MULTIDISCIPLINARY STUDIES OF INDIVIDUAL STRATOSPHERIC MICROMETEORITES. Fraundorf P., McKeegan K. D., Patel R. I., Sandford S. A., Swan P. and Walker R. M., McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130 USA.

In this paper we discuss element abundance patterns found in the preliminary examination of several hundred stratospheric particles [1]. We then report initial results of an effort to complement this data with combined observations of the mass, volume, infrared absorption spectra, local composition, and internal structure of selected individual particles.

1. Preliminary Examination

Particles are transferred from collectors to a nuclepore mount where they are cleaned and then examined using an SEM/EDX system [2]. In Fig. 1 we show a plot of characteristic EDX peak height ratios for Mg/Si vs. Al/Si. The data are plotted for a) roughly 80 medium-sized (5-20 μm) particles from collector U18 (+'s), and b) approximately 40 larger (10-40 μm) particles from prototype collector R18 (o's) for the express purpose of investigating aircraft-related contamination. For approximately 20% of the particles in the set plotted, only upper limits on the Mg peak height could be determined; another 5% did not plot within chart boundaries.

Three populations of particles are apparent. Particles in the lower center of Fig. 1 are clustered near the average values of Mg/Si and Al/Si observed for small particles from the matrices of chondritic meteorites such as Allende or Orgueil. The particles in this group also tend to show approximately chondritic abundances for Fe, S, Ca and Cr, and generally include the so-called "chondritic" subset of collected dust [3]. Particles in the second group at lower Mg/Si and slightly higher Al/Si commonly show detectable K, as well as ratios of Ni/Fe lower than chondritic. The number of particles in this group is highly variable from collector to collector, and most are probably terrestrial dust. The third group of particles at high Al/Si ratios consists largely of "Al-primes", discussed in a separate abstract [4]. We now focus on the "chondritic" subset, whose extraterrestrial origin has been confirmed by trace element [5] and noble gas isotopic [6] studies.

Two compositional parameters which have been cited as diagnostic of internal differences between "chondritic" particles are the elemental ratios of Ca/Si and S/Fe. Specifically, D. Brownlee et al. [7,8] have pointed out that a small subset (∿10%) of particles show hydrated silicate lines in X-ray diffraction. Particles of this type exhibit atypically low Ca/Si ratios and "smooth" surface morphologies. Secondly, a subset of the abundant class of particles which contain enstatite "whiskers" [9] has been reported by Fraundorf [10] to exhibit i) whole-particle S/Fe peaks greater than 1, ii) atomic S/Fe ratios >2 in some locations, and iii) to consist mostly of a noncrystalline "chondritic" material. These particles often exhibit the reentrant "cluster of grapes" morphology [1].

Ca/Si and S/Fe peak ratios for the "chondritic" particles picked from collectors U18 (+'s) and U21 (□'s) are plotted in Fig. 2. The observed spread in the parameters are much larger than variations resulting from matrix absorption effects, continuum subtraction errors, or counting noise. Average Orgueil falls somewhat below center of the field of particles, while the average for powdered Allende falls slightly left of and above center.

2. High S/Fe particles.

Two particles with S/Fe peak ratios near 1, in addition to the 3 particles previously reported [10], have now been examined by transmission electron microscopy (o's in Fig. 2). All of these particles contain occasional enstatite (or clinoenstatite) laths, and show local atomic S/Fe ratios in some places approaching 2. The four particles with highest values for S/Fe also consist largely of noncrystalline material. Although this material is often approximately "chondritic" in composition, in at least one of the particles (U21-5-2) a distinct "low-Z" phase, probably carbonaceous in nature, was also present in abundance. A fragment of this particle had a measured density of ∿1g/cc [11]. Whether this is a typical density for such particles is not yet known. A sixth lath-containing particle with lower bulk S/Fe has been briefly examined and is also included in Fig. 2.

The 5 high S/Fe particles examined were obtained from 4 different stratospheric collectors, and particles of this type apparently constitute ∿10% of collected "chondritic" particles. For the 4 particles with highest values of S/Fe, the observations show that heating on atmospheric entry has been insufficient to cause significant recrystallization. Other particles which contain enstatite laths evidence lower values for S/Fe and a larger amount of matrix crystallinity. Since both recrystallization and loss of sulfur are likely to occur on heating [1,12], the high S/Fe particles may represent relatively unheated specimens of the same material.

These particles represent promising candidates for i) annealing experiments and ii) the laboratory search for particles with the "amorphous silicate" 10 and 18 micron infrared features [13] observed in cometary emission spectra [14]. An

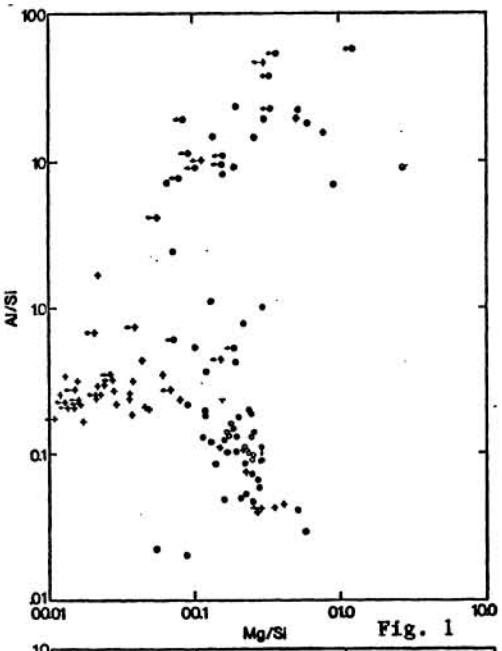

Fig. 1

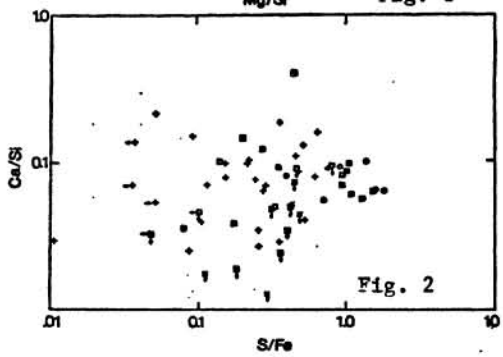

Fig. 2

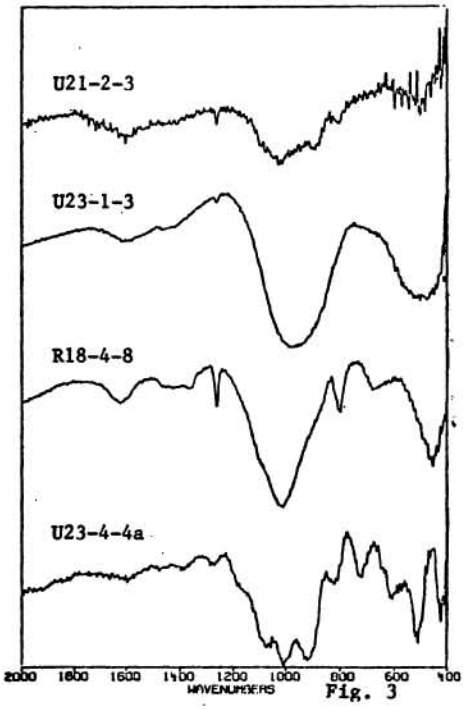

Fig. 3

absorption spectrum obtained from one of these high S/Fe particles (U21-2-3) is shown in Fig. 3. In spite of the large size (15 μm) of this particle, the features are suprisingly weak. A considerably larger particle of this type will probably be required before a detailed spectrum can be obtained.

3. Low Ca/Si particles.

Hydrated silicates, similar to those found in C1 and C2 carbonaceous chondrites, have been identified in "chondritic" particles with low values for Ca/Si using X-ray diffraction techniques [7]. We previously reported an infrared absorption spectrum similar to that from the C2 chondrite Murchison for one such particle [13]. This particle and three others which have been examined by Fourier Transform infrared spectroscopy are plotted in Fig. 2 (x's). One of the newly examined particles (R18-4-8) also shows a Murchison-like absorption spectrum (Fig. 3). The other two particles, which plot in Fig. 2 at considerably lower values for Ca/Si and S/Fe, were spectroscopically quite different. One of them (U23-1-3) exhibited very broad unstructured features (Fig. 3). The other (U23-3-7) exhibited structured 10 and 20 μm absorption features, similar to those reported earlier for a composite mount of 3 particles [13], and to that shown in Fig. 3 for particle U23-4-4a. These structured features are suggestive of crystalline pyroxene. The particle U23-4-4a, used as an example of this spectral "type", was a highly reentrant particle (mass ∿2.5 ng, density ∿0.7 g/cc [11]) which plots roughly in the center of the cloud of particles in Fig. 2. It is one piece of a "spray" of 15-20 μm particles found on collector U23. Particles of larger initial size are more likely to experience severe heating on atmospheric entry. This may indicate that structured infrared spectra are associated with more severely heated particles.

4. Other Compositional Types.

From the wide range of structural differences reported earlier [10] and infrared spectral differences reported here, it is clear that the "chondritic" particles represent a diverse and poorly understood collection of objects. Distinct subsets of even rarer particle types are also found on the collectors. Two particles have been found with major elements (Ca, Al, Si, Ti) similar in abundance to those in refractory inclusions from carbonaceous chondrites. It would be interesting to perform isotopic measurements on these particles if sufficiently sensitive methods can be developed.

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