

**ASSEMBLAGE OF DIOPSIDE, PYROXENE, AKIMOTOITE, AND RINGWOODITE IN THE HEAVILY SHOCKED SIXIANGKOU L6 CHONDRITE: FURTHER CONSTRAINTS ON CONDITIONS OF SHOCK METAMORPHISM.** A. Zhang<sup>1</sup>, W. Hsu<sup>1</sup>, R. Wang<sup>2</sup>, and M. Ding<sup>1</sup>, <sup>1</sup> Laboratory for Astrochemistry and Planetary Sciences, Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, China, aczhang@pmo.ac.cn, wbxu@pmo.ac.cn, mwdinga@hotmail.com, <sup>2</sup> State Key Laboratory for Mineral Deposits Research and Department of Earth Sciences, Nanjing University, Nanjing 210093, China, rcwang@nju.edu.cn.

**Introduction:** Sixiangkou is a heavily shocked L6 ordinary chondrite. Previous studies revealed several high-pressure minerals in the shock-induced melt veins, such as ringwoodite, majorite, magnesiowüstite, majorite-pyroxene, lingunite, and phase A (a high-pressure phase of chlorapatite) [1-3]. These high-pressure mineral phases indicated the crystallization conditions of the melt veins at pressures between 20 and 23 GPa and at temperature above 2000°C [1-2, 4].

We report here the occurrence of diopside, pyroxene, akimotoite, and ringwoodite in the shock-induced melt veins of Sixiangkou and discuss its implication to the shock metamorphism.

**Observations:** Optical microscopy, Raman spectroscopy, and electron microprobe analyses were carried out to identify mineral phases in the thin sections of Sixiangkou. In the chondritic portion, rock-forming minerals are olivine, low-Ca pyroxene, plagioclase (completely transformed to maskelynite), diopside, FeNi metal and sulfide, and minor phases include phosphate and chromite. Sixiangkou contains several shock-induced melt veins with varying widths up to 1 cm. In these veins, two different lithologies occur: fragments of the host rocks and fine-grained matrix. The fragments are mainly composed of olivine and pyroxene, which were partially or completely transformed into respective high-pressure polymorphs, while the matrix is mainly composed of fine-grained majorite-pyroxene solid solution, magnesiowüstite, metal-sulfide, and minor lingunite, magnetite, phase A, and whitlockite [3].

The assemblage of diopside, pyroxene, akimotoite, and ringwoodite was identified in the fragment in one shock-induced melt vein (Fig. 1). The assemblage is ovoid in shape, in that diopside, pyroxene+akimotoite, and ringwoodite are in triple-angle contact. Electron microprobe analyses yielded the chemical compositions of diopside ( $\text{En}_{45}\text{Fs}_9\text{Wo}_{46}$ ), pyroxene ( $\text{En}_{77}\text{Fs}_{21}\text{Wo}_1$ ), akimotoite ( $\text{En}_{78}\text{Fs}_{21}\text{Wo}_1$ ), and ringwoodite ( $\text{Fo}_{75}\text{Fa}_{25}$ ). Akimotoite has the same composition as associated pyroxene. And it is also similar to akimotoite reported in Tenham chondrite [5], but differs significantly from those in Acfer 040 [6], Umbarger [7], and Tanhem [8].

Raman spectra of pyroxene + akimotoite, diopside, and ringwoodite are displayed in Fig. 2. The spectra of

diopside and ringwoodite are consistent with previous results [9]. Akimotoite was identified with three characteristic peaks at 798, 617, 474  $\text{cm}^{-1}$  in the stretching region 200–1200  $\text{cm}^{-1}$  (Fig. 2a). These peaks cannot be attributed to other high-pressure polymorphs (e.g., clinoenstatite, majorite and perovskite) of pyroxene, and the bands are in good agreement with the result of Ohtani et al. [9]. Raman spectra of akimotoite also exhibit some majorite peaks characterized by the typical band at 934  $\text{cm}^{-1}$  (Fig. 2a). It implies that a fraction of pyroxene had been partially transformed into majorite.

**Discussions:** Akimotoite has been previously reported in a few L6 shocked chondrites (Acfer 040, Tenham, Umbarger, Yamato 791384) [5-9]. Two models were proposed for its formation: solid-state transformation [5] and crystallization metastably from a melt under high pressures [6-8]. Tomioka and Fujino [5] observed chemical similarities among clinoenstatite, akimotoite, and perovskite in Tenham and suggested their formation through solid-state transformation of pyroxene at high pressures. Our results in Sixiangkou are consistent with those of Tomioka and Fujino [5]. On the other hand, akimotoite grains in Acfer 040 and Umbarger have different chemical compositions from their respective host pyroxenes. In particular, akimotoite in Acfer 040 and Umbarger is rich in  $\text{Al}_2\text{O}_3$ , indicating crystallization from the shock-induced melt [6-7].

Akimotoite ( $\text{En}_{78}\text{Fs}_{21}\text{Wo}_1$ ) in the Sixiangkou chondrite has a similar mineral chemistry as that in Tenham [5] and Y791384 [9], but differs significantly from that in Acfer 040 ( $\text{En}_{94}\text{Fs}_6$ ) [6] and in Umbarger ( $\text{En}_{88}\text{Fs}_{11}\text{Wo}_1$ ) [7]. This may indicate that akimotoite has a rather large compositional stability field. However, up to date, no compositional effect on stability of akimotoite has been reported.

Akimotoite did not appear in the Allende high-pressure phase diagram [4]. Gasparik [10] reported that akimotoite occurs along with ringwoodite between 18 and 25 GPa in the enstatite-forsterite system. Xie and Sharp [7] observed that akimotoite cocrystallized with ringwoodite in the Umbarger shock-induced melt vein. Ca-rich clinopyroxene occurs interstitially between akimotoite and ringwoodite. A pressure range of 18–24 GPa was inferred based on the analogy to the enstatite-forsterite system [10]. In the Sixiangkou

chondrite, the akimotoite + pyroxene aggregate closely associates with diopside and ringwoodite (Fig. 1). This petrographic texture differs from that in Umbarger [7], especially with the occurrence of diopside. Oguri et al. [11] found that the upper limit pressure for the stability of diopside is about 18 GPa. Thus, we conclude that the occurrence of assemblage of akimotoite plus pyroxene, diopside, and ringwoodite in the fragment of Sixiangkou shock veins implies a transformation pressure around 18 GPa. The discrepancy of estimated pressures between this study and those of Chen et al. [1] and Gillet et al. [2] probably implies the heterogeneity of pressure in the shock-induced melt veins.

**References:** [1] Chen M. et al. (1996) *Science*, 271, 1570–1573. [2] Gillet P. et al. (2000) *Science*, 287, 1633–1636. [3] Chen M. et al. (1995) *LPS XXVI*, 237–238. [4] Agee C. B. (1995) *JGR*, 100, 17725–17740. [5] Tomioka N. and Fujino K. (1999) *Am. Mineral.*, 84, 267–271. [6] Sharp T. G. et al. (1997) *Science*, 277, 352–355. [7] Xie Z. D. and Sharp T. G. (2004) *Meteoritics & Planet. Sci.*, 39, 2043–2054. [8] Xie Z. D. (2003) Ph.D. thesis. [9] Ohtani E. (2004) *EPSL*, 227, 505–515. [10] Gasparik T. (1992) *JGR*, 97, 15181–15188. [11] Oguri K. et al. (1997) *PEPI*, 104, 363–370.

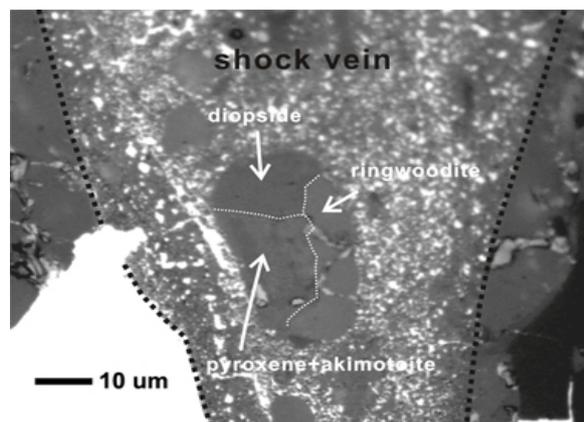


Figure 1. Reflectance microscopic photos of diopside, pyroxene, akimotoite, and ringwoodite in the shock-induced melt vein of the Sixiangkou chondrite.

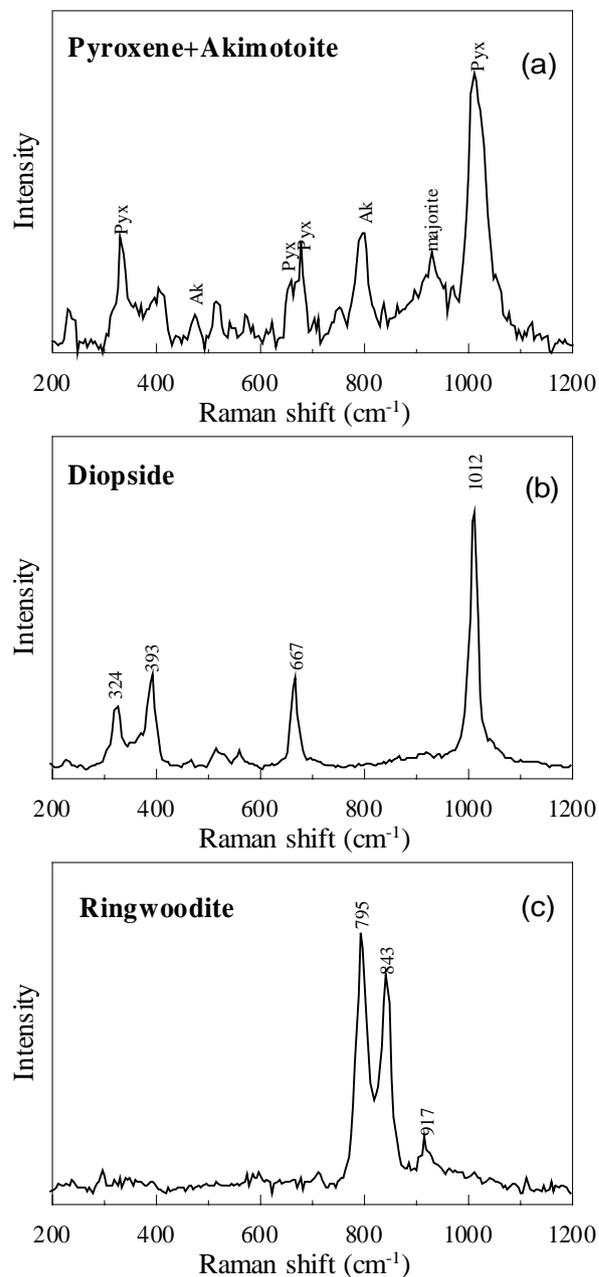


Figure 2. Raman spectra of pyroxene + akimotoite, diopside, and ringwoodite.