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THE DISTRIBUTION OF ASTEROIDS: EVIDENCE FROM ANTARCTIC MICROMETEORITES. M. J. Genge and M. M. Grady, Department of Mineralogy, The Natural History Museum, Cromwell Road, London SW7 5BD (email: M.Genge@nhm.ac.uk).

Introduction: Antarctic micrometeorites (AMMs) are that fraction of the Earth's cosmic dust flux that survive atmospheric entry to be recovered from Antarctic ice. Models of atmospheric entry indicate that, due to their large size ($>50\ \mu\text{m}$), unmelted AMMs are derived mainly from low geocentric velocity sources such as the main belt asteroids [1]. The production of dust in the main belt by small erosive collisions and the delivery of dust-sized debris to Earth by P-R light drag should ensure that AMMs are a much more representative sample of main belt asteroids than meteorites.

The relative abundances of different petrological types amongst 550 AMMs collected from Cap Prudhomme [2] is reported and compared with the abundances of asteroid spectral-types in the main belt. These comparisons, together with considerations of the dynamics of dust transport and capture by the Earth, indicate that AMMs are an extensive sampling of main belt asteroids. Evidence from the relative abundances of AMM types also suggest that C-type asteroids consist of a range of primitive materials ranging from petrologic type 3.1 to type 1 and suggest that S-type asteroids consist primarily of chondrule-rich materials that have not been significantly altered by water.

AMM Types: Numerous petrological types of AMM are recognised on the basis of their mineralogies, textures and compositions. Melted micrometeorites consist of Cosmic Spherules (CS) and Scoriaceous Micrometeorites (SMMs), and are described in detail elsewhere []. Unmelted micrometeorites are subdivided into fine-grained particles (fgMM), which have similarities to the fine-grained matrices of the chondrites, and coarse-grained MMs that consist mainly of olivine, pyroxene, metal and glass and often have igneous textures. Unmelted MMs can be sub-divided on the basis of the affects of entry heating, however, in the current study a classification scheme based on key primary features is used in order to make direct comparisons with the chondrites and asteroid spectral classes.

Fine-grained MMs can be split into three genetic groups on the basis of their textures and mineralogy. C2 fgMMs have compact matrices which are heterogeneous in Fe/Mg on scales of $5\text{-}20\ \mu\text{m}$ producing distinct variations in backscattered potential in backscattered electron images (BEIs). These micrometeorites have affinities to the matrices of petrologic type 2 carbonaceous chondrites. Their heterogeneity represents the replacement of anhydrous silicates by clay minerals

due to aqueous alteration. Some C2 fgMMs contain tochilinite and are probably directly related to the CM2 chondrites, however, others may differ from CMs in their mineralogy.

C1 fgMMs are particles with compact matrices that are homogeneous in Fe/Mg and show little contrast in BEIs. These are similar to the CI1 chondrites and do not contain recognisable pseudomorphs after anhydrous silicates and thus have been intensely altered by water. C1 fgMMs often contain framboidal magnetite clusters.

C3 fgMMs have porous matrices (often around 50% by volume) and are dominated by micron-sized Mg-rich olivine and pyroxenes linked by a network of finer-grained acicular to sheet-like silicates. These are probably clays or their thermal decomposition products. Framboidal magnetite is also commonly present within C3 particles and indicates that they have been altered by water. The presence of abundant small Mg-rich anhydrous silicates and their high porosity suggest that these particles have not been intensely altered by water and are petrologic type 3.0 to 3.1. The compositions of their matrix anhydrous silicate grains, however, distinguish them from CV3 and CO3 matrices. Because of their high porosities these materials are fragile and are unlikely to survive atmospheric entry as larger objects. They are, therefore, probably derived from primitive asteroids that are not sampled by meteorites.

Heating during atmospheric entry can cause significant recrystallisation of the matrices of fine-grained micrometeorites that largely obscure the differences between the different groups of fgMMs. Such particles are described merely as fine-grained (or as cored MMs (CMMs) where they have experienced surface melting).

The majority of cgMMs have igneous textures and 'chondritic' mineralogies of pyroxene, olivine and aluminosilicate glass. Composite micrometeorites, consisting of a mixture of fine-grained and coarse-grained materials are relatively common and suggest that many cgMMs were small objects on the same parent bodies as C2 and C3 fgMMs. These are thus likely to be fragments of chondrules [3].

Three types of cgMM are observed: (1) reduced type I particles dominated by Mg-rich silicates and often containing iron-nickel metal droplets, (2) oxidised type II particles dominated by Fe-rich silicates and usually lacking metal, and (3) radiating pyroxene

(RP) cgMMs. These are, therefore similar to porphyritic, granular and RP chondrules observed in chondrites. No barred olivine (BO) cgMMs have been observed and their absence is problematic.

Most igneous cgMMs contain aluminosilicate glass and show no evidence for aqueous alteration in contrast to the C1, C2 and C3 fgMMs. However, many chondrules in CM2 chondrites, and most in CV3 and CO3 chondrites likewise retain glass. Several cgMMs in which the glass has been altered to hydrous minerals and are consistent with derivation from petrologic type 2 chondrites.

Relative Abundances of AMM Types and Comparisons with Asteroids: The relative abundance of AMM types in the current collection are shown in figure 1 and can be used to estimate the contributions from different types of asteroid. Some of the cgMMs will be derived from chondrules on the same parent asteroids as the hydrated fgMMs. Taking relative abundances of chondrules from carbonaceous chondrite groups would suggest <15% chondrules for the C2 parent bodies, ~40% chondrules for the C3 parent bodies (cf CV3 chondrites) and 0% chondrules for the C1 parent bodies. This would imply that 35% of the observed igneous cgMMs are derived as chondrule fragments from the same parent bodies as the C2 and C3 fgMMs. The remaining cgMMs represent ~31% of the unmelted AMMs and would have to be derived from a chondrule-rich group of parent bodies lacking hydrated fine-grained matrix. Such a group of parent asteroids is, therefore, broadly similar to the ordinary chondrites.

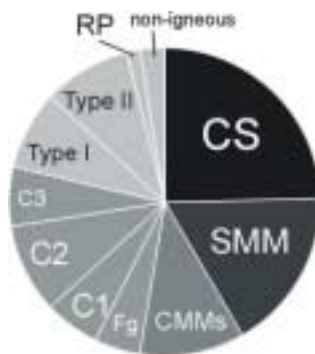


Figure 1. The relative abundances of AMM types.

Considerations of the capture of asteroidal dust by the Earth and entry heating indicate that dust from low eccentricity, low inclination sources is most likely to reach the surface of our planet. Dust bands, related to the main asteroid families, have been suggested to be a major source of asteroidal dust [4]. The lowest eccentricity and inclination dust band, however, is produced by the Koronis family of S-type asteroids and cannot

dominated the AMMs which are mostly CC-like materials. The only possible conclusion is, therefore, that the dust bands do not dominate the asteroidal dust flux and that AMMs are derived from a large number of main belt asteroids, albeit those with low eccentricities and inclinations.

Given this realisation the relative abundance of AMMs can be used to interpret the overall distribution of main belt asteroids. The observation that 70% of AMMs (both fgMM and cgMM) may be derived from a CC-like source and 30% from an OC-like source is remarkably similar to the overall abundance of C- and S-type asteroids in the main belt, if S-types are considered to be OC-like.

The relative abundances of cgMM types supports the suggestion that the chondrule-dominated asteroidal source is similar to the ordinary chondrites. Type I and Type II cgMMs are present in nearly equal numbers, however, Type I objects comprise ~90% of chondrules in CCs. If the relative abundance of chondrule types in the parent bodies of the CC-like AMMs is similar to the chondrites then the chondrule-rich source of many cgMMs must contain abundant Type II chondrules. The majority of composite AMMs have C2- and C3-like fine-grained matrix and Type I igneous portions and thus suggest that the CC-like parent bodies do have relative chondrule abundances similar to CC meteorites.

Ordinary chondrites are chondrule-rich (~85% by vol) and contain abundant Type II chondrules (~50%) and are, therefore, appropriate analogs for the source asteroids for many cgMMs. Pyroxene is the most abundant silicate within cgMMs in marked contrast to OCs and CCs. Only the S(IV)-type asteroids are thought to be appropriate sources for OCs (given reddening of their spectra by space weathering). S(IV)s, however, comprise only 25% of main belt asteroids. Most of the remaining S-type (VI-VIII) asteroids are considered too pyroxene-rich to be OCs. The current data, however, suggests these S-type asteroids are chondrule-rich and share many petrological and textural properties with the OCs.

Conclusions: The relative abundances of AMMs, therefore, suggest: (1) that C-type main belt asteroids consist of roughly equal numbers of C1, C2 and C3 carbonaceous chondrite-like bodies and (2) that S-type asteroids consist of chondrule-rich materials, similar to ordinary chondrites, which contain high abundances of oxidised type II chondrules.

References: [1] Love S. G. & Brownlee D. E. (1991) *Icarus* 89, 26-43., [2] Maurette M. M. et al., (1991) *Nature* 351, 44, [3] Genge M. J. and Grady M. M. (2001) *MAPS*, 36, A63, [4] Kortenkamp S. J. & Dermot S. F. (1998) *Icarus*, 135, 469.