Majorite-olivine–high-Ca pyroxene assemblage in the shock-melt veins of Pervomaisky L6 chondrite

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ABSTRACT

High-pressure minerals—majorite-pyrope garnet and jadeite—were found in the Pervomaisky L6 ordinary chondrite. Majorite-pyrope (79 mol% majorite) was observed within the fine-grained silicate matrix of a shock-melt vein (SMV), coexisting with olivine and high-Ca pyroxene. This is the first report of a garnet–olivine–high-Ca pyroxene assemblage that crystallized from the melt in the SMV matrix of meteorite. P-T conditions of the formation of the SMV matrix with olivine fragments are 13.5–15.0 GPa and 1750–2150 °C, the lowest parameters among all known majorite-bearing (H,L)-chondrites. The estimated conditions include the olivine/(olivine + ringwoodite) phase boundary and there is a possibility that observed olivine is the result of wadsleyite/ringwoodite back-transformation during a cooling and decompression stage. In the framework of this hypothesis, we discuss the problem of survival of the high-pressure phases at the post-shock stage in the meteorites and propose two possible P-T paths: (1) the high-pressure mineral is transformed to a low-pressure one during adiabatic decompression above the critical temperature of direct transformation; and (2) quenching below the critical temperature of direct transformation within the stability field of the high-pressure phase and further decompression. The aggregates with plagioclase composition (Ab11(An14Or3)) occur in host-rock fragments near (or inside) of the SMV, and have a radial, concentric “spherulite-like” microstructure previously described in the Novosibirsk meteorite, and that is very similar to the texture of tissintite in the Tissint martian meteorite. It is likely that jadeite is related to crystallization of the SMV and could have formed from albite feldspar (plagioclase) melt at 13.5–15.0 GPa and ~2000 °C.

Keywords: L6 chondrite Pervomaisky, olivine high-Ca pyroxene majorite-pyrope assemblage, jadeite, shock-melt vein history

INTRODUCTION

Heavily shocked chondrites are unusual natural objects, containing various assemblages of high-pressure polymorphs of rock-forming minerals (olivine, pyroxene, and feldspar) formed by shock metamorphism during collisions of meteorite parent bodies. The shock events caused the melting of the host-rock, forming shock-melt veins (SMVs). The SMVs are the result of a combination of several processes: the compaction of pore space (e.g., Wünnemann et al. 2008), friction/shear heating (e.g., Langenhorst et al. 2002; van der Bogert et al. 2003) and localized stress and temperature at the interfaces of mineral grains (e.g., Stöfler et al. 1991). High-pressure and high-temperature phases in the shocked chondrites appear inside or near the SMVs.

Majorite is a high-pressure polymorph of pyroxene with garnet structure. Static experiments at high-pressure and high-temperature conditions indicate that the stability field of majorite in the system MgO–SiO2–FeO–Al2O3 is at about 15–23 GPa at temperatures above 1000 °C (e.g., Ringwood 1967; Ringwood and Major 1971; Akaogi and Akimoto 1977; Irfune 1987; Ohtani et al. 1991; Akaogi et al. 2002; Gasparik 2003). However, the formation of majorite-pyrope solid solutions related to pyroxene dissolution in a garnet structure begins at ~9 GPa (Ringwood 1967; Akaogi and Akimoto 1977).

Majorite-pyrope was found in SMV of L6 chondrite Coorara (Smith and Mason 1970) coexisting with ringwoodite. Majorite has been described in many shocked chondrites along with other high-pressure minerals, such as wadsleyite, ringwoodite, akimotoite, MgSiO3-perovskite (bridgmanite), magnesiowüstite, lingsuite, etc. (Price et al. 1979; Chen et al. 1996; Kimura et al. 2000, 2003; Xie et al. 2001; Tomioka and Kimura 2003; Ohtani et al. 2004; Zhang et al. 2006; Ozawa et al. 2009; Miyahara et al. 2011; Acosta-Maeda et al. 2013; Tsuchaner et al. 2014).

Two types of majorite have been recognized. One forms by melting of the host rock and its crystallization under high-pressure conditions, forming the SMVs with other minerals (e.g., Smith and Mason 1970; Chen et al. 1996; Xie et al. 2001; Ohtani et al. 2004). This type of majorite is enriched in Al, Ca, and Na compared with low-Ca pyroxene in the host-rock, and usually forms micrometer-size idiomorphic grains inside the matrix of the SMVs. Another type of majorite forms by a solid-state transformation of pyroxene in the coarse fragments of the host rock enclosed in the SMVs (Chen et al. 1996; Xie et al. 2001; Ohtani et al. 2004; Zhang et al. 2006; Xie and Sharp 2007). The chemical composition of such majorite is similar to that of pyroxene in the host rock.

The meteorite shower of the Pervomaisky L6 ordinary chondrite