Science Fact

Space Dust: How an Asteroid Altered Life on Earth . . . Millions of Years Before the Dinosaurs

Richard A. Lovett

Four hundred sixty-six million years ago, two large asteroids collided.

We know that it happened because meteorite hunters have found fragments of it on Earth. Called L-chondrites, they are so common, in fact, that roughly one-third of all meteorite falls, even today, are remnants of that giant crash. (They are called "L"-chondrites because they are low in iron compared to other chondrites, also known as stony meteorites). We know *when* it happened, because the collision was powerful enough to punch the reset button on one of the most important radiometric clocks used to date ancient rocks: the potassium-argon decay cycle, in which potassium-40, a rare isotope of potassium, decays into argon-40 with a half-life of 1.25 billion years.

Argon is a gas that easily diffuses out of molten rock, but is trapped once the rock solidifies. Thus, the relative amounts of potassium-40 and argon-40 can be used to determine the time at which a rock solidified.

Trapped argon, however, can be lost when a rock is severely disturbed, as appears to have happened to the L-chondrites. "All of the L-chondrites have experienced a heavy shock that made them lose argon and [reset] the potassium-argon clock to zero," says Birger Schmitz of Lund University, Lund, Sweden, who has spent years studying the aftereffects of the collision. Based on this, he says, the collision that produced them can be dated with remarkable precision to 466 million years ago—ancient by our standards, but quite recent in the 4.5-billion year history of the Solar System.

A cross section of a large L chondrite. Source: Wikipedia. Photo by H. Raab

There is also evidence that the L-chondrite collision was a whopper. "This is the largest asteroid breakup we know of in the past three billion years," Schmitz says.

Part of this evidence comes from efforts to determine which of today's known asteroids might be giant shards from that collision. These fragments, some scientists believe, include a 128-kilometer-wide asteroid known 8 Flora, which is part of a family of 13,000 smaller asteroids that appear to have originated from a major breakup at about the right time in the past.

Not that this hypothesis isn't without some difficulties. In 1991, NASA's Jupiter-bound Galileo spacecraft flew by one of the larger members of the Flora family, 951 Gaspra (average diameter 12 kilometers), at a distance of 1,600 kilometers. That was close enough to get good pictures of its surface, allowing scientists to count the number of craters of varying sizes: a common method for estimating how long a surface has been exposed to bombardment by space rocks.

Based on this, a Cornell University team concluded that 951 Gaspra broke from its parent body about thirty to three hundred million years ago.[1] That isn't the same thing as 466 million, but given the fact that the study was done more than a quarter-century ago, it might not be as different as it seems. Age dating by crater counting is based on knowing the rate at which surfaces are pummeled by space rocks, and our estimates of that continue to improve. If the study were to be redone today, it's not impossible that it might give a somewhat different age estimate—one that makes it more likely that 951 Gaspra and the rest of the Flora family are indeed fragments of the L-chondrite progenitor.

All of that, I realize, is a bit speculative, but it raises an interesting question: if something as big as 8 Flora (and its family) is a remnant of it, just how big was the original body?

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Rooftop Visitation

A more recent answer to this question comes from a 630-gram L-chondrite that, after a rather dramatic sonic boom, crashed onto a roof in eastern China in 1989. The crash was well-documented—it's not every day that a space rock that size falls on a house—and pieces were recovered not only from the startled family's roof, but from their vegetable garden and a nearby road.

Since then, that space rock has been extensively examined, culminating in a 2018 study in which Chinese scientists examined how the impact shock that broke it from the L-chondrite parent body affected its mineral grains. In a paper in *Meteoritics & Planetary Science*, they concluded that the parent body measured 150 kilometers in diameter . . . and was hit (at five to six kilometers per second) by a second body measuring twenty kilometers across.[2]

But how, if at all, did that giant crash affect the Earth? Yes, the asteroids involved were vastly larger than the one believed to have wiped out the dinosaurs, 400 million years later, but the dino-killer hit us directly. This collision was hundreds of millions of miles away.

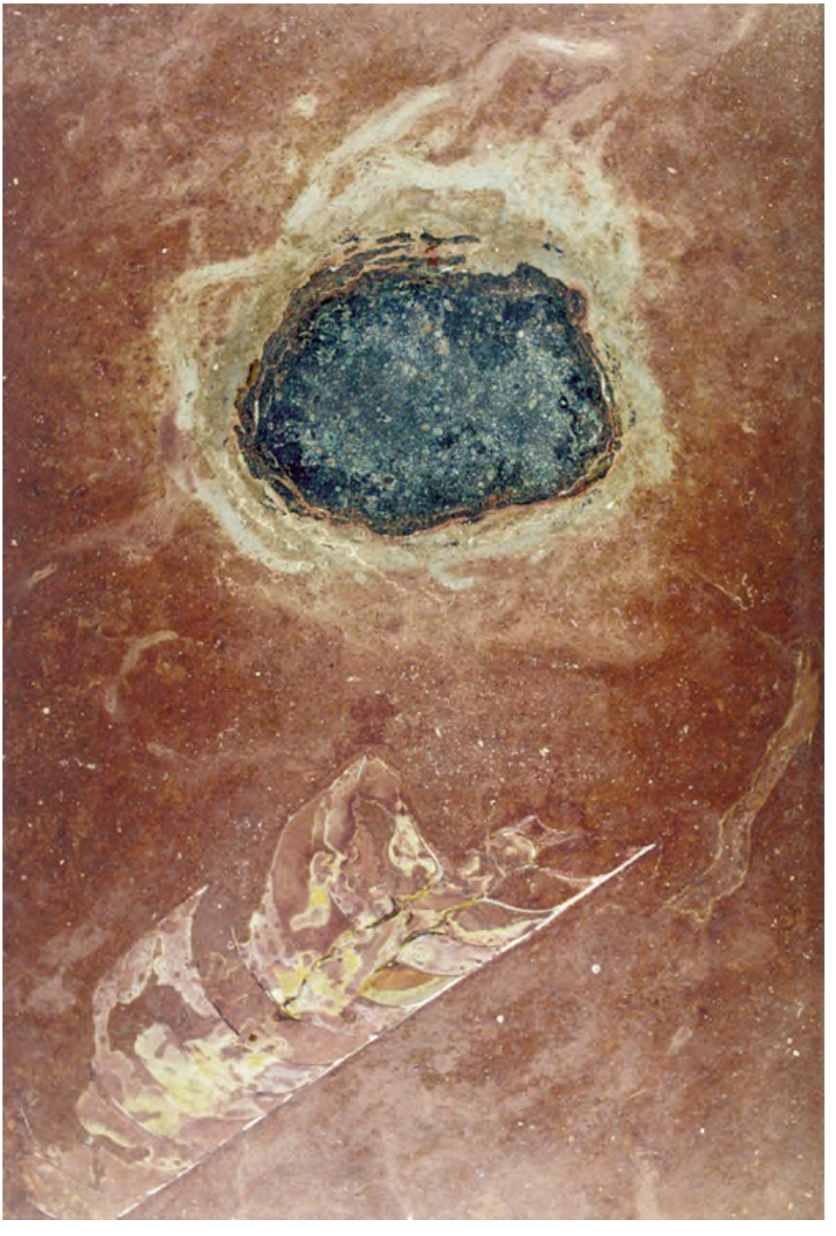
Still, even if that was far enough away to assure that none of the big fragments hit us (at least immediately; I have seen it hypothesized that the dino-killer asteroid was actually a remnant of this collision, which hit us very belatedly)[3], the collision did produce an enormous explosion of pebbles and dust. Schmitz compares it to putting a vacuum cleaner bag full of dust on your living room floor and stomping on it. The initial expulsion of dust from that giant stomp represents what must have occurred in the immediate aftermath of the collision. But, he notes, all of that dust wouldn't settle out of your living room air instantly. Remnants would linger, hours later. That's what we see today, as L-chondrites, mostly no larger than flecks of dust, continue to bombard us.

Today, those remnants are the stuff of shooting stars and the occasional space-rock landing on someone's roof. But 466 million years ago? That was probably a different story, says Philipp Heck, a cosmochemist at the Field Museum of Natural History in Chicago, Illinois. Different enough it might have made the night sky a lot more dramatic than what we see today.

To begin with, Heck says, the "zodiacal light"—the faint plume of reflections from interplanetary dust sometimes seen stretching above the horizon at dawn and dusk—would have been orders of magnitude brighter than it is now. And that's just the beginning. "If we could travel back in time, we might also see many more shooting stars," he says.

Zodiacal light seen from near Chile's Paranal Observatory. Source: Wikipedia.

There is also evidence that a lot of these shooting stars produced fragments big enough to fall to the Earth's surface. In a single quarry in southern Sweden, Schmitz's team found 130 such "fossil" meteorites ranging in size from marbles to Ping-Pong balls, all in a thin layer of limestone laid down on the seabed about 466 million years ago. "All are L-chondrites," he says.



Cross-section of Ordovician limestone from Kinnekulle, Sweden, with fossil meteorite. Credit: Birger Schmitz.

But that's just the big stuff. What about smaller, dust-sized particles?

To find out how many of them there were, Schmitz's team returned to the limestone layer where they'd found the fossil meteorites, taking samples from both that quarry and a related outcrop near St. Petersburg, Russia. Then, they painstakingly dissolved 1,320 kilograms of limestone in acid, sifting what remained for interplanetary dust too small to otherwise have been detected.[4]

They found a lot of it, enough to suggest that the amount falling to Earth in the two million years after the L-chondrite progenitor's breakup was vastly larger than today. They also found that neon, helium, and osmium isotopes in these dust particles were similar to those in the fossil L-chondrite meteorites, indicating that the dust and the meteorites came from the same source.

Today, says Heck (who was part of Schmitz's team), interplanetary dust represents only 1% of the total amount of dust in the air. The rest comes from windblown soil, volcanic eruptions, sea salt, and pollution. But 466 million years ago, he says, the amount of interplanetary dust hitting the Earth would have been one thousand to ten thousand times larger—enough to overwhelm other sources and increase the total amount of dust in the Earth's upper air by a factor of ten to a hundred. "Normally," Heck says, "Earth gains about forty thousand tons of extraterrestrial material every year. Imagine multiplying that by a factor of a thousand or ten thousand."

At the same time, dust from the collision would have spread far enough through interplanetary space that some of it would have wound up between the Earth and the Sun, reducing the amount of sunlight able to reach us. In combination, Heck says, these two factors—dust in the Earth's atmosphere and dust blocking sunlight—"definitely had an effect on climate."

In fact, he and Schmitz say, it might have triggered an ice age.

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Evidence for this comes from changes in grain sizes in the limestone being deposited as the L-chondrite dust was falling to Earth. Coarser grains mean shallower waters, and while it's hard to tell exactly how shallow these waters were, the change in grain size is all that matters: a shift toward coarser grains mean the water was becoming shallower. This is confirmed by a shift in fossils toward shallow-water species.

All of this means that at the time the L-chondrite dust was falling, sea levels were dropping; *i.e.*, in the reverse of what's happening today, glaciers were growing, causing water to accumulate in ice sheets rather than in the oceans.

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Mid-Ordovician Ice Age

Other geological evidence also points to the existence of a major ice age at this time, including signs that ice caps had developed in parts of Africa and South America that were then near the South Pole. But the cause of that ice age, known as the mid-Ordovician ice age, has long been a mystery because, overall, the Ordovician was a very warm period in Earth's history.

The sudden influx of dust from the L-chondrite progenitor's breakup, however, looks a lot like a smoking gun—especially when combined with the possibility that the dust cloud created by that breakup might have significantly reduced the amount of sunlight even managing to reach the Earth, let alone reaching the ground. "The timing appears to be perfect," Schmitz says.

The next step, Heck says, is to determine if there was enough cooling to produce an ice age. Figuring that out, he says, will be the province of computer modelers, including not only climate researchers, who can determine how much the extra dust in the Earth's atmosphere would have affected the amount of sunlight reaching its surface, but orbital dynamics modelers, who can determine how much dust from the collision would have wound up between the Earth and the Sun.

Already, however, intriguing ideas are emerging. To start with, we tend to think of climate change as an ecological disaster. Human-induced global warming, for example, appears to be setting in motion changes that could lead to the extinction of a substantial fraction of the Earth's terrestrial species.[5] Climate change related to an asteroid that struck the Yucatan 66 million years ago had even more dramatic effects, killing off not only the dinosaurs, but two-thirds of the Earth's other species. And climate change from massive volcanism in what is now Siberia, 252 million years ago, probably triggered an even greater die-off, the Permian-Triassic extinction, when perhaps 90% of the Earth's species (96% by some estimates) disappeared.[6]

The mid-Ordovician ice age, however, had no such effect. Rather, it was an era of spectacular biodiversity, known as the Great Ordovician Biodiversification Event. Entire new classes of animals, like brachiopods—a type of marine filter feeder that still exists—owe their origins to that period, while many other groups of species diverged into increasingly diverse subgroups.

The reason for the difference between the mid-Ordovician and other times of climate change, Heck says, appears to be that it didn't happen instantly. Instead, dust from the L-chondrite progenitor smash-up took at least two million years to filter down to Earth, producing a relatively gradual cooling. "It's very different from the climate change caused by the meteorite that killed the dinosaurs, and it's different from global warming today," he says. "This was a gentle nudge."[7]

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Schmitz argues that his team has gone so far as to develop an entire new science: astrogeobiology, in which "we do astronomy by looking down instead of up."

The L-chondrite progenitor's breakup isn't the only thing his team is studying in this manner; they are also dissolving tons of sedimentary rock from other time periods, trying to extract "very, very rare" minerals from micrometeorites that fell to Earth in different geological eras. But linking the L-chondrite progenitor breakup to the Great Ordovician Biodiversity Event is their greatest success to date—one that Schmitz compares to the discovery of the dino-killer asteroid. "This is [only] the second time anyone has shown a relationship between something coming from space and an important event in the evolution of life," he says.

Other scientists are impressed. "It seems reasonable to have lots of dust arrive on Earth from this event," says Humberto Campins, an asteroid researcher from Central Florida University, Orlando. "I like this paper."

Melinda Hutson, curator of the Cascadia Meteorite Laboratory at Portland State University, Portland, Oregon, agrees. The smash-up of the L-chondrite progenitor asteroid was well known, she says, as were the Swedish fossil meteorites. But, she says, "I hadn't thought about the amount of dust that would be produced, and its effect on sunlight. The authors had to have a good combination of background specialties to put this all together."

As an aside, she notes that the effects might well have spread beyond the Earth. "I found myself wondering if Mars experienced any noticeable climate change," she says. Though, she adds, "we're not close to having the kind of data we need to look at this scale of climate change on Mars."

Still, that's an interesting idea that might even be fodder for a science fiction story. The L-chondrite progenitor breakup isn't the only giant asteroid crash in Solar System history; it's merely the most recent. Could an earlier one have tipped the climate of Mars, billions of years ago, especially since Mars is closer to the Asteroid Belt, and therefore much more vulnerable to its dust than the Earth?

And if that might occur on Mars, what might be the case on a Mars-like planet in another solar system, where an alien intelligence might watch such a collision happen, realize the climate threat, and try to figure out how to protect themselves?

But we can take it farther than that. In the final paragraphs of their paper, Schmitz's team asks if asteroid dust might be used to solve today's global warming. Not by somehow injecting millions of tons of it into the upper atmosphere, but by parking a small asteroid between the Earth and the Sun, and blowing enough dust off its surface to dim sunlight enough to offset the buildup of planet-warming greenhouse gasses like carbon dioxide and methane.

It's not a totally insane idea. A number of suggestions have been floated in recent years for how to move asteroids into different orbits, either to keep them from hitting Earth or to bring small ones into nearby orbits where they could be mined for anything from rocket fuel to building materials for orbital habitats.

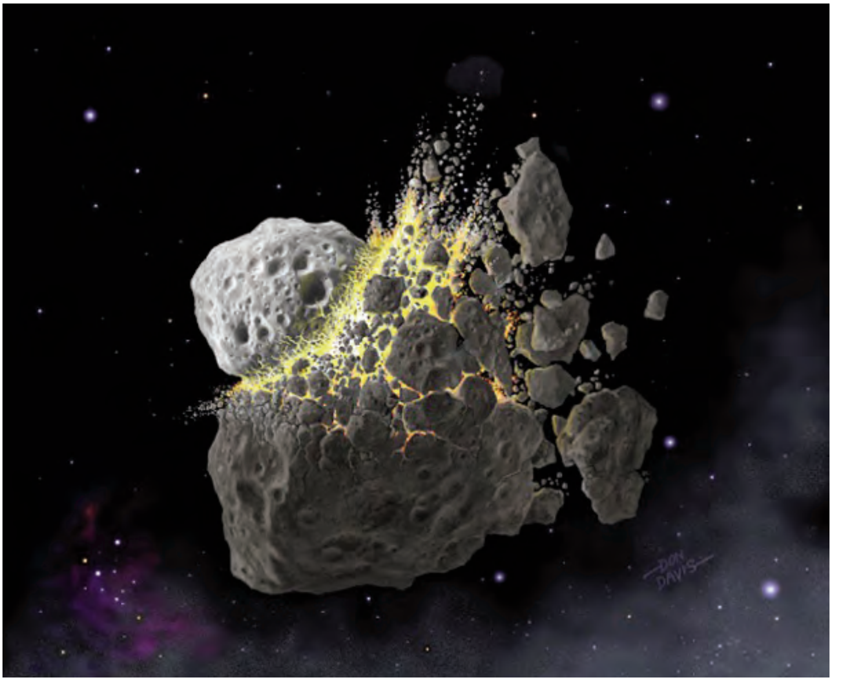
One of these is the "gravity tractor," in which a spacecraft hovers above an asteroid with just enough power not to fall to its surface. Since gravity works both ways—on the asteroid as well as the spacecraft—this allows the spacecraft to gently tug the asteroid from one orbit to another.

That way, a near-Earth asteroid could be slowly pulled into the L-1 Lagrange point, which lies between the Earth and the Sun, about a million miles away from Earth. Once there, gravitational forces would keep it more or less in place, while dust could be gently blown off its surface in sufficient amounts to create the desired sunlight-dimming cloud. "It's possible," Schmitz says.

Not that possible and wise are always the same thing. "Geoengineering proposals should be evaluated very critically and very carefully, because if something goes wrong, things could become worse than before," Heck says. "[But] we're experiencing global warming—it's undeniable. Any idea that's reasonable should be explored."

If we ever get to another solar system, this might also be a way to cool, and therefore terraform, a too-hot planet.

Green Venus? Maybe it's not all that impossible.



Artist's concept of the giant asteroid collision in outer space that produced the dust that led to an ice age on Earth. ©Don Davis, Southwest Research Institute.

Endnotes

1 J. Veverka; M. Belton; K. Klaasen; C Chapman (1994). "Galileo's Encounter with 951 Gaspra: Overview". *Icarus*. 107 (1): 2–17. *doi:10.1006/icar.1994.1002.*

2 Shaolin Li and Weibiao Hsu. The nature of the L chondrite parent body's disruption as deduced from high–pressure phases in the Sixiangkou L6 chondrite. *Meteoritics & Planetary Science*, Volume 53, Issue 10, pages 2107-2122 (October 2018). *Doi:10.1111/maps.13110.*

3 This suggestion appears in a 2010 *Science News* article, but I know of no journal articles supporting it. *See* Irene Klotz, "Smashed asteroids may be related to dinosaur killer," *Science News*, February 2, 2010 (https://www.reuters.com/article/us-space-asteroid/smashed-asteroids-may-be-related-to-dinosaur-killer-idUSTRE61154120100202).

4 Birger Schmitz, Kenneth A. Farley, Steven Goderis, Philipp R. Heck, Stig M. Bergström, et al. An extraterrestrial trigger for the mid-Ordovician ice age: Dust from the breakup of the L-chondrite parent body. *Science Advances*, Volume 5, number 9 (September 2019), *doi:10.1126/sciadv.aax4184.*

5 See C.D. Thomas, A. Cameron, R.E. Green et al. Extinction risk from climate change. *Nature*, volume 427, pages 145-148 (2004), which concluded that 15% to 37% of these species will be "committed to extinction," based on "mid-range" climate change projections. Other factors, such as habitat destruction and failures to protect remaining undeveloped areas are contributing to this. *See* Moreno DiMarco, Simon Ferrier, Tom D. Harwood, Andrew J. Hoskins, and James E. M. Watson, "Wilderness areas halve the extinction risk of terrestrial biodiversity," *Nature* volume 573, pages 582-585 (September 2019)

6 Hillel J. Hoffman, "The Permian Extinction—When Life Nearly Came to an End," *National Geographic* (https://www.nationalgeographic.com/science/prehistoric-world/permian-extinction/).

7 Not that extraterrestrial dust is the only possible explanation for the Great Ordovician Biodiversity Event. Other researchers have suggested increased nutrient supply due to tectonic activity and a fortuitous arrangement of the continents as possible contributors.
See Alycia L. Stigall. How is biodiversity produced? Examining speciation processes during the Great Ordovician Biodiversification Event. *Lethaia*, 51:165-172 (2018). *Also see* Joseph P. Botting and Lucy Y. Muir. Unravelling Causal Components of the Ordovician Radiation: the Builth Inlier (Central Wales) As a Case Study. *Lethaia*. 41: 111–125 (2008)

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