Name: _____ Date: _____

The Clay That Was Meant to Be a Clock

Reading level 14 · 1781 words

In a gorge outside the hill town of Gubbio, in central Italy, the rock walls are pale limestone that settled on an ancient seafloor, one thin layer upon another, over an immense stretch of time. Near the middle there is a seam you could cover with a fingertip: about a centimeter of clay. Below it, the stone is packed with the fossils of tiny sea creatures of many kinds. Inside the clay there are none, and above it only a few kinds remain. The seam marks the end of the Cretaceous period, the same moment at which the non-bird dinosaurs vanish from the fossil record on land. In the 1970s a geologist named Walter Alvarez kept walking past it, because he was there for something else.

The something else was magnetism. Earth's magnetic field flips at irregular intervals, so for long stretches a compass would have pointed south, and sediment on the seafloor records each flip as its grains settle. Alvarez was sampling the limestone of the Apennine Mountains to pin down the timing of those flips, which had become key evidence for plate tectonics. The clay was a distraction, but it raised a question he could not put down. Had the change at the seam taken a few years, or many thousands? At the time, most fossil experts pictured a slow decline. The answer depended on how long one centimeter of clay had taken to build up, and nobody knew how to measure a span of time that had closed some sixty-six million years earlier.

His father offered a timer. Luis Alvarez, a physicist who had won the Nobel Prize in 1968, suggested beryllium-10, a radioactive isotope that drifts into sediment at a steady rate and then decays. Measure how much is left, correct for the decay, and in principle you can work out how long the layer took to collect. The plan failed before a single sample was run, because the published decay rate for beryllium-10 turned out to be wrong. With the corrected figure, any beryllium laid down in clay that old would have decayed away completely. The clock had run down long before anyone came to read it. It was the first false start in the story, and not the last.

Luis's second idea was cleverer. A fine rain of meteorite dust falls on Earth all the time, at a fairly steady rate, and that dust carries iridium, a metal that is very scarce in Earth's crust. So the iridium in the clay should record how much time had passed. If the layer had built up slowly, it would hold a small but measurable dusting, about one atom of iridium for every ten billion other particles. If it had formed in a geological instant, the iridium would be too faint to detect. Either result would have answered Walter's question. What the chemists Helen Michel and Frank Asaro found was about three parts per billion, more than thirty times what either guess allowed. The clock had not been read. Something had swamped it.

A result that extreme might have been a local accident, so Walter searched the published studies for another place where the same boundary was exposed, and he found one in Denmark. A colleague ran the test, and the iridium spike was there too, so whatever had happened was not limited to one patch of seafloor. The first explanation at hand was an old one. In 1971 a paleontologist and a physicist had proposed that a nearby supernova, an exploding star, had killed the dinosaurs. A supernova would scatter iridium, but it would also leave plutonium-244. The team tested for it, and when the first sample came back positive, they were elated. Then they repeated the test and found that the first sample had been contaminated by an experiment in a nearby lab. There was no plutonium at all.

With the supernova ruled out, the team proposed in 1980 that a large asteroid had struck Earth. It would have thrown enough crushed rock into the air to darken the sky around the world, halting photosynthesis and collapsing food webs. The idea set off one of the most productive arguments in modern science: within ten years, more than two thousand papers had been written about it. Because no one had seen the event, the idea had to be tested by its effects. An impact that size should leave grains of quartz scarred by a shock wave, drops of melted rock cooled into glass, and jumbled beds laid down by giant waves. Unless moving plates had since destroyed it, it should also leave a crater. One by one, each of these turned up at the boundary, and the crater came last.

The crater, as it happens, had already been seen. In 1978, Glen Penfield and Antonio Camargo were working for Pemex, the state oil company of Mexico. They were part of a survey that flew over the Gulf of Mexico, north of the Yucatán Peninsula, measuring the magnetism of the rocks below. When Penfield laid the magnetic readings over gravity maps, he saw a shallow, buried bullseye about 180 kilometers across. To him it could only be an impact, but the company said the feature came from volcanoes and kept the data private. It did let the two men present their results at a conference in 1981. After the Alvarez paper came out, Penfield wrote to Walter Alvarez about the structure and got no answer. When he asked for rock cores from old wells in the area, he was told they had been lost or destroyed.

The pieces were joined by a graduate student and a newspaper reporter. Alan Hildebrand, at the University of Arizona, knew nothing of Penfield's work; he and his adviser were hunting for the crater by following thick deposits of impact debris, first in Texas and then around the Caribbean. In 1990 Carlos Byars, a reporter who had written about Penfield's claim years before, told Hildebrand about it. Hildebrand and Penfield then tracked down two drill samples from the Pemex wells that had been sitting in storage in New Orleans for decades, and the rock showed clear signs of shock. Their paper naming the Chicxulub crater came out in 1991. One of the great finds of twentieth-century geology had waited more than ten years, not because the idea was weak but because of a company rule, missing cores and an unanswered letter.

Since then the event has been measured with a precision that would have amazed the Alvarezes. In 2013 Paul Renne, of the Berkeley Geochronology Center, used argon-argon dating to place the impact at 66.043 million years ago, with an uncertainty of about 11,000 years either way. In 2016 an international team co-led by Sean Gulick of the University of Texas drilled into the ring of peaks inside the crater. In the rock they brought up, they found that about 425 feet of material had piled into the crater within a single day, a pile taller than a thirty-story building and one of the fastest rates of buildup ever found in rock. The cores held charcoal from burned land and rubble swept in by the backwash of the tsunami. What they did not hold was sulfur.

That absence is the key to the extinction. The seafloor rock around Chicxulub is rich in minerals that contain sulfur, so their absence from the cores suggests that the impact turned them to vapor and threw at least 325 billion metric tons of sulfur into the atmosphere, roughly ten thousand times the sulfur released by the eruption of Krakatoa in 1883. High in the stratosphere, droplets of sulfuric acid may have cut the sunlight reaching the ground by more than half, while soot and fine dust deepened the shade. Freezing weather probably lasted at least three years. Gulick summed it up as a short burst of fire near the crater, followed by a long chill across the planet. Once plants and plankton could no longer make food from sunlight, the food chains that depended on fresh growth failed from the bottom up, on land and in the sea.

The survivors make sense in that light. Almost no land animal heavier than about 25 kilograms came through. The mammals that did were mostly the size of rats, able to shelter in burrows and live on insects, worms and snails, which in turn fed on dead plants and animals: a food chain that did not need the sun. About half of the crocodile groups, which can go months without eating, survived, though none of the large ones did, and more than four in five turtle species made it. Nothing in the fossils suggests that the last non-bird dinosaurs could dig, swim or dive to shelter. And if, as a growing number of experts think, they were warm-blooded, their large bodies needed far more food than the broken world could supply. Of all the dinosaurs, only a small fraction of the birds survived, and their descendants number at least 11,000 species today.

None of this has settled the argument, and the argument has not always been gentle. While the last dinosaurs lived, eruptions in western India were laying down the lava fields now called the Deccan Traps, releasing gases that changed the climate over perhaps two million years. The paleontologist Gerta Keller has long argued that the volcanoes, not the asteroid, did the decisive damage. In 2010, forty-one scientists wrote a review in the journal Science that blamed Chicxulub, and dozens of others challenged its methods and its conclusions, and at times the dispute turned from the evidence to the honesty of the people presenting it. Newer evidence has complicated both sides. The Deccan eruptions began before the impact, but their flow more than doubled right after it, and some models suggest that the shaking from the

impact helped to set them off.

So what, exactly, caused the extinction? The question is less simple than it sounds. On Seymour Island, off the tip of Antarctica, one team found that species vanished in two pulses, one matching a volcanic warming and the other matching the impact. A 2020 study modeled dinosaur habitats under many scenarios and found that dimming from the impact wiped out good habitat nearly everywhere, while no volcano scenario did. Ancient climate is hard to model, though, and how much blame each deserves is still open. The original clock, at least, has been read. In 2001 a team used helium-3, another trace of the steady rain of space dust, and found that the boundary clay had settled in about ten thousand years: a blink for geology, and fast enough to mean that life had turned over extremely quickly.

Questions

1. Why did Walter Alvarez want to know how long the clay took to form?

A. To find oil under it
B. To tell whether the extinction was sudden or gradual
C. To date the town of Gubbio

2. Why did the beryllium-10 plan fail?

A. The real decay rate meant none would be left to measure
B. The clay had no beryllium in it at all
C. The Danish site was too far away

3. What does "contaminated" mean in the account of the plutonium test?

A. Proved correct
B. Measured twice
C. Spoiled by material from somewhere else

4. What does the Chicxulub story suggest about how discoveries get made?

A. Good evidence is always accepted at once
B. Evidence can wait years for reasons that have nothing to do with science
C. Oil companies never find anything useful

5. Why was the missing sulfur in the crater cores so important?

A. It showed the sulfur had been blasted into the sky, where it dimmed the sun
B. It proved there was no impact
C. It meant the crater was a volcano

6. Which statement best matches the evidence about the Deccan volcanoes?

A. They played no part at all
B. They began before the impact and grew stronger right after it
C. They erupted only after the dinosaurs were gone

Words to know

isotope: atom variety
iridium: rare metal
supernova: exploding star
stratosphere: high atmosphere
photosynthesis: plants making food
contaminated: accidentally polluted

Answer key: The Clay That Was Meant to Be a Clock

1. B. To tell whether the extinction was sudden or gradual
2. A. The real decay rate meant none would be left to measure
3. C. Spoiled by material from somewhere else
4. B. Evidence can wait years for reasons that have nothing to do with science
5. A. It showed the sulfur had been blasted into the sky, where it dimmed the sun
6. B. They began before the impact and grew stronger right after it