SHOCKED TYPE 3 ORDINARY CHONDRITES

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Introduction: The outermost surface of an asteroid consists of type 3 ordinary chondrite based on the onion shell model. Such parent-bodies of ordinary chondrites are considered to have experienced dynamic events. The surface portions in the vicinity of the impact site record the highest shock pressure conditions. However, it is not easy to apply the conventional shock barometer for type 3 chondrites, because their constituents are fine-grained, and little amounts of feldspar are contained. Accordingly, the shock pressure conditions recorded in type 3 ordinary chondrites have not been investigated in detail so far. Recently, our preliminary optical microscope observations found several type 3 ordinary chondrites with melting textures and deformed chondrules, which are clear evidences for dynamic events occurred on their parent-bodies. In the present study, we focus on the aspect ratios of the deformed chondrules and melting textures in the type 3 ordinary chondrites to evaluate the shock pressure conditions.

Materials and experimental methods: We observed about three hundreds petrographic thin sections of Antarctic type 3 ordinary chondrite (H-, L- and LL-type) stored in the NIPR with an optical microscope to pick up those with distinct melting textures. Through the preliminary observations, eight type 3 ordinary chondrites with distinct melting textures were found: Y-981139 (H3), A-87170 (L3), A-87220 (L3), Y 000886 (L3), Y-86706 (L3), Y-981327 (L3), A-881199 (LL3.4) and A-881981 (LL3). Thirty three thin sections of type 3 ordinary chondrites without melting textures were also selected for this study. All these thin sections were scanned with a field-emission scanning electron microscope (FE-SEM) to observe the fine-textures, melting textures and the morphologies of chondrules. Mineral identification was carried out by a laser micro-Raman spectroscopy. The chemical compositions of constituents were determined using an electron probe microanalyzer (EPMA). A part of the thin section was extracted by a focused ion beam (FIB) system for transmission electron microscope (TEM) observation.

Results and discussion: FE-SEM observations show that melting textures always occur around the boundary between the chondrules and matrix in the type 3 ordinary chondrites. The localized distribution of the melt would be suggestive of heterogeneous temperature distribution in the type 3 ordinary chondrite during the dynamic event [1]. Most melting textures are isolated, not connected each other, which is similar to melt-pockets found in Martian or lunar meteorites. Fine-grained quench crystals of silicates and the spherules of metallic iron-nickel + iron sulfide with an eutectic texture fill the melt-pockets. Fragments enclosing chondritic glasses were entrained in the melt-pockets of A-881199 (LL3) and A-881981 (LL3). BSE image depicted that many fine-grained crystals occur in some chondritic glasses (plagioclase + pyroxene composition). Raman shifts appeared at 372, 693 and 1032 cm^{-1} from the chondritic glass enclosing fine-grained crystals, corresponding to those of Na-rich clinopyroxene. TEM observations revealed that the chondritic glass enclosing fine-grained crystals consists of omphacite and silica (or silica-rich amorphous material). Sharp Raman peaks appeared at ~520 cm^{-1} besides 372, 693 and 1032 cm^{-1} from some chondritc glasses enclosing fine-grained crystals. It is likely that the chondritic glasses enclosing fine-grained crystals consist of omphacite and coesite. Although the pressure and temperature conditions of the dissociation reaction from chondritic glass to omphacite + coesite have not been investigated, the existence of coesite indicates that the shock pressure is ~2 GPa at least. The ellipticity of chondrules [1 – (short axis/long axis)] in the type 3 chondrites with and without the melting textures was measured using BSE images. The mean ellipticity of the chondrules in L3 chondrites with the melting textures (n = 206) is ~0.27 or more. In case of LL3 chondrites, the mean ellipticity (n = 162) is ~0.32 or more. On the other hand, in case of H3 chondrites, there are little differences in the ellipticity between with the melting (n = 87) or without melting. The long axes of chondrules in the chondrites with the melting textures appear to be preferentially oriented. The ellipticity and orientation degree of the chondrules would be available for estimating shock pressure condition. Shock experiments using Allende CV3 and Murchison CM2 carbonaceous chondrites were previously conducted to investigate the relationship between the shock pressure condition and the ellipticity of chondrules [2]. We applied the relationship to estimate the shock pressure conditions in the type 3 ordinary chondrites with the melting textures, although there are several differences in the natures (e.g., chondrule/matrix ratios and densities) between carbonaceous and ordinary chondrites. The estimated shock pressure conditions are ~15 GPa, ~18–23 GPa and ~21–25 GPa for H3, L3 and LL3, respectively.

References: [1] Bland P.A. et al. (2014) Nat. Commun. 5:5451, [2] Tomeoka K. et al. (1999) Geochim. Cosmochim. Acta 63, 3683–3703.