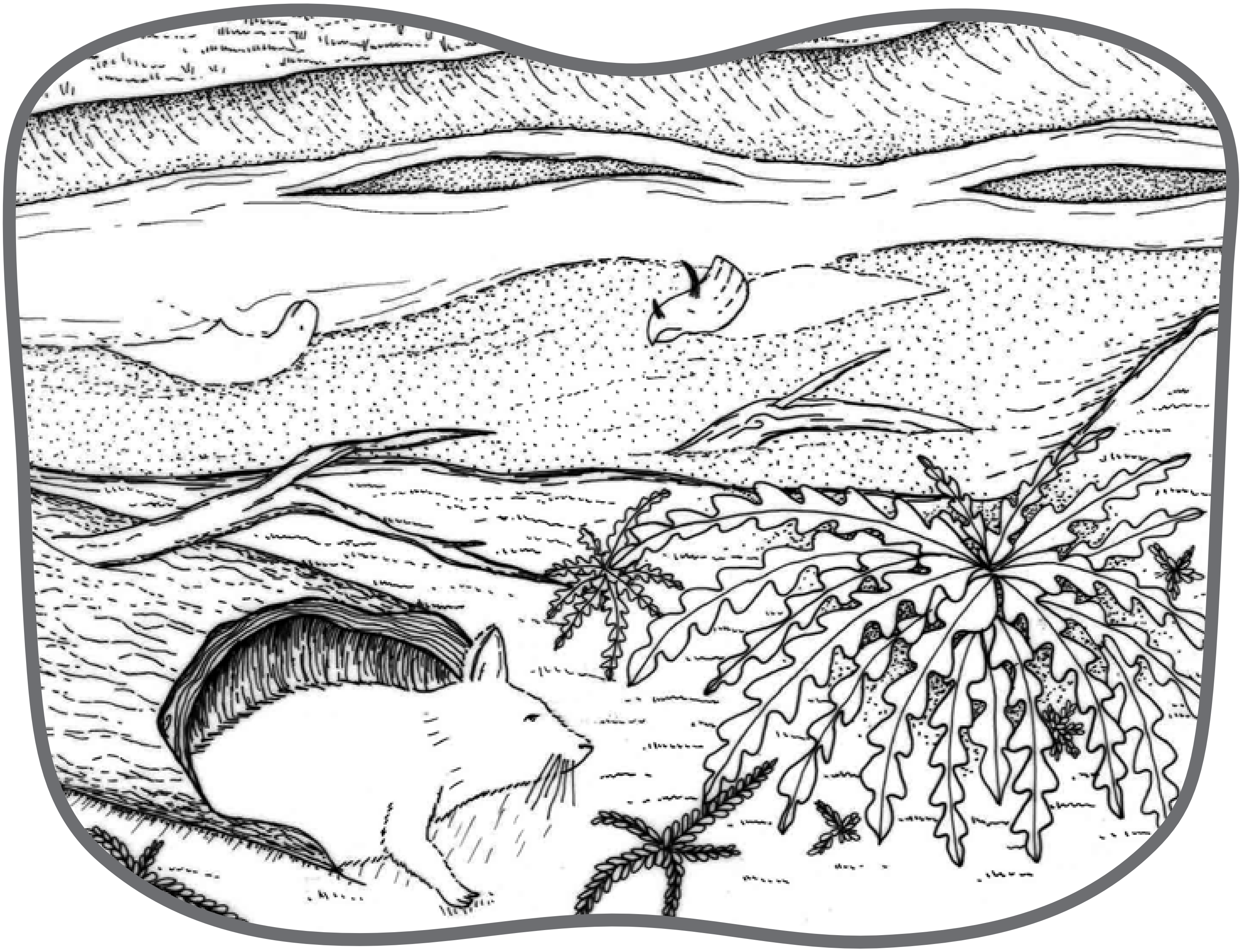
Since that time, other geologists have found an iridium-rich layer separating Cretaceous rocks from Cenozoic layers at many locations around the world (see the table on page 3 for the order of geologic time). The layer also contains glassy particles and microscopic diamonds that form only under conditions of high temperature and great pressure; a large asteroid impact on Earth can create those conditions.

There is a giant crater beneath the seafloor of the Caribbean Sea. Evidence shows that a large asteroid impacted near the present-day Yucatan Peninsula near Chicxulub, Mexico. The Chicxulub asteroid is estimated to have been 6 to 9 miles wide! The asteroid crash left a crater 93 miles wide, which makes it one of the largest known impact structures on Earth!

The impact ejected pulverized rock particles and dust containing iridium into the atmosphere. The cloud of impact dust surrounded the Earth for several years, blocking sunlight and causing global temperatures to cool during what some geologists call a "long dark winter." This caused nearly 75 percent of animal and plant species to go extinct at the end of the Cretaceous Period, including the dinosaurs—although their descendants survived as birds!

Because of the drastic changes in life on Earth from this event, this iridium layer is commonly referred to as the "K-Pg" boundary. The symbol "K" represents the Cretaceous Period and the symbol "Pg" represents the Paleogene Period (see the table on page 3). This is the boundary line between when dinosaurs stopped being the dominant life forms and when mammals started becoming the dominant life forms on Earth.

Life Goes on After the Asteroid: The Cenozoic Era and the "Age of Mammals"



The asteroid impact at the end of the Cretaceous caused a global extinction that changed the world. The landscape started to recover as the atmosphere began to clear following the "long dark winter" and plants could grow again. Ferns gradually became dominant plants that flourished in the carbon dioxide-rich atmosphere, like growing in a greenhouse (geologists call warm climates caused by high carbon dioxide "greenhouse climates").

Many groups of sharks and other fish survived extinction, as did smaller cold-blooded animals such as turtles, snakes, lizards, and crocodilians. All warm-blooded dinosaurs except birds went completely extinct during the "long winter," as did many groups of large reptiles such as the marine mosasaurs and flying pterosaurs. Some scientists suggest that animals who ate seeds, like small mammals and birds, avoided extinction and survived.

The surviving mammals and birds rapidly evolved and diversified to fill the **vacant** habitats left by the extinct dinosaurs and marine reptiles. Paleontologists call such bursts of rapid evolution an "adaptive radiation." The early Cenozoic Era is referred to as the "Dawn of the Age of Mammals" because mammals started to become the dominant life on Earth during that time. Following the mass extinction caused by the asteroid impact at the end of the Cretaceous, mammals evolved from small rodent-like creatures into animals like elephants, cats, and rhinos on the land, and seals, dolphins, and whales in the oceans.

The Incredibly Fun Science of Dinosaur Fossil Excavations!

An animal or plant begins to fossilize after it dies and is covered by sediment. Body parts like bones and teeth are **porous** (having many small openings) and act like sponges when mineral-rich water in the soil and sediment soaks through them and leaves minerals behind. Over time, the openings in the bone become filled with minerals that typically make the bone harder, heavier, and different colors.

The scientific gathering of information begins once someone finds a fossil. Paleontologists examine the ground for more fossil pieces, which they bag and label. These scientists spend a lot of time writing careful notes.

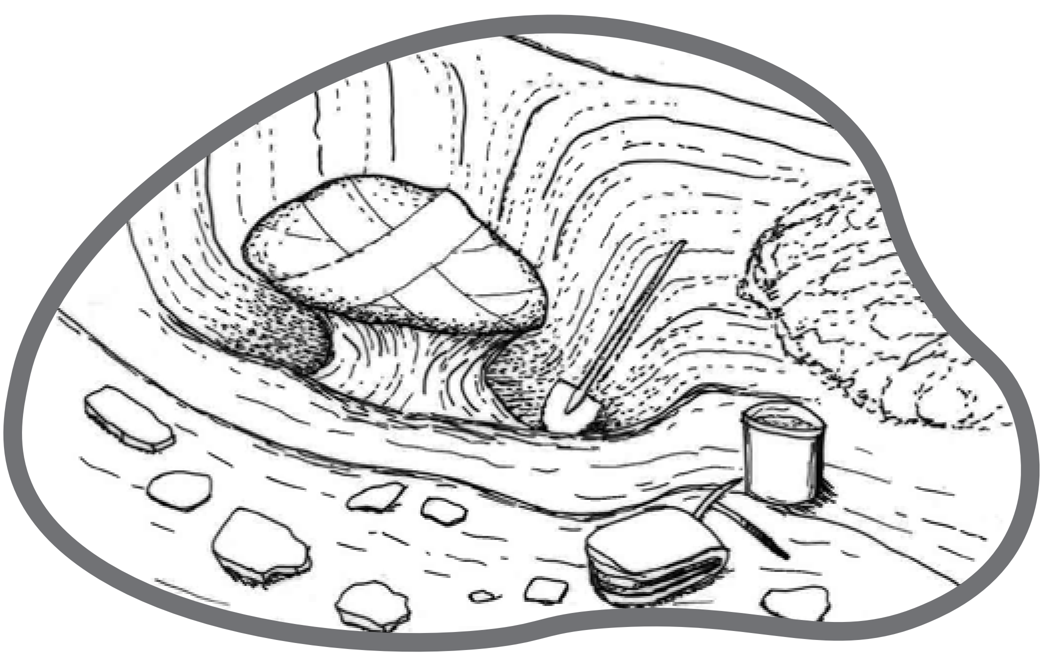
Valuable information about fossil excavations comes from writing down observations and collecting samples of the rock layers that fossils are found in. Rock samples provide clues about the environment the bones were buried in. Some rocks can be dated if they contain radioactive minerals, telling scientists exactly how old the rocks and bones are.

Paleontologists draw maps and sketches showing how bones in a quarry are arranged. Sometimes bones can be part of the skeleton from a single animal, and sometimes many skeletons of animals are buried together by large floods, sandstorms, and other natural catastrophes. Modern scientific equipment allows paleontologists to record information about fossils in new and more precise ways than in the past.

Complete fossil skeletons are rare, and the reasons why are often provided in clues from the excavation site. Predators and scavengers eating prey and scattering bones prior to burial result in broken skeletons with missing parts and may leave behind bite marks on bone or broken teeth.

If the fossil is a large bone or complete skeleton, workers dig around the fossil using small hand tools and brushes, leaving the bone safely supported on top of a pedestal of rock. Wet tissue paper is put onto any exposed fossil bone and is pressed gently onto the bone surface with a paint brush. Scientists mix plaster until it is as thick as pancake batter, and strips of burlap (a very rough cloth) are soaked in the plaster. Next, they tightly wrap the plaster-soaked burlap strips around the fossil and its pedestal of supporting rock, creating what paleontologists call a “field jacket.” A field jacket is like a hard cast around a person’s broken bone, and like a cast it protects the fossil bone inside.

Once the plaster is dry, workers carefully break the pedestal away from the rock beneath, and the field jacket is flipped over so the bottom can be covered in plaster-soaked burlap to complete the field jacket. The completed field jacket looks like a hard cocoon that protects the fossil inside when it is moved to a museum.



Tools of the Trade

You just learned about some of the tools that paleontologists use. Now it's time to test your knowledge. In the space below each tool, take your best guess of what each tool is used for on the excavation site.

Plaster:

Brush:

Whisk broom:

Chisel:

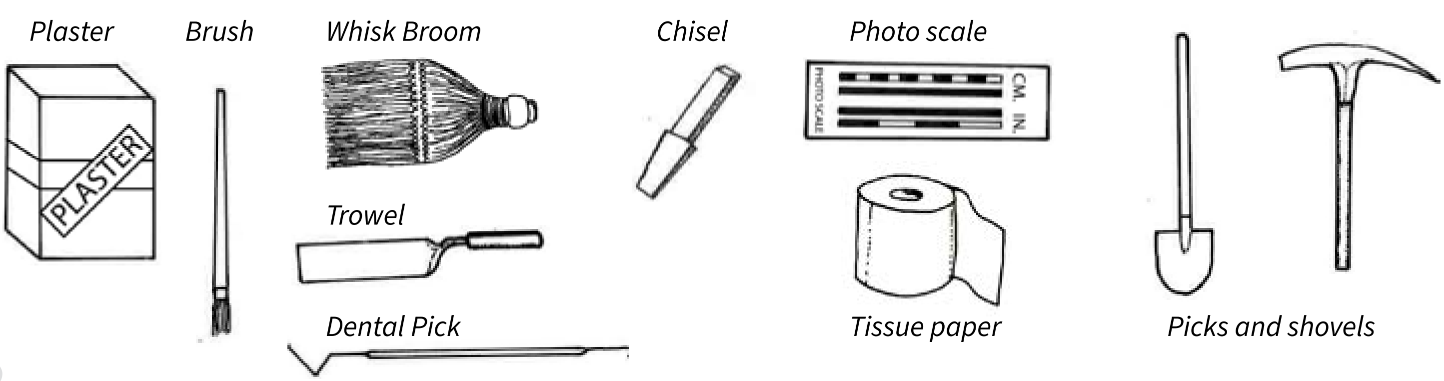
Photo scale:

Dental pick:

Trowel:

Tissue paper:

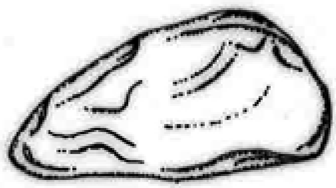
Picks and shovels:



Is This Really a Fossil?

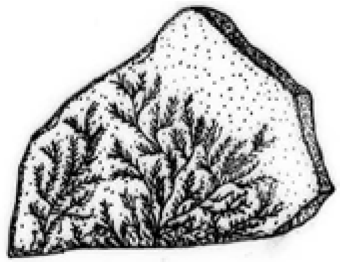
Fossils are any evidence of past life—both plants and animals—and are usually preserved in rock. Common fossils include leaf imprints and shells, such as clams, ammonites, and corals. All of these are the preserved hard parts of ancient organisms. However, there are also rocks that look like fossils but are not.

Can you guess which of the following things are true fossils and which are just rocks? Circle either TRUE or FALSE for each picture. Check your answers on the back page and learn about unique fossil evidence of former life.



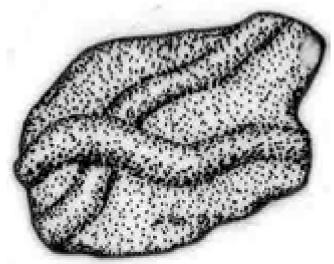
Gastrolith

TRUE | FALSE



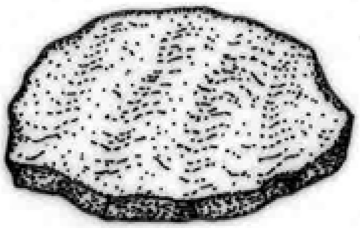
Dendrite

TRUE | FALSE



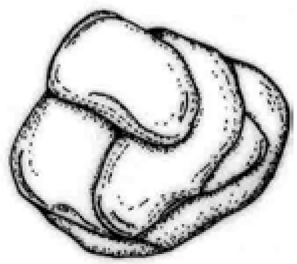
Tube shapes in rock

TRUE | FALSE



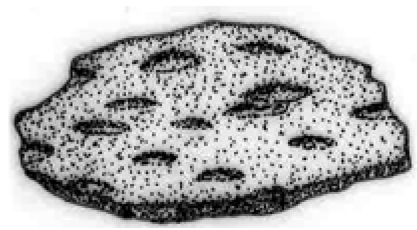
Ripple marks

TRUE | FALSE



Coprolite

TRUE | FALSE

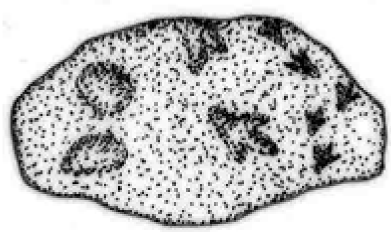


Small shallow holes

TRUE | FALSE

Shaped rocks

TRUE | FALSE



Tracks

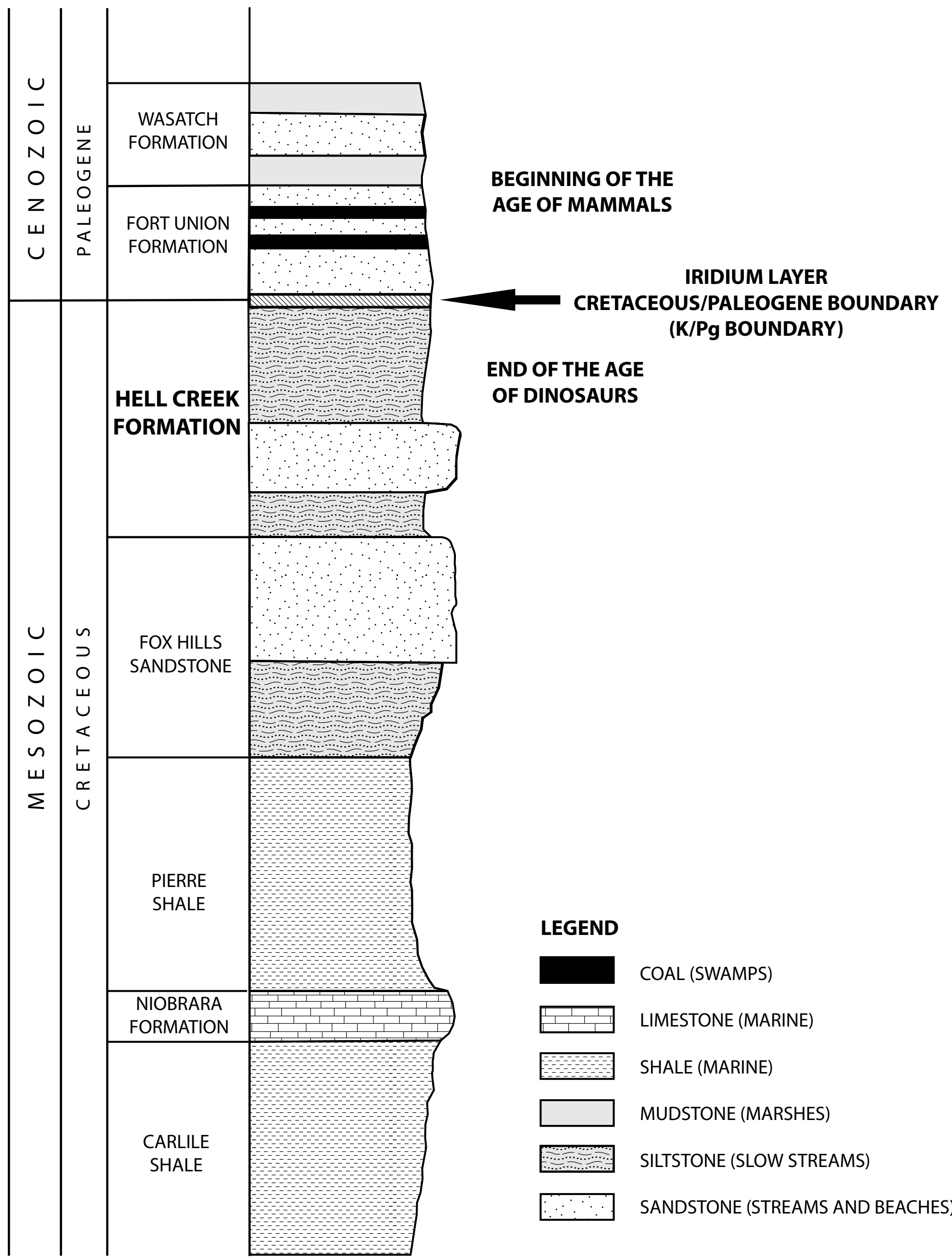
TRUE | FALSE

The Secrets Are in the Rock Layers

In this booklet, you learned about sediment **deposition,** volcanic events, and the spread and retreat of shallow seas across the landscape. Paleontologists know these events happened because of the clues left behind in the geologic record.

Sediments deposit in a predictable way, like building a cake: the first layer is on the bottom and is older than the layers above. Over time, younger top layers squeeze the sediments below, and the pressure slowly turns the sediments to rock. Geologists call this lithification. Geologists use the word stratification to describe stacked layers of rock, one upon the other. Each layer is a stratum. A graphic of multiple stratum is called a stratigraphic column, and it can be used to describe the geologic history of an area.

This illustration shows a stratigraphic column of rock units from just below and above the iridium-rich layer at the end of the Cretaceous, including the Hell Creek Formation. Use the explanation below the figure, called the legend, to find out how each stratum was deposited. The answers come from studying the sediments that make up each stratum.



Glossary

deposition (de-pə-**zi**-shən): an act or process of laying something down

element (**e**-lə-mənt): any of the fundamental substances that consist of atoms of only one kind and that singly or in combination constitute all matter

geologist (jē-**ä**-lə-jist): a scientist who studies geology, the science that deals with the history of the Earth and its life especially as recorded in rocks

sediment (**se**-də-mənt): the matter that settles to the bottom of a liquid; material deposited by water, wind, or glaciers

marine (mə-**rēn**): of or relating to the sea

meteorite (**mē**-tē-ə-rīt): a meteor that reaches the surface of the Earth without being completely vaporized

paleontologist (pā-lē-än-**tä**-lə-jist): a scientist who studies paleontology, the science dealing with the life of past geologic periods as known from fossil remains

porous (**pȯr**-əs): possessing or full of pores; capable of absorbing liquids

terrestrial (tə-**re**-st(r)ē-əl): of or relating to land as distinct from air or water

vacant (**vā**-kənt): being without content or occupant; not lived in

vertebrate (**vər**-tə-brət): of or relating to animals with a spinal column

Accented syllables are in **bold.** Marks and definitions are from the Merriam-Webster dictionary and are limited to the word's meaning in the booklet.

What Is the Forest Service?

The Forest Service is part of the U.S. Department of Agriculture (USDA). The Forest Service manages 154 national forests and 20 national grasslands. These are large areas of land with trees, streams, and prairies. National forests are similar in some ways to national parks. Both are public lands, meaning they are owned by the public and managed for the public's use and benefit. Both national forests and national parks provide clean water, homes for the animals that live in the wild, and places for people to do fun things in the outdoors. National forests also provide resources for people to use, such as trees for lumber, minerals for batteries and phones, and plants used for medicines. These public lands also protect the geology and fossils that you learned about in this booklet. Some people in the Forest Service are scientists who look for and help us learn about fossils. Forest Service scientists work to protect and preserve these amazing resources!

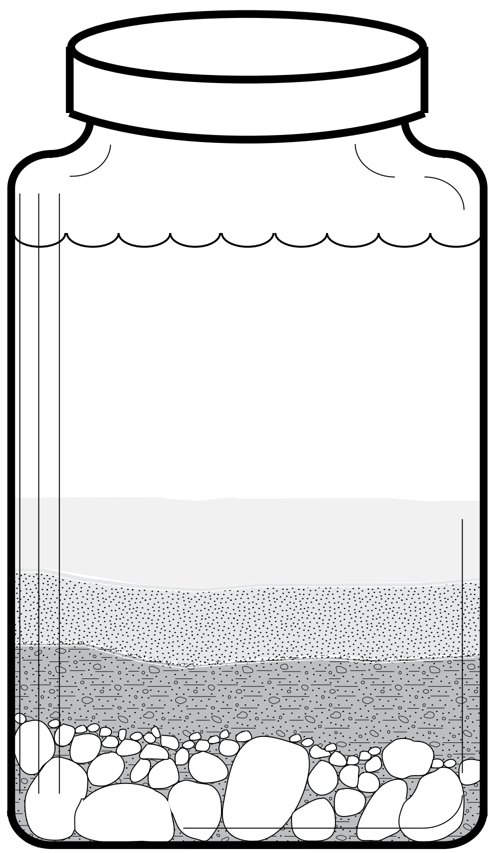
Activity: Race you to the bottom!

Who wins the particle size race? The Hell Creek Formation is made up of sediments with very tiny grains (much smaller than sand grains on a beach) that were deposited by very slow-moving streams in the environment. Faster flowing waters deposit larger sediment grains like sand, gravel, and pebbles. What does this mean? Here is an activity to learn!

Take a large jar with a tight-fitting lid (a quart-size canning jar works well, but any large clear jar will work). Go outside and dig up some sediments. Try to get different sizes including some small pebbles, some sand, and some clayey goo. Fill your jar about half full of this mixture and add water, almost to the top. Stir to mix all the sediments together.

Screw the top on tight and gently shake your sediment mixture, being careful not to drop the jar. Set the jar on a flat surface and watch as the sediments settle out. Which size falls to the bottom first? Leave the jar alone for several days until all the sediments have sunk through the water to the bottom of the jar.

What do you see and what does this mean? When you shake the jar, you create a “high energy” environment in which the small pebbles are mixed in with the sand and smaller-grained material. Setting the jar down creates a “low energy” environment. The pebbles and sand-size particles soon settle at the bottom. The smallest particles like the clay take a very long time to settle after the jar is left undisturbed. Think about lazy streams, marshes, or swampy areas where water flows very slowly, and you have the low energy environments where very fine particles are deposited. These are the types of environments where the sediments of the Hell Creek Formation were deposited!



Word Search

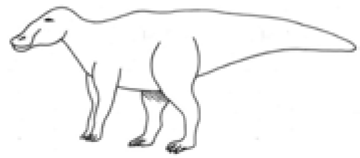
Try to find the following words in the grid below. Answers are in the back of the book.

FORMATION	FERNS	PLASTER
CRETACEOUS	DEPOSITION	TURTLE
SWAMP	VOLCANIC	ASH
DINOSAUR	SEDIMENTS	COPROLITE
MAMMAL	BONE	RAY
CROCODILE	TEETH	PLANTS
CLIMATE	EXCAVATE	PALM
FOSSIL	TRICERATOPS	GINKGO
IRIDIUM	PEDESTAL	SEAWAY
EXTINCTION	TYRANNOSAURUS	AMPHIBIAN
ASTEROID	MAGNOLIA	REPTILE

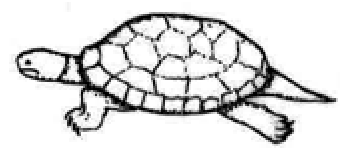
N	J	D	R	E	E	A	W	P	T	Y	R	A	N	N	O	S	A	U	R	U	S
C	M	K	U	S	L	R	U	X	R	R	S	Y	D	B	G	Y	V	X	B	C	U
N	C	K	A	V	I	C	B	W	P	L	K	F	I	E	K	E	H	C	E	Z	O
L	A	T	S	E	D	E	P	O	X	L	P	G	X	J	N	S	V	L	I	K	E
E	Z	Y	O	T	O	E	E	M	L	A	P	X	Q	O	I	D	K	I	P	A	C
L	M	H	N	U	C	B	P	A	R	A	Y	R	B	I	G	M	E	M	A	R	A
I	A	E	I	R	O	N	U	M	M	U	I	D	I	R	I	A	I	A	E	Z	T
T	G	X	D	T	R	W	O	L	A	X	V	K	K	P	W	M	A	T	Z	M	E
P	N	C	Q	L	C	A	S	I	F	W	V	O	T	X	J	M	S	E	C	T	R
E	O	A	V	E	S	L	B	V	T	N	S	W	L	F	F	A	T	S	F	V	C
R	L	V	G	R	D	Z	B	I	C	C	B	I	O	C	L	L	E	Y	O	S	K
S	I	A	A	M	P	H	I	B	I	A	N	R	P	P	A	A	R	A	S	Q	C
T	A	T	B	U	X	L	X	X	X	M	M	I	F	L	W	N	O	C	S	X	V
N	W	E	P	M	R	Y	D	C	J	A	C	V	T	A	A	Y	I	B	I	D	G
E	I	M	F	R	T	O	W	U	T	Z	K	J	Y	X	K	N	D	C	L	X	F
M	L	Y	G	O	E	Y	T	I	L	Q	Y	Z	Q	I	E	Z	T	T	Y	Q	E
I	H	U	I	D	E	P	O	S	I	T	I	O	N	I	A	J	K	S	Y	P	R
D	Y	O	W	E	T	N	R	C	O	P	R	O	L	I	T	E	K	X	Q	P	N
E	X	A	S	H	H	P	O	W	L	I	Q	W	O	R	W	W	I	G	A	Y	S
S	I	F	D	Q	D	Y	S	P	O	T	A	R	E	C	I	R	T	O	J	R	J

Scrambled Words

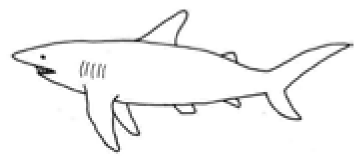
The creatures shown below are all fossils in the Hell Creek Formation, but their names are scrambled. Try to unscramble each name and then connect the name to the drawing. As a hint, there is a drawing of each creature. Answers are in the back of the book.



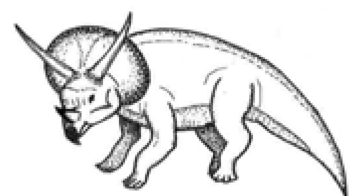
1. G R O F ______________________



2. A A E A N L M R S D ______________________



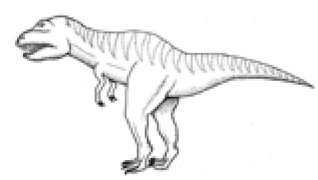
3. S L S A A R N O K U Y U ______________________



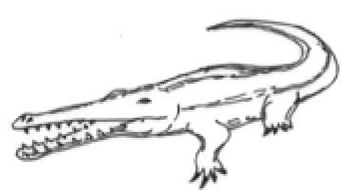
4. L O O C C D R I E ______________________

5. R S T U U O N S R Y A A N ______________________

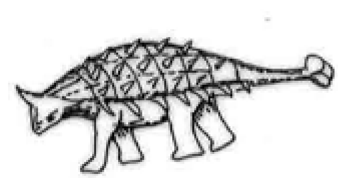
6. K H R A S ______________________



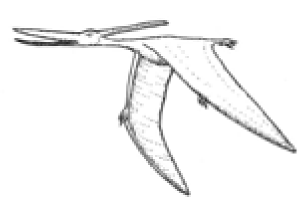
7. R T R T E A O C S I P ______________________



8. A O A R R H S U D ______________________



9. E U T T L R ______________________



10. O R P D O T E N A N ______________________

Coded Messages

Try to decipher the secret messages below. Each letter in the alphabet represents another letter. Write your answer below the code. A clue for each coded message is given at the bottom of the page.

Answers are in the back of the book.

Message 1:

L T M T M N N O I M M W Q R I G S L U R E U A E S G M J Q R I U L A
R C L O I R B S N R E V T M N N O I M M W U E G R E L S E S

Message 2:

K Q O C M Z Z T X Z T B K Q O Q O X X N F O O D C M F R E K T M B
J F M P T L O T B Z T S Q K T B K M X T C O T B K Q O X E K O
N F O K E N O M A Z

CLUES - Message #1: N represents the letter L; Message #2: T represents the letter I

Answers

Creteceous Critter Puzzle

Ankylosaurus

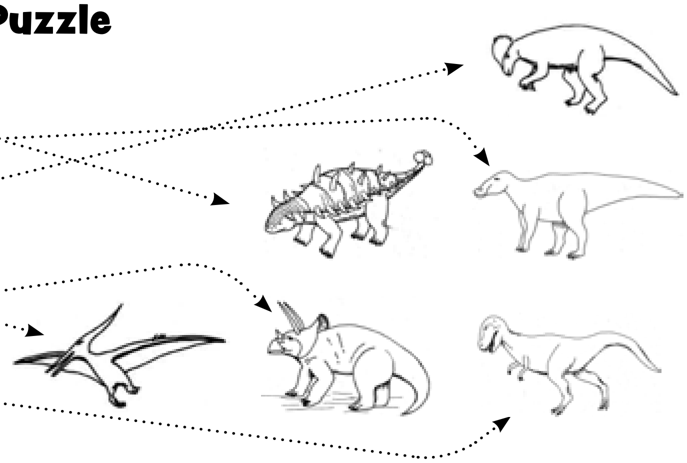
Edmontosaurus

Pachycephalosaurus

Pteranodon

Triceratops

Tyrannosaurus



Is this really a fossil?

(A) Gastrolith: TRUE. A gastrolith is a gizzard stone, like gizzard stones found in modern chickens and turkeys. Some birds, reptiles, and dinosaurs swallowed rocks to help grind food. A gastrolith is a rock that was deliberately swallowed by an animal which became very smooth and polished from rubbing against other rocks in the creature's gut. Not all polished rocks are gastroliths. Only polished rocks that are found very close to or inside fossil skeletons might be gastroliths.

(B) Dendrite: FALSE. Although it looks like a plant, a dendrite is a mineral deposit on stone.

(C) Tube shapes: TRUE. Prehistoric worms burrowed through soft sediments just like modern worms do. They left traces of their passing as rounded tubes crisscrossing through rock. The soft body of the worm is not preserved, only the traces of its tunnels. This is an example of a trace fossil, and trace fossils are a record of animal behavior.

(D) Ripple marks: FALSE. Ripple marks are made by running water or wind. You can see these today along streams, lakes, the seashore, and in sand dunes. Ripple marks are not fossils because they are not evidence of former life.

(E) Coprolite: TRUE. A coprolite is fossilized feces (poop!). Scientists find valuable information about the diet of prehistoric animals by studying coprolite contents. Sometimes fossilized bits of plants or animal bones are found in coprolites.

(F) Holes in a rock: FALSE. Rocks with many holes may be preserved rain drop prints or caused by natural weathering of the rock. Although interesting, many rocks with holes may not be fossils.

(G) Shaped rock: TRUE. Small rocks with peculiar shapes, especially when found in groups, could be fossils. These are prehistoric fish scales.

(H) Tracks: TRUE. Tracks left by fossil animals and preserved in stone are fossils and tell us about the behavior of the creatures that left them.

Word Search

N	J	D	R	E	E	A	W	P	T	Y	R	A	N	N	O	S	A	U	R	U	S
C	M	K	U	S	L	R	U	X	R	R	S	Y	D	B	G	Y	V	X	B	C	U
N	C	K	A	V	I	C	B	W	P	L	K	F	I	E	K	E	H	C	E	Z	O
L	A	T	S	E	D	E	P	O	X	L	P	G	X	J	N	S	V	L	I	K	E
E	Z	Y	O	T	O	E	E	M	L	A	P	X	Q	O	I	D	K	I	P	A	C
L	M	H	N	U	C	B	P	A	R	A	Y	R	B	I	G	M	E	M	A	R	A
I	A	E	I	R	O	N	U	M	M	U	I	D	I	R	I	A	I	A	E	Z	T
T	G	X	D	T	R	W	O	L	A	X	V	K	K	P	W	M	A	T	Z	M	E
P	N	C	Q	L	C	A	S	I	F	W	V	O	T	X	J	M	S	E	C	T	R
E	O	A	V	E	S	L	B	V	T	N	S	W	L	F	F	A	T	S	F	V	C
R	L	V	G	R	D	Z	B	I	C	C	B	I	O	C	L	L	E	Y	O	S	K
S	I	A	A	M	P	H	I	B	I	A	N	R	P	P	A	A	R	A	S	Q	C
T	A	T	B	U	X	L	X	X	X	M	M	I	F	L	W	N	O	C	S	X	V
N	W	E	P	M	R	Y	D	C	J	A	C	V	T	A	A	Y	I	B	I	D	G
E	I	M	F	R	T	O	W	U	T	Z	K	J	Y	X	K	N	D	C	L	X	F
M	L	Y	G	O	E	Y	T	I	L	Q	Y	Z	Q	I	E	Z	T	T	Y	Q	E
I	H	U	I	D	E	P	O	S	I	T	I	O	N	I	A	J	K	S	Y	P	R
D	Y	O	W	E	T	N	R	C	O	P	R	O	L	I	T	E	K	X	Q	P	N
E	X	A	S	H	H	P	O	W	L	I	Q	W	O	R	W	W	I	G	A	Y	S
S	I	F	D	Q	D	Y	S	P	O	T	A	R	E	C	I	R	T	O	J	R	J

Coded Messages

Message 1: THE HELL CREEK FORMATION IS NAMED FOR HELL CREEK IN MONTANA

Message 2: THE FOSSILS IN THE HELL CREEK FORMATION TELL US ABOUT LIFE IN THE LATE CRETACEOUS

Scrambled Words:

1. FROG
2. SALAMANDER
3. ANKYLOSAURUS
4. CROCODILE
5. TYRANNOSAURUS
6. SHARK
7. TRICERATOPS
8. HADROSAUR
9. TURTLE
10. PTERANODON