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Petrology and mineralogy of the shock-melted H chondrites Yamato−791088 and LaPaz Ice Field 02240

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Abstract

We studied the petrology and mineralogy of two types of shock-melted H chondrites: Yamato (Y)−791088 and LaPaz Ice Field (LAP) 02240. Y−791088, which consists of numerous coarse-grained relict phases (40%) and euhedral fine-grained minerals solidified from the shock melt (60%), experienced incomplete melting; a quiescent melt is indicated by the existence of abundant relict phases, pseudomorphed chondrules, and two types of glass. LAP 02240, which consists of small amounts of coarse-grained relict phases (∼10%) and fine-grained minerals (∼90%), experienced near-complete melting; a rapidly cooled mobilized melt is indicated by the homogeneous compositions of glass and opaque veins.

The homogeneous compositions of relict olivines indicate that the precursors of both chondrites were equilibrated H chondrites. The melting features of Y−791088 and LAP 02240 are very similar to those of Y−790964 (LL) and the fine-grained lithology of Y−790519 (LL), respectively. These two types of shock-melted ordinary chondrites possibly formed *in situ* during dike formation. The quiescent melt is thought to have originated from the injection of shock-heated chondrite blocks into mobilized melt. These two types of melting could have occurred during dike formation on the H chondrite parent body. The textures of the two types of shock melts were not simply affected by the degree of shock melting: they were also controlled by the degree of shear stress.

Keywords: Y−791088; LAP 02240; Ordinary chondrite; Shock melt; Petrogenesis

1. Introduction

Shock-melted chondrites produced by extensive melting on their parent bodies provide important clues regarding the nature of dynamic shock events such as crater formation on the surface of the parent body and catastrophic disruption of the parent body. Ordinary chondrites may have experienced shock events on their parent bodies, thereby recording shock features such as fracturing, brecciation, degassing, melting, and loss of volatile elements. Based on the mineralogy and petrology of ordinary chondrites, Stöffler et al. (1991) classified the shock stages of such rocks into stages S1−S6, plus the shock-melted stage. Some shock-melted ordinary chondrites experienced near-complete melting that overprinted the original chondritic textures (Y−790519 (LL): Okano et al., 1990; Patuxent Range 91501 (L): Mittlefehldt and Lindstrom, 2001).

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Most shock-melted ordinary chondrites contain large amounts of relict minerals and retain chondritic textures; e.g., the H chondrites Y−791088 (Fujimaki et al., 1993), Rose City (Rubin, 1995; Yolcubal and Sack, 1997), Dar al Gani 896 (Folco et al., 2004), and Portales Valley (Kring et al., 1999; Rubin et al., 2001; Ruzicka et al., 2005); the L chondrites Cat Mountain (Kring et al., 1996), Chico (Norman and Mittlefehldt, 2002; Yolcubal and Sack, 1997), and Ramsdorf (Yamaguchi et al., 1999); and the LL chondrite Y−790964 (Okano et al., 1984, 1990; Yamaguchi et al., 1998).

Yamaguchi et al. (1998, 1999) conducted a petrological study of the chondritic regions in Y−790964 (LL) and Ramsdorf (L), and observed abundant "chondrule ghosts" that appear to resemble common objects such as chondrules containing olivine and pyroxene that were crystallized from the shock melt. Fujimaki et al. (1993) reported the presence of pseudomorphed chondrules, similar in texture to "chondrule ghosts", in Y−791088; however, the authors did not describe the detailed textures of the shock melt.

Previous studies have examined the petrology of Y−790964 and paired shock-melted LL chondrites (e.g. Okano et al., 1990; Yamaguchi et al., 1998). Y−790964 comprises coarse-grained (several tens to hundreds of microns in size) relict olivines and chondrule fragments, euhedral pyroxenes, two types of glassy materials, and irregular vesicles in a glassy matrix (Okano et al., 1990; Sato et al., 1982). Y−790519 (LL), which is possibly paired with Y−790964, comprises two different unbrecciated lithologies: a fine-grained (FG) lithology that experienced near-complete melting, and a coarse-grained (CG) lithology comprising relict olivines (several tens to hundreds of microns in size), euhedral pyroxenes, and irregular vesicles in a glassy matrix similar to that in Y−790964 (Okano et al., 1990; Sato et al., 1982). The fayalite (Fa) contents of olivine in the FG lithology do not overlap with the range of Fa values obtained for equilibrated LL chondrites, but are within the range of Fa values obtained for L chondrites (Sato et al., 1982). This FG lithology contains olivine fragments that are several tens of microns in size. The FG and CG lithologies coexist in Y−790519, suggesting that they formed via a single impact event. Sato et al. (1982) and Okano et al. (1990) conducted petrological studies of Y−790519; however, they did not focus on the relationships among different types of shock-melted lithologies.

To clarify the formation conditions of shock-melted chondrites, especially those of H chondrites, we examined the mineralogy and petrology of the shock-melted H chondrites Y−791088 and LAP 02240.

2. Analytical methods

We examined polished thin sections (PTSs) of Y−791088 (91−1; surface area of 78 mm^2) and LAP 02240 (7; surface area of 104 mm^2) together with two shock-melted LL chondrites as reference samples: Y−790964 (81−1) and Y−790519 (73−3). All PTSs were observed using an optical microscope with polarized light for transparent phases and reflected light for opaque phases. The microtextures of all samples were observed using a scanning electron microscope (JEOL JSM−5900 LV) operated at an accelerating voltage of 15 kV. Constituent phases were analyzed using an electron probe microanalyzer (JEOL JXA−8200) operated at an accelerating voltage of 15 kV and electron beam current of 9 nA with a focused beam for minerals, and a current of 3 nA with a defocused beam (10 μm) for glassy phases, to avoid the loss of alkaline elements during analysis. Bence and Albee's correction method (Bence and Albee, 1968) was used for silicates, glasses, and oxides, and the ZAF correction method was used for metals and sulfides. We obtained Raman spectra for glassy phases using a JASCO NRS−1000 Raman microspectrometer operated with a focused laser-beam with a wavelength of 531.91 nm and intensity of 11 mW.

3. Results

3.1. Petrography of Y−791088

The bulk chemical composition of the Y−791088 H chondrite (original mass: 2.1 kg) is in the range of that of H chondrites (Dodd, 1981; Yanai and Kojima, 1995). The interior of Y−791088 is apparently homogeneous, as judged from its monotonous external features. The major constituent phases of Y−791088 and their modal abundances are olivine (39%), pyroxene (28%), opaque minerals of Fe−Ni metals and troilite (23%), glassy phases (8%), and vugs (2%) (Figs. 1a−c, 2−4). The minor minerals are chromites and merrillites. Y−791088 contains coarse-grained lithic fragments (∼40%) in a fine-grained matrix (∼60%). The fragments have irregular shapes and consist of olivine, pyroxene, and Fe−Ni metals rimmed by troilite. The matrix minerals in Y−791088 are the same as those in the lithic fragments. Representative analyses of the constituent phases are listed in Tables 1−5.

3.1.1. Olivine

Olivines in coarse-grained lithic fragments are irregular in shape and are up to ∼1 mm in size (Fig. 2a).