ATMOSPHERIC ALTERATION IN FINE-GRAINED ANTARCTIC MICROMETEORITES; Matthew J. Genge, Monica M. Grady, and Robert Hutchison. Mineralogy Department, Natural History Museum, London SW7 5BD, Great Britain.

Summary. The textures and compositions of 89 Antarctic micrometeorites (AMMs) in the size range 50-100μm were examined by scanning electron microscopy and electron microprobe techniques to differentiate primary 'pre-atmospheric' characteristics from those originating from alteration in the atmosphere. Results indicate that the majority of particles (61) are completely or partially melted during atmospheric deceleration attaining peak temperatures in excess of ~1600°C. A significant number of particles (18) containing relict phyllosilicates have evidently been heated to temperatures less than 600-900°C. The matrix compositions of the examined AMMs broadly support previous theoretical predictions that all particles >50μm have suffered some degree of partial vaporisation or melting during aerobraking, however, they also imply that predicted peak temperatures are severely overestimated. It is infered from particle textures that cosmic dust particles >50μm can support both high thermal gradients (~1000°C) and may develop hydrodynamical bow-shocks: phenomena which are specifically excluded from theoretical treatments. Matrix compositions also testify to volatile enrichments of the elements K, Cl, F, and P presumably as the result of reactions with atmospheric species. A reaction mechanism is suggested for the observed coupled enrichment of K and Cl.

Introduction. Major aims of studies of cosmic dust at the present time are to identify particles derived from cometary sources and to establish links between asteroidal dust and known meteorite groups. Achieving this aim is complicated by the alteration of particles during both atmospheric entry and terrestrial residence. Theoretical modelling of atmospheric heating during aerobraking of cosmic dust suggests that all particles >50μm in size suffer some degree of partial vaporisation or melting [1]. Observations of large unmelted fine-grained AMMs, some of which preserve low-temperature mineral assemblages including phyllosilicates [2], contradict these theoretical assertions. It is critically important to evaluate the extent to which atmospheric alteration affects the compositions and textures of fine-grained AMMs since these materials are both more representative of the commonest dust size range accreting to the Earth at the present time [3] and are available in larger quantities than the smaller interplanetary dust particles. We report the results of a study of 89 fine-grained AMMs in order to constrain their degree of atmospheric alteration.

Samples and Techniques. AMMs used in this study were recovered by melting and filtering of blue ice, near Cap Prudhomme, Antarctica by Maurette and co-workers in 1991 [4]. All particles were prepared as polished sections and examined by backscattered electron imaging and wide beam electron microprobe techniques.

Particle Textures. The majority of AMMs (61 out of 89) demonstrate textural evidence for complete or partial melting indicating that they have attained temperatures in excess of ~1600°C. Fifteen of the 61 melted particles are composite particles with unmelted cores and melted scoriaceous rims. These cored micrometeorites (CMMs) imply that cosmic dust particles >50μm in size can support high thermal gradients. The presence of phyllosilicates within the cores suggest maximum temperatures less than 600-900°C and imply rim to core temperature differences of up to ~1000°C. CMMs also exhibit textural evidence for the development of hydrodynamical bow shocks: some unmelted cores containing open vesicles with melted scoriaceous rims, which indicates melting by a super-heated gas phase. Of the 28 particles lacking textural evidence for melting, 18 particles retain phyllosilicates. Only 8 particles demonstrate no textural evidence for melting or devolatilisation.

Matrix Compositions. The matrix compositions of all observed particles are approximately chondritic demonstrating Mg/Si, Fe/Si, Ti/Si, and Mn/Si within factors of 2-3 of CI. The melted AMM groups

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(cosmic spherules (CSs), scoriaceous MMs (SMMs) and the melted rims of CMMs) exhibit elemental fractionations that are consistent with partial vaporisation.There is a general decrease in elemental abundance with increasing volatility for most elements (fig.1); the behaviour of K, Cl, F and P are considered below. Unmelted particles lack evidence for fractionation of refractory elements, but demonstrate depletions in the more volatile elements Na and S by devolatilisation (fig.1). All particles show loss of Ca relative to CI and the more volatile elements Mg and Si. Depletions in Ca exhibit approximate positive correlations with Na for unmelted AMMs (fig.2a) consistent with volatile loss of Ca at sub-solidus temperatures by dissociation of Ca-bearing volatile species. CSs have very low Na contents and large variations in Ca abundance. Correlations of Ca with Al and Ti (fig.2b) imply the refractory gain of Ca due to the preferential vaporisation of more volatile species at high temperature. The elevated Ca/Na ratios of some SMMs may imply that these are competing processes at intermediate temperatures. Ca depletions in most CSs clearly indicate that their precursor materials were similar to observed unmelted particles. Enrichments in K, Cl, F, and P in relation to Na, a less volatile element, were observed in all particles and possibly represent chemical alteration through low-temperature reactions with atmospheric species. K and Cl enrichments are correlated with Na contents and are suggested to arise through reaction of atmospheric KCl complexes with the Na component of AMMs to halite. These results are consistent with previous observations of volatile element enrichments in IDPs [5] and AMMs [2].

Conclusions. The matrix compositions of fine-grained AMMs observed in this study are dominated by the effects of atmospheric alteration to an extent that their primary 'pre-atmospheric' compositions, at least for elements more volatile than Fe, are obscured. These results are therefore consistent with previous theoretical predictions that all particles >50µm suffer some degree of partial vaporisation. The preservation of phyllosilicates and the constraints provided by Ca depletions, however, suggest that some particles retain low-temperature phases perhaps including carbonates and may have attained maximum peak temperatures as low as ~400°C. These results imply that theoretically predicted peak temperatures are significantly too high. It is suggested that current theoretical models are inappropriate for the description of the thermal behaviour of particles >50µm in size which can evidently support large internal temperature gradients and exhibit the development of hydrodynamical bow shocks.

Acknowledgements: *We would like to thank M.Maurette (C.S.N.S.N, Paris) for his efforts in the collection of AMMs and in training in sample handling techniques. This work is supported by PPARC.*

References: [1] Love S. G. and Brownlee D. E. (1991) Icarus 89, 26-43, [2] Kurat G. et al. (1994) Geochim. Cosmochim. Acta 58, 3879-3904, [3] Love S. G. and Brownlee D. E. (1993) Science 262, 550-553, [4] Maurette M. et al. (1991) Nature 351, 44-47., [5] Jessberger E. K. et al (1992) Earth Planet. Sci. Lett. 112, 91-99.

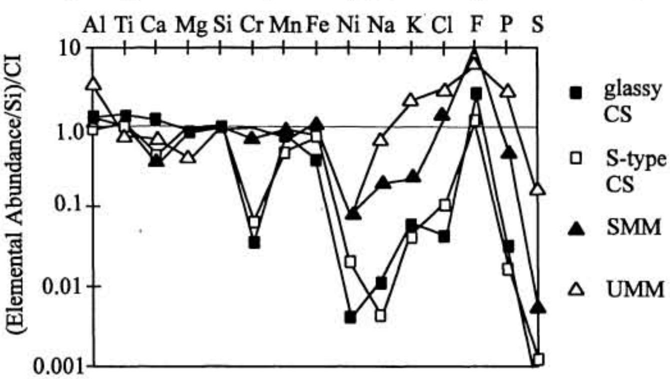

Figure 1. Elemental abundances of the matrixes of 4 AMMs normalised to CI. Elements arranged in order of increasing cosmochemical volatility.

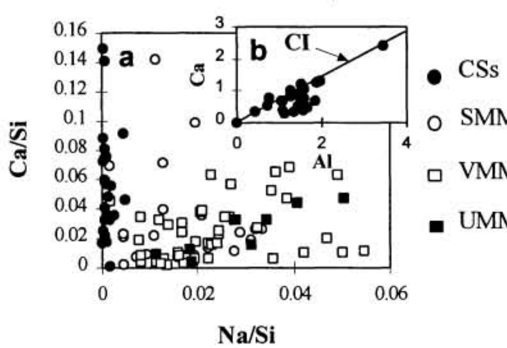

Figure 2. Elemental correlations in AMM matrixes: (a) Ca and Na in all groups, (b) Ca and Al in Css. Note VMMs are vesicular unmelted AMMs.