Can high-pressure polymorphs clarify an ordinary chondrite parent-body breakup?

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An ordinary chondrite is the biggest clan in the meteorites. The ordinary chondrites are the building blocks of an ordinary chondrite parent-body that broke up by an impact in the solar nebula. The breakup process of the ordinary chondrite parent-body is one of the intriguing conundrums. Most ordinary chondrites have evidence for the impact event. Shock-induced melting textures and high-pressure polymorphs are the most distinct clues for the impact event. Chen et al. (1996) suggested that the high-pressure polymorphs occurring in the shock-induced melt can be a clue for clarifying the impact event occurred on the parent-body because we can constrain several parameters for the impact such as shock pressure and impact velocity based on the formation conditions of the high-pressure polymorph assemblage. Accordingly, many previous studies have worked on the high-pressure polymorphs in the ordinary chondrites for several decades. Most previous investigations have focused on the L6 chondrite because the meteorite type is abundantly recovered on the Earth. On the other hand, few previous studies have worked on other petrologic types such as L5 and L4. The inventories of the high-pressure polymorphs in shocked H- and LL-group ordinary chondrites have been barely described. The ordinary chondrite parent-body is expected to have an onion shell-like structure. H-, L-, and LL-group ordinary chondrites originate from their individual parent-bodies. We have to clarify the inventories of the high-pressure polymorphs included in all petrologic types and groups to elucidate the breakup processes of the ordinary chondrite parent-bodies. Accordingly, we initiated the systematic investigations of the high-pressure polymorphs included in the shocked ordinary chondrites. About sixty H-group, eighty L-group, and fifty LL-group ordinary chondrites with the shock-induced melting textures were systematically investigated by SEM and Raman spectrometer. There was the distinct difference in the modes of shock-induced melting between petrologic type 3–4 and type 5–6 in all groups. In the petrologic type 3–4, the melting occurred at the boundaries between the chondrules and surrounding matrices as a melt-pocket. In the petrologic type 5–6, melting occurred as isolated veins or networks. There was also a clear difference in abundance of the high-pressure polymorphs among H-, L-, and LL-groups: the high-pressure polymorphs are abundant in L- and LL-groups, whereas rare in H-group. The species and assemblages of the high-pressure polymorphs depended on the petrologic types. The abundance and assemblages of the high-pressure polymorphs in L- and LL-group were similar to each other, suggesting that both parent-bodies have similar impact histories. The shock-pressure conditions were estimated based on the identified high-pressure polymorph assemblages: from ~13 to ~24 GPa for L/LL6, from ~3 to ~12 GPa for L/LL4 and L/LL5, and less than ~3 GPa for L/LL3. When we adopted the estimations into the onion-shell-structured parent-body, the shock pressure condition on the parent-body surface is much lower than its interior, which is unlikely for a head-on impact. We cannot explain the parent-body breakup phenomenon based only on the estimation using the high-pressure polymorphs. There are clear differences on their petrographic structures between type 3–4 and type 5–6: the former consists of accumulated chondrules and the latter has equilibrated texture. It is also expected that type 3–4 and type 5–6 chondrites have different initial density and porosity. These differences will affect the

response to the shock metamorphism. Unless we take these factors into the estimation, we cannot clarify the parent-body breakup phenomenon by using the high-pressure polymorphs.

Reference: Chen et al. Science 271: 1570–1573 (1996)

Keywords: Shock, Ordinary chondrite, High-pressure polymorph

