Mn-Cr ISOTOPE SYSTEMATICS OF FAYALITE-SILICA INTERGROWTHS FROM THE STARDUST MISSION TO COMET 81P/WILD 2. J.E.P. Matzel[1], H. A. Ishii[2], D. Joswiak[3], D. Brownlee[3], and I. D. Hutcheon[1], [1]Lawrence Livermore National Laboratory, Livermore, CA, USA, [2]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Manoa, HI, USA, and [3]University of Washington, Seattle, WA, USA.

Introduction: Among the dust particles returned by NASA's Stardust mission to the coma of comet 81P/Wild 2 are several fragments of a particle referred to as "Ada". These fragments exhibit distinctive fayalite-silica intergrowths (Fig. 1). Two competing models for the origin of fayalite in chondrites have been proposed. The first model involves high temperature (>1000˚C) gas-solid condensation under highly oxidizing conditions in the protoplanetary disk following chondrule formation (e.g. [1]). The second model involves low temperature (<300˚C) formation during fluid-assisted thermal metamorphism on a chondrite parent body (e.g. [2]). Aqueous activity is thought to have begun several million years after CAI formation on carbonaceous chondrite parent bodies and persisted, perhaps episodically, for 10-15 Ma [3, 4]. In this study, we measured the Cr isotopic composition of Ada fayalite in order to detect radiogenic ^{53}Cr produced from the decay of short-lived ^{53}Mn. Developing a Mn-Cr chronology for fayalite-bearing fragments from Comet Wild 2 may distinguish between the proposed formation mechanisms and further constrain the timeframe during which inner solar system materials were incorporated into Comet Wild 2.

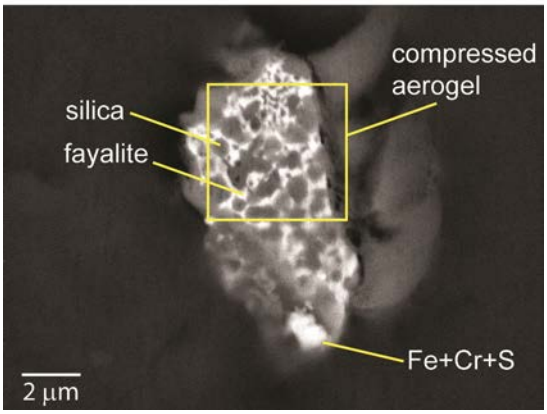

Figure 1. Back-scattered electron image of Ada-C fragment 4. The region outlined in yellow is shown in the ion images in figure 2.

Petrographic Description: Two fragments of Ada-C (track 26, fragments 3 and 4) were embedded in acrylic, and then the acrylic mesa was pressed into indium metal and carbon-coated. A San Carlos olivine crystal (~100 μm in length) was also pressed into indium adjacent to the acrylic mesa for standardization. The sample was then imaged using the JEOL 7401-F SEM at LLNL. Back-scattered electron (BSE) images of the fragments reveal fine-scale intergrowths of fayalite and silica and Fe-sulfide and Fe-Cr sulfide grains around the periphery of the fragments. STEM images of microtome slices also show nm-sized Fe-sulfide grains in fayalite, and chromite around the margin of the fragments.

Isotope Systematics: The Mn and Cr isotope measurements were made using the NanoSIMS 50 at LLNL during two analytical sessions. The analyses were performed using a $^{16}O^-$ primary ion beam rastered over areas of 5μm^2 to 8 μm^2. Secondary ion intensities were measured by combined multicollection and magnetic field peak jumping: $^{25}Mg^+$ (in the first session only), $^{30}Si^+$, $^{52}Cr^+$, and $^{55}Mn^+$ were collected with the first magnetic field setting, and $^{53}Cr^+$ and $^{56}Fe^+$ were collected in the second. A mass resolving power of ~5700 was used to resolve any potential isobaric interferences.

The primary difference between the two analytical sessions reflected a change in the ion source used to generate the O^- primary ion beam. In the first session, the standard Cameca duoplasmatron ion source was used to generate a 2 pA ion beam focused to an ~250 nm spot size. In the second session, a new Hyperion II ion source (Oregon Physics) was used to generate a 3 pA primary ion beam focused to ~140 nm spot size.

$^{55}Mn/^{52}Cr$ and $^{53}Cr/^{52}Cr$ ratios were calculated for selected regions of the analyzed areas using image processing software (*L'Image* by L. Nittler). The $^{55}Mn^+/^{52}Cr^+$ ion ratios were converted to atomic ratios using relative sensitivity factors of 1.05±0.008 (1σ SE) and 1.14±0.004 (1σ SE) in the first and second sessions, respectively. The relative sensitivity factor was determined from repeated measurements of San Carlos olivine (Fo90).

Images of the Mn and Cr secondary ion intensities show that both species are correlated with areas of fayalite in the SEM images and $^{56}Fe^+$ ion images (Fig. 2). The $^{55}Mn/^{52}Cr$ and $^{53}Cr/^{52}Cr$ ratios were calculated by summing the counts of each isotope from all pixels in a region defined as fayalite based on the $^{55}Mn^+$ ion image (see figure 2). The isotope results are shown in figure 3. Data from fragment 4 show good agreement between analytical sessions. Neither of the fragments show evidence for excess ^{53}Cr outside analytical uncertainties.

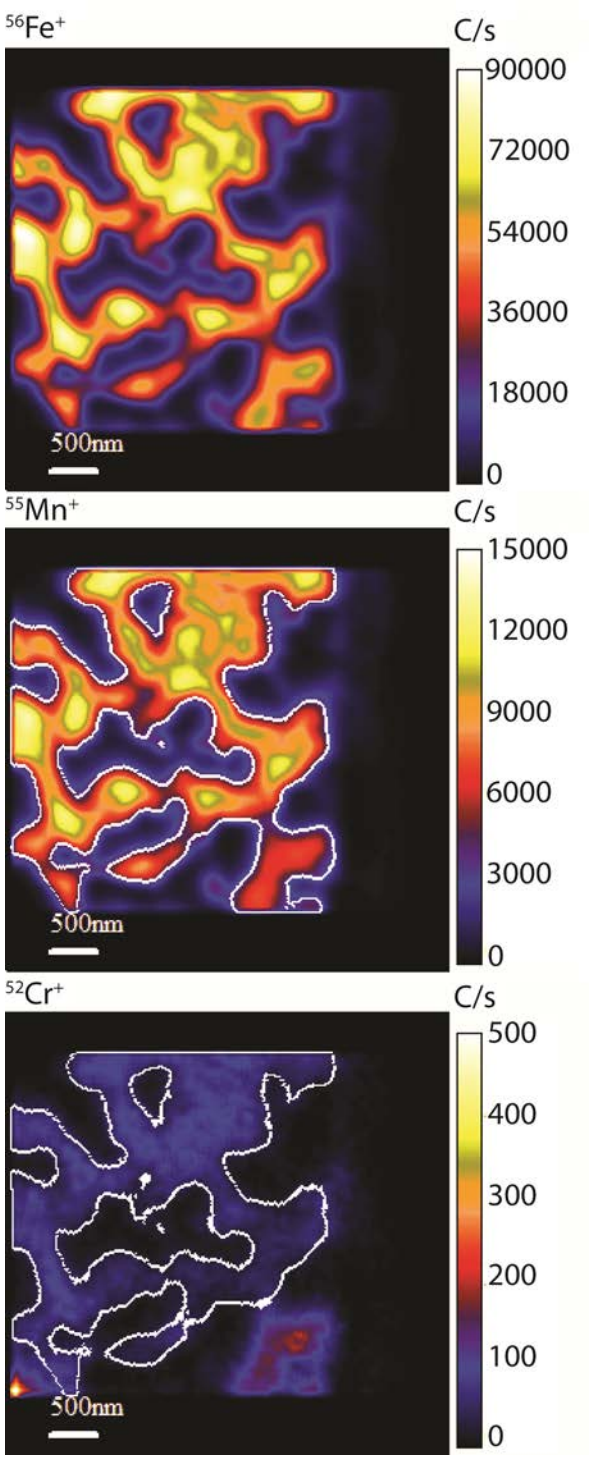

Figure 2. Quantitative images of ion intensity from a region of Ada-C fragment 4 seen in figure 1 obtained using the new Hyperion II ion source. White line in the ^{55}Mn+ ion image is the region defined as fayalite based on the ^{56}Fe+ ion image. The white line in the ^{52}Cr+ image surrounds the pixels used to calculate the ^{55}Mn/^{52}Cr and ^{53}Cr/^{52}Cr ratios shown in figure 3. A small region in the lower right corner was excluded from the calculation because of higher Cr content.

The measured ^{55}Mn/^{52}Cr ratios of both fragments are significantly lower than expected based on previous measurements of Mn and Cr in fayalite in CV3 chondrites that showed Mn/Cr > 10,000 [3]. The improved spatial resolution obtained in the second analytical session using the Hyperion source shows that the relatively high Cr ion intensities (and hence relatively low Mn/Cr ratios) are not the result of sputtering adjacent Cr-rich phases on the margins of the fragment, but rather from Cr contained within the fayalite.

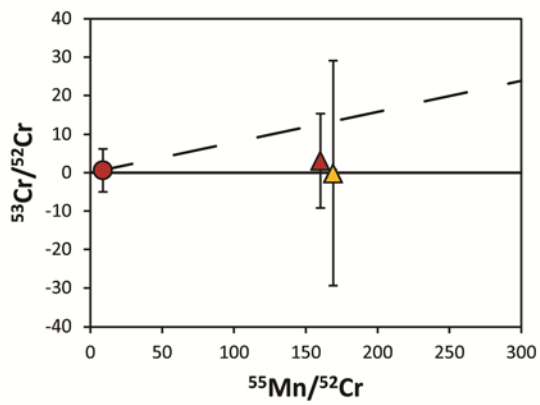

Figure 3. Mn-Cr isotope measurements from Ada-C fragments 3 (red circle) and 4 (red and orange triangles). Data collected during the second analytical session are shown in red. The dashed line represents an initial ^{53}Mn/^{55}Mn ratio of $9e^{-6}$ for reference.

Conclusions: Ada comprises several fragments that contain distinctive fayalite-silica intergrowths associated with Fe sulfide and Fe+Cr sulfide. This mineral assemblage is comparable to fayalite mineral assemblages present in the matrices of metamorphosed ordinary and carbonaceous chondrites. No excess ^{53}Cr was measured outside analytical uncertainty. The relatively low Mn/Cr ratios result from Cr contained within fayalite, rather than from sputtering of adjacent Cr-rich phases on the margins of the fragment. The relatively high Mn content of Ada fayalite contrasts with the near total absence in fayalite in CV3 chondrites, suggesting the fayalite-silica intergrowths were not produced during low-T, fluid assisted metamorphism.

References: [1] Lauretta, D.S., et al. (2001) *Geochimica et Cosmochimica Acta, 65*: 1337-1353. [2] Krot, A.N., et al. (2004) *Antarctic Meteorite Research, 17*: 153-171. [3] Hutcheon, I.D., et al. (1998) *Science, 282*: 1865-1867. [4] Krot, A.N., et al., (2006) in *Meteorites and the Early Solar System II*. p. 525-553.