HIGH-PRESSURE MINERALS IN LL6 NWA 757 SUGGEST S6 SHOCK STAGE AND A SHOCK PRESSURE OF 22-25 GPA. J. Hu, B. H. Kent and T. G. Sharp, School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, U.S.A. jinping.hu@asu.edu.

Introduction: Highly shocked L6 chondrites are common and contain high-pressure minerals that provide constraints on shock pressures and the impact history of the L chondrite parent body. Very few LL chondrites have similar shock effects. Jadeite was reported in three of five shocked LL chondrites investigated by Kimura et al. [1]. NWA 757 is a type 6 LL chondrite with numerous shock-melt veins, maskelynite and ringwoodite [2]. We are further investigating the high-pressure mineral assemblages in NWA 757 to constrain the shock pressure conditions and to compare the shock features to those found in the more common L6 chondrites. Here we report new results from polarized light microscopy, Raman spectroscopy and scanning electron microscopy.

From the composition of olivine and pyroxene in NWA 757, it is shown to be an LL chondrite [2]. The thin section, provided to us by A. Bischoff, contains numerous shock-melt veins and pockets, ranging in thickness from a few µm to one mm. Shock melt veins and pockets contain abundant blue ringwoodite, indicating the shock stage is S6 for the melt veins. In areas far from the melt veins, the appearance of plagioclase and maskelynite indicates a shock stage of S4 to S5, which is also supported by planar fractures and mosaicism of olivine. This is in agreement with previous results [2].

Results: ***Olivine-Ringwoodite.*** Our thin section of NWA 757 contains ringwoodite within and on the boundary of the shock melt veins. As indicated by Raman spectroscopy, ringwoodite varies in color from dark blue to light blue or colorless in plane polarized light. In some large individual grains, continuous variation in color is visible. Raman spectra are similar for the different ringwoodite colors. The two main peaks at 799 cm^{-1} and 844 cm^{-1} and a broad and intense peak at 232 cm^{-1} are present in all ringwoodite spectra. Some colorless grains provide a mixed Raman spectrum of olivine and ringwoodite with peaks at 232 cm^{-1}, 824 cm^{-1} and 855 cm^{-1}. Intergrowths of ringwoodite and olivine, including ringwoodite lamellae in olivine, are observed in backscattered electron images.

Pyroxenes. Both low-Ca and high-Ca pyroxenes are common in NWA 757. Raman spectroscopy shows that they are mainly diopside and enstatite. No evidence of high-pressure pyroxene polymorphs has been found in this sample.

Feldspars. Feldspar composition phases in NMA 757 comprise shocked plagioclase, maskelynite and lingunite. Far from melt veins, the plagioclase has low birefringence or is nearly isotropic, whereas within and near melt veins it consists of completely isotropic maskelynite. These maskelynites are surrounded by radial fractures, which indicates post-shock expansion. Raman spectroscopy confirms that most of the plagioclase composition material in melt veins is maskelynite, but fine-grained lingunite, the high-pressure polymorph with the hollandite structure, occurs in the thickest melt pocket. The diagnostic Raman peak for lingunite occurs at 769 cm^{-1} (Fig. 1)

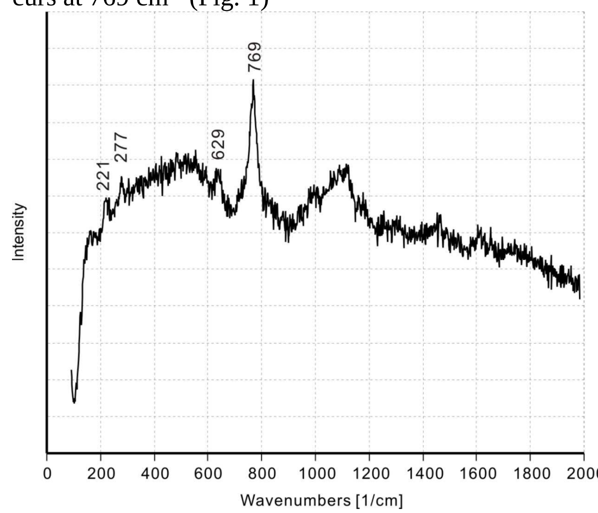

Figure 1. Raman spectrum of Lingunite within shock melt pocket from NWA 757 meteorite

Phosphates. Energy dispersion X-ray spectroscopy (EDS) measurement shows the existence of phosphate minerals in NWA757, including chlorapatite and merrillite. They are distinguished by the chlorine content from EDS measurement. Some of these grains occur in melt veins adjacent to partially transformed olivine and are inferred to be transformed or partially transformed to a high-pressure polymorph (Fig. 2). The structures of those polymorphs are under investigation by Raman spectroscopy.

Melt-vein Matrix. The melt veins matrix of NWA 757, like melt veins in highly shocked L chondrites, consist of a silicate component surrounding round metal-sulfide droplets. These are inferred to represent two immiscible liquids during shock. There is a range of microstructures in the silicate components that suggests variation in the crystallization mineral assemblages. The most common matrix comprises well defined, but irregularly shaped, silicate crystals surrounded by a lighter contrast phase (Fig. 3a). These crystals are much too small, less than half a micron, for SEM EDS measurements or Raman spectroscopy. But the matrix is not fully uniform. In larger melt veins and pockets, the matrix microstructure is consistent with an assemblage of majorite-pyrope garnet solid solution and ferro-periclase (Fig. 3b). EDS analyses of the larger crystals are also consistent with a majorite-pyrope garnet. Size of garnet crystals is rarely larger than 2 µm. In many L chondrites, similar textures have been observed for the majorite-pyrope garnet plus and ferro-periclase assemblage. However, most melt-vein matrix assemblages are too fine grained to characterize by FESEM. Samples are being prepared for TEM by focused-ion-beam (FIB) methods.

Discussion: NWA 757 and shocked L chondrites have quite similar high-pressure minerals assemblage. From our investigation, a main difference is that transformation of pyroxene to garnet is lacking in NWA 757. Large grains of polycrystalline majorite, transformed from pyroxene, are common in shock melt veins of many L chondrites [3]. But in our sample, the pyroxene fragments that were entrained in the melt veins and pockets remained as enstatite and diopsite. This suggests that the temperature was insufficient to transform pyroxenes to their high-pressure polymorphs.

Phosphate minerals in NWA 757 appear to have transformed to high-P polymorphs, as seen in Sixiangkou and Suizhou L6 chondrites [4, 5]. Suizhou chondrite contains melt-vein matrix textures that are very similar to matrix textures seen in NWA 757 (Fig. 3a). However, the high-P polymorph of merrillite in Suizhou chondrite, trigonal γ-$Ca_3(PO_4)_2$, coexists with ringwoodite, majorite and lingunite, whereas partial transformation of phosphate occurs in large clasts along thin veins in NWA 757.

Melt vein matrix is texturally heterogeneous, suggesting variations in mineralogy and possibly shock pressures during melt-vein quench. Evidence for majorite-pyrope garnet crystallization suggests crystallization and shock pressure of approximately 22-25 GPa.

Although very few LL chondrites show evidence for shock stage S6, NWA 757 clearly has S6 melt-vein crystallization and transformation features. The crystallization pressure inferred from the apparent presence of majorite-pyrope garnet crystallization (22-25 GPa) is the same as in most L6-S6 chondrites. This suggests that the LL chondrite parent body experienced similar shock pressure and therefore impact events to that of the L chondrite parent body. Unlike, the L chondrite body, which was heavily shocked at about 500 Ma, the LL shock may represent a much older impact history.

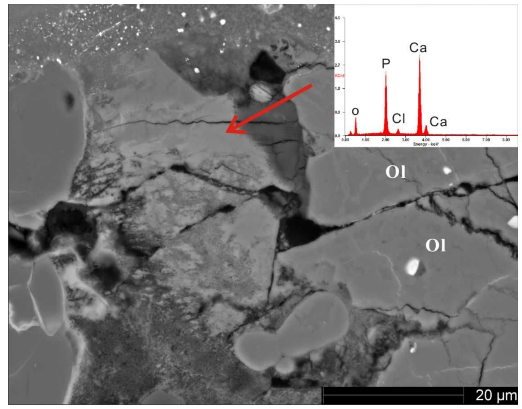

Figure 2. Chlorapatite inferred to be transformed in shock melt vein from NWA 757 meteorite

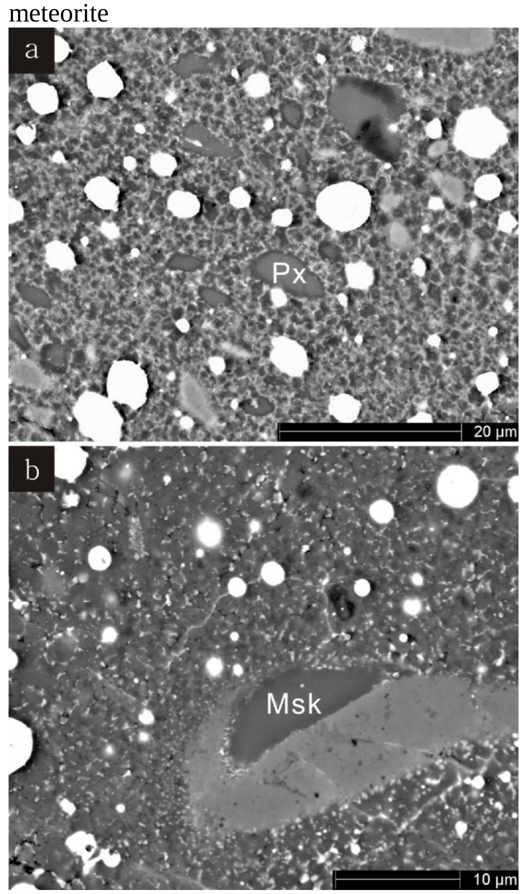

Figure 3. ***a.*** Common shock melt vein matrix texture from NWA 757 meteorite ***b.*** Majorite-pyrope garnet crystallization in shock melt vein matrix from NWA 757 meteorite

Reference: [1] Kimura M. et al. (2001) ***Meteorit. Planet. Sci.***, 36, A99. [2] Bischoff A. (2002) ***LPSC*** XXXIII, #1264. [3] Xie Z. et al. (2006) ***Meteorit. Planet. Sci.***, 41, 1883-1898. [4] Chen M. et al. (1995) ***LPS*** XXVI, 237-238. [5] Xie X. et al. (2002) ***Geochim. Cosmochim. Acta***, 66, 2439-2444