HIGH PRESOLAR SILICATE ABUNDANCE IN GIANT CLUSTER IDP U2-20GCA OF PROBABLE COMETARY ORIGIN.

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Introduction: Chondritic porous interplanetary dust particles (CP-IDPs) are thought to originate from comets rather than asteroids due to their textures, mineralogy, chemical compositions, and high abundance of presolar grains. The giant cluster IDP U2-20GCA was collected in the upper atmosphere and is thought to have been ~350 μm in diameter before hitting the collector. Due to its fragile and porous nature, the IDP pancaked during collection and its particles span a region >1.5 mm. The IDP is comprised of thousands of anhydrous sub-μm to ~40 μm sized grains. U2-20GCA shares many similarities to comet 81P/Wild 2 samples [1-5], including mineral diversity, noble gas composition, O isotopic compositions of coarse silicates, and high abundances of nebular and presolar materials, thus making a cometary origin highly likely.

Presolar silicate grains are affected by parent body aqueous alteration such that more pristine samples retain higher abundances. Many CP-IDPs have high presolar silicate abundances [e.g., 6-8], similar to the calculated abundance in comet Wild 2 [9]. Whereas IDPs are typically ~20 μm in size, the significantly larger mass of U2-20GCA allows for a more accurate presolar grain abundance determination. We are conducting coordinated isotopic and mineralogical studies of fine grains from U2-20GCA. Initial analyses indicated abundant presolar grains and anomalous organic matter [2], and identified an ^{16}O-rich early Solar System enstatite condensate [10]. As with Wild 2 samples, the presence of ^{16}O-rich refractory grains in U2-20GCA infers large-scale mixing of inner Solar System material out to the comet forming region.

Sample and Methods: *Sample preparation:* Fine-grained particles (sub-μm) were placed on a glass slide using a needle. U2-20GCA was collected in silicone oil, so a hexane wash was used to remove this oil. Particles from the glass slide were repeatedly collected onto a 50 μm-sized silicone rubber, acrylic, or epoxy mesa until the desired concentration of fines was achieved. The mesa was then embedded into acrylic or epoxy and microtomed. A series of the 70 nm-thick microtome slices were placed on TEM grids for mineralogical analysis while adjacent series of slices were placed on clean Au foil for NanoSIMS isotopic analysis.

NanoSIMS analysis: Isotopic analysis was performed with the JSC NanoSIMS 50L. A focused Cs^+ primary ion beam of ~0.7-1 pA was rastered over 20 μm fields of view, 512×512 pixels, on a microtome slice. 60 layers were measured for each analyzed area. The isotopes ^{16}O, ^{17}O, ^{18}O, ^{12}C^{14}N, ^{12}C^{15}N, ^{28}Si, and ^{24}Mg^{16}O were measured simultaneously as negative ions. An electron flood gun was used for charge compensation. Individual San Carlos olivine grains and 1-hydroxy benzotriazole hydrate served as external isotopic standards for O and N, respectively.

Results and Discussion: A total area of ~70 μm^2 was analyzed over 5 imaged regions. 59 areas 1 μm in size or smaller showed enrichments in ^{15}N up to ~800 ‰. These enrichments fall within the range observed in other CP-IDPs and meteorites [e.g., 11,12] and are likely associated with organic matter that originated in the molecular cloud or protoplanetary disk. Five grains 150 – 310 nm in size had O isotopic anomalies that deviated by at least 4σ from Solar System material. These grains are likely silicates based on their ^{28}Si/^{16}O and ^{24}Mg^{16}O/^{16}O ratios. We are working to coordinate the grain locations with the adjacent TEM microtome slices to obtain the mineralogy and chemical compositions of the grains.

The O isotopic compositions of the anomalous grains are shown in Figure 1 along with presolar oxides and silicates. Two of the grains are enriched in ^{17}O and condensed in the stellar outflows of red giant branch or asymptotic giant branch stars. Two grains are enriched in ^{18}O and are most likely supernova (SN) condensates [13,14]. One grain is depleted in both ^{17}O and ^{18}O (δ^{17}O = -199 ± 59 ‰; δ^{18}O = -117 ± 27 ‰). Refractory inclusions that condensed in the early Solar System have ^{16}O-rich compositions that extend to ~ -50 ‰ along the carbonaceous chondrites anhydrous minerals (CCAM) mixing line. The grain in this study has a more ^{16}O-rich composition than observed for early Solar System condensates and does not fall on the CCAM line, but its composition is similar to other presolar grains. Presolar grains that are ^{17}O- and ^{18}O-poor could have origins in low-metallicity stars or SNe. It has been argued that grains having ^{17}O and ^{18}O depletions and ^{18}O/^{17}O ratios higher than the solar value of 5.2 are likely SN grains [15]. The ^{17}O- and ^{18}O-poor grain from this study has a ^{18}O/^{17}O ratio of 5.8 and is a plausible SN condensate.

We determined a presolar silicate abundance of 3360 ppm for U2-20GCA based on the total O-rich area analyzed. Note that this is the abundance among the fine-grained material and the bulk abundance for this IDP would be lower. While the provenance of IDPs are not unequivocally known, IDPs L2054 G4 and E1 were captured during the targeted comet Grigg-Skjellerup dust stream collection and have very high presolar silicate abundances of 15,000 ppm and 3500 ppm, respectively [6]. The high abundances of presolar grains and molecular cloud material in these L2054 IDPs support an origin in comet Grigg-Skjellerup [6]. The initial presolar grain abundance in comet Wild 2 was estimated to be 600-830 ppm [9]. The high presolar silicate abundance in U2-20GCA and the parallels to Wild 2 samples previously mentioned make a cometary origin for this IDP highly probable.

While ~12% of all presolar silicate and oxide grains have O isotopic compositions that are consistent with condensation in SN outflows, our analysis of U2-20GCA thus far indicates a much greater abundance of SN grains (3 out of 5 presolar silicates, or 60%). Of course the errors are large due to limited statistics, but this finding is similar to that for IDP L2054 G4, where 4 out of 7 presolar grains were ^{17}O-poor and likely SN grains [7]. In fact on average, IDPs have over three times higher abundances of SN silicates and oxides (~40 %) than chondrites (~12 %) [data from 16]. This can be seen in Figure 1 where IDPs have a higher proportion of SN grains; i.e., ^{18}O-rich grains and ^{17}O-, ^{18}O-poor grains with ^{18}O/^{17}O >5.2. A similar enrichment of SN grains was not observed in Wild 2 samples, where 1 of the 5 identified presolar O-rich grains was a SN condensate [9,17]. Studies of Antarctic micrometeorites (AMMs) also indicate greater abundances of SN grains [18,19]. A 27% abundance of ^{18}O-rich SN grains was found within a large analyzed area of AMMs (39,900 μm^2) [19]. These observations all suggest that the parent bodies of IDPs and AMMs sample regions of the solar nebula that was enriched in SN grains relative to the regions sampled by meteorite parent bodies. This heterogeneous distribution of presolar grains in the solar nebula could be explained by injection of material from a nearby SN explosion. The amount of material available for analysis is much lower in IDPs compared to meteorites and AMMs, but further isotopic analysis of the giant IDP U2-20GCA will improve the statistics to verify whether this IDP truly contains a significant abundance of SN grains.

The bulk O (δ^{17}O = -3.9 ± 4.4 ‰, δ^{18}O = -6.1 ± 1.9 ‰) and N (δ^{15}N = 181 ± 2.8 ‰) isotopic compositions of the analyzed fine-grained material of U2-20GCA fall within the range of compositions observed for bulk anhydrous IDPs [20,21]. The bulk O isotopic composition of U2-20GCA lies above, but within 2σ error of, the CCAM line. While the anhydrous IDPs studied by [20] fall along the CCAM line, all of the anhydrous IDPs studied by [21] lie above the CCAM line, which they explained as ^{17}O enhancement due to the presence of abundant ^{17}O-rich presolar silicates. Excluding the presolar silicates shifts the bulk O isotopic ratio of U2-20GCA to within 1σ of the CCAM line. The bulk ^{15}N enrichment of U2-20GCA is modest and does not represent sample primitiveness as assessed by the presolar silicate abundance.

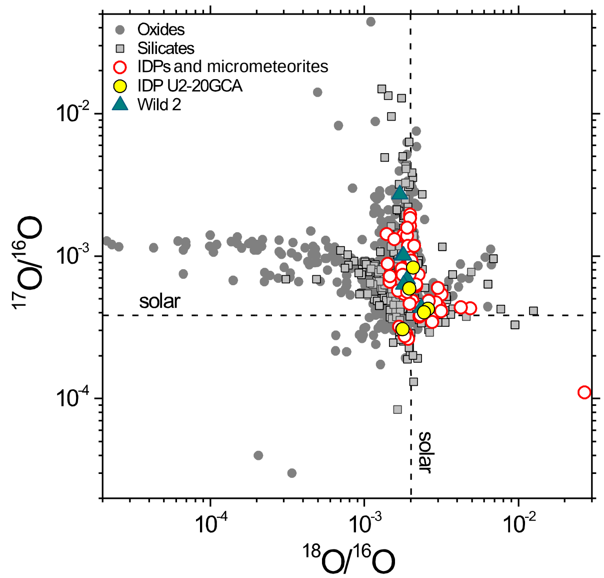

Figure 1. O isotopic ratios of presolar silicates from U2-20GCA found in this study compared to presolar silicates and oxide grains from the Presolar Grain Database [16].

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