Vesta is not an intact protoplanet

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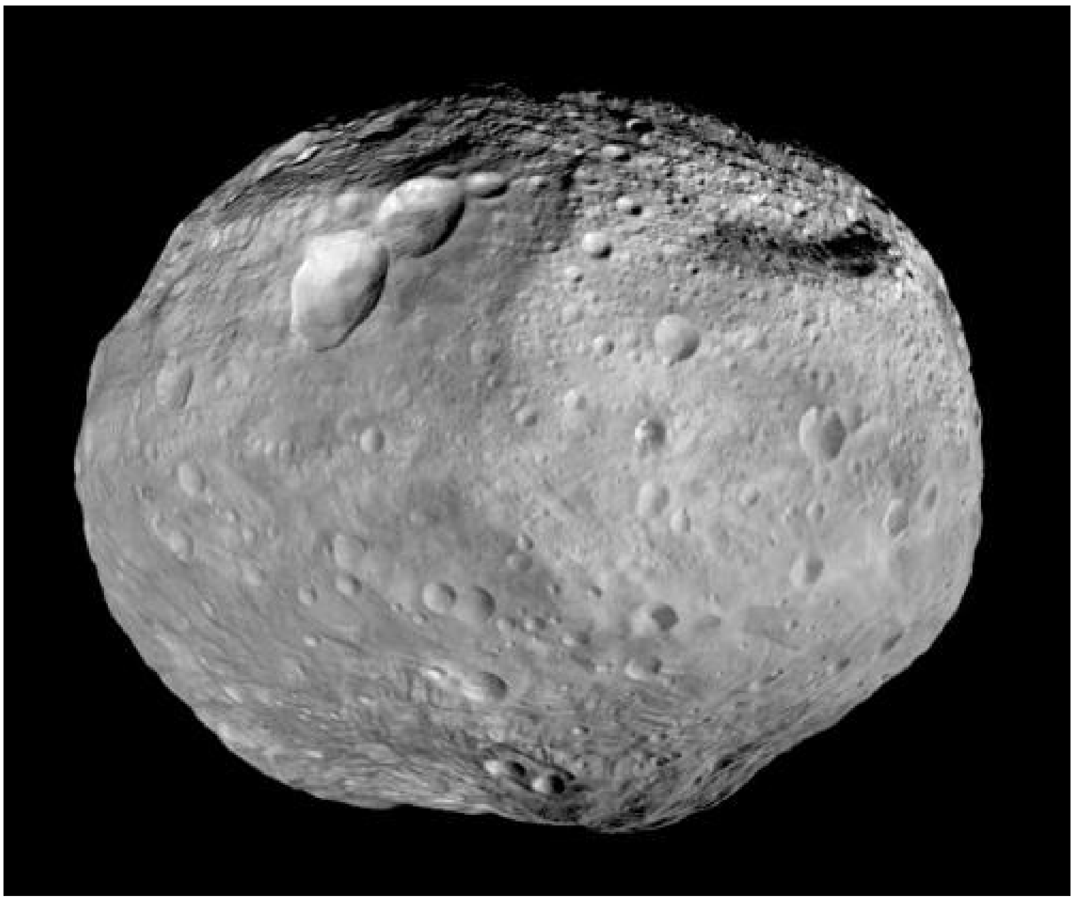

Asteroid Vesta. Credit: NASA/JPL-Caltech/UCAL/MPS/DLR/IDA

Nearly forty years ago, Guy Consolmagno was young graduate student at the University of Arizona's Department of Planetary Sciences; his work there with the late Michael Drake first proposed that asteroid Vesta was the parent body of the Howardite-Eucrite-Diogenite (HED) clan of basaltic meteorites. Last month, at the annual meeting of the AAS Division for Planetary Sciences, that identification was called into question by the same scientist who first proposed it.

Consolmagno (who now divides his time between the Specola Vaticana near Rome and the Vatican Observatory Research Group in Tucson) and a team of scientists organized by Diego Turrini (INAF, Rome) through the International Space Science Institute of Bern, Switzerland, have shown that Vesta could not be a parent body capable of matching the chemistry of the HED meteorites. While they acknowledge that most HED meteorites in our collections were chipped off Vesta's surface, they argue that Vesta as we see it today could not have been the place where those meteorites were originally melted and crystallized.

The HED meteorites are among the oldest materials in the solar system; their parent body melted and crystallized at the same time that the formation of Jupiter and the disk-driven migration of the giant planets also occurred. Thus it was expected that Vesta could provide an intact record of large-scale early episodes of planetary migration and bombardment, as has been proposed in the Jovian Early Bombardment and "Grand Tack" scenarios. However, according to Consolmagno and his colleagues, the results from NASA's Dawn spacecraft (which orbited Vesta from 2011 to 2013) show that the Vesta we see today has been radically altered from the body that originally produced the HED meteorites so long ago.

The argument starts with those results from forty years ago. Spectra taken in the early 1970s had shown that Vesta's colors matched those of the meteorites, but work by Consolmagno and Drake in 1977 went further, arguing that Vesta uniquely had to be not just similar to HED meteorites but the actual source of the meteorites in hand today.

All proposed models for the generation of the HEDs, starting with the

Consolmagno and Drake work of 1977, show that these meteorites could only represent about ten percent of the bulk of their parent body. The meteorites are ten-times enriched in trace elements and aluminum compared to ordinary chondrites; thus if they came from a chondritic protoplanet, the rest of that parent body would had to have included nine times as much depleted material, presumably an olivine-rich mantle and iron core. But while nearly 1,500 HED meteorites have been found, there are essentially no meteorites representing the olivine mantle. Thus they concluded that only the crust of the HED parent asteroid could be exposed to be chipped away into the meteorites we see today; the olivine and core must still be protected beneath that crust. The parent body must be intact. And Vesta is the only large asteroid with a HED surface. Thus the HED parent must be Vesta, they concluded.

However, Dawn revealed two overlapping deep impact craters on Vesta's south pole; current models calculate that these impacts must have excavated material from a depth of at least eighty kilometers. But there is no abundant mantle olivine visible in that basin, nor elsewhere on Vesta, nor in the Vestoid family asteroids. If the HED crust of Vesta is at least 80 km thick, it ought to manifest itself in other ways such as Vesta's density structure and bulk chemical composition.

Consolmagno and his co-authors compared what Dawn revealed about Vesta's density and the large iron core inferred from the gravity field observed by Dawn, against the known densities of HED meteorites and possible olivine-rich mantles, which also show that Vesta must have a thick HED crust. But such a crust, with large metal core seen by Dawn, leave no room left inside Vesta for the amount of olivine needed to make the HED meteorites. Furthermore, when they calculate the chemical abundances in that mantle, given the observed depletions of sodium and potassium in the HEDs, the trace element and FeO enrichments of the HED, and the amount of metallic iron needed to make the inferred core, they show that it is impossible to reconcile a

Vesta containing cosmic proportions of the major elements with anything even remotely approaching a mantle composition actually capable of making the HEDs.

Thus they face a basic conundrum. Vesta is certainly covered with a great thickness of HED meteorite material. But the Vesta that Dawn saw could not have produced those HEDs.

Apparently, sometime after the HEDs were formed (in a much larger proto-Vesta?) that body lost most of its mantle while holding onto both its HED crust and its metallic core. How is that possible? The Vesta we see today, Consolmagno and his colleagues argue, must be a reaccretion of material from now-destroyed protoplanetary parent bodies—perhaps the result of hit-and-run collisions. The very early formation of the HED meteorites, concurrent with the formation and migration of Jupiter, means that the environment where they were forming would have been one of frequent and intense collisions among protoplanets. It should not be surprising, they conclude, if Vesta is not itself a remnant protoplanet but a radically altered, chemically stripped and possibly reaccreted body.

Thus, while Vesta is not the intact protoplanet that the Dawn team hoped to explore, it nonetheless does provide the new and strong evidence that the Dawn team were looking for concerning the violent nature of the solar system at the time when the planets were first being formed.

Provided by Vatican Observatory Foundation

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