NEW ESTIMATION OF PRESOLAR GRAIN ABUNDANCES IN THE PARIS METEORITE.

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Introduction: C-rich and O-rich stardust grains have been extensively studied over the last decades [1]. Their isotopic and chemical compositions, as well as their microstructures, have shed light on matter-forming processes occurring in their different stellar birthplace, *i.e.*, AGB stars, novae, supernovae and neutron merging events [1]. Their O and C isotope compositions exhibit large deviations from solar values (up to tens of thousands permil) that make them easily distinguishable from the surrounding matrix in meteorites when imaged with the NanoSIMS [1]. However, their mineralogy and small size make them sensitive to aqueous alteration and/or metamorphism on asteroidal parent bodies. Presolar silicates in particular can be easily lost to secondary processes [2] and their abundances within meteorites have consequently been used as tracers of the intensity of those processes [3].

The Paris meteorite exhibits different lithologies with one characterized as a 2.9 [4], which makes Paris the least altered CM chondrite, even though this title might have recently been contested [5,6]. However, presolar silicates appear to be scarce in this meteorite, with an initial study leading to no detection [7]. Last year, we reported the first observations of presolar silicates, oxides and SiC within Paris [8]. However, reported abundances, while consistent with previous CM measurements were still unexpectedly low (22 ppm at most for SiC). Here we report further investigation of our previous dataset as well as a new one acquired on another section. The Paris presolar grain contents were revised upward with abundances above the CM averages for both O-rich and C-rich presolar grains.

Methodology: We identified coarse-mineral free regions of matrix in two polished thick sections of Paris (2010-1 and MNHNCC#1) from the Museum National d'Histoire Naturelle de Paris with both SEM and optical microscopy. Oxygen isotopes were mapped in those regions along with ^{12,13}C, ^{28}Si and ^{27}Al^{16}O with the Carnegie NanoSIMS 50L in imaging mode over three different sessions. C isotopes and Si enabled the detection and identification of presolar SiC and graphite, while the AlO signal helped in distinguishing presolar silicates from oxides as the latter are usually aluminum-enriched phases such as spinel ($MgAl_2O_4$) or corundum (Al_2O_3).Each measurement was preceded by a presputtering of ~250s over a 11×11 or 17×17 μm region with a 100-200 pA Cs$^+$ primary beam. The central 10×10 or 15×15 μm region of the sputtered area was then imaged for 20 cycles (~1h) with the beam current adjusted between 0.9 and 0.3 pA (beam diameter of 100-160 nm) to avoid saturation of the electron multipliers (EMs).Correction for the 44 ns deadtime of EMs and of any detected QSA effect were conducted using the L'image software (L. Nittler). We corrected the data for instrumental mass fractionation by internally normalizing C- and O-isotopic measurements to the average ratios of the analyzed regions, as these are very close to solar, compared to the highly anomalous ratios of presolar grains.Isotopic anomalous regions were considered to be presolar grains when (i) their isotopic compositions differed by at least 4σ from their surrounding material, (ii) anomalies were recorded over at least three consecutive cycles, and (iii) the O-anomalous area shape was grain-like. Data were then corrected for dilution following a procedure inspired by [9].

Results and Discussion: Most alteration scales are unsuited for a microscale evaluation of the extent of alteration as they rely solely on bulk measurements, either bulk H, C and N [10], or PSD-XRD on crushed samples [11]. Though the Rubin scale is widely used because it relies on chemical and mineralogical observations easily accessible on a section [12], the robustness of its criteria remains debated [13]. Therefore, we discriminated between metal-rich (MR) and metal-poor (MP) lithologies as has been reported in previous studies [*e.g.*, 14]. Unidentified clasts of fine-grained material with very low amounts of coarse grains were observed only in section MNHNCC#1. We also observed an unusual clast in section 2010-1 that exhibits a gradient in Ca along its length, and is composed entirely of fine-grained material.

A total of approximately 70,000 μm^2 were mapped over the two sections, with 43,000 μm^2 and 27,000 μm^2 in the MP and MR lithologies respectively. Inter-chondrule matrix (ICM), chondrule fine-grained rims (FGR) as well as clasts of fine-grained material were analyzed for presolar grains.

Fifty-seven C-rich and fifty-eight O-rich presolar grains were detected. ^{13}C-rich grains are likely to be SiC, while most ^{13}C-depleted grains are probably organics and/or graphites. We could not distinguish oxides and silicates based on measured AlO/O and Si/O secondary ion ratios [15], since no discontinuity was observed in the AlO/O distribution. Most of the O-anomalous grains have isotopic compositions falling in the group 1 range (^{17}O/^{16}O: 3.853×10^{-4}-1.196×10^{-3} and ^{18}O/^{16}O: 1.931×10^{-3}-2.477×10^{-3}) originating from AGB stars of 1.2-2.2 M$_\odot$ (Fig. 2) [1]. One grain is a potential group 3 from low-metallicity AGB stars while 23 others could belong to group 4 as defined in [16]. However, 13 of those grains fall into a relatively narrow range (δ^{17}O:1-360‰, δ^{18}O:180-500‰). The presolar origin of those grains is matter to debate as this composition overlaps with some rare solar system materials [17] and further work is ongoing to assess this issue. Our most anomalous grain has δ^{17}O~3400‰. None of our grains display as extreme compositions as reported in the literature. While those extreme grains are scarce, the narrow range of compositions observed here could attest to the effect of light aqueous alteration.

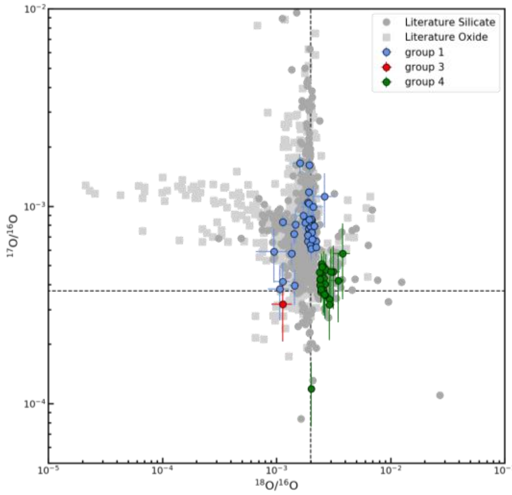

***Figure 1** – O-isotopes compositions of O-rich grains in Paris. Literature from [18]. Errors are 1σ.*

Abundances were calculated as the ratio of O-rich grains cumulated surface over the total studied area excluding cracks, coarse grains and holes. When the dataset was large enough, errors were calculated following the procedure of [15], otherwise tables from [19] were used. Reevaluated presolar grain abundances in Paris are ~37 ppm and ~42 ppm for O-rich grains and SiC respectively. Those abundances are above the CM FGR averages which confirm the classification of Paris as the least-altered CM. O-rich grains are lost to alteration even in its early stages as abundances drop from ~49 ppm to ~26 ppm between the MR and the MP lithologies. A similar behavior is observed for SiC with a comparable ~50% drop in abundance (~56 to 30 ppm). However, MR region SiC are systematically the most significantly anomalous. Interestingly, SiC and O-rich grains have comparable abundances in the MR region independently of the nature of the host region. However, as previously reported in CR2 [20], grains in FGR of chondrules are more efficiently protected from the effect of alteration as attested by the measurements in the MP lithology. These results confirm the almost pristine nature of the Paris MR lithology. However, even there, the abundance is much lower than the 100s of ppm reported for presolar silicates in the least-altered CR, CO3, and ungrouped chondrites. Nonetheless, a further investigation of the preserved presolar grains in the MP lithology might bring new constraints on the early stage conditions of alteration.

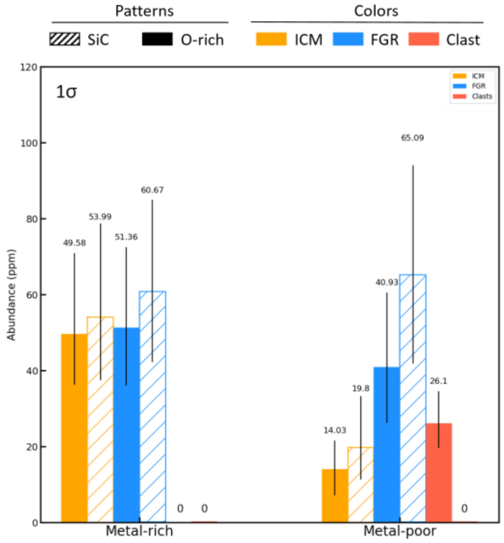

***Figure 2** – Abundances of O-rich and SiC presolar grains between the metal-rich and metal-poor lithologies based on the nature of the host material.*

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References: [1] Nittler L. R. and Ciesla F. (2016), *ARAA, 54,* 53-93. [2] Floss C. and Stradermann F. J. (2012), *MAPS, 47,* 992-1009. [3] Leitner J. et al. (2019), *MAPS,* 1-31.[4] Hewins R. H. et al. (2014), *GCA, 124*, 190-222. [5] Kimura M., et al., 82nd Annual Meeting of The Meteoritical Society 82, 2019, #6042. [6] Nittler L.R. et al. (2020), this conference, #2276. [7] Mostefaoui S. (2011), *74th Meteor. Soc. Conference,* Abstract #5170. [8] Verdier-Paoletti M. J. et al. (2019), *LPSC L*, #2948. [9] Nguyen A.N. et al. (2017), *MAPS*, 52, 2004-16. [10] Alexander C.M.O'D. et al. (2013), *GCA*, 123, 244-60. [11] Howard K.T. et al. (2014), *GCA*, 149, 206-22. [12] Rubin A.E. et al. (2007), *GCA*, 71, 2360-82. [13] Verdier-Paoletti M. J. et al. (2019), *MAPS*, 54, 1-18. [14] Vacher L.G. et al (2017), *GCA*, 213, 271-90. [15] Nittler L.R. et al. (2018), *GCA*, 226, 107-31. [16] Nittler L.R. et al. (2019), *MAPS*, 1-16. [17] Seto Y. et al., GCA, 72, 2723-34. [18] Hynes K.M. and Gyngard F. (2009), *LPSC XL*, #1198 [19] Gehrels N. (1986), *APJ, 303*, 336-346. [20] Haenecour P. et al. (2018), *GCA*, 221, 379-405.