LACK OF EVIDENCE OF IN-SITU DECAY OF ALUMINUM-26 IN A FEO-POOR FERROMAGNESIAN CRYSTALLINE SILICATE PARTICLE, PYXIE, FROM COMET WILD 2. D. Nakashima[1], T. Ushikubo[1,2], M. K. Weisberg[3,4], M. E. Zolensky[5], D. S. Ebel[4], and N. T. Kita[1]. [1]WiscSIMS, Dept. Geoscience, University of Wisconsin-Madison, Madison, WI 53706 (naka@geology.wisc.edu), [2]Kochi Institute for Core Sample Research, JAMSTEC, Kochi 783-8502, Japan. [3]Dept. Phys. Sci., Kingsborough College, City University of New York, Brooklyn, NY 11235. [4]American Museum of Natural History, Dept. Earth Planet. Sci., New York, NY 10024. [5]NASA Johnson Space Center, Houston, TX 77058.

Introduction: One of the important discoveries from the Stardust mission [1] is the observation of crystalline silicate particles that resemble Ca, Al-rich inclusions (CAIs) and chondrules in carbonaceous chondrites [2-3], which suggests radial transport of high temperature solids from the inner to the outer solar nebula regions and capture by accreting cometary objects [e.g. 4].

The Al-Mg isotope analyses of CAI-like and type II chondrule-like particles revealed no excess of ^{26}Mg derived from in-situ decay of ^{26}Al ($\tau_{1/2}$ = 0.705Myr; [5]), suggesting late formation of these particles [6-8]. However, the number of Wild 2 particles analyzed for Al-Mg isotopes is still limited (n = 3). In order to better understand the timing of the formation of Wild 2 particles and possible radial transport in the protoplanetary disk, we performed SIMS (Secondary Ion Mass Spectrometer) Al-Mg isotope analyses of plagioclase in a FeO-poor ferromagnesian Wild 2 particle, which is the most abundant type among crystalline Wild 2 particles [e.g. 9].

Analytical Methods: A terminal particle (C2092,7,81,1,0) extracted from Stardust track 81 was cast in an 8mm epoxy disk (potted butt) and had a polished flat surface for oxygen isotope analyses [10], though the plagioclase was covered with a thin layer of epoxy (< 1μm). Thickness of the particle was estimated as ~ 2μm using X-ray computed tomography at the American Museum of Natural History. The plagioclase surface was exposed by grinding down the epoxy.

For precise aiming of SIMS analysis spots in plagioclase in the tiny particle, we removed 1μm^2 area of the surface carbon coating by focused ion beam (FIB; Fig. 1) and identified the location by $^{27}Al^+$ ion imaging with a 10μm×10μm square prior to a SIMS spot analysis [cf. 10]. The Al-Mg isotope analyses were made using a ~ 2μm O^- primary beam (~ 3pA) under conditions similar to those in [11], but secondary Mg^+ and $^{27}Al^+$ ions were detected with an axial electron multiplier by magnetic peak switching. Intensities of $^{24}Mg^+$ were ~ 1-2×10^{3}cps. Synthetic anorthite composition glass with 0.6wt% MgO was used as a running standard.

Sample: The Wild 2 particle "Pyxie" (= F1/T81 in [10]) mainly consists of low-Ca pyroxene ($En_{92}Wo_3$) and plagioclase ($An_{65}Ab_{35}$; 0.4wt% MgO; Fig. 1) [10]. A pyroxene lath occuring in plagioclase is slightly enriched in Ca and Al compared to the larger low-Ca pyroxene (detected by SEM-EDS), consistent with the observation of Ca-rich pyroxene along with a polycrystalline aggregate of low-Ca pyroxene and plagioclase in a TEM section of the same particle [12]. Oxygen isotope ratios of low-Ca pyroxene in Pyxie were reproducible within analytical uncertainties, and the average $\Delta^{17}O$ (= $\delta^{17}O - 0.52 \times \delta^{18}O$) value is –1.1 ± 0.8‰ (2SE; n = 5; [10]).

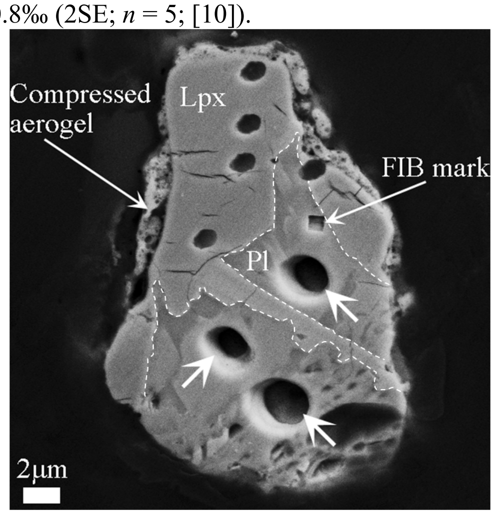

Fig. 1: Backscattered electron image of C2092,7,81,1,0 "Pyxie". The dashed line is a boundary line between low-Ca pyroxene (Lpx) and plagioclase (Pl). Arrows show spots sputtered for Al-Mg isotope analyses. Small five spots are SIMS pits for oxygen isotope analyses [10].

Results: We made three spot analyses on plagioclase in Pyxie (Fig. 1). The $^{27}Al/^{24}Mg$ ratios range from 64 to 67 (Fig. 2), which are similar to those of plagioclase in chondrules in type 3.0 chondrites (typically < 100; [e.g. 11]). Plagioclase in Pyxie shows no resolvable excess of ^{26}Mg. The $\delta^{26}Mg^*$ values are from –1‰ to +2‰ with uncertainty of ±4‰ (2SE). A regression of the data yields an isochron with a slope of 0.002 ± 0.034 (95% confidence) with the assumption that the regression line goes through the origin (Fig. 2). The initial $(^{26}Al/^{27}Al)_0$ ratio of plagioclase in Pyxie is estimated as (0.03 ± 0.47)×10^{-5}, and the inferred upper limit is 0.5×10^{-5}.

Discussion: Although secondary alteration cannot be totally ruled out considering the low An# (65) and MgO content (0.4wt%) in Pyxie plagioclase [cf. 13] and a suggestion that the petrologic grade of Wild 2 is up to 3.10-3.15 [14], disturbance in the ^{26}Al-^{26}Mg isotope system in Pyxie is unlikely, because 1) Pyxie plagioclase does not have any evidence for nephelinization which is accompanied by loss of ^{26}Mg excess [cf. 13], as the K content was below detection limits using EPMA and SEM-EDS, 2) recognition of low temperature products cubanite [15] and Mg-carbonate [16] in Wild 2 particles constrains the upper limit of the temperature (< 210°C; [15]), where diffusion of Mg in plagioclase of An_{65} is very limited (<< 1nm; [17]) even for 4.5Gyr, and 3) Mg diffusion in plagioclase of An_{65} during capture in aerogel ($T \leq$ 2000K, $t <$ 1μs; [1]) is less than 1nm [17]. No resolvable excess of ^{26}Mg indicates that Pyxie plagioclase crystallized in the (near) absence of ^{26}Al, similarly to other Wild 2 particles [6-8]. Assuming homogeneous distribution of ^{26}Al in the early solar system, the crystallization period of Pyxie is estimated as > 2.4Ma after CAIs ((^{26}Al/^{27}Al)$_0$ = 5.25×10^{-5}; [cf. 18]) from the upper limit of 0.5×10^{-5} for (^{26}Al/^{27}Al)$_0$.

Nakashima et al. [10] inferred a link between ferromagnesian Wild 2 particles including Pyxie and chondrules in CR chondrites from their similar systematic trends of Mg# and Δ^{17}O values that can be explained by addition of ^{16}O-poor water ice (Δ^{17}O > 0‰) as an oxidizing agent to the anhydrous solid precursors [e.g. 19]. Furthermore, lack of evidence for in-situ decay of ^{26}Al of Pyxie (< 0.5×10^{-5}, Δ^{17}O ~ –1‰) and Iris (< 0.3×10^{-5}, Δ^{17}O ~ –0.3‰; [8]) is consistent with the relation of CR chondrules (chondrules with Mg# < 98 and Δ^{17}O > –3‰ do not show ^{26}Mg excesses, while those with Mg# > 98 and Δ^{17}O ~ –5‰ show ^{26}Mg excesses [20]), which is distinct from chondrules in LL, CO, and Acfer 094 ((^{26}Al/^{27}Al)$_0$ ratios of 0.2-1.0×10^{-5}, regardless of Mg# and Δ^{17}O [e.g. 11]). It should be noted that plagioclase in Pyxie (An_{65}) is not as anorthitic as that in CR chondrules (An_{80-99}; [13]). In spite of this difference, similarities of Δ^{17}O, Mg#, and lack of ^{26}Mg excess of chondrules in comet Wild 2 and CR chondrites with Δ^{17}O > –3‰ suggest that they formed late in local disk environments that had similar oxygen isotope ratios and redox states, which could be the furthest regions of chondrule formation [10].

It is worth mentioning that Wild 2 particles analyzed so far consistently show no resolvable excess of ^{26}Mg [6-8, this study], suggesting their late formation, regardless of various chemistries (refractory-rich and FeO-rich and -poor ferromagnesian) and oxygen isotope ratios (Δ^{17}O from –20‰ to ~ 0‰) [2, 8, 10, 21-22, this study], which reflect formation environments. Note that, for CAI-like particles, the late formation is more likely than formation prior to the ^{26}Al injection into the early solar system, given the mineralogy of the particles [6]. The Wild 2 particles with no ^{26}Mg excess could represent younger generations of high temperature solids that formed in regionally heterogeneous oxygen isotope compositions and redox states in the inner solar nebula and were then radially transported to the outer solar nebula regions.

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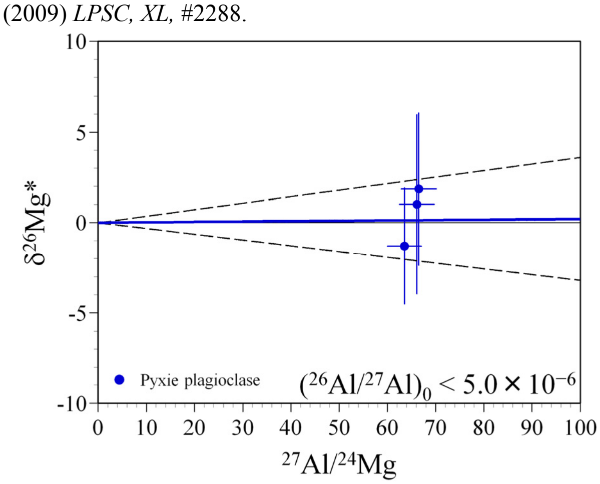

Fig. 2: Al-Mg isochron diagram of Pyxie. Errors are 95% confidence. Dashed lines represent 2σ confidence lines for the regression line (blue solid line).