SPACE WEATHERING PRESERVED IN STARDUST COMET WILD2 SAMPLES. J. C. Bridges[1], L. J. Hicks[1] and S. J. Gurman[2], [1]Space Research Centre, Dept. of Physics & Astronomy, University of Leicester LE1 7RH, UK j.bridges@le.ac.uk, [2]Dept. of Physics & Astronomy, University of Leicester LE1 7RH, UK.

Introduction: Terminal grains from the Comet Wild2 tracks of the *Stardust* mission are revealing new and unexpected insights about this Jupiter Family comet. One of the features of 81P/Wild2 is that it has a reddish, oxidised surface [1]. Previously, chondrule and refractory inclusion fragments [2-4] have been identified, showing that the components of the comet have undergone high temperature e.g. ≥1500 K processing within the inner or outer Solar System and contain unexpected mineral assemblages similar to those from asteroidal bodies. Here we show the results of further terminal grain analyses and show that Comet Wild2 contains more, previously unreported mineralogical diversity.

Synchrotron X-ray Absorption Spectroscopy allows the identification of micron-sized mineral assemblages and is thus ideal for the study of Comet Wild2. We use X-ray Absoption Near Edge Spectroscopy (XANES) and Extended X-ray Absorption Fine Structure (EXAFS) to characterise a terminal grain from Track #170.

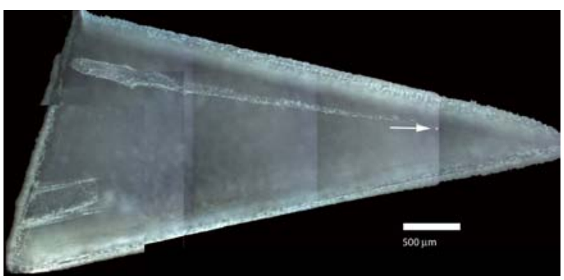

Figure 1. Track #170 with terminal grain arrowed. 500 µm scale bar.

Sample: We have analysed a track within keystone C2112,4,170,0,0. Track #170 is type A and 3.6 mm long (Fig. 1). The terminal grain is approximately 18 µm diameter. This keystone also contains two smaller Type A tracks but no terminal grains were found on these either by optical microscopy or synchrotron analyses.

Methods: XRF, Fe-K and Cr-K XANES and EXAFS analyses were made using the I18 Microfocus Spectroscopy Beamline of the UK *Diamond* Synchrotron. This can provide a 2 x 2.5 µm spot size. XRF mapping for elements with Z >20 were made to locate grains in the tracks and provide some elemental compositions. In addition some analyses for S made with a Vortex EDX detector in helium atmosphere. Mg cannot be detected by this technique. EXAFS were studied using an energy spectra range from 6900 to 7500 eV, with 0.2-0.4 eV energy steps.

The EXAFS spectra were fitted using EXCURV which produces reciprocal, k-space parameters, and followed by a Fourier Transform to produce bond lengths, within different shells, in angstroms [5]. Results were compared to expected values for different phases from the Chemical Database Service [6].

Results:

Fe-K and Cr-K XANES. The Fe-K XANES plot of the terminal grain is notable in its absence of a clear pre absorption edge feature (Fig. 2). In contrast our pyroxene and chromite analyses always show such features, which are related to the Fe^{3+}/Fe^{2+} ratio. In this respect it is similar to our Fe metal foil analyses. This shows that the Fe within the terminal grain is dominantly metallic. The absorption edge position of the terminal grain Fe-K XANES is 7119.1 eV, which is similar to that of Fe metal foil 7118.9 eV.

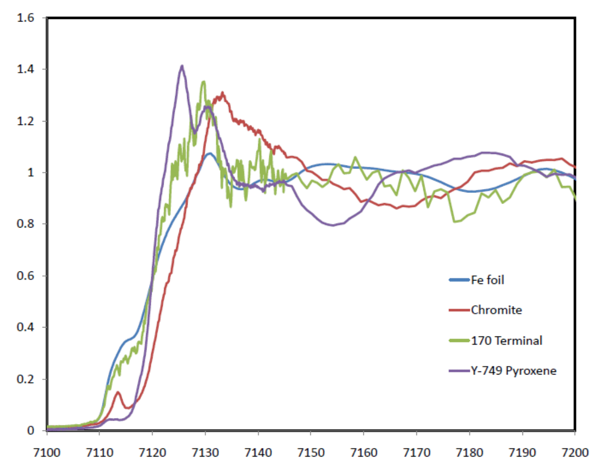

Figure 2. X-ray absorption spectra (normalised intensity) around the Fe-K absorption edge for the Track 170 terminal grain, chromite standard, Fe metal foil and an Fe-rich augite pyroxene from the Y000749 nakhlite. The pre-edge region is arrowed, metal foil and the terminal grain have similar pre-edge absorption features, distinct from those of oxides and silicates.

XRF analyses did not show any Ni or S, so this metal is pure Fe rather than an FeNi alloy or sulphide. Some Ca was also detected in the terminal grain. Fe-

NiS grains were identified near the entrance to the track but not at the terminal grain.

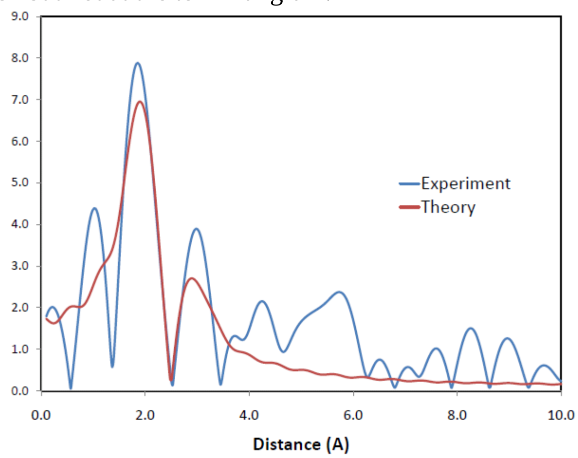

Figure 3. Fourier Transform of Track 170 Cr-EXAFS spectra. The closest fit suggests e.g. a Cr-O, first shell bond distance of 2.06 Å which is consistent with an origin as a silicate rather than as a oxide such as chromite.

EXAFS. The terminal grain has a first shell, interatomic Cr-O distance of 2.06 Å and we also calculate a more approximate Cr-O-Si distance of 2.80 Å, based on a weak peak (Fig. 3). This is in contrast to our chromite standard which has a first shell Cr-O distance of 1.98 Å and a second shell Cr-O-Cr distance of 2.94 Å. Thus we establish that this terminal grain is not an oxide.

Discussion: Our analyses show that the terminal grain in Track #170 contains a mixture of Fe metal and Cr-bearing silicate. Although we cannot test for the presence of Mg, the most obvious explanation for our results is that this grain consists of Fe metal grains within a silicate such as Mg-rich, Fe-poor, Cr-, Ca-, bearing silicate, probably a pyroxene. We have not found metallic Fe scattered within the sample showing that it is not terrestrial contamination. The absence of Ni and S also rules out an origin through impact heating of FeNi sulphides along the track during capture.

Fe metal in other planetary materials. Space weathering has been identified in samples returned by *Hayabusa* from Asteroid Itokawa. This takes the form of nanoglobules including sulphur-free Fe-rich nanoparticles inside (<60 nm) FeMg silicates [7]. They are believed to have formed through the *in situ* reduction of Fe^{2+} resulting from solar wind implantation and sputtering. If the metallic Fe in the terminal grain of Track #170 is the result of space weathering then this would also explain the reddish colour of the outer surface of Comet Wild2 [1]. This possibility was raised previously as an explanation for some of the Fe particles in other tracks, though their partial oxidation complicates the interpretation of those particles, oxides in Comet Wild2 having a variety of origins [8].

An alternative explanation can also be considered. Clouding of pyroxene from eucrites has been shown to be due to the presence of microscopic inclusions including Ni-free metal [9]. The eucrite pyroxene (and plagioclase) clouding was interpreted as being the result of exsolution of minor components during metamorphism ~900°C and fO_2 10^{-16} to 10^{-18}. However, in addition to Fe metal, the eucrite pyroxene also contained inclusions of ilmenite and chromite, troilite and other phases, which we have not identified in this terminal grain.

Conclusions: Fe K XANES and XRF shows that the Fe in the 18 µm terminal grain from Track #170 is predominatly metallic, but without Ni. Cr-EXAFS shows that the surrounding phase is a silicate, probably pyroxene, rather than an oxide. The absence of metallic Fe in other parts of the track or keystone rules out contamination. This assemblage suggests that the *Stardust* samples have preserved some of the space weathering products identified on the surface of this comet.

References: [1] Farnham T. L. & Schleicher D. G. (2005) Physical and compositional studies of Comet 81P/Wild 2 at multiple apparitions. *Icarus 173*, 533-558. [2] Nakamura T. et al. (2008). Chondrule like objects in Short-Period Comet 81P/Wild 2. *Science, 321*, 1664-1667. [3] Chi M. et al. (2009) The origin of refractory minerals in comet 81P/Wild 2. *GCA 73*, 7150-7161. [4] Bridges J.C. et al. (2012) Chondrule Fragments from Comet Wild2: Evidence for High Temperature Processing in the Outer Solar System, *EPSL* in rev. [5] Gurman S.J. (1984) A rapid curved-wave theory of EXAFS. *J. Phys. C: Solid State Phys. 17*, 143-151. [6] Fletcher D.A et al. (1996). The United Kingdom Chemical Database Service. *Inf. Comput. Sci., 36*, 746-749. [7] Noguchi T. et al. (2011) Incipient Space Weathering Observed on the Surface of Itokawa Dust Particles. Scince, 333, 1121-1125. [8] Bridges J.C. et al. (2010) Iron oxides in Comet 81P/Wild 2 Samples. *Meteorit. Planet. Sci. 45*, 55-72. [9] Harlow G. E. & Klimentidis R. (1980) Clouding of pyroxene and plagioclase in eucrites: Implications for post-crystallization processing. *Proc. LPSC, 11th*, 1131-1143.