IRON-ISOTOPIC COMPOSITIONS OF MAGNESIUM-25-RICH PRESOLAR SILICATE GRAINS FROM THE QUEEN ALEXANDRA RANGE 99177 METEORITE. P. Hoppe[1] and J. Leitner[1], [1]Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, 55128 Mainz, Germany (peter.hoppe@mpic.de).

Introduction: Primitive Solar System materials contain small quantities of presolar grains that formed in the winds of evolved stars and in the ejecta of stellar explosions [1]. Silicates make up the most abundant group of presolar grains with stellar origins [2]. They can be identified only in situ by ion imaging techniques, preferentially in the NanoSIMS. Originally it was thought that the vast majority of presolar silicates, making up O isotope Group 1 [3], formed in the winds of low-mass (1.2-2.2 M☉) asymptotic giant branch (AGB) stars of about solar metallicity [3, 4]. However, recent studies of O-, Mg-, and Si-isotopic compositions suggest that a significant fraction (~40%) of Group 1 silicate grains formed in intermediate-mass AGB stars, supernovae (SNe), and supergiants, based on observed Mg-isotopic anomalies [5-7]. Only some 60% of Group 1 silicate grains appear to come from low-mass AGB stars; these grains exhibit characteristic Mg- and Si-isotopic patterns established by Galactic chemical evolution (GCE) [7].

Here, we report on high-resolution O, Mg, Si, and Fe isotope measurements on five presolar silicate grains in the Queen Alexandra Range (QUE) 99177 CR2 chondrite. The major goal of this study is to expand the isotopic systematics of presolar silicates to Fe.

Experimental: In a first step we searched for presolar O-rich grains by O ion imaging with the NanoSIMS at MPI for Chemistry. For this purpose, a focused primary Cs^+ ion beam (~1 pA, 100 nm) was rastered over ~7000 μm^2 of fine-grained matrix material in a thin section of QUE 99177. The five identified presolar silicate grains, with sizes from 200 to 800 nm, were subsequently analyzed for Mg-, Si-, and Fe-isotopic compositions. For this purpose, a focused O^- ion beam (~0.5 pA, <100 nm) was rastered over 3×3 μm^2-sized areas around the presolar silicate grains, and positive secondary ion images of ^{24}Mg, ^{25}Mg, ^{26}Mg, ^{27}Al, and ^{28}Si (session 1; all grains), and of ^{24}Mg, ^{28}Si, ^{29}Si, ^{30}Si, ^{54}Fe, ^{56}Fe, and ^{57}Fe (session 2; three category A grains only, see below) were recorded in multi-collection and in a combined multi-collection/peak jumping mode, respectively. Oxygen-, Mg-, Si-, and Fe-isotopic ratios were normalized to those of the surrounding matrix and corrected for primary ion beam tailing [8, 9].

Results and Discussion: The five identified presolar silicates represent some 185 ppm of matrix material, in line with earlier studies [10-12]. Four of these grains are O isotope Group 1 grains, and one is a Group 4 grain. Three of the grains (two from Group 1, one from Group 4) are so-called category A grains, i.e., have Mg isotope anomalies >2σ [9].

In the following, we will concentrate on the two category A grains from Group 1 (M3_L@1-8-1, M3_M@1-4-1). These grains have $^{17}O/^{16}O$ ratios of 5.4 x 10^{-4} and 1.8 x 10^{-3}, respectively, and about solar $^{18}O/^{16}O$. Both are ^{25}Mg-rich, i.e., fall significantly (>3σ) above the slope 1 line in a Mg three-isotope-plot (Fig. 1). Silicon-29 is slightly depleted, $^{30}Si/^{28}Si$ about solar, and ^{54}Fe slightly enriched in both grains (relative to solar abundances). Grain M3_L@1-8-1 exhibits a significant (>3σ) enrichment in ^{57}Fe of ~17% (Fig. 2), as similarly observed for some SN SiC X grains [13].

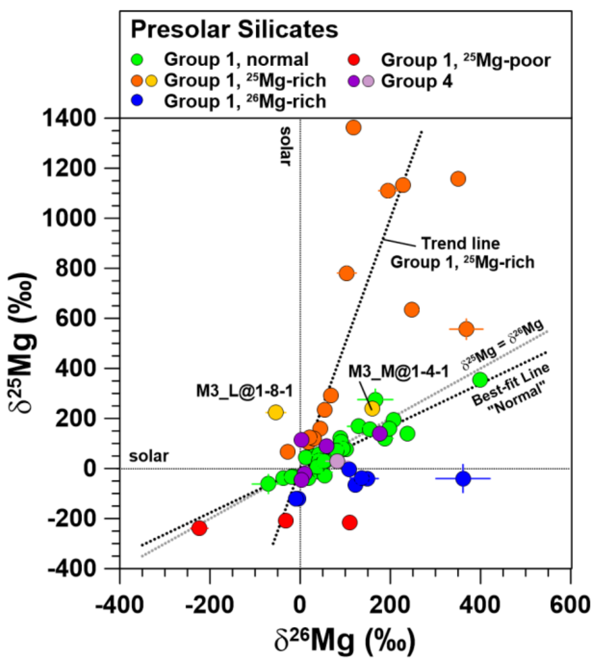

Figure 1. Mg-isotopic compositions of three presolar category A silicate grains from this study (yellow, light purple) along with data of Groups 1 and 4 grains from [5, 7]. Errors are 1σ.

Although grain M3_M@1-4-1 plots close to the slope 1 line in Fig. 1, which can be considered a good proxy for Galactic chemical evolution of Mg isotopes [7], its Si-isotopic composition clearly supports affinity to the subgroup of ^{25}Mg-rich Group 1 grains [7]. Core-collapse supernovae (SNe) and, for grains with ^{25}Mg anomalies of <300 ‰, also intermediate-mass (4-5 M☉) AGB stars of super-solar metallicities have been favored as stellar sources of ^{25}Mg-rich Group 1 grains [5, 7].

Core-collapse SNe that experienced H ingestion into the He shell prior to the explosion form a so-called O/nova zone [14] which shows strongly enhanced ^{25}Mg/^{24}Mg, while ^{26}Mg/^{24}Mg is much lower (Fig. 3). Mixing with matter from outer shells and the pre-SN wind can account for Mg- and Si-isotopic compositions of the subgroup of ^{25}Mg-rich Group 1 silicates [5, 7]. In the O/nova zone ^{57}Fe/^{56}Fe is strongly enhanced and ^{54}Fe/^{56}Fe depleted relative to solar (Fig. 3). Mixing matter from the O/nova zone with matter from the outer shell and pre-SN wind in appropriate proportions can account for observed Mg-, Si-, and Fe-isotopic compositions of grains M3_M1-4-1 (model 25T-H [14]) and M3_L@1-8-1 (model 25T-H10 [14]); all isotopic ratios are matched within a few percent (Fig. 2).

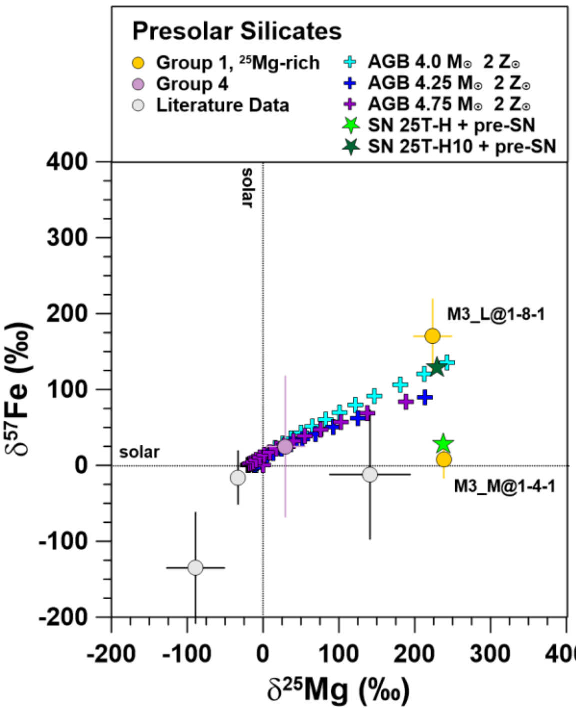

Figure 2. δ^{57}Fe vs. δ^{25}Mg of presolar ^{25}Mg-rich Group 1 and Group 4 silicate grains from this study (yellow, light purple) along with data of Group 3 and 4 grains from the literature [15] and model predictions for intermediate-mass AGB stars [16] and SNe [14]. Errors are 1σ.

Besides enrichments in ^{25}Mg, intermediate-mass AGB stars with super-solar metallicites are also expected to produce significant ^{57}Fe enrichments (Fig. 2) and δ^{25}Mg and δ^{57}Fe values of grain M3_L@1-8-1 can be matched [16] (Fig. 2). However, the negative δ^{26}Mg value of this grain (Fig. 1) is hard to reconcile with an origin from an AGB star of super-solar metallicity. In contrast, the ^{25}Mg enrichment and about solar ^{57}Fe/^{56}Fe ratio of grain M3_M@1-4-1 cannot be matched by the predictions for intermediate-mass AGB stars with super-solar metallicities [16].

In conclusion, models of SNe with H ingestion can well reproduce Mg-, Si-, and Fe-isotopic compositions of the two ^{25}Mg-rich Group 1 grains studied here; models of intermediate-mass AGB stars with super-solar metallicities are less successful. However, it remains to be seen whether studies of additional ^{25}Mg-rich Group 1 grains support these findings.

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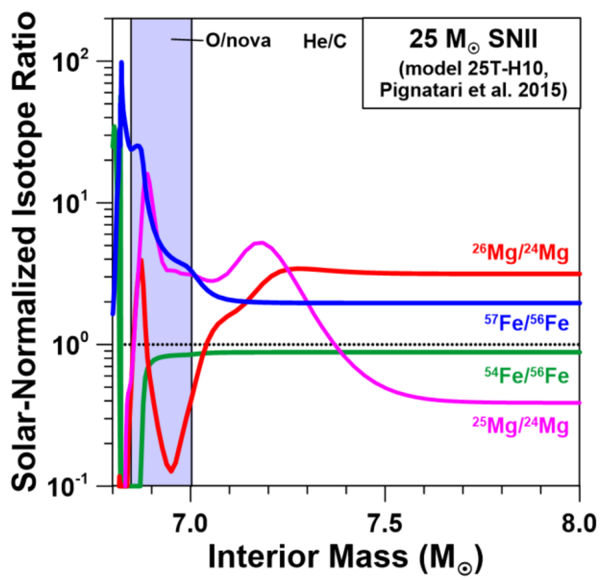

Figure 3. Profiles of solar-normalized Mg- and Fe-isotopic ratios in the interior (O/nova and He/C zones) of SN model 25T-H10 [14].

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