GLYCINE SURVIVAL IN HYPERVELOCITY IMPACTS IN THE LABORATORY INTO AEROGEL AND ONTO ALUMINIUM FOIL. M. J. Burchell[1], M. J. Cole[1], M. C. Price[1], A. T. Kearsley[2] and A. Nixon[1]. [1]School of Physical Science, University of Kent, Canterbury, CT2 7NH, UK (m.j.burchell@kent.ac.uk), [2]IARC, Department of Mineralogy, Natural History Museum, London, SW7 5BD, UK.

Introduction: The results from the Stardust mission to comet 81P/Wild2 [1] are producing many questions in a wide range of fields. The reports of detection of glycine in the returned aerogel samples [2-3] are particularly relevant to astrobiology, as this amino acid is often held as a key pre-biological molecule, and its discovery in a proven comet sample is a significant milestone. However, all the Stardust samples were obtained from impacts onto aerogel or aluminum (Al) foil, at 6.1 km s^{-1} and this needs to be taken into account. Previously, a wide range of laboratory experiments have been carried out to obtain particle size calibrations for Stardust samples, both for capture in aerogel [4] and impact cratering on Al foils [5-6]. Diverse mineral samples have also been used to study their preservation state, but here we ask a rather different question: what happens to glycine during impacts onto aerogel and Al foil at 6.1 km s^{-1}? Glycine is a crystalline material, with a low thermal decomposition temperature (233 °C). It is therefore not clear how it will behave during hypervelocity impacts.

The two collector materials produce very different shock histories in impactors. Impacts on the foil result in craters which are lined with fragmented and melted residue. The associated peak shock pressures are typically in the range 60 – 80 GPa, dependent on projectile composition [7], yet not all the impactor melts or loses its original structure. In [8] laboratory experiments with mineral projectiles on Al at ~6 km s^{-1}, showed that it was possible to obtain Raman spectra of the impactor from the crater. Equally significantly, TEM studies of mineral residues on Stardust craters have shown that some crystalline structure is found [9]. It is therefore not unreasonable to ask what the residue would look like from a glycine impact onto foil.

Impacts into aerogel produce lower peak shock pressures than those in the Al Foil, estimated at just under 1 GPa peak for a typical silicate, with a sustained mean value of only ~300 MPa [10]. Several track types can occur, A: long thin carrot tracks, B: tracks with bulbous initial cavities with thinner individual tracks underneath and C: tracks with only a bulbous cavity [4, 11]. However, most studies have been made with metal or mineral projectiles (see [12] for a review). Some studies with organic projectiles have been done. In [13] it was shown that large (100 – 300 µm) PMMA and PEMA grains produced carrot shaped (A) tracks in aerogel and Raman spectra were obtainable from the terminal grains. However, in [14] it has recently been shown that polystyrene particles of 20 µm initial diameter, suffer 86% mass loss during capture in aerogel at 6 km s^{-1} and the terminal grains no longer give recognizable Raman spectra.

Method: The samples used were polydispersive grains of glycine. They were fired in shotgun-like shots in the two stage light gas gun at the University of Kent [15]. One shot (5.89 km s^{-1}) of glycine was made onto Al foil (type Al1100, 103µm thickness) similar to that used on Stardust. A control blank shot was also made onto foil, with all launch conditions the same, but no projectiles were actually present in the sabot. Two shots (6.06 and 6.18 km s^{-1}) were made into aerogel of density ~30 kg m^{-3} within the range of values for the density gradient Stardust aerogel which had a nominal front face density of 5 kg m^{-3} rising to 50 kg m^{-3} at a depth of 3 cm. Note: An analysis of the Stardust tracks suggested they could be considered as resulting from impacts on aerogel of mean density 20 kg m^{-3} [16].

Foil Analysis: After the shots the foils were initially examined by optical microscopy, and were then studied by two analytical techniques: Raman spectroscopy at Canterbury; and energy dispersive X-ray (EDX) micronalysis on a scanning electron microscope (SEM) at NHM. Optical microscopy revealed craters whose internal walls and floors had a linear or polygonal fracture pattern that we associate with impacts by organic projectiles [17]. The Raman spectrometer used a HeNe laser with spot size of order a few µm (see [14] for more details of the system). The Raman analysis found that both the foil impacted by glycine and the control foil were contaminated with carbon from the light gas gun. None of the distinctive Raman lines from glycine were observed from examination of 5 craters on the foil hit by glycine. The craters were examined on the crater floor, walls and over-turned rim.

SEM-EDX analyses at both high (20 keV) and low (5 keV) beam energy for 100 seconds acquisition from µm-scale spots and broader areas within the craters revealed peaks for carbon (C), nitrogen (N) and oxygen (O). Spectra taken outside the crater had much smaller C and O peaks, and no discernible N. An X-ray map taken for 16 hours using a 5 kV beam (Fig. 1a) revealed N distribution consistent with presence of a residue layer within the crater, the apparent crescentic shape is due to the sample and detector geometry (see [18] for a detailed discussion of this type of artefact).

Aerogel Analysis: The aerogel tracks were type C (see Fig. 2), i.e. bulbous cavities lined with fine grained (5 µm and smaller) fragments of the projectile. Raman analysis failed to show a spectrum of glycine, although spectra were successfully obtained from a small grain pressed by hand into the aerogel to a depth of 5 mm (similar to the track depth) as a test. One track was cut from the block and crushed between two microscope glass slides, to crack melted aerogel rims from the grains. Again, no Raman spectra for glycine were found from analysis of the liberated grains.

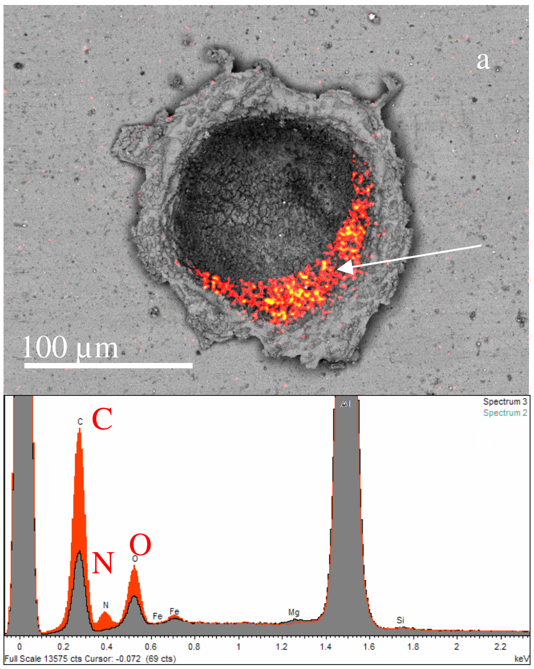

Fig. 1. (a) Backscattered electron image of a crater on the foil impacted by glycine, areas rich in N are coloured (marked with an arrow). (b) EDX spectrum from within a crater, showing C, N and O above foil background (grey).

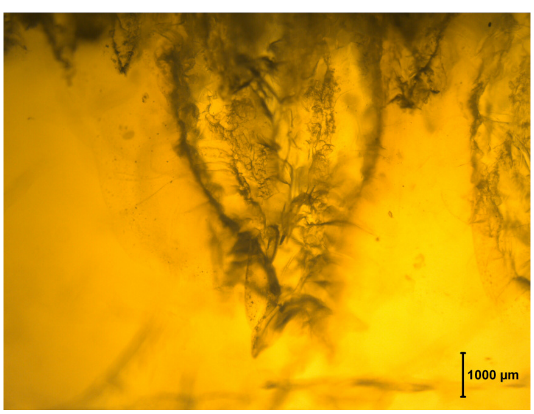

Fig. 2. Side view of a type C track made by impact of glycine on aerogel. The impact was from the top.

Discussion: That the glycine did not survive intact in the foil craters (as evidenced by the lack of a Raman signal) is perhaps not a surprise. The low thermal decomposition temperature compared to the temperature of the molten aluminium crater wall may be responsible. However, the texture of the crater walls was indicative of an organic impactor, and residues were located inside the craters by EDX. Further work is underway to determine if the ratios of C, N and O reflect the composition of glycine (NH_2CH_2COOH).

The nature of the tracks resulting from impacts in aerogel, i.e. finding fine grained fragments in the walls of a bulbous cavity, may be significant in understanding the absence of Raman signal from these fragments. Such fragments are usually intimately wrapped in molten aerogel, and it has been estimated [19] that they can experience temperatures of ~2100 °C for ~0.1 ms. At such temperatures these small and relatively delicate grains will experience extensive thermal processing even on the short time scale involved.

Conclusions: We did not find recognizable macroscopic remnants of the glycine projectile in either the foil craters or aerogel tracks, although we have seen evidence of nitrogen retention in craters. Next, more sensitive tests of the samples need to be carried out, including focused ion beam sectioning, analytical transmission electron microscopy, and surface analysis using the same sophisticated techniques as in [2-3].

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