Moganite in lunar meteorite, Northwest Africa 773 clan: Trace of H_2O Ice in the Moon's Subsurface

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Lunar water locally concentrates as a result of the migration of H_2O molecules on the sunlit surface towards the colder regions. The molecular water is subsequently cold-trapped as ice on the permanently shadowed regions, the poles and theoretically Moon's subsurface. Although a few trace of subsurface H_2O has been observed by remote sensing spectrometers (e.g., LCROSS), it has not been reported in the Apollo and Luna samples and lunar meteorites yet. In this study, lunar meteorites, the Northwest Africa (NWA) 773 clan, were investigated and thereby moganite, a monoclinic SiO_2 phase precipitated from alkaline fluids, was discovered by various microanalyses. A formation process of this lunar moganite was also interpret to evaluate origin of the Moon's subsurface H_2O.

Lunar meteorites of the NWA 773 clan were selected for Raman spectroscopy, electron microscopies and synchrotron X-ray diffraction (SR-XRD). The KREEP-like NWA 773 clan commonly consists of gabbroic and/or basaltic clasts.

Silica occurred as anhedral micrograins between the constituent minerals in the lunar meteorite. Raman spectra of the silica micrograins exhibited pronounced peaks at 128, 141, 217 and 503 cm^{-1}, which corresponded to those of moganite. Coesite Raman peaks were also identified together with the moganite signature. Raman intensity mapping revealed that the silica micrograins contain abundant moganite in its core, surrounded by coesite. SR-XRD of several silica micrograins also confirmed moganite and coesite. Transmission electron microscopy clarified that the silica micrograins consist of nanocrystalline particles with an average radius of 4.5 nm. Most of the SiO_2 nanoparticles were identified as moganite by selected area electron diffraction (SAED) patterns. Moganite was accompanied by small amounts of coesite, according to SAED analyses of the SiO_2 nanoparticles.

Moganite-bearing silica micrograins in the NWA 773 clan precipitated from lunar alkaline fluids rather than terrestrial weathering for the following reasons: (1) Occurrence only in a part of the NWA 773 clan. (2) Moganite surrounded by the coesite rim. (3) High moganite content contradicting reduced content to <20 wt% under dry desert condition over terrestrial age.

A formation process for lunar moganite can be explained as follows. A host gabbroic and basaltic rock of the NWA 773 crystallised within the Procellarum KREEP Terrene (PKT). Subsequently, carbonaceous-chondrite collisions occurred on the surface of the PKT, followed by ejection of the host rock due to the impact events. The alkaline water delivered by the carbonaceous chondrite was captured as a fluid during the brecciation on the impact basin. Below the freezing point, this fluid got cold-trapped as H_2O ice in the subsurface. Simultaneously, the moganite-rich silica micrograins precipitated from the captured alkaline fluid on the sunlit surface. The NWA 773 clan was launched from the PKT by the latest impact event, thus producing transformations to coesite from moganite.

Keywords: Lunar meteorite, Moon, Subsurface water, H2O ice

