SHOCK METAMORPHISM, BRECCIATION, AND IMPACT MELTING IN METEORITES.

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Introduction: The shock metamorphic scheme for ordinary chondrites and an extension of the classification of lunar breccias provides a firm foundation for evaluating the shock and impact histories of many kinds of meteorites [1]. Shock pressure estimates are very dependent on the initial state of the target and may be upper limits, e.g., if targets were initially hot or porous [2-3]. Thus, mild shock at elevated temperatures may generate shock stage S1-2 rocks with certain features like those in more heavily shocked rocks [4]. The interpretation of shock and brecciation in meteorites is also more complex than for planetary rocks as asteroids may have experienced impacts that were much more diverse than the cratering events that affected planetary rocks.

Early disruption of differentiated asteroids: Stony-iron meteorites like pallasites and mesosiderites that form from molten metal and unshocked broken rock may have formed in low-velocity hit-and-run impacts possibly between protoplanets [5] rather than in hypervelocity asteroidal collisions. Destruction at 1-2 AU prior to capture of debris in the asteroid belt by protoplanets may also help to explain how Vesta's crust survived.

Howardites, eucrites and diogenites: Most HEDs are shocked, brecciated, and have Ar-Ar ages of 3.5-4.1 Gyr consistent with impact heating and breccia formation on Vesta during the late heavy bombardment (LHB) [6]. HEDs probably come from one or more Vesta family asteroids, which formed at ~3.5 Gyr. About half the unbrecciated eucrites (7% of HEDs) are largely unshocked and have Ar-Ar ages of 4.48 Gyr. These may date excavation and removal from Vesta and subsequent storage in a ~10 km sized asteroid that escaped the LHB [7]. The general lack of HEDs and H chondrites with Ar-Ar ages of 4.1-4.5 Gyr suggests that if the primordial asteroid belt was 10^3 times more massive than the current belt and was dynamically excited by Jupiter's formation, the size distribution did not resemble the current one. The dearth of early impacts may result from formation of 100-1000 km diameter planetesimals by gravitational instabilities rather than by binary accretion of km-sized planetesimals.

Unshocked and unbrecciated angrites: If angrites represent ancient basalts and crustal rocks like the eucrites, why are angrites unshocked and unbrecciated? A plausible explanation is that the angrites were removed early from their parent body and stored in a ~10 km asteroid, like the 4.48 Gyr old eucrites.

Catastrophic disruption of the L chondrite parent body: The demolition of the 100-150 km diameter parent asteroid of the Gefion family created thousands of 1-15 km fragments and probably accounts for the abundance of heavily shocked L chondrites, their 470 Myr shock ages, and the almost immediate accumulation of fossil L chondrites on Earth [8].

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