CHARACTERIZING COMET 81P/WILD 2 WITH ACFER 094 ANALOG FOILS. B. A. Haas[1], T. K. Croat[1], C. Floss[1], A. T. Kearsley[2], and M. J. Burchell[3], [1]Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO 63130, USA (bahaas@wustl.edu), [2]Impacts and Astromaterials Research Centre, Natural History Museum, London, UK, [3]Centre for Astrophysics and Planetary Sciences, School of Physical Science, University of Kent, Canterbury, UK.

Introduction: NASA's Stardust mission provided the first known cometary material for study, flying through comet 81P/Wild 2's coma at a relative velocity of 6.1 km/s. Aluminum foils present on the cometary collector largely succeeded in returning Wild 2 fine material. However, this material experienced extensive alteration due to the violent collection process [1]. The lack of presolar grains in the collected cometary material suggests the returned samples are biased against the survival of certain materials and may not be fully representative of Wild 2's composition [2].

Hypervelocity impact experiments simulating the Stardust capture conditions can improve our understanding of the collected Wild 2 material and the biases inherent in the Stardust collection method. In this study analog foils were created using material from Acfer 094 as the impactor. Acfer 094 is an ungrouped primitive carbonaceous chondrite that is likely to be similar in composition to comet Wild 2 [3]. By comparing the residues found in the analog foils to the unaltered meteoritic material [4] and to similar studies of Stardust craters [5], we gain information on the impact process and the survival of material compositionally relevant to the cometary matter. Here we report new results from our ongoing FIB-TEM analyses of the Acfer 094 analog craters.

Experimental Methods: Material from Acfer 094 was ground into a fine powder before being fired at flight-spare Stardust foils with the University of Kent's light gas gun [6] under conditions similar to those experienced by the Stardust sample collector. The foils were examined by SEM, and EDX spectra were obtained from a variety of craters to document compositional variety in the residues. Impact craters were selected for further analysis based upon their EDX-determined elemental composition, in order to allow detailed study of a wide range of impacting material. Cross sections were extracted from the craters and thinned to electron transparency with a FEI Quanta 3D FIB-SEM prior to analysis with a JEOL 2000 TEM at Washington University.

Results: 201 craters ranging in size from 400 nm to 50 µm were imaged and elementally characterized by SEM-EDX. Four craters ranging from 450 to 900 nm, twelve ranging from 0.8 to 2.3 µm, and six ranging from 5.0 to 10.0 µm were selected for TEM analysis based on initial SEM-EDX analysis to cover a wide range of Mg-Si-Fe compositions (Fig. 1) [4].

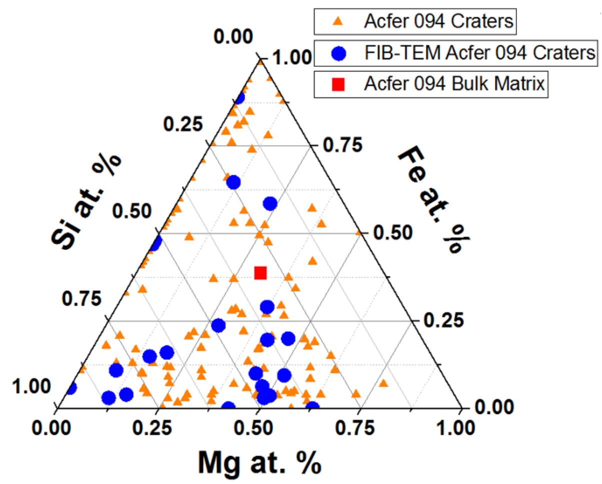

Figure 1: Plot of Mg-Fe-Si compositions of Acfer 094 analog craters as determined by SEM-EDX [4]. The impact craters show a wide variety of compositions. 22 of the 201 analyzed craters were selected for FIB-TEM analysis. The Acfer 094 bulk matrix composition is shown for reference [7].

The impact residues from all of the craters are dominated by homogeneous melt layers composed of Si-Mg-Fe or Fe-S-Ni (Fig. 2). Virtually no surviving crystalline material was found. Incorporation of Al from the foils into the melt layers is universal, with Al comprising over 50% of the melt in most craters. TEM-EDX analysis was conducted on Fe-Ni-S melt layers to determine the Fe to S ratios. We compared this to SEM-EDX analysis on unfired, Fe-rich Acfer 094 material, and observed higher Fe to S ratios in the fired material, indicating loss of S upon impact (Fig. 3). Several of the larger craters also show the presence of Fe-vesicles within the melt layers (Fig. 4), with two instances occurring in the 0.8-2.3 µm samples and four instances occurring in the 5.0-10.0 µm samples.

Discussion: The ubiquitious melt layers observed in all of the Acfer 094 analog craters studied to date, as well as evidence for the incorporation of Al and loss of S in the melt layers, attest to the high temperatures and pressures experienced by the impactor materials.

The formation of Fe-vesicles in the larger analog craters suggests that the melt layers experienced prolonged liquification, allowing Fe dissociation and migration. Similar Fe-vesicles have been observed in large aggregate impact analogs [8]. However, the smaller analog craters in our study do not show this type of vesiculation. This suggests that smaller craters experience more rapid solidification at lower temperatures.

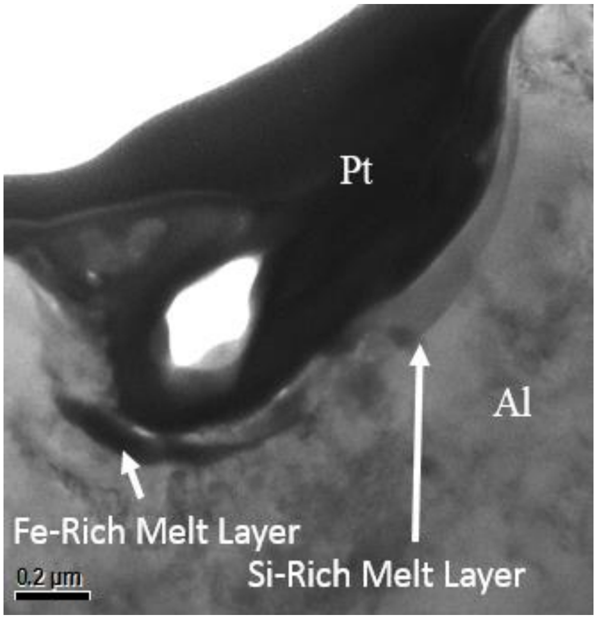

Figure 2: *TEM image showing the cross section of a 1.4 µm Acfer 094 analog crater. Both darker Fe-rich and lighter Si-rich melt layers are visible between the Pt cap and the Al foil. Al melt from the foil is the primary component in both layers.*

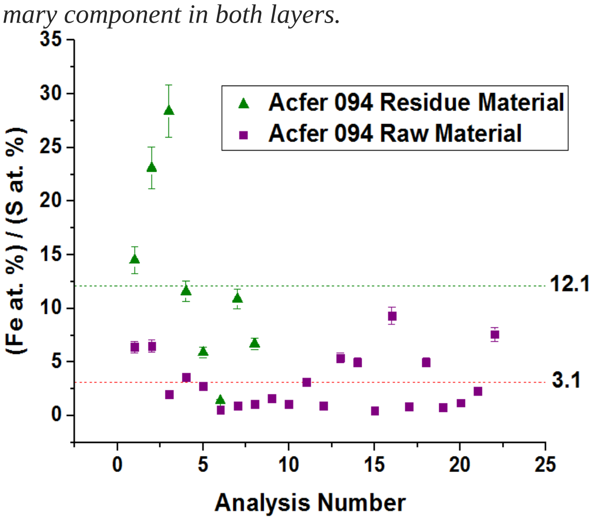

Figure 3: *Comparison of Fe to S ratios observed in Acfer 094 analog melt layers and those seen in Fe-rich unfired Acfer 094 material. All residue material came from craters 1-3 µm in size. The average Fe/S value of the Acfer 094 residue material (12.1) is nearly four times larger than that of the unfired component (3.1).*

Finally, the lack of surviving crystalline material in the Acfer 094 analog craters is consistent with other aggregate analog studies [8], but differs from results seen in FIB-TEM studies of actual Stardust craters [5]. Of eight Stardust craters ranging from 1-3 µm in size (within the size range of the analog craters studied here), four showed the presence of surviving crystals ~50 nm in diameter; a fifth crater also contained a ~500 nm enstatite grain [5].

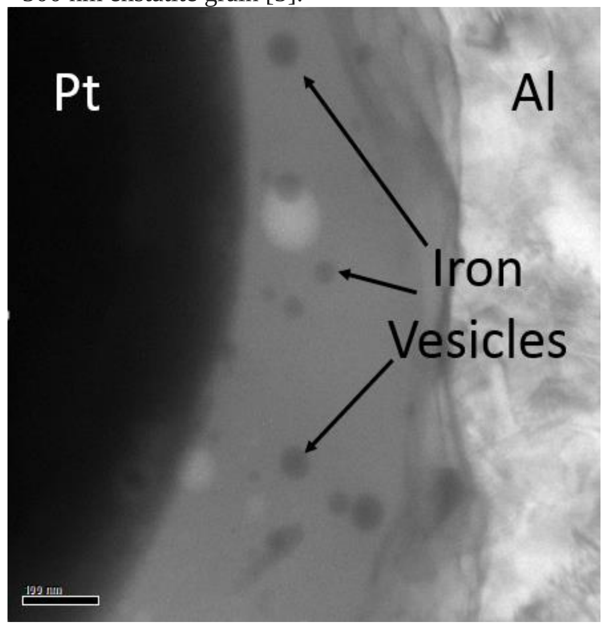

Figure 4: *TEM image of a melt layer in a 5.6 µm Acfer 094 analog crater. Dark spherules in the melt are the result of Fe migration during post-impact liquification of the impactor.*

The discrepancies observed between our analog craters and the actual Stardust samples indicate that impact processes in the foils are not yet fully understood. The lack of crystalline material in our samples, along with evidence for higher temperatures and prolonged liquification of melt layers in the larger craters, suggests that the Acfer 094 analog foils experienced more energetic impacts than their Stardust counterparts. Smaller craters appear to have been less affected and in previous analog experiments have been shown to be capable of allowing crystalline material to survive [9]. Thus, small craters may be the best candidates for identifying surviving crystalline material from both analog and Stardust foils, and for understanding the original Wild 2 impactor compositions.

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