PRIMARY VARIATIONS IN MICROMETEORITES WITH ENTRY VELOCITY. M. J. Genge, Department of Earth Sciences and Enginneering, Imperial College, Royal School of Mines, Prince Consort Road, London SW7 2BP, UK (m.genge@imperial.ac.uk).

Introduction: Micrometeorites are that fraction of the extraterrestrial dust flux that survives atmospheric entry to be recovered from the Earth's surface. The majority of large micrometeorites (>50 μm), recovered from Antarctic ice, experience significant heating during atmospheric entry with the result that volatile-bearing phases, such as clay minerals, have thermally decomposed. A significant proportion of particles also have been partially or completely melted [1].

The degree of heating depends on peak temperature and duration of the thermal pulse caused by the hypervelocity collision of air molecules during deceleration and is a function of entry velocity, entry angle and particle size. The dependence on entry angle ensures that even a single velocity population of micrometeoroids will experience a range of heating effects. The overall degree of entry heating, however, will nevertheless increase with velocity [2]. Since dust particles from the same source will have a restricted range of geocentric velocities, changes in the pre-atmospheric mineralogical and chemical properties of micrometeorites with degree of entry heating may allow identification of discrete populations of particles within the micrometeorite flux.

Analyses of petrological variations with degree of heating are complicated by changes in the mineralogy and composition of particles accompanying heating. Identifying the primary features of heated micrometeorites, particularly in particles which have experienced melting, is problematic, however, large (>5 μm) anhydrous silicates are found as relict phases within melted particles and allow comparison with unmelted particles. The current study presents data on variations in the abundance and nature of primary anhydrous silicates to enable entry heating affects to be correlated between different particle types.

Primary Anhydrous Silicates: Mg-rich pyroxene and olivine are the most abundant anhydrous silicates within large micrometeorites. In contrast to carbonaceous chondrites, pyroxene is most abundant. Anhydrous silicates are found in two forms in unmelted particles: (1) as isolated grains, often with fragmental outlines, embedded in the matrices of fine-grained MMs (fgMMs), and (2) as grains within coarse-grained MMs (cgMMs), which are often present as phenocrysts in particles with igneous textures. Fine-grained MMs have been interpreted as equivalent to the fine-grained matrices of C1-C3 chondrites, although clay minerals have typically decomposed to amorphous dehyroxylates or recrystallised to sub-micron olivine and pyroxene [3]. The majority of cgMMs have been interpreted as fragments of chondrules from C2-C3 chondrites since the presence of fine-grained matrix attached to some particles indicates an origin as small igneous objects from similar parent bodies to fgMMs [4].

The relative abundance of micrometeorites dominated by large anhydrous silicates (cgMM-derived), of isolated anhydrous silicates within fine-grained matrix/mesostasis (fgMM-derived) and those lacking primary anhydrous silicates thus may be used to evaluate variations with entry heating.

Effects of Entry Heating: Anhydrous silicates show few changes due to heating at subsolidus temperatures, however, on melting both reaction with the melt and direct fusion occur. In fine-grained particles heating first results in partial melting of the matrix and

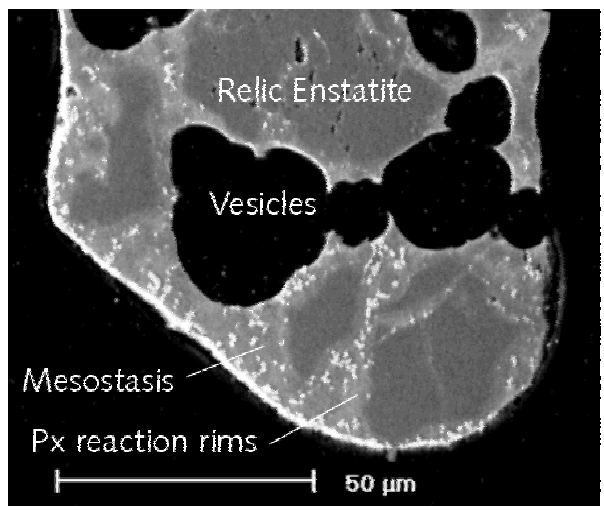

Figure 1. Entry heating effects in a partially melted coarse-grained micrometeorite.

leads to microporphyritic textures of micron-sized Fe-bearing olivine phenocrysts within a glassy, highly vesicular mesostasis. In many particles melting initially occurs around the outside of the particle with high thermal gradients supported by endothermic decomposition of volatile-rich phases [5]. Such cored micrometeorites are relatively common and have melted rims around unmelted cores.

Once the majority of the fine-grained matrix of the particles has melted particles become Scoriaceous Micrometeorites (SMMs). Anhydrous relict silicates

within such particles are fragmental (possibly due to thermal fracturing) and have reaction rims of more Fe-rich pyroxene and also overgrowths of Fe-bearing olivine with similar compositions to those within the mesostasis.

Further heating of fgMMs produces cosmic spherules, which are spherical igneous objects typified by the absence of a magnetite rim. Relict anhydrous silicates are found within those cosmic spherules dominated by zoned olivine phenocrysts known as porphyritic spherules. Typically the anhydrous silicates occur as the rounded Mg-rich cores of olivine-phenocrysts, however, large relict Fe-bearing olivine is not unknown in porphyritic spherules.

The mineralogy and petrology of cgMMs also changes with increasing entry heating. Melting in coarse-grained particles appears to occur in several different ways. Some cgMMs have melted rims similar in mineralogy and composition to those of fgMM (cored particles) dominated by Fe-bearing olivine microphenocrysts in a vesicular glassy mesostases. These probably formed by the melting of selvages fine-grained matrix attached to the exterior surface of the particle. Some porphritic cgMMs also show textural evidence for the 'melting' of primary interstitial glass with the presence of overgrowths of olivine and vesicles. The occurrence of vesicles within the glassy mesostasis of cgMMs has been cited as evidence that these are not fragments of chondrules since vesicles are rare in chondrules from meteorites. However, vesicles are abundant in the glassy mesostases of chondrules close to the fusion crust of meteorites and presumably from due to the reaction of dissolved reduced carbon to from CO_2 during heating in the atmosphere.

Direct melting of anhydrous silicates is observed within intensely heated cgMMs (Figure 1). These particles are frequently rounded and their melted portions are either entirely glassy or contain olivine dendrites and/or microphenocrysts. Coarse-grained particles which have experienced high degrees of melting from cosmic spherules. Occasionally these may be identified by their compositions which can diverge from the chondritic compositions of fgMMs. Many cgMMs, like chondrules, are also broadly chondritic and it is unlikely that composition can be used as a definitive test of the derivation of Cosmic Spherules from cgMMs.

Correlating Degrees of Heating: Correlating between the degree of entry heating experienced by cgMMs and fgMMs is important if the relative abundances of particle types are to be related to entry velocities. Heating experiments on meteorites suggest that dehydroxlyates of phyllosilicates will recrystallise at temperatures of around 700°C. Partial melting of fine-grained matrix will occur at temperatures of ~1300°C although, under rapid heating where degassing has not been complete, lower solidus temperatures may occur. The transition from unmelted fgMMs to SMMs, however, probably does occurs at around this temperature.

Remobilisation of glassy mesostasis and formation of vesicles in cgMMs will begin to occur at the glass transition temperature. This is approximately 2/3 of the equilibrium melting temperature. Since typical eutectic temperatures of such residual melts are ~1200°C remobilisation of glass may occur at temperatures as low as 800°C in the mesostases of cgMMs.

Melting of relict anhydrous silicates will depend on Fe-content. Most Mg-silicates observed in micrometeorites will survive to significantly higher temperatures. Relict forsterites, for example, may still exist at 1875°C, particularly if kinetic effects prevent appreciable equilibration with the coexisting liquid. Complete fusion of Mg-rich Type-I cgMMs thus requires temperatures high enough for significant vaporisation of silicates to occur.

Implications: Correlating the entry heating temperatures of cgMMs and fgMMs will allow the abundances of matrix-derived and chondrule/achondrite-derived particles to be broadly related to geocentric velocity through statistical analysis.

Isolated anyhdrous silicates are, for example, only found in C2 and C3 fgMMs and not in C1 particles. The abundance of relic silicates in cosmic spherules will, therefore, probably be inversely proportional to the amount of parent C1 materials. Variations in the abundance of relic silicates with particle size could, therefore, be used to identify whether such materials are more abundant in a particular range of entry velocities corresponding to a dynamically restricted source. Any mineralogical or petrological features that can be correlated with peak temperature could similarly be used to constrain possible entry velocity dependance of micrometeorite populations.

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