SHOCK METAMORPHISM IN NORTHWEST AFRICA 8159, TISSINT AND ELEPHANT MORAINE A79001: IMPLICATIONS FOR THERMAL HISTORIES AND GEOCHRONOLOGY.

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Introduction: Shock metamorphic effects in Martian meteorites provide a record of recent impact events on Mars. The key to interpreting this record is understanding the shock conditions and relating these to impact processes [1-2]. Martian meteorites have experienced shock effects, ranging from nearly unshocked (S1) to very highly shocked (S6). The shock effects observed are typically heterogeneous and local shock effects depend on pressure, deformation and thermal histories. In this study we examine shock pressures and thermal histories of three Martian meteorites and discuss implications for shock resetting of isotope systems. Each sample experienced a different P-T-t path, resulting in different textures and mineral assemblages.

Samples and Methods: We examined the textures and mineralogy associated with shock melting in three highly shocked Martian basalts: NWA 8159, Tissint and EET A79001. We used polarizing light microscopy, Raman spectroscopy, and SEM to characterize the microstructures and compositions of minerals associated with shock veins. FIB lift-out and TEM were used to characterize nano-mineralogy of the shock veins and transformation effects in associated minerals.

Results: NWA 8159 is an augite-plagioclase basalt with several 1-mm-thick shock-melt veins. The plagioclase (An_{49-61}) is predominantly crystalline except in the vicinity of shock veins where it is stoichiometric and isotropic maskelynite. In contact with shock melt, fayalitic olivine is partially transformed to ahrensite (Fe_2SiO_4-rich ringwoodite) [3]. The shock vein matrix consists of a mixture of majoritic garnet, stishovite and clinopyroxene. Our sample of Tissint contains abundant shock melt veins and pockets ranging from in size from 10s of µm to 1.4 mm [4]. Fayalitic olivine is transformed to ahrensite along shock veins and many olivines are transformed to magnesiowüstite plus pyroxene or pyroxene-composition glass. The assemblages that crystallized from melt vary from ringwoodite + stishovite + pyroxene in the thinner veins to olivine + clinopyroxene + vesiculated glass in the largest shock melt pockets. EET A79001 contains shock veins with entrained fragments of partially transformed olivine with granular and lamellar ringwoodite, inferred to represent post-shock back transformation [5]. FIB-TEM confirms the transformation of ringwoodite by polycrystalline olivine. Plagioclase in both Tissint and EET A79001 has been completely converted to maskelynite throughout the host rock. In Tissint, plagioclase (An_{59-69}) in direct contact with quenched shock melt has been transformed to tissintite – a defect-rich clinopyroxene with plagioclase composition. In EET A79001 plagioclase (An_{50-65}) glass exhibits vesicles and flow features in contact with shock melt.

Discussion: The variable mineral assemblages and textures reflect different shock conditions and thermal histories. NWA 8159 has no evidence of low-pressure shock melt crystallization or back-transformation. This sample experienced a moderately high crystallization pressure of ~ 16 GPa that lasted throughout crystallization of mm-scale shock veins [3]. This implies that the shock pulse was longer than the duration of shock-vein quench. Tissint experienced a shock pressure (> 19 GPa) sufficient to transform olivine to bridgmanite + magnesiowüstite. However, in this case the pressure pulse was shorter than the quench time for 1.4 mm shock melt pockets. Locally, the sample remained hot enough after shock to back transform bridgmanite to pyroxene [4]. Finally, EET A79001 experienced a minimum shock pressure of ~ 18 GPa [5], but the sample remained hot enough after decompression to transform much of the ringwoodite back to olivine. Back-transformation kinetic data for ringwoodite and wadsleyite [6] indicates that the sample must remain at temperatures > 1200 K for seconds after decompression for back transformation. Alternatively, the sample may have remained between 1200 and 900 K for much longer. This implies that EET A79001 either had a short shock-pressure pulse relative to cooling time for the melt-vein and associated ringwoodite fragments, or the entire sample remained between 900 and 1200 K for a prolonged period. The observation that NWA 8159 and Tissint have little or no back transformation implies that their high-pressure minerals cooled below 1200 K very quickly (less than seconds). This implies that all but the hottest parts of Tissint and NWA 8159 remained cool or cooled quickly enough to avoid resetting of isotopic systems. The notion that shock metamorphism in Martian meteorites has pervasive resetting of isotopic systems is not consistent with the preservation of high-pressure minerals in these sample.

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