THE ELEMENTAL COMPOSITION OF INTERPLANETARY DUST

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We have determined the elemental abundances of 199 stratospheric micrometeorites to better define the compositional range of these particles and to look for correlations of bulk composition with morphological class. The particles used in the study were randomly chosen except that sulfide-dominated particles, spheres and particles smaller than 4 μm were not included. The selected particles range in size from 4 μm to 40 μm but most are in the 6 μm to 15 μm range. For a morphological classification the particles were grouped into three classes; smooth, porous and single mineral. "Smooth" particles, also called CS [1], are nonporous and contain micron and larger areas that have roughly chondritic compositions ; some have platey, cracked, fibrous or vesicular surfaces. These particles comprise 36% of the IDPs studied. Previous TEM work suggests that this class is predominantly composed of hydrated silicates [2]. "Porous" particles (47% of group) are fine-grained aggregates that have interior pore spaces (CP) [1]; they include particles with filled pores (CF) [1]. TEM studies indicate that most of the members of this class are composed of anhydrous phases [2] and infrared measurements indicate that they fall into the "pyroxene" IR class [3]. "Single mineral" particles (17% of the population) are either single mineral grains or particles dominated by large mineral grains.

All particles were analyzed in the SEM using a conventional energy dispersive x-ray (EDX) analyzer and 30 were additionally analyzed with a thin window EDX (Kevex Quantum) analyzer to determine the abundances of oxygen and carbon. The particles were mounted on carbon-coated Nuclepore filters and were individually rastered with a 20KV electron beam that just covered the particle. For O and C analyses, a 13KV raster one-fourth the particle size was used in order to reduce contribution from the substrate. Peak integrals were measured using the "super ML" integration algorithm and K values were referenced to flat mineral standards. Abundances were computed using the Armstrong-Buseck ZAF procedure for particles. To verify the accuracy of these techniques we analyzed fifty 10 μm sized particles produced by crushing olivine, pyroxene, and NBS glass standards between boron carbide plates. These tests verified that the techniques used measure major element ratios to a mean accuracy of better than 6%. The carbon analyses have greater uncertainty because of effects of electron sidescatter, complex absorption and contamination.

The results from this study are consistent with previous analyses of 57 IDPs [4] but the new data is more comprehensive and of higher accuracy. While most of the particles analyzed would normally be considered to have "chondritic" compositions, there are systematic deviations from the CI norm [5], differences in dispersion of different element ratios and definite correlations with morphological type (figure 1). The Si-normalized means of Mg and Al are depleted by 10% from the CI norm. If real, this depletion indicates an important distinction from CIs and the millimeter-size meteoroids that produce ablation spheres collected on the sea floor and in Greenland. These small depletions could be spurious if the particles contain 5 wt% silicone oil residue from the collection process. The importance of this effect will be tested by the time of the conference by analysis of particles that were not collected on the silicone oil substrates. If there is no Si contamination problem, then the mean IDP composition is very similar to L chondrite abundances except for S and C which are much higher in the IDPs. For comparison with chondrite classes the most diagnostic of the studied elements are C, S and O because they are strongly fractionated among the meteorites. Sulfur is well determined in the particles and the mean S/Si ratio is higher than in all chondrites except CIs. The carbon abundance is also higher than in other meteorites, but we feel that our C measurements cannot be trusted until they are verified by analysis of interior microtome sections. Our mean O/Si ratios are higher than those of ordinary chondrites but lower than in CIs. The O/Si ratios in these particles are being investigated as an indicator of oxidation state and OH content. The observed mean depletions of S and Fe are influenced by our exclusion of sulfide-dominated particles. The bulk Fe/Si ratio of the parental materials could be CI only if 25% of the total Fe was in 10 μm or larger sulfide or metal grains. Calcium and sulfur show the largest compositional dispersions and the largest depletions from CI. Sulfur could have been depleted from some particles during atmospheric entry, but preservation of solar flare tracks in IDPs indicate that most particles have not been heated sufficiently for S loss. The Ca depletions are undoubtedly intrinsic properties of the particles and there are clear differences in Ca abundance and morphological type. Figure 1 shows that "smooth" particles are usually strongly depleted in Ca and also exhibit mean depletion of Mg. Smooth particles usually contain hydrous minerals and it is likely that the Ca depletion is the result of redistribution by aqueous alteration similar to that which has occurred in CI and CM meteorites. If such alteration is restricted to asteroid-like bodies, then Ca depletion for a particle class is evidence against a cometary origin. Calcium is an element that also shows depletion and disturbance in the cosmic deep sea spheres.

The ternary diagrams in figure 2 show the compositional dispersion in the imaginary "IDP mean parent body" at a size scale of 10 μm. The clustering around CI values is much tighter than for comparable volumes of all chondrites indicating that IDPs are more homogeneous (in elemental composition) than meteorites and in a sense are less processed. These diagrams also provide constraints on bulk mineralogy. In the left ternary, Fe in FeS has been subtracted to indicate the mean major element composition of silicates. It is seen that less than 10% of the particles can be dominated by olivine. Of the three infrared classes [3], one is olivine. Our data implies that the majority of IDPs are composed largely of either pyroxene or phyllosilicates, and that olivine-dominated particles are rare. It is interesting that the 10 μm IR feature in comet Kohoutek could be matched by a composite of pyroxene and layer-lattice silicates, but not olivine [3].

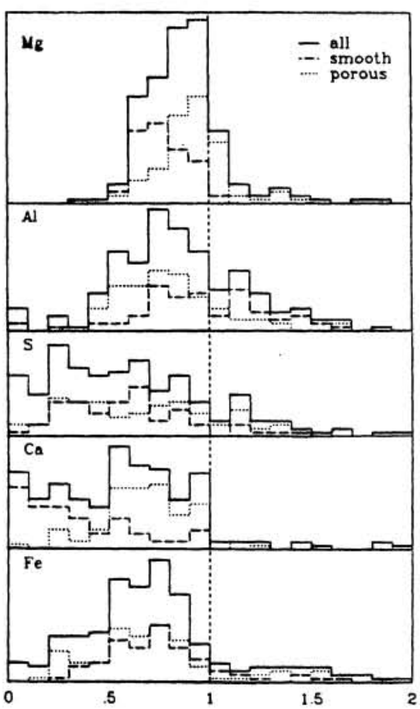

Figure 1. Major element to silicon ratios normalized to average C1 chondrite abundances [5] for 199 IDPs. Ratios greater than twice C1 chondrite ratios are not shown.

Table 1. Atom to silicon ratio means for 199 interplanetary dust particles by morphological type.

Type	C*	O*	Na	Mg	Al	S	Ca	Cr	Fe	Ni
smooth	1.321	4.489	.051	.822	.081	.337	.021	.014	.733	.032
porous	2.391	3.978	.056	1.012	.071	.418	.052	.016	.723	.024
single	1.312	3.806	.038	1.221	.074	.228	.115	.012	.571	.020
all	1.748	4.171	.052	.979	.075	.356	.052	.015	.699	.026

*Carbon and oxygen analyses were done for only 30 particles.

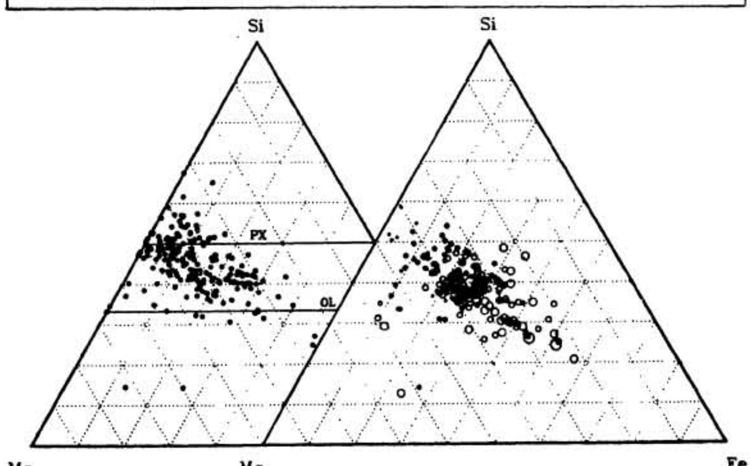

Figure 2. Si-Mg-Fe atom compositions of 199 IDPs. The right ternary diagram shows unmodified compositions; increasing dot size means increasing sulfur abundance. The left ternary shows residual "FeS-removed" compositions calculated by assuming all S is in FeS.

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