A RECONNAISSANCE SURVEY OF MICROMETEORITES FROM ANTARCTICA

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Introduction: Micrometeorites (MMs) are millimeter to sub-millimeter-sized dust particles that are liberated as debris tails from asteroids and comets and are constantly captured by Earth. They are decelerated at high altitudes, often heated and partially melted, yet survive atmospheric entry to be recovered from Earth's surface environments. They have been successfully separated from Antarctic ice and investigated in detail using numerous analytical techniques, which has improved our understanding of the source population of small bodies, their compositions and aqueous processing of materials [1–4]. Additionally, the study of MMs provides a complementary perspective on meteorite studies as well as regolith samples obtained from sample return missions like *Hayabusa2* and *OSIRIS-REx*.

Identifying the parent bodies of MMs and understanding their relationship to known meteorite groups improves our knowledge of solar system geological diversity during the age of early planetesimals. Such a classification requires a detailed investigation of the MM mineralogy, chemical characteristics, and oxygen isotope compositions. Here, we report on a quantitative and semi-quantitative analysis of the mineralogy of several unmelted MMs from Antarctica. We focus on the textural setting of P-bearing minerals with surrounding phases, which has not received particular attention. Furthermore, selected MMs will be investigated for O-isotopes.

Samples and Methods: We investigated a subset of small (<150 µm) MMs from the Cap Prud'homme MM collection [4]. These are blue-ice derived particles, hand-picked from filter papers in 1994. Mineralogy of the particles was ascertained using energy dispersive spectroscopy (EDS) and wavelength dispersive spectroscopy (WDS) on the JEOL JXA-8530F electron microprobe (EPMA) at Arizona State University. Analyses were conducted with a beam current of 15 nA, an acceleration voltage of 15 keV, and a beam size of 1 to 5 µm. High-resolution elemental maps of K, P, Si, Al, Na, Mg, Cl, S, Ti, Fe, Mn, Ca were collected.

Results: CP94-050 epoxy mount has 80 MMs; data on sixty-seven MMs, often with CI and CM-like characteristics have been previously published [4–7]. The remaining MMs range in size from ~80 µm to ~135 µm in diameter and are primarily irregular in shape. Of these, four are fine-grained MMs (FgMMs), two are scoriaceous fine-grained MMs, and seven are coarse-grained MMs. Of the FgMMs, three are type C2 (compact and chemically heterogenous), and one is type C3 (highly porous) based on the classification scheme of [4].

We conducted sixty-nine WDS spot analyses of about 5×5 μm^2 regions in the MM suite. Thirty-one of these target regions are from MMs previously unstudied in this capacity. These regions are either fine-grained matrix or larger coarse grains. Individual grains vary from spherical to irregular to elongated. WDS analyses outside the range of 97 to 101 wt. % were rejected, unless the spot was taken from a porous, fine-grained matrix, in which case a threshold of >94 wt. % was used (e.g., [4]). Twenty-four grain analyses met the former criteria. Eight of these spots are olivine ($Fo_{85.1\text{-}99.3}$), 12 are pyroxene ($En_{88.5\text{-}97.4}Fs_{1.5\text{-}7.8}Wo_{0.6\text{-}4.2}$), one is Ca-rich augite ($En_{55.5}Fs_{0.8}Wo_{43.7}$), and two are SiO_2 grains. The remaining grain is non-stoichiometric with a Si/O ratio is 1/3 and with Mg and Al enrichments.

Sixty-nine spots were analyzed for P with WDS. Considering 97 to 101 wt. % totals, we identified two grains that are olivine while 2 are pyroxene; the remaining grains show non-stoichiometric compositions. The P content of these silicate grains vary from >0.01 to 0.035 wt.%. We also found five fine-grained, porous regions with lower totals (>94 wt. % criteria) that contain P (0.012–0.0127 wt.%). Several of these contain Mg and Ca, suggestive of thermally metamorphosed apatite minerals. Elemental maps show that P is evenly distributed in most MMs, although a few MMs show hotspots. For example, one MM displays a 5×5 μm^2 hotspot, contains elevated levels of Fe (18.3 wt. %) and S (1.07 wt. %), and exhibits non-stoichiometric elemental composition. Several P hotspots contain Fe and are either Fe-phosphide inclusions or Fe-Ni metal altered to ferrihydrite.

Discussion: The study of the phases containing S and P can provide valuable insights into (1) element reservoirs and (2) redistribution during metasomatic fluid processing on asteroid parent bodies. Phosphorus is present in Fe-Ni metal in the most primitive carbonaceous chondrites [8]. Secondary processes oxidize P to form phosphates and phosphides [9]. We identify P in olivine and pyroxene minerals, and in grains that contain P in association with S, Mg, and Ca in non-stoichiometric proportions. We argue that fluid-mediated processing occurred in these MM parent bodies and P is not completely lost from the MMs during re-entry through Earth's atmosphere.

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