USDA

U.S. Department of Agriculture

The Story of the Gallatin Petrified Forest

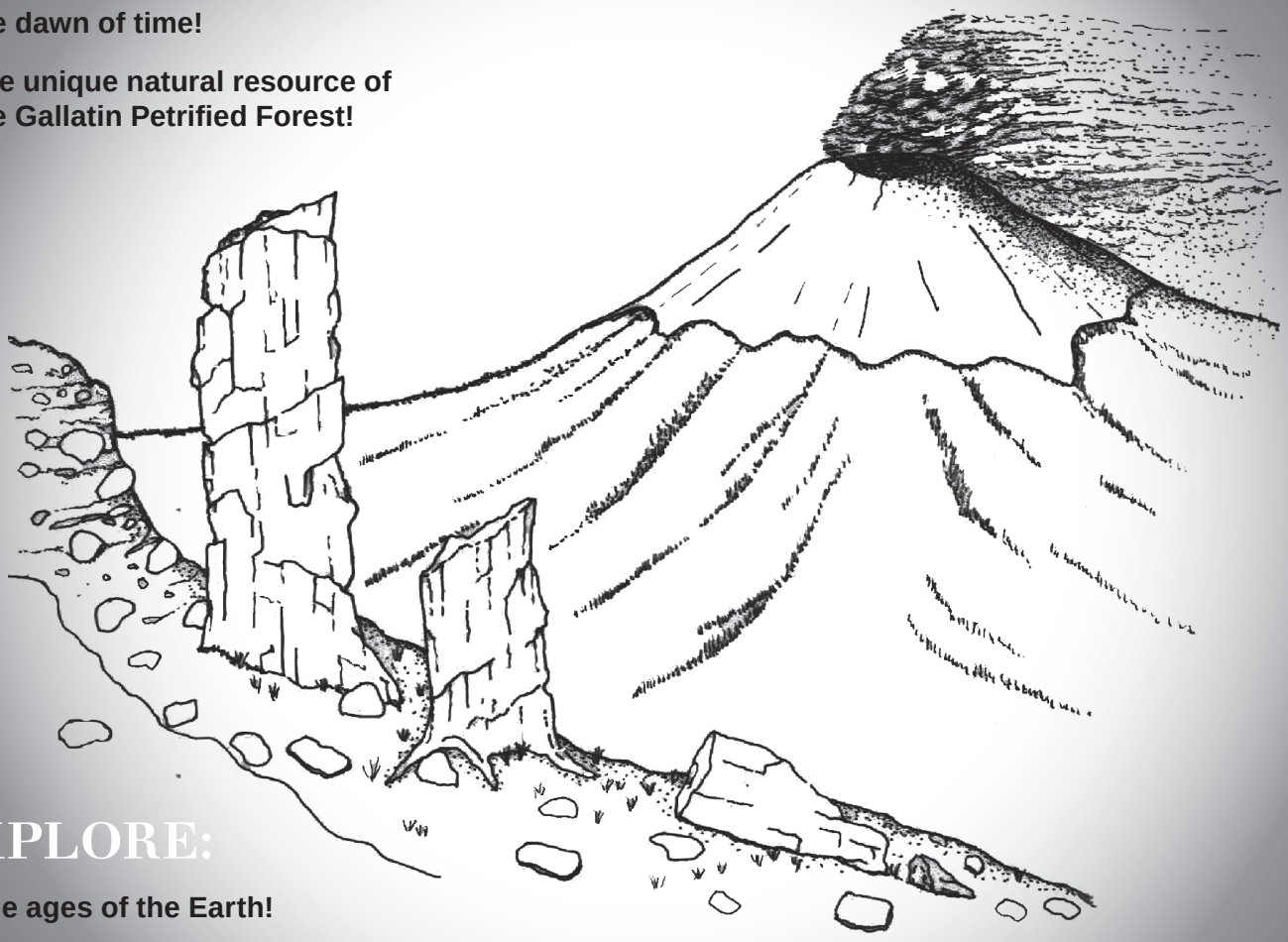
Ancient Forests Petrified During Volcanic Eruptions When Prehistoric Mammals Walked the Land.

DISCOVER:

- **Entire forests petrified by exploding volcanoes!**
- **Montana covered by an ancient ocean and swamps!**
- **Prehistoric life in Montana at the dawn of time!**
- **The unique natural resource of the Gallatin Petrified Forest!**

LEARN:

- **How to decipher rock layers**
- **All about the petrified forest**



EXPLORE:

- **The ages of the Earth!**
- **Montana's geologic past!**

BUT WAIT,

THERE'S MORE!

Secret coded messages! Coloring pages! Puzzles!

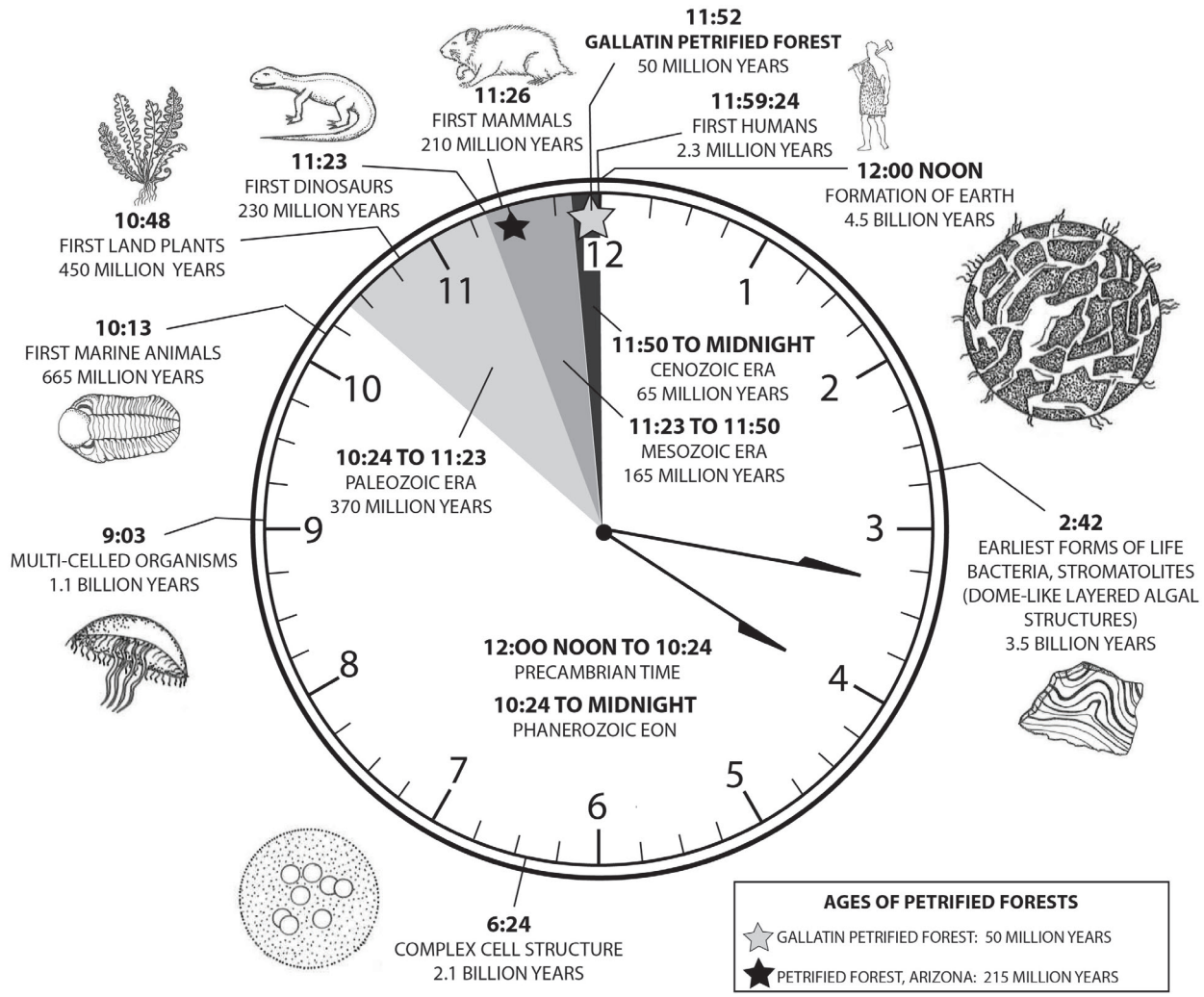
Forest Service FS-1104 March 2018

Introduction

The Gallatin Petrified Forest in Montana is a truly remarkable fossil resource, with layer upon layer of petrified forests preserved as upright trees dating back nearly 50 million years. The total thickness of these fossilized forest layers is more than 2,000 vertical feet! Erupting volcanoes that dotted the landscape during the Eocene Epoch, when giant, now extinct mammals walked the Rocky Mountain region, preserved these forests. This activity book will introduce you to the remarkable fossil resources of the Gallatin Petrified Forest, as well as the geologic history of the surrounding area. As you color the pages and solve the puzzles, you will learn about the remarkable geologic story of the Gallatin Petrified Forest.

The Age of the Earth as a Clock

Imagine the age of the Earth as a 12-hour clock face. The Earth formed at 12:00 noon and the history of the Earth proceeds over the next 12 hours. Every hour represents 375 million (375,000,000) years. The clock face displays major events in the history of the Earth. The shaded portions of the clock face display the ages of the geologic eras. Stars mark the ages of the Gallatin Petrified Forest and the Petrified Forest National Park in Arizona, another famous petrified wood site.

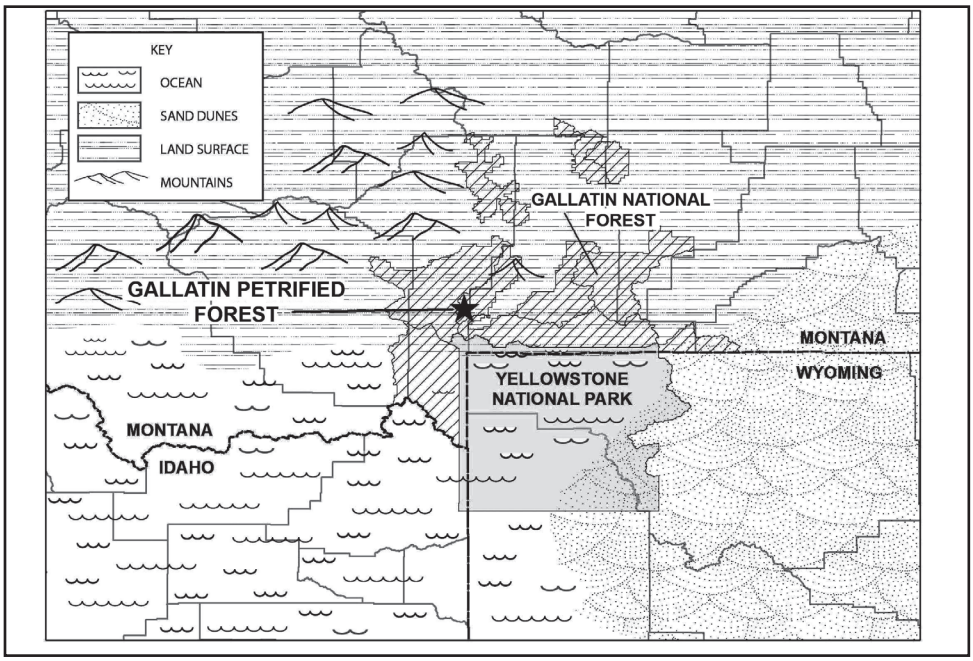


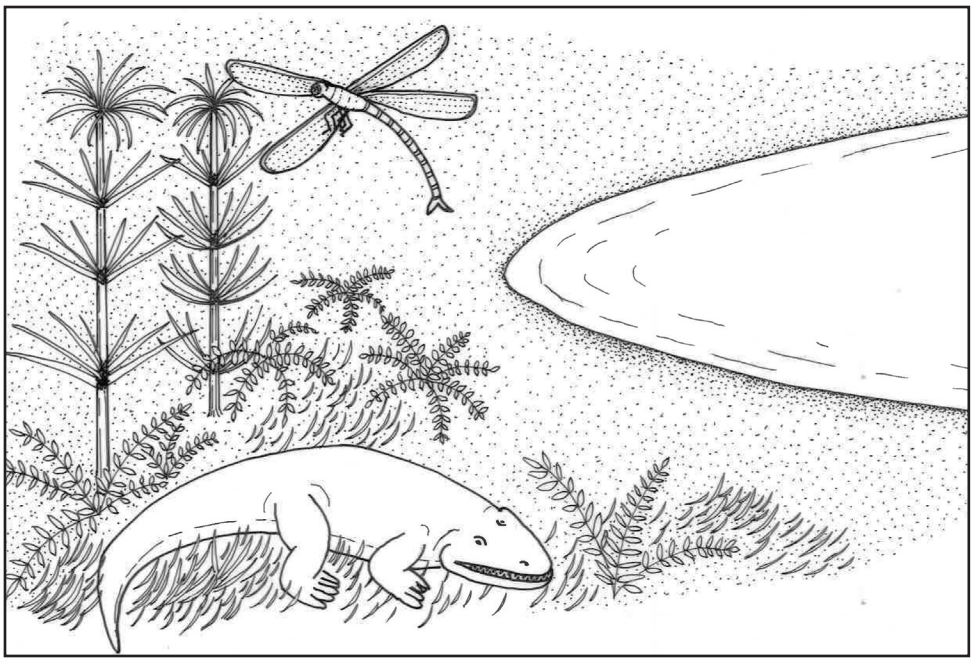
The Phanerozoic Eon: "Time Of Revealed Life"

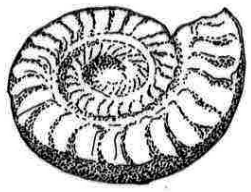
The Phanerozoic Eon is the last 1 hour and 36 minutes of the 12-hour clock face shown on the previous page. The eon is divided into three eras that are further divided into periods, as shown in the table below. We know more about the Phanerozoic Eon than any other period in Earth's history. Why? Geologists have put together the history of the Earth by studying the rock layers and the fossils in them. Geologists know that limestone accumulates on an ocean floor, sand collects on a beach or desert, coal forms in swamps, and volcanoes eject ash and lava. Younger sediments accumulate on top of older rock layers and, if they remain undisturbed, they stay that way. From this and other information, geologists have recreated the history of the Earth. The table below summarizes the history of the area that is now the Gallatin Petrified Forest.

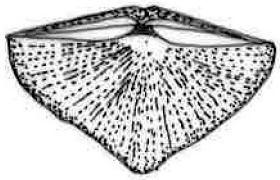
ERA	PERIOD / EPOCH	SYMBOL	APPROXIMATE AGE	GEOLOGIC EVENTS IN SW MONTANA
CENOZOIC – AGE OF MAMMALS	QUATERNARY	Qu		
	HOLOCENE		PRESENT TO 10,000	THE "RECENT" COMING OF HUMANS IN NORTH AMERICA
	PLEISTOCENE		10,000 TO 2 M.Y.	THE ICE AGE: GLACIATION OF THE ABSAROKA MOUNTAINS AND YELLOWSTONE VALLEY
	TERTIARY	T		VOLCANIC ERUPTIONS OF THE YELLOWSTONE CALDERA, NOW YELLOWSTONE NATIONAL PARK
	PLIOCENE		2 M.Y. TO 6 M.Y.	DRY BARREN DESERT
	MIOCENE		6 M.Y. TO 22.5 M.Y.	REGIONAL UPLIFT, FOLDING AND FAULTING OF BEDROCK, MOUNTAIN BUILDING
	OLIGOCENE		22.5 M.Y. TO 36 M.Y.	
	EOCENE		36 M.Y. TO 58 M.Y.	VOLCANIC ACTIVITY, DEPOSITION OF THE ABSAROKA VOLCANIC SUPERGROUP
	PALEOCENE		58 M.Y. TO 65 M.Y.	EROSION OF OLDER SEDIMENTS
MESOZOIC – AGE OF DINOSAURS	CRETACEOUS	K	65 M.Y. TO 141 M.Y.	LARAMIDE OROGENY–EPISODE OF MOUNTAIN BUILDING THAT CREATES THE PRESENT DAY STRUCTURE OF THE ROCKY MOUNTAINS
	JURASSIC	J	141 M.Y. TO 195 M.Y.	DEPOSITION OF MARINE, NEAR SHORE, LAGOON, AND TERRESTRIAL DEPOSITS
	TRIASSIC	T	195 M.Y. TO 230 M.Y.	
PALEOZOIC – TERRESTRIAL LIFE	PERMIAN	P	230 M.Y. TO 280 M.Y.	TERRESTRIAL DEPOSITION–FLOODPLAIN, MARSH, AND DUNE DEPOSITS
	PENNSYLVANIAN	IP	280 M.Y. TO 310 M.Y.	EROSION OF LAND SURFACE WITH DEPOSITION ON FLOODPLAINS, DELTAS
	MISSISSIPPIAN	M	310 M.Y. TO 345 M.Y.	SHALLOW MARINE DEPOSITION, FOLLOWED BY STRUCTURAL UPLIFT OF LAND SURFACE
– FISH	DEVONIAN	D	345 M.Y. TO 395 M.Y.	SHORELINE AND SHALLOW MARINE DEPOSITION
	SILURIAN	S	395 M.Y. TO 435 M.Y.	MARINE DEPOSITION
– LIFE EXPLODES IN THE SEAS	ORDOVICIAN	O	435 M.Y. TO 500 M.Y.	MARINE DEPOSITION
	CAMBRIAN	€	500 M.Y. TO 600 M.Y.	MARINE DEPOSITION
PRECAMBRIAN		p €		

Mississippian-Pennsylvanian Periods: 280 to 345 Million Years Ago

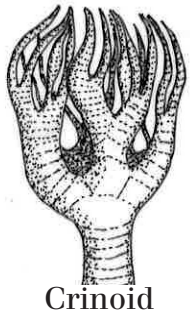


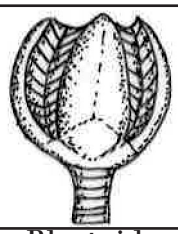



Ammonoid


Brachiopod

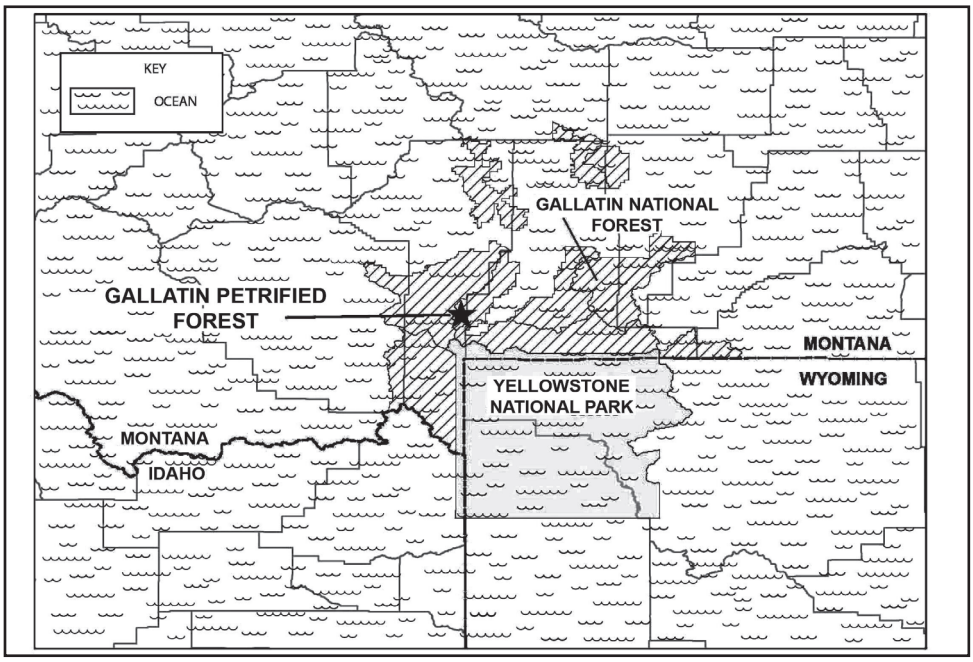

Gastropod

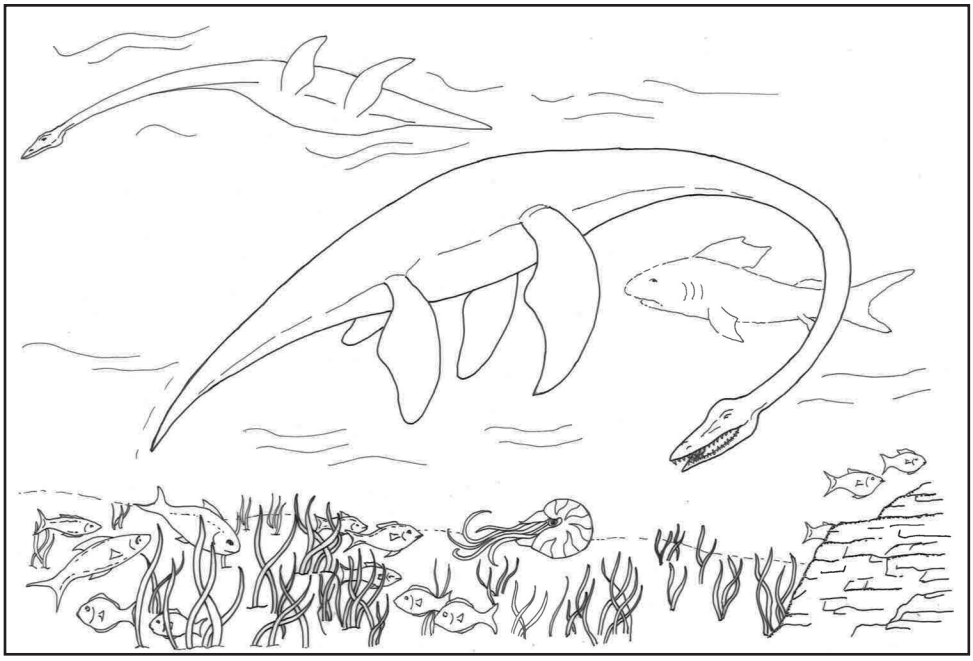

Crinoid

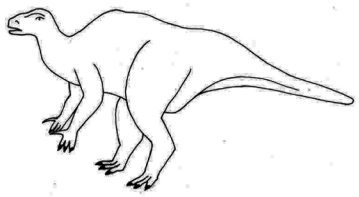

Blastoid

During the Mississippian and Pennsylvanian Periods, the area that is now the Gallatin National Forest was at the shoreline of an ocean that advanced and retreated over long periods of time. The oceans teemed with life, including crinoids and blastoids, that attached themselves to the ocean floor. These creatures looked much like plants, but they were actually related to starfish. Familiar mollusks, such as the gastropod (snail), were also present. Plant life was well established on the land, especially in swamps. Over time, thousands of feet of sediment buried the swamps, which later metamorphosed into coal. Giant insects flew through the air, including dragonflies the size of eagles. Early amphibians, like the one shown above, were abundant; reptiles were also present and were becoming more widespread in the warm, humid terrestrial environment.

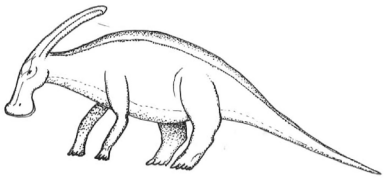
Cretaceous Seaway: Around 90 Million Years Ago



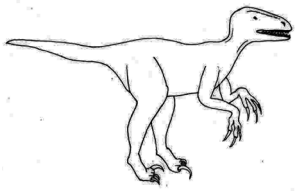




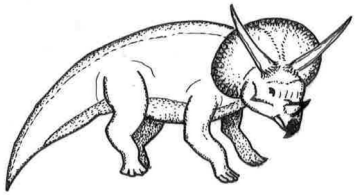
Iguanodon



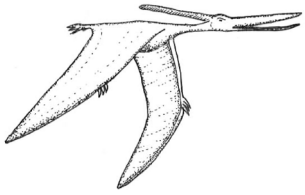
Hadrosaur



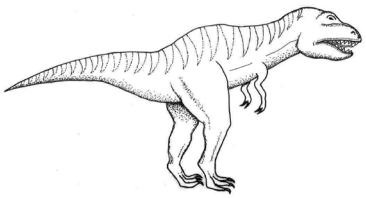
Utahraptor



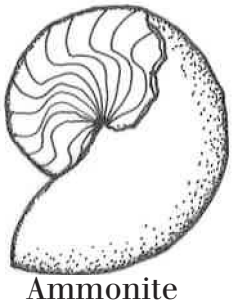
Triceratops



Pteranodon



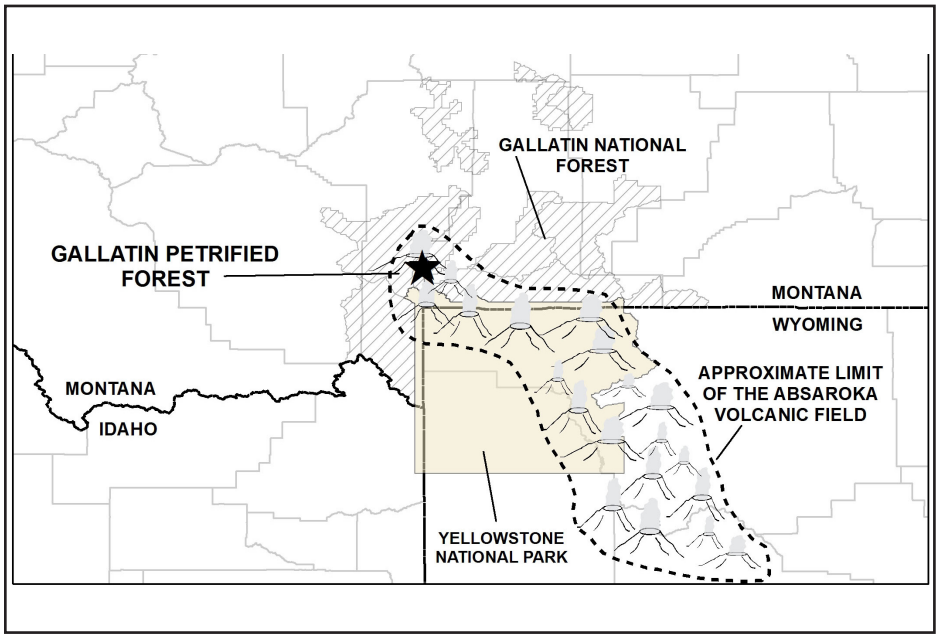
Tyrannosaurus

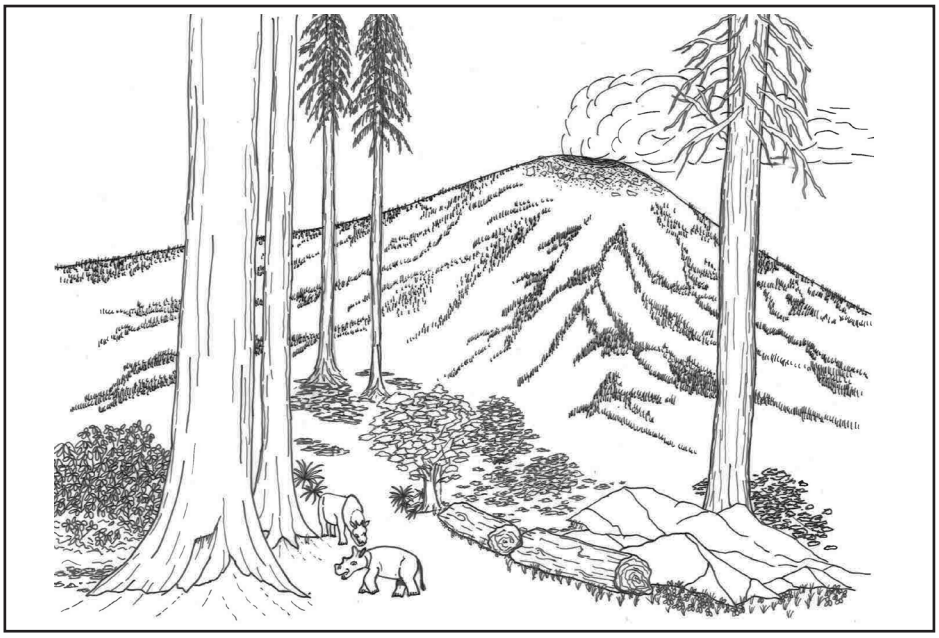


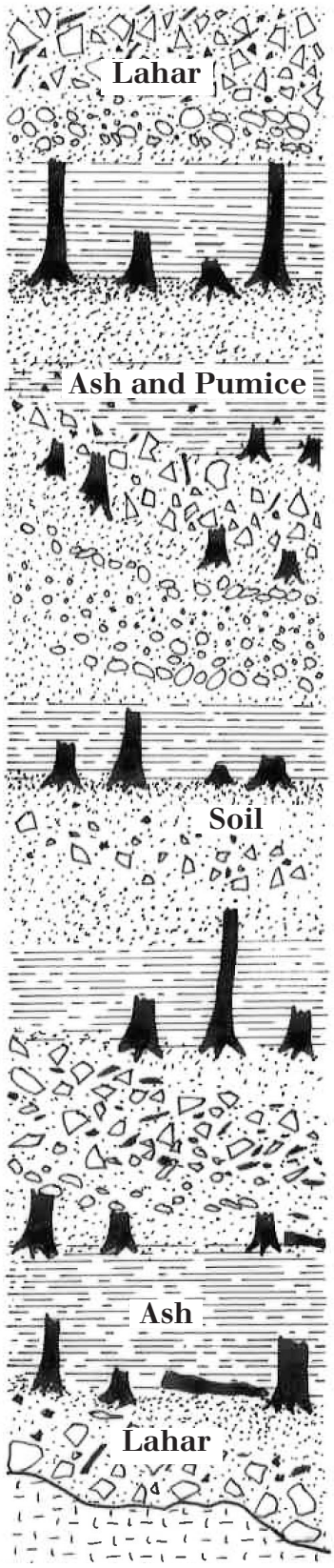
Ammonite

At one point during the Cretaceous Period, a shallow sea extended from north to south across what is now the Rocky Mountains. Geologists know this from marine fossils found on present day dry land, including shark teeth and coiled ammonite (a squid-like creature) shells. A plesiosaur pursues an ammonite in the drawing above. Over time, the sea gradually withdrew, and swamps and beaches covered southwestern Montana. Near the end of the Mesozoic Era, the "Age of Dinosaurs," the great predators, including Tyrannosaurus and Utahraptor, hunted the coastal swamps and forests. Pteranodons glided across the sky while hadrosaurs, iguanodonts, and Triceratops grazed in the forests.

Gallatin Petrified Forest, Montana, and the Absaroka Volcanic Supergroup of the Eocene Epoch, 50 Million Years Ago

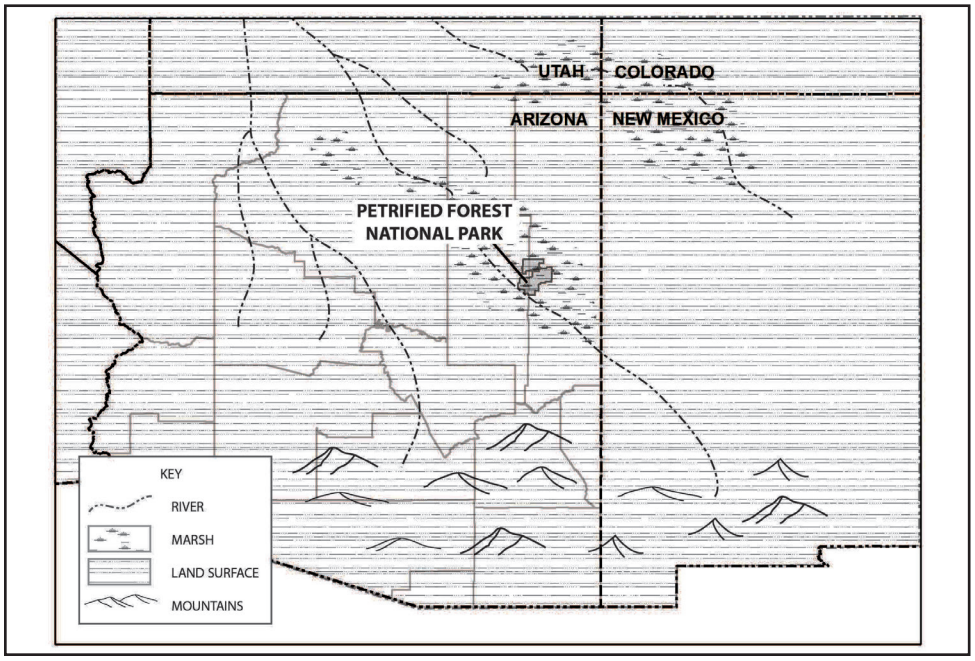


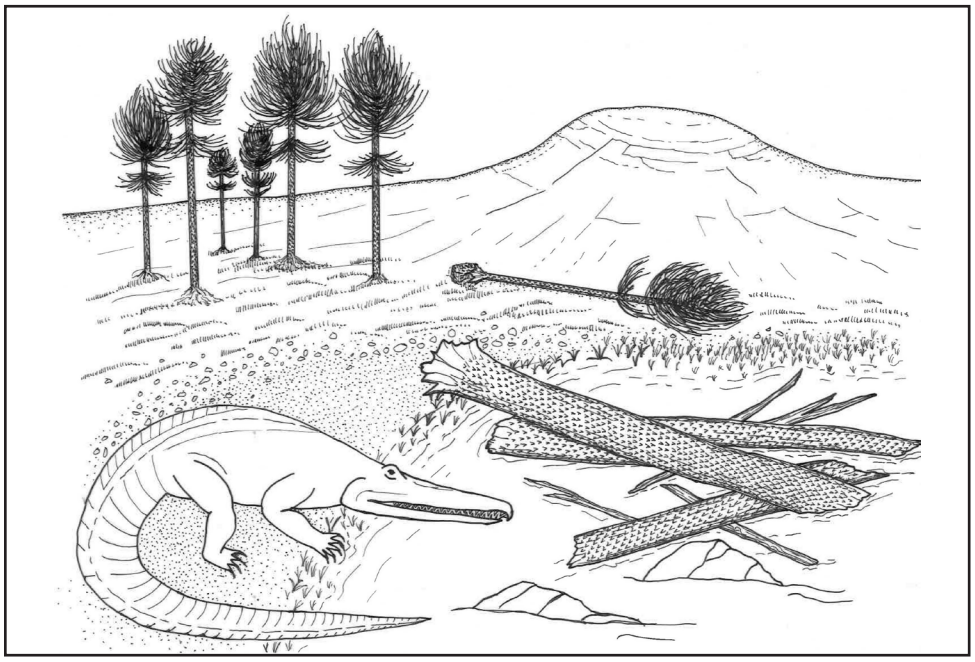


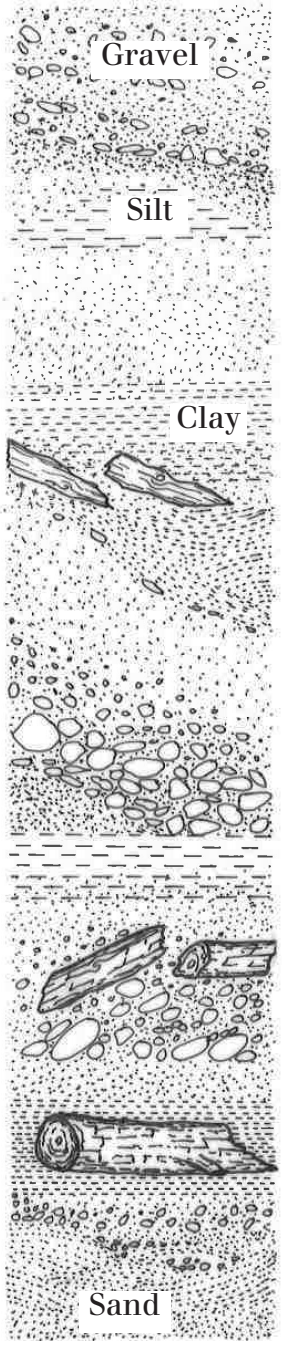


Compare the scene from the Gallatin Petrified Forest above with the one on the next page. The Gallatin site is about 165 million years younger than Petrified Forest National Park. Eocene rhinos graze in a redwood forest. The volcano in the distance is about to erupt. The volcanic activity will bury the tall trees in the forest. The trees may be covered by ash and pumice ejected from the volcano or they may be covered by volcanic debris flows (lahars). The volcanic activity will knock down some trees, but many trees will remain upright and be buried by volcanic particles (ejecta). Look at the sediments in the column on the right. Notice how angular rock and debris from the volcano buried the forests. This burial happened very quickly by the standards of geologic time.

Petrified Forest National Park, Arizona, and the Chinle Formation of the Triassic Period, 215 Million Years Ago







The Petrified Forest National Park is a world-famous fossil wood site. The trees in this forest washed downstream from where they grew during floods and were buried in stream sediments. Gradual mineralization in the wood pores formed the petrified logs. Streams transported and later deposited the logs, producing sedimentary rock layers with clay, silt, sand, and gravel beds (named the “Chinle Formation” by geologists), similar to those in the drawing on the right. This type of petrified wood is common in many rock formations. Because the trees washed downstream many miles from where they grew, they are not really a fossil forest, but simply accumulations of petrified wood. Trees petrified by volcanic activity and still standing upright where they grew, such as the trees in the Gallatin Petrified Forest, are very rare.

The Story of the Gallatin Petrified Forest

The Gallatin Petrified Forest is a remarkable forest of trees made of stone. Even more remarkable is that the Gallatin Petrified Forest is not just a single forest, but rather layer upon layer of fossilized trees and wood fragments stacked more than 2,000 feet thick. The Gallatin Petrified Forest is unlike most petrified forests in which fragments of wood are scattered and buried by stream sediment before being fossilized. Volcanic material buried the trees at the Gallatin Petrified Forest and literally turned them to stone where they grew. The volcanic eruptions that buried these ancient forests also created massive changes to the landscape in the Eocene Epoch, about 50 million years ago.

Just like the ancient Roman cities of Pompeii and Herculaneum, volcanic ash and pumice buried many of the ancient trees of the Gallatin Petrified Forest almost instantly. In most cases, the fossil trees still stand upright in the same location at which they grew. The fossil remains of the ancient forests provide geologists with insight into what the vegetation and climate were like 50 million years ago, and what kinds of changes have taken place since then.

The petrified wood and fossilized seeds, leaves, needles, and cones indicate forest growth that appears similar to modern day forests. Scientists have identified sycamores, oaks, maples, dogwoods, magnolias, buckthorn, laurels, chestnuts, and redwood trees from the fossil remains. Some other trees identified from the fossils have since become extinct in North America, including the katsura and chinquapin trees presently found in Asia. Other plants identified include ferns, pine trees, elms, and willows.

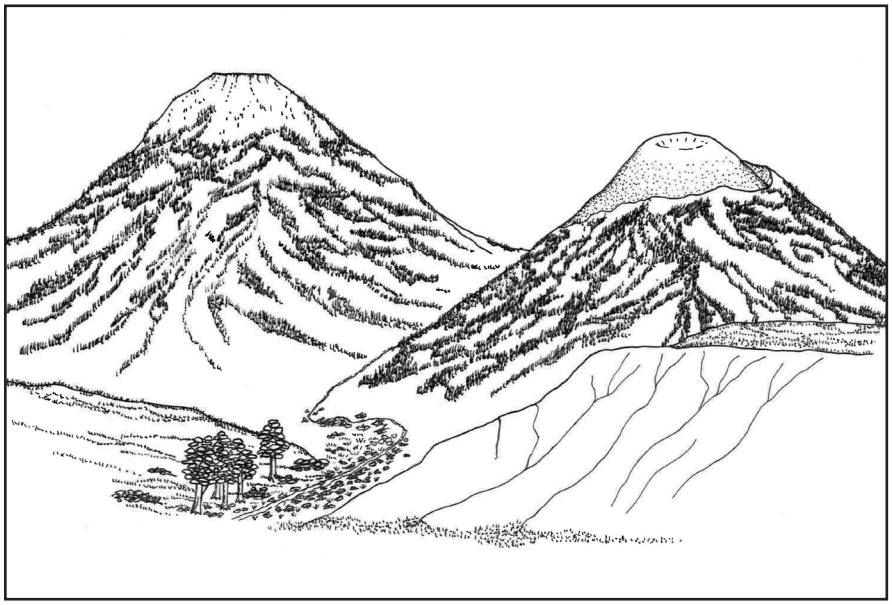
Plant fossils found at the Gallatin Petrified Forest tell of a climate much warmer than present day Montana. Assuming that the ancient trees grew in similar environments to their present day relatives, scientists believe that the lowlands in this volcanic field probably had a warm, humid climate similar to the one found in today's Southeastern United States.

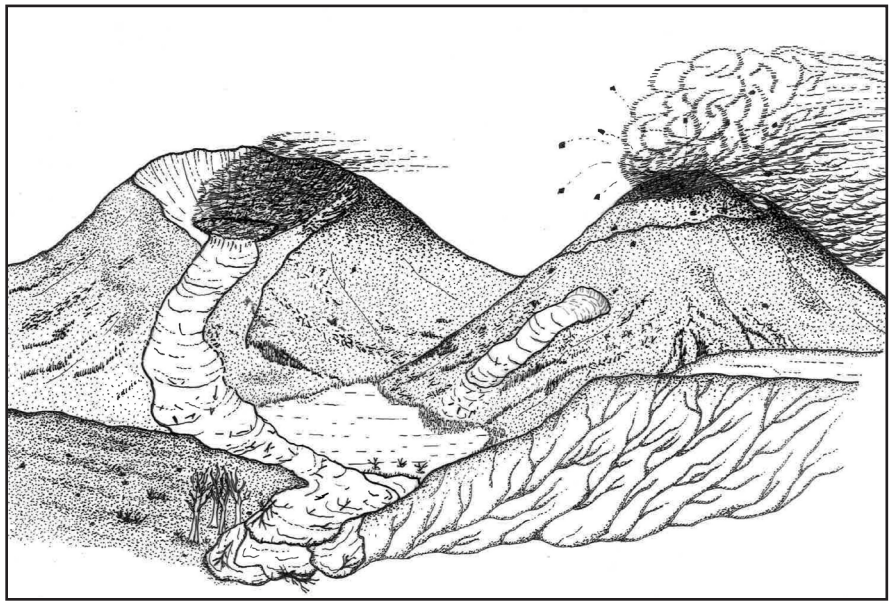
The Eocene Epoch (58 to 36 million years ago) was not a quiet time in southwestern Montana and northwestern Wyoming. A period of mountain building, called the "Laramide Orogeny" by geologists, was just ending, marked by the eruptions of a series of volcanoes in what geologists call the "Absaroka Volcanic Field." During these eruptions, volcanic vents ejected ash and pumice rock. This ash billowed down from the vent openings and covered the forests growing on the slopes of the volcanoes.

The drawings on the next page show reconstructions of Eocene landscapes before (top) and after (bottom) volcanic eruptions. Thriving forests that once covered the slopes of the volcanoes before the eruptions all died and were covered with ash. In the bottom drawing, a snowcap covering the high volcanic peak on the left has melted and mixed with ash and debris to form a mudflow. This mudflow (or lahar) cut a destructive path down the mountain slope and dammed a stream, creating a debris-filled lake. As the water in the lake rose, it drowned and killed the trees once growing along the stream. The water in the lake would eventually rise high enough to overflow the debris dam and surge down the old drainage channel as a flash flood.

The bottom drawing also shows a volcano that is still erupting. The force of the eruption has triggered a landslide that fills the lake with even more soggy debris. Falling ash covers the land, burying the trees and vegetation in the foreground. These trees would later become petrified. Eruptions like these could completely destroy the plant and animal life in the surrounding area, leaving only a barren wasteland. Gullies form quickly in soils without vegetation, and the erosion of hillsides increases. Geologists estimate that a single volcanic eruption could cover the landscape with debris layers up to 35 feet thick! Volcanic eruptions have the power to completely change the face of the landscape.

Gallatin Petrified Forest: Before and After

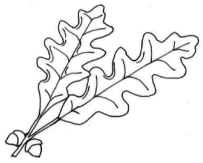




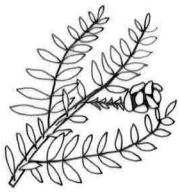
Magnolia

Sycamore

Buckthorn



Oak



Redwood

Laurel

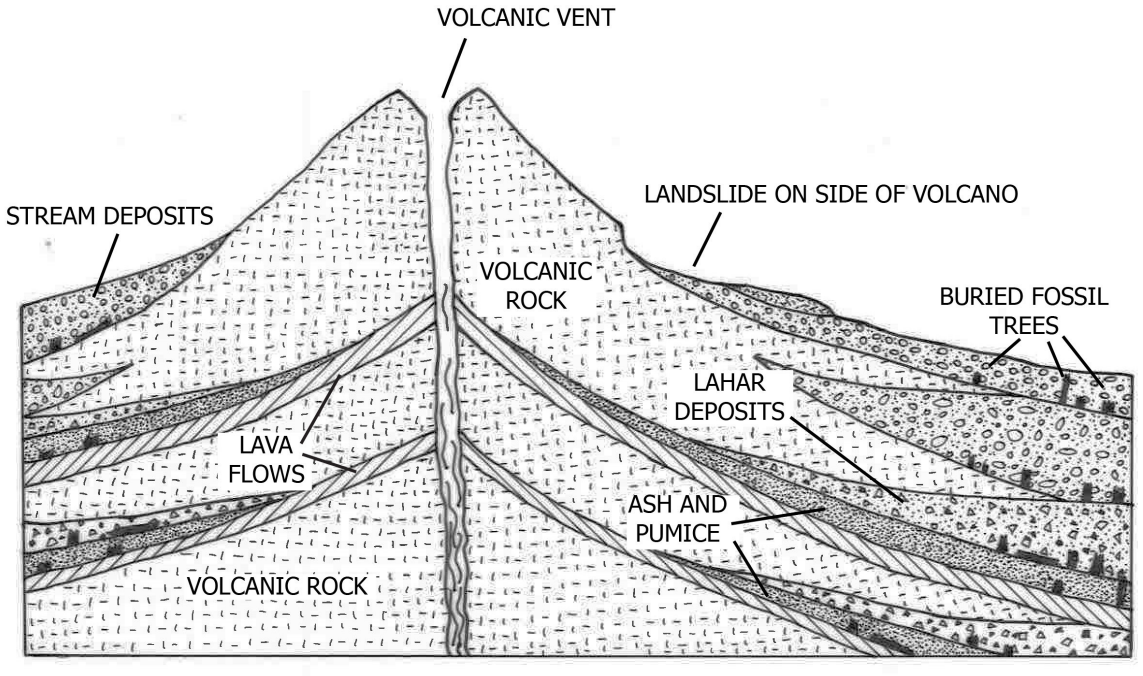
Geologists believe that as many as 27 different volcanic eruptions occurred in the Gallatin and Yellowstone areas. How do they know this? The rocks at the Gallatin Petrified Forest site are stacked in multiple layers of fossil forests, with younger forests overlying the older ones. Geologists have documented 27 layers of fossil forests in bed upon bed of volcanic rocks more than 2,000 feet thick. With each new eruption, volcanic sediments destroyed and buried the new forest growing on the land surface.

Over time, a new soil horizon gradually formed on the volcanic sediments and new trees took root. A new forest grew and thrived, and Eocene wildlife, such as prehistoric species of rhinos, horses, and camels, returned to the area. After an interval of time, geologic forces deep in the Earth caused the volcanoes to again stir to life, erupt, and bury the new forest in debris, killing the plants and animals living there. Geologists estimate that each episode of eruption activity may have lasted for about a year, with about 300 years between eruption episodes. Every eruption created a new fossil forest "in situ," meaning the eruption preserved the standing trees in place.

The Absaroka Volcanic Supergroup of the Eocene Epoch

Geologists identify how rocks formed and group similar rocks into units called "formations," which the geologists name and map. The formations in the Gallatin Petrified Forest area are all closely related by their volcanic origins and lumped into "groups," which in turn are collectively lumped into a much thicker unit called the "Absaroka Volcanic Supergroup." This is because the sedimentary and volcanic rocks of the supergroup, including ash and pumice, lahars, lava flows, and alluvium (stream and lake deposits) all resulted from volcanic eruptions. A volcanic eruption is a very powerful and sudden force. It has the power to change the course of streams, dam rivers to form lakes, create massive lahars, and form new mountains from the lava and volcanic rock ejected in the eruption. The formations of the Absaroka volcanoes really are a "supergroup" that preserved ancient forests.

The picture below shows a volcano cut in half (geologists call this a "profile drawing"). You can see the many different formations that are associated with a volcanic eruption. These formations of the Absaroka Volcanic Supergroup are described below.

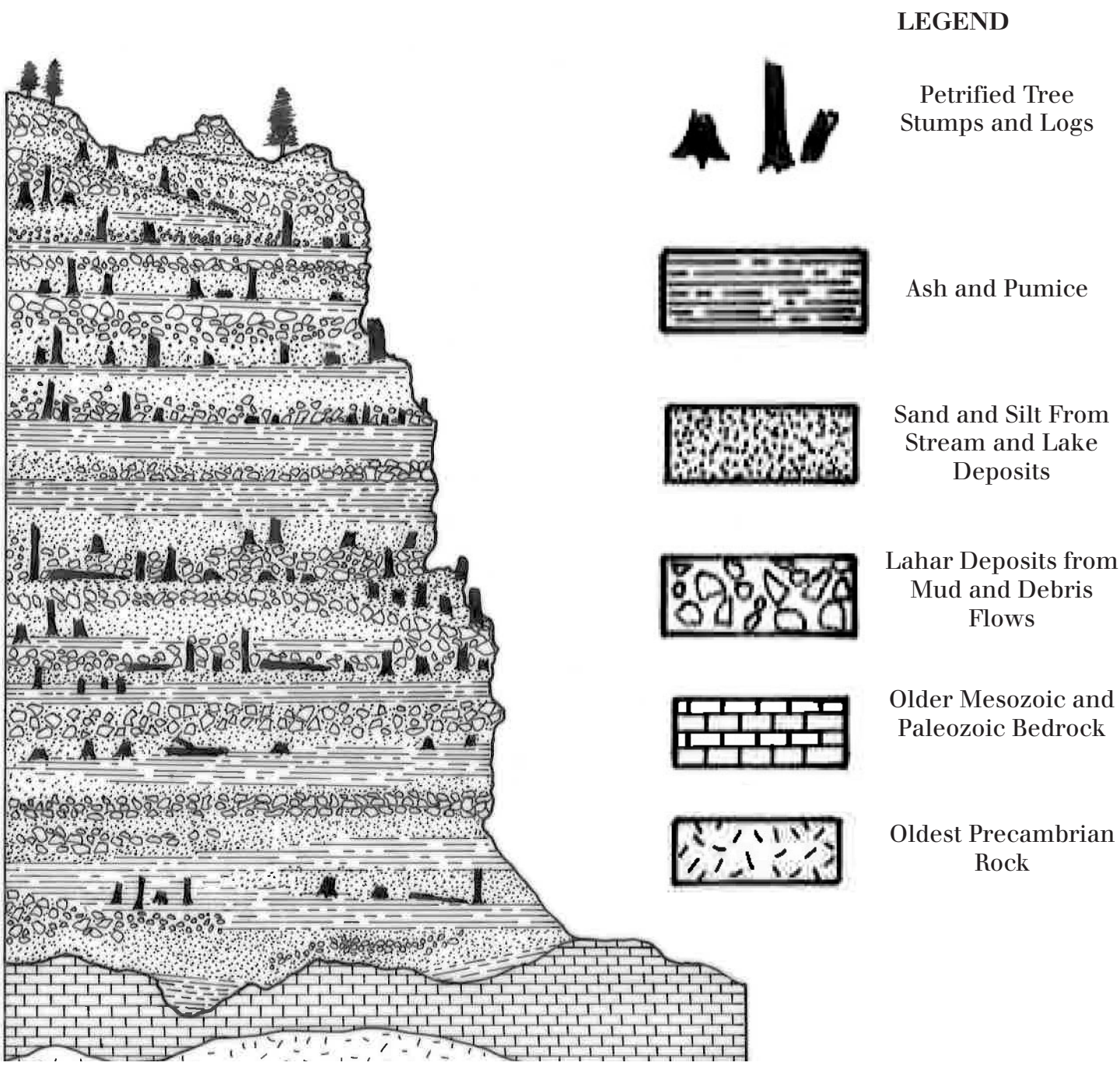


Lahar deposits: Imagine a volcanic peak covered with snow. When the volcano erupts, the intense heat melts the snow, creating a mud slurry that flows down the side of the volcano, sweeping away everything in its path. Lahar deposits are also called mudflows and debris flows.

Lake and stream deposits: When a lahar flows into a stream, it can dam up the drainage and create an instant lake where only a valley existed before. Trees growing in the valley are submerged as the lake levels rise. Once the water level rises above the lahar dam, erosion from the flowing water can pierce the dam and floodwaters rush down the drainage. Stream channels may shift, flooding trees that once grew in the stream valley.

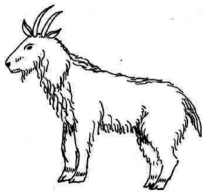
Ash, Pumice, and Lava Flow deposits: The volcano ejects ash and pumice into the air that can drift downwind in the atmosphere for many miles before falling to earth or can roll down the side of the volcano as a hot, glowing cloud of debris. Molten rock flows down the slopes of the volcano as lava or is ejected high into the air. Ash or molten rock can cover or burn trees growing on the slopes of the volcano. In almost an instant, the landscape changes dramatically. These rock types are all common in the formations of the Absaroka Volcanic Supergroup.

Profile of the Absaroka Volcanic Supergroup

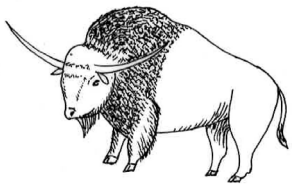


If you were able to cut across a cliff in the Gallatin Petrified Forest, you might see something like the drawing above. The drawing, called a "stratigraphic section," shows the many layers of fossil trees and the different rocks deposited during successive volcanic eruptions. This stratigraphic section shows the magnitude of the massive volcanic deposits at the Gallatin Petrified Forest—more than 2,000 feet thick! Geologists use different symbols to show each type of rock, which are identified in the Legend. The stratigraphic section shows that the volcanoes deposited rocks on much older Mesozoic, Paleozoic, and Precambrian rocks over an erosional surface called an "unconformity." An unconformity represents a break in the rock record over a long period of time, during which rocks were either not deposited or were eroded away. In this case, the break in time in some places is almost 550 million years!

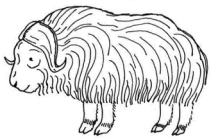
Pleistocene Epoch (The Ice Age): 10,000 to 2 Million Years Ago



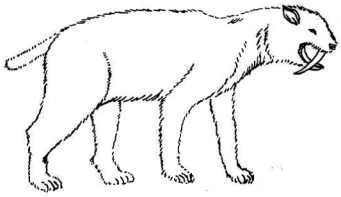
Mountain Goat



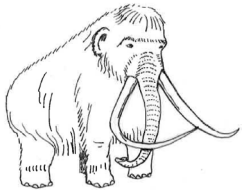
Bison



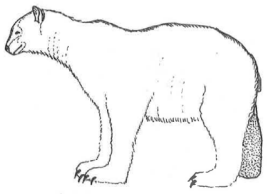
Musk ox



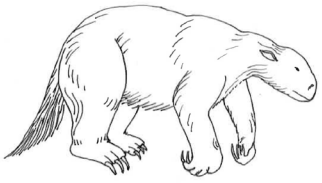
Sabetooth cat



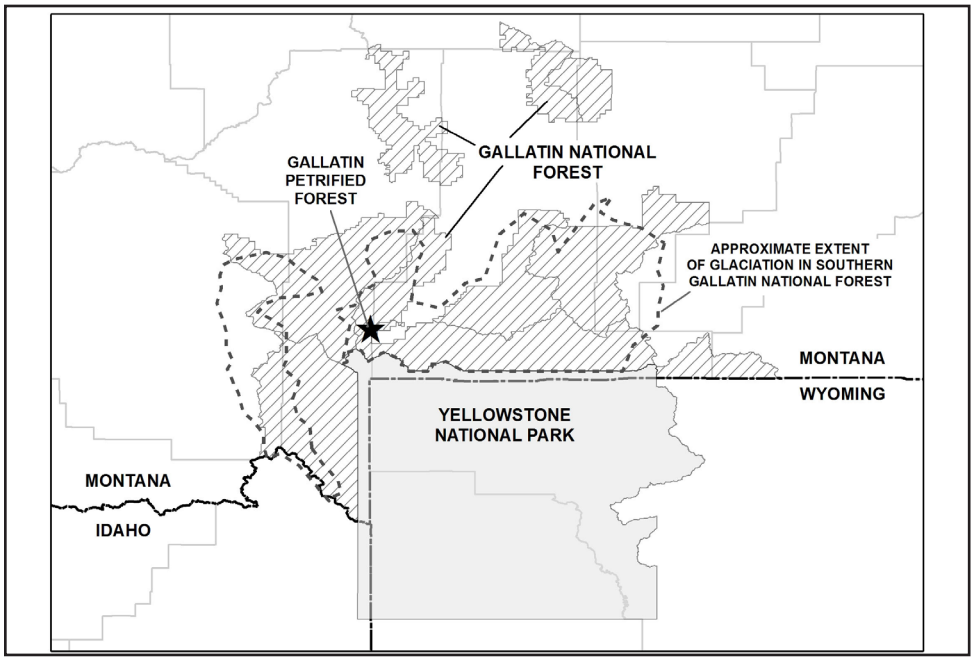
Mammoth

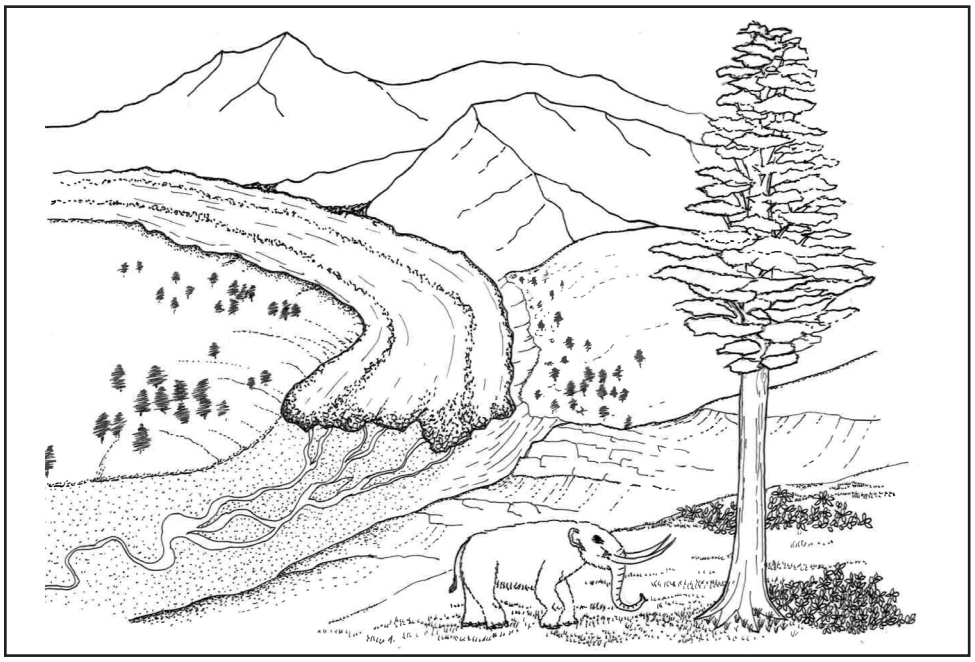


Short-faced bear



Ground sloth





The Pleistocene is called the “Ice Age” for good reason. Across the North American continent, a vast ice sheet descended down from Canada. In the Rocky Mountains, ice collected along mountain ranges and flowed down valleys as massive glaciers. The map shows the approximate extent of the glacial ice within the Gallatin National Forest. Ice also covered Yellowstone National Park and a glacier flowed north along the valley of the Yellowstone River. Pleistocene wildlife was very different from modern wildlife and many large species, such as the mastodon above, became extinct at the end of the Ice Age.

The Present Is the Key to the Past

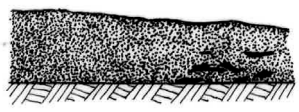
This is one of the first lessons learned by geologists. What it means is that the geologic events we observe today likely also took place in the past and shaped our world in a manner similar to what we see today. Volcanoes, floods, ocean tides, winds, rivers, and gravity behaved in the same manner throughout time. Our world is a very dynamic place, though we don't always notice the pace of most changes, except for major disasters like volcanic eruptions, earthquakes, landslides, and floods. A human lifespan is just a tiny moment in the age of the Earth. Geologists work to understand geologic time and the events that have occurred in the past.

The driving force of much of this change is "plate tectonics," the movement of the large plates of the Earth's crust, which results in the changing shapes and global positions of continents and oceans over geologic time. As the plates slowly move across our globe, volcanoes and earthquakes provide evidence of the immense powers at play. Other forces of change include glacial ice advancing and carving deep, U-shaped valleys, wind and water eroding mighty mountains until the mountains are flat, and basins filling with rock and debris washed down from highlands. Change is truly a constant in our world.

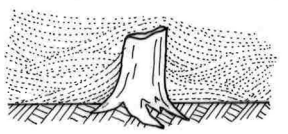
Fossils preserved in rocks provide clues about ancient environments and the kinds of plant and animal life that existed in the geologic past. Fossilized tropical ferns suggest warm, moist environments, while fossilized shark teeth, shells, and fish indicate that oceans once covered portions of the Earth that are now above sea level. Long before volcanoes erupted at the Gallatin Petrified Forest, southwestern Montana was at the bottom of an ancient sea where prehistoric creatures swam. Later, a vast mountain range formed and glacial ice covered the land. The geologic history of the Gallatin National Forest is a fascinating story!

Stratigraphic Puzzle

Many different types of deposits from volcanic eruptions buried the fossilized trees of the Gallatin Petrified Forest. The deposits dammed streams to form lakes that swamped the trees, channels migrated to new drainages and flowed down the mountains as floods, and mudflows swept down the sides of volcanoes, covering the trees. Ashfalls and lava flows from volcanoes also buried the trees. See if you can match the pictures below with the process that buried the tree. Hint: Think like a geologist about the energy of the process that deposited the sediments and the impact on a tree. For example, an ash fall has less impact than a flash flood. Think about the type of material deposited as well, such as hot lava; silty lake deposits; or coarse, gravelly streambed sediments (look at the legend on page 10). The direction of flow is from the left toward the right. The answers are provided on the back page of this book.



A



C

E

Lake Deposits _____

Slow Flowing Steam with Sand _____

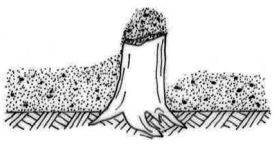
Molten Rock-Lava Flow _____

Ash and Pumice _____

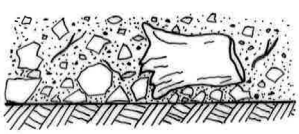
Lahar/Debris Flow _____

Fast Flowing Steam with Rocks _____

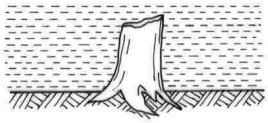
B



D



F



Word Search

GALLATIN
ABSAROKA
FORMATION
GLACIER
GEOLOGY
OAK
MAMMOTH
LAHAR
IGNEOUS
STUMP
BUCKTHORN
ERUPTION
FIR
CONGLOMERATE
EOCENE
REDWOOD
LOG
SYCAMORE
VOLCANO
PALEOZOIC
SANDSTONE
FOREST
MAGNOLIA
ASH
LAUREL
FOSSIL
MESOZOIC
TREE
PETRIFIED
SPRUCE
STRATIGRAPHY
AMMONITE
PALEONTOLOGY
CENOZOIC
WOOD

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

Coded Messages

Try to decipher the messages below. Each letter in the alphabet represents another letter. Write your answer below the code. A clue is given at the bottom of the page. ANSWERS ARE ON THE BACK OF THE BOOK.

Message #1:

ZSO BQONOTZ RN ZSO EOA ZW ZSO BCNZ

_____

Message #2:

IAM ORGGRIEF XMIBEZEMN ZCBMVI ARV VCSM

_____

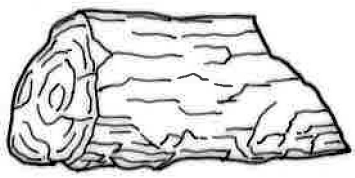
CZ IAM SCVI VXMJIRJKGRB ZCVVEG IBMMV EF IAM QCBGN

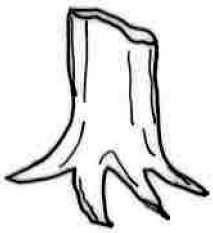
_____

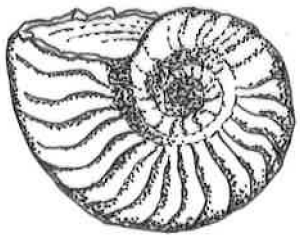
Scrambled Words

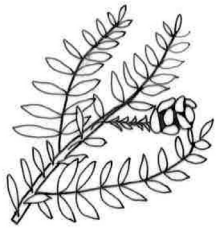
These words describing the Gallatin Petrified Forest are scrambled. Try to spell the word. As a hint, there is a drawing of what each word is. ANSWERS ARE ON THE BACK OF THE BOOK.

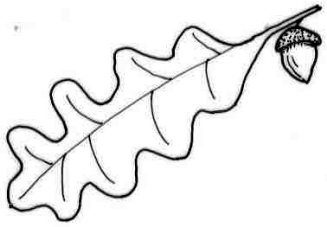
1. T D E E I I R F P O L G _____
2. K A O _____
3. O O A V C N L _____
4. P S M T U _____
5. A O M Y C E S R _____
6. D D E W O R O _____
7. N G L A A M O I _____
8. A E L L U R _____
9. K N H B U O R C T _____
10. E A I M N M O T _____
11. R D C I I O N _____

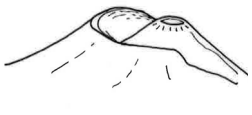


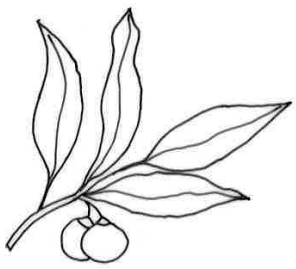












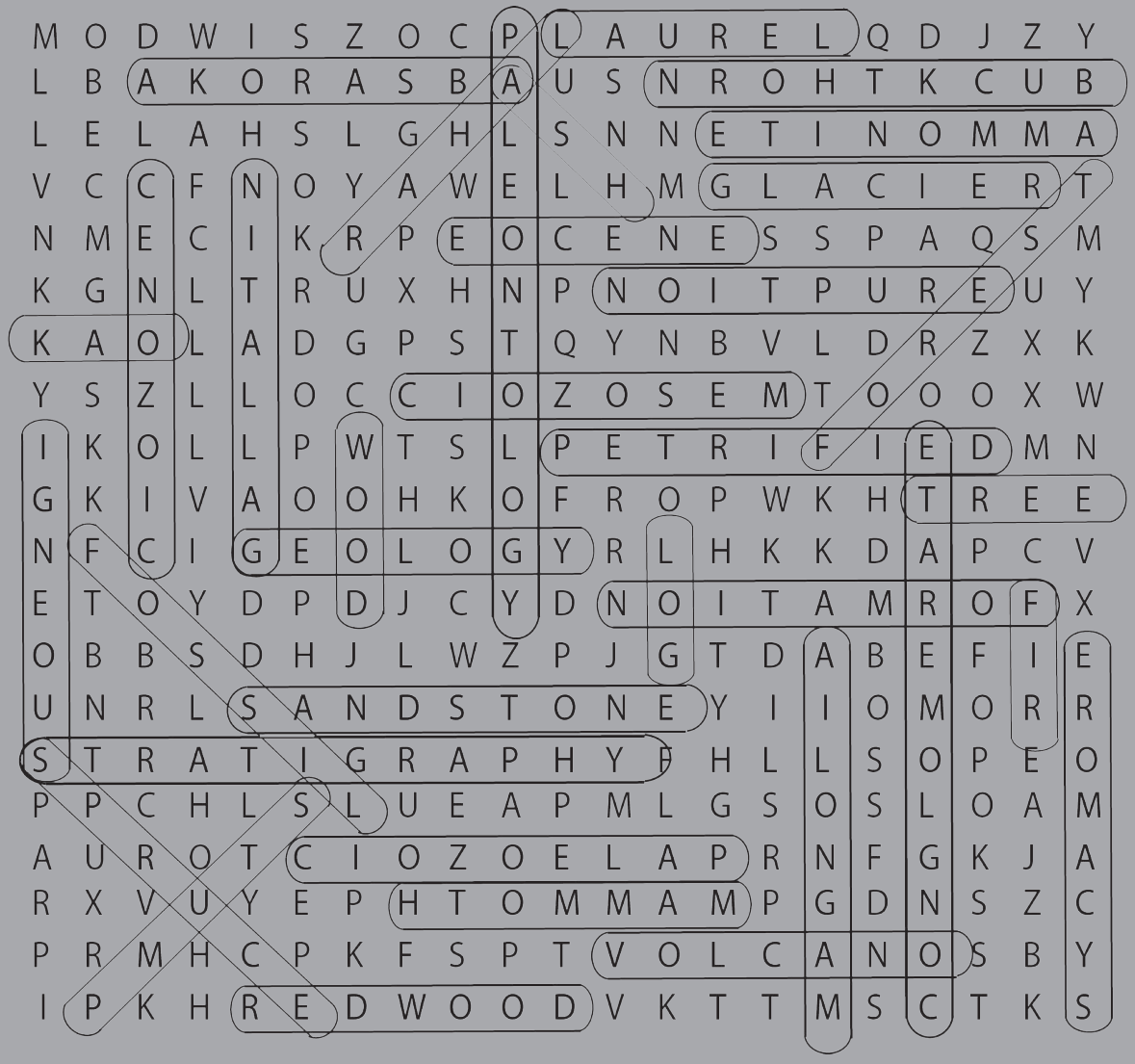
MESSAGE #1 CLUE: B REPRESENTS THE LETTER P; MESSAGE #2 CLUE: I REPRESENTS THE LETTER T

Answer Page

Stratigraphic Puzzle:

LAKE DEPOSITS - **F**
ASH AND PUMICE - **B**
LAHAR - **D**
SLOW FLOWING STREAM - **C**
FAST FLOWING STREAM - **E**
BASALT/LAVA FLOW – **A**

Word Search:



Coded Messages: The present is the key to the past.

The Gallatin petrified forest has some of the most spectacular fossil trees in the world.

Scrambled Words:

1. Petrified log
2. Oak
3. Volcano
4. Stump
5. Sycamore
6. Redwood
7. Magnolia
8. Laurel
9. Buckthorn
10. Ammonite
11. Crinoid

Illustrations and graphic design by Nancy Lamm.