



# Albite dissociation reaction in the Northwest Africa 8275 shocked LL chondrite and implications for its impact history

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Received 30 January 2017; accepted in revised form 22 August 2017; Available online 26 August 2017

## Abstract

An impact event recorded in the Northwest Africa (NWA) 8275 LL7 ordinary chondrite was investigated based on high-pressure mineralogy of pervasive shock-melt veins present in the rock. NWA 8275 consists of olivine, low-Ca pyroxene, plagioclase (albite–oligoclase composition), and minor high-Ca pyroxene, K-feldspar, phosphate minerals, metallic Fe–Ni and iron sulfide. Plagioclase and K-feldspar grains near the shock-melt veins have become amorphous, although no high-pressure polymorphs of olivine and pyroxene were identified in or adjacent the shock-melt veins. Raman spectroscopy and focused ion beam (FIB)-assisted transmission electron microscopy (TEM) observations reveal that plagioclase entrained around the center portion of the shock-melt veins has dissociated into a jadeite + coesite assemblage. Alternately stacked jadeite and coesite crystals occur in the original plagioclase. On approaching the host rock/shock-melt vein, only jadeite is present. Based on the high-pressure polymorph assemblage, the shock pressure and temperature conditions recorded in the shock-melt veins are  $\sim 3$ – $12$  GPa and  $\sim 1973$ – $2373$  K, respectively. Following a Rankine–Hugoniot relationship, the impact velocity was at least  $\sim 0.45$ – $1.54$  km/s. The duration of high-pressure and high-temperature (HPHT) conditions required for the albite dissociation reaction is estimated a maximum of  $\sim 4$ – $5$  s using the phase transition rate of albite, implying that a body of up to  $\sim 9$ – $12$  km across collided with the parent body of NWA 8275. The coexistence of jadeite and coesite, the latter of which rarely accompanies jadeite in shocked ordinary chondrites, as a dissociation product of albite requires relatively long duration HPHT conditions. Thus, the impact event recorded in NWA 8275 was likely caused by a larger-than-typical projectile.

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**Keywords:** Albite; Dissociation; Jadeite; Coesite; Shocked meteorite

## 1. INTRODUCTION

In a shocked meteorite, high-temperature conditions are achieved along fractures as a result of localized frictional melting; concomitantly, high-pressures are induced by the

dynamic event, thus leading to formation of a shock-melt vein. Albite (or albitic feldspar) is one of the major constituents of ordinary chondrites. Albite grains entrained in, or adjacent to, shock-melt veins experience high-pressure and high-temperature (HPHT) conditions. Phase equilibrium diagrams deduced through static HPHT synthetic experiments indicate that albite transforms into  $\text{NaAlSi}_3\text{O}_8$  with a hollandite structure (lingunite), or  $\text{CaFe}_2\text{O}_4$ -type  $\text{NaAlSiO}_4$ +stishovite subsequent to jadeite

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+ coesite or stishovite, with increasing pressure and temperature conditions (Liu, 1978, 2006; Holland, 1980; Yagi et al., 1994; Tutti, 2007). Kimura et al. (2000) first confirmed the existence of jadeite in grains of albitic composition entrained in or adjacent to a shock-melt vein in the Yamato (Y)-75100 (H6) chondrite by laser micro-Raman spectroscopy. When jadeite forms through an albite dissociation reaction, a SiO<sub>2</sub> phase should accompany jadeite based on stoichiometry as described above. However, Kimura et al. (2000) could not find any clear evidence for any SiO<sub>2</sub> phases based on Raman spectroscopy analysis. Similar identifications of jadeite using Raman spectroscopy have been reported from many shocked H, L and LL ordinary chondrites (Ohtani et al., 2004; Miyahara et al., 2008, 2009, 2010, 2011; Ozawa et al., 2009, 2014). The albite dissociation reaction is controlled by grain-boundary diffusion

and is time dependent. Kubo et al. (2010) conducted HPHT synthetic experiments using albite as a starting material, and proposed that the nucleation rate of stishovite as a dissociation product of albite was significantly slower than that of jadeite. The approximate duration of the HPHT conditions induced by dynamic events that occurred on the parent bodies of ordinary chondrites is estimated to be from several milliseconds to a few seconds (Ohtani et al., 2004; Beck et al., 2005; Xie et al., 2006; Miyahara et al., 2010). Therefore, high-pressure polymorphs of silica as a dissociation product of albite are not expected to be readily formed in shocked ordinary chondrites because of the limited duration of the HPHT conditions and the critical differences in nucleation rates (Kubo et al., 2010; Miyahara et al., 2013).

In contrast to L-type ordinary chondrites, high-pressure polymorphs in LL-type ordinary chondrites have not been investigated in detail (Tomioaka and Miyahara, 2017). Northwest Africa 8275 (NWA 8275) is classified as an LL7 ordinary chondrite in the Meteoritical Bulletin database, although the definition of type 7 has been under debate (e.g., Mittlefehldt and Lindstrom, 2001; Tait et al., 2014). NWA 8275 includes pervasive shock-melt veins, suggestive of a heavy shock event that occurred on its LL-type ordinary chondrite parent body. Several albitic feldspar grains are found in the shock-melt veins of NWA 8275, and it is possible that these grains include high-pressure polymorphs, as found in other shocked L chondrites. In our study, we scrutinize the albitic feldspar grains entrained in the shock-melt veins using a high-resolution field-emission scanning electron microscope (FE-SEM) and a field emission transmission electron microscope (FE-TEM) in addition to conventional Raman analysis. We also estimate the magnitude of the impact recorded in NWA 8275 using the phase-transition rate of albite.

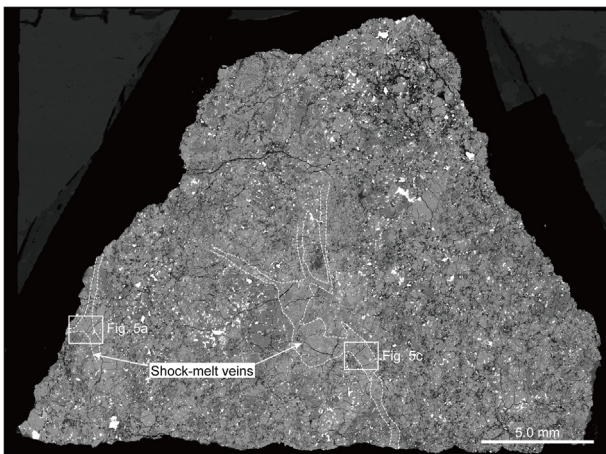


Fig. 1. Back-scattered electron (BSE) image of the NWA 8275 sample studied here.

Table 1  
EPMA analyses of olivine and pyroxene in host-rock and shock-melt vein.

Oxides	Olivine				Low-Ca Pyroxene				Ca-Pyroxene	
	Host-rock		Shock-vein		Host-rock		Shock-vein		Host-rock	Shock-vein
	Ave.	1σ	Ave.	1σ	Ave.	1σ	Ave.	1σ	Ave.	
SiO <sub>2</sub>	37.58	0.18	37.62	0.27	54.68	0.30	53.22	4.96	53.97	53.98
TiO <sub>2</sub>	0.02	0.02	0.02	0.01	0.21	0.04	0.20	0.06	0.36	0.41
Al <sub>2</sub> O <sub>3</sub>	0.01	0.01	0.01	0.01	0.19	0.06	0.16	0.06	0.59	0.41
Cr <sub>2</sub> O <sub>3</sub>	0.01	0.02	0.03	0.03	0.25	0.09	0.23	0.08	1.08	0.99
FeO	27.48	0.34	27.52	0.24	16.02	0.28	17.26	3.33	6.75	6.54
MnO	0.46	0.04	0.44	0.02	0.44	0.03	0.44	0.02	0.29	0.26
MgO	35.02	0.29	35.00	0.37	26.26	0.35	27.09	2.54	16.41	16.25
NiO	0.05	0.06	0.04	0.03	–	–	–	–	–	–
CaO	0.03	0.02	0.03	0.02	1.72	0.37	1.64	0.55	19.99	20.88
Na <sub>2</sub> O	–	–	–	–	0.05	0.02	0.04	0.02	0.60	0.56
K <sub>2</sub> O	–	–	–	–	<0.01	–	<0.01	–	<0.01	0.02
Total (wt%)	100.66	0.37	100.72	0.46	99.85	0.39	100.31	0.57	100.06	100.30
Fa	30.4	0.4	30.5	0.4	–	–	–	–	–	–
Wo	–	–	–	–	3.4	0.7	3.2	1.1	40.4	41.9
En	–	–	–	–	71.4	0.7	71.1	0.5	46.2	45.4
Fs	–	–	–	–	25.1	0.4	25.5	1.1	11.1	10.6
n=	20		11		19		11		2	1

#All iron is assumed to be ferrous. n: number of analyses. –: not determined.

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