OXYGEN ISOTOPE SYSTEMATICS OF CRYSTALLINE SILICATES IN A GIANT CLUSTER IDP: A GENETIC LINK TO WILD 2 PARTICLES AND PRIMITIVE CHONDRITE CHONDRULES.

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Introduction: Anhydrous IDPs are one of the most primitive extraterrestrial materials that likely originated from outer solar system comets. They are similar to comet Wild 2 particles returned by the "*Stardust*" mission and primitive chondrite materials in regards to (i) major components, i.e. forsteritic olivine, magnesian pyroxene, Fe-Ni metal, Fe-sulfide, silicate glass, and carbonaceous materials; (ii) occurrences of CAIs, AOAs, and chondrules [1, 2].

While mineralogical observations indicate possible genetic relationships among anhydrous IDPs, Wild 2 particles, and primitive chondrite materials, their isotope signatures provide additional information to their relationships and significance. Here we determined the oxygen isotope ratios of crystalline silicate particles extracted from a giant cluster IDP (GCIDP), U2-20GCA, to better understand the genetic relationships of these three.

Sample and methods: U2-20GCA was collected in the stratosphere by a NASA U2 aircraft. It is extremely porous and fragile, consisting of a ~ 350 µm core of thousands of dark and transparent particles (up to 42 µm), surrounded by a ~ 1 mm low density debris halo [3]. Coarse-grained (≥ 5 µm) particles were extracted from its core for TEM mineralogical examination and SIMS oxygen isotope analysis. The sample preparation procedures and TEM analytical conditions are described in [3].

Oxygen isotope ratios of these particles were determined using the WiscSIMS IMS 1280. A focused Cs^+ primary beam with a size of ~ 2 × 1.5 μm^2 and an intensity of 2.5-3 pA was utilized. The analytical errors (2SD) for $\delta^{18}O$, $\delta^{17}O$, and $\Delta^{17}O$ are typically ≤ 2‰. The analytical condition and procedures are similar to those described in [4, 5].

Results: A total of 20 particles with a longest dimension ranging from 5 µm to 35 µm were studied. Six particles are monomineralic and 9 are polymineralic, all dominated by olivine and/or pyroxene. Five particles are chondrule-like (i) LT11 and LT24 are dominated by enstatite and feldspar/feldspathic glass; (ii) LT17 and LT23 have barred-olivine textures consisting of olivine bars, chromite, and mesostasis; (iii) LT410 is composed of forsterite with minor anorthite and Al-diopside and may be an Al-rich chondrule fragment (Fig. 1). The Mg# [atom% Mg/(Mg+Fe)] of olivine and pyroxene

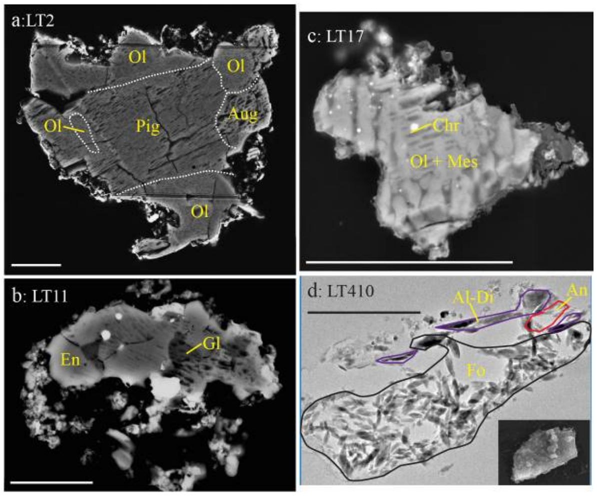

Fig. 1. BSE images of a polymineralic (LT2) and two chondrule-like particles (LT11 and LT17), as well as a TEM bright-field image of a chondrule-like particle LT410. Scale bars are 5 µm. Ol = olivine; Pig = pigeonite; Aug = augite; Chr = chromite; Mes = mesostasis; En = enstatite; Gl = glass; Al-Di= Al-diopside; Fo = forsterite; An = anorthite.

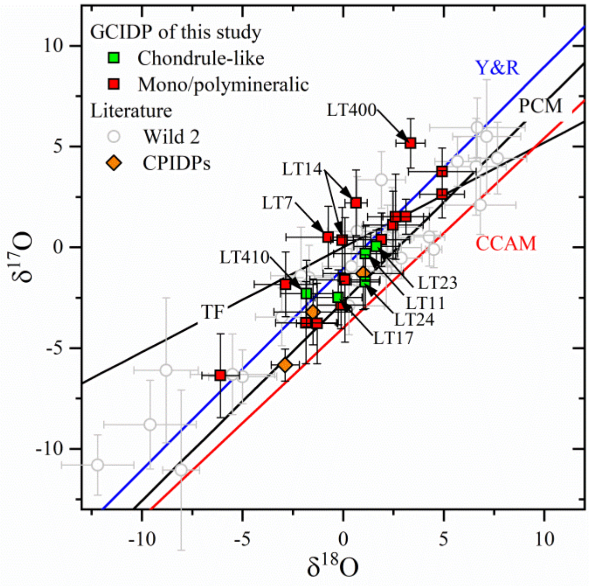

Fig. 2. Mean oxygen isotope ratios of crystalline silicate particles in the GCIDP and literature anhydrous IDPs [6, 7], as compared with Wild 2 particles [4, 5, 8-10].

vary from 72 to 99 with peaks at >90 and 75-80. Olivine and pyroxene from single polymineralic particles typically have similar Mg# values; however, LT14 has an iron-rich olivine (Fo_{78}) and a magnesium-rich pyroxene (En_{97}).

A total of 71 analyses on the 20 particles show $\delta^{18}O$, $\delta^{17}O$, and $\Delta^{17}O$ varying from –6.2 ± 1.0‰ to 6.8 ± 1.9 ‰, from –6.7 ± 2.6‰ to 5.3 ± 1.2‰, and from –5.2 ± 2.6‰ to 3.4 ± 1.5‰, respectively. Multiple oxygen isotope analyses on monomineralic particles and on several minerals of polymineralic particles are homogeneous. Therefore, only mean oxygen isotope ratios for each fragment are discussed.

Discussion: Oxygen isotope ratios of most particles fall in the range defined by chondrules in CR, CV, CO, CM, Acfer 094, and Tagish Lake chondrites (Fig. 2). Their $\Delta^{17}O$ values are well correlated with their Mg# values, i.e. $\Delta^{17}O$ of Mg# > 90 particles typically cluster around –3‰, and their $\Delta^{17}O$ gradually increases to ~ 0‰ as Mg# decreases from 90 to 80 and finally cluster around 0‰ in Mg# = 75-80 particles (Fig. 3a). This Mg#–$\Delta^{17}O$ trend is very similar to the ^{16}O-poor Wild 2 particles, i.e. Mg# > 97 particles have $\Delta^{17}O$ of ~ –2‰ and Mg# < 97 particles have $\Delta^{17}O$ varying from –4‰ to +2‰ (Fig. 3b). A two samples, two dimensional (Mg# and $\Delta^{17}O$) Kolmogorov–Smirnov (K-S) test returns a *p*-value of 0.61 for the two datasets, indicating that they are very likely from the same population. In comparison with primitive chondrite chondrules, this Mg#–$\Delta^{17}O$ relationship is closest to CR chondrite chondrules, i.e. $\Delta^{17}O$ gradually increases from −6‰ to −1‰ as Mg# decreases from 99 to 94; the rest, with Mg# < 90, show variable $\Delta^{17}O$ between –2‰ and +2‰, while the low *p*-value (0.005) returned by K-S test indicate they are not from the same population.

Among the 5 chondrule-like particles, LT11 ($\Delta^{17}O$ = –0.9 ± 1.8‰) and LT24 ($\Delta^{17}O$ = –2.3 ± 1.4‰) have nearly identical oxygen isotope ratios to similar enstatite-rich chondrule-like Wild 2 particles "Pyxie" ($\Delta^{17}O$ = –1.1 ± 0.9‰) and "Gen-chan" ($\Delta^{17}O$ = –2.3 ± 1.4‰), respectively [8]. Similar Type IB chondrules with negative oxygen isotope ratios have been reported in carbonaceous chondrites (except CH-CB) [11, 12]. LT17 ($\Delta^{17}O$ = –2.4 ± 1.6‰) and LT23 ($\Delta^{17}O$ = –0.8 ± 1.0‰) are isotopically similar to iron-rich BO chondrule particles in CR and CO chondrites ($\Delta^{17}O$: ~ –2‰ to ~ 0‰) [11]; however, similar objects have not been found in Wild 2 particles. LT410 ($\Delta^{17}O$ = –1.4 ± 1.4‰) has oxygen isotope ratios close to a Wild 2 Al-rich chondrule fragment "Bidi" ($\Delta^{17}O$ = –2.2 ± 2.0‰) [9]. Similar Al-rich chondrules with $\Delta^{17}O$ ~0‰ are typically found in OC, CR, and CH-CB chondrites [13].

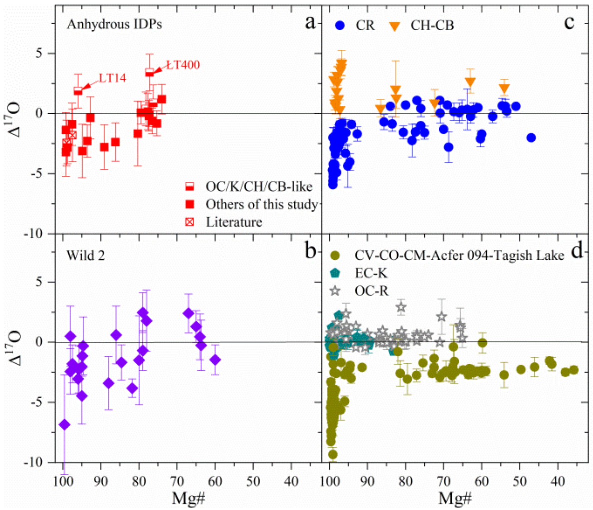

Fig. 3. Mg# vs $\Delta^{17}O$ of crystalline silicate particles in the GCIDP and literature anhydrous IDPs [6, 7], as compared with Wild 2 particles [4, 5, 8-10] and chondrules in CV, CO, CM, CR, CH-CB, OC, EC, R, K, and Acfer 094 and Tagish Lake chondrites [11, 12].

As exceptions, LT7 and LT14 have oxygen isotope ratios overlapping with OC-R chondrite chondrules, while LT400 overlaps with CH-CB chondrite chondrules, possible suggesting that they have common origins to OC-R and CH-CB chondrites, respectively. While olivine and pyroxene have distinct Mg# in LT14, they have indistinguishable oxygen isotope ratios. It is likely that olivine experienced Fe-Mg exchange in the solar nebula or on the parent body.

Conclusions: Our oxygen isotope results indicate that this GCIDP sampled extremely heterogeneous materials formed in both the inner and the outer solar system, similar to Wild 2 particles [2]. Most particles may have a similar origin to CR chondrite chondrules, while few are genetically related to OC-R and CH-CB chondrite chondrules.

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