

## **The Dinosaur Prophecy**

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We live in a dangerous cosmic neighborhood. In 1992, Jupiter's tidal forces tore Comet Shoemaker-Levy 9 into more than 20 fragments, some over 2 kilometers wide. In 1994, these fragments crashed, piece after piece, into Jupiter's atmosphere – causing fireballs of extremely hot gas, plumes of debris raining onto the planet and lingering dark dust patches – all more spectacular than astronomers had expected.

In November 2005, astronomers saw a meteoroid slam into a dark lava plain, producing a new crater on the moon. The pockmarked lunar surface indicates that such impacts have happened many times in the moon's long history.

Earth has also suffered dramatic impacts, but moving continents and mountain building have destroyed most records of Earth's past. To understand Earth's violent history, we have selected four locations from four different times – places where the evidence of tragedy and death remain.

65 million years ago, Earth was a much warmer world. There were no ice caps, sea level was higher and much of the planet was comfortable for life.

130 million years ago, the Atlantic had closed. South America and Africa were joined and Antarctica no longer collected ice.

150 million years ago, South America, Africa, and Antarctica were together with dinosaurs roaming from the Arctic to the Antarctic.

210 million years ago, all the continents belonged to a single great super-continent called Pangaea.

The first dinosaurs appeared in Pangaea in the Triassic – Some were fierce two-legged carnivores that may have hunted in packs.

The largest dinosaurs that ever lived flourished in the favorable climate of the late-Jurassic.

By the early Cretaceous, dinosaurs with feathers and light hollow bones shared the planet with their feathered cousins, the birds.

As the Cretaceous ended, some dinosaurs developed bony heads while others grew specialized arms. Except for the birds, all of these well-adapted and successful dinosaurs vanished in a moment of geologic time. And in their disappearance we find clues about our own future.

***The Immersive Earth Project***  
***Presents***  
***The Dinosaur Prophecy***

**Time: the late Triassic, 210 million years ago**

**Location: Ghost Ranch, New Mexico**

### *Death of a Colony*

Ghost Ranch, New Mexico hides one of the world's oldest and best-preserved dinosaur graveyards – buried under layers of sand and mud, turned to stone. Today scrub grass, mesquite, and desert mammals, reptiles and birds live here. When dinosaurs roamed this land, there were no birds and no flowering plants, none of the familiar shade trees, shrubs and grasses of today – only ferns and moss covered the ground under pine and ginkgo trees.

Geologic processes constantly recycle rock, laying it down in some places and eroding it away in others. Layers of various colors show different weathering and different types of rock with younger rock strata usually resting on top of older layers. These layers show that this area had cycles of severe drought and flooding.

To uncover the graveyard here, we must dig – excavating where nature has revealed dark red siltstone– a desert tomb 210 million years old. This graveyard preserves one of the oldest known dinosaurs in North America – a meat-eater called *Coelophysis*.

This rock layer has yielded over 1,000 individual fossils, almost all *Coelophysis*. For some reason these dinosaurs gathered together, perhaps looking for water, and then died together.

Lab inspection of slabs reveals that the adult *Coelophysis* was about the size of a large dog -- a fast and deadly predator with powerful hind legs and a long slender body.

The long narrow skull houses a mouth filled with sharp serrated teeth and a double-hinged lower jaw for slicing prey. It ate almost anything it could catch - including other *Coelophysis*!

The arrangement of these fossils and the sandy siltstone around them suggests that they collected like a logjam in a river. However the extreme arch of these spines and necks shows that the bodies dried out after death, but before their watery burial.

Many of these skeletons are complete with little evidence of chewing. This lack of scavenging or weathering indicates that these *Coelophysis* died together. Their bodies dried out and the water returned to bury and preserve them.

*From these slabs we can imagine a group of Coelophysis searching for water or food and then trapped by a devastating flood.*

*Current evidence only hints at the cause of death. It may have been drowning in a flash flood or dying of thirst as the land turned to desert.*

**Time: the late Jurassic, 150 million years ago**  
**Location: Dinosaur Monument Quarry, Utah**

### *Death of an Ecosystem*

The Green River meanders through Northeastern Utah. Its ivory sandbars arc around river bends as mud and sand settle in layer after layer. 150 million years ago a similar winding river buried thousands of dinosaur bones in sand and gravel.

Today this buried sandstone forms one wall of the Dinosaur Monument Quarry, formerly known as the Carnegie Quarry. Within it are more than 1,600 dinosaur bones. Nowhere else on Earth can you stand on the very spot where dinosaurs once lived and see so many of their bones still in their final resting place.

Giant sauropods like the *Apatosaurus* and *Diplodocus* make up about 75% of the quarry's dinosaur fossils. Bones of meat-eaters account for less than 5% – a common ratio in ecosystems. Many of these specimens are among the best ever found, including juveniles and skeletons complete with skulls.

Bones show how the dinosaurs looked. Footprints tell how they behaved. Drawn to shallow lakes and meandering streams, huge dinosaurs left their prints to dry and harden in fine-grained mud. Later water washed sediment over the tracks – protecting and preserving them.

A sauropod weighing well over 10 tons made these footprints. This dinosaur walked on four huge feet – each making a deep print in the mud.

*Over time, long fingers of the sea flooded this valley. Layer after layer of mud, silt, and sand buried the land and its pockets of dinosaur bones -- closing this chapter in the dinosaur story.*

**Time: the Early Cretaceous, 130 million years ago**  
**Location: Liaoning, China**

### *Death of a Community*

Located in northeastern China, Liaoning is famous for farmland and factories—and for some of the most important fossil beds in the world. Two vertical walls define this famous excavation site. A large metal and glass structure has been built to preserve a section of this historic quarry and to display fossils just as they were discovered.

On the quarry wall inside, dark layers represent lava ash, deposited between other sediments. These rocks are called paper shales because each layer is as thin as a sheet of tissue paper.

Some of the most spectacular specimens were crushed flat by the ash. Instead of mounting these dinosaurs as standing skeletons, we must imagine how they would look if they could crawl, swim, or fly out of the stone slabs.

All kinds of animals and plants have been found here. Fish, leaves, and insects are the most common, but frogs, lizards and turtles thrived here as well.

This quarry is most famous for its birds and non-flying feathered dinosaurs. More than a dozen true birds have been identified. Some of the non-flying dinosaurs have feathers that look like those on modern birds. The ash even preserved the long intricate tail feathers of this *Confuciusornis*. These fossil imprints tell each feather's shape, but not its color. The Liaoning Museum of Paleontology displays models showing feathered dinosaurs with the coloration of modern birds. These models also show that the feathers needed for flight evolved long before feathered dinosaurs began to fly.

Using the richness and detail of these fossil imprints, the American Museum of Natural History has reproduced the forest of Liaoning. This is the marshy shore of a giant lake. Primitive birds fly overhead, while other feathered dinosaurs climb the trees.

In the distance a volcano rumbles.

Chasing food on the forest floor is the *Sinornithosaurus*, a small relative of the *Allosaurus* with real feathers on both fore and hind limbs. Feathers probably kept this dinosaur warm.

The *Microraptor gui* is a very birdlike dinosaur that also has feathers on all four limbs. It may have glided from tree to tree like a flying squirrel.

*Closer to the volcano, we find the nest of a Confuciusornis. This is the most common bird found in Liaoning. It might have laid eggs in a nest just as modern birds do and protected its nest from predators.*

*Birds like the Confuciusornis evolved from a feathered dinosaur millions of years before this scene. Fossils show that birds and other feathered dinosaurs like the sinornithosaurus lived at the same time and would have interacted as they searched for food in the shadow of a great volcano.*

*Although these flying and non-flying dinosaurs were predator and prey, their real enemy towered in the distance.*

**Time: the late Cretaceous: 65 million years ago**

**Location: the Badlands of North Dakota**

### ***Death of All Dinosaurs***

Sixty-five million years ago, a sudden and catastrophic event may have caused the disappearance of all dinosaurs in a blink of geologic time. In the Badlands of southwestern North Dakota,

scientists have found a site with a continuous fossil record of the time when the dinosaurs vanished. The uplift of the Rocky Mountains has folded the rocks here, creating cliffs that expose millions of years of geologic deposition.

A mysterious orange layer in the rock strata forms a boundary – The mudstone below it represents a floodplain deposit and contains the bones of many dinosaurs. In the orange layer are small glass balls that may have fallen through the atmosphere. A microscope shows quartz fragments shocked by an explosion. The orange soil is rich in iridium – perhaps from a volcano or outer space. Above it, the bones of non-flying dinosaurs are gone and only the birds remain.

The Pioneer Trails Regional Museum in Bowman, North Dakota houses thousands of fossils from below and above this orange layer. These leaves are from plants that nourished the dinosaurs. Above the orange layer, these plants vanished – replaced by new plants adapted to a new environment.

This aquatic turtle was found just above the orange layer marking the dinosaur extinction. A white plaster cast preserves its fragile shell. Inside the shell a scientist measures the length of a bone and compares its length to the same bone of a much larger turtle. These fossils indicate that some larger animals did survive the dinosaur extinction, perhaps because of their reclusive habits or scavenger diet.

Unlike the turtle, the *Triceratops* died. Today we can see the frill and one horn of a *triceratops* protruding from the rock layer. Perhaps the complete skull is still buried in the hillside. In the lab, curators restore a Triceratops frill and horn. These fossils are from the *Triceratops* found closest to the orange layer. Each piece must be carefully positioned to determine the size and condition of North Dakota's last dinosaur.

Small fossils from many dinosaurs tell us about the behavior of individuals and the health of a community. This dinosaur dung contains the remains of the last meal of a *Tyrannosaurus rex* and includes a *T-rex* tooth. Either this dinosaur swallowed its own tooth or was eating another *T-rex* before it died. Teeth reveal much about the T-Rex, Groves in the outer edge of this *T-rex* rib were made by teeth of another *T-rex* – further evidence that *T-rexes* did eat each other. Most isolated *T-rex* teeth found here are from juveniles, rather than adults – indicating a healthy *Tyrannosaurus rex* population with many young.

These fossils show what life was like before the mysterious orange layer fell from the sky, 65 million years ago.

*Far south of the Dakotas, a 10-kilometer wide asteroid raced toward Earth. Its plunge through the atmosphere created temperatures hotter than the sun's surface. It landed in a shallow sea of sulfur-rich rock – producing a sulfuric acid rain strong enough to burn skin. Because of the low impact angle, much of the debris flew down range toward North America. Oxygen levels in the air were 10% higher than today - fueling fires all over the continent.*

*In the Badlands, a wall of darkness rolled in from the south, filling the entire sky. Soon a rain of burning rock set fire to the forests. Soot and floating ash could have blotted out the sun for*

*months, possibly years. The fallout contained glass balls, shocked quartz and iridium-rich debris– all deposited in an orange layer.*

*Up to 70% of all species, including the non-flying dinosaurs, perished -- leaving only their bones behind as a warning.*

### ***Hope for Humanity***

Disasters challenge us today, but we have better eyes for warning and more options for action. High overhead NASA and NOAA satellites watch the Earth for storms, floods, and signs of volcanic eruptions. We can see ice caps retreating, rainforests disappearing, temperate forests increasing, and changes in ocean currents. We look for temperature changes on land and sea and measure atmospheric levels of greenhouse gases. We monitor forest fires, volcanic plumes, and tsunami waves. We can track hurricanes from tropical storms to landfall. Each year we know more about the condition of our world and are more prepared for survival.

While satellites watch the Earth, astronomers search space, looking for approaching asteroids. In 2004, they identified a near-Earth asteroid called Apophis – a massive boulder wider than three football fields. On April 13, 2029, Apophis will come within 3 Earth diameters of our planet – inside the orbit of the highest satellites. An asteroid this large comes this close to Earth only once every 1,500 years

In 2036, Apophis has a 1 in 5000 chance of hitting Earth. Scientists are proposing a gravity tug spacecraft to nudge Apophis enough to miss our planet – a challenging mission to attract the spinning asteroid and drag it very slowly out of our way.

The dinosaur extinction gives us a clear warning, that we must understand the changes on our planet and guard against threats from space. We are responsible for our survival on Earth.