



Asteroid 433 Eros and partially differentiated planetesimals: bulk depletion versus surface depletion of sulfur

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The composition of asteroid 433 Eros, as determined by the NEAR Shoemaker spacecraft, is very similar to ordinary chondrites, but with one exception: the S/Si ratio is much lower than in any chondritic meteorite. Hypothetical explanations fall into two broad categories: surface sulfur depletion and bulk depletion. Surface depletion has generally been favored (e.g., Killen, *Meteoritics and Planetary Science* **38**[2003], 383; Kracher and Sears, *Icarus*, in press). Here I argue that while surface depletion may well be the more likely explanation, evidence so far available does not rule out bulk depletion.

Eros may have lost much of its sulfide by partial melting. Pure FeS melts at 1188°C; the Fe-S eutectic temperature is 988°C, and Ni in the metal further lowers the melting point. Thus troilite (FeS) in contact with nickel-iron is the lowest melting major mineral assemblage in a chondritic body at 950° to 960°C. By contrast, a fully differentiated body like Vesta requires an internal peak temperature above 1500°C. There must be many planetesimals that reached a peak temperature somewhere between these extremes. Between 1000° and 1100°C a small sulfide-rich core forms, but little melting of dry silicates occurs, leaving an essentially chondritic but sulfur-depleted mantle. The optical spectrum of such a body may well be indistinguishable from that of a truly chondritic one, especially considering additional uncertainty due to space weathering.

Gravity measurements rule out a core inside Eros, but the asteroid could be a mantle fragment from a partially differentiated planetesimal. The lower size limit for a body from which Eros could have been broken off is around 26km in radius and

$\sim 2.5 \times 10^{17}$ kg mass. Of course, the hypothetical parent could have been any size bigger than this. Eros would then represent $< 3\%$ of the parent mass.

Mineral assemblages in some meteorites (winonaites, acapulcoites, silicate inclusions in some irons) indicate peak temperatures in the range required for partial differentiation. The main argument against associating Eros with a partially differentiated body is that these meteorites are generally lower in $fe\#$ [i.e., $Fe/(Fe+Mg)$ ratio in the mafic silicates] and higher in pyroxene-to-olivine ratio than Eros.

However, not all asteroid types are represented in meteorite collections, and partially differentiated bodies with higher $fe\#$ may well exist. Even if such bodies have reached peak temperatures where reduction of FeO in silicates is kinetically possible, this process is limited by the amount of available reducing agent (in most cases elemental C). Not all chondritic material contains sufficient carbon to reduce the silicates to the $fe\#$ of winonaites. If little or no reduction occurred in the putative Eros parent, the low pyroxene-to-olivine ratio of the original chondritic material would be preserved, accounting for the difference between Eros and winonaites.

The scenario presented here is possible, but whether it is more or less plausible than the more commonly assumed surface depletion depends on whether any of the mechanisms proposed for the latter (e.g., solar wind sputtering, preferential vaporization by impacts, mechanical sorting, etc.) actually work. Laboratory simulations should be able to provide important information, but a conclusive answer will likely have to wait until returned asteroid samples can be examined in a terrestrial laboratory.