TECHNIQUE FOR COMPARISON OF MICRO-CAI CONCENTRATIONS IN 81P/WILD2 FINE-GRAINED MATERIAL AND PRIMITIVE METEORITE MATRICES

A. J. Westphal[1], S. Fakra[2], A. L. Butterworth[1], Z. Gainsforth[1], C. E. Jilly-Rehak[1], [1]Space Sciences Laboratory, U. C. Berkeley, westphal@berkeley.edu, [2]Advanced Light Source, Lawrence Berkeley National Laboratory

Introduction: Samples of Jupiter-family comet 81P/Wild 2, returned by the Stardust spacecraft, consist of coarse-grained (>>1µm) rocks [1,2,3], in association with fine-grained material [4,5]. This mixture is broadly reminiscent of primitive chondrites, scaled down by two orders of magnitude. The relationship, if any, between the fine-grained material in Wild 2 and the fine-grained matrix in primitive meteorites is an unsolved problem[6]. Here we report the development of a synchrotron- and SEM-based technique that allows for direct comparison of the concentration of micro-CAIs in Wild 2 and meteorite matrices. We also report preliminary results.

Sample preparation and data acquisition:

Cometary fine-grained material. Using the keystoning technique [7], we extracted Stardust cometary track C2052, 0, 74 from its aerogel tile. We separated the terminal particles – we have reported extensively on one of the terminal particles, Iris, which is a chondrule-like igneous object [2,8]. We dissected the bulb into two open halves, thus exposing captured the mixture fine-grained material and melted aerogel in the bulb walls. We mounted one half-bulb between two 50nm-thick silicon nitride windows. We then carried out microfocused X-ray fluorescence (µXRF) mapping at the Advanced Light Source (ALS) bending-magnet beamline 10.3.2 with the storage ring operating at 500 mA and 1.9 GeV [9]. All data were recorded in fluorescence mode using an XR-100SDD (Amptek) detector. A mini He chamber was used to exclude air in the sample-detector path and between the incident beam ionization chamber and the sample. Maps and µXRF spectra collected on each pixel of the maps at 4188 eV (150 eV above the Ca K-edge), with a beam spot size $(2.5\ \mu m)^2$, and counting times of 100 ms per pixel. We calibrated the Al and Fe measurements using an ALD Al standard [10] and a thin-film Fe micromatter standard.

Primitive meteorite matrix. We used a thin section of a very primitive (petrologic grade ~3.0) CR meteorite, QUE99177. We scanned an area of matrix using a TESCAN Vega SEM with Oxford 80 mm^2 EDX detector. We also mapped orthoclase and Fo87 standards for detector calibration with the identical beam parameters.

Results and discussion: Joswiak et al. [11] recently reported that ~2% of Stardust cometary tracks contain CAI material. This measurement, while valuable, does not by itself allow for a direct comparison of CAI concentration with meteoritic materials, because a normalization is needed. Comparison of CAI concentration between meteorites is relatively straightforward through standard petrographic techniques using thin sections. However, comparison of microCAI concentration between cometary material returned by Stardust and primitive meteorite matrix is complicated by the fact that cometary materials were captured at 6.1 km/sec in aerogel and Al foil collectors. Because of very high shock pressures, fine-grained material survived capture in Al foil poorly [12], but refractory fine-grained material probably has a high survival efficiency in aerogel, even if it is thermally modified [13]. Here we search for microCAIs similar to Inti [14] by searching for Al-rich pixels in synchrotron XRF maps. We chose Al because almost all minerals in CAIs contain major Al; Ca is a poor choice because it is a ubiquitious contaminant in aerogel. Al-rich pixels can be subsequently analyzed by long-dwell spot analyses for major and minor elements (Ca, Ti, V, Cr, Fe). In order to compare to meteorites, a normalization is needed. We chose to normalize to Fe, because the silica aerogel capture medium prevents a measurement of cometary Si. The derived quantity is the atomic ratio of Al in CAIs above a certain size to total Fe.

We found no Al-rich pixels in the half bulb of track 74. After accounting for attenuation in the maximum possible melted aerogel in the track bulb, and in the silicon nitride windows, we set an upper limit of Al(CAI>2.6µm)/Fe < 0.01 (2σ). This upper limit already allows a comparison to meteorites from the published literature: in CV meteorites, which are CAI rich, Al(CAI)/Fe ~0.15, while this ratio in CR meteorites is ~0.01, comparable to our upper limit for Wild 2. However, these ratios include Al in macroscopic CAIs, so a more meaningful comparison is that of micro-CAIs in primitive meteorite matrix and cometary fine-grained material. Using the SEM/EDX scan of QUE99177 matrix, we find Al(CAI>2µm)/Fe = ~0.001. Further analyses of Wild 2 samples will allow for a direct comparison of CR matrix and Wild 2 fine-grained material.

[1] Brownlee, D. *et al.* (2006) *Science* 314, 1711 [2] Gainsforth Z. *et al.* (2015) MAPS 50, 976 [3] Defouilloy *et al.* (2017) EPSL 465, 145 [4] Joswiak, D. *et al.* MAPS 47, 471 [5] Gainsforth Z. *et al.* (2018) MAPS, submitted [6] Westphal A. J. *et al.* (2017) MAPS 52, 1859 [7] Westphal A. J. *et al.* (2004) MAPS 39, 1375 [8] Ogliore R. *et al.* (2012) ApJLett 745, L19 [9] Marcus, M. A. (2004) J. Synch. Rad. 11, 239 [10] Becker, N.G. et al. (2018) Journal of Vacuum Science & Technology A **36**, 02D403 [11] Joswiak, D. *et al.* (2017) MAPS 52, 1612. [12] Floss C. *et al.* (2013) ApJ 763, 140 [13] Stodolna J. *et al.* (2012) GCA 87, 35. [14] Simon, S. B. *et al*. (2008) MAPS 43, 1861

Acknowledgments: This research used resources of the Advanced Light Source, which is a DOE Office of Science User Facility under contract no. DE-AC02-05CH11231.