Forum

End-Permian catastrophe by bolide impact: Evidence of a gigantic release of sulfur from the mantle: Comment and Reply

COMMENT

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Kaiho et al. (2001) report sulfur isotope and chemical data for samples from the Meishan (China) Permian-Triassic (P-T) boundary section, which they interpret as evidence for a large-scale impact event that penetrated Earth's mantle and formed a crater ~1000 km in diameter. We disagree with their interpretation in all major points.

First, Kaiho et al. interpret Fe-Ni-Si–rich grains as ''impact-metamorphosed grains.'' This interpretation is not supported by their (or other) data. The data in Table 1 of Kaiho et al. are of insufficient quality. Variations in the amounts of Ni, Al, Mn, and Cu do not indicate the presence of extraterrestrial matter. It is not clear which elements occur as oxides and which as metals. The only publications cited by Kaiho et al. in support of an impact-related origin of such grains are by Miura et al. (1999). These two short reports present low-quality data from undocumented sources (impact structures, volcanic features) as well as cryptic statements, which contrast with the well-established criteria for the identification of extraterrestrial components in impact-related materials (e.g., Koeberl, 1998).

The presence or absence of very small grains of badly known composition does not constitute evidence for or against an impact event. The statement of Kaiho et al. that ''the presence of grains of Fe-Si-Ni also represents evidence for an impact event'' is in conflict with well-documented data from known impact structures and deposits (Koeberl, 1998).

Second, the stratigraphic horizon analyzed by Kaiho et al. is said to be characterized by strong Ni enrichment. This statement is supported neither by analytical data (other than their Fig. 1), nor by elemental abundances that would point toward a definitive extraterrestrial source (e.g., platinum group element data). Furthermore, the authors do not attempt to ascertain the carrier phase of Ni, an element that can be enriched by various terrestrial processes. Does Ni reside in primary meteoritic matter, impact-generated phases, or minerals that result from biogenic or diagenetic origins?

Third, the suggestion that the lack of shocked quartz implies an oceanic impact event is misleading. Shock metamorphic effects are not restricted to quartz, but occur in all rock-forming and accessory minerals, which are abundant in ocean-floor rocks.

Fourth, impact-induced volcanism and/or the excavation of mantle material is implausible (e.g., Melosh, 2000, 2001; Ivanov and Artemieva, 2002). No known impact on Earth has ever had such consequences. The authors mistakenly assume complete vaporization of target material inside the crater cavity. From calculated degassed sulfur volume, the authors suppose a crater diameter of 600–1200 km. However, this is an estimate of the zone of vaporization. In fact, the actual size of the crater should be much larger. For a crater with a diameter of 600–1200 km, the amount of vaporized material is equal to 2–3 times the mass of a projectile at 20 km/s impact (O'Keefe and Ahrens, 1977). Hence, for such a large crater, the volume of vaporized target rock is 10^4 to 10^5 km^3, a factor of 1000 less than the $3 \cdot 10^7$ to $3 \cdot 10^8$ km^3 assumed by the authors. A projectile with a diameter of 750–1500 km would be required to produce these assumed values. The largest main belt asteroid has a diameter of 1000 km and the largest crater formed on the terrestrial planets in the past 500 m.y. is Mead Crater on Venus, with a diameter of ~280 km. This would seem to be an upper limit for plausible catastrophic impacts during the Phanerozoic on Earth.

Fifth, Kaiho et al. observe a range in $\delta^{34}S$ values for sulfate of between +28.6‰ and +2.0‰, with more ^{34}S-depleted values coincident with the change from limestones to more organic carbon–rich marls and claystone. Uncertainty over the evidence for a large impact around the P-T boundary (Farley and Mukhopadhyay, 2001), Kaiho et al.'s miscalculation of the amount of material vaporized, and the implausibility of impact-induced volcanism (Melosh, 2000, 2001), all suggest a more parsimonious interpretation of the data. There is substantive global evidence for initially dysoxic and ultimately anoxic conditions in many P-T sections (e.g., Isozaki, 1997; Wignall et al., 1998), and the $\delta^{34}S$ values observed by Kaiho et al. can readily be explained by fractionation via bacterial sulfate reduction and reoxidation of isotopically light H_2S, superimposed on a signature of Late Permian seawater. This has been observed in other Permian-Triassic evaporites (e.g., Spötl and Pak, 1996). Similarly, the authors have not considered detrital sulfate as a source for the ^{34}S-depleted values, despite the evidence of detrital input from their own Sr isotope data.

We conclude that none of the points raised by Kaiho et al. provides even a vague suggestion of an impact event at the P-T boundary. While an impact event is one of several possibilities to explain this mass extinction, the interpretations presented by Kaiho et al. are poorly documented, inconclusive, and bypass more obvious explanations of the data. Attempts to utilize the questionable interpretations by Kaiho et al. to support the equally controversial (cf. Farley and Mukhopadhyay, 2001) claims for the presence of extraterrestial ^3He in fullerenes at the P-T boundary represent circular logic.

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