PANNING FOR GOLD: A CASE STUDY IN EVALUATING THE ELEMENTAL COMPOSITION OF COMET WILD 2 DUST IN AEROGEL.

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Introduction: NASA's Stardust mission returned in January of 2006 after a fly-by of Comet 81P/Wild 2 with the first unquestionably cometary samples for study on Earth. These samples represent a unique opportunity to study material believed to have been preserved since the solar system formed. Since the return, Stardust samples have been studied by a number of analytical methods including synchrotron x-ray microprobe [1]. Micro-synchrotron x-ray fluorescence (micro-SXRF) measurements provide the ability to map out the location of cometary material still in the silica aerogel capture medium and to measure the non-volatile elemental composition of material localized in discrete several-micron-sized particles as well as dispersed along the walls of impact tracks. With sufficient measurements, a bulk composition of the Wild 2 cometary material can be established for comparison with other extraterrestrial materials; however, these measurements are complicated by non-homogeneous contamination in the aerogel itself. We present here the unexpected discovery of gold in the Stardust samples and establish that it is likely present as localized, near-surface contamination in the aerogel which, in some cases, has become intermixed with the cometary deceleration track.

Experimental Methods: Five impact tracks extracted as keystones [4] from the aerogel tiles returned by Stardust were mapped in the Stanford Synchrotron Radiation Laboratory's Beam Line 6-2 hard x-ray scanning fluorescence microprobe. (See [1], SOM and [2] for details.) Figure 1 contains the optical images of the impact tracks that contain gold. Figure 2 shows the x-ray – sample interaction region in which the focused x-ray probe excites fluorescence from the sample. Helium flows over the region to reduce air absorption, ozone generation and Ar fluorescence (from air). An x-ray transparent mirror provides x-ray line-of-sight viewing of the sample with an optical microscope. Mapping of each cometary impact track in aerogel was carried out with a 14 keV focused spot size of 15x19 microns^2 with 2×10^{10} ph/s and step sizes equal to spot size. At each map pixel, a fluorescence spectrum was collected by an ultraclean Si(Li) detector with dwell times ranging from 30 to 500 seconds. Total spectra for the entire impact track and for particles are generated by summing the relevant map pixels.

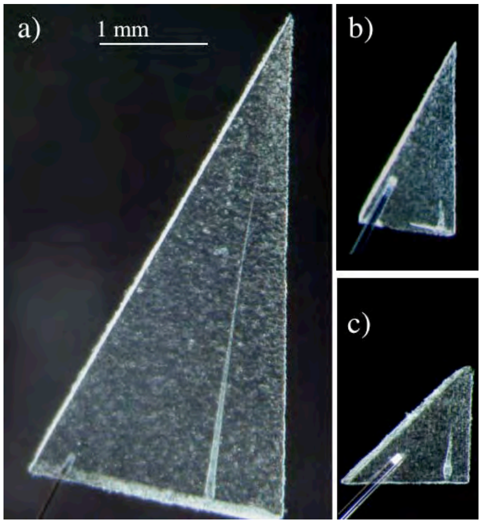

Figure 1: Optical microscope images of the three Stardust comet dust impact tracks in aerogel keystones that contained gold when analyzed by micro-SXRF: a) Track 4 (C2044,0,38), b) Track 5 (C2044,0,39) and c) Track 9 (C2044,0,42).

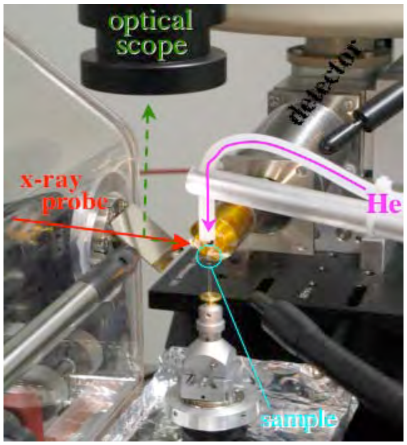

Figure 2: SSRL Beam Line 6-2 x-ray microprobe: x-ray – sample interaction region.

In order to remove a local aerogel background and maximize the sensitivity to elements present in the cometary material, map pixels in each track map are separated into categories using the dual threshold approach described in [2,3]. The approach is important since the silica aerogel capture medium is contaminated by elements of interest in the cometary material, and the contamination is non-uniform.

Gold in Stardust samples: Au was identified by the presence of the Lα and Lβ peaks in Tracks 4, 5 and 9. In Track 4, Au is located at the terminal particle. In

Track 5, the measured Au level is 5 orders of magnitude greater than solar abundance. These results are completely unexpected and are not reported in [1]. For Track 9, a map generated from the energy-windowed signal at the Au Lβ peak shows that the majority of the Au is not coincident with the deceleration track but is separate and very close to the aerogel external surface. This is evident in the comparison the energy window maps in Figure 3 a), the Fe Kα signal in the region surrounding the track and Figure 3 b), the Au Lβ signal in the same region. Figure 4 a) contains the cometary material and aerogel background spectra, and Figure 4 b) contains the spectrum from the pixels containing Au contamination. The Au-selected pixels contain ~0.45 ng of Au which, if included in the compositions of all five tracks measured as part of the preliminary examination [1], would yield Au levels ~150,000x above solar abundance levels. Au in Tracks 4 and 5 is intermixed with cometary material at the size scale of the x-ray spot size. It is likely that, in these cases, incident comet dust carried Au contamination into the impact track during hypervelocity capture. Track 5 contains ~1.0 ng of Au in the entire track, and Track 4 contains ~0.14 ng of Au at the terminal particle location.

Conclusions: High levels of Au in Stardust impacts are likely to be due to near-surface contamination, possibly flakes from an autoclave used in aerogel processing. In some tracks, Au was unfortunately entrained by impacting dust and is difficult, if not impossible, to separate on a pixel-by-pixel basis. Windowing of certain energy regions of collected spectra is one method for identifying such contamination, as well as full-spectrum fitting followed by mapping of the resulting elemental intensities. Due to the presence of Au off-track in the one impact track, it is ignored in reporting cometary abundances for all tracks. While Au is exotic and thus suspect in Stardust analyses, other less exotic localized contaminants (eg. Ca and Fe which are cosmochemically relevant) may also be susceptible to entrainment in the tracks and would be generally indistinguishable from cometary material.

References: [1] Flynn G. J. et al. (2006) *Science, 314,* 1731-1735. [2] Ishii H. A. et al. (2007) Recovering the elemental composition of Comet Wild 2 dust in five Stardust impact tracks and terminal particles in aerogel, submitted to *Meteoritics & Planet. Sci.* [3] Ishii H. A. et al. (2007) *LPS XXXVIII*, this volume. [4] Westphal A. J. et al. (2004) *Meteoritics & Planet. Sci. 39,* 1375-1386.

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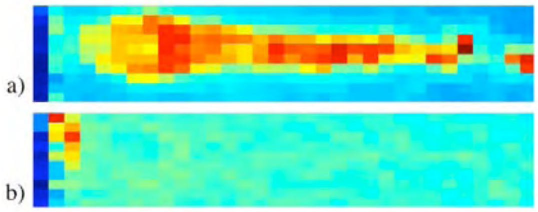

Figure 3. X-ray fluorescence maps for Track 9 generated by setting energy windows encompassing the a) Fe Kα and b) Au Lβ lines. Gold is located at the aerogel surface offset from the impact track.

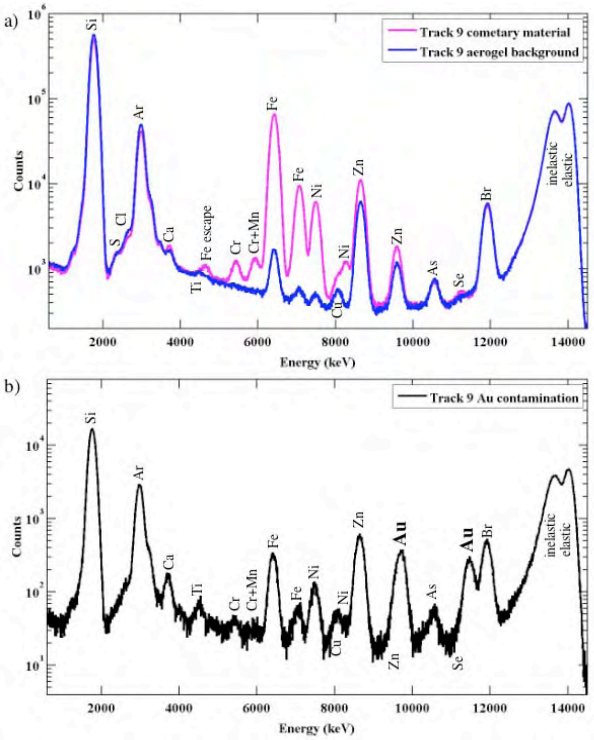

Figure 4. Result of dual threshold analysis of cometary material for Track 9. a) Sum spectra for the cometary material and normalized aerogel background, and b) sum spectrum of those pixels containing Au fluorescence isolated from the map of Track 9.