ELEMENTAL COMPOSITIONS OF LARGE CLUSTER IDPs. G. J. Flynn[1], A. Lanzirotti[2], and S. R. Sutton[2,3]. [1]Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh NY 12901 (george.flynn@plattsburgh.edu), [2]CARS, Univ. of Chicago, Chicago IL 60637, [3]Dept of Geophysical Sciences, Univ. of Chicago, Chicago IL 60637.

Introduction: The ~10 μm interplanetary dust particles (IDPs) collected from the Earth's stratosphere are enriched in many moderately-volatile elements by a factor of ~3 over the CI meteorites [1]. We have examined the matrix material from the few meteorites that are sufficiently fine-grained to be samples of potential IDP parent bodies. This search has, thus far, not produced a compositional and mineralogical match to either the hydrous or anhydrous IDPs. This result, coupled with sub-micron scale element mapping, which indicates the enrichment of moderately volatile elements is not due to surface contamination [2], suggests IDPs are not simply matrix material from a parent body sampled by meteorites, but are a new type of extraterrestrial material. However, the IDP measurements provide no direct constraint on the bulk elemental composition of the parent body (or parent bodies) of the IDPs.

Collisions are believed to be the major mechanism for dust production by the asteroids, producing dust by surface erosion, cratering and catastrophic disruption. Impact experiments at ~5 km/sec, the mean collision velocity in the main belt [3], on ordinary chondrite meteorites and the carbonaceous chondrite meteorite Allende show that the 10 μm debris is dominated by matrix material while the debris larger than ~25 μm is dominated by chondrule fragments [4]. If the IDP parent body is similar in structure to the chondritic meteorites, then the ~10 μm IDPs over-sample the fine-grained component of their parent body.

These meteorite fragmentation results suggest that compositional measurements on ~10 μm IDPs only provide a direct constraint on the bulk chemical composition of the IDP parent body if the size-scale of the grains in the parent body is <<10 μm. The stratospheric collections include many non-chondritic, mono-mineralic grains, collected along with the fine-grained chondritic IDPs. Some of these mono-mineralic grains, which include volatile-poor olivine and pyroxene as well as chalcophile-rich sulfides, have fine-grained, chondritic material (i.e., small bits of typical IDPs) adhering to their surfaces. This indicates that at least some of the non-chondritic grains found on the stratospheric collectors are fragments from the same parent as the fine-grained IDPs. Thus, the bulk composition of the IDP parent body can only be reconstructed by adding to the fine-grained, chondritic IDPs the *correct amount* of this non-chondritic material.

Qualitatively, the addition of olivines and pyroxenes will reduce the mean content of many moderately-volatile elements while the addition of sulfides will increase the content of some of these elements. However, the quantitative task of adding these mono-mineralic grains to the fine-grained IDPs cannot be accomplished by simply adding the non-chondritic material in proportion to its occurrence on the stratospheric collectors because:

1) it is not clear that all of the olivines, pyroxenes, sulfides or other mineral grains found on the stratospheric collectors are extraterrestrial,

2) the settling rate of a particle depends on its density and shape, thus the concentration factor for these high-density, mono-mineralic grains is lower at the collection altitude than it is for the lower-density, fine-grained aggregate IDPs, and,

3) atmospheric entry survival is a function of density, so higher density grains (e.g., sulfides) are more likely to vaporize on entry, even if they enter with the same velocity as lower-density aggregates.

The collection of "cluster IDPs," which enter the atmosphere as large particles, some larger than 50 μm in diameter, containing both fine-grained aggregate material and mono-mineralic grains 10 μm in size and sometimes even larger, provides an opportunity to characterize the bulk chemistry and the mineralogy of the IDPs and their parent body at a significantly larger size scale than we have done previously.

A 10 μm IDP weighs only a few nanograms, while a 50 μm IDP of the same density weighs about 125 times as much and frequently includes mono-mineralic grains up to at least ~10 μm size. By completely characterizing the composition and mineralogy of a single cluster IDP we characterize the IDP parent body at a mass-scale more than two orders-of-magnitude larger than has been done by analyzing 10 μm IDPs.

We expect to find both hydrous and anhydrous cluster IDPs, but we are particularly interested in characterizing the anhydrous clusters, since anhydrous ~10 μm IDPs are enriched in the moderately volatile elements by ~3 to 4 times the CI contents [5] while the hydrous ~10 μm IDPs have ~CI contents of these elements [6].

Although most ~10 μm IDPs are not significantly altered by atmospheric deceleration, the peak temperature reached depends on properties of the particle (size, density, emissivity) as well as the entry angle, which is not known for any given particle. Modeling indicates only ~10% of 50 μm IDPs with a density of 1 g/cc are not heated above 1000 K on entry [7]. It has previously been shown that low Zn-content, Zn/Fe <0.3xCI, correlates with indicators of significant entry heating, including low solar wind He content [8] and the development of magnetite rims [9]. Thus, heated particles, which most likely experienced loss of moderately-volatile elements during atmospheric deceleration, can be recognized by depletions of Zn. In this effort, we identify "pristine" cluster IDPs, which we expect to have preserved their original, pre-atmospheric composition, by selecting only IDPs with Zn/Fe ≥0.3xCI.

Samples and Analysis Techniques Cluster particles were transferred in a drop of silicone oil to a 7 µm thick Kapton film by the Cosmic Dust Curatorial Facility at the Johnson Space Center. We previously established that silicone oil is sufficiently clean for the elements we analyze, providing only a minimal background at Fe and Br, and that the silicone oil does not interfere with X-Ray Diffraction (XRD).

We performed x-ray fluorescence (XRF) mapping in a raster scan, with an ~8x10 µm beam in 5 to 7 µm steps, over each cluster at the X26A beamline at the National Synchrotron Light Source. The XRF accumulation was 12 to 24 hours for each cluster, with about one-third of that time on particle fragments and the remainder on Kapton between fragments. The element detection limits are comparable to our normal 3-hour analysis of individual IDPs (i.e., ~3 ppm for elements from Ni to Br). We obtained the bulk composition of each cluster particle by summing the point spectra at all pixels that had detectable fluorescence. XRD mapping over the area of each cluster particle is in progress.

Results: Last year we reported the analysis of five essentially complete cluster particles – L2008Z1 (CLU#17), L2008Z2 (CLU#16), L2009R1 (CLU#14), L2009R2 (CLU#13), and L2021S1 (CLU#6) – each having a large total mass. Only two, L2008Z2 and L2009R2, were anhydrous and had Zn/Fe ≥0.3xCI. This year we analyzed three essentially complete, large cluster IDPs – L2005AS10, L2005AS11, and L2005AS14 – selected by the Curator because other investigators have determined that small fragments from each of these clusters were anhydrous (M. Zolensky, pers. communication). Each of the three clusters analyzed this year has Zn/Fe ≥0.3xCI. The CI- and Fe-normalized element abundances for each of the five clusters with Zn/Fe ≥0.3xCI, as well as the mean composition of these five clusters, are shown in Figure 1.

The S content of these large, cluster IDPs is significantly higher than previously reported for ~10 µm IDPs, suggesting that large sulfide grains have been incorporated into these particles, and are now included in the mean composition. The extent of incorporation of large anhydrous silicates can only be determined by XRD mapping or TEM examination.

Conclusions: For these five large, cluster IDPs most elements show only a factor of two variation around the mean. However, the order-of-magnitude variation in Ge and S suggests these elements are concentrated in phases that are inhomogeneously distributed even at the size scale of these large cluster particles. The enrichment of moderately-volatile elements, which is a prominent feature of ~10 µm IDPs, is significantly reduced in these five large, cluster IDPs.

These results may have significant implications for the elemental composition reported during Preliminary Examination of the Comet 81P/Wild 2 samples collected by NASA's Stardust spacecraft. On average, the moderately-volatile elements Cu, Zn, and Ga were enriched relative to CI for the 23 whole tracks analyzed. But, the Fe masses of the 23 particles ranged from 180 fg (an ~1 µm chondritic particle) to 6.4 ng (an ~30 µm chondritic particle). If ~10 µm Wild 2 grains have a higher moderately-volatile element content than larger grains, as we find for IDPs, then analysis of the larger Wild 2 particles collected by Stardust (several >10^{-4} g) is required to better constrain the bulk composition of the non-volatile component of the comet.

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References: [1] Flynn, G. J. et al. (1996) in *Physics; Chemistry; and Dynamics of Interplanetary Dust,* ASP Conf. Series; **104**, 291-297 [2] Flynn et al. (2004) *Lunar and Planet. Sci. XXXV*, Abst. #1334. [3] Bottke, W. F. et al. (1994) *Icarus*, **107**, 255-268. [4] Flynn, G. J. and D. D. Durda (2004) *Planet. and Space Sci.*, **52**, 1129-1140. [5] Flynn, G. J. et al (1993) *Meteoritics*, **28**, 349. [6] Flynn, G. J. et al. (1994) *Lunar & Planet. Sci. XXV*, 381-382. [7] Flynn, G. J. (2001) in *Accretion of Extraterrestrial Matter Throughout Earth's History*, Kulwer Pub., 107-127. [8] Kehm, K. et al. (2002) *Meteoritics & Planet. Sci.*, **37,** 1323-1335. [9] Flynn, G. J. et al. (1992) *Lunar & Planet. Sci. XXIII*, 375-376.

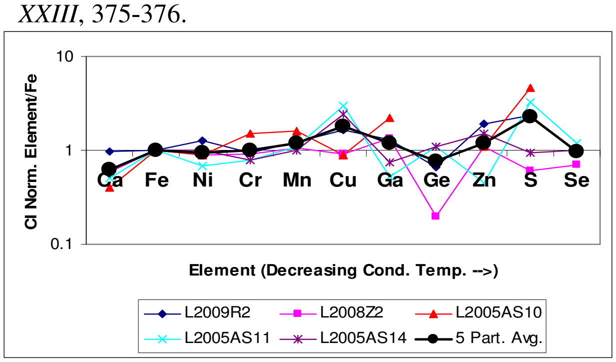

Figure 1: CI and Fe normalized element abundances for five large, normal-Zn cluster IDPs and the mean composition of the group of five particles.