MINERALOGY OF PRESOLAR GRAINS OF VARIED STELLAR ORIGINS IN GIANT CLUSTER IDP U2-20GCA.
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Introduction: Chondritic porous interplanetary dust particles (CP-IDPs) are among the most primitive astromaterials available for study. Their textures, chemical compositions, and mineralogy are suggestive of cometary origins. Presolar silicates and glass with embedded metal and sulfides (GEMS) are abundant constituents in CP-IDPs [1-6] and are rapidly altered or destroyed by parent body hydrothermal alteration [7]. The relative depletion of these grains in chondrites [8] indicates the more altered nature of chondrite parent bodies compared to those of CP-IDPs. Presolar grain abundances determined in IDPs, however, incur much larger uncertainties than abundances in chondrites owing to the limited amount of material available for analysis and calculation based on a few presolar grains. While CP-IDPs are typically less than ~20 µm, the giant cluster IDP U2-20GCA is uniquely large and was estimated to have been ~350 µm in size. The porous nature, abundant anhydrous mineralogy, and similarities to comet 81P/Wild 2 samples suggest U2-20GCA has a cometary origin [9-11].

We have been analyzing the fine-grained material from U2-20GCA to refine the abundance of presolar grains in IDPs [12] and to determine the mineralogy of these grains. Relatively few presolar grains in IDPs have been analyzed for their mineralogy and our studies aim to expand the mineralogical characterization of presolar grains in these likely cometary particles.

Sample and Methods: *Sample Preparation:* Sub-µm grains were scooped from the original flag that U2-20GCA was collected on and placed between two glass slides that were moved gently to disaggregate clumps. The two slides were washed with hexane to remove silicone oil and heated in air at 500 °C to burn off carbon and organics. Particles were concentrated onto a small area of an ~45×120 µm^2 epoxy mesa by repeated "stamping". A thin film of epoxy was put on the mesa and 60 nm-thick microtome slices were prepared. Alternate serial slices were placed on C-coated TEM grids for mineralogical characterization and on Au foil mounts for NanoSIMS isotopic analysis.

NanoSIMS Analysis: Four microtome slices were analyzed for C and O isotopes, ^{28}Si, and ^{24}Mg^{16}O using the CAMECA NanoSIMS 50L at NASA JSC to search for isotopically anomalous C-rich and O-rich grains. These isotopes were analyzed simultaneously by rastering a ~1 pA Cs$^+$ primary beam focused to ~100 nm over 20 µm fields of view for multiple planes. The C and O isotopic ratios were corrected for instrumental mass fractionation using USG-24 graphite and San Carlos olivine, respectively.

TEM Analysis: Three presolar grains that were identified in one of the microtome slices on Au foil were located in an adjacent slice that was placed on a TEM grid. The grains were analyzed for their microstructures and chemical compositions using the JEOL 2500SE field-emission scanning transmission electron microscope (STEM) at NASA JSC. Elemental maps were acquired in STEM mode using a JEOL 60 mm^2 silicon drift detector using a 2 nm incident probe. Bright-field (BF) and dark-field (DF) STEM images and selected area electron diffraction (SAED) patterns were also acquired. NanoSIMS analysis of these three grains are planned to confirm that they are also isotopically anomalous.

Results and Discussion: A total area of 860 µm^2 was analyzed by NanoSIMS and 16 presolar grains were identified (Fig. 1). Grain sizes ranged from ~265–450 nm. Grain S5_3 has an extremely large enrichment in ^{17}O (^{17}O/^{16}O = (5.12 ± 0.05) × 10^{-3}) and is likely a nova grain. Mg and Si isotopic analyses of S5_3 are planned to constrain the stellar source. Eleven grains have ^{17}O enrichments up to ~2500 ‰ and near-terrestrial ^{18}O/^{16}O. These grains most likely come from asymptotic giant

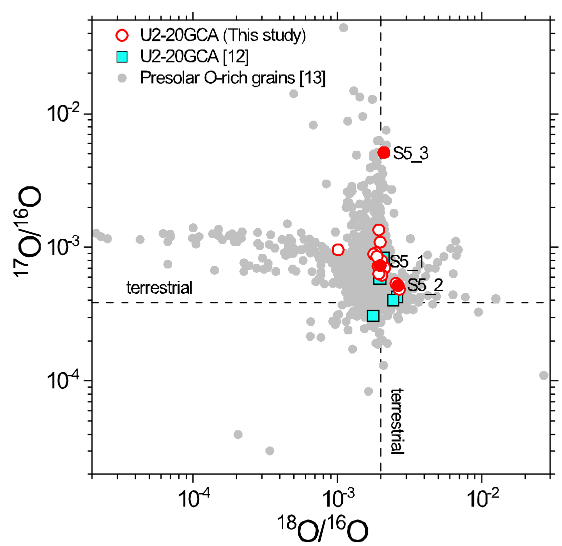

Fig. 1. O isotopic ratios of presolar grains from U2-20GCA (this study, [12]) and the literature [13]. TEM data were acquired for grains shown as filled red points.

branch (AGB) stars, but some could have supernova (SN) origins [14]. The ^{17}O-rich and ^{18}O-poor grain likely came from an AGB star that experienced extra mixing processes. The three ^{18}O-rich grains are SN grains. Thirteen of the presolar grains had NanoSIMS ^{28}Si/^{16}O ratios that are typical for silicates. One ^{17}O-rich grain, the ^{18}O-poor grain, and ^{18}O-rich SN grain S5_2 had low ^{28}Si/^{16}O ratios and could be oxide grains. Of the three possible oxides, S5_2 had a relatively high ^{24}Mg^{16}O/^{16}O ratio. No C-rich anomalous grains were identified.

The moderate ^{17}O enrichment of grain S5_1 (905 ‰) suggests an AGB star origin rather than a SN origin. However, a SN source cannot be ruled out without measuring its Mg isotopic ratio. TEM analysis of S5_1 found it to be an ~500 nm S-poor GEMS grain (Fig. 2) with at.% ratios of Mg/Si=0.67, S/Si=0.02, and Fe/Si=0.78. The GEMS grain contains nanophase FeNi grains but FeNi sulfides are essentially absent. The majority of presolar grains identified in IDPs are GEMS [15, 16] and the survival of presolar GEMS in U2-20GCA is further support that it is cometary.

Nova grains are extremely rare (~1% of presolar grains) and few have been studied by TEM. Plucking during microtomy resulted in very little material remaining of nova grain S5_3 in the microtome section analyzed by TEM. However, our preliminary analysis indicates the remaining material is a ~200 nm GEMS grain with at.% ratios Mg/Si=0.86 and Fe/Si=0.48. Sulfur was below detection limits. We plan to analyze an additional microtome slice containing S5_3 by TEM. If the phase identification is confirmed, this would be the first nova GEMS grain identified.

SN grain S5_2 is a composite grain consisting of an ~100 nm euhedral Mg-Fe oxide grain with adhering S-poor GEMS-like material (Fig. 3). The electron diffraction data are consistent with a spinel-structured oxide similar to magnesioferrite ($MgFe_2O_4$). The oxide and GEMS material occur in two adjacent grains, which likely separated from each other during sample preparation. One other compound presolar oxide and silicate grain was identified previously in a CP-IDP [6]. This AGB grain is a crystalline spinel ($MgAl_2O_4$) with an amorphous Mg-rich silicate mantle having an elemental composition within the range for bulk GEMS. These two compound oxide-silicate grains trace the changing conditions during condensation in their parent stellar atmospheres, one of which was a circumstellar envelope and the other a SN outflow.

Presolar grain abundances in anhydrous IDPs display a wide range from ~150 ppm to 1.5% ([6] and references therein), with many having much greater abundances than chondrites. The abundance of presolar grains in U2-20GCA was determined by dividing the area of presolar grains by the total area analyzed. In this study we determine an abundance of O-rich presolar grains to be 1105^{+351}_{-273} ppm (1σ). Combined with our previous study of fines from U2-20GCA [12], we have an abundance of 1280^{+344}_{-277} ppm. This abundance is similar to that in comet Wild 2 (600-830 ppm; [17]) and is significantly greater than the abundance in even the most unmetamorphosed chondrites. Our continued studies of this giant cluster IDP will further refine the abundance and characteristics of presolar grains in a likely cometary parent body.

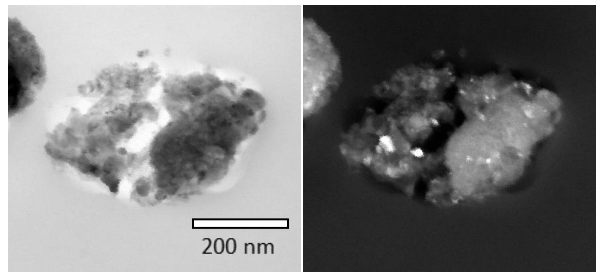

Fig. 2. BF (left) and DF (right) STEM images of ^{17}O-rich GEMS grain S5_1. The nanophase FeNi grains are apparent in the DF STEM image.

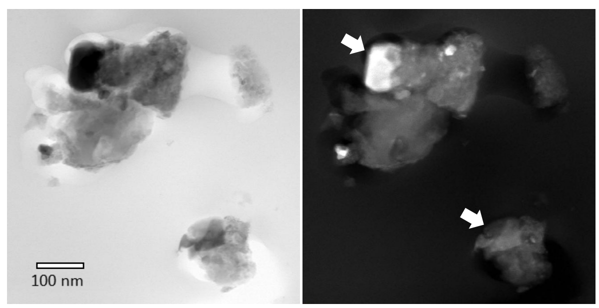

Fig. 3. BF (left) and DF (right) STEM images of SN grain S5_2. The arrows indicate the crystalline oxides, which are associated with GEMS material.

References: [1] Bradley J.P. (1994) *Science. 265,* 925-929. [2] Messenger S. et al. (2003) *Science. 300,* 105-108. [3] Busemann H. et al. (2009) *EPSL. 288,* 44-57. [4] Floss C. et al. (2011) *MAPS. 45,* 1889-1905. [5] Davidson J. et al. (2012) *MAPS. 47,* 1748-1771. [6] Nguyen A.N. et al. (2022) *GCA. 336,* 131-149. [7] Nakamura-Messenger K. et al. (2011) *MAPS. 46,* 843-856. [8] Floss C. and Haenecour P. (2016) *Geochem. J.. 50,* 3-25. [9] Joswiak D.J. et al. (2017) *MAPS. 52,* 1612-1648. [10] Zhang M. et al. (2021) *EPSL. 564,* 116928. [11] Pepin R.O. et al. (2015) *LPS. XLVI,* Abstract #1705. [12] Nguyen A.N. et al. (2020) *LPS*, Abstract #2487. [13] Hynes K.M. and Gyngard F. (2009) *LPS. XL,* Abstract #1198. [14] Hoppe P. et al. (2022) *Nat. Astron. 6,* 1027-1034. [15] Keller L.P. and Messenger S. (2011) *GCA. 75,* 5336-5365. [16] Floss C. et al. (2006) *GCA. 70,* 2371-2399. [17] Floss C. et al. (2013) *ApJ. 763,* 140-150.