LITHIUM, BORON, AND SULPHUR ISOTOPIC RATIOS IN LARGE PRESOLAR SIC GRAINS FROM MURCHISON.

F. Gyngard[1], S. Amari[1], E. Zinner[1], R. Gallino[2], R. S. Lewis[3], [1]Laboratory for Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130, USA, fmgyngar@wustl.edu, [2]Dipartimento di Fisica Generale, Univ. di Torino, Torino, Italy, [3]Enrico Fermi Institue and Chicago Center for Cosmochemistry, University of Chicago, Chicago, IL 60637, USA.

Introduction: Almost all measurements of presolar SiC grains in meteorites have focused on grains of size approximately < 5μm. A notable exception is the Virag et al. [1] study in which 41 grains from the Murchison L series, ranging in size up to 26μm, were analyzed for their C, N, Mg, and Si isotopic compositions. The L series separation was used largely for the development of the now standard presolar grain separation process and as such, was done in a more indirect fashion than subsequent separations [2]. Virag et al. [1] have shown that SiC grains from the LS and LU separates contain several unique features: some are very large (over 20μm); many of these large grains appear to have flat and smooth surfaces (see Fig. 1), unlike the euhedral surfaces observed in smaller grains; and the Si isotopic composition of many of these grains seems to cluster in 3 groups.

By exploiting the large size and flat surface morphology of these LS and LU grains, we have performed isotopic measurements of the elements Li, B, and S. Lyon et al. [3] recently measured Li and B in individual SiC grains and found no isotopic anomalies; however, they did report high Li/Si and B/Si ratios, which appear to be correlated. The smooth and relative crack-free nature of many of the large LS and LU grains enables us to make contamination-free measurements of these trace elements. Here we report Li, B, and S isotopic ratios in 9 presolar SiC grains.

Experimental: Grains in isopropanol suspensions from Murchison separates LS and LU [2] were deposited and dried on microscope slides. These slides were then manually scanned in an optical microscope for large SiC grains. Grains of size roughly > 8μm were transferred onto a clean gold foil with the help of a micromanipulator and pressed into the foil with a quartz disk. SEM-EDX analysis identified forty grains as SiC.

The C and Si isotopic compositions of 9 of the largest SiC grains were measured in multicollection with the Washington University NanoSIMS. In a separate session, negative secondary ions of the ^{32}S, ^{33}S, ^{34}S, and ^{36}S isotopes were measured on the same grains in a combination of multicollection and magnetic peak-jumping. Positive secondary ions of ^{6}Li, ^{7}Li, ^{10}B, and ^{11}B were measured in multicollection in another measurement run. Murchison matrix was used

as a S standard and a NBS glass (610) was used as a Li and B standard. All errors reported are 1σ.
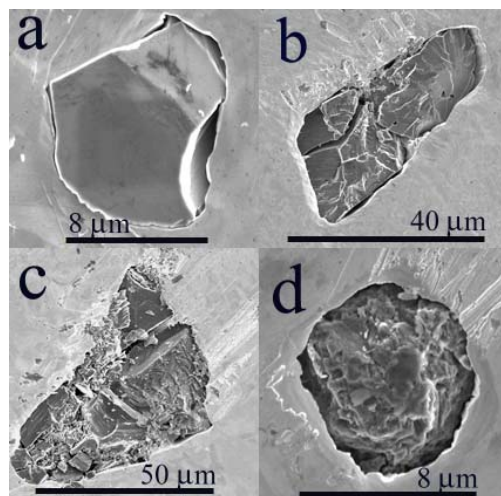
Figure 1: SEM images of four LS-LU grains with "typical" morphologies: (a) smooth, very flat grain; (b) and (c) very large and flat, with irregular edges; (d) euhedral SiC, often seen in the K series.

Results and Discussion: We discovered that there exists an even larger subset of presolar SiC grains in the LS and LU fractions than had been seen previously. We found 5 grains with at least one dimension greater than 30μm, including two grains of size 65μm × 38μm and 60μm × 65.5μm. By pressing the grains into the gold foil, it is possible that we fractured the grains into sizes greater than before pressing. However, inspection of the SEM images shows that most of the grains have remained fairly well intact.

C and Si isotopes. Carbon and Si isotopic ratios confirm the presolar nature of these grains, as seen in a Si 3-isotope plot in Fig. 2. The similar C and Si isotopic compositions of the six grains circled in Fig. 2 makes it likely that they originate from a single source. Virag et al. [1] grouped the large grains of their study into three clusters based on the C and Si isotopic compositions; these 6 isotopically similar grains would probably be members of Cluster II. Interestingly, these grains represent the largest of the 9 grains analyzed and share similar morphological features – grains pictured in Fig. 1b and 1c are two of the six

grains. Whether these 6 unique grains are individual condensates from the same star or pieces of an even larger SiC crystal is unclear; however, conchoidal fractures along the sides and irregular shapes of the edges, which are not artifacts from pressing, would seem to imply the latter.

S Isotopes. Eight out of nine of the grains of this study show depletions in ^{34}S more than 2σ from standard solar system values, with $\delta^{34}S/^{32}S$ values ranging from -9 to -44‰. Two grains also show depletions in ^{33}S, with $\delta^{33}S/^{32}S$ = -16±5‰ and -45±16‰, while all other grains have normal ^{33}S within 2σ. This scenario – modest depletions in ^{33}S and ^{34}S, with $\delta^{34}S < \delta^{33}S$ – is consistent with expected S production in a $2M_O$ AGB star of half solar metallicity. Theoretically expected $\delta^{36}S/^{32}S$ values for such a star range up to several hundred permil, but unfortunately, the abundance of ^{36}S is too low to allow $^{36}S/^{32}S$ measurements. Although the grains do appear to show anomalous S compositions, we cannot rule out a systematic shift in the grains' S isotopic composition due to the quasi-simultaneous arrival (QSA) of two ions on a detector being counted as a single ion [4]. This problem arises from a combination of high transmission and high sensitivity to S in the NanoSIMS, which could produce slight ^{33,34}S excesses relative to ^{32}S in the Murchison standard (where S is contained at large concentrations in small sulfide grains) and depletions in the SiC grains after normalization to the standard. We are continuing to investigate the magnitude of this possible effect on our grain data.

Li and B Isotopes. Lithium and B isotopic ratios and elemental concentrations are shown in Table 1. We find ^{6}Li enrichments (up to ~300‰), more than 2σ from solar, in eight out of nine grains. We also see ^{10}B enrichments in two of the grains. Previous studies [3,5-6] have found no isotopic anomalies, despite even measuring some grains that had been isolated without harsh chemical treatments that could erode surface coatings. In the 9 grains we measured, we fail to see an obvious correlation between Li and B concentrations, contrary to observations by [3], although our statistics are more limited.

In stellar environments, Li and B are consumed by proton captures at relatively low temperatures ($\sim2.5\times10^6$ K) [7]. ^{7}Li can be produced in low-mass AGB stars during deep mixing and cool-bottom processing by the Cameron-Fowler mechanism [8]. ^{6}Li, on the other hand, is not produced by this mechanism and is even more likely to be destroyed in stellar atmospheres. The formation of Li isotopes solely by galactic cosmic ray spallation would yield δ^6Li values of ~5000‰ [9]. The ^{6}Li excesses seen in these grains are

therefore likely not indigenous values from their parent stars, but rather the result of cosmic ray spallation produced either in the highly energetic, star-forming region close to the grains' AGB parent stars [3] or in the interstellar medium during travel to the solar system.
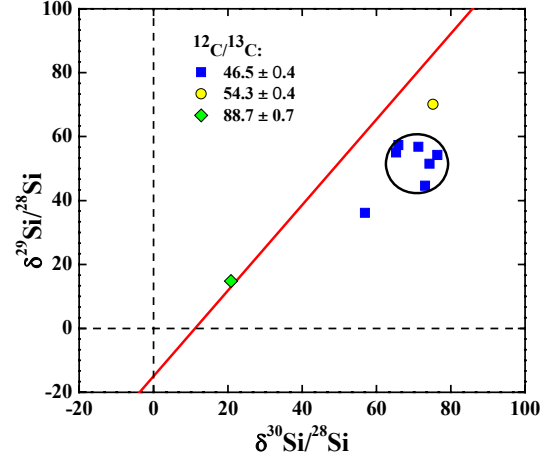
Figure 2. Silicon isotopic ratios of presolar SiC from the Murchison LS and LU separates, expressed as delta values. Different symbols correspond to different $^{12}C/^{13}C$ values, and the ellipse encapsulates grains thought to come from a single source. The mainstream correlation line (slope = 1.34) is also plotted.

Grain	Size (µm)	$\delta^6Li/^7Li$	$\delta^{10}B/^{11}B$	Li / Si	B / Si
1	60 x 60.5	108±36	37±14	$(3.6\pm0.3)\times10^{-8}$	$(3.0\pm0.02)\times10^{-6}$
2	8.5 x 5	57±33	-34±70	$(8.9\pm0.9)\times10^{-7}$	$(2.5\pm0.07)\times10^{-6}$
3	65 x 38	294±44	17±30	$(2.4\pm0.2)\times10^{-7}$	$(7.2\pm0.07)\times10^{-6}$
4	7 x 6	72±22	65±59	$(1.8\pm0.1)\times10^{-6}$	$(2.7\pm0.05)\times10^{-6}$
5	41 x 20	246±24	9±22	$(4.8\pm0.4)\times10^{-8}$	$(7.2\pm0.06)\times10^{-7}$
6	33 x 19	117±23	20±15	$(1.8\pm0.1)\times10^{-7}$	$(5.5\pm0.03)\times10^{-8}$
7	39 x 30	229±38	17±12	$(1.2\pm0.1)\times10^{-8}$	$(2.1\pm.009)\times10^{-6}$
8	7.5 x 7.5	128±17	40±17	$(3.7\pm0.4)\times10^{-7}$	$(4.3\pm0.07)\times10^{-6}$
9	11 x 8	65±26	38±20	$(3.0\pm0.2)\times10^{-7}$	$(5.8\pm0.04)\times10^{-6}$

Table 1: Measured Li and B isotopic compositions and atomic concentrations in grains from this study. Errors are 1σ.

References: [1] Virag A. et al. (1992) *GCA 56*, 1715-1733. [2] Amari S. et al. (1994) *GCA 58*, 459-470. [3] Lyon I. et al. (2006) *LPS XXXVII,* Abstract #1750. [4] Slodzian G. et al. (2004) *App. Surf. Sci. 231-232*, 874-877. [5] Huss G. et al. (1997) *GCA 61*, 5117-5148. [6] Hoppe et al. (2001) *ApJ 551*, 478-485. [7] Travaglio C. et al. (2001) *ApJ 559*, 909-924. [8] Sackman I.-J. and Boothroyd A.I. (1999) *ApJ 510*, 217-231. [9] Meneguzzi M. et al. (1971) *Astron. & Astrophys. 15*, 337-359.