HIGH ABUNDANCE OF SILICATE STARDUST FROM SUPERNOVAE IN THE QUE 99177 METEORITE.

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Introduction: Primitive Solar System materials contain small quantities of presolar grains that formed in the winds of evolved stars and in the ejecta of stellar explosions [1]. Besides diamonds, whose origin is still a matter of debate, silicates constitute the most abundant presolar grain type with abundances of ~375 ppm on average in isotopically primitive interplanetary dust particles (IDPs) and of ~200 ppm in the fine-grained matrix of the most primitive meteorites [2]. Based on O-isotopic compositions presolar silicates (and oxides) are divided into four distinct groups [3]. It is well established that the majority of presolar silicates (Groups 1 and 2) formed in the winds of low-mass red giant and asymptotic giant branch (AGB) stars [4]. The question on the abundance of grains from supernovae (SNe), the Group 4 and some Group 3 grains, is not yet settled but our recent high-resolution (HR) NanoSIMS ion imaging study on the ungrouped carbonaceous chondrite Acfer 094 [5] suggested that their abundance might be significantly higher than the 10 % (by number) initially determined by lower resolution (LR) ion imaging studies.

Here, we report on results from a HR NanoSIMS ion imaging survey of fine-grained matrix material in the Queen Alexandra Range (QUE) 99177 meteorite, a CR2 chondrite known to host high abundances of presolar O-rich grains [6,7]. This work is an extension of our previous work on Acfer 094 [5] to verify whether the high abundance of SN grains detected in Acfer 094 by HR ion imaging is also seen in other primitive meteorites.

Experimental: About 2100 μm^2 of fine-grained matrix material, identified in secondary electron images with our Leo 1530 FE-SEM, were analyzed in the QUE 99177 meteorite for O-isotopic compositions with a Cameca NanoSIMS 50 ion probe at nominal spatial resolution of 50 nm. This approach permits identifying presolar grains down to <100 nm in size, compared to >150 nm in LR ion imaging surveys (spatial resolution of nominal 100 nm). Negative secondary ion images (256 x 256 pixels) of $^{16,17,18}O$, ^{28}Si, and $^{27}Al^{16}O$, produced by rastering a 0.1-0.2 pA Cs^+ primary ion beam over 82 5 x 5 μm^2 sized areas, were acquired in multi-collection. Presolar grains were identified from isotope anomalies (significance >5.3σ) in $^{17}O/^{16}O$ and $^{18}O/^{16}O$ ratio images in a fully automated way [5].

Results and Discussion: The fully automated processing of O isotope images revealed 17 O-rich presolar grains (all silicates, inferred from NanoSIMS ^{28}Si and $^{27}Al^{16}O$ ion images) with sizes between 80 and 220 nm and a median size of 150 nm. This corresponds to a presolar silicate abundance of 214 ± 52 ppm. If only the 9 grains with sizes >150 nm are considered, which are likely to have been identified by LR ion imaging, then the abundance of O-rich presolar grains is 158 ± 53 ppm. These abundances are compatible with what was found previously for QUE 99177 by LR ion imaging (160 ± 26 ppm [7] and 220 ± 40 ppm [6]). However, the presolar grain density from HR ion imaging (1 grain per 120 μm^2) is about a factor of 3 higher than that inferred from LR ion imaging.

As for our HR ion imaging studies of Acfer 094 [5], no presolar grains with large ^{16}O enrichment, the expected predominant signature of SN grains, were found. However, five grains, two Group 3 grains with about solar $^{18}O/^{16}O$ and half-solar $^{17}O/^{16}O$ and three Group 4 grains with ^{18}O enrichments up to a factor of 2.6, have a likely SN origin. These grains represent 29% by number and 28% by mass of all identified presolar silicate grains. This confirms our finding for Acfer 094 and taken together we find a relative abundance of SN silicates of 32% by number and 22% by mass, with 2σ lower limits (according to [8]) of 17% by number and 12% by mass. The relative abundance by number is significantly higher than that (~10%) inferred by LR ion imaging. This suggests that SN grains are more abundant among the smaller presolar silicates and that the relative abundance of SN grains among presolar silicates is comparable to the 25% inferred for presolar graphite grains [9]. The relative abundance (by mass) of SN silicates is also significantly higher than the theoretical estimate of 5% inferred by [10] and suggests that the model underestimates the contribution of SNe to dust in the interstellar medium (ISM) or indicates a heterogeneous distribution of SN dust in the local ISM at the time of Solar System formation.

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