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Significance of nano minerals in the planetary materials science

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Introduction: Nowadays we can investigate diverse planetary materials in laboratories: meteorites, interplanetary dust particles, micrometeorites, returned samples from the Moon, the Wild 2 comet, and the asteroid Itokawa, and so on. These planetary materials often contain submicron minerals (hereafter nano minerals).

Nano minerals in planetary materials: Why nano minerals are common among planetary materials? Their small sizes are probably related to their formation conditions and/or mechanisms. Now we look out several examples of nano minerals in planetary materials.

Nano minerals in hydrated chondritic meteorites: CIs, CMs, CVoxBs, CRs, CHs, CBs, and some UOCs contain various amounts of hydrated minerals [e. g. 1]. Phyllosilicates in them are saponite and/or serpentine. Their crystallinity is poor and only a few to at best a few tens repetitions of (001) lattice fringes can be seen in TEM images. When they coexist, they often form mixed layers. After accretion of anhydrous materials, water ice and organics, water ice was melted probably by ^{26}Al decay heat and water was reacted with anhydrous materials within their parent bodies to form hydrated minerals and the other minerals such as carbonates. The alteration temperatures and water/rock ratios are estimated to have been different between CIs and CMs: $>$100 ^{o}C and ˜1 and $<$20 ^{o}C and 0.3-0.6, respectively [e. g. 1]. Low water rock ratios and possibly stagnant fluids might be related to their poor crystallinity. Because no remarkable elemental fractionation by aqueous alteration is not observed in these meteorites, fluid may have been lost by freeze-dry on their parent bodies.

Aqueous alteration products in Martian meteorites: Nakhlites are a kind of Martian meteorites formed in lava flows or shallow intrusions [e. g. 2]. The meteorites are unique because they contain aqueous alteration products formed on Mars, which typically appear as reddish brown veinlets in olivine phenocrysts. The alteration product of Lafayette meteorite is composed of siderite, poorly crystalline saponite and serpentine, and silicate gel. The hydrothermal assemblage suggest that a CO_2-rich hydrothermal fluid reacted at 150-200 ^{o}C, pH 6-8 with a water/rock ratio of $<$300 [3]. Because elemental fractionation is remarkable in the alteration product, the fluid obviously moved along clacks. Another intriguing example is ALH84001 orthopyroxenite containing bacteria-like objects [4]. Although it contains truncated nanomagnetite, debates on its origin have not finished even today [5].

Nano minerals in chondritic porous interplanetary dust particles: Chondritic porous interplanetary dust particles (CP IDPs) are typically ˜10 micron-sized planetary materials, which have been regarded as cometary dust and the most primitive planetary materials that can be investigated in laboratories even after the Stardust mission [6]. They are loose aggregates of nano minerals with some isolated minerals larger than 1 micron. Because CP IDPs experienced almost no modification on their parent bodies, each constituent has its own history. The most curious object in CP IDPs are GEMS (glass with embedded mental and sulfide), which is $<$500 nm spheroidal amorphous silicate containing nanocrystals of Fe-Ni metal and Fe sulfide [7]. Its origin is still in dispute [8].

Summary: As described above, nano minerals in planetary materials hold the key to understand their formation conditions and origins although some are still in debate.

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