

COORDINATED ANALYSES OF DIVERSE COMPONENTS IN WHOLE STARDUST COMETARY TRACKS.

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Introduction: Analyses of samples returned from Comet Wild-2 by the Stardust spacecraft have resulted in a number of surprising findings that show the origins of comets are more complex than previously suspected [1]. Stardust aerogel tracks show considerable compositional diversity and the degree of impact related thermal modification and destruction is also highly variable. We are performing systematic examinations of entire Stardust tracks to discern the representative mineralogy and origins of comet Wild 2 components and to search for well preserved fine grained materials. Previously, we used ultramicrotomy to prepare sequential thin sections of entire “carrot” and “bulbous” type tracks along their axis while preserving their original shapes [2]. This technique allows us to characterize the usually well-preserved terminal particle (TP), but also any associated, fine-grained fragments that were shed along the track pathway. This report focuses on coordinated analyses of surviving indigenous cometary materials (crystalline and amorphous) along the aerogel track walls, their interaction with aerogel during collection and comparisons with their TPs. We examined the distribution of fragments throughout the track from the entrance hole to the TP.

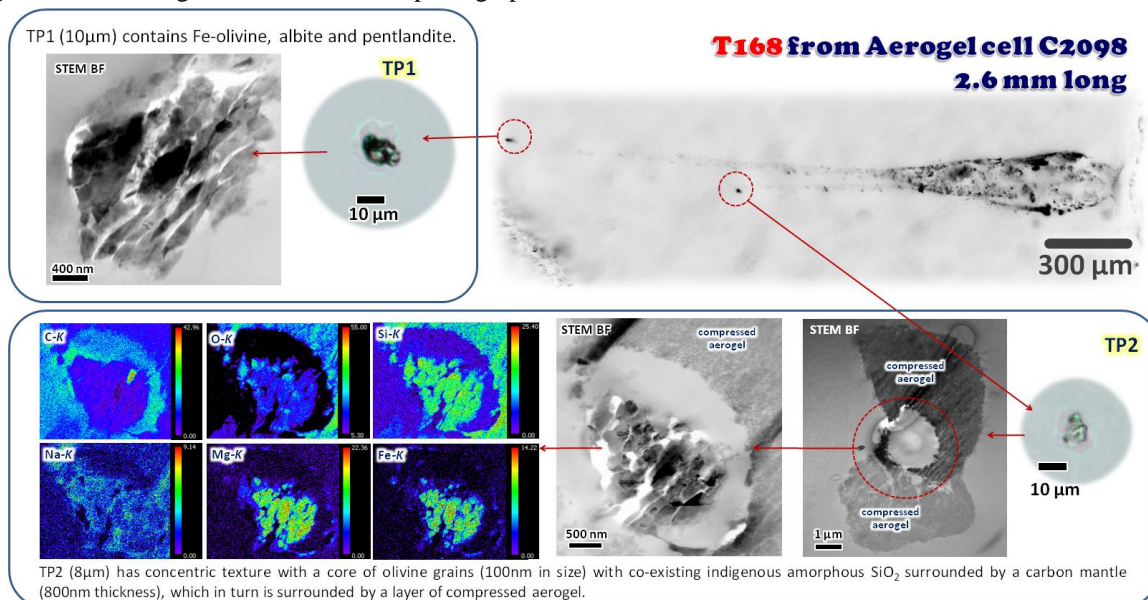
Experimental methods: The walls of tracks #147 (4600 μ m long with 7 TPs) and #168 (2640 μ m long, 3 TPs) were photo-documented using an extended depth-of-field image processing technique that generates a single in-focus image from a series of photographs.

The cometary sample fragments in the ends of aerogel cracks along the track walls and the TPs were removed, embedded in epoxy, and ultramicrotomed separately. Nanometer-scale quantitative compositional maps in microtome thin sections of these samples were obtained using a JEOL 2500SE 200 keV field-emission scanning-transmission electron microscope (STEM) equipped with a Noran thin window energy-dispersive X-ray (EDX) spectrometer. This approach enabled spatially resolving the target sample from fine-scale mixtures of compressed aerogel and melt.

Results and Discussion:

Track #168: We obtained mineralogical analyses of 2 TPs from T168. T168,TP1 (10 μ m) contains Fe-olivine, albite and pentlandite. T168,TP2 (8 μ m) has a concentric texture with a core of olivine grains (100nm in size) with co-existing indigenous amorphous SiO₂ surrounded by a carbon mantle (800nm thickness), which in turn, is surrounded by a layer of compressed aerogel. Thus far, three fragments from cracks along the track #168 were investigated, but no cometary crystalline material was observed, only Mg- and Al-rich cometary melts. The compositions of these melt particles are not as diluted with molten aerogel as the melt particles found in the track wall.

Track #147: We obtained mineralogical analyses of 3 TPs from Track #147. T147TP2 (18 μ m) entirely consists of Fe-Ni alloy with 5 at% Ni. T147TP3 (19 μ m) contains Fa28 with partial olivine-pyroxene inter-



growth and minor albite. T147TP4 (12 μ m) contains pentlandite, Fe-olivine, albite and high Ca pyroxene with Na and Cr (kosmochlor component). The Fe-olivine+albite+Ca-pyroxene assemblage is common in other Wild-2 samples as well [3]. A nebular origin as possible precursors to type II chondrules in ordinary chondrites has been proposed for the Fe-olivine+albite+Ca-pyroxene assemblages in Wild2 [3]. However, in T147, this assemblage coexists with pentlandite which is not a stable phase in the nebula [4].

Crystalline grains in the track cracks: We observed three 500-1000 nm-sized irregularly shaped polycrystalline grains in the largely melted fragments along the aerogel track cracks. The mineral constituents are enstatite, forsterite, pyrrhotite (some grains contain minor Ni), diopside, and amorphous Mg-Al-Na, Si-rich mesostasis (Figure). The crystals in the grains are 10-200 nm in size, have euhedral shapes and show equilibrium grain boundaries. The composition of the amorphous mesostasis differs from typical aerogel melts, and is not vesiculated suggesting that these objects were never completely molten. The mineralogy, texture and chemistry of the polycrystalline objects along the aerogel cracks are similar to equilibrated aggregates (EAs) common in anhydrous chondritic porous interplanetary dust particles (CP-IDPs) [5-7]. Brownlee et al. [6] proposed that GEMS (glass with embedded metal and sulfides) grains were the amorphous precursors to EAs in IDPs based on controlled heating experiments which produced EA-like objects from GEMS grains. The chemical and isotopic properties of EAs are also consistent with formation by annealing of GEMS grain precursors [7]. GEMS grains are the most common amorphous silicates in CP-IDPs. Definitive GEMS grains have not been observed among the Wild-2 sam-

ples to date, but similarities between GEMS grains and 'relict' GEMS-like amorphous silicates among the aerogel melt mixture in the track wall have been recognized [8,9]. The EAs in track #147 occur within an aerogel crack 200 μ m away from the track wall (Figure). Unlike the fragments on the track wall, the material captured in the cracks may have escaped the intense heating and mixing with aerogel during capture such that the indigenous EA texture and chemistry were preserved. Alternatively, amorphous precursors may have been heated during collection and annealed but not to the point where they melted.

Conclusions: The mineralogy of the track #147 and #168 terminal particles are consistent with formation at high temperatures in the inner solar system and subsequent transport to the comet forming region. The presence of EAs in the Comet Wild-2 samples provides further evidence of similarities between CP IDPs and comet Wild-2 samples. Particle fragments occurring in cracks along the track walls are better preserved and show less interaction with aerogel than particles occurring within the track bulb. Analysis of these fragments and the TPs provide a clearer picture of the nature of comet Wild-2. In future work, NanoSIMS will be used for isotopic analyses, and ultrafast two-step laser mass spectrometry (*ultra L²MS*) to investigate the nature and distribution of organic phases.

References: [1] Brownlee, D.E. *et al.* (2006) *Science* 314, 1711-1716. [2] Nakamura-Messenger K. *et al.* (2011) *MAPS*. 46, 1033-1051. [3] Joswiak, D. *et al.* (2009) *MAPS*. 44, 1561. [4] Brearley A.J. (1999) *Science* 285, 1380. [5] Bradley, J. P. (1994) *GCA*, 58, 2123-2132. [6] Brownlee, D. E. *et al.* (2005) *LPSC XXXVI*, #2391. [7] Keller, L.P. *et al.* (2009) *LPSC XXXX*, #2121. [8] Keller, L.P. *et al.* (2006) *Science*, 314, 1728. [9] Leroux *et al.* (2009) *LPSC XXXX*, 1785.

