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Development of a new analytical scheme for micrometeorites and discovery of micrometeorites with intriguing mineralogy

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Introduction: Combined mineralogical and isotopic studies of individual Wild 2 cometary particles revealed that the materials formed in the inner solar system had been transported to the outer solar system before the formation of the Wild 2 comet [e. g . 1,2,3,4]. We sought another analytical scheme for MM (micrometeorite) studies. In this new analytical scheme, we have two objectives: identification of nonchondritic MMs and identification of asteroidal MMs with mineralogy indistinguishable from CP IDPs, which are regarded as cometary grains [5].

Samples and methods: MMs used in this study were found in the surface snow collected near the Dome Fuji Station, Antarctica in 2003 and 2010. The surface snow was melted and filtered in a clear room. After identification of MMs, we performed SR-XRD, FIB section preparation, TEM, micro-Raman, SEM, EPMA, INAA, and/or noble gas mass spectroscopy for each MM.

Results and discussion: We investigated twelve MMs and could classify them into five types based on their mineralogy: refractory MMs, chondrule-like MMs, fine-grained polycrystalline MMs, coarse-grained crystalline MMs, and phyllosilicate-rich MMs. Here we show the mineralogical results of two MMs with intriguing mineralogy.

Refractory MM A MM is composed mainly of anorthite, diopside, and spinel. A BSE image of the cross section of the MM showed that it has an amoeboid structure, in which small ($<$5 micrometer) Al-rich and Ti-bearing diopside exists on its surface and its interior and anorthite fills the interstices of diopside. The major minerals are similar to those in type C CAIs [6]. Although its amoeboid structure suggests low degrees of melting during the formation event, the MM has a compact interior, in which diopside and anorthite have triple junctions with ˜120^o angles. Therefore, the refractory object was probably formed by low degrees of melting and subsequent prolonged cooling. It is different from meteoritic type C CAIs that experienced intense melting and crystallization from melt droplets. Fine-grained material attached on the refractory object is composed of GEMS (glass with embedded metal and sulfide)-like objects, olivine, pyrrhotite, and carbonaceous material. Because GEMS-like objects have not been identified among meteorites yet, this MM may have derived from a comet.

Fine-grained polycrystalline MM A MM is composed of small ($<$400 nm) crystals of Fe-bearing olivine, Fe-free low-Ca pyroxene, Fe-Ni metal, Fe sulfide, amorphous silicate, and interstitial carbonaceous material. Although these crystals have often triple junctions with ˜120^o angles suggestive of recrystallization, both olivine and low-Ca pyroxene show almost no compositional zoning. The low-Ca pyroxene crystals elongate near the a-axis direction and are composed of a unit cell-order mixture of ortho and clino low-Ca pyroxene with stacking disorders. Its microstructure indicates rapid cooling ($>$20-30 K hr^{-1}) form above 1275K [7]. Both olivine and low-Ca pyroxene in this MM contain abundant tracks with ˜5 x 10^{10} cm^{-2}, which corresponds to ˜10^4-year exposure to the solar wind [8]. Tracks in olivine are erased by flash heating above ˜600 ^{o}C [9]. Because typical cometary IDPs are heated to $>$720 ^{o}C [10], it is plausible that the MM was derived from an asteroid instead of a comet although any materials similar to this MM have not been found among meteorites.

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