IRON AND STONY-IRON METEORITES AND THE MISSING MANTLE METEORITES AND ASTEROIDS

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Introduction: Why do we lack olivine meteorites and asteroids from the mantles of the 50 odd parent bodies that supply iron meteorites from their cores? Olivine mantles may have been pulverized by numerous projectiles whereas irons, which are much tougher than stones, survived for 4.5 Gyr [1]. But this is contrary to spectral and meteorite evidence for Vesta's basaltic surface and lack of mantle olivine in its regolith. A radically new explanation is that iron and stony-iron meteorites formed in grazing hit-and-run collisions in which the smaller of two roughly similar-sized protoplanets was eviscerated [2,3]. Recent studies of four groups of these meteorites strongly support such an origin <10 Myr after CAI formation.

Iron Meteorites: The three recently studied groups, IIIAB, IVA and IVB, all show ranges of cooling rates that require mantle removal before cooling. IVA irons cooled below 650°C at 100-6600 K/Myr showing that they cooled in a metallic body of radius 150±50 km with <1 km of silicate mantle [4]. IVB irons cooled at 475-5000°C/Myr in a metallic body of radius 65±15 km without a mantle [5]. The IIIAB irons cooled at 50-350 K/Myr in a body several tens of km in radius with a mantle that was only a few km thick [6]. In each case, the primary bodies were at least ~150-600 km across and cores were partly or wholly molten on impact. Clean removal of mantle from core metal is not feasible in conventional collisions with smaller projectiles. Projectiles that are energetic enough to extract core metal will partly disperse the core leaving mixed core and mantle. Hit-and-run collisions separate metal and silicate more efficiently [2]. The IVA and IIIAB primary bodies, which had molten cores when impacted, were probably reduced to strings of metal-rich bodies by such impacts [2]. For IVB, the core was largely solid when extracted.

Pallasites: Main group (MG) pallasites cooled at 2-20 K/Myr, excluding links with IIIAB irons [7]. Low Ir contents, non-uniform cooling rates, and the absence of related irons suggest that the primary parent body was torn apart when the core had largely solidified so that residual Fe-Ni melt was mixed with mantle material to form the MG pallasite body. The remarkably uniform small size of olivine grains in pallasites from at least six different bodies (mm to cm sized) is quite unlike fragmental debris from conventional impacts, which has a power law size distribution. In hit-and-run collisions, impact energy is spread relatively uniformly throughout the projectile's mantle by tidal distortion and shear forces on timescales of hours, rather than heterogeneously by shock in seconds. Longer timescales allow fragmentation on grain boundaries. The lack of mantle meteorites probably reflects early destruction of differentiated protoplanets by hit-and-run collisions at 1-2 AU [8], the small size of mantle fragments, and the difficulty of shock-welding monomineralic refractory mantle fragments into rocks. Conventional collisions into smaller differentiated bodies may also form rare olivine-rich A type asteroids.

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