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Composition of micrometeorites compared to carbonaceous chondrites and comet 67P/Churyumov-Gerasimenko

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Abstract

Three Antarctic Micrometeorites (AMMs) from the Concordia collection and four different types of carbonaceous chondrites were analyzed by Raman spectroscopy and EDX analysis to compare their organic and mineralogical composition. One of the AMMs shows organic material and a mineralogy that is very similar to cometary material. The organic material detected in two of the carbonaceous chondrite samples is also very unprocessed and rather similar to the organic material of comets.

1. Introduction

These AMMs are submillimeter-sized dust particles collected in the Antarctic snow. Some of these micrometeorites could have formed in the outer solar system and brought to the inner solar system by comets [1]. Former chemical analyses identified several micrometeorites to be very similar to CM and CR carbonaceous chondrite groups [1]. CI and CM chondrites are the least thermally altered meteorites with a chemical composition close to the solar composition [2]. They have suffered a moderate to high aqueous alteration on their parent bodies [3].

2. Methods

The three micrometeorite samples analyzed are fragments of larger AMMs and have sizes of 38 µm x 67 µm x 32 µm; 23 µm x 20 µm x 11 µm and 23 µm x 20 µm x 29 µm. For the analysis they were deposited on gold targets. The carbonaceous chondrites samples, also fragments of larger meteorites, have sizes from 45 µm x 45 µm x 17 µm to 700 µm x 300 µm x 20 µm. They were pressed on a gold target to have an almost flat surface. All samples were analyzed by Raman Spectroscopy and Raster Electron Microscopy.

The samples were analyzed by confocal Raman Spectroscopy using a Witec Alpha 3000 microscope with a spatial resolution of 1 µm and a power between 0.5-3.5 mW. The power was set as low as possible to avoid damaging the organic material. A 3D scan was used to produce a topographic view of the particles with steps between 0.25 µm and 2 µm in the lateral dimension and 1 µm in depth.
The EDX analyses were performed at a pressure of 2.1 x 10^{-5} mbar with an acceleration voltage of 15-20kV. Element mappings were acquired with a resolution of 300-500 raster points. Individual spectra were taken with 60-200 live seconds in order to measure their bulk composition. The mappings were acquired with 600 -12,600 live seconds.

3. Results

As a first step using both the Raman spectra and the EDX analyses we can identify the mineralogy of the AMMs (Tab.1).

Tab. 1: Identified components of the AMMs with detailed chemistry.

	DC 06-07-45-7	DC 06-07-162	DC 06-09-249
Identified compounds	Pargasite Anorthite Troilite Pyroxene Olivine Hematite Organics	Pyroxene Magnetite Sulfates Organics	Pyroxene Maghemite Hematite
Detailed chemistry			
Pyroxene	$En_{97.5}Fs_{2.5}$ to $En_{70}Fs_{30}$ + hints for very Ca-rich Px	$En_{44}Fs_{04}Wo_{50}$	$En_{50}Fs_{50}$ to $En_{90}Fs_{10}$
Olivine	$Fo_{37\pm19}$ to $Fo_{99\pm16}$	-	-
Sulfates	-	$(Na,K)_2SO_4$	-

4. Discussion

The mineralogy of DC 06-07-45-7 mostly consists of rather unaltered components like very Mg-rich olivine and pyroxene, troilite, anorthite and organics that have not been much processed by aqueous alteration. These organics are very similar to the organics that were observed in Interplanetary Dust Particles (IDPs) (Fig. 1).

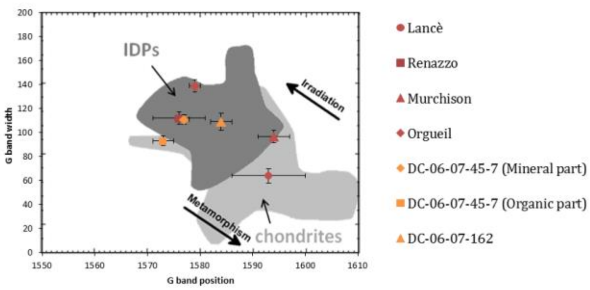

Fig. 1: Modified plot from Brunetto et al. [4]. G band parameters for meteorites and IDPs are compared to our samples. The G band parameters change with the degree of thermal alteration.

DC-06-07-162 still contains organic material that was slightly more processed by thermal alteration than DC-06-07-45-7 (Fig. 1). The mineralogy is typical for a hydrothermally altered object. That particle could have undergone aqueous alteration on its parent body, similarly to CI and CM chondrites. DC 06-09-249 contains no organic material and has a very processed mineralogy. It is likely coming from a larger parent body, or has entered in the Earth's atmosphere at a very high velocity.

Pargasite that has been detected in particle DC-06-07-45-7 is an amphibole that is very rare in chondrites and that has not been reported so far in micrometeorites. It is very common in larger parent bodies from which achondrites might originate and requires temperatures about 600°C to be formed [5]. Looking at the whole composition of our particle we can exclude an achondritic origin. Some studies [6] claim that pargasite could be formed by solar nebula processes from pyroxene with water. That would be more consistent with our particle composition.

Among these AMMs, particle DC-06-07-45-7 is the particle showing most similarities with cometary materials, in particular with particles of comet 67P/Churyumov–Gerasimenko. It has a similar porous morphology as these particles [7] and also contains complex organic material [8]. It also shows the typical mineralogy of cometary material: anhydrous silicates, sulfides, and inclusions of Ca-Al silicates.

5. Conclusion

The analysis of the AMMs already shows a broad and diverse mineralogy implying different degrees of alteration on their parent bodies. This shows that the micrometeorites retrieved in Antarctic ices originate from a diversity of objects and a comparison of their composition with well-known meteorites as well as cometary data from space missions (e.g. Stardust, Rosetta) is necessary to assess their possible origin.

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