Collection of Antarctic micrometeorites using the freeze-drying method of snow

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Antarctic micrometeorites (AMMs) were recovered from blue ice in 1980s and 1990s by French [1] and Japanese [2, 3] researchers. At that time, a hot water generator [1] or a radiator heater [2, 3] was used to melt ice and resultant water was filtered in-situ. After 2000s, Antarctic snow was used to collect AMMs [e. g. 4, 5]. In these studies, snow was also melted and the resultant water was filtered. Collection of AMMs without contacting water has been explored because water-soluble substances may leach out and/or change during contact with water. Taylor et al. [6] collected AMMs by filtering air near the Amundsen-Scott South Pole Station. Here, we report collection of AMMs without contacting water by freeze-dry system.

Surface snow collected near the Dome Fuji Station, Antarctica by 59th JARE team and transferred to National Institute of Polar Research, Tokyo (NIPR) in a frozen state and stored in the storage room in -30 ^{o}C. The recovered snow was transferred to a refrigerator in a clean room in NIPR for freeze-dry processing. About 1-kg snow was placed on a Teflon® sheet set in the chamber of the freeze-dry system EYELA FDU-1200 in a single batch. To avoid back-diffusion of pumping oil that may affect later analysis, a dry vacuum pump NeoDry 7E-S 100V was used in the freeze-dry system. The Teflon® sheets were transferred to Kyushu University after each freeze-dry processing.

We are collecting AMM candidate particles from the Teflon® sheet using a micro-manipulator under a stereomicroscope in a clean booth. The candidate particles were placed on a platinum plate for SEM-EDS observation by FIB-SEM JEOL JIB4501 equipped with EDS. We identified small particles rich in O, Mg, Si, S, and Fe as AMMs.

To date, we have observed and analyzed 1439 candidate particles and identified 4 chondritic porous (CP) MMs (Fig 1a), 4 chondritic smooth (CS) MMs (Fig 1c), and 3 spherules in 17 kg snow sublimated on 6 Teflon® sheets. The vast majority of these particles were carbon grains that would be soot grains probably generated by a snow vehicle, Fe rust grains that were also related to the snow vehicle, and chloride and sulfate grains that were easily deliquesce in the air, which would be sea salt grains. Their average dimensions of the AMMs range from 10 to 54 µm. The average size of CP MMs, CS MMs, and spherules are 20 ± 10, 34 ± 20, and 17 ± 10, respectively.

Although collection of AMMs from the residues after freeze-dry of snow is incredibly tough work as described above, we found ~0.6 AMM from 1-kg snow. This value is considerably smaller than our previous studies ~1 AMM/ 1-kg snow [5]. Taylor et al. [6] identified 19 extraterrestrial particles larger than 5 µm in diameter from filters exposed from November, 2016 to January, 2019 although they had predicted to collect 300-900 AMMs. Automatic elimination of terrestrial dust particles is a key to collect AMMs from the freeze-dry residues in future study.

The CP MMs are highly porous and composed of a loose aggregate of sub-µm-sized components with some large mineral grains. An euhedral crystal with ~5 µm ×~5 µm is low-Ca pyroxene based on the EDS spectrum. Bulk EDS spectrum of this AMM shows remarkable peaks of O, Mg, Si, with smaller peaks of S, Fe, Al, and Ca. In the case of CS IDPs, they have a larger peak of Fe relative to Mg and Si, suggestive of abundant Fe-bearing phyllosilicate. We are going to make ultrathin sections of these AMMs and observe them with TEM. In addition, we have a plan to analyze macromolecular organic material in these AMMs by XANES and nanoSIMS.

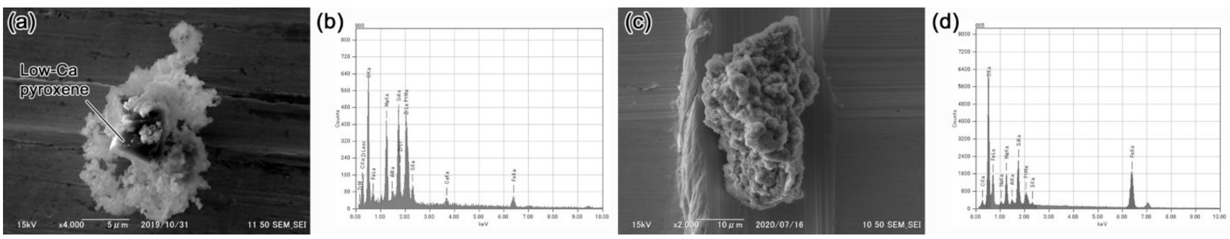

Fig. 1 Typical AMMs recovered in this study. (a) Secondary electron (SE) image of a chondritic porous AMM. (b) EDS spectra of this CP MM. (d) SE image of a chondritic smooth (CS) AMM. (d) EDS spectra of this CS MM.

References

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