TRANSFORMATION TEXTURES AND CRYSTALLIZATION OF WADSLEYITE AND RINGWOODITE IN SAHARA 00293 AND 98222.
C. Fudge, J. Hu and T. G. Sharp [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, U.S.A. cfudge@asu.edu

Introduction: High-pressure mineral assemblages in highly shocked meteorites provide information on the pressure and temperature conditions that result from impacts on their parent bodies. Among the most primitive of meteorites, ordinary chondrites contain shock-induced melt veins and associated high-pressure minerals, and serve as important indicators of impact events in our solar system. The typical high-pressure olivine polymorphs associated with shock-melt veins and pockets in L6 ordinary chondrites include spinel-structured ringwoodite, as well as the modified-spinel-structured wadsleyite.

The transformation of olivine to ringwoodite and wadsleyite are not only important for us to understand planetary impacts, but also because these phase transitions have important implications for the internal structure of terrestrial planets. Both phases form by either the solid-state transformation of olivine within or adjacent to shock-melt veins, or by direct crystallization from the shock-induced melt. Ringwoodite fragments within and along shock-melt veins have been thoroughly studied since their initial discovery [1], however wadsleyite + ringwoodite fragments coexisting in the same sample occur less frequently [2]. The purpose of this study is to use crystallization assemblages to estimate the shock conditions resulting from the impact event on the L-chondrite parent body, and to understand why wadsleyite and ringwoodite exist together in these samples. Here, we present evidence of partial to complete solid-state transformation of olivine to wadsleyite and ringwoodite within olivine fragments in two L6 ordinary chondrites: Sahara 00293 and 98222.

Methods: Polarized light microscopy was used to observe the occurrence and distribution of wadsleyite and ringwoodite relative to melt veins in two petrographic thin sections. Partial and complete solid-state transformation textures of clasts entrained in shock melt and adjacent to melt veins were investigated with scanning electron microscopy (SEM) and chemical composition measured with energy-dispersive X-ray spectroscopy (EDS). We followed our textural analysis with Raman spectroscopy in order to correlate transformation textures with phase identification. The L6 chondritic classification of the samples was verified with electron microprobe analysis (EPMA).

Results: *Sahara 00293 and 98222*. A complicated, interconnected network of shock-melt veins and pockets were observed in each sample with width from 0.25 to 2.0 millimeters. Shock veins are fine-grained, with irregular metal sulfides and equant, euhedral to subhedral silicates. We infer, based on textural comparisons to other shocked L6 chondrites that the silicate assemblage is majoritic garnet + magnesiowüstite in melt vein centers [3]. The melt texture transitions to sub- to anhedral majorite immediately adjacent to host rock with round metal sulfides. The olivine in host rock adjacent to melt and polycrystalline fragments entrained in the shock-induced melt are partially to completely transformed to wadsleyite and ringwoodite.

Wadsleyite is optically identifiable by its dark green color in plane-polarized light and its low, but visible, birefringence in crossed polarized light. Wadsleyite occurs as homogeneous polycrystalline aggregates on olivine grain boundaries and fractures adjacent to shock melt in the host rock. Generally, wadsleyite transitions to partially transformed olivine and ringwoodite (*Figure 1*). In cases where the wadsleyite transitions to ringwoodite, it can be optically and texturally difficult to discern the two, but Raman spectra indicate the presence of both ringwoodite and wadsleyite, or olivine + ringwoodite or wadsleyite.

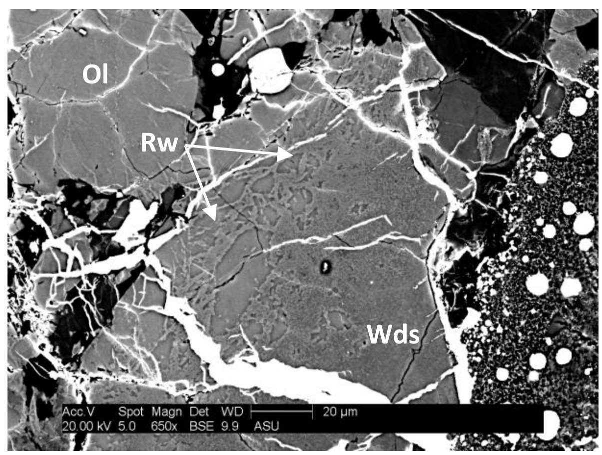

Figure 1: Back-scattered electron (BSE) image of olivine in host rock of Sahara 98222 adjacent to shock-melt vein with polycrystalline texture in wadsleyite, transitioning into ringwoodite lamellae away from melt.

The partially transformed fragments entrained in melt veins show nucleation of wadsleyite along fractures and grain boundaries of the original olivine, generally absent of ringwoodite. Ringwoodite occurs along shock- melt veins and pockets as polycrystalline aggregates after wadsleyite, which progress to lamellar textures toward the interior of the host rock. It also occurs as lamellae within the interiors of large polycrystalline fragments that have polycrystalline wadsleyite rims adjacent to melt (*Figure 2*) similar to what is observed in some transformed olivine in host rock.

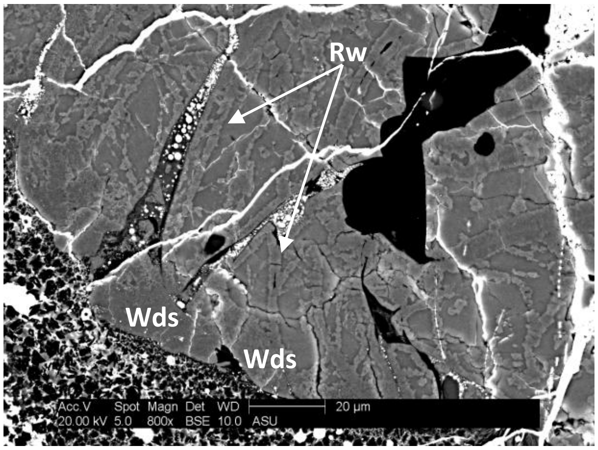

Figure 2: BSE image of a polycrystalline fragment entrained in shock-melt vein of Sahara 00293. Olivine transformation progresses from polycrystalline wadsleyite in contact with melt to ringwoodite lamellae away from melt.

Discussion: *Shock conditions and the coexistence of ringwoodite and wadsleyite.* Sahara 00293 and 98222 are L6 ordinary chondrites with pervasive sub- to two-millimeter shock-melt veins and pockets. The presence of ringwoodite along melt veins indicates shock stage (S6), however the occurrence of planar fractures in the host rock olivine reflects shock stage (S4) [4]. The abundance of full to partial solid-state transformation textures observed for wadsleyite and ringwoodite within and along melt are directly associated with the high temperatures of shock-melt veins. These veins provide the required thermal energy needed to overcome energy barriers necessary for the nucleation and growth of high-pressure phases [5].

Previous studies have interpreted wadsleyite coexisting with ringwoodite to have formed by fractional crystallization from an olivine melt [6]. However, our EDS measurements show nearly identical chemical composition of olivine, wadsleyite and ringwoodite within the same grains, which is inconsistent with crystallization from an olivine melt. The lack of Fe-Mg partitioning between olivine and wadsleyite or ringwoodite implies interface-controlled growth rather than diffusion-controlled growth. We therefore conclude that the transformation mechanism for olivine in our samples is an interface-controlled solid-state transformation rather than crystallization from melt.

The presence and distribution of these polymorphs with respect to shock-induced melt demonstrates the importance of temperature heterogeneity during shock. Wadsleyite commonly occurs as rims in fragments directly in contact with melt, while ringwoodite is generally distributed in cooler regions and less commonly in contact with melt. This can be explained by wadsleyite nucleating at the highest temperature regions of the olivine, along the original olivine melt interface. At somewhat cooler temperatures within the olivine grains, ringwoodite has formed.

Sahara 98222 was previously studied by Ozawa et al., who identified abundant wadsleyite in their study, but did not observe ringwoodite [7]. Based on their observations they assigned a relatively low shock pressure of 13-16 GPa for Sahara 98222. However if the melt vein matrix in our samples is composed of majoritic garnet and magnesiowüstite, it suggests somewhat higher shock conditions of approximately 22 GPa. At this pressure, the crystallization of wadsleyite can occur at high temperatures which cross the stable wadsleyite-ringwoodite boundary. The occurrence of wadsleyite and ringwoodite likely reflects the range of temperatures that occur adjacent to shock melt during the shock event [8].

References: [1] Binns R. A. et al. (1969) *Nature, 221, 943-944.* [2] Price G. D. (1983) *PEPI, 33, 137-147.* [3] Xie Z. et al. (2006) *Geochim. Cosmochim. Acta, 70, 504-515.* [4] Stöffler D. et al. (1991) *Geochim. Cosmochim. Acta*, 55, 3845-3867. [5] Sharp T. G. and DeCarli P. S. (2006) *MESS II*, 653-677. [6] Miyahara et al. (2008) *Proceedings of NAS., 105, 8542-8547.* [7] Ozawa S. et al. (2009) *Meteoritics & Planet. Sci., 44 (11), 1771-1786.* [8] Fudge C. et al. (2014) *Lunar Planet. Sci. XLV,2237.pdf*