EARLY IMPACT HISTORY OF ORDINARY CHONDRITE PARENT BODIES INFERRED FROM TROILITE-METAL INTERGROWTHS

Edward R. D. Scott[1], Joseph I. Goldstein[2], Jijin Yang[3]. [1]Univ. of Hawaii (escott@hawaii.edu) [2]Univ. of Massachusetts [3]Carl Zeiss SMT Inc.

Introduction: Understanding shock effects in ordinary chondrites (OCs) is essential for determining the impact and thermal histories of their parent bodies. OCs contain three major types of troilite-metal intergrowths formed by impact melting: dendritic textures from quenched Fe-Ni-S melts and two others (we call type 1 and type 2) that lack dendritic textures and have controversial origins. Rubin [1], for example, inferred from the latter (and other phases) that *all* type 4-6 OCs including S1-S2s were shocked to stage S3-6.

Type 1: A few OCs contain micrometer-scale intergrowths of irregularly shaped metal and troilite grains due to impact melting after kamacite formation. These intergrowths called fizzed troilite [see 2] are much more common in iron meteorites [3], which lack dendritic intergrowths. Mildly shocked irons (≤14 GPa) and shock stage S1-2 OCs may contain type 1 intergrowths at the boundary of metal and FeS grains that show twinning, mosaicism and finely recrystallized shear zones [3]. Fe-FeS melts form more readily under pressure as the Fe-FeS eutectic temperature decreases from 998°C at 1 bar to 860°C at 14 GPa [4]. Higher shock pressures create larger intergrowths but are not required to initiate melting. Lack of dendrites and the presence of shocked fragments of troilite and other minerals suggest the intergrowths formed not from total impact melts [5], but from melts laden with fragments. Steep shock and thermal gradients exclude formation by thermal conduction of impact heat over meters [6]. Type 1 intergrowths are not formed in S5-S6 shocks (contrary to [1] and [2]), as they make dendritic intergrowths from total melts.

Type 2: In many S1-S4 OCs, some taenite grains with normal Ni zoning and cloudy taenite contain clusters of irregularly shaped troilite grains 2-20 µm across [1]. These intergrowths are unlike dendritic and type 1 varieties and are not well characterized. The seemingly isolated troilite grains have the same optical orientation as large troilites abutting the zoned taenite, implying that they are part of a larger single crystal that extends ~10-50 microns into the taenite. Tetrataenite rims around the zoned taenite also enclose the troilite grains indicating prior formation of the intergrowth.

Discussion: We infer that type 2 intergrowths formed from type-1-like precursors, but unlike Rubin [1], we favor impact melting during ^{26}Al-induced metamorphism, followed by subsequent recrystallization on cooling. Any intergrowths formed during accretion should have been erased by coarsening during metamorphism. Type 6 chondrites would have required only minor shock and impact heating as their maximum temperatures are close to the eutectic Fe-FeS temperature. Mild shocks are also indicated by the localized nature of type 2 intergrowths and by their presence in porous OCs like Miller (Arkansas). Their ubiquity (present in 50% of S1-S2 type 5 and 6 OCs [1]) favors hit-and-run glancing impacts by Vesta-to-Moon-sized bodies, rather than conventional asteroidal impacts. One of these may also have formed the Portales Valley H6 breccia.

References: [1] Rubin A. E. 2004. Geochimica et Cosmochimica Acta 68:673-689. [2] Bennett M. E. and McSween H.Y. 1996. Meteoritics & Planetary Science 31:255-264. [3] Buchwald V. F. 1975. Handbook of Iron Meteorites. Univ. California Press. [4] Fei Y. et al. 1997 Science 275:1621-1623. [5] Teshima J. et al. 1986 Geochimica et Cosmochimica Acta 50:2073-2087. [6] Tomkins A. G. 2009. Meteoritics & Planetary Science 44:1133-1149.