Intriguing but puzzling

The latest signs of extraterrestrial debris at the P-T are getting a mixed reception. "I don't have any doubt that" the fragments are meteoritic, says meteoriticist Jeffrey Grossman of the U.S. Geological Survey in Reston, Virginia. "The mineral chemistry is the same, the texture is the same, there is some metal." So no one is denying that these Antarctic fragments came from outer space. But meteoriticists and impact geologists alike are stunned that tiny, fresh-looking, unaltered fragments of a meteorite should have survived burial for 251 million years. "It's astonishing, it's incredible, it's unbelievable," says Grossman. Adds Kring, "You have to ask how they got there."

Meteoritic minerals such as forsterite and metallic iron are "incredibly unstable at the surface of the Earth," Kring notes; meteoriticists like to say that "If a meteorite falls in the [rainy U.S.] Pacific Northwest, it's going to be soil the next year." Basu has no explanation for the extraordinary stability. "There's something peculiar about this deposit that needs to be worked out," he says.

Not every meteorite that falls to Earth weathers away without a trace, of course. Chunks of large impactors have in fact been recognized in the geologic record. Geochemist Frank Kyte of the University of California, Los Angeles, convinced colleagues that a few-millimeter piece of totally altered rock he found in 65-million-year-old North Pacific sediments is probably a bit of the dinosaur killer. And geochemist Birger Schmitz of the University of Göteborg in Sweden has found fist-sized meteorites in 480-million-year-old sedimentary rock in southern Sweden, although nothing unaltered was left except traces of the exceptionally resistant mineral chromite. Microscopic, unaltered meteoritic fragments surviving a quarter-billion years "would really be remarkable," says Schmitz. "I get the gut feeling it's wrong."

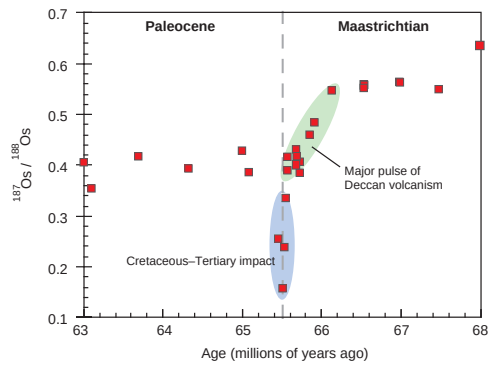
Schmitz had the same feeling about the essentially unaltered micrometeorites found in samples of 1.4-billion-year-old sandstone from Finland. In their 1998 report in *Nature*, meteoriticist Alexander Deutsch of the University of Münster in Germany and three colleagues demonstrated that the spherules were without a doubt meteoritic. But they offered no explanation at the time of how the submillimeter objects survived a clearly hostile environment that long.

The answer, it turned out, is that they hadn't. Deutsch and some of his colleagues from the *Nature* paper resampled the Finnish sandstone and concluded that it does not contain any micrometeorites whatsoever. They have failed to find any obvious route of contamination in the field or lab, however.

Extinction by a Whoosh, Not a Bang?

Ever since scientists realized that a huge impact gave the dinosaurs their comeuppance 65 million years ago, extraterrestrial whacks have become the leading suspect in almost every mass extinction (see main text). But some say that massively erupting volcanoes are capable of similar mayhem. One new study fingers the largest volcanic eruption ever as the leading cause of the greatest mass extinction 251 million years ago. At the same time, however, in this issue of *Science* (p. 1392), a second study seems to diminish greatly the role of another great eruption in the death of the dinosaurs.

The problem with volcanoes as extinction triggers has been the difficulty of pinning down when they spewed their noxious, climate-altering gases. The stunningly exact coincidence of the impact 65 million years ago with the disappearance of numerous creatures in the sea was obvious once scientists recognized impact debris in the geologic record within a hair's breadth of the last fossils of doomed animals. But the huge, although relatively quiet, nonexplosive lava eruptions called flood basalt eruptions didn't leave an obvious mark in the records of mass extinctions. So it's been up to geochronologists to link the two events by dating both eruptions and extinctions.



Eruption, then impact. A declining osmium isotope ratio denotes an earlier volcanic eruption, and a downward spike marks the dinosaur-killer impact.

What may be the best possible geochronological tie between eruption and extinction appeared in the 10 September issue of *Earth and Planetary Science Letters*. Geochronologist Sandra Kamo of the University of Toronto and her colleagues reported a new uranium-lead radiometric age for the beginning of the Siberian Traps eruption—the most voluminous known—of 251.7 ± 0.4 million years. According to her second new date, 6.5 kilometers of lava and ash—most of the Siberian Traps production—had erupted by 251.1 ± 0.3 million years ago. And the midpoint of this eruption falls exactly at the uranium-lead age for the great Permian-Triassic mass extinction, as determined in 1998 by Samuel Bowring of the Massachusetts Institute of Technology and his colleagues.

Similar improvements of radiometric ages for eruptions and extinctions are tightening the links between a number of mass extinctions and flood basalts. But uncertainties of many hundreds of thousands of years remain. Already, a paper in this issue of *Science* looks to break up another proposed eruption-extinction pair.

Geochemists Gregory Ravizza of the University of Hawaii, Manoa, and Bernhard Peucker-Ehrenbrink of the Woods Hole Oceanographic Institution in Massachusetts propose a new geologic marker of volcanism: the mix of stable osmium isotopes recorded in ocean sediments. In sediment cores from around the world, they trace a steady decline in the ratio of osmium-187 to osmium-188 starting about 66.0 million years ago, followed by a sharp downward spike 65.5 million years ago. Ravizza and Peucker-Ehrenbrink attribute the initial decline to the Deccan Traps of India. As the traps weathered, they fed low-ratio osmium into the sea. Half a million years later, the asteroid or comet that took out the dinosaurs dumped even more low-ratio osmium, say the geochemists, causing the downward spike.

The Deccan Traps eruption came half a million years too soon to trigger the extinction. However, the greenhouse gases from the eruption probably set off the warming recorded then, Ravizza says. That warming possibly weakened the biota before the devastating impact. If this timing is correct, one thing is certain: Impacts trigger extinctions, but they don't trigger great eruptions. **–R.A.K.**

A failure to replicate

Impact geologists would like to see Basu's findings replicated before they accept them. But if fullerenes—the other hot alternative impact marker—are any example, that could take a while. Ten years after the first report of fullerenes in a geologic sample, "their origin and occurrence remain elusive," wrote Peter Buseck of Arizona State University, Tempe, in a review last year. His 1992 paper in *Science* (10 July 1992, p. 215) was the first to report the detection of natural fullerenes, from a sample of an odd, organic-rich rock from western Russia called shun-

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