MICROBEAM ANALYSIS OF INTERPLANETARY DUST PARTICLES FOR MAJOR ELEMENTS, OXYGEN AND CARBON;

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Introduction Interplanetary dust particles (IDP's) collected in the stratosphere are now recognized to almost certainly include dust from comets. Recent data from the Halley Comet Vega and Giotto missions emphasizes the similarity to the known data on interplanetary dust particles as well as the importance of light elements. Most of the particles detected by Giotto consisted of light elements (H, C, O, N, and their compounds) or significant amounts of these elements mixed with more chondritic elements (Na, Mg, Si, Ca, Fe) [1,2,3]. The Halley results make it important to acquire good chemical data on IDP's for comparison and reconstruction of the possible mineralogy. Few quantitative analyses of IDP's exist [4], therefore we have analyzed some particles using energy dispersive x-ray techniques including the measurement of light elements carbon, nitrogen and oxygen using a windowless detector.

Method Five IDP's (from 3 to 12 um in size), which were selected from the JSC Cosmic Dust Catalogs as likely to be chondritic, were mounted on beryllium substrates by the JSC curatorial staff. Uncoated, untreated samples were analyzed at 10 kV on a JEOL 35CF SEM equipped with a PGT windowless detector and at 40 kV on a JEOL 100C TEM/SEM equipped with a PGT beryllium window detector. Mineral and oxide standards were used for heavier elements, polished graphite for carbon, and quartz for oxygen. Spectra were processed through PGT BSAM and Dust2 correction procedures [5]. Point analyses were made on each sample as well as an overall analysis of the entire particle.

Results Table 1 presents the overall particle compositions using the 40 kV data for major elements and the 10 kV data for carbon and oxygen. As is necessary in most particle analyses, results have been normalized to 100%. The data are presented as oxides for major elements; sulfur and carbon are presented as elements. Some of the Fe may be present as metal or as sulfide, and some of the carbon may be present as carbides, or as complex compounds with oxygen and possibly hydrogen. Stoichmetric oxygen is presented based on the assumption that all of the major cations (except sulphur and carbon) are oxidized. A comparison of this stoichmetric oxygen with measured oxygen shows that the stoichmetric oxygen sometimes deviates considerably from analyzed oxygen. This suggests either that some of the cations are not fully oxidized and that metal and sulfide are likely constituents in these particles or that extra oxygen is present in a low-Z phase. We looked for nitrogen, titanium, chromium, and manganese, but detected none in any of the particles.

Discussion Inspection of Table 1 shows that the analyses are in reasonable agreement with the composition (normalized water-free) of C1 chondrites [6]. The mean is in even closer agreement. Several differences should be noted. Two of the IDP's have appreciably higher Na_2O by a factor of 2 to 3, and the mean of all the grains is a factor of 2 higher. While the mean MgO is close to C1, individual grains show more than a factor of 2 variation. SiO_2 is similar to C1 for two of the particles, but is higher for the other three so that the mean is somewhat higher. CaO is significantly lower than C1 in all of the grains; in three it was below the limit of detection (about 0.3 Wt%). Fe varies inversely with Mg by about a factor of 5 but the mean is remarkably close to C1. Sulfur varies by nearly a factor of 20 among the grains but, again, the mean is remarkably close to C1. These sulfur results are significant because they suggest that stratospheric sulfur does not play a major role [7]. Carbon varies by only a factor of 2 among grains and the mean is nearly identical to C1.

It is clear that the composition of these IDP's is essentially that of C1 carbonaceous chondrites. The variation among grains may be related to the size of the volume analyzed and the mean analyses more closely approachs C1 as larger volumes are averaged together. Individual grains are very heterogeneous, however, and deviate greatly from C1 composition as smaller volumes are analyzed. Figures 1 and 2 present a series of focused beam point analyses of two grains at both 10 and 40 kV along with the bulk analyses of each grain. The bulk analyses at 10 kV are very similar to those at 40 kV for most of the grains. However, the individual point analyses vary considerably, probably reflecting greater or lesser proportions of constituent minerals (or amorphous phases) in each volume of excitation. We conclude from these analyses of a subset of chondritic IDP's that while individual grains can be very heterogeneous on a fine scale (~1 µm^3), they are much more homogeneous on a coarser scale (10's to 100's of µm^3), and that aggregate chondritic IDP's may closely approach C1's in bulk composition. This conclusion applies only to a subset of similar IDP's, others are clearly much less chondritic in composition and approach the composition of individual minerals or simple mixtures of minerals, and low-Z IDP's are also clearly different. It is interesting to note that many if not most of the impacts analyzed on the Giotto spacecraft were in the size range of 1 µm or less [1,2]. Thus the high degree of heterogeneity of those dust particles is not inconsistent with our data showing that heterogeniety of IDP's increases significantly as the analyzed volume decreases to the order of 1 µm^3.

[1] Kissel et al. (1986) Nature 321,280. [2] Kissel et al. (1986) Nature 321, 336. [3] Balsiger et al. Nature 321, 330. [4] Fraundorf (1981) Geochim.Cosmochim.Acta 45, 915. [5] Armstrong and Busek (1975) Anal.Chem. 47, 2178. [6] Mason (1979) Data of Geochemistry, Geol.Surv.Prof.Pap. 440-B-1. [7] Mackinnon and Mogk (1985) Geophys.Res.Lett. 12, 93.

TABLE 1

Bulk Analyses of Interplanetary Dust Particles

	U2015E7	W7028*C2	U2022F6	U2022G7	U2017A2	Mean	C1
Na_2O	2.73	2.18	0.82	1.21	---	1.74	0.90
MgO	16.55	20.43	12.57	15.72	31.46	19.35	21.11
Al_2O_3	3.83	2.86	3.69	3.56	6.75	4.14	2.13
SiO_2	36.68	31.23	30.03	39.37	42.95	36.05	29.21
CaO	0.59	0.52	---	---	---	0.56	1.96
FeO	34.79	31.39	43.54	23.32	8.52	28.31	31.37
NiO	1.98	0.66	---	0.43	---	1.02	1.27
S	0.55	6.63	5.99	10.97	4.69	5.77	7.81
C	2.38	4.12	3.35	5.44	5.62	4.18	4.24
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
O/K	33.18	30.97	34.40	27.04	27.67		
O/S	37.82	35.38	33.76	36.46	42.85		

FIGURE 1

COSMIC DUST U2015E7

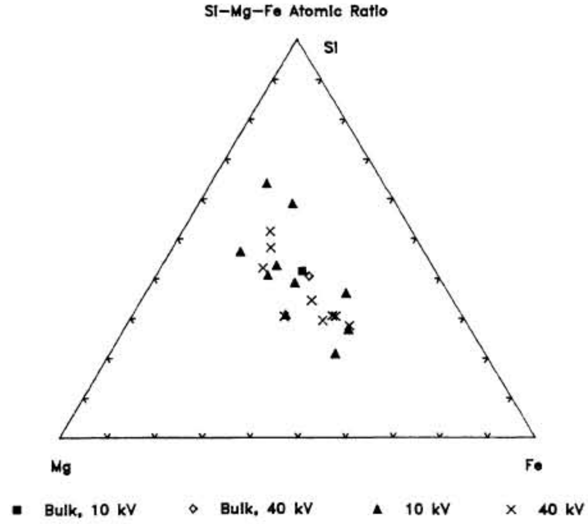

FIGURE 2

COSMIC DUST U2022G7