NORTHWEST AFRICA 10658, A UNIQUELY SHOCKED EUCRITE WITH A RANGE OF DEFORMATION, TRANSFORMATION AND RECRYSTALLIZATION EFFECTS

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Introduction: Impacts are a fundamental geologic process that has influenced the formation and modification of asteroids and planets throughout time. An important part of the impact history of the solar system is recorded in shocked meteorites. The asteroid Vesta has experienced large impacts, evidenced by two ~400-500 km impact structures that overprint the south pole region. While a range of shock-induced effects such as brecciation, melting and the formation of maskelynite has been reported in howardite-eucrite-diogenite (HED) meteorites originating from Vesta, high-pressure minerals have previously only been described in two eucrites [1-2]. Here, we present results on an inventory of shock effects and high-pressure minerals preserved in the polymict eucrite NWA 10658.

Sample and Methods: A thin section of NWA 10658 was studied in polarized and reflected light to observe deformation and transformation features, and to map the distribution of shock induced melt veins and pockets. Backscattered electron (BSE) imaging of transformation textures and sample chemistry were acquired with electron probe microanalysis at Arizona State University (ASU). We verified the structural state of polymorphs with Raman spectroscopy at ASU, and electron back-scatter diffraction (EBSD) at the California Institute of Technology (Caltech).

Results: NWA 10658 is a polymict breccia, consisting of two clast populations up to 4 mm with distinct textures and compositions embedded in a brecciated matrix [3]. This matrix exhibits a range of brittle-ductile deformation textures, consisting of compacted fragments up to 100 μm. Some regions of the matrix have been sheared, rounded and locally melted to a glass. Shock-induced melt pockets and veins with entrained host rock fragments approach 600 μm in apparent thickness. The smaller melt vein assemblages consist of pyroxene, glass + iron sulfides, while the larger melt pockets consist of clinopyroxene, garnets + iron sulfides. Expansion cracks emanate from transformed feldspars and silica fragments, propagating into the host rock and/or crosscutting melt. Plagioclase ($Ab_{7-16}An_{82-92}Or_{0.1-2.6}$) has been partially to completely transformed to maskelynite. Crystalline plagioclases exhibit planar deformation features and/or mosaicism. Maskelynite grains entrained in or in contact with shock melt have locally been partially to completely transformed to tissintite and/or a grossular garnet-like phase [4-5]. EBSD orientation mapping of the shock melt in NWA 10658 shows that melt-pocket garnets and garnet replacing plagioclase share similar orientations. Silica fragments are untransformed or are partially to completely converted to a glass. BSE imaging of transformed SiO_2 grains indicates the presence of two transformation textures, ranging from polycrystalline, flow-like textures to blocky domains with high contrast in a glassy silica matrix. Raman spectroscopy of these regions confirms the presence of coesite in silica glass. In other SiO_2 fragments, we observe textures resembling that of stishovite and/or the post-stishovite polymorph seifertite, however we have not yet confirmed the presence of these polymorphs. Pyroxenes in NWA 10658 exhibit a range of deformation effects, including mosaicism and planar fractures. So far, we have not observed evidence for the transformation of pyroxenes associated with shock melt to garnet or akimotoite.

Discussion: The formation of high-pressure minerals from silica and plagioclase in NWA 10658 is restricted to fragments that are entrained in, or are in close association with the shock-induced melt. The partial transformation of anorthitic plagioclase to maskelynite suggests an equilibrium shock pressure of ~24 GPa [6]. The pressure stability of coesite, ~3-12 GPa [7], indicates a shock pressure of at least 3 GPa and possibly much higher. Textural evidence for other silica polymorphs suggest that the coesite formed metastably at pressures where stishovite and even post-stishovite phases are stable relative to quartz. NWA 10658 is a uniquely shocked eucrite and represents the third eucrite retaining high-pressure polymorphs. The transformation of anorthitic plagioclase to garnet has not been observed in eucrites or other shocked meteorites. More detailed analysis is underway to completely characterize the shock transformation effects recorded in this sample.

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