Si AND Mg-Al ISOTOPIC STUDIES OF PRESOLAR GRAPHITE FROM ORGUEIL. M. Jadhav[1], T. Maruoka[1]*, S. Amari[1], K. K. Marhas[1], E. Zinner[1], [1]Laboratory for Space Sciences and the Physics Department, Washington University in St. Louis, One Brookings Dr., St. Louis, MO 63130, USA. (manavijadhav@wustl.edu), *present address: Department of Geosciences, Osaka City University, Sugimoto, Sumiyoshi-ku, Osaka 558-8585, Japan.

Introduction: Last year we reported the successful isolation of presolar graphite from Orgueil and presented C, N, O and Si isotopic ratios on individual graphite grains from seven density fractions, with grain sizes > 1μm (Table 1) [1, 2]. Except for fractions ORG1b and 1h, all fractions analyzed were found to contain presolar carbonaceous grains that are morphologically and isotopically similar to Murchison graphite [3, 4]. These grains exhibit a large range of C isotopic ratios ($^{12}C/^{13}C$ ~ 4-1746). The abundance of grains with isotopically light carbon increases with increasing density. A minor population of grains with $^{12}C/^{13}C$ ~ 10 is observed in all the fractions. Some grains in the low-density fractions ORG1c and 1d are enriched in ^{18}O and ^{15}N. The ^{18}O excesses indicate a SN origin [5] as in the KE3 fraction (1.65 – 1.72 g cm^{-3}) from Murchison where a third of the grains are SN graphite [5]. In higher-density fractions (ORG1f, 1g and 1i), however, the $^{14}N/^{15}N$ and $^{16}O/^{18}O$ ratios are normal, similar to Murchison graphite, where these normal ratios have been attributed to isotopic exchange with normal N and O, either on the parent body or in the laboratory [5]. Thus, the N and O ratios of high-density grains cannot be considered to be representative of their stellar sources. Morphologically, most of the Orgueil grains look similar to the high-density, onion-type graphite grains from Murchison [3, 4]. We did not find any cauliflower-type grains observed in Murchison. Orgueil grains also tend to be larger at higher densities, contrary to the trend seen in Murchison graphite [3, 4].

Here we report Si isotopic analyses on graphite grains from ORG1c, 1d, 1f, 1g and 1i, and Mg-Al analyses from ORG1d and 1f.

Experimental Methods: Previously identified and analyzed graphite grains were measured with the NanoSIMS. N and Si isotopes were measured in multidetection mode by counting $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{28}Si^-$, $^{29}Si^-$ and $^{30}Si^-$ secondary ions produced by bombardment of the grains with a Cs^+ beam. Positive secondary ions of ^{24}Mg, ^{25}Mg, ^{26}Mg and ^{27}Al produced with an O^- beam were detected in multidetection mode. We measured ^{12}C in a fifth detector to facilitate locating the graphite grains. Table 1 shows the type of isotopic data collected for the various density fractions of Orgueil.

Results and Discussion:

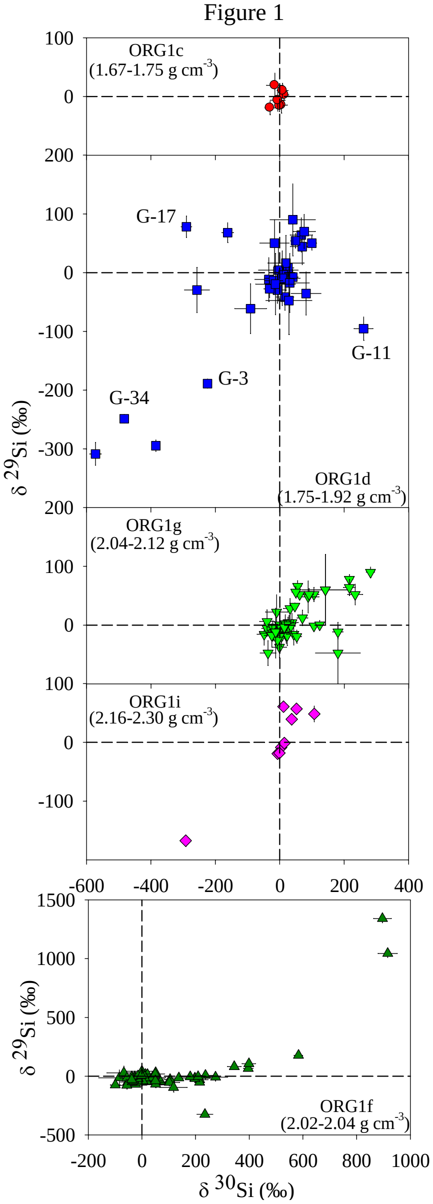
Si isotopes: The silicon data indicate distinctive trends that depend on the density of the grains (Figure 1). The low-density fraction ORG1d contains 4 grains with large ^{28}Si excesses. These excesses correlate with ^{18}O and ^{15}N excesses [1, 2]. Excesses in ^{28}Si and ^{18}O indicate a SN origin [5]. The high-density fractions, ORG1f, 1g, and 1i, however, are enriched in ^{29}Si and ^{30}Si. Most of these high-density, ^{30}Si-rich grains contain isotopically light carbon. These signatures are predicted for low-metallicity AGB stars where more ^{12}C and $^{29,30}Si$ from the He shell is dredged up into the envelope during the thermally pulsing phase than in stars of solar metallicity. Thus, low-metallicity AGB stars are the most likely source for the high-density graphite grains with excesses in ^{30}Si and ^{12}C [6, 7].

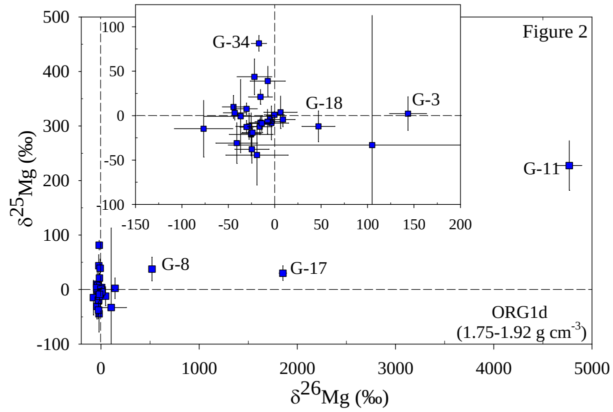
Krypton isotopic measurements of bulk samples indicated the presence of AGB graphite grains in the highest-density fraction from Murchison [8]. However, before the present study and a recent study by Amari et al. [9], only few such grains have been identified from single-grain isotopic analysis. Before the advent of the NanoSIMS, the high-density Murchison KFB1 and KFC1 graphite grains were analyzed with the IMS-3f [4]. The NanoSIMS allows us to measure the Si isotopes of high-density graphite grains with much higher precision and hence, finally, allows us to investigate graphite grains from low-metallicity AGB stars. A recent NanoSIMS study by Amari et al. [9] of the Murchison KFB1 and KFC1 fractions, has also found graphite grains with an apparent origin in low-metallicity AGB stars.

***Mg-Al isotopes*:** Mg isotope results for the low-density fraction ORG1d are plotted as δ-values of $^{25}Mg/^{24}Mg$ and $^{26}Mg/^{24}Mg$ in permil (‰) in Figure 2. Most grains from this fraction have normal Mg isotopes within ~2σ. Five grains (G-11, G-17, G-8, G-3 and G-18), however, exhibit ^{26}Mg excesses from the decay of short-lived ^{26}Al ($t_{1/2} = 7.2 \times 10^5$ yr). G-11 and G-17 have the most extreme excesses of 4769‰ and 1853‰, respectively. G-11 is also enriched in ^{25}Mg (227‰). The remaining four grains have close-to-normal $^{25}Mg/^{24}Mg$ ratios. G-34 shows an excess in ^{25}Mg (81‰) and a very large excess in ^{28}Si (see Figure 1), but has normal ^{26}Mg. Interestingly, four grains (G-11, G-17, G-8 and G-3) that contain ^{26}Mg excesses are also enriched in ^{18}O but only G-3 has a ^{28}Si excess. Figure 3 shows the inferred $^{26}Al/^{27}Al$ ratios of the grains that have evidence for ^{26}Al. G-11 and G-17 have $^{26}Al/^{27}Al$ ratios of ~ 0.04 and 0.05, respectively. Even higher $^{26}Al/^{27}Al$ ratios (up to 0.6) have been seen in SiC-X grains [10]. The low-density KE3 fraction of Murchison graphite also has high $^{26}Al/^{27}Al$ ratios (up to 0.146). The high $^{25}Mg/^{24}Mg$ and $^{26}Al/^{27}Al$ ratios, along with an ^{18}O excess in G-11 indicate a SN origin for this grain. The $^{12}C/^{13}C$ ratio of this grain is 6 and it has a deficit in ^{29}Si and an enrichment in ^{30}Si (see Figure 1). These are not the typical signatures seen in SN grains but Type II supernovae do show such ratios in different shells [11]. A Wolf-Rayet origin could also explain the ^{30}Si excess. A feature that has been observed before is that the grains with high ^{26}Al/^{27}Al ratios have close-to-solar ^{12}C/^{13}C ratios, except for grain G-11. This observation agrees with calculations for Wolf-Rayet stars that are in the transitional phase between hydrogen and helium burning stages or the WN and WC stages [12]. Only upper limits could be obtained for the inferred ^{26}Al/^{27}Al ratios of G-13, G-24 and G-10 because of the large errors associated with the measurements.

The high density fraction, ORG1f, exhibited normal δ^{25}Mg and δ^{26}Mg within ~2σ. The Al/Mg ratios in the grains of this fraction were quite low so that even if the grains had ^{26}Al/^{27}Al ratios typical for AGB stars (~0.001), we could not have detected the resulting ^{26}Mg excesses.

Figure 1





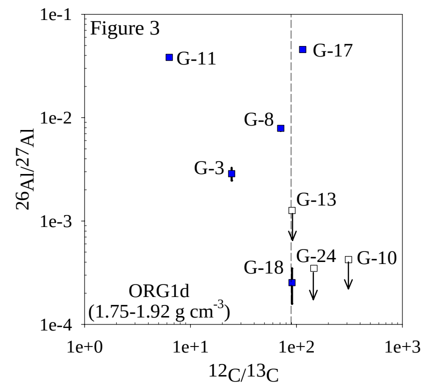


Table 1

Fraction Name	Density (g cm^{-3})	# of carbonaceous grains identified and type of isotopic data obtained: C	N	O	Si	Mg-Al	# of presolar grains found
ORG1b	1.59-1.67	22	-	22	-	-	0
ORG1c	1.67-1.75	7	7	7	7	-	2
ORG1d	1.75-1.92	32	32	32	32	32	19
ORG1e	1.93-2.02	-	-	-	-	-	-
ORG1f	2.02-2.04	72	72	72	72	59	65
ORG1g	2.04-2.12	52	51	52	51	-	38
ORG1h	2.12-2.16	18	-	18	-	-	0
ORG1i	2.16-2.30	9	9	9	9	-	6

Conclusions: The Si isotopic ratios of presolar graphite in Orgueil indicate that low-density grains have a SN origin while high-density grains probably originate from low-metallicity AGB stars. The high ^{26}Al/^{27}Al ratios of the low-density grains are in agreement with a SN origin but also a Wolf-Rayet origin. Similar Mg-Al measurements are needed for grains from the remaining fractions. Measurements of other elements such as Ca and Ti will help to better constrain the stellar sources of these grains.

References: [1] Jadhav M. et al. (2005) *LPS XXXVI*, Abstract # 1976. [2] Jadhav M. et al. (2005) *MAPS*, 40, A75. [3] Zinner E. et al. (1995) *Meteoritics*, 30, 209-226. [4] Hoppe P. et al. (1995) *GCA*, 59, 4029-4056. [5] Travaglio C. et al. (1999) *ApJ*, 510, 325-354. [6] Hoppe P. et al. (1997) *ApJ*, 487, L101-L104. [7] Busso M. et al. (1999) *Ann. Rev. Astron. Astrophys.*, 37, 239-309. [8] Amari S. et al. (1995) *GCA*, 59, 1411-1426. [9] Amari S. et al. (2005) *MAPS*, 40, A15. [10] Nittler et al. (1995) *ApJ*, 453, L25-L28. [11] Woosley S. E. and Weaver T. A. (1995) *ApJ Suppl.*, 101, 181-235. [12] Arnould M. et al. (1997) in: *Astrophysical Implications of the Laboratory Study of Presolar Materials*, (eds. T. J. Bernatowicz and E. Zinner), 179-202, AIP, New York.