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学 位 論 文 要 旨
Dissertation Summary

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論　文　名: High-pressure subsolidus and melting phase relations of Na-rich plagioclase:
(Dissertation Title)　implications for the shock metamorphism of plagioclase in shocked meteorites

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Shock metamorphism in meteorites provides evidences to support that some minerals in meteorites underwent high pressures and high temperatures during impact. Plagioclase is a typical constituent mineral in chondritic and Martian meteorites, and shock metamorphism of plagioclase has been widely discovered. Lingunite (aluminosilicate hollandite with ~ 80 mol % Na) is a typical shock-metamorphic phase of albitic plagioclase in strongly shocked meteorites, and has been frequently discovered in or adjacent to the shock veins. However, its formation condition remains unclear, and its formation mechanism is still under debate. Based on the flow textures of lingunite, some previous studies suggested that lingunite crystallized from molten plagioclase under high pressures (Gillet et al. 2000; Xie and Sharp 2004). Following this view, subsolidus and melting phase relations of two feldspathic compositions, $K_{0.2}Na_{0.8}AlSi_3O_8$ and $K_{0.05}Na_{0.85}Ca_{0.10}Al_{1.1}Si_{2.9}O_8$ (the latter is similar to that of the albitic plagioclase in meteorites), have been studied by multi-anvil experiments mainly at pressure-temperature (P-T) conditions of 22 GPa and 2273-2700 K, and the P-T conditions are typical for the shock veins in strongly shocked meteorites.

The high-pressure and high-temperature (HPHT) experiments using $K_{0.2}Na_{0.8}AlSi_3O_8$ as starting materials yielded phase assemblages of hollandite + stishovite + jadeite or calcium ferrite-type $NaAlSiO_4$ at 2273 K below or above 22 GPa, respectively. Hollandite single phase with a composition of $K_{0.2}Na_{0.8}AlSi_3O_8$ was synthesized at 22 GPa and 2273 K. Partial melting of $K_{0.2}Na_{0.8}AlSi_3O_8$ was achieved at ~ 23 GPa and 2575-2675 K. Stishovite is the liquidus phase, and jadeite is the solidus phase. Due to the melting, hollandite released $NaAlSi_3O_8$ components, and jadeitic melts and stishovite were formed.

Large-sized (20-50 μm) hollandite grains with high Na contents of 63-82 mol % crystallized from the jadeitic melts during quenching.

The HPHT experiment using a starting material of $K_{0.05}Na_{0.85}Ca_{0.10}Al_{1.1}Si_{2.9}O_8$ yielded a jadeite-bearing phase assemblage of jadeite + stishovite + hollandite + CAS phase at 22 GPa and 2273 K. Partial melting of $K_{0.05}Na_{0.85}Ca_{0.10}Al_{1.1}Si_{2.9}O_8$ was achieved at 22 GPa and 2475-2700 K. The melting sequence is jadeite (the solidus phase), hollandite, CAS phase and finally stishovite (the liquidus phase). Melting of stishovite was not observed in the experiments, and incongruent melting of jadeite, hollandite and CAS phase probably produced jadeitic melts and stishovite. Hollandite could contain 74-80 mol % Na plus Ca at 22 GPa and 2273-2500 K. At 22 GPa and 2273 K, CAS phase could contain only 35 mol % Na plus K, and was just a minor phase in the subsolidus phase assemblage. In contrast, CAS phase could contain 62-71 mol % Na plus K at 22 GPa and 2475-2700 K, and became a major phase in the phase assemblages of partial melting. Na-rich hollandite (Na/(K+Na+Ca), ~ 0.73) and Na-rich CAS phase (Na/(K+Na+Ca), ~ 0.69-0.78) crystallized from the jadeitic melts during quenching. In the sample recovered at 22 GPa and 2700 K, an intergrowth of CAS phase and stishovite was observed by Raman spectroscopy.

The experimental results indicate that both Na-rich hollandite and Na-rich CAS phase can form in albitic compositions at 22 GPa in two ways: (1) equilibrium formation in the stability regions and (2) non-equilibrium formation as quench crystals during quenching. However, both subsolidus and melting phase relations of $K_{0.05}Na_{0.85}Ca_{0.10}Al_{1.1}Si_{2.9}O_8$ can hardly elucidate the occurrence of lingunite in strongly shocked meteorites, although compositionally lingunite-like hollandite has been reproduced in this study. This is because lingunite-like hollandite is a minor phase in subsolidus phase assemblages of albitic plagioclase, and kinetic factors are required to be studied in order to interpret the dominant occurrence of lingunite in plagioclase-like grains (which has been frequently found in strongly shocked meteorites), if lingunite formed via solid-state transformation. On the other hand, if lingunite formed by liquid crystallization, CAS phase should occur as quench crystals together with lingunite, while no CAS phase has been found in the shock metamorphism of albitic plagioclase.

Plagioclase in Martian meteorites has labradoritic compositions (e.g., $Ab_{47}An_{51}Or_2$), and a shock-metamorphic phase assemblage of CAS phase plus stishovite has been discovered within labradorite-like grains in some Martian meteorites. In comparison to the shock-metamorphic CAS phase, the quench-formed CAS phase observed in this study exhibits similar appearance under electron microscopic observation. The intergrowth of CAS phase and stishovite from the jadeitic melt in this study resembles the shock-metamorphic phase assemblage of CAS phase plus stishovite in some Martian meteorites. These similarities suggest that the CAS phase found in Martian meteorites probably formed through a similar mechanism of liquid crystallization, as proposed by Beck et al. (2004) and El Goresy et al. (2013). In this scenario, some labradoritic plagioclase was completely melted at 22 GPa above 2700 K during collision, and subsequently, CAS phase and stishovite crystallized from the labradoritic melt during quenching under high pressures. Furthermore, crystallization duration of CAS phase during collision might be at the same magnitude as that during quenching in the HPHT experiments of this study, based on the similarity in grain sizes between the shock-metamorphic CAS phase in Martian meteorites and the quench-formed CAS phase in this study.