OXYGEN ISOTOPE RATIOS OF LARGE COSMIC SPHERULES: CARBONACEOUS AND ORDINARY CHONDRITE PARENT BODIES.
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Introduction: Based on petrographic and ion probe investigation of small micrometeorites (150–250 µm), previous studies (e.g. [1]) have concluded that 99% of them should come from carbonaceous, possibly cometary parent bodies (CM/CR related). Our oxygen isotope measurements of 33 large (>500 µm) silicate type cosmic spherules (CS), using IR-laser fluorination/mass spectrometry, indicate that 30% of the CS are above the terrestrial fractionation line (TFL), i.e. are unrelated to carbonaceous chondrites but rather to ordinary and R chondrites.

Samples and Methods: Thirty three silicate CS from the Transantarctic Mountains collection [2] were selected for this study. Their masses range from 262 µg to 877 µg after the weathered rim was leached out using diluted HCl. SEM images of the samples were taken, non destructive chemical analyses were made with a X-Ray Fluorescence microscope, and magnetic properties were measured, at CEREGE, France. SEM images (Figure 1) allowed to distinguish between barred olivine (BO, 23 CS), porphyritic olivine (PO, 3 CS) and glassy (7 CS) textures [3]. This proportion is similar to that of large collections (e.g. [4]), assuming that cryptocrystalline and BO textures are merged.

Measurements of $\delta^{18}O$ and $\delta^{17}O$ were carried out on 28 spherules at the Stable Isotopes Laboratory of CEREGE, France. Molecular oxygen was extracted using the IR-laser fluorination technique [5-6] and the three oxygen isotopic composition was measured with a dual inlet mass spectrometer. The gas was passed through a –114°C slush to refreeze potential interfering gases before being sent to the mass-spectrometer. In order to get sufficient 34/32 and 33/32 signals (2-3 V), the oxygen from <0.3 mg standards and all CS samples was concentrated in the mass spectrometer in an autocooled 800 µL microvolume filled with silica gel and directly connected to the dual-inlet system. $\delta^{18}O$ and $\delta^{17}O$ values of the reference gaz were fixed through the analysis of NBS28. The oxygen isotope results are expressed in ‰ relative to V-SMOW. Measured $\delta^{18}O$ and $\delta^{17}O$ values of the samples were corrected on a daily basis using a 1.5mg quartz laboratory standard "Boulangé" ($\Delta^{17}O$=0.006, SD=0.034, n=37). Replicate analyses of 1.5mg NBS28 ($\Delta^{17}O$=–0.004‰, SD=0.055‰, n=11), San Carlos olivine ($\Delta^{17}O$=–0.024‰, SD=0.031‰, n=18) and UWG-2 [7] ($\Delta^{17}O$=–0.004‰, SD=0.055‰, n=8) were made during the analyzing period.

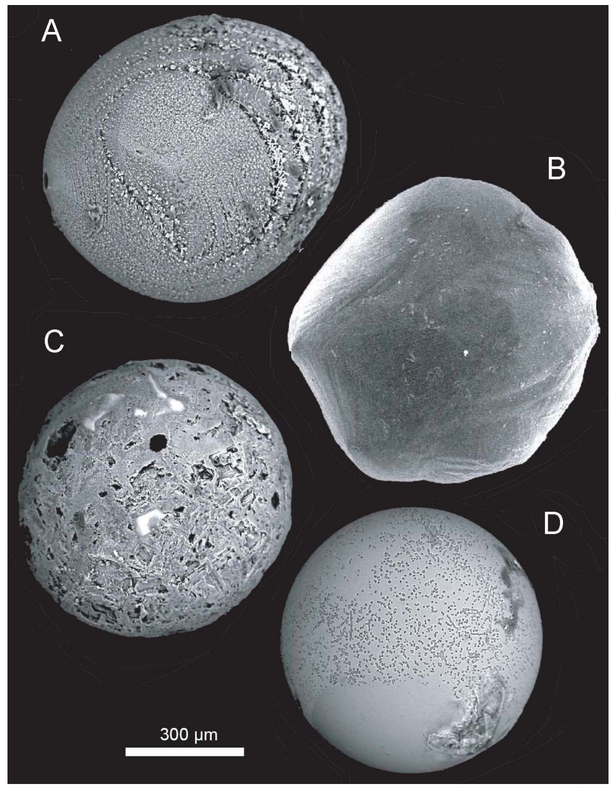

Figure 1: Back-scattered electron images. **A-B**, Barred olivine cosmic spherules for which oxygen isotope ratios show relationship with carbonaceous chondrites (A) and ordinary chondrites (B). **C**, Porphyritic olivine cosmic spherule. **D**, Glassy cosmic spherule.

Measurements of small masses (0.2–0.7 mg) of quartz and olivine show a systematic negative offset on the value of $\delta^{17}O$ (–0.2‰, SD=0.05‰, n=9). Therefore, a direct +0.2‰ correction was made on the value of $\delta^{17}O$ for CS samples. Five more BO-PO spherules were measured at the Open University, UK following a different method [8].

Results and Discussion: As CS melt during atmospheric entry, their oxygen isotopic composition is a mixture between primary extraterrestrial components and high altitude atmosphere interaction (defined by iron oxide spherules [9-10] at $\delta^{18}O$=40–60‰ and

$\Delta^{17}O$= 0‰). From the results, we can distinguish 4 families of extraterrestrial components:

– Most BO CS (16/23, or 48% of the total) have $\Delta^{17}O$≈–3 to –5‰ and $\delta^{18}O$ in the 10–30‰ range (similar to values typically obtained by ion microprobe [11]). These values correspond to the atmospheric contamination of a parent material with ratios on the carbonaceous chondrite anhydrous minerals (CCAM) line, e.g. typical of CO/CV carbonaceous chondrites.

– 5 BO CS and 2 glassy CS (21% of the total) have $\Delta^{17}O$ around –1‰ and $\delta^{18}O$ in the 15–35‰ range (similar to values typically obtained by ion microprobe [11-12]). These values could correspond to atmospheric contamination of hydrothermally processed carbonaceous material, e.g. CM/CR parent material.

– 2 BO, all 3 PO (Figure 1C), and 3 glassy CS (24 % of the total) have $\Delta^{17}O$≈0.4 to 0.8‰ and $\delta^{18}O$ in the 10–20‰ range. These values could correspond to atmospheric contamination of ordinary chondrite parent material. It is the first time that any evidence has been uncovered for ordinary chondrite parent material for CS.

– Finally, 2 glassy CS (6% of the total) have $\Delta^{17}O$≈+1.8‰ and $\delta^{18}O$≈41‰, which is close to the value found for one glassy CS in a previous study [11]. The only known parent material could be an R chondrite, or the high $\Delta^{17}O$ component observed in the magnetites [13] and the mesostasis of unequilibrated ordinary chondrites [14]. Enrichments in ^{17}O and ^{18}O are known for some atmospheric components and therefore a possible atmospheric effect in these glassy CS with very high $\delta^{18}O$ cannot be entirely ruled out. These specimens may also be related to two cryptocrystalline CS with very large ^{17}O enrichments previously reported [11].

For the first two families (below the TFL) a positive correlation is found between the value of $\delta^{18}O$ and the amount of magnetite determined by magnetic measurements. This correlation can be interpreted as a control of both $\delta^{18}O$ value and magnetite formation from primary olivine by the amount of contamination with atmospheric oxygen. The proportion of contamination can be estimated in the 30–70 % range from the $\delta^{18}O$ values of end members (C chondrites and iron oxide spherules).

Conclusions: Oxygen isotope ratios measurements allowed to relate cosmic spherules to at least 3 distinct parent materials: carbonaceous chondrite material, hydrothermally processed carbonaceous material, and ordinary chondrite material. Interestingly, texture is not discriminative for BO spherules, as specimens with similar texture can be related to any parent material (Figure 1A-B); however, all the so far measured specimens with PO textures are related to ordinary chondrite parent material. Glassy spherules also have a variety of isotopic signa-tures, as they can be related to hydrothermally reprocessed carbonaceous material as well as ordinary chon-drite material; furthermore, part of the specimens have a very high $\delta^{18}O$ and positive $\Delta^{17}O$ that could indicate another parent material, or be due to an unknown atmospheric effect. Our finding of 30% of spherules above the TFL, while previous studies by ion probe [1,12] found none (or 6% [11]), may be related to the lower precision of the ion probe (e.g. not allowing to decipher the ordinary chondrite related family from the TFL), and/or to a higher proportion of ordinary chondrite related material in our large (>500 µm) spherules, that may show an intermediate proportion between meteorites (80% above TFL) and small micrometeorites (0-6% above TFL).

References:

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