THE RELATIVE FREQUENCY OF SMALL CI METEOROIDS

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CI meteorites are unique among chondrites in that they have the highest volatile contents, the highest Fe/Si ratios, the most extensive alteration by aqueous processes [1], and they do not contain chondrules. An additional distinction is that they are exceedingly rare, only five have been found. It is often suggested that CI's may be cometary debris. However, the ancient age of aqueous alteration implied by the primitive Sr isotopic composition of Orgueil carbonate veins [2] indicates a thermal history which may be incompatible with cometary origin. Because CI's are often cited as the best approximation to solar abundances and they are often considered to be a primitive solar system "base line" material, it is of interest to determine the relative abundance of CI meteoroids in the interplanetary medium. The abundance of CI's in falls must be considered a lower limit to their abundance in space because survival of atmospheric entry favors stronger materials such as ordinary chondrites. A better approximation to the abundance of CI's in space is probably their frequency as submillimeter meteorites. The peak dynamic pressures that the smaller objects must survive during atmospheric entry are orders of magnitude smaller than that experienced by meteorites of conventional size and strength selection effects should not be as significant.

The available samples of submillimeter meteorites are micrometeorites (<50μm) collected in the stratosphere and the rare unmelted "mini meteorites" which have been found in sizes up to a millimeter in deep sea sediments [3]. It is usually difficult if not impossible to reliably classify a single submillimeter meteorite as a member of an established meteorite type because the classes of meteorites rarely contain definitive characteristics which can be measured on a single submillimeter fragment. Fortunately CI's do have unique characteristics which in same cases can be used to identify fragments of CI material as small as 10μm in size. The most important of these features is pure magnetite which has abundance of ∿ 8wt% [4] in CI's and occurs frequently in the highly distinct morphological forms described by Jedwab [5]. This mode of magnetite occurrence is not seen in other meteorites. Other unique characteristics include deposits of magnesium sulfate and other water soluble minerals.

In an SEM search of a large number of stratospheric micrometeorites, three were found which contain clusters of submicron magnetite grains with morphologies identical to those described by Jedwab. The three particles contain phyllosilicates and have relatively good chondritic elemental compositions. The discovery of three micrometeorites containing CI magnetite implies that at least 0.5% of the micrometeorites examined in the study are CI material. Considering the small probability of finding magnetite clusters on the surface of a single 10μm CI particles, the real abundance of CI micrometeorites must be an order of magnitude higher or in the range of 1 to 10% of all of the particles collected and analyzed. The three CI micrometeorites are members of a micrometeorite group

we call CS (chondritic smooth) because they contain regions that are smooth on the scale of microns and have chondritic relative abundances. Studies of a limited number of CS particles has shown that at least some contain phyllosilicates. The sulfates common to CI's have not been seen in the CS particles and systematic depletions of Na, S and Mn reported for CI "matrix" [6] have not been observed although many of the CS particles are depleted in Ca.

To investigate particles somewhat larger than those that can be collected in the stratosphere, we examined over twenty (0.1mm-1mm) unmelted "minimeteorites" that were collected from the sea floor [3]. Survival of unmelted meteorites of this size requires low entry velocity, low entry angle and a certain level of structural integrity. These samples are probably a more biased sample of the meteoroid complex than smaller particles but they are important because they allow analysis to be done on a larger size scale than is possible for particles collectable in the stratosphere. The majority of the examined particles are chondritic in composition and appear to be fine grained carbonaceous chondrite material. Unfortunately the matrix in most of these samples has been altered both by sea water weathering and by thermal effects from entry. However, large grains of mafic silicates and even CAI material have survived in good shape and can be used as diagnostic indicators. Most of these particles contain a much greater fraction of large mafic grains than are seen in CI's and in several ways large grains in the particles indicate similarity to CM material. In particular, forsterite grains enclosing Cr bearing FeNi spherules and CAI inclusions composed of thin diopside rims surrounding perovskite and spinel are relatively common in the examined minimeteorites. These features are unique to CM meteorites. Only one case of relic magnetite was found and its morphology is not of a distinctive CI type. On the basis of these observations we estimate that less than 10% of the 0.5mm meteorites which survive atmospheric entry are CI material.

The present study indicates that while CI meteoroids are much more common than implied by their frequency in meteorite falls, their abundance does not appear to be larger than 10% of meteoroids smaller than a millimeter.

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