Most precise dates yet suggest comet or asteroid impact was last straw for dinosaurs

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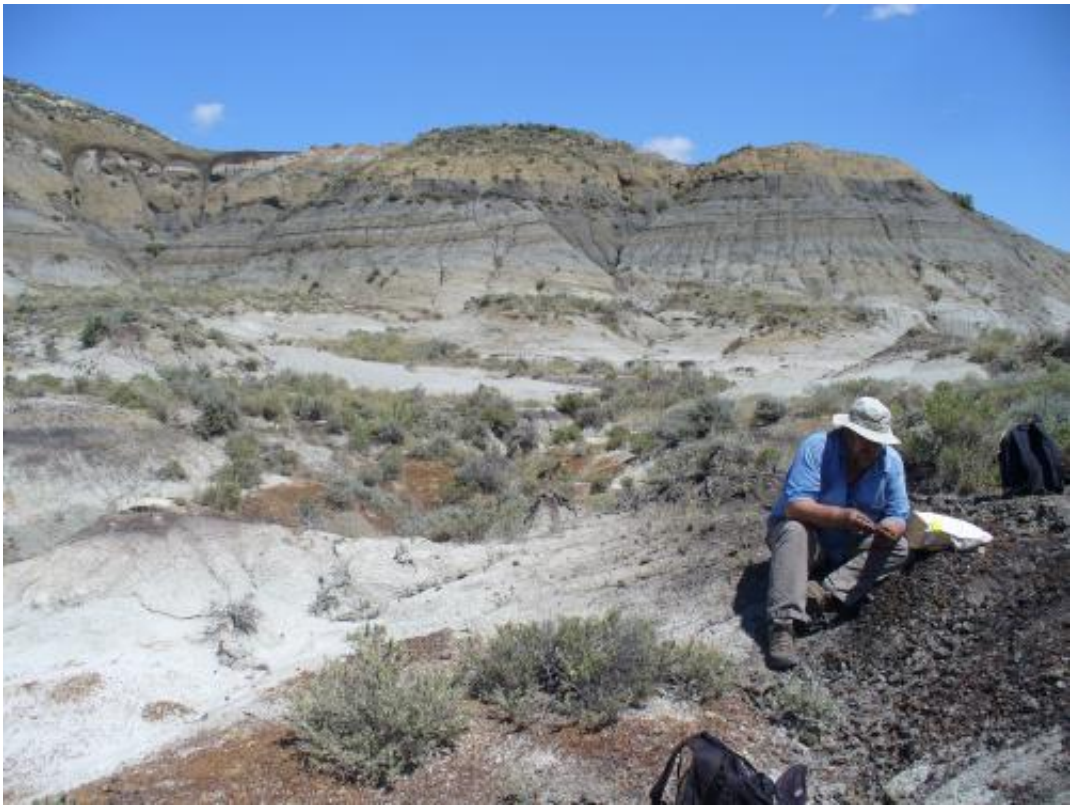

Team leader Paul Renne collecting a volcanic ash sample from a coal bed within a few centimeters of the dinosaur extinction horizon. Credit: Courtney Sprain

While many assume that a comet or asteroid impact killed off the dinosaurs, the actual dates of the impact and extinction are imprecise enough that some have questioned the connection. UC Berkeley and Berkeley Geochronology Center scientists have now dated the extinction

with unprecedented precision and concluded that the impact and extinction where synchronous. While global climate change probably brought dinosaurs and other creatures to the brink, the impact likely was the final blow.

The demise of the dinosaurs is the world's ultimate whodunit. Was it a comet or asteroid impact? Volcanic eruptions? Climate change?

In an attempt to resolve the issue, scientists at the Berkeley Geochronology Center (BGC), the University of California, Berkeley, and universities in the Netherlands and the United Kingdom have now determined the most precise dates yet for the dinosaur extinction 66 million years ago and for the well-known impact that occurred around the same time.

The dates are so close, the researchers say, that they now believe the comet or asteroid, if not wholly responsible for the global extinction, at least dealt the dinosaurs their death blow.

"The impact was clearly the final straw that pushed Earth past the tipping point," said Paul Renne, BGC director and UC Berkeley professor in residence of earth and planetary science. "We have shown that these events are synchronous to within a gnat's eyebrow, and therefore the impact clearly played a major role in extinctions, but it probably wasn't just the impact."

The revised dates clear up lingering confusion over whether the impact actually occurred before or after the extinction, which was characterized by the almost overnight disappearance from the fossil record of land-based dinosaurs and many ocean creatures. The new date for the impact – 66,038,000 years ago – is the same within error limits as the date of the extinction, said Renne, making the events simultaneous.

He and his colleagues will report their findings in the Feb. 8 issue of the journal *Science*.

The extinction of the dinosaurs was first linked to a comet or asteroid impact in 1980 by the late UC Berkeley Nobel Laureate Luis Alvarez and his son, Walter, who is a UC Berkeley professor emeritus of earth and planetary science. A 110-mile-wide crater in the Caribbean off the Yucatan coast of Mexico is presumed to be the result of that impact. Called Chicxulub (cheek'-she-loob), the crater is thought to have been excavated by an object six miles across that threw into the atmosphere debris still found around the globe as glassy spheres or tektites, shocked quartz and a layer of iridium-enriched dust.

Renne decided last year to re-date the dinosaur extinction, which occurred at the boundary between the Cretaceous and Tertiary periods – the KT boundary – after recalibrating the 20-year-old accepted date and discovering that it now occurred 180,000 years BEFORE the impact. That earlier date was obtained in 1993 by BGC researchers using the same argon-argon method, which relies on the decay rate of a radioactive isotope of potassium.

"Everybody had always looked at the age for the KT boundary and compared it with the ages that we had gotten for the tektites and the melt rock from the Chicxulub crater and said, 'Ooh yeah, this is pretty much the same age,'" Renne said. "But they are not. They differ by 180,000 years, actually. So, from simply this esoteric calibration issue, I started to realize, 'Wow, there is a real problem here.'"

"Accurately dating the major Cretaceous-Paleogene extinction, including that of the dinosaurs, has been controversial," says H. Richard Lane, program director in the National Science Foundation (NSF)'s Division of Earth Sciences, which funded the research.

Renne and his BGC colleagues dated tektites from Haiti, analyzing them using a recalibrated argon-argon technique to determine how long ago the impact occurred. The tektite results agreed with recalibrated previous data but were more precise. They did the same for altered volcanic ash collected from the Hell Creek Formation in Montana, the source of many dinosaur fossils and one of the best sites to study the change in fossils from before and after the extinction.

The new extinction date is precise to within 11,000 years.

"When I got started in the field, the error bars on these events were plus or minus a million years," added paleontologist William Clemens, a UC Berkeley professor emeritus of integrative biology who has led research in the Hell Creek Formation for more than 30 years but was not directly involved in the study. "It's an exciting time right now, a lot of which we can attribute to the work that Paul and his colleagues are doing in refining the precision of the time scale with which we work so that we can integrate what we see from the fossil record with data on climate change and changes in flora and fauna that we see around us today."

Despite the synchronous impact and extinction, Renne cautions that this doesn't mean that the impact was the sole cause. Dramatic climate variation over the previous million years, including long cold snaps amidst a general Cretaceous hothouse environment, probably brought many creatures to the brink of extinction and the impact kicked them over the edge.

"These precursory phenomena made the global ecosystem much more sensitive to even relatively small triggers, so that what otherwise might have been a fairly minor effect shifted the ecosystem into a new state," he said. "The impact was the coup de grace."

One cause of the climate variability could have been a sustained series of

volcanic eruptions in India that produced the extensive Deccan Traps. Renne plans to re-date those volcanic rocks to get a more precise measure of their duration and onset relative to the dinosaur extinction.

Renne and his colleagues also dated rocks above the KT boundary where previous researchers had looked at carbon isotopes, and concluded that Earth's atmospheric carbon cycle returned to normal within about 5,000 years of the impact. This is in stark contrast to the world's oceans, which studies show took between 1 and 2 million years to return to normal. Renne attributes this to a sluggish recovery of pre-impact ocean circulation patterns, though he concedes that this remains poorly understood.

The study's results also clarify some inconsistencies between different estimates for the age of the KT boundary based on Earth's orbital rhythms recorded in sedimentary rocks. The new independent results agree within the margins of error with an age of 65,957,000 years determined using this approach by Dutch colleagues Frederik J Hilgen of Utrecht University and Klaudia F. Kuiper of Vrije University.

"This study shows the power of high precision geochronology," said coauthor Darren F. Mark of the Scottish Universities Environmental Research Center in Kilbride, UK, who conducted independent argon-argon analyses on samples provided by Renne. "Many people think precision is just about adding another decimal place to a number. But it's far more exciting than that. It's more like getting a sharper lens on a camera. It allows us to dissect the geological record at greater resolution and piece together the sequence of Earth history."

More information: "Time Scales of Critical Events Around the Cretaceous-Paleogene Boundary," by P.R. Renne et al., *Science*, 2013.