**CONTINUED STUDY OF Ba ISOTOPIC COMPOSITIONS OF PRESOLAR SILICON CARBIDE GRAINS FROM SUPERNOVAE.** K. K. Marhas, P. Hoppe and U. Ott, Max-Planck-Institut für Chemie, Abteilung Kosmochemie, D-55020 Mainz, Germany (kkmarhas@mpch-mainz.mpg.de).

**Introduction:** Presolar grains condense in the winds or ejecta of evolved stars, thereby acquiring the characteristic isotopic compositions of the parent stars. Heavy elements such as Sr, Mo, Zr, and Ba in these grains have served as astrophysical diagnostic tools, which can be used to unravel the different nucleosynthesis and mixing processes taking place in the interior of the parent stars. In order to better understand the heavy element nucleosynthesis, we took up the project of Ba isotopic measurements in different types of presolar SiC grains.

Barium has seven stable isotopes. $^{130,132}$Ba are p-process isotopes, $^{134}$Ba and $^{136}$Ba are pure s-process isotopes and $^{135,137,138}$Ba have contributions from both the r- and s-process. In a previous report [1] we showed that Ba isotopic measurements of individual SiC mainstream grains with sizes >1 µm are feasible by NanoSIMS. A total number of 32 mainstream grains (1.0-2.6 µm) has been analysed since then. Our results are consistent with those obtained by TIMS for SiC bulk samples [2] and by RIMS for individual SiC mainstream grains [3]. The mainstream grains exhibit a Ba-isotopic pattern with depletions in $^{135,137,138}$Ba (Fig. 1). This signature is well explained by the s-process taking place in low-mass (1-3 $M_{\odot}$) AGB stars [3]. The Ba isotopic compositions of four SiC X grains from the Murchison meteorite, believed to originate from supernovae (SN), were reported by [4,5]. All X grains show patterns with lower than solar $^{135}$Ba/$^{136}$Ba, slightly lower than or close to solar $^{137}$Ba/$^{136}$Ba and higher than solar $^{138}$Ba/$^{136}$Ba, inconsistent with the classical r-/s-processes. This work is a continued effort to understand the heavy element (Ba) nucleosynthesis in the parent stars of X grains.

**Experimental:** The experimental work consisted of six parts: (a) separation of presolar grains, (b) Si ion imaging for the identification of type X grains, (c) SEM studies to verify that objects of interest are single grains, (d) short measurements of Si isotopes to verify the X grain signature, (e) ion imaging of $^{28}$Si and $^{138}$Ba to verify that Ba is intrinsic to the grain, and (f) Ba isotopic measurements.

Presolar SiC grains were chemically separated from the Murray and Murchison CM2 meteorites using methods similar to those of [6]. Compared to Murchison SiC grains, Murray grains are smaller in size (average size ~700 nm vs. ~1 µm).

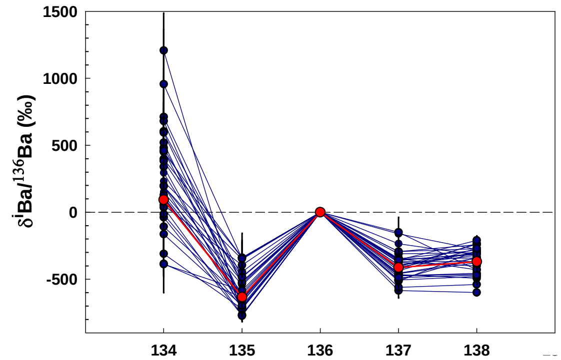


**Figure 1.** Ba isotopic compositions of 32 individual presolar SiC mainstream grains. Errors are 1σ. The red line indicates the average of all 32 mainstream grains.

To identify the rare X grains, Au mounts with SiC grains were screened in the IMS3f (Murchison) and NanoSIMS (Murray) ion microprobes. Silicon ion images were acquired in several areas, each 100 x 100 µm$^2$ (Murchison) and 30-40 x 30-40 µm$^2$ (Murray) in size (Fig. 2). Three X grains from Murchison were identified by the conventional ion imaging using $Cs^+$ as primary ions. The remaining X grains were found using $O^-$ as primary ions. This approach has the advantage of avoiding $^{133}CsH_x$ interference problems for the Ba measurements.

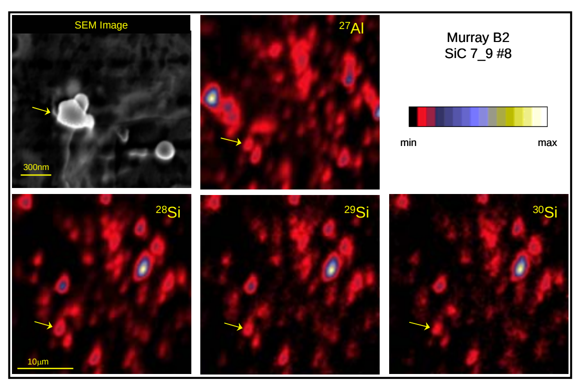


**Figure 2.** SEM image and $Al^+$ and $Si^+$ ion images for X grain SiC#7_9#8 (arrow). Field of view in the ion images is 30 x 30 µm$^2$.

Ten grains from Murchison and five grains from Murray were identified as X grains (large depletions in $^{29}$Si and $^{30}$Si, cf. Fig. 3). For Murray we identified in addition one Z grain (depletion in $^{29}$Si, large enrichment in $^{30}Si$) and one "strange" SiC grain with large enrichments in $^{29}Si$ and $^{30}Si$.

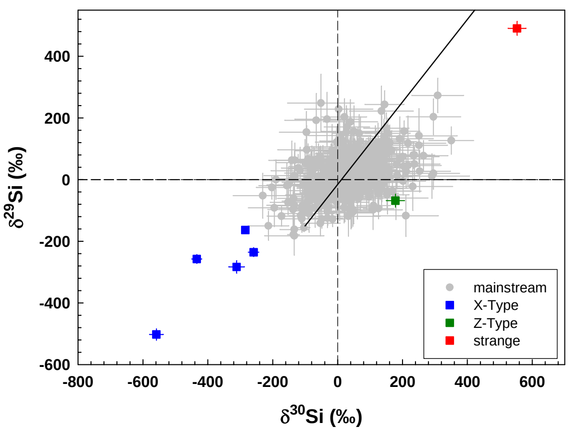


**Figure 3.** Si isotopic compositions of presolar SiC grains from Murray. Errors are 1σ. Mainstream grain data from ion imaging, data for the others from single grain studies.

The Ba isotopic ratios were measured in the 15 X grains, the Z and the "strange" grain. Positive secondary ions of $^{28}Si$, $^{88}Sr$, $^{90}Zr$, $^{133}Cs$, $^{134,135,136,137,138}Ba$, $^{139}La$, and $^{140}Ce$ produced by a primary $O^-$ ion beam of ~10 pA were analyzed in a combined multi-detection/peak-jumping mode. The primary beam was defocussed (~2 µm) for the Murchison grains and rastered (raster size ~2x grain size, beam diameter ~300 nm) for the Murray grains.

**Results:** Two of the Murray X grains, about 200 nm in size, showed no counts in Ba at all. The remaining three Murray X grains had sizes between 300 and 600 nm. For these grains the typical $^{138}Ba$ secondary ion signal was only 1 cps. The same holds for 7 Murchison grains of unknown size. In spite of the longest possible measurement times it was impossible to collect enough secondary ions to obtain sufficiently precise Ba data. Two Murchsion X grains (reported earlier by [4]) had sizes of 1.3 and 2.3 µm and the Ba count rates were high enough for obtaining Ba data with acceptable precision. The same holds for one Murchsion X grain of unknown size. These three X grains exhibit a pattern relative to $^{136}Ba$ and solar with depletions in $^{135}Ba$ and $^{137}Ba$ and enrichment in $^{138}Ba$. Relative to the mainstream grains $^{135}Ba/^{136}Ba$, $^{137}Ba/^{136}Ba$ and $^{138}Ba/^{136}Ba$ ratios are higher (Fig. 4).

**Discussion:** The expectations for Ba isotopic compositions in the SN X grains are enrichments in the r-process isotopes, i.e, in $^{135}Ba$, $^{137}Ba$, and $^{138}Ba$. A possible explanation for the depletion in $^{135}Ba$ and $^{137}Ba$ seen in the X grains is that the relatively long-lived radioactive $^{135}Cs$ and $^{137}Cs$ (half-lives of 2 Ma and 30 a, respectively) serve as shields in the r-process. Cs is a volatile element which is not expected to condense into SiC. From a Ti-V study of X grains it is known that the X grains condense within a year or so of the supernova explosion [7]. This may at least qualitatively explain the observed signature if in addition mixing with s-process Ba is considered.

The unusual Mo isotopic pattern of some X grains [5] is not consistent with predictions for the classical r- and s-process and a n-burst model has been invoked to account for the observed signature [8]. In this scenario n-capture reactions are taking place when the SN shock wave passes through He-rich matter. However, for Ba it is expected that $^{136}Ba$ is largely destroyed while $^{135}Ba$ is enriched and $^{137}Ba$ and $^{138}Ba$ remain essentially uneffected, a signature which is clearly incompatible with the Ba-isotopic signature of our three X grains. But again, shielding of $^{135}Ba$ and $^{137}Ba$ by $^{135}Cs$ and $^{137}Cs$ and mixing with s-process Ba can qualitatively produce the signature of the observed Ba isotopic patterns.

The work described here is complicated by the small size of most X grains and low Ba concentrations. Clearly, to get additional Ba data for X grains requires the identification of X grains with sizes > ~1.5-2 µm, making Murchison SiC grains the better target.

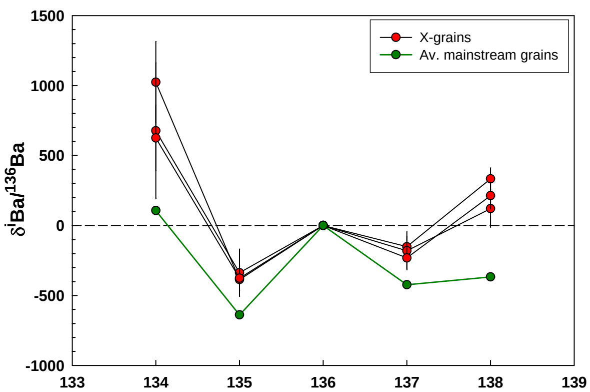


**Figure 4.** Ba isotopic compositions of presolar SiC X grains from Murchison. Errors are 1σ.

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**References:** [1] Marhas K. K. et al. (2003) *MAPS* **38**, A58.[2] Prombo C. A. et al. (1993) *ApJ* **410**, 393. [3] Savina M. R. et al. (2003) *GCA* **67**, 3201. [4] Marhas K. K. et al. (2004) *MAPS* **39**, A61. [5] Pellin M. J. et al. (2000) *LPSC* **31**, abstract #1917. [6] Amari S. et al. (1994) *GCA* **58**, 459. [7] Hoppe P. and Besmehn A.(2002) *ApJ* **576**, L69. [8] Meyer B. S. et al. (2000) *ApJ* **540**, L49.