THE DISTRIBUTION OF PRESOLAR GRAINS IN CI AND CO METEORITES. K. K. Marhas[1, 2], P. Hoppe[2], F. J. Stadermann[1], C. Floss[1] and A. S. Lea[3], [1]Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO 63130, USA, [2]Max-Planck-Institute for Chemistry, P.O Box 3060, Mainz 55020, Germany, [3]Pacific Northwest National Laboratory, Richland, WA 99352, USA. Email: kkmarhas@wuphys.wustl.edu

Introduction: Presolar grains have been identified by huge isotopic anomalies in the chemical residues from primitive meteorites. Recently, presolar silicates, which can not be separated by conventional chemical procedures, have been identified in-situ in polished thin sections [1-5]. To date, more than 100 presolar silicates have been reported from various type 3.0 unaltered primitive meteorites, with a maximum abundance reported for Acfer 094 of 180 ppm [4].

In addition to the information inferred from astronomical observations [e.g, 6-7], the abundance as well as mineralogy and chemical composition of presolar grains from different meteorite classes can help to understand (1) the different processes effecting the growth of these grains in circumstellar environments, (2) the variations/alterations taking place within different peterological types of meteorites, and (3) the destruction of grains in the ISM. A larger data set on presolar silicates from various meteorite classes is needed to obtain information on all of these aspects.

Previous work on the Tagish Lake meteorite indicated an abundance of 4 ppm for presolar silicates (matrix area covered ~ 29,250 μm^2) and also a probable carbonaceous presolar grain within the matrix area of 5,400 μm^2 [8]. Here, we report on the continued in-situ search for various types of presolar grains (oxides/silicates/nitrides/carbides) in the Tagish Lake meteorite and on new results of an in-situ search for presolar silicates and oxides in Yamato 81025.

Samples and measurement conditions: Tagish Lake has isotopic signatures lying between CM and CI meteorites and is considered to be the first representative of the CI 2 group. Yamato 81025 belongs to the CO 3.0 group. Both meteorites are thought to be rich in presolar grains [4, 8, 9].

The NanoSIMS ion microprobe (at the MPI, Mainz) was used in multi-detection mode, and raster images of 10x10 μm^2 (256 x 256 px) were obtained for the isotopes ^{16,17,18}O, ^{28}Si, and ^{27}Al^{16}O (oxide/silicate search; Fig. 1) and for ^{12,13}C, ^{14,15}N, and ^{28}Si (nitride/carbide search). A primary beam of Cs$^+$ (< 1 pA) with a diameter of less than 100 nm was used to collect 4 sets (layers) of images, with integration times of around 15 minutes each. Grains with anomalous O-isotopic compositions were considered to be presolar if (1) the anomaly is more than 4 σ away from the average of the surrounding matrix, (2) the grain covers more than 5 pixel, and (3) the anomaly is visible in at least two subsequent image planes.

The NanoSIMS was used in automatic imaging mode (chained analysis) and a total area of 42,850 μm^2 (silicates/oxides) and 34,200 μm^2 (carbides/nitrides), respectively, was scanned for Tagish Lake, and 21,520 μm^2 for Yamato 81025.

Seven out of 9 presolar grains from Yamato 81025 were later identified with the FE-SEM (at MPI, Mainz). For Tagish Lake it was impossible to identify any of the presolar grains in the FE-SEM.

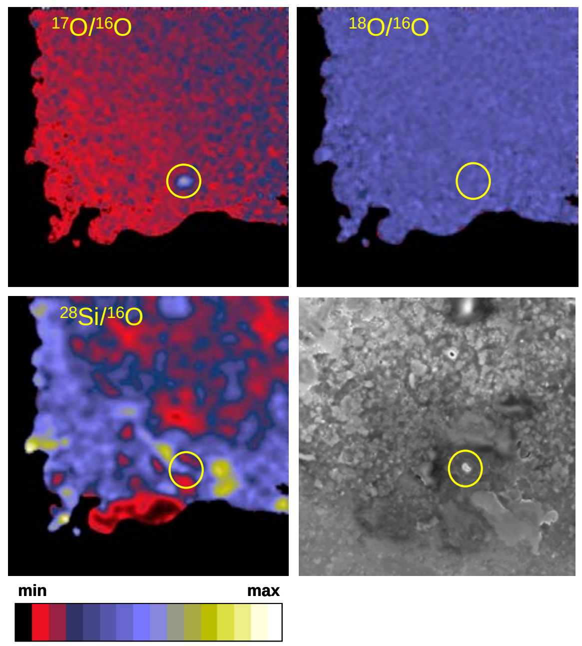

Figure 1. NanoSIMS ratio images and backscattered FE-SEM image indicating one of the presolar silicate grains in Yamato 81025. The field of view is 10x10 μm^2.

Results: Our continued search for presolar silicates in Tagish Lake yielded no additional grains. If we consider the results from our previous study (1 grain, 350 nm [8]) then the abundance of presolar silicates in Tagish Lake is around 2 ppm. However, seven presolar C-rich grains with sizes varying between 160 nm and 320 nm were identified within the fine-grained matrix of Tagish Lake. Two of the carbonaceous grains with low Si/C [^{28}Si$^-$/^{12}C$^-$ < 0.1] ratios seem to be presolar graphites, the rest are likely to be presolar SiCs (δ^{13}C ~ 265 ‰ to 560 ‰). The abundance of ~8 ppm calculated for SiC is consistent with results from combustion experiments [9]. The inferred abundance of graphite is ~4 ppm, thus the total abundance of carbonaceous presolar grains in Tagish Lake is ~12 ppm. Ninety-three isotopically anomalous grains with sizes from 200 to 500 nm are ^{15}N-rich with $\delta^{15}N$ ~ 150 to 700 ‰. The abundance of ^{15}N-rich presolar grains in Tagish Lake is calculated to be ~150 ppm.

In Yamato 81025 we found 9 presolar grains on the basis of their anomalous O-isotopic compositions, one of which, according to the Si/O ratio, is an oxide. The remaining 8 grains are probably silicates. The abundance calculated for presolar silicates is 36 ppm and that for oxides (based on only one grain) is 4 ppm.

Unfortunately, all the grains we have analysed so far are <400 nm and we were unable to get precise compositional information by SEM/EDX. To overcome this problem, several of the presolar grains from Yamato 81025 were analysed by high spatial resolution Auger spectroscopy for their major element composition [10, 11]. These analyses were complicated by the fact that the presolar grains were covered with an SEM-induced C layer after the NanoSIMS measurements. After sputter cleaning the section, the Auger measurements were successful for 3 of the presolar grains and their identification as silicates could clearly be confirmed. One of the analyzed presolar silicates was very Fe-rich and another was relatively Mg-rich compared to a variety of randomly selected reference grains from the same section. The third presolar silicate had intermediate Fe and Mg concentrations.

Determination of the mineralogy of presolar silicates can help constrain the conditions under which these grains formed in stellar outflows. An optimized analytical protocol that includes quantitative Auger spectroscopy immediately after the NanoSIMS measurements would help to establish a database which could then be used to determine stellar formation conditions as well as subsequent alteration processes in the solar system and interstellar medium.

Discussion: In an oxygen 3-isotope plot (Fig. 2), all presolar silicates from this study plot in the range defined as group 1 [12], except for the one from Tagish Lake, which falls into group 4. Group 1 grains exhibit large excesses in ^{17}O and a close to solar $^{18}O/^{16}O$, and are believed to have formed in winds of low- to intermediate-mass AGB stars [12]. 80 % of the presolar oxides and 70 % of presolar silicates fall into this group [4]. The rare group 4 grains have a more uncertain origin and could come either from supernovae or high metallicity AGB stars [12].

The low abundance of presolar silicates of 2 ppm in Tagish Lake can be explained in terms of aqueous alteration. Silicates are easily destroyed by aqueous alteration. Other type 2 meteorites studied for the presence of presolar silicates are NWA 530 (CR2), Murchison (CM2) and Renazzo (CR2) [2, 14, 15]. The reported abundance of presolar silicates in NWA 530 (CR2) and Murchison (CM2) meteorite is 3 ppm, similar to that reported here for Tagish Lake. No presolar silicates were found in Renazzo (CR2).

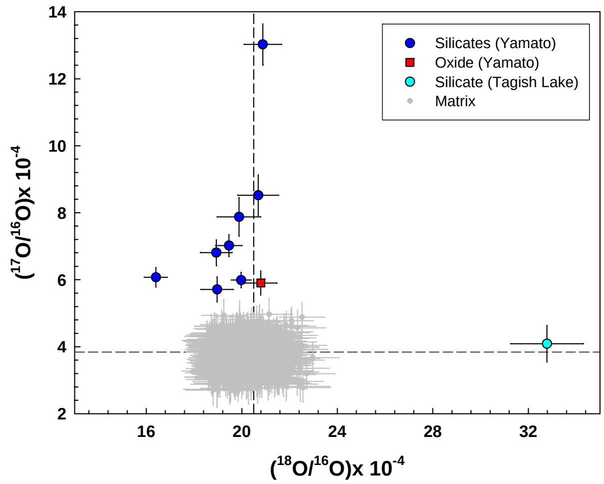

Figure 2: Oxygen 3–isotope plot of oxygen-rich presolar grains identified in Tagish Lake and Yamato 81025.

The presolar silicate abundance in Yamato was expected to be higher than actually observed in view of the results obtained by [3]. These authors reported an abundance of 58 ppm, using a Cameca IMS 1270 along with SCAPS in their search for presolar grains. The expectation of finding higher abundances using the NanoSIMS is based on the better spatial resolution of the NanoSIMS compared to SCAPS. SCAPS studies of Acfer 094 yielded an abundance of 8 ppm whereas the abundance observed by NanoSIMS was >100 ppm. It is currently not clear why these two methods yield comparable results in one case, but large differences in another. One possibility is a heterogeneous distribution of presolar silicates in Acfer 094. It is also possible that the size distribution of the presolar grains affects this comparison. More work and an improved statistical basis is clearly needed to obtain a better understanding of these differences.

References: [1] Mostefaoui S. and Hoppe P. (2004) *ApJ*, 613, L149-L152. [2] Nagashima K. et al. (2004) *Nature*, 428,921-924. [3] Kobayashi S. et al. (2005) *LPSC XXXVI*, Abstract # 1931. [4] Nguyen A. N. (2005) *Thesis*, Washington University, St. Louis. [5] Nguyen A. N. and Zinner E. (2004), *Science* 303, 1496-1499. [6] Waters L. B. F. M. et al. (1996) *A&A* , 315, L361-364. [7] Kemper F. et al. (2004) *ApJ*, 609, 826-837. [8] Marhas K. K. and Hoppe P. (2005) *MAPS*, 40, A95. [9] Grady M. et al. (2002) *MAPS*, 37, 713-735 [10] Stadermann F. J. et al. (2005) *MAPS* 40, A146. [11] Stadermann F. J. et al. (2006) *this conference.* [12] Nittler L. R. et al. (1997) *ApJ*, 483, 475-495. [13] Floss C. et al. (2005) *MAPS*, 40, A49. [14] Nagashima K. et al. (2005) *LPSC XXXVI*, Abstract # 1671 [15] Floss C. and Stadermann F. J. (2005) *LPSC XXXVI*, Abstract #1390.