PRESOLAR GRAIN ABUNDANCE VARIATION IN THE MILLER RANGE 090019 CO3.1 CHONDRITE.

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Introduction: Presolar grains condensed in the outflows of evolved red giant stars and the ejecta of supernovae (SNe) and novae. These grains have greatly anomalous isotopic compositions compared to solar system material, reflecting their stellar origins [1]. They have been identified in primitive meteorites, interplanetary dust particles (IDPs), Antarctic micrometeorites, and comet Wild 2 samples returned by NASA's Stardust mission. Presolar silicates are one of the most abundant presolar phases and their concentrations extend up to 1.5% in primitive IDPs believed to derive from comets [2]. These grains are highly susceptible to alteration and destruction by secondary processing in the interstellar medium, nebula, and asteroid or comet parent body. Presolar silicate abundance variations between primitive meteorites and chemical and mineralogical studies provide indications of the extent of secondary hydrothermal alteration [3, 4]. The abundance of presolar SiC grains is generally consistent among chondrites, but lower abundances in some meteorites have been attributed to thermal alteration [5, 6]. Presolar grain abundance variations attributed to localized alteration have also been reported within different regions of a chondrite [e.g., 7].

Carbonaceous chondrites from the CO and CR groups have the highest abundances of presolar silicates among meteorites, attesting to their primitive nature. The CO3 chondrite Dominion Range (DOM) 08006 has the highest presolar O-rich grain abundance of ~260 ppm [8, 9]. Miller Range (MIL) 090019 is classified as a CO3.1 chondrite and has affinities to Acfer 094, DOM 08004/6 and Allan Hills (ALH) 77307. These chondrites have high presolar silicate abundances and contain high abundances of various types of refractory inclusions. We previously conducted detailed studies of CAIs in MIL 090019 [10, 11]. Here we evaluate its presolar grain inventory to assess the degree of parent body alteration and compare to other chondrites.

Experimental: A polished thin section of the MIL 090019 chondrite was characterized at the University of Chicago by scanning electron microscopy and the mineralogy and petrography were characterized using the JOEL JXA-8530F field emission electron probe microanalyzer at NASA JSC [10]. Three regions of the thin section containing matrix material were selected for C and O isotopic mapping using the Cameca NanoSIMS 50L at NASA JSC. Prior to data acquisition, each 20 x 20 μm^2 area to be analyzed was sputtered with a high current Cs^+ primary ion beam to remove the conductive C coat and to implant Cs. A focused ~1 pA Cs^+ primary ion beam was then rastered over these areas for 30 planes and negative secondary ions of ^{12}C, ^{13}C, ^{16}O, ^{17}O, ^{18}O, ^{28}Si, and $^{24}Mg^{16}O$ were simultaneously detected in electron multipliers. An electron flood gun was used for charge compensation. Grains having isotopic compositions that were 5σ away from that of the surrounding matrix were identified as presolar. The C and O isotopic ratios of anomalous grains were normalized to the surrounding matrix material.

Results: Total areas of 11,625 μm^2, 15,820 μm^2, and 8,130 μm^2 were measured in Regions 1, 2, and 3, respectively. A total of 50 presolar O-rich grains and 15 presolar C-rich grains were identified. Their isotopic compositions are shown in Figures 1 and 2 and the presolar grain abundances for the different regions are given in Table 1. While phase identification based on NanoSIMS measurements bears large uncertainty [12], 3 of the presolar O-rich grains have lower $^{28}Si/^{16}O$ ratios than the surrounding matrix and could be oxides rather than silicates. One ^{17}O-, ^{18}O-rich grain has a $^{28}Si/^{16}O$ ratio two times greater than the average value for the other presolar O-rich grains and could be SiO_2. The $^{12}C/^{13}C$ ratios of the C- rich anomalous grains range from 18 to 123 (Fig. 2). Most of the grains are likely SiC. The three ^{13}C-poor and three ^{13}C-rich grains have low $^{28}Si/^{12}C$ and could be graphite or organic matter.

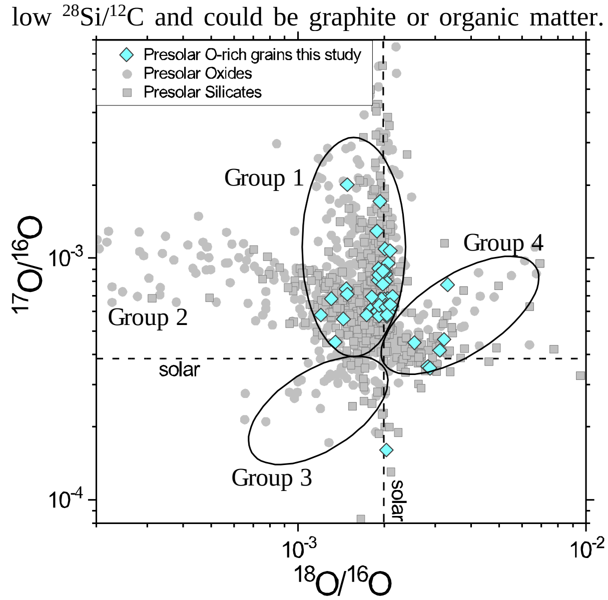

Figure 1. Oxygen isotopic compositions of presolar O-rich grains in MIL 090019 compared to those of presolar oxides and silicates from [13].

However, the abundance of presolar graphite in chondrites is low [~1 ppm; 1] and it is unlikely that 40% of the C anomalous grains are graphite.

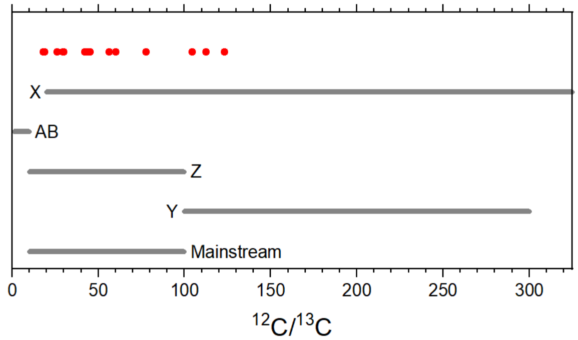

Figure 2. C isotope ratios of presolar C-rich grains in MIL 090019 (red dots) compared to the range for presolar SiC types (grey bars) [1]. Note presolar graphite have a similar range of $^{12}C/^{13}C$ ratios as SiC.

Table 1. Presolar grain abundances in MIL 090019

Region	Presolar O-rich grain abundance	Presolar C-rich grain abundance
1	28 ± 11 ppm	44 ± 22 ppm
2	93 ± 18 ppm	99 ± 35 ppm *42 ± 15 ppm
3	113 ± 27 ppm	26 ± 15 ppm

*Abundance adjusted for large presolar SiC.
1σ errors based on Poisson statistics

Discussion: Most of the presolar O-rich grains have isotopic compositions that fall into the Group 1 classification and these grains were thought to derive from low-mass asymptotic giant branch (AGB) stars [14]. However, recent Mg isotopic analyses of Group 1 grains indicate 3-12% have SN origins [15]. The six ^{17}O-, ^{18}O-rich grains and the ^{17}O-poor grain (Fig. 1) likely have SN origins. The origins of the presolar C-rich grains cannot conclusively be deduced based solely on C isotopic ratios, but most of the grains are likely mainstream SiC grains that condensed around ~solar metallicity AGB stars. An unusual ^{17}O- and ^{13}C-rich AGB grain was found. The ^{17}O- and ^{13}C-rich regions are slightly offset from one another spatially but have significant overlap, so it is not likely two distinct grains. It is possible that it is an intergrowth of C- and O-rich phases, though O-rich phases are not thought to condense under a reduced environment, or the grain could be a silicate with a C coating. FIB-TEM mineralogical analysis of this grain is planned.

The presolar O-rich grain abundances in Regions 2 and 3 are the same within 1σ error but are greater than the abundance determined for Region 1 (Table 1). There was a higher concentration of Ca in the matrix material of Region 1 and a proximate melilite-rich CAI displayed sodic alteration (sodalite + nepheline) at the margins. The low presolar silicate abundance in Region 1 indicates a higher degree of parent body alteration compared to the other two regions analyzed. It is plausible that the fluid that altered the CAI also altered the surrounding matrix. Analysis of the mineralogy and chemical compositions of the different matrix areas by FIB-TEM will help to characterize the alteration that affected the silicate grains. The combined presolar O-rich grain abundance of the less altered regions (99 ± 15 ppm) is moderate and similar to CR chondrites that have undergone some alteration [16], but is lower than the abundances in Acfer 094 [~160 ppm; 17, 18] and the CO3 chondrites ALH 77307 [~180 ppm; 8, 12], LAP 031117 [~180 ppm; 8], and DOM 08006 [~260 ppm; 8, 9]. The parent body of MIL 090019 thus experienced more hydrothermal alteration than the parent bodies of these CO3 chondrites and the most primitive CR chondrites [~160-220 ppm; 19].

The presolar C-rich grain abundance in Region 2 is larger than the other two regions due to one comparatively large (1 μm) presolar SiC. The abundance becomes 42 ppm if we use the average grain size of 0.328 μm rather than 1 μm. This adjusted abundance is the same as that in Region 1. Though the abundance of presolar C-rich grains appears lower in Region 3, it is within error of Regions 1 and 2 (Table 1). The abundance of presolar C-rich grains in MIL 090019 is similar to the CO3 chondrites ALH 77307 [8, 12], LAP 031117 [8], and DOM 08006 [8, 9], and to CR chondrites [5]. Note that a lower abundance was reported in ALH 77307 by [5] and this was attributed to parent body thermal metamorphism and oxidation of SiC grains [4]. The abundance in MIL 090019 indicates that such metamorphism did not occur extensively on the parent body though it is petrographic grade 3.1.

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