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X-CT morphological study of giant antarctic micrometeorites

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Abstract

Micrometeorites (MMs) dominate the flux of extraterrestrial materials to Earth [1] and provide samples from a variety of dust-producing bodies in our Solar System. This makes them highly valuable to obtain constraints on their parent bodies and on the dynamical evolution of the cosmic-dust in the primitive Solar System through laboratory analyses [2]. In this study, we have examined the 3D morphological structure and petrofabric of 23 giants MMs. We show here that such data provide information on the petrogenesis of micrometeorites (parent body geology and atmospheric entry) and serve as a guide to maximize subsequent multi-analytical approach on such small and precious planetary materials.

1. Introduction & Methods

Giant MMs (400-2000 μm) are exceedingly rare and valuable [3], while also being more representative of their parent's bodies petrography. These samples are a great opportunity to study the compositional heterogeneity of primitive bodies, which is the result of a complex set of pre and post accretional processes [2]. Indeed, the 3D morphology of the samples can be modified by several processes, including intense aqueous alteration leading to pseudomorphic chondrules formation [4], shocks inducing a privileged orientation of structures [5], or peculiar atmospheric entry dynamics.

In this study, 23 giant MMs, derived from the $\simeq$ 1-million-year-old Transantartic Mountain collection, were analyzed. These measurements were performed on PSICHE beamline of synchrotron SOLEIL, using a monochromatic beam, operating at 25keV, partially focused to increase the flux and with an exposure time of 0.6s per projection, resulting in a 0.66 μm voxel size. We reconstructed the 3D distribution of the linear attenuation coefficient thanks to *tomopy*. MMs porosity was estimated, thanks to an home-made python program and orientation of pores was obtained thanks to QUANT3D [6]. Precise examination of the images provided information on chondrules and on rims present inside each sample.

2. Global porosity and classification of samples

We calculated the porosity for all the selected samples. Values (see Fig. 1) are comparable with the literature [7] and confirm a good classification. The higher porosity detected for the scoriaceous MMs with respect to the unmelted confirms that atmospheric entry does increase it [7].

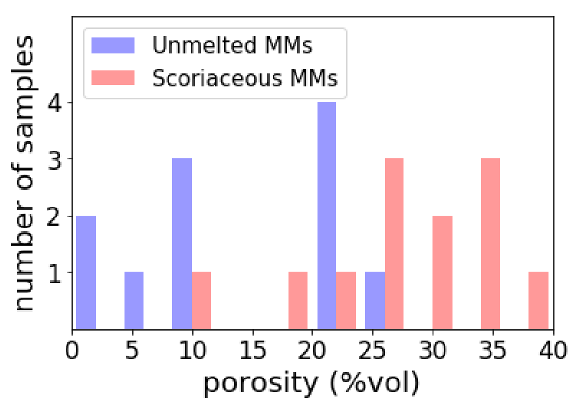

Figure 1: Porosity derived for unmelted and scoriaceous MMs.

3. Shape of the pores and implications for spatial processes

The shape of the structures present inside the MMs, especially the shapes of the voids, provided important information: cracks testify shock processing on the parents bodies and/or thermal decomposition during atmospheric entry; spherical voids witness aqueous alteration could lead to more spherical voids [5]. For each sample, we estimated the anisotropic index of the cumulative distribution of the voids, which indicates how far the pores are from spherical vesicles [6]. This metric varies from 1 to 6. An important anisotropy coefficient, like for MM 50.9 (see Fig 2.a) indicates a strong petrofabric. Slices inside this sample (see Fig 2.b) well show the peculiar orientation of the crystals and the voids.

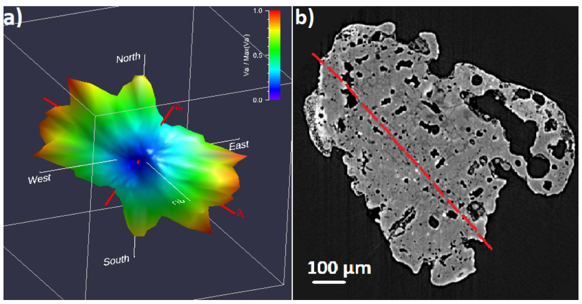

Figure 2: X-CT porosity data from micrometeorite MM 50.9. A) Cumulative distribution of pores. B) A X-CT slice of the whole specimen.

The study of peculiar micro-structures gave us complementary information. We observed pseudomorphic chondrules inside several samples, suggesting that they are intensely altered samples. By resolving the microstructure of 23 giant MMs, we have generated a comprehensive 3D study for this extraterrestrial class, currently still understudied.

4. First step of a characterization program

For such precious samples, it's critical to be able to optimize the collected information. Thus, non-destructive initial characterization enables their classification [8], as also to identify substructures of interest. This allow us to tailor the most effective analytical technique for each sample for subsequent analyses (isotopic measurement, FTIR spectroscopy). This work is a first step of an efficient and non-destructive analytical sequence optimized for the analysis of valuable extra-terrestrial dust particles with sizes between 1 μm to 1 mm.

5. Summary and Conclusions

We characterised 23 MMs and we conclude that the porosity of the unmelted samples varies between 0-25 vol% while for scoriaceous MMs it varies between 10-40 vol%. Critically, X-CT also enabled the non-destructive textural classification of MMs and the identification of sub-regions of interest. Thus, future destructive analysis can be directed towards specific regions of interest, maximising the data recovered from each particle.

Acknowledgements

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