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Shock History and Formation Mechanisms of High-pressure minerals in Grove Mountains (GRV) L-chondritic meteorites

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Introduction: Of 83 shocked Grove Mountains (GRV) ordinary chondrites, 21 L5-6 samples with melt veins were studied with SEM, Raman, EMPA and FIB-TEM, in order to estimate the P-T conditions of the shock events, and discuss formation processes of the high-pressure minerals.

Results: The matrix of the melt veins consists mainly of fine-grained majorite-pyrope solid solution and ringwoodite. The host-rock clasts entrained in the veins are mostly rounded or ovoid. Ringwoodite, majorite, akimotoite, pyroxene glass, jadeite, lingunite and maskelynite were identified by Raman in the clasts.

We encountered abundant Olivine-Ringwoodite (Ol-Rgt) assemblages with novel textures and diverse chemical compositions. These assemblages contain FeO-depleted, dendrite-like Ol cores and FeO-enriched polycrystalline Rgt rims (up to 10 micrometers in width). Nodule-shaped objects of Rgt islands also occur inside the Ol core parts of the large assemblages. The Rgt rims and islands consist of idiomorphic Rgt crystals (~ 1 micrometer) showing 120^o triple junction. The dendritic cores are composed of fine-grained Ol(<= 100 nm) with interstitial Rgt crystallites. Rgt are Fe-enriched (Fa_{36-82}), while Ol shows a bimodal Fa-distribution (Fa_{8-14} and Fa_{22-25}). Difference in the FeO-contents between Rgt and Ol is up to 74 mol%. Intergrowth textures of Ol grains with single crystals of Rgt were commonly observed.

Most low-Ca pyroxene grains entrained in the melt veins have been partially or entirely transformed into akimotoite-pyroxene glass (Aki-Px Gl) assemblages. Idiomorphic Aki grains (100-400 nm, Fs_{15-17}) scatter in Px Gl (Fs_{31-39}). The CaO contents of Px Gl (0.4-4.5 wt%) are slightly higher than those of Aki (0.1-3.1 wt%) and the Px grains in the host rock (0.8-1.0 wt%). However, the Al_2O_3 contents of them are almost identical.

Discussion: The presence of majorite-pyrope solid solution and ringwoodite in the melt veins is similar to that reported in other shocked L6 meteorites[1-3], suggestive of a peak shock pressure and temperature of 18-23 GPa and $> 2,000^o$C, respectively, according to the phase diagrams obtained by high-pressure and -temperature melting experiments of Allende and peridotites [e.g., 4].

The textural and compositional features of Ol-Rgt assemblages are suggestive of fractional crystallization from Ol melts [5-6], starting with MgO-rich wadsleyite (Fa_{8-14}) followed by relatively FeO-richer olivine/wadsleyite (Fa_{22-25}) from the shock-induced Ol melts. Rgt with high FeO-content (Fa_{28-82}) crystallized from the residual melt. During the decompression, MgO-rich wadsleyite probably transformed back to Ol of the same chemical composition.

The euhedral grains and heterogeneous compositions of Aki suggest crystallization from pyroxene melts. The FeO content of the Px Gl is significantly higher than the maximum solubility of FeO in perovskite under 18-23 GPa [7], which indicates that the Px Gl could not have been back-transformed from preexisting silicate-perovskite. As crystallization of Aki with high Mg# commenced, the residual melt became enriched in Fe and Ca, which quenched to Px Gl under high pressure.

It is generally accepted that the high-pressure polymorphs encountered in melt veins of meteorites were formed directly via solid-state transformation from their parental minerals [e.g., 8]. Our studies of Ol-Rgt and Aki-Px Gl assemblages from GRV chondrites supply with robust evidence for fractional crystallization from mono-mineral melts [5, 6, 9], which can be another essential formation mechanism of high-pressure minerals.

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