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She pointed out, however, that earlier research has found that to explain the high nickel content of ocean island basalts, oceanic crust must reach the deep mantle (bit.ly/olivine-free-mantle). "This study does not cite that paper," she said. "I think that needs reconciliation."

"To most mantle geochemists, these would have to be alarming conclusions, running contrary to a scientific consensus crafted over the past four decades."

The study was "too simplistic," said Marco Brenna, a petrologist with the University of Otago in Aotearoa New Zealand who was not involved in the study. Its use of a global dataset, he said, "hides the local heterogeneities."

"The problem is that there are more… unknown parameters than we can put our fingers on, and therefore every model, especially global ones that just blur the local particularities, will be misleading at best," he wrote in an email.

Jon Woodhead, a geochemist at the University of Melbourne who was not involved in the study, wrote in an email that he initially also found the premise of the study "very hard to accept."

"To most mantle geochemists, these would have to be alarming conclusions, running contrary to a scientific consensus crafted over the past four decades," he wrote. However, he noted that he tested the idea using some geochemical data he had on hand. He wrote that "to my surprise," he found "very convincing trends" that corroborated the study's findings.

"It does seem clear that there is potentially a previously unrecognized issue at play here," Woodhead wrote.

"Further research will likely be required before we can say whether any modification, or even upheaval, of the existing paradigm will result," he wrote.

By **Bill Morris,** Science Writer

A Close Asteroid Encounter May Have Once Given Earth a Ring

Rings are a pretty common phenomenon in our solar system: All of the large planets have them, as do several dwarf planets. Now, a new look at old impact craters suggests that Earth may once have had a temporary ring created by the breakup of a passing asteroid that got too close.

"In the Ordovician, 466 million years ago, there's a cluster of impact craters," said lead researcher Andrew Tomkins, a planetary scientist and petrologist at Monash University in Melbourne, Vic., Australia. "It's the only time in the Earth's impact crater record when there was a distinct spike in the cratering rate."

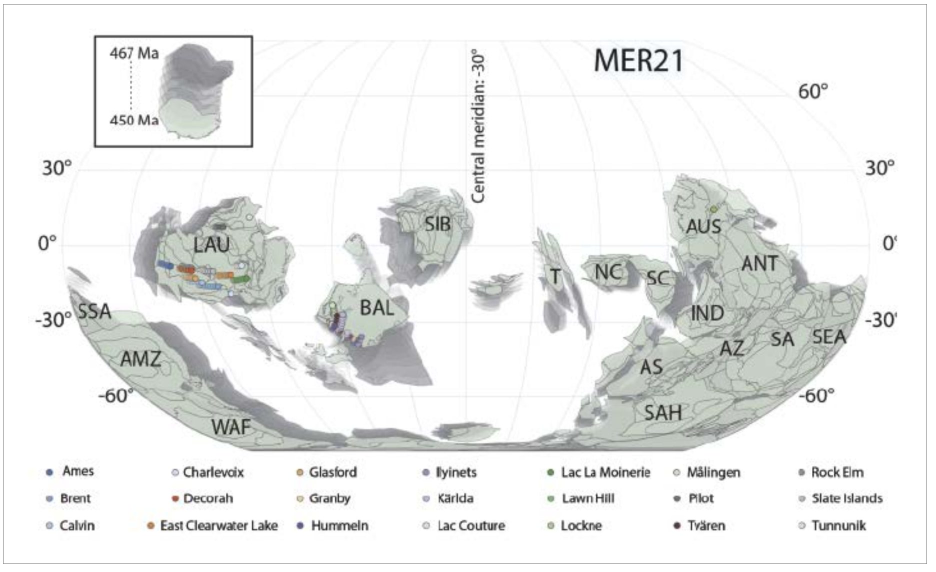
The flurry of impacts occurred between 485 million and 443 million years ago. Limestone around the world geochemically records the beginning of this spike with a heavy enrichment of L chondrite meteorite and micrometeorite debris. There are also 21 impact craters scattered across the continents that date back to this period.

How Did Those Craters Get There?

Tomkins and his colleagues wanted to investigate the origins of the impactors. Did a collision in the asteroid belt send L chondrite fragments hurtling randomly in all directions (including at Earth), or did the impactors' journeys start closer by?

"The impact structures are really obvious, and we wouldn't miss them if they were there."

The team used six plate tectonic reconstruction models to turn back the clock on Earth's surface and trace the impact craters from their present-day locations back to their original locations. The models showed that 466 million years ago, all of the craters were concentrated within 30° of the equator. Plenty of crater-preserving crust was outside that narrow strip, so it's not likely that nonequatorial Ordovician craters escaped notice.



Upon impact, the Ordovician craters (colored dots) were concentrated within 30° of the equator. MER21 refers to the plate tectonic model used to reconstruct the positions of the continents, and other labels are abbreviations of continent names: AMZ, Amazonia; ANT, Antarctica; AS, Arabian Shield; AUS, Australia; AZ, Azania; BAL, Baltica: IND, India; LAU, Laurentia; NC, North China; SA, Southern Africa; SAH, Saharah; SC, South China; SEA, Southeastern South America; SIB, Siberia; SSA, Southern South America; T, Tarim; WAF, West Africa. Credit: Tomkins et al., 2024, https://doi.org/10.1016/j.epsl.2024.118991, CC BY 4.0 (bit.ly/ccby4-0)

"The impact structures are really obvious," Tomkins said, "and we wouldn't miss them if they were there." The equatorial concentration is "quite unusual," he added.

If the impactors originated from a collision in the distant asteroid belt, the meteorites would have struck random locations on Earth, rather than falling along a narrow strip, Tomkins explained. What's more, there would also have been a flurry of impacts on the Moon and Mars at the same time, and there is no evidence of that.

Together these lines of evidence suggest that the Ordovician impacts are "all related to each other by a single L chondrite body that broke up around the Earth," Tomkins said.

For that to happen, an asteroid would have had to pass within Earth's Roche limit, a theoretical boundary within which Earth's gravity overcomes an object's internal strength and shreds it to pieces. (We saw this phenomenon happen to the comet Shoemaker-Levy 9 in 1992 when it got too close to Jupiter.)

Given enough time, debris within the Roche limit can concentrate into a ring. "That's what we're suggesting explains the distribution of impact craters," Tomkins said.

The hypothesized equatorial ring would have gradually dissipated over at least 40 million years, which is in line with theories that ring systems in the solar system are typically young and temporary features.

Using data collected from recent spacecraft missions to asteroids, the team calculated that the ring-generating asteroid was 10.5–12.5 kilometers (6.5–7.8 miles) across.

These results were published in *Earth and Planetary Science Letters* (bit.ly/Earth-ring).

Earth could have had rings at some point in its past. Credit: NASA; Kevin Gill, CC BY 2.0 (bit.ly/ccby2-0)

Must Be Rare, but Not Too Rare

Not everyone is convinced, however, that a ring is the best explanation for the Ordovician impact clustering. "The idea of a ring is supported by the volume of material and the size of craters linked to the event," said Elizabeth Catlos, a geoscientist at the University of Texas at Austin who was not involved with this research. "But," she added, "the data might be equally compatible with a single, large, fragmented asteroid with several pieces that happened to fall to Earth at different times over a segment of Ordovician time."

Catlos, who has studied Ordovician impacts, noted that it's notoriously hard to pin down exact ages for impact craters and that some of the minerals used to date them are susceptible to being reset by later heating, further confusing the geologic record. Some of the Ordovician craters might not be Ordovician at all. "The ring theory should be tested by pushing our analytical limits to get more precise dates from radiometric minerals reset during impacts," she said.

She added, "The ring idea is an exciting one to get other researchers, students, and the general public interested in the challenge of timing meteorite impacts."

"I would expect that the folks who do those sorts of studies are probably warming up their computers right now."

Andy Rivkin, a planetary astronomer at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md., who was not involved with this research, said that the proposed close encounter "seems plausible."

"The meteorite compositions being considered are very common among near-Earth asteroids," which is a mark in favor of the ring theory, said Rivkin, who studies asteroids and their interactions with other objects.

Ten-kilometer-wide asteroids probably pass Earth every 70–80 million or so years, Rivkin estimated. He added that the alleged ring's lifetime of 40 million years is relatively short compared with Earth's lifetime but still long enough to account for the spread in crater ages. A ring-producing encounter is rare, which is why Earth doesn't have rings now, but probably not so rare that it's never happened at all.

Advanced simulations of Earth-asteroid encounters that more precisely calculate the likelihood of such an encounter, as well as account for the physical properties of L chondrite asteroids, would help convince Rivkin of the past existence of a ring.

"I would expect that the folks who do those sorts of studies are probably warming up their computers right now," he joked.

In fact, the researchers are currently working with astrophysics modelers to dial in on the likelihood that a ring formed and, if it did, exactly how big it would have been. Maybe down the line, Tomkins added, others might look into how opaque the ring was and whether its shade could have had an impact on global climate. If so, paleoclimate records might lend further credence to the idea of Earth's ephemeral ring.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer