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Evidence for multiple dynamic events and subsequent decompression stage recorded in a shock vein

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ABSTRACT

We investigated a shock vein of the Yamato 791384 L6 chondrite to clarify the nature and sequence of the dynamic processes that resulted from the shock events. The chondritic host-rock of Y-791384 mainly consists of olivine ($Fa_{24–25}$), low-Ca pyroxene ($Fs_{18–22}$), albitic feldspar ($An_{9–10}Ab_{84–86}Or_{5–7}$), troilite and metallic Fe–Ni. The shock vein contains majorite (or majorite-pyrope$_{ss}$) and magnesiowüstite (+ minor jadeite) as high-pressure polymorphs. Two different dynamic events were recorded in the shock vein. The majorite grain contained vitrified (Mg,Fe)SiO_3-perovskite inclusions. The (Mg,Fe)SiO_3-perovskite was crystallized from a chondritic melt, and is a remnant of a first dynamic event. The majorite and magnesiowüstite were also crystallized directly from a chondritic melt but induced by a second dynamic event. The pressure condition for the first and second dynamic events would be >~24 GPa and <~22 GPa, respectively. Pervasive feather-shaped olivine (Fa_{16}) nucleated on the magnesiowüstite and majorite. This feather-shaped olivine is evidence for rapidly grown olivine from the melt related to the shock event. Phase relations deduced from high-pressure melting experiments of the Allende meteorite and peridotite indicate that the magnesiowüstite and majorite + olivine pair cannot coexist at equilibrium condition. The disequilibrium assemblage reflects a decompression stage. These features demonstrate the complexity of events during a natural dynamic process.

1. Introduction

Black-colored veins observed in some shocked meteorites were formed by friction along fractures or localized concentration of stress (impact compression) induced by collisions of planetesimals in the solar nebula. Hence, the black-colored shock veins record dynamic high-pressure and -temperature conditions. High-pressure polymorphs of olivine, pyroxene, feldspar, phosphate, chromite and silica exist in and around the shock veins (Chen et al., 2003; Collerson et al., 2010; Gillet et al., 2000; Miyahara et al., 2011; Miyajima et al., 2007; Ohtani et al., 2011; Ozawa et al., 2009; Putnis and Price, 1979; Sato and Nakamura, 2010; Tomioka and Fujino, 1997; Xie et al., 2006). Some high-pressure polymorphs in and around the shock veins were considered to be formed from original minerals through a solid–solid state transformation mechanism (e.g., Chen et al., 2004; Ferroir et al., 2008; Ohtani et al., 2004; Xie et al., 2010). Several studies have proposed that some high-pressure polymorphs were formed from chondritic or mono-mineral melts (Chen et al., 1996; Chen and El Goresy, 2000; El Goresy et al., 2007; Miyahara et al., 2008a, 2009). Although only a few shock experiments show that some high-pressure polymorphs may be formed from a melt during a dynamic event (Tschauner et al., 2009), most shock experiments still throw doubt on the melting and formation of high-pressure polymorphs during a dynamic event.

The assemblages of high-pressure polymorphs in the shock veins are identical to those in synthetic samples recovered from static high-pressure and -temperature melting experiments using the Allende meteorite and KLB-1 peridotite mimicking ordinary chondrites (Agee et al., 1995; Asahara et al., 2004; Herzberg and Zhang, 1996; Wang and Takahashi, 2000), indicating that equilibrium was achieved in the shock veins during the dynamic event. A dynamic event proceeds as follows: 1) increasing pressure and temperature (compression stage), 2) duration of equilibrated peak pressure condition (equilibrium stage), and 3) decreasing pressure and temperature (decompression stage). The equilibrated high-pressure polymorph assemblages allow for the estimation of the peak pressure and temperature conditions recorded in the shock veins during the dynamic event (e.g., Chen et al., 1996; Ohtani et al., 2004; Ozawa et al., 2009; Xie et al., 2006). On the other hand, the decompression stage has not been clarified substantially. In addition, we

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Table 1
Chemical compositions obtained by EMPA.

Oxide	O1	σ	Pyx	σ	Fd	σ
SiO_2	38.85	0.72	55.68	0.29	67.19	0.84
TiO_2	0.02	0.02	0.17	0.04	–	–
$A1_2O_3$	0.03	0.03	0.15	0.03	21.43	0.46
Cr_2O_3	0.09	0.08	0.11	0.05	–	–
FeO	23.69	0.96	13.88	0.46	0.83	0.29
MnO	0.48	0.03	0.44	0.03	–	–
MgO	39.60	0.71	29.28	0.39	–	–
NiO	0.06	0.06	–	–	–	–
CaO	–	–	0.89	0.79	1.92	0.10
Na_2O	–	–	0.04	0.05	9.52	0.13
K_2O	–	–	0.01	0.00	0.96	0.13
Total (wt.%)	102.82		100.63		101.86	
Formula						
O =	4		6		8	
Si	0.989		1.981		11.630	
Ti	0.000		0.004		–	
A1	0.001		0.006		4.372	
Cr	0.001		0.003		–	
Fe	0.505		0.413		0.121	
Mn	0.010		0.013		–	
Mg	1.503		1.553		–	
Ni	0.001		–		–	
Ca	–		0.034		0.356	
Na	–		0.003		3.195	
K	–		0.000		0.213	
Total	3.010		4.011		19.888	
Fa =	25					
		Wo =	2	An =	9	
		En =	77	Ab =	85	
		Fs	21	Or =	6	
n =	8		10		5	

All iron is assumed ferrous. n = number of analyses, – = not determined.
O1 = olivine, Pyx = low-Ca pyroxene, Fd = feldspar.

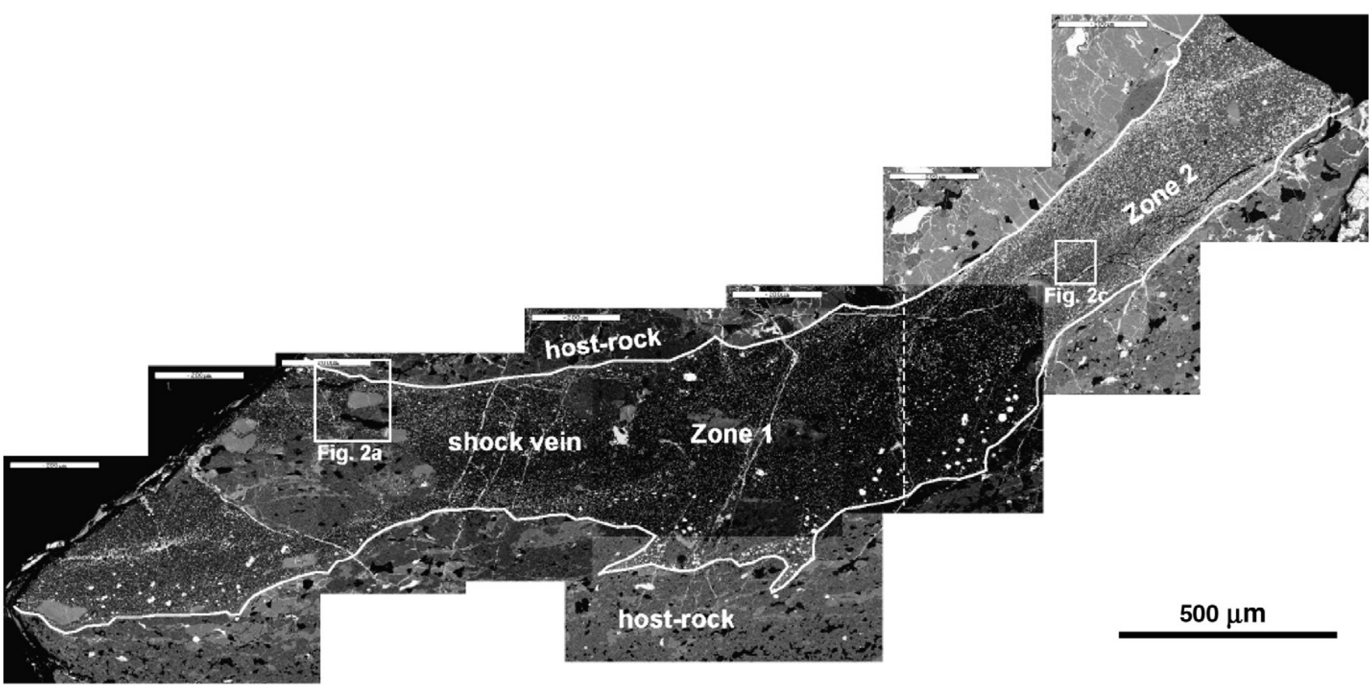

Fig. 1. Low-magnification back-scattered electron (BSE) image of a shock vein in Y-791384. Zone 1 = rapidly grown olivine + glassy material + magnesiowüstite + metallic Fe–Ni + troilite + minor majorite. Zone 2 = majorite surrounded with rapidly grown olivine + glassy material + magnesiowüstite + metallic Fe–Ni + troilite.