C/O ATOMIC RATIOS IN MICROMETER-SIZE CRUSHED GRAINS FROM ANTARCTIC MICROMETEORITES AND TWO CARBONACEOUS METEORITES.

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Antarctic micrometeorites (AMMs) have similarities (but also differences) with primitive meteorites, such as unequilibrated mineral assemblages [1,2]. To further assess such similarities we have measured the carbon content of micrometeorites and meteorites (Orgueil and Murchison), as determined in a random selection of micrometer-size crushed grains, with an analytical transmission electron microscope. Such analyses yield the C/O atomic ratio, the major and minor elements contents, and the textural features of the grains on a scale of ≈100 nanometers. An important proportion of micrometeorites from both the 100-400 μm and the 50-100 μm size fractions contains much more carbon than CI chondrite Orgueil. The average C-content of all micrometeorites in these two size fractions amounts to ≈1.8xCI, and ≈0.8xCI, respectively (CI refers to the bulk C-content of Orgueil, of about 3.5% by weight). Carbon is usually not homogeneously distributed in the micrometeorite but is concentrated in C-rich grains. So far most of these grains are amorphous, and seem to be associated with an oxidized Fe-rich phase (possibly a variety of "dirty" magnetite). About 5% of them have the composition of "COPS", a phase additionnally enriched in O, P, and S [4].

Experimental

With a 20-30X binocular we preselect at random a family of dark/irregular particles, that are enriched in AMMs. Each particle is first splitted into several fragments. One fragment is polished, and examined with a SEM equiped with an EDS system, for a preliminary characterization. This way, all particles with chondritic compositions are identified and roughly classified as indicated elsewhere [1]. A second fragment of each chondritic particle is directly crushed onto a gold electron microscope grid held between two glass plates. The resulting micrometer-size crushed grains (embedded into the gold grid) are randomly analyzed with both the energy loss electron spectrometer (EELS) and the thin window EDX spectrometer of a 400 kV analytical transmission electron microscope (JEOL 4000FX). This procedure considerably minimizes carbon contamination, as shown by the analysis of single crystals of olivine, mounted and analyzed in the same way [3]. Chunks of Orgueil and Murchison with sizes of ≈100 μm were then processed and analyzed in a similar way.

C/O ratios on a microscale

In the Table we list individual EELS analyses of: Orgueil (15 grains); Murchison (6 grains); 8 AMMs from the 100-400 μm size fraction (109 grains), and 5 AMMs from the 50-100 μm size fraction (33 grains). Some preliminary analyses of the 100-400 μm size particleshave been already published [4]. In the Table we have included analyses of 3 new micrometeorites in this size range. No analysis of AMMs from the 50-100 μm size fraction was reported before. The value listed in the last column represents the mean value of the C/O ratio. In the Figure we report the EELS and the EDX spectra of a tiny "COPS" inclusions from AMMs No.91-32-11, showing a C/O ratio of 0.34.

Discussion

Thomas et al. [5] measured high carbon contents (0.5-7xCI) in ≈10 μm size chondritic IDPs, relying on a different technique (based on SEM analyses). We independently reported an average carbon content of ≈2xCI in a first selection of 100-400 μm AMMs [4], which well agrees with the new value inferred from the Table (≈1.8xCI). But here we observe a smaller value of the average C-content of 5 AMMs from the 50-100 μm fraction (≈0.8xCI). Such variations of the C-content in a large size range (≈10 up to ≈200 μm) are difficult to understand in term of either the loss of some pyrolizable C-rich material during frictional heating in the atmosphere (as described by classical modelings, that look more and more inappropriate), or ice, water [7,8] or atmospheric "weathering", which should somewhat be related to the settling time of the particles in the atmosphere.

Most C-rich grains in AMMs are amorphous. Carbon is frequently associated with high Fe and O contents, suggesting that the dominating C-rich species are a form of "dirty" magnetite, not observed yet in conventional meteorites (with the exception of the fusion crust of Murchison [6].Carbon is not associated with a single crystalline phase (SiC, diamond, carbonate, carbide). Only two amorphous C-rich grains composed only of carbon, were

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observed (they were rejected from the Table on the suspicion that they might represent a terrestrial contamination). About 5% of the C-rich grains are in addition enriched in P and S, thus defining the "COPS" phase, more appropriately discussed in our companion paper [6]. SEM observation shows that the C-poor grains (such as 92-21-07) all originate from crystalline AMMs, mostly consisting of a few single crystals of olivine and pyroxene. Most fine grained unmelted AMMs, show high C-contents.

The average carbon content of >100 µm size AMMs is larger than the bulk content of Orgueil, quoted as the most carbon-rich meteorite so far. Moreover, in both the large and small AMMs size fractions an important proportion of the grains are definitively much richer in C-rich material than is Orgueil. Such feature could be taken as to suggest that micrometeorites of all sizes represent a new variety of primitive solar system objects not represented in the collection of meteorites. This conclusion is independently supported by studies of mineral compositions [2] and trace element contents of AMMs [7,8]. We shall extend these measurements to AMMs from the 25-50 µm size fractions, and in collaboration with J.L. Bada we expect to characterize soon the C-rich component of AMMs relying on the powerful technique of "Two Steps Laser Mass Spectrometry" [9].

Size	*Samples*	*C/O ratios*	*Mean Values*
100µm	*Orgueil (2 samples)*	1.24 1.18 1.00 0.50 0.58 0.28 0.21 0.19 0.04 0.03 0 0 0 0 0	0.35
	Murchison	0.60 0.33 0.18 0.16 0 0	0.21
100 to 400µm	*91-32-04*	2.17 1.91 1.03 1.03 0.97 0.97 0.68 0.50 0.48 0.40 0.45 0.21 0.13 0.07 0 0 0 0	0 0055
	91-32-05	3.13 2.63 1.72 1.39 1.37 1.20 1.09 0.96 0.90 0.81 0.72 0.69 0.67 0.65 0.20 0.06	1.14
	91-32-08	0.43	0.43
	91-32-09	2.44 2.31 1.90 1.39 1.24 1.13 0.97 0.81 0.78 0.73 0.30 0 0	1.08
	91-32-11	0.65 0.34 0.25 0.12 0.08 0.07 0 0 0 0 0 0 0	0.12
	91-32-12	1.22 0.98 0.78 0.46 0.19 0.02	0.61
	91-32-15	1.63 1.10 0.64 0.55 0.50 0.16 0.10 0.06 0.04 0.01 0.01 0 0 0 0	0.32
	91-32-18	0.25 0 0 0 0	0.05
50 to 100µm	*92-21-01*	0.58 0.48 0.07 0.04 0.01 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.05
	92-21-04	1.00 0.93 0.79 0.71 0.60 0.51 0.40 0.30 0.31 0.24 0.23 0.22 0.08 0.03	0.45
	92-21-05	0.69 0.60 0.21 0 0	0.3
	92-21-07	0 0 0 0 0	0
	92-21-16	1.25 1.19 0.72 0.70 0.63 0.55 0.44 0.42 0.33 0.26 0.19	0.61

Table : C/O ratios in primitive meteorites and micrometeorites

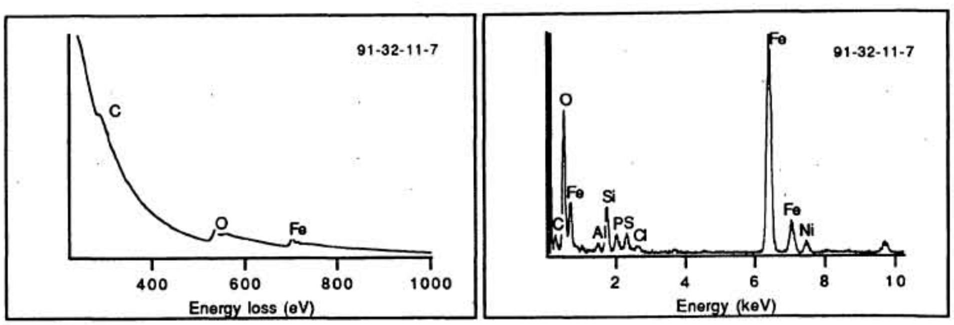

Figure : TEM analysis of a "COPS" inclusion

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