NANOSCALE CHEMICAL HETEROGENEITY IN AN ANTARCTIC MICROMETEORITE REVEALED BY ATOM PROBE TOMOGRAPHY.

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Introduction: Extra-terrestrial material entering the atmosphere undergoes significant processing that affects its morphology, texture and geochemistry. Micrometeorites (MMs) – cosmic dust particles 10 μm to 2 mm in size [1] recovered from the Earth's surface – can be used to understand this interaction by retaining a compositional record of entry processing that can be studied in the laboratory. This may allow the reconstruction and modelling of atmospheric entry parameters, such as MM velocities [2]. Nanometre-scale characterization of MMs gives the opportunity to observe compositional trends at higher resolutions that could be used as proxies for entry heating. Recently, atom probe tomography (APT) has been used to characterize extra-terrestrial processes affecting lunar grains [3] and phase boundaries in an iron meteorite [4]. We have also previously reported on other features observed in our APT data from an Antarctic MM (5, 6). Here, we report our latest findings, with a focus on understanding geochemical trends in metallic elements and carbon (C).

Methods: MM CS94_03 was recovered from blue ice near Cap Prud'homme, Antarctica by Maurette et al. [7]. Distinct rim and core regions with compositional layering, notably in iron (Fe) and oxygen (O), were highlighted using electron probe microanalysis (EPMA) [8]. For APT analysis, focused ion beam (FIB) techniques were used to create two lamellae (A and B) and APT needles from locations across the core-rim boundary of the MM. The APT needles were run on either a LEAP-5000XS or -5000XR. The output HITS data files were processed using Cameca's IVAS software to produce 3D tip reconstructions.

Results & Discussion: We observe a number of notable features across both lamellae areas. A tip from lamella A shows a metallic region with elevated concentrations of Fe and its associated O complex ions, copper (Cu) and zinc (Zn). These species are heterogeneously distributed within the region itself, notably with localised concentrations of Fe, ~2 nm in size. At least three tips contain plate-like C horizons: ~2 nm-wide concentrations with similar orientations throughout the tips, discontinuous from one another. A further tip shows an interplay of C with Fe, O, and silicon (Si), where voids in the latter species are infilled by enrichments in C. Previous authors detected C-rich phases, known as "COPS", in Antarctic MMs, occurring within voids and cavities [9]. It is possible that we observe the same phenomenon here on the nanometre-scale. Another tip shows surfaces of increased Fe, O, Cu, Zn and Si concentrations in the lower half that are ~4 nm in thickness with parallel orientations. These surfaces are composed of the same species as concentration lineations seen elsewhere in this MM [5]. These features may be a product of the phase transition and could be related to the creation of microchannels by devolatilization [10] or the presence of high thermal gradients affecting diffusional behaviour during entry [11].

Concluding Remarks: We have demonstrated the successful application of APT to cosmic dust and have identified heterogeneous chemical distributions that may represent the consequences of atmospheric entry processing. 3D nanometre-scale reconstructions allow the characterization of geochemical trends, previously unseen at lower resolutions.

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