PRESERVATION AND MODIFICATION OF FINE-GRAINED COMETARY DUST CAPTURED BY STARDUST: THE FATE OF AGGREGATE COMPONENTS IN HYPERVELOCITY IMPACTS ON ALUMINIUM FOIL. A. T. Kearsley[1], T. Salge[2], P. J. Wozniakiewicz[1,3], M. C. Price[3], R. Terborg[2], M. J. Burchell[3], and M. J. Cole[2] [1]Science Facilities, Natural History Museum, London, SW7 5BD, UK (antk@nhm.ac.uk) [2]Bruker Nano GmbH, Schwarzchildstrasse 12, 12489 Berlin, Germany [3]School of Physical Science, University of Kent, Canterbury, CT2 7NH, UK.

Introduction: Stardust aerogel tracks [1,2] and aluminium foil craters [3,4] can provide much information about cometary dust structure and composition. Experimental studies of appropriate analogue materials impacted under similar conditions to the Wild 2 encounter (6.1 km s^{-1}) have helped to explain preservation and modification of coarser (>>µm) minerals [5,6]. Analyses of bulbous aerogel track walls have shown that their creation caused extensive processing of finer-grained dust components, with prolonged high temperatures and mixing with silica yielding homogenised compositions like bulk CI chondrite [7]. The original proportion of pristine amorphous material, and the full range of mineralogy within the finer-grained components are still difficult to assess. Mixed sulfide and silicate residues [4] found in small (< 20 µm) foil craters (e.g. Fig. 1), can include original crystalline materials [8], suggesting that despite high peak shock pressures (10's of GPa), craters may contain the most accessible remnants of finer polymineralic dust.

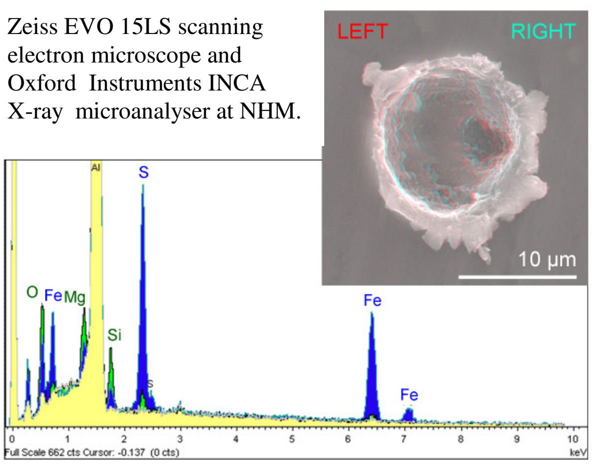

Fig. 1. Stereo anaglyph of a Stardust cometary crater on foil C092W[illegible]n which energy dispersive X-ray (EDX) spectra show intimate mixtures of Mg silicate (green) and Fe sulfide (blue) residues on foil (yellow).

How much compositional homogenisation occurs by impact melting in such craters has not yet been quantified, although loss of distinctive isotopic signatures from presolar grains [9] does suggest that most fine (< µm) amorphous silicate grains probably blend with surrounding material. To test preservation of known fine-grained minerals, and to determine the size thresholds at which they lose their integrity, we have conducted experimental impacts of artificial aggregates. We used a new type of X-ray detector to map the distribution of elemental signatures at high resolution across the entire surface of relatively deep impact craters like those of Stardust.

Methods: Polymineralic aggregate projectiles were made by aerosol impregnation of a dried slurry of mixed < 8 µm olivine, < 8 µm diopside and < 10 µm pyrrhotite powders (the same method as in [2 and 4]).

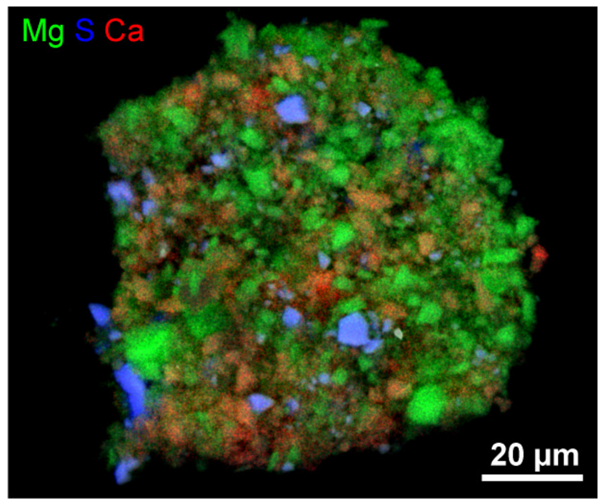

Fig. 2. Artificial aggregate: combined X-ray maps (Mg green; S blue and Ca red); 20 kV, Zeiss EVO 15LS.

Polydisperse grains were fired as a powder at 6.05 km s^{-1} in the light gas gun at Canterbury [10], giving impacts on a 1.5 cm foil sample G150709#2. Craters were imaged in a Zeiss Supra 55VP field emission scanning electron microscope (SEM) in Berlin, fitted with a Bruker XFlash 5060F annular multi-segment silicon drift EDX detector beneath the pole-piece, giving very high count rates from a high take-off angle. X-ray maps were acquired at 12 and 6 keV beam energy, the latter giving a sub-µm spatial resolution for O, Mg, Al, Si, S, Ca and Fe (based on L line emission). Maps were contrast-stretched, then colour-coded and combined to show the distribution of components derived from olivine (Mg green), pyrrhotite (S blue) and diopside (Ca red) respectively. A Zeiss EVO 15 LS SEM at the Natural History Museum was later used for stereometric shape reconstruction of the most complex crater.

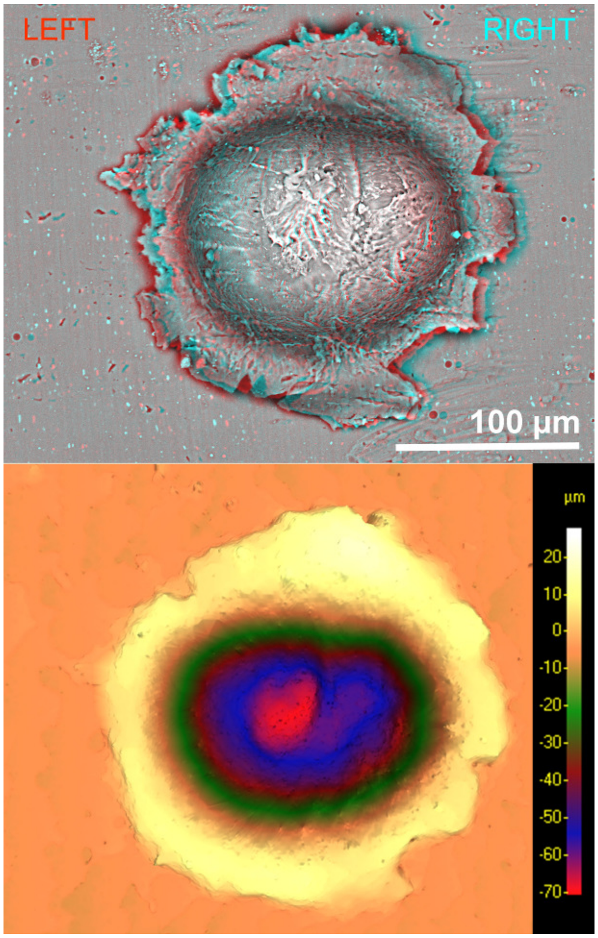

Fig. 3. (top) Stereo anaglyph and (below) depth model of a crater made by an artificial aggregate. Images from Zeiss EVO 15LS, Natural History Museum, London.

Results: The X-ray maps show abundant residues from the three mineral components in the crater interior (e.g. Fig. 4). Compositional mixtures, resolved as varying proportions of sub-µm silicate and sulfide melt with flow texture, were widespread. Mg-rich fragments (probably olivine) occur as clustered, µm-scale angular particles, as do occasional Fe- and S-rich grains. Fragments of diopside were not observed, although vesicular (bubbly) residue patches rich in Ca were abundant.

Conclusions: Our results demonstrate that an XFlash 5060 detector will show locations of impact residue throughout all the complex topography seen in Stardust aluminium foil craters. The very high count rate at even low beam energy and current can reveal textures and compositions below micrometre-scale. Our aggregate craters will now be used in laser Raman mapping, prior to focussed ion beam section preparation for transmission electron microscopy, to locate and measure regions of crystalline structure and surviving stoichiometric composition (i.e. single mineral origin).

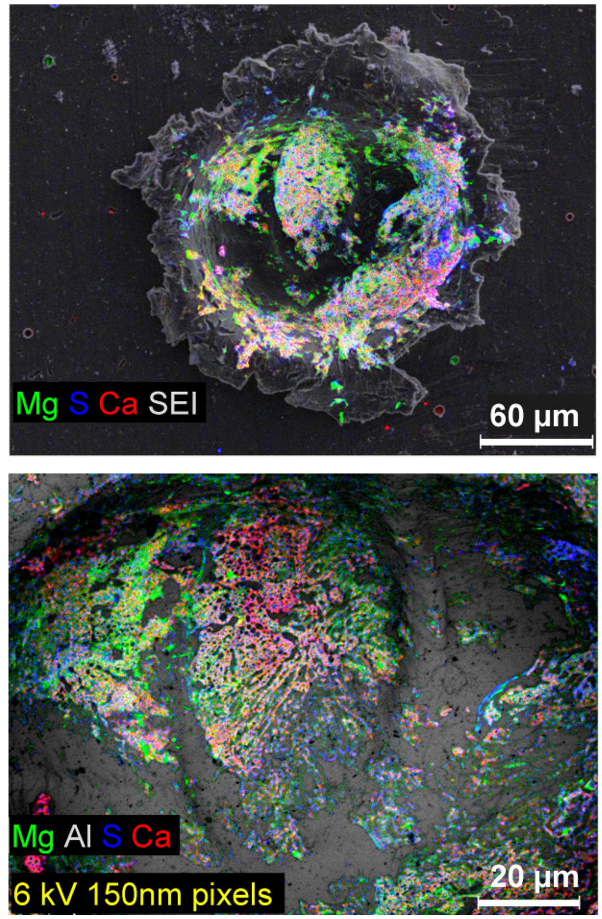

Fig. 4. Crater as Fig. 3; X-ray maps from Bruker XFlash detector on Zeiss Supra 55VP, at 6 kV. Residues from single mineral species appear as the three primary colours (red, green and blue), with intimate mixtures of diopside and pyrrhotite appearing purple; and olivine-with-diopside mixtures as orange to yellow-ish green. Whole crater in top image; details of the central part in lower image, this would be 'shadowed' and not seen by a conventional inclined detector.

References: [1] Brownlee D. E. et al. (2012) *Meteoritics & Planet. Sci., 47,* 453-470. [2] Kearsley A. T. et al. (2012) *Meteoritics & Planet. Sci., 47,* 737-797. [3] Hörz F. et al. (2006) *Science, 314,* 1716-1719. [4] Kearsley A. T. et al. (2008) *Meteoritics & Planet. Sci., 43,* 41-73. [5] Wozniakiewicz P. J. et al. (2011) *Meteoritics & Planet. Sci., 46,* 1007-1024. [6] Wozniakiewicz P. J. et al. (2012) *Meteoritics & Planet. Sci., 47,* 708-728. [7] Stephan T. et al. (2008) *Meteoritics & Planet. Sci., 43,* 233-246. [8] Leroux H. et al. (2008) *Meteoritics & Planet. Sci., 43,* 143-160. [9] Floss C. et al. (2013) *The Astrophysical Journal,* in press. [10] Burchell M. J. et al. (1999) *Meas. Sci. Tech., 10*, 41-50.