MG-ISOTOPIC COMPOSITION OF O-RICH PRESOLAR GRAINS IN UNEQUILIBRATED ORDINARY AND CARBONACEOUS CHONDRITES.

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Introduction: O-rich presolar grains (silicates and oxides) are found in the matrices of primitive chondrites [1]. Their often highly anomalous isotopic compositions are inherited from the nucleosynthetic processes that occurred within their parent stars. Presolar O-rich grains are typically identified by their O isotopic compositions measured by automated NanoSIMS isotopic mapping of chondrite thin sections. For the vast majority of O-rich presolar grains only their O isotopic compositions are known, whereas their minor and/or trace element isotopes are not well-documented. Correlating the O, Mg and Si isotope systematics of individual presolar grains is required to better understand the processes that formed them; however, in-situ spatially-resolved measurements of Mg isotopes are challenging [2].

Recent studies used the high-resolution Hyperion RF plasma O primary ion source for the NanoSIMS to measure Mg isotopes in ~100 presolar silicates [3–6]. These studies found: (i) A large fraction of grains had isotopically normal Mg and may have been re-equilibrated after formation; (ii) most of the Mg-anomalous grains have correlated anomalies in ^{25}Mg and ^{26}Mg, probably reflecting galactic chemical evolution (GCE); (iii) some Group 1 (G1) grains (^{17}O-rich, slightly ^{18}O-poor) grains fall off the main trend indicating distinct origins, including highly ^{25}Mg-rich grains that may have formed in Type-II supernovae (SNII) or super-AGB stars and ^{25}Mg-poor and/or ^{26}Mg-rich grains that likely formed in SNII or red supergiants; (iv) silicon isotopes tend to follow the trend seen for presolar SiC grains, reflecting GCE.

Almost all grains analyzed so far are from carbonaceous chondrites (CC). However, the systematic offset observed by [7] in many bulk nucleosynthetic isotope anomalies between CCs and ordinary chondrites (OCs) ("CC-NC dichotomy") suggests that presolar grain distributions may be different as well. We recently obtained a large dataset on presolar grains in unequilibrated ordinary chondrites (UOC) [8]. Here we report Mg and Si data for many of these grains as well as a large number from two highly primitive CCs.

Samples and Methods: We measured the Mg and Si isotopic compositions of O-rich presolar grains (mostly silicates) that were found in previous studies of the following unequilibrated carbonaceous and ordinary chondrites: Asuka 12169 (CM 2.7–2.9, 72 grains [9]), Miller Range 090657 (CR2.7, 29 grains [10]), Semarkona (LL3.00, 20 grains [8]), Meteorite Hills 00526 (L/LL3.05, 56 grains [8]) and Northwest Africa 8276 (L3.00, 5 grains [8]).

We used the Carnegie NanoSIMS 50L with a Hyperion RF primary ion source to analyze $^{24–26}$Mg, ^{27}Al, and $^{28–30}$Si isotopes in multicollection mode, with a ~2 pA O^- primary beam. The presolar grain isotopic ratios were normalized to the surrounding matrix. Unlike the study of [5], we did not correct our data for isotope dilution from surrounding materials, since modeling indicates such corrections may be unreliable [8].

Results: We have analyzed 101 O-rich presolar grains in CC samples and 81 grains in UOC samples. In addition, we discovered 15 Mg-anomalous grains that were not visible in the original O measurements, either because they are not anomalous in O, or they were still buried during O analysis. Almost all grains have Mg-anomalous compositions of >2σ (Category "A" grains as defined by [4]). The Mg isotopic compositions of most grains fall in-between –200 to +300 ‰ in δ^{25}Mg and –100 to 300 ‰ in δ^{26}Mg (Fig. 1) with a majority plotting along the δ^{25}Mg=δ^{26}Mg trendline, which probably represents GCE [4]. We also detected both ^{25}Mg-poor and ^{25}Mg-rich grains that clearly fall off the GCE trendline. A presolar hibonite (A12169-23, [9]) lies outside the plot with δ^{26}Mg = 1174 ‰, reflecting in-situ decay of ^{26}Al. Three G1 grains from CCs and one from a UOC are similar to previously reported ^{25}Mg-rich G1 grains [3, 5, 6], though the ^{25}Mg enrichments (δ^{25}Mg up to 854 ‰) do not reach the highest values seen before (up to ~2200 ‰ [6]). Additionally, one Group 4 (G4) (^{18}O-rich) grain, A12169-25, is highly ^{25}Mg-rich with a slight ^{26}Mg depletion (Fig. 1).

More than half of all grains measured are isotopically normal in Si. Most grains with anomalies range from –100 ‰ to 200 ‰ in δ^{29}Si and in δ^{30}Si. They largely plot along the SiC mainstream line as seen previously [5]. The few outliers have relatively large errors due to counting statistics.

Discussion: The Mg and Si isotopic distributions observed here for presolar O-rich grains generally overlap with data previously reported in the literature (Fig. 1). There are no obvious systematic differences in the Mg isotopic compositions of presolar O-rich grains in UOCs and CCs and their compositions overlap well in Fig. 1. However, the abundance of highly ^{25}Mg-rich G1 grains appears to be substantially lower in the UOCs than CCs (e.g., grains with δ^{25}Mg>400 ‰ make up 1.5 % of G1 grains in the former and 6 % of G1 grains in the latter). This could reflect a heterogeneous distribution of such grains in the solar nebula, perhaps related to the CC-NC dichotomy. However, the statistical significance of the difference is not high, due to the small number of grains, and thus the difference may be a fluke.

The possible origins and implications of the various Mg isotope groups for presolar grains have been discussed in detail in the literature [5, 11, 12]. We focus here on two interesting grains from Asuka 12169.

A12169-17 is an Al-rich silicate with a ^{25}Mg-rich G1 signature (Fig. 1). Prior studies [3, 5] have proposed that these grains originated in SNII in which H has been ingested into the He shell leading to explosive H-burning nucleosynthesis during the SN explosion, since calculations predict large ^{25,26}Mg excesses with ^{25}Mg>^{26}Mg in an "O/nova zone" [13]. However, explosive H-burning produces copious ^{26}Al as well and the model predicts this zone to have ^{26}Al/^{27}Al>1 [13]. Based on the mixing calculations of [3, 5], we estimate that a grain with the observed ^{25}Mg/^{24}Mg ratio originating from such a stellar site would have ^{26}Al/^{27}Al>0.1 (corresponding to δ^{26}Mg>1000 ‰ for A12169-17). In contrast, we estimate a much lower upper limit of ^{26}Al/^{27}Al<0.03 for this grain based on the assumption that its measured 20 % ^{26}Mg excess is solely due to ^{26}Al decay. This result suggests that H-ingestion SNII are not the origin of ^{25}Mg-rich G1 grains and other sites (e.g., super-AGB stars) should be investigated in more detail.

A12169-25 is a G4 grain (δ^{17}O≈0 ‰, δ^{18}O≈+500 ‰) with a unique Mg-isotope composition (Fig. 1). G4 grains are generally thought to originate in SNII [11, 14], but this conclusion is based on multi-element data for a very small number of grains. Most G4 grains with Mg anomalies are ^{26}Mg-rich and ^{25}Mg-poor, consistent with SNII mixing models. In contrast, the unusual ^{25}Mg-rich, ^{26}Mg-poor signature of A12169-25 is not predicted in any SNII zone [15]. Moreover, this grain belongs to the class of G4 silicates with ~solar ^{17}O/^{16}O, an unlikely composition to arise from mixing of zones within a single SNII. Additional investigations are needed to better understand the origin(s) of these grains.

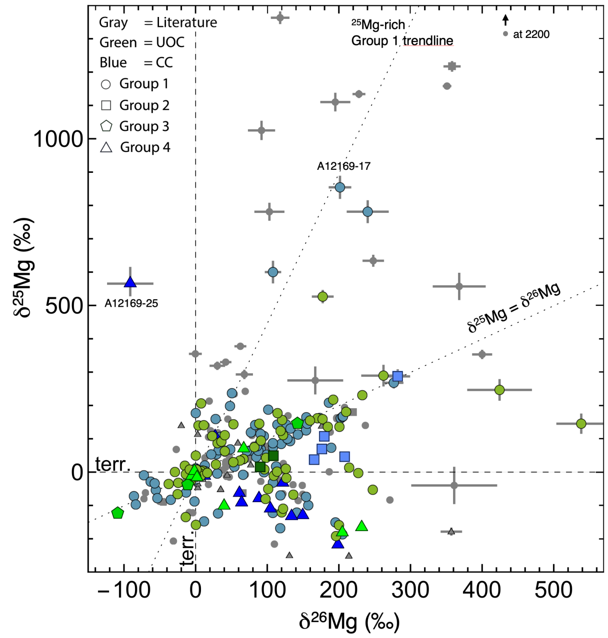

Fig. 1: Mg-isotopic composition of presolar O-rich grains from ordinary and carbonaceous chondrites compared to literature data of carbonaceous chondrites [2, 5, 6]. The ^{25}Mg-rich Group 1 trendline was taken from [5]. We note that the literature data by [5] are corrected for isotope dilution, and our data are not. Errors are 1σ.

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