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Planetesimal collision on the Moon at 2.7 Ga indicated by silica high-pressure polymorph

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The existence of a high-pressure polymorph in a meteorite is suggestive of its parent body having gone through a dynamic event. The moon's many craters and thick regoliths imply that it has experienced heavy meteorite bombardments. Several previous studies proposed that only a very few high-pressure polymorphs are contained in lunar surface materials (lunar meteorite and Apollo samples) because most high-pressure polymorphs melted and disappeared through high-temperature condition induced by a dynamic event under rarefied atmosphere on the moon [1-2]. However, Ohtani et al (2011) [3] studied lunar meteorite, Asuka 881757 in detail, and identified high-pressure polymorphs of silica, coesite and stishovite. ^{40}Ar-^{39}Ar radiometric age of Asuka 881757 indicates that coesite and stishovite were formed by a dynamic event occurred at 3.8 Ga, which is relevant to a planetesimal collision occurred during late heavy bombardment. In this study, we studied another lunar meteorite, NWA 4734 by a Raman spectroscopy, scanning electron microscope (SEM), synchrotron X-ray diffraction (XRD) and transmission electron microscope (TEM) to search for high-pressure polymorphs and clarify planetesimal collision history on the Moon.

NWA 4734 originates from lunar basalt, and contains many shock-melt veins and melt-pockets, implying that NWA 4734 was heavily shocked. Many cristobalite grains with mosaic-like textures exist in NWA 4734. Back-scattered electron (BSE) images show that cristobalite adjacent to the shock-melt veins and melt-pockets have tweed-like textures. Such portions including tweed-like textures were excavated with a focused ion beam (FIB) system, and became block pieces. We scanned the block pieces with a synchrotron X-ray at SPring-8 BL-10. We identified a high-pressure polymorph of silica, alpha-PbO2 type silica (seifertite) based on the X-ray diffraction (XRD) patterns. Seifertite was reported only from shocked Martian meteorites up to now [4]. BSE images show that cristobalite grains in the host-rock of NWA 4734 have lamellae-like textures. Raman spectroscopy analysis and XRD patterns reveal that such portions include stishovite. Dendritic coesite was also found in the shock-melt veins. Phase equilibrium diagram deduced from high-temperature and -pressure synthetic experiments indicate that the stable pressure filed of seifertite is ˜100 GPa or more. On the other hand, recent several studies propose that the stable pressure filed depends on the differences of starting materials for the synthetic experiments and impurities (e.g., Al)[5-6]. Original silica in NWA 4734 is not quartz but cristobalite and contains small amounts of Al and Na. Accordingly, now, it is difficult to estimate shock-pressure condition recorded in NWA 4734 based on present phase equilibrium diagram. Nonetheless, high-pressure condition of ˜40 GPa or more would be essential for the formation of seifertite at least [6]. ^{40}Ar-^{39}Ar radiometric age of NWA 4734 is 2.7 Ga [7], which is the one of the youngest age among lunar meteorites. We could regard 2.7 Ga as planetesimal collision age because 40Ar-39Ar radiometric age is very sensitive to thermal metamorphism. Our present study allows us to infer that catastrophic planetesimal collision had continued on the Moon till 2.7 Ga at least.

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