The systematic investigations of high-pressure minerals in lunar basaltic meteorites

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The Moon has recorded the impact history for ca. 4.5 Ga, which is closely related with the orbit evolution of asteroids and planets in the solar system. The impact events occurred on the moon can be clarified using lunar meteorites. The lunar meteorites have several kinds of evidence for the impact events: e.g., brecciation, shock-induced melting, and high-pressure polymorphs. The high-pressure polymorph is one of the important clues for clarifying the impact events because we can constrain several physical parameters (e.g., shock pressure) for the impact events. However, only a few lunar meteorites were investigated about the high-pressure polymorphs. Several radio-isotope ages in the lunar meteorites were measured to deduce when the impact events occurred. However, the relevance between the radio-isotope ages and the shock features has not been clear. Accordingly, we initiated to investigate the shock features, especially the shock-induced melting and high-pressure polymorphs in the lunar mare basalt, NWA 032, NWA 479, NWA 2727, NWA 2977, and NWA 4898 using FE-SEM, Raman, EMPA, and FIB-TEM techniques to obtain the clues for clarifying the impact events occurred on the moon.

NWA 032 consisted of a basaltic portion and a small amount of breccia. Olivine, Ca-pyroxene, and low-Ca pyroxene occurred as phenocrysts in the basaltic portion. The matrix was filled with spherulitic textures consisting of plagioclase and Ca-pyroxene. Several shock-melt veins and melt-pockets occurred in the basaltic portion. Several olivine grains next to the shock-met veins have transformed into ringwoodite. The estimated shock pressure is ~13 GPa at least. The petrological and mineralogical features of NWA 479 were similar to those of NWA 032. Olivine grains entrained in the shock-melt veins dissociated into bridgmanite + (Mg, Fe)O. The estimated shock pressure is ~23 GPa at least. NWA 4898 showed the basaltic texture. Olivine occurred as phenocrysts. The matrix portion consisted mainly of Ca-pyroxene and plagioclase. A trace amount of silica minerals was entrained in the shock-melt veins. Some silica minerals in the shock-melt veins were stishovite. Ca-pyroxene next to the shock-melt veins dissociated into ahrensite, pyroxene-glass, and (probably) silicate titanite. The estimated shock pressure is ~9 GPa at least. NWA 2977 showed a gabbroitic texture and consisted mainly of olivine, low-Ca pyroxene, Ca-pyroxene, and plagioclase. Olivine grains next to or entrained in the shock-melt veins have transformed into ringwoodite. The estimated shock pressure is ~16 GPa at least. Two third of NWA 2727 was breccia and the other was gabbroitic. The gabbroitic portion consisted of olivine, low-Ca pyroxene, Ca-pyroxene, and plagioclase. The breccia portion included silica besides the fragments of the gabbroitic portions. Silica minerals entrained in the shock-melt veins or melt-pockets have transformed into coesite. The estimated shock pressure is ~3 GPa at least.

The shock-induced melting textures were observed in all investigated lunar mare basalt samples. Although the high-pressure polymorphs of olivine, Ca-pyroxene, and silica minerals were identified, the high-pressure polymorphs of plagioclase, which are abundant in other shocked meteorites, were not identified. In addition to previous studies [1–3], the present study reveals that many kinds of high-pressure polymorphs occur in the lunar mare basalt, implying that most lunar mare basalts have experienced the heavy impact events.

References

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