OXYGEN THREE-ISOTOPE RATIOS OF PARTICLES FROM THE COMET 81P/WILD 2: SYSTEMATICS WITHIN INDIVIDUAL TRACKS. N. Chaumard[1], C. Defouilloy[1], D. J. Joswiak[2], D. E. Brownlee[2], A. J. Westphal[3], and N. T. Kita[1], [1]WiscSIMS, Department of Geoscience, University of Wisconsin-Madison, Madison, WI 53706, USA, [2]Department of Astronomy, University of Washington, Seattle, WA 98195, USA, [3]Space Sciences Laboratory, U.C. Berkeley, CA 94720, USA.

Introduction: Comets accreted ice and silicate in cold regions of the Solar System, so that the particles collected from the comet 81P/Wild 2 and returned to Earth by the Stardust spacecraft provide new clues to the composition of primitive material [1]. It has been shown that returned samples are composed of a large range and diversity of materials such as presolar grains [2, 3], organic matter [e.g., 4], refractory minerals [e.g., 5–7], and chondrule-like objects [e.g., 8–12].

Olivine and pyroxene particles from the comet 81P/Wild 2 show a correlation between Mg# and Δ^{17}O [10, 12]. The increase of Δ^{17}O values as a function of decreasing Mg# defined by the Wild 2 particles displays several similarities with those observed among chondrules, especially from CR chondrites [13]. Indeed, one of the Wild 2 particles with Mg# >98 shows Δ^{17}O values down to ~–7‰ while particles with Mg#'s <98 have Δ^{17}O values ranging from –4‰ to +2‰ [12]. This distribution of the Δ^{17}O values indicate that ^{16}O-poor Wild 2 crystalline silicate particles could be genetically related to chondrules in meteorites and thus may derive from a similar isotope reservoir.

We measured O-isotope ratios of eleven new Wild 2 particles (7 with Mg# <90) in order to distinguish the potential contribution of CR-like materials. The dataset then available for Wild 2 particles including data from previous studies gave us the opportunity to discuss the chemical and isotopic composition variability within single tracks. Indeed, single mineral or mineral assemblages (e.g., chondrule fragments) and mixtures (structurally weak and/or porous) of coarse- and fine-grained materials (e.g., chondritic matrix+clasts) are supposed to be at the origin of type A and B tracks, respectively [9, 14].

Samples and analytical procedures: We analyzed three particles from Track 22 (T22), two from Track 149 (T149), three from Track 191 (T191), one from Track 77 (T77), one from Track 172 (T172), and one from Track 175 (T175). Track 191 is an 11-mm long, type B track with large pyrrhotite terminal particles, at least one of which is associated with GEMS-like fine-grained material [15]. The particle T191/F1 is a pyroxene grain ($En_{94}Wo_{0.7}$), while the other particles are grains of olivine with Mg# contents ranging from 60 to 99.8. Particles have sizes ranging between ~3 μm and ~6 μm. The particles were extracted from the tracks as 100 μm wide acrylic cubes. Then, each cube was pressed, along with a San Carlos olivine standard, into an indium metal disk of 1.4 mm in diameter at the center of an aluminum disk of 25 mm in diameter.

Oxygen 3-isotope analyses were performed using WiscSIMS IMS 1280 under the conditions described in [12]. The location of analyses were marked using FIB [10] and were aimed accurately at 0.2 μm precision by SIMS [12]. A Cs^+ primary beam was tuned to produce a ~2 μm × 1 μm diameter spot with a primary ion intensity of ~3 pA. The contribution of the tailing of $^{16}O^1H^-$ interference to the $^{17}O^-$ signal was corrected using the method defined by [16].

Because of their small sizes, only one analysis was performed for each particle analyzed, bracketed by six analyses on San Carlos olivine grains mounted in the same disks. The external reproducibility of the running standards was 2.2‰, 2.6‰, and 1.9‰ for $\delta^{16}O^-$, $\delta^{17}O^-$, and $\Delta^{17}O^-$, respectively, which were assigned as analytical uncertainties of individual analyses [10]. We analyzed several olivine and pyroxene standards that cover the range of compositions of unknowns for instrumental bias corrections [10, 12].

Results: A total of 11 spot analyses were obtained from 11 particles. SEM images of SIMS pits confirmed accurate aiming of 8 particles in respect to their FIB marks, while 3 particle measurements were stopped at the middle of the analyses. Oxygen isotopic ratios of the particles analyzed are shown in Fig. 1. Values range from 6.9±2.4‰ (T22/F8, Mg#: 86) to –50.4±2.4‰ (T175/F1, Mg#: 99.8) in δ^{18}O while Δ^{17}O values vary between 3.1±2.9‰ (T22/F8, Mg#: 86) and –23.3±1.4‰ (T175/F1).

Discussion: The Mg# and Δ^{17}O values of the particles analyzed in this study are distributed within the same range as those previously obtained for ferromagnesian crystalline silicates from Wild 2 (Fig. 2). However, in addition to a cluster around ~–2‰ for Mg#'s >94, our results indicate that Δ^{17}O values range between ~–1.5‰ and ~3‰ for Mg#'s <85 (Fig. 2). By comparison with CC chondrules (e.g., in CR chondrules [e.g., 13]), Wild 2 particles with low Mg# (<85) are dominated by ~0 and positive Δ^{17}O values (Fig. 2). This population of crystalline silicates could be a real cometary feature, or at least a signature of the outer part of the Solar System. This observation is consistent with the presence of FeO-rich chondrules with similar Mg#-Δ^{17}O values in CR and CH chondrites that likely accreted in more outer regions of the Solar System by comparison with objects from its inner parts such as other groups of CCs [19].

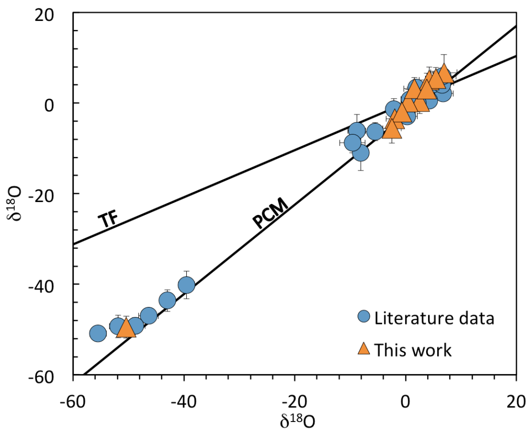

Fig. 1: Oxygen 3-isotope ratios of the eleven new Wild 2 particles analyzed in this work (orange symbols) along with data from the literature (blue symbols). Literature data from [8,10–12,17,18].

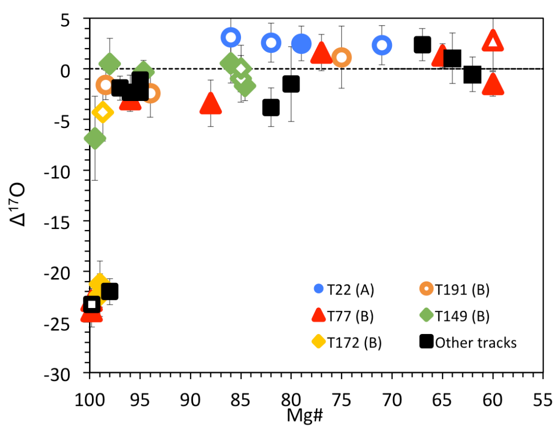

Fig. 2: Mg#-$\Delta^{17}O$ relationship for the eleven Wild 2 particles analyzed (open symbols) and literature data (filled symbols) from [8,10–12,17,18]. Letter in parenthesis correspond to the track type.

The nearly pure forsteritic olivine grain analyzed (T175/F1) displays a ^{16}O enrichment similar to those observed for LIME olivine, pure forsterite and enstatite particles [10, 12, 20] and in the same range as the CAI-like particle Inti [21]. The forsterite particle (T175/F1) is not a LIME olivine, but has very low abundance (<0.5 wt.% ox.) of minor elements that is consistent with an origin by direct condensation from the nebular gas and may have a genetic link to amoeboid olivine aggregates (AOAs) [9, 10, 12, 20].

Including literature data, three or more particles (*n*) were analyzed in the T77 (*n*=8, [10, 11, this work]), T149 (*n*=7, [12, this work]), T22 (*n*=4, [10, this work]), T191 (*n*=3, [this work]), and T172 (*n*=3, [12, this work]) (Fig. 2). For different ranges of Mg#'s, T22, and to a lesser extent T191 contain particles displaying similar $\Delta^{17}O$ values, from 2.3 to 3.1‰ (Mg#: 71–86) and –2.4 to 1.1‰ (Mg#: 75–98.4), respectively. The track T22 is composed of an aggregate of isotopically similar crystalline silicates (type A track, so initially not associated with fine-grained/porous material before impact into the aerogel). Regarding the uncertainties of the measurements, the tracks T77 and T191 (type B tracks) appear to contain two populations of crystalline silicates with different $\Delta^{17}O$ values, of around –2‰ for Mg#'s 85–99 and ≥0‰ for Mg#'s <85. In addition to these two populations of crystalline silicates, T77 also contains ^{16}O-rich particles [10] possibly formed by condensation in the same regions of the protoplanetary disk than CAIs and AOAs. ^{16}O-rich particles (two crystalline pyroxenes) were also analyzed in track T172 [12]. This latter and track 149 also contain crystalline olivines similar to type I chondrule silicates in term of $\Delta^{17}O$ and Mg# values [e.g., 13], –4.3‰ and 98.7, –6.9‰ and 99.5, respectively. With the exception of this crystalline olivine, track T149 only contains the –2‰ - Mg#'s 85–99 population.

Conclusions: The increasing number of high-precision O-isotope measurements of Wild 2 particles reveals the presence of two populations of crystalline silicates, with $\Delta^{17}O$ values ~–2‰ for Mg#'s 85–99, and ≥0‰ for Mg#'s <85. This latter is not commonly observed in CCs, except for CR and CH chondrites [22, 23], which further suggest links between cometary particles and CR-CH clan meteorites [e.g. 10].

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