Seeking the deadly roots of the dinosaurs' ascent

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Drilling deep beneath the modern landscape of New Jersey brings up layers of ancient soils from the time of the extinction. They hold extremely high levels of carbon dioxide. Credit: Kim Martineau/Earth Institute

Over the past 450 million years, life on earth has undergone at least five great extinctions, when biological activity nosedived and dominant groups of creatures disappeared. The final one (so far) was 65 million years ago, when it appears that a giant meteorite brought fires, shock waves and tsunamis, then drastically altered the climate. That killed off the dinosaurs, setting the stage for mammals–and eventually us–to evolve. Many scientists are now starting to think we are on the edge of a sixth extinction—this one driven by human destruction of other species and their habitats, and our quickening releases of carbon dioxide into the air, which threatens to bring another round of rapid climate change.

The causes of the fourth extinction–the one that paved the way for the dinosaurs–are a mystery. This is the province of paleontologist Paul Olsen and geologist Dennis Kent of Columbia University's Lamont-Doherty Earth Observatory. They have been studying it for decades. After gathering clues from sites including ancient lava flows in Morocco, wave-washed sea cliffs along the coast of Wales, and in rocks deep beneath the modern landscapes of New Jersey and Pennsylvania, they may be getting closer to an answer–one that could have parallels to today. (See a slideshow from England and Wales.)

This Triassic-Jurassic extinction (also known as the End-Triassic)–happened 201.4 million years ago. It wiped out half the species on earth: eel-like fish called conodonts; mammal-like swamp-dwelling therapsids; early crocodilians; monkey-faced tree-dwelling lizards; many broad-leaved plants; and others. Dinosaurs were until then a relatively minor group, but hung on and subsequently evolved rapidly in size and diversity. Until recently, the exact timing remained murky, but by 2002 evidence from fossils and other sources showed it was extremely sudden—spanning just a few thousand years or maybe less, at 201.4 million years ago. As for the causes, among other things, scientists have contemplated gradual shifts in climate and sea levels that reached a deadly tipping point. However, bets today have shifted to massive volcanic eruptions that alternately cooled and heated the atmosphere with soot and carbon dioxide–much like human pollutants today. Recently, Olsen and Kent have introduced another possibility: a meteorite like the one that killed the dinosaurs. But evidence for all the ideas remains incomplete. "The only thing we can say for certain about the Triassic-Jurassic extinction is that it happened," said Olsen. "It could have happened over 10,000 years, or it could have happened in a day." [(Hear an interview with Olsen on the coast of Wales)]

The rocks may eventually reveal "great lessons about what lies ahead for us in the future," says paleontolgist Paul Olsen.

The two researchers have been at this for a long time. When Olsen was 14, he and a friend heard that dinosaur footprints had been discovered in a quarry near their suburban New Jersey home. They raced over on their bikes. The boys were soon cataloging thousands of fossils and footprints from the late Triassic and early Jurassic. In the course of a successful public drive to preserve the quarry, the teen Olsen appeared in Life magazine and got a commendation from then-president Richard Nixon. He went on to become a leading paleontologist. Kent, also from New Jersey, is a top expert in dating ancient events using periodic reversals of earth's magnetic field, which are preserved in rocks. He is a pioneer in the field on many levels. In 1977, he published one of the first papers showing that the extinction associated with the end of dinosaurs was very sudden, helping set the stage for the later acceptance of the meteorite theory, around 1991. Last year, he coauthored a study pushing back the date of the earliest sophisticated human tools in east Africa to 1.8 million years ago.

In 2002, Olsen and Kent coauthored a paper in the journal Science showing that large dinosaurs showed up in what is now New Jersey just 10,000 years after the Triassic extinction. Moreover, they showed that rocks from that time contain a spike of iridium–an element rare in earth's crust, but abundant in meteorites. Could an earlier meteorite have cleared the way for the dinosaurs, as well as having later killed them off? (It was a separate layer of iridium found by other researchers that helped clinch the meteorite theory of the dinosaurs' demise.) Soon, other researchers found seemingly related evidence near the Triassic-Jurassic boundary, including roughly matching iridium layers in Morocco and Nova Scotia, and quartz in Italy apparently shattered by some gigantic impact. But the case was inconclusive; for one thing, there was no known meteorite crater from that time big enough to have spread such an iridium layer, nor caused global damage.

Swamp-dwelling therapsids, characteristic of Triassic times, quickly disappared, to be replaced by dinosaurs. The dinosaurs later disappeared just as suddenly. Credit: Arthur Weasley, Dmitry Bogdanov, Wikimedia Commons

Meanwhile, Kent, Olsen and others began to build the case for volcanism. Roughly concurrent with the extinction, the single giant continent of Pangaea, then comprising most of earth's landmass, began splitting up. One rift evolved into the Atlantic Ocean, as new continents moved apart; this was accompanied by repeated massive outpourings of lava over hundreds of thousands of years, forming the Central Atlantic magmatic province—igneous rocks that underlie today's coasts of eastern North America and parts of Brazil and west Africa. Sulfur particles from eruptions would have darkened skies for years, chilling the planet. Such particles settle quickly, but another major component of volcanic eruptions is carbon dioxide, which stays in the air for centuries, warming it up. Thus, alternate chills and heat waves would have prevailed.

Kent and Olsen have gathered perhaps the clearest evidence of such a scenario so far. Last year, in another Science paper, they showed that lava flooded what is now the U.S. northeast several times in spurts separated by about 200,000 years each. Using deep drill cores penetrating below today's heavily settled landscape, they have analyzed those lava sheets, along with intervening layers of ancient soils built up during pauses in the volcanism. The soils, they found, contain spikes of carbon dioxide five to ten times the levels of today—enough to kill off much plant and animal life with excess heat, and acidify the oceans with chemical reactions. "The flipping back and forth between extremes of hot and cold, quite possibly would be worse than either one alone," said Olsen. The earliest lavas in the U.S. northeast seem to come about 10,000 years after the sharp extinction boundary, so it is hard to show a connection there; but lavas in the Atlas Mountains of Morocco that Olsen has sampled seem to coincide directly with it. This year, the scientists drilled more cores in New Jersey in an attempt to refine their data.

In 2010, the meteorite idea popped up again, when a separate research group re-dated a badly eroded meteorite crater near Rochechouart, western France, previously thought to be 214 million years old. Instead, they found it is 201.4 million years old—exactly matching the T-J boundary. The crater is only a sixth the size of Mexico's Chicxulub crater, which is correlated with the dinosaurs' demise, and probably not big enough to cause global catastrophe—but enough to intrigue Olsen and Kent. They have been drawn also by accounts of recently identified sedimentary rocks along sea cliffs in England, Wales and Northern Ireland from the same time. One layer seems to have been formed or altered by some giant tsunami or earthquake—a possible product of the impact. "We still favor volcanism, but a role for a meteorite in softening up ecosystems for the onslaught that followed is not impossible," said Olsen. "At this point, we have a big hole; evidence of shaking; an iridium layer; and a disappearance,. All around the same time. But we don't know if it was at exactly the same time." As Kent recently told Nature reporter Roff Smith: "The only way we are ever going to be able to unravel this mystery is to work out a timeline, as precise as we can make it, of all the various events around the world that led up to it."

In 2011, Kent and Olsen headed to the United Kingdom to investigate how the rocks there relate to the extinction—specifically, whether they contain an iridium spike indicating a meteorite strike.Olsen has also visited the Atlas Mountains of Morocco, where giant sheets of volcanic basalt and other rocks dating to this time lie exposed. In 2012, they also returned to a site that is a staple for college geology-class field trips: a rock layer in Exeter, Pa., that is one of the few places where the sharp but often deeply buried Triassic-Jurassic boundary is clearly visible to the naked eye and easily accessible. The layer sits exposed in a bluff near a housing development. They hope to drill this site as well.

Whatever the exact mechanisms of the extinction, the researchers see parallels with today. Rapid changes to the atmosphere, including massive carbon dioxide releases, obviously took a toll–possibly on time scales similar to our own current boom in carbon-dioxide production and the resulting warming of the world. “There probably are very significant lessons to be learned about processes in the doubling of CO2,” said Olsen. “We have to get, however, the pattern, and the basic chronology and the basic history right first, before we try to learn great lessons about what lies ahead for us in the future.”

Provided by Columbia University