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Iron Oxide Grains in Stardust Track 121 Grains as Evidence of Comet Wild 2 Hydrothermal Alteration

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IRON OXIDE IN STARDUST TRACK 121 GRAINS AS EVIDENCE OF COMET WILD2 HYDROTHERMAL ALTERATION. J. C. Bridges¹, H. G. Changela¹, J. D. Carpenter¹, I. A. Franchi² and the UK Stardust Consortium, ¹Space Research Centre, Dept. of Physics and Astronomy, University of Leicester, Leicester, UK, LE1 7RH, j.bridges@le.ac.uk. ²PSSRI, Open University, Milton Keynes, UK, MK7 6AA.

Introduction: We have studied terminal particles extracted from Track 121 of Stardust tile C2005 (samples C2005,2,121,1,0 and C2005,2,121,2,0) by SEM and EDS in order to help characterise their mineralogy and origin. The samples have also been studied with microRaman as part of a larger collaborative UK Consortium study of different Stardust samples using a variety of analytical techniques.

Method: The NASA-JSC curatorial team prepared the samples by microtoming Track 121 and then pressing separated terminal particles and some enclosing aerogel onto Au substrates that were prepared at the Open University. Firstly in the UK these samples were studied by Raman spectroscopy, the University of Kent [1] for C2005,2,121,2,0. Laser Raman microprobe maps of particle C2005,2,121,1,0 were performed at the Open University. This used a 1.5 micron resolution. Long integration times with a 60 μ W 514 nm laser were employed.

The grains were then studied with reflected light microscopy, an FEI Sirion Field Emission SEM (FEG-SEM) and a Philips XL30 Environmental SEM at Leicester University. The FEG-SEM was operated at 4-9 kV and a beam current of 400 pA for imaging. EDS point analyses and X-ray mapping were performed at 12.5-15 kV, \leq 650 pA beam current with a PGT EDS system on the FEG-SEM. The ESEM (with Link EDS) was used at 1 torr pressure when sample charging on C2005,2,121,2,0 occurred during some analyses using the FEG-SEM. EDS analysis times ranged from 50-1000s for point analyses depending on our assessment of sample charging, potential damage and elemental concentrations. In one case (Fig. 2b) spectra X-ray counts from across the sample were added together to produce a representative spectrum.

Further work will be carried out on these samples including TEM and SIMS.

Results: C2005,2,121,1,0. This sample consists of a 10 x 10 μ m mixture of aerogel and cometary grains (Fig 1). Spot analyses showed that there is a high concentration of iron oxide grains (Fig 2a). As some aerogel was attached to the iron oxide grains sizes were difficult to measure accurately but ranged up to approximately 100-200 nm. A second element signature for some grains was Mg-Fe, consistent with the presence of forsterite olivine in many of the Stardust samples [2].

C2005,2,121,2,0. This sample consists of a 6 x 4 μ m aggregation of aerogel and scattered cometary grains. Like the first sample this contained Mg-Fe signatures (Fig. 2b). However surrounding aerogel precluded imaging discrete grains. Unlike C2005,2,121,1,0 all of the X-ray spectra of cometary grains contained at least some Mg in addition to Fe.

MicroRaman analyses of C2005,2,121,1,0. A number of pixels showed strong D and G band features characteristic of disordered carbonaceous material, similar to that seen in other Wild2 particles [3]. The position and width of the D (1355 cm^{-1}) and G (1597 cm^{-1}) band positions fall at the least primitive end of the spectrum displayed by other Wild2 particles. Further characterisation of the carbonaceous material is required to establish if such characteristics reflect relatively pristine cometary material, or organics heavily processed during capture, or significant aerogel contamination.

Discussion: The X-ray spectra are consistent with the presence of Mg-rich silicate (probably forsterite) and iron oxide. The iron oxide haematite has been identified by Raman spectroscopy in C2005,2,121,2,0 [1]. Thus the Fe-rich signatures that we have obtained in that sample and in C2005,2,121,1,0 are assumed to include haematite. Iron oxide is found in IDPs where it is the result of the heating and oxidation of silicates during atmospheric entry [4] and in primitive chondrites such as CI chondrites e.g. [5,6]. The latter pure Fe oxide (mainly magnetite but Fe_2O_3 as maghemite can also be present) was precipitated from low temperature hydrothermal fluids on asteroidal parent bodies. Haematite could in turn be the product of magnetite oxidation [7]. Thus the iron oxide studied here could be either the result of cometary silicate grain oxidation during capture or relicts of magnetite that formed on the Comet Wild2 nucleus.

Hypervelocity studies show the presence of melting at grain surfaces during capture in aerogel [8]. Similarly, studies of Comet Wild2 material along the aerogel tracks have shown that they largely consist of Fe-sulphides, Fe-Ni metal and Mg-Fe silicates that have undergone varying degrees of melting during capture [9]. Iron oxide – as might be expected to have formed during capture if the silicate and sulphides had been oxidised – has not been described in those assemblages. This suggests that the abundant iron oxide

in the tracks studied here is derived from Wild2 and – even if there has been recrystallisation of magnetite to haematite – it was not created during sample capture. Iron oxide-rich grains from the coma may mark the traces of low temperature hydrothermal activity at some point in the comet nucleus history.

References: [1] Foster N. J., Burchell M. J. et al. (2008) *LPSXXXIX*. [2] Zolensky M. E. et al. (2006) *Science.*, 314, 1735-1739. [3] Rotundi A. et al (2008) *Meteorit. Planet. Sci.* (in press). [4] Bradley J. P. et al. (1996) *Meteorit. Planet. Sci.* 31, 394-402. [5] Madsen M. B. et al. (1986) *Nature*, 321, 501-503. [6] Choi B.-G. and Wasson J. T. (2003) *Geochim. Cosmochim. Acta* 67, 4655-4660. [7] Haggerty S. E. and Baker I. (1967) *Contrib. Mineral. Pet.* 16, 233-257. [8] Noguchi T. et al. (2007) *Meteorit. Planet. Sci.* 42, 357-372. [9] Leroux H. et al. (2008) *Meteorit. Planet. Sci.* (in press).

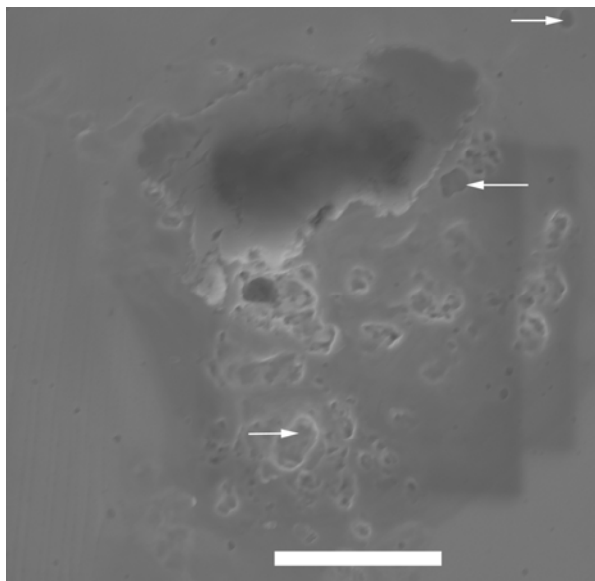


Fig. 1a. Backscattered electron (TLD) image of C2005,2,121,1,0. White arrows point to some of the iron oxide grains. The main mass is mainly composed of aerogel. The substrate is Au. Scale bar 5 μm .

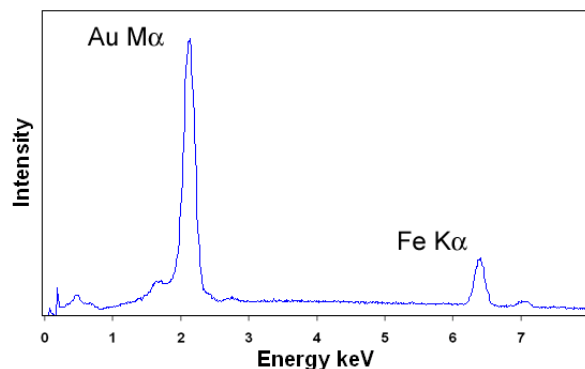


Fig. 2a. EDS Spectrum from C2005,2,121,1,0. The Au peak is from the substrate on which the particle was pressed. This spectrum is typical of those obtained from this sample and is interpreted as resulting from the presence of Fe oxide grains.

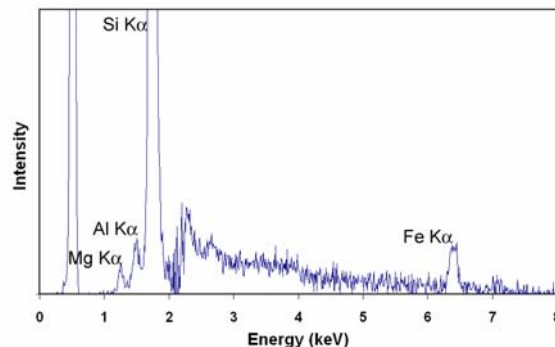


Fig. 2b. Averaged EDS Spectrum from C2005,2,121,2,0. The Al and Si peaks are the result of excitation of aerogel and the underlying Al stub rather than from within the sample. Au X-rays from the substrate were removed from the spectrum for clarity and to aid distinguishing peaks from the background. This spectrum is interpreted as resulting from a mixture of Fe-oxide and forsteritic olivine mixed with aerogel. Total acquisition time for this spectrum is 12000s, achieved through adding the X-ray counts for a series of similar spectra across the sample.

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