Parent Bodies of Antarctic Micrometeorites

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Antarctic micrometeorites (AMMs) are small extraterrestrial material less than 1 mm recovered from Antarctica. They are small particles recently swept out from small planetary bodies such as asteroids and comets, because they contain only a small amount of noble gases produced by cosmic-ray exposure in the interplanetary space. Small particles are subject to heavy alteration during heating at atmosphere and also during residence at Antarctic ice field, which changes both mineralogical and isotope properties of micrometeorites. It is therefore crucial to select micrometeorites that experienced minimum alteration and thus retain primary records of the parental objects. More than 5000 samples of AMMs were investigated by electron microscopy to select the least-altered micrometeorite samples. Approximately 300 samples were selected and further analyzed by synchrotron X-ray diffraction and transmission electron microscopy. In addition, some samples are analyzed by mass spectrometery for oxygen and noble-gas isotope ratios. Quantitative element analysis using a thin-window energy dispersive spectrometer showed that most AMMs are rich in carbon. Carbon concentrations of AMMs are comparable or even higher than those in carbonaceous chondrites of CI, CM, and Tagish Lake types.

Some large AMMs with 200 microns in diameter were found to contain a large amount of carbonaceous material. Carbon concentration is at least 10 times higher than that observed in CI, CM, and Tagish Lake types. Carbonaceous material forms a complex framework structure in an entire region of the micrometeorites and small, variable compositions of olivine, low-Ca pyroxene, and pyrrhotite disperse within the carbonaceous material. Synchrotron X-ray diffraction analysis showed that the carbonaceous material is amorphous. Laser microprobe noble gas analysis of one micrometeorite revealed that it contains solar-wind derived light noble gases and undetectable amounts of cosmogenic Ne, suggesting a short exposure to cosmic-rays. The AMM experienced high-temperature brief heating upon atmospheric entry, since silicates at outermost portions are melted and removed, and the carbonaceous framework is directly exposed. The framework appears to have served as a heat insulator that has shielded inner silicates and sulfides during the atmospheric frictional heating. The high carbon concentration, the high-velocity atmospheric entry, and the short cosmic-ray exposure are all consistent with the cometary origin of this micrometeorite rather than the asteroidal origin.

Phyllosilicates are a main component of hydrous asteroids and the phyllosilicate mineralogy varies between the asteroids based on the mineralogy of hydrous carbonaceous chondrites. However, phyllosilicates are easily decomposed by heating and, as a result, only limited number of AMMs retain phyllosilicates. During the survey of X-ray diffraction analysis over 300 least-altered AMM samples, 48 samples have been identified as phyllosilicate-rich AMMs. Among 48 phyllosilicate-rich samples, the relative abundance between saponite and serpentine varies greatly, but predominant phyllosilicate is saponite: 36 samples contain only saponite, 5 samples contain only serpentine, and the remaining 7 samples contain both saponite and serpentine. The relative abundance of phyllosilicates is a measure for the identification of parental objects: Tagish Lake chondrite is dominated by saponite, CM chondrites are dominated by serpentine, and CI and CR chondrites contain both phyllosilicates. Our results thus indicate that the phyllosilicate variation of AMMs covers a whole range of carbonaceous chondrites and further implies that micrometeorites with saponite-dominated mineralogy is one of the main components in interplanetary dust, which shows a clear contrast to the very rare occurrence of saponite-dominated materials (Tagish Lake) as a meteorite-size object.