CHARACTERIZATION OF A NEW HIGH-PRESSURE ASSEMBLAGE AFTER ANORTHITIC PLAGIOCLASE IN POLYMICT EUCRITE NORTHWEST AFRICA 10658

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Introduction: Investigations of shock-induced deformation, transformation, and recrystallization effects in meteorites are important for estimating shock pressure and temperature conditions. Plagioclase is a common constituent of meteorites and impact rocks on Earth that records these shock effects. Recently, a range of high-pressure mineral assemblages after Ca-rich plagioclase have been described in shocked meteorites [1-3]. Here, we summarize investigations of a new, garnet-bearing assemblage after anorthitic plagioclase in a shocked eucrite.

Sample and Methods: Northwest Africa (NWA) 10658 was purchased by Michael Farmer from a dealer at the 2014 Tucson Gem and Mineral show [4]. A thin section of the sample was provided by the Center for Meteorite Studies (CMS) at Arizona State University. The section was investigated using a combination of polarized and reflected light microscopy to document host rock deformation, and localized transformation and melting. We followed these preliminary investigations with field-emission scanning electron microscopy (FE-SEM) in backscattered electron (BSE) imaging mode to characterize the microtextures of transformed and/or recrystallized regions. We verified the mineralogy using Raman spectroscopy, electron backscatter diffraction (EBSD), and transmission electron microscopy (TEM).

Results: The plagioclase (An_{82-92}) in NWA 10658 has been partially to completely converted to an isotropic glass (maskelynite). The extent of amorphization increases with proximity to the shock-induced melt. Birefringent (crystalline) plagioclase remnants in partially converted grains exhibit mosaicism and planar deformation features. Plagioclase fragments entrained in quenched shock melt have been partially transformed to tissintite. BSE images of a transformed plagioclase fragment entrained in a shock melt pocket exhibit a dendritic texture, with dendrites extending inward from grain margins (Fig. 1).

Raman spectroscopic investigations of the transformed plagioclase indicate the presence of a grossular-like garnet [5]. However, the strong contrast variation in high-resolution BSE images of this region indicate the presence of at least three materials: 1) high contrast, poikilitic crystals that enclose 2) prismatic, euhedral crystals, and 3) an interstitial low-contrast material (Fig. 2). We used EBSD and TEM to identify these phases.

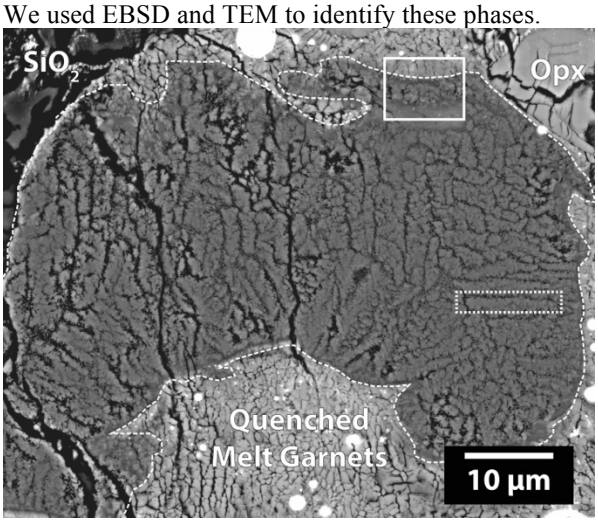

Figure 1: BSE image of plagioclase fragment (outlined by dashed line) entrained in a quenched shock melt pocket in NWA 10658. The plagioclase has been pseudomorphically replaced by dendritic-textured material, and is surrounded by Fe-rich garnets which quenched from the shock melt. Solid white box: location of Figure 2. Dashed white box: FIB location. *Opx: orthopyroxene*

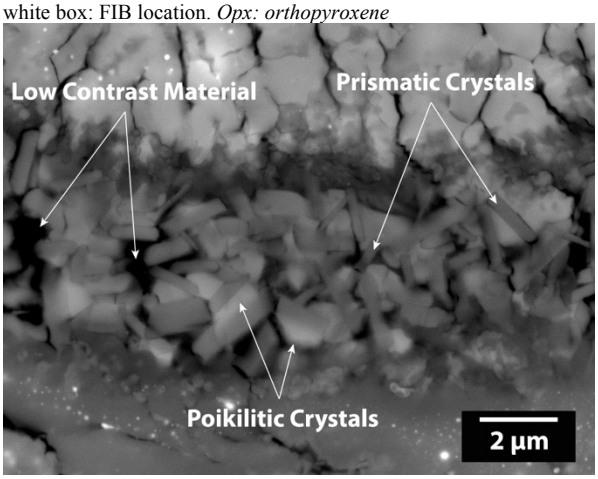

Figure 2: High magnification BSE image of region outlined by the solid white box in Figure 1. The difference in contrast and textural morphologies within the plagioclase precursor implies the presence of three phases.

The indexed EBSD diffraction patterns collected from the upper edge of the grain (Fig. 2) indicate the presence of garnet (*Ia-3d*) and clinopyroxene *(C 2/c)*. EBSD data also confirmed the presence of garnet in the quenched shock melt. EBSD orientation mapping reveals that the garnets after plagioclase have the same orientation as the quenched melt garnets.

We used TEM to investigate a FIB section extracted from the center of the transformed plagioclase (Fig. 1) to identify the phases and to acquire EDS chemical data. Bright-field TEM images (Fig. 3) reveal morphologies similar to those observed in BSE images (Fig. 2) with prismatic crystals enclosed by poikilitic crystals. The bright interstitial material shows no diffraction contrast and is inferred to be amorphous. Selected area electron diffraction (SAED) shows that the prismatic crystals are zagamiite (a high-pressure calcium aluminosilicate [2]), and that the enclosing phase is garnet. Our EDS data show that this is a Ca-rich garnet with excess Si, implying that it has a majorite component. These analyses also indicate excess Al, implying that some of the aluminum is incorporated in the X-site. The zagamiite here is more Al-rich than the type material discovered in Zagami. The interstitial amorphous material is nearly pure SiO_2. Further work is underway to refine site occupancies in the garnet and zagamiite.

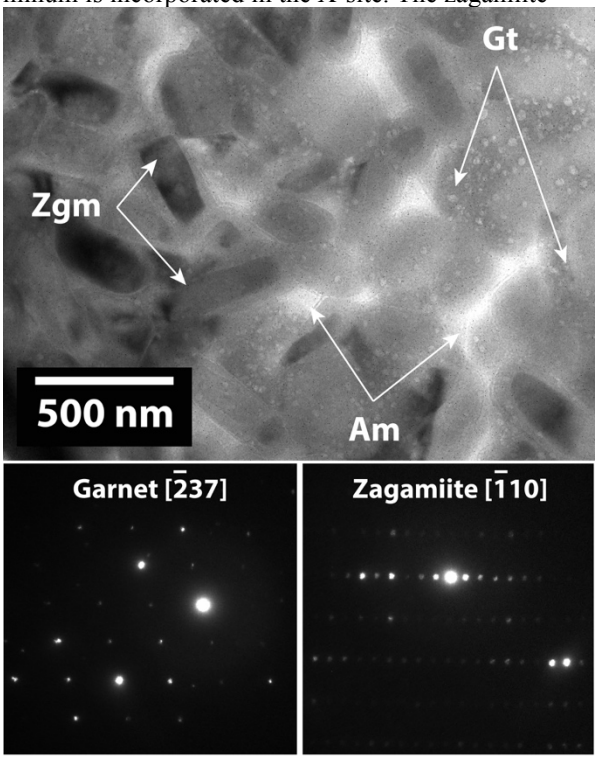

Figure 3 (Top): Bright-field TEM image of a portion of the FIB section extracted from the transformed plagioclase (Dashed white box, Figure 1). Prismatic crystals (zagamiite) coexist with a light contrast material (amorphous) and an interstitial phase with intermediate contrast (garnet). **(Bottom):** Indexed diffraction patterns with Ia-3d (garnet) and $P6_3/mmc$ (zagamiite) structures. *Zgm: zagamiite, Gt: garnet, Am: amorphous material*

Discussion: Our EBSD and TEM results show that the transformation assemblage in NWA 10658 is not uniform throughout the plagioclase precursor. The core consists of garnet + zagamiite + SiO_2-rich glass, surrounded by a rim of clinopyroxene + garnet. Synchrotron X-ray diffraction data suggests that the clinopyroxene here is the vacancy rich, high-pressure clinopyroxene tissintite [1]. The dendritic morphologies observed in FE-SEM images and the presence of interstitial SiO_2-rich glass suggest that the plagioclase transformation involved melting. However, there is only minor evidence of mixing with the surrounding shock melt.

Previous studies on high-pressure garnets have reported majorite-pyrope solid solutions in shock veins from shocked L-chondrites [6-7], and Ca-rich majorites in martian meteorites and terrestrial samples [8-10]. These garnets are distinct from the classic members of the garnet supergroup, in that they accommodate excess silicon in octahedral coordination under shock compression [11-12]. They are relatively resistant to post-shock back transformation or subsequent alteration, and are therefore important indicators of shock [13-14]. The Ca-Al-Si rich garnet in NWA 10658 provides new insight into the compositional range of high-pressure garnets.

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