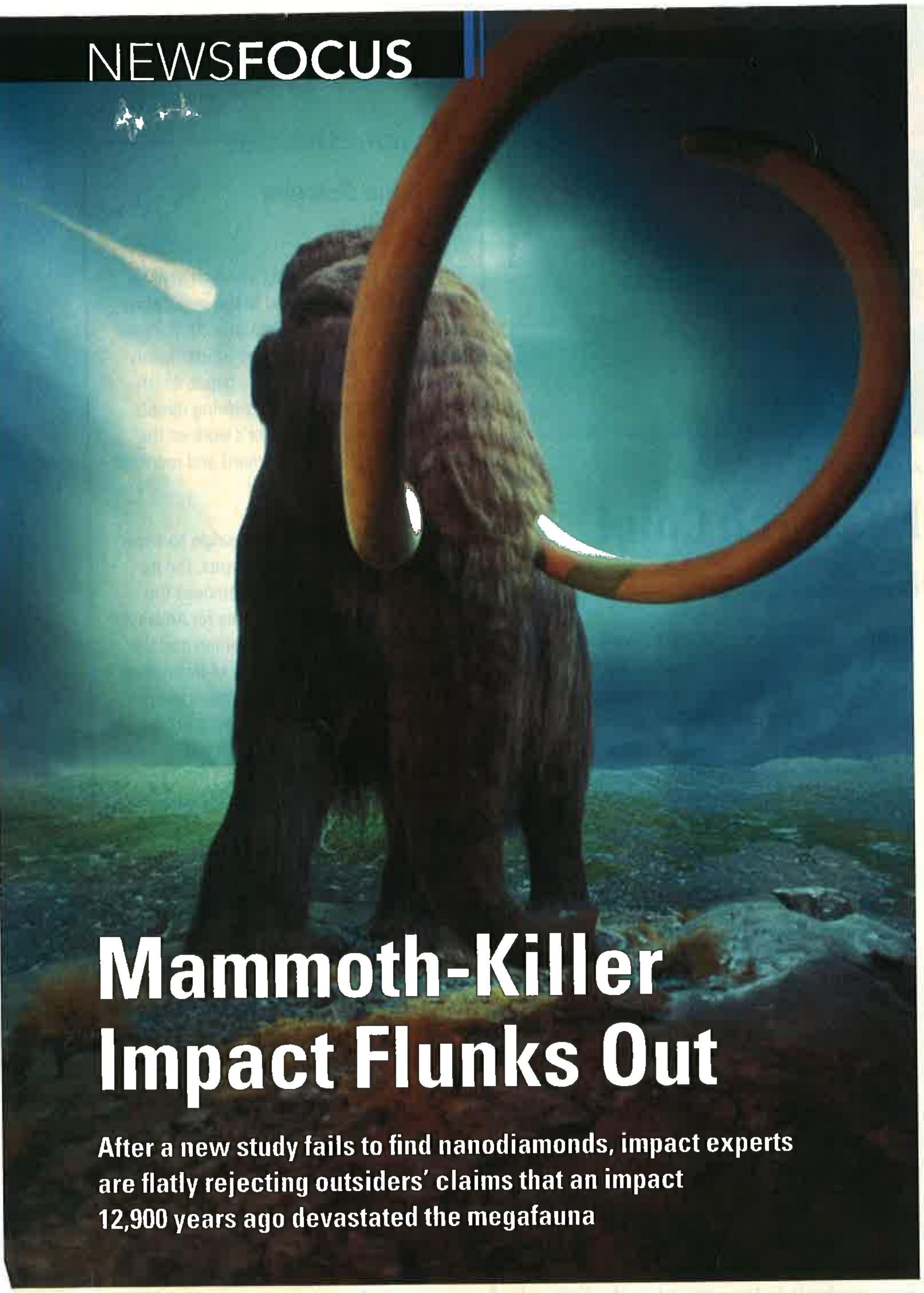

Mammoth-Killer Impact Flunks Out

After a new study fails to find nanodiamonds, impact experts are flatly rejecting outsiders' claims that an impact 12,900 years ago devastated the megafauna

DID A CONTINENT-SEARING COMET IMPACT wipe out the mammoths and other great beasts? Impact specialists have now weighed in on that widely publicized possibility. Their verdict: There never was a mammoth-killer impact. Proponents' evidence "is not internally consistent, not reproducible, and certainly not consistent with being produced by impact," says geochemist Christian Köberl of the University of Vienna, who has been publishing on impacts for 27 years.

Since impact specialists went looking on their own, Köberl says, "nobody has found anything." The final blow, in the eyes of some, comes this week in a paper reporting failure to find proponents' most promising trace of an impact, a particular crystal form of nano-size diamond.

Core supporters of the impact scenario are sticking to their guns. "It's an hypothesis," says paleoceanographer James Kennett, professor emeritus at the University of California, Santa Barbara, and a prominent member of the loose confederation of assorted impact proponents. "If anything clearly shows it to be wrong, I'll abandon it," Kennett says—but not yet.

Evolutionary origins

The mammoth-killer impact hypothesis got its start in the late 1980s, says retired geophysical consultant Allen West of Prescott, Arizona, who became a prominent impact proponent. That's when William Topping, a retired archaeologist in New Mexico, went looking in sediments for evidence of a cosmic episode in Earth's history. He found unusual mineral grains—tiny magnetic spherules—at a pivotal point in the geologic and archaeological records: 12,900 years ago, about when the 1000-year-long cold snap called the Younger Dryas began, megafauna such as the mammoth disappeared, and the distinctive arrowheads and spear points crafted by the Paleo-Indian Clovis people vanished from the record.

By 2001, the Younger Dryas mineral grains had spawned the "nuclear catastrophe" hypothesis. Topping and nuclear chemist Richard Firestone of Lawrence Berkeley National Laboratory in California proposed that an earlier "nearby supernova or cosmic ray jet" had triggered "a sequence of events that may have included solar flares, impacts, and secondary cosmic ray bombardments" that did in the Clovis culture as well as the mammoths. Topping's magnetic "spherules," they proposed, had formed in the heat and pressure of the cataclysm.

Online
sciencemag.org
Podcast interview with author Richard A. Kerr.

By 2007, however, the supernova and its great irradiation had been put aside and a single North American impact had become the focus. And the cast of characters had grown. At the May meeting of the American Geophysical Union (AGU) (*Science*, 1 June 2007, p. 1264), a loose consortium of more than 25 people including Firestone, West, Kennett, and Topping presented a half-dozen chemical and mineralogical traces of an impact that were recovered from sediments laid down at the onset of the Younger Dryas—that is, at the Younger Dryas boundary (YDB). In their new scenario, a comet blew up in the atmosphere over North America or blasted into the lingering Laurentide Ice Sheet in Canada. They also presented soot, charcoal, and other carbonaceous debris from the YDB as evidence of continent-engulfing wildfires touched off by the impact.

Then, in an October 2007 paper in the *Proceedings of the National Academy of Sciences* (*PNAS*), 26 authors led by Firestone, West, and Kennett—a member of the National Academy of Sciences—made their case in the peer-reviewed literature. Only one of the 26 had previously worked on impact markers, and her specialty—molecular cages of carbon atoms containing trapped helium—remains unconfirmed as an impact marker (*Science*, 7 March 2008, p. 1331).

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No impact, thank you

Now, 3 years later, of the 12 lines of evidence presented for an impact, "nanodiamonds are the last man standing. Everything else has failed to be corroborated," says geologist Nicholas Pinter of Southern Illinois University, Carbondale, who with colleagues has looked for YDB markers.

Supposed chemical evidence has withered under scrutiny, says impact geochemist Philippe Claeys of the Free University of Brussels. Claeys and colleagues probed YDB samples—both his own from Europe, and others from West—for claimed traces of an impacter. The targets included iridium, the exotic element that first put researchers on the trail of the dinosaur-killer impact. In a December 2009 *PNAS* paper, Claeys and colleagues reported their results: nil. "The geochemical story is finished; it's over," Claeys says. "There is nothing, no meteoritic signal. No one I know of has come to their defense."

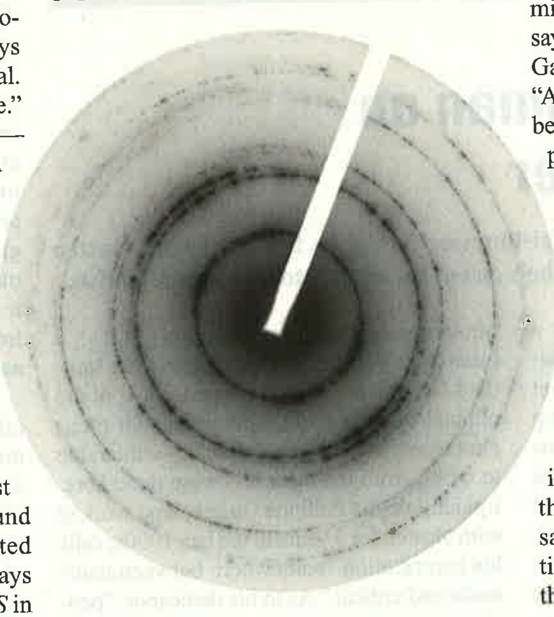
Microscopic magnetic spherules—Topping's original find, later supported by Firestone and colleagues—haven't panned out either, say other researchers who have looked for them. Archaeologist Todd Surovell of the University of Wyoming in Laramie and colleagues found the minerals at four of seven YDB sites they searched, but the spherules occurred sporadically before, at, and after the YDB. Surovell and his team also looked for irregular magnetic mineral grains, reportedly one of the most reliable markers of the impact, but found "zero major peaks [of grains] associated with the onset of the Younger Dryas," says Surovell, who reported the result in *PNAS* in October 2009.

Lingering charred traces of impact-triggered wildfires are also in short supply, say researchers not proposing an impact. "I've done dozens of [YDB] sites, and charcoal is rare outside of Clovis cooking sites. It isn't there," says archaeologist C. Vance Haynes, professor emeritus at the University of Arizona in Tucson. Paleobotanist and fire scientist Andrew Scott of Royal Holloway, University of London, in Egham, U.K., goes further. "None of these people has spent their lives looking at carbon material in sediments," he says. "I've spent 35 years looking at it. I see no evidence of an exceptional fire event across North America."

The last nail?

None of those types of evidence is considered conclusive, however, specialists point out. Of the markers impact proponents have proposed, just one mineral bears the indelible signs of the crushing shock that in nature only an impact can create: high-pressure hexagonal diamond, or lonsdaleite. Using transmission electron microscopy (TEM), Douglas Kennett of the University of Oregon, Eugene (the son of James Kennett), James Kennett, West, and 14 colleagues reported the detection of such hexagonal nanodiamond at the YDB in a 20 July 2009 *PNAS* paper.

Two other groups have now looked for lonsdaleite at the YDB and found none. At the December 2009 AGU meeting, Claeys, microscopist Dominique Schryvers of the University of Antwerp in Belgium, and colleagues reported they could find no hexagonal diamond at a YDB in Belgium, only cubic diamond unrelated to an impact. And in a *PNAS* paper this week, physicist Tyrone Daulton of Washington University in St. Louis, Pinter, and Scott report searching samples from three YDB sites in the United States. Douglas Kennett and his co-authors had reported nanodiamonds at two of these sites, including hexagonal diamonds at one.



Diamond or dross? Transmission electron microscopy suggests to some there's no impact diamond.

Site of controversy. Proponents say traces of impact mark this 12,900-year-old dark layer.

CREDITS (TOP TO BOTTOM): TYRONE DAULTON/ WASHINGTON UNIVERSITY IN ST. LOUIS; ALLEN WEST

On the basis of TEM analysis, "I'm convinced there's no [hexagonal] diamond present," says Daulton. TEM patterns of some material "matched closely what Kennett reported. I knew immediately this wasn't diamond." Instead, the material was aggregates of sheetlike forms of carbon, including graphene. "If you don't look too closely at it, you could convince yourself it is [lonsdaleite]. Theirs was a gross misidentification as lonsdaleite."

Daulton's judgment is reliable, other microscopists say. "He's a real TEM person," says meteoriticist and microscopist Laurence Garvie of Arizona State University, Tempe. "All the other [YDB] nanodiamond stuff has been written by people who aren't TEM people. If he says there are no nanodiamonds, there are no nanodiamonds."

Proponents of a Younger Dryas impact disagree. "The Daulton *et al.* claim that we have misidentified diamonds is false and misleading," writes Douglas Kennett in an e-mail. His complaints about Daulton *et al.* focus on sampling, sample processing, and interpretation. Impact proponents level similar criticisms at other outside studies of traces of impact and fire. Kennett sees little evidence that Daulton and his colleagues actually sampled the YDB, an often thin and sometimes hard-to-recognize layer. He also says that they probably analyzed too few carbonaceous particles—in which nanodiamonds reside—to find any diamond and that their sample processing may have destroyed diamond that was there. What's more, Kennett says, the TEM-determined crystalline structures of hexagonal diamond and graphene are so easily distinguished that misidentification is unlikely. "There's been a real problem of data quality," Kennett sums up.

This debate will likely go on for years. Impact specialist Köberl, for one, thinks it has already lasted too long. If impact proponents "had involved the mainstream community and listened to them, probably none of these papers would have been published," he says. Meanwhile, many researchers drawn from more mundane work to hunt for a killer impact are calling it quits. "I spent 16 months in the lab and found very little evidence to support their hypothesis," says Surovell. "I have other things to worry about."

–RICHARD A. KERR