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Science **305**, 492 (2004);
DOI: 10.1126/science.1098481

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Comet or Asteroid Shower in the Late Eocene?

Roald Tagle[1] and Philippe Claeys[2]*

In the late Eocene [~34 to 36.5 million years ago (Ma)], the deep-water carbonates of the Massignano section (Italy) were enriched in extraterrestrial ^{3}He, indicating a higher delivery of interplanetary dust particles (IDPs) to Earth (*1*). This ~2.5-million-year–long increase in the flux of IDPs is attributed to the arrival in the inner solar system of long-period comets, triggered by a perturbation of the Oort cloud (*1*). The two largest terrestrial craters in the Cenozoic, the 100-km Popigai (dated 35.7 ± 0.2 Ma) in northern Siberia and the 85-km Chesapeake Bay (dated 35.5 ± 0.6 Ma) just offshore Virginia, formed during the same time interval (*2*); they are likely the result of cometary impacts (*1*).

Meteorites are enriched in platinum group elements (PGEs) compared to crustal rocks. The PGE elemental ratios in the rocks melted by an impact compared with those of known meteorites document the composition of the crater-forming projectile. Popigai impact-melt rock (32 samples) and target lithologies (3 samples) were analyzed for PGEs with a NiS fire assay combined with inductively coupled plasma mass spectrometry (ICP-MS) (*3*) (table S1). Major and trace element compositions, measured by x-ray fluorescence, were homogeneous, but all impact-melt samples showed a major enrichment (up to 15 times higher) in PGEs compared to the target lithologies. The meteoritic contamination of the Popigai melt rock is ~0.2 weight percent; its PGE pattern and Ni/Cr ratio are chondritic. The Popigai PGE elemental ratios systematically overlap the field of ordinary chondrites (Fig. 1A). Combining ratios of elements with low (Pd and Rh) and high (Pt and Ru) condensation temperatures refines the identification of the projectile to an L-chondrite (Fig. 1B), whose source is possibly the type S(IV) asteroids from the inner asteroid belt.

An L-chondrite bolide is difficult to reconcile with a cometary origin. The PGE concentration of comets is unknown. Nonetheless, it is unlikely that a cometary bolide would display PGE elemental ratios similar to those of L-chondrites. Comets are believed to be primitive bodies with a composition like that of carbonaceous chondrites, which differ in PGE concentrations from ordinary chondrites (Fig. 1). Because asteroids may form ~1% of the inner Oort cloud objects (*4*), it cannot be excluded that a comet shower would include an L-chondrite body; however, this is a rather remote possibility. Popigai is most likely an asteroid impact. The probability that it coincides with a comet shower is also low. A 5-km object, required to produce Popigai, strikes Earth only once every ~26 million years (*5*).

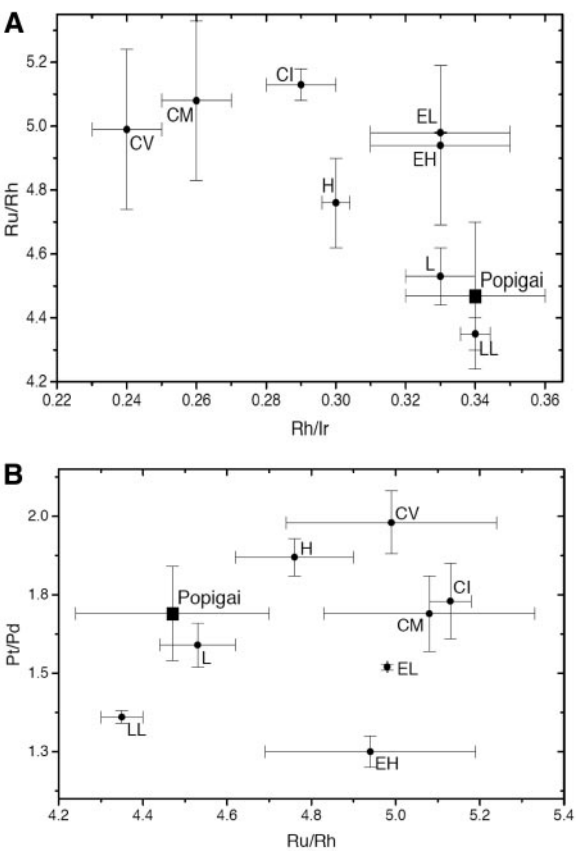


Fig. 1. (**A** and **B**) PGE elemental ratios in the impact melt of the Popigai crater compared to the elemental ratios for different types of chondrites. The error bars represent one standard deviation. Chondrite types: L, low iron; LL, low iron and low metal; H, high iron; CV, carbonaceous Vigarano; CM, carbonaceous Mighei; CI, carbonaceous Ivuna; EL, enstatite low iron; EH, enstatite high iron.

The large impacts and the increase in IDPs of the late Eocene could be the results of a major collision in the asteroid belt. This possibility was discarded by Farley *et al.* (*1*) because they relied on modeling that estimated a decay of IDP production rate over much longer periods than the 2.5-million-year IDP enrichment observed at Massignano. However, in the case of asteroid collision, recent work supports time scales of a few million years for the delivery of asteroidal material toward Earth (*6*). A major collision in the asteroid belt could produce dust and inject a large number of fragments into resonances capable of sending them into Earth-crossing orbits. An asteroidal collision would explain both the high delivery of IDPs and the occurrence of two large impacts, one of them by an ordinary chondrite, over an interval of a few million years. This event may be comparable to the disruption ~480 Ma of the L-chondrite parent body, which induced the higher accretion rate of micrometeorites and cosmic dust found in the middle Ordovician marine limestone of Sweden (*7*). This asteroidal collision hypothesis can be tested: The identification of the Chesapeake Bay crater projectile may confirm (or not) the asteroidal origin of the flux of IDPs and larger objects of the late Eocene.

References and Notes

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8. We thank the three anonymous reviewers for substantially improving this manuscript and J. Erzinger for his assistance with the ICP-MS and for providing access to the analytical facilities at the GeoForschungsZentnum-Potsdam. Supported by Funds for Scientific Research–Flanders (Belgium), a Vrije Universiteit Brussel–Onderzoeksraad grant, and the Deutsche Forschungsgemeinschaft (grant nos. Cl147/2-1 and Cl147/2-2).

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Table S1

30 March 2004; accepted 13 May 2004

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