**XRD ANALYSES OF STARDUST TRACKS 176, 177, 178: TERMINAL GRAINS FROM MAGNETITE-RICH, CHONDRITE-LIKE MATRIX**

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**Introduction:** The terminal grains of the *Stardust* keystones have preserved the least thermally altered Comet Wild2 samples and some of the most pristine cometary material currently available for analysis. The micron-scale of the terminal grains requires synchrotron analyses to perform X-ray diffraction (XRD) and X-ray Absorption, Fluorescence (XAS, XRF). In particular, we have studied Fe oxides in order to be able to make increasingly detailed comparisons to carbonaceous chondrites and understand the variation in Fe oxidation state within Wild2 [1,2]. Fe oxides, including magnetite or magnetite-hematite mixtures have been identified along track walls [1,3] and leave a characteristic oxidized iron signature on keystone Fe-K XANES and XRF maps. However, the potential effects of capture heating, and terrestrial oxidation, has meant that the origin of the scattered Fe oxides has required further study through comparison to a terminal grain.

**Methods and Samples:** XRD analyses were made at Beamline I18 of the *Diamond* synchrotron, Oxfordshire, UK. We used a spot size of 2.5 x 2.5 µm, with XRF mapping of elements of Z>20, across the tracks. Fe-K X-ray Absorption Near-Edge Structure (XANES), and Extended X-ray Absorption Fine Structure (EXAFS) were also gathered [2]. The transmission XRD measurements reported here were taken at 13 keV, and the observable d-spacing range was ~9 to ~1.5 Å, corresponding to $2\theta = 5.5$ to $38.4^{o}$. XRF and Fe K XANES analyses and maps, with a 2.5 µm pixel resolution, were also obtained.

The Comet Wild2 samples used in this study are keystones: C2112,4,170,0,0 (#170); 2045,2,176,0,0 (#176); C2045,3,177,0,0 (#177); and C2045,4,178,0,0 (#178). The terminal grains vary in size from <5 µm to 20 µm in diameter, with Type A (#170 and #177) and B (#176 and #178) tracks based on the classification of [4]. The #178 terminal grains are 10 and 6 µm diameter (Fig. 1). This is a part of a wider consortium study on these tracks, with microRaman being performed by Price et al. [5]. Keystones were mounted between SiN wafers by NASA-JSC.

**Results:**

*Track #178.* The main grain in the terminal assemblage and the second stylus in Track #178 (Fig. 1) have d-spacings at 4.839 Å, 2.957 Å, 2.525 Å, 2.419 Å, 2.085 Å, 1.714 Å, 1.611 Å, 1.478 Å. This is nearly identical to our magnetite standard (Fig. 2). We used Fe-K XANES to analyse the subgrain in the main terminal assemblage (Fig. 3). This shows a near identical pattern to San Carlos olivine, with an absorption edge position of 7120.5 eV, a pre-edge feature at 7112.6 eV and a marked white line.

*Tracks #176, #177.* Fe-K XAS and XRD analyses of ~4 µm terminal grains in Track #177 and the second styli of #176 shows olivine, with d-spacings in #177 of 3.496, 2.454, 2.262, 1.730, 1.618, 1.573. Enstatite pyroxene has been identified in the main 6 µm diameter terminal grain of Track #176, with d-spacings 3.177 Å, 2.873 Å, 2.465 Å, 2.115 Å, and 1.611 Å (Fig. 4).

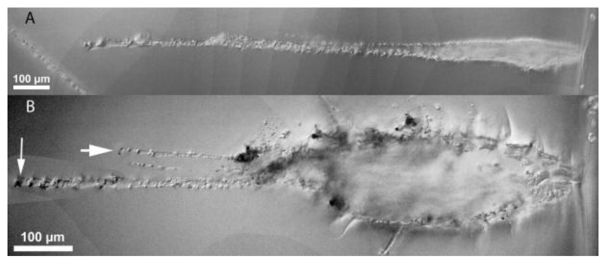


*Figure 1. A. Track #177.* This Type A track has an olivine terminal grain. *B. Track #178.* Arrows point to terminal assemblage (magnetite and subgrain of olivine) and second terminal grain (magnetite) on shorter stylus of this Type B track.

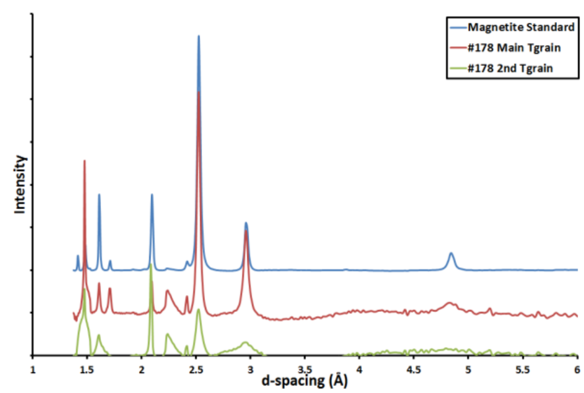


*Figure 2. XRD Analyses of Magnetite in Track #178.* Magnetite is present within the largest, 10 µm, terminal grain and a smaller terminal grain within an adjacent bulb stylus.

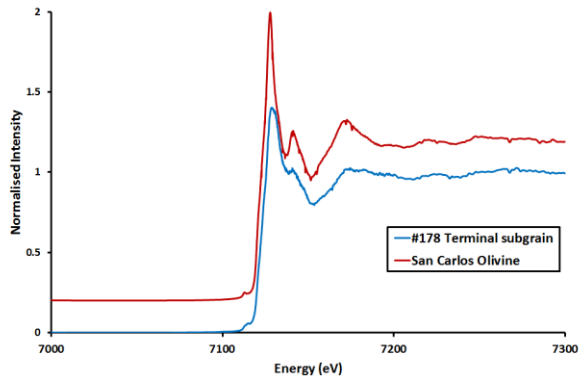


*Figure 3. Fe-K XANES Analysis of Olivine in Track #178 Terminal Assemblage.* The pre-absorption edge feature at 7112.6 eV and the strong white line are characteristic of olivine in the Track #178 terminal assemblage and San Carlos olivine standard.

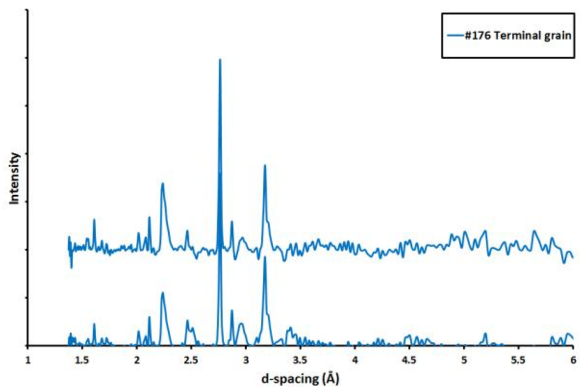


*Figure 4. XRD Analyses of Track #176 terminal grain.* The d-spacings of 3.177 Å, 2.873 Å, 2.465 Å, 2.115 Å, and 1.611 Å show the presence of enstatite.

**Discussion:** The Track #178 bulb area is carbon-rich [5] consistent with a volatile-rich cometary assemblage, perhaps associated with a chondritic matrix [4,6]. This is consistent with our identification of magnetite in the terminal grains of Track #178, which is also typical of carbonaceous chondrite matrices, as is the co-existence with olivine in the terminal assemblage. Other work has identified chondrule [7-8], and CAI fragments [9] in different tracks, strengthening the link to carbonaceous chondrites.

**Conclusions:** Transmission X-ray Diffraction, together with X-ray Absorption Spectroscopy, and complementary Raman analyses [5] allow the non destructive mineralogical identification of Comet Wild2 terminal grains. The terminal grains of Tracks #176, 177 are enstatite and forsteritic olivine, Track #178 contains magnetite and forsteritic olivine. The results from Track #178 suggest that much of the nanometre-micron scale Fe oxides present in many *Stardust* tracks are fragments of larger magnetite grains. This, in turn, is consistent with formation in material similar to carbonaceous chondrite matrix.

**References:** [1] Bridges J. C. et al. (2010) *MAPS, 45*, 55-72. [2] Changela H. G., Bridges J. C. and Gurman S. J. (2012) *GCA*, *98*, 282-294. [3] Stodolna J. et al. (2010) *LPS XXXXI*, #1657. [4] Burchell M. J. et al. (2008) *MAPS*, *43*, 23-40. [5] Price M. P. et al. (2014) *LPS XXXXV*, abstract (subm.). [6] Zolensky M.E. et al. (2008) *MAPS*, *43*, 261-272. [7] Bridges J. C. et al. (2012) *EPSL*, *341-344*, 186–194. [8] Butterworth A.L. et al. (2010). *LPS XXXX*, #2446. [9] Simon S.B. et al. (2008) *MAPS*, *43*, 1861–1877.