UNDERSTANDING FEATURES FROM THE GENESIS CAPSULE EARTH IMPACT. Y. S. Goreva[1], D.S. Woolum[2], J.M. Paque[3], and D.S. Burnett[3] [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive Pasadena CA [2]Dept. of Physics, CA State Univ. Fullerton. [3]California Institute of Technology, Div. of Geol. and Planet. Sciences, Pasadena CA.

Introduction: Surface contamination resulting from the Genesis re-entry crash is the major impediment to large area (>10 mm^2) solar wind analyses. Previous SEM [1-4] and FIB-TEM [5] studies have shown that the major contaminant on bulk collectors is "accretionary Si" deposits. These discontinuously cover hundreds of microns in area, are a few microns thick, and are highly resistant to etching. The Si is from Genesis collectors and is highly pure; however, the issue is the amount of harmful contaminants "co-deposited" with the Si. Welten et al. [6] confirmed what was inferred from Kuhlman's earlier SEM studies that the accretionary Si on both Si and sapphire collectors are sources of contamination for other elements. It is one thing to know that co-deposited contaminants are qualitatively present, but it is possible for some elements (e.g., Fe and Ni) that, quantitatively, the amounts of contamination are not significant compared to the amounts of solar wind in large areas. A total, large area, contamination inventory is required.

JPL has developed automated confocal laser optical microscope scanning techniques that can inventory sizes, and volumes of particles with micron-size x-y sensitivity and submicron z sensitivity. Efficient scanning of areas up to 1 cm^2 are possible. This gives us the unique capability of a complete inventory of the contaminants (and damage pits as well) on a given sample. On a Si sample we expect that the majority of contaminants will be accretionary Si, but, post confocal, SEM mapping of the largest features can check this expectation. Other (co-deposited or not) contaminants can also be identified with the SEM analyses.

With a complete contaminant volume inventory, along with the identities and sizes of the non-Si contaminants, estimates of the relative amounts of contamination to solar wind in large area analysis can be made. Fe and Ni are likely target elements.

JPL confocal microscopy. Our initial study is on 62073, a small (≈ 8 mm^2) bulk SW Si sample with a relatively clean surface. The largest accretionary Si (Feature A) is shown in the confocal 3D image (**Fig. 1**). The collector surface (green-yellow) is at a 3.8 micron reference depth. Regions below the collector surface (i.e., pits) are shown in blue. Regions in yellow, orange, red are deposits, ranging up to about 3-4 microns in thickness. It is obvious that the 3D confocal images are a powerful assessment tool. All the features in Fig. 1 can be seen in high power reflected light optical examination, but hours of observation are required with no good way to capture and present the quantitative depth/height information. The excavated size of the largest pit is about 20 x 30 microns with the deepest part (approx. 3 microns) about 10 x 10 microns in size. There are two small oval satellite pits to the NE and SW of the main pit. Feature A has at least three subparallel NE-SW trending ranges of deposits. A smooth veneer of roughly 1 micron apparent thickness lies between these two ranges; this may not be a deposit, but instead could be an uplifted slice of the Si collector. The large pit in Feature A is possibly unique. It would probably be missed in low power reconnaissance imaging, but the authors have spent many hours examining surface features at high power and would never have missed a pit of this size. Many accretionary Si features appear entirely depositional; they have no >10 micron size pits.

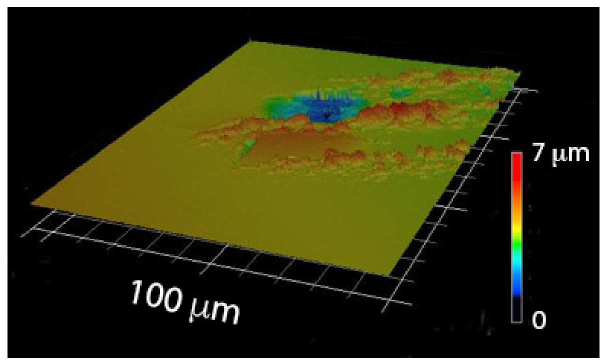

Fig.1 3D view of large accretionary Si (A) area topography using confocal laser. Cold colors – negative relief, indicating pits, warm colors – surface particles.

The Genesis sample return capsule struck the ground with a velocity of less than 0.1 km/sec. Even allowing for vapor driven particle acceleration, one does not expect multi-ring basins formed by impacts on Genesis collectors. The overall extensive damage and breakage of collectors was produced by the shock of hitting the ground; it was not caused by particle impacts. Although it is tempting to conclude that the Feature A deposits were debris from the impact of the particle which made the pit, colocation of the pit and the deposit could be fortuitous. It is also strange that, for a pit of this size in a very brittle material, no obvious fractures are seen radiating from the pit.

Caltech SEM Characterization. *Large Accretionary Si.* X-ray spectra of Feature A, both rastered and spot images of high contrast features, revealed nothing except Si plus small amounts of C, and in about half of the spectra, a small trace of Al. At high magnification several submicron flecks in the uplift area appear to be

Al. Feature B is a somewhat smaller accretionary particle than Feature A; it has only a very small pit relative to the amount of deposited material. In both A and B, Si spectra showing traces of Al that are best interpreted as small amounts of Al metal co-deposited with Si.

Particle survey. Most Genesis SEM contamination studies focused on detailed studies of large features. We adopted a different approach to the study of 62073, other than for large features, e.g., A and B. Because most contaminants are very different from Si (mostly higher Z), we surveyed a large fraction of 62073 with backscattered electrons (BSE), stopping to take an X-ray spectrum primarily with high contrast features. A relatively large number of ≈10-100 micron dark areas showed higher amounts of C but still with a large Si peak, indicating that the C deposits were thin and thus do not contain even 0.1 micron grains of high Z contaminants.

The cleaner regions of 62073 still contain a relatively high density of 1-10 micron Si accretionary particles. **Figure 2** shows a high magnification BSE image of area C3 which is a 100 x 20 micron accretionary Si particle with a fluffy porous texture, but containing ≈ 0.1 micron grains of Ge and "white paint" (ZnGa spinel), common contaminants. Note how easily these small grains can be recognized. The BSE survey revealed a wide variety of submicron high Z particles. Particles not found on Genesis samples previously: Cu, In, TiO_2, ZnO, FeZn, FeZnP, Fe (not stainless steel). In addition to C films and Al, previously seen contaminants were: Ge, white paint and gypsum (the only Utahogenic particle). Post SEM optical examination of the sample revealed no appreciable additional contamination in the handling involved in the confocal and SEM examination.

Discussion: From a materials science perspective Genesis surface contamination is very complex, but at this point, relatively well-documented. As returned from Utah, collector material fragments have a superficial debris coating that is almost entirely removed by ultrasonic ultrapure water cleaning at JSC. The surviving particles are tightly bound. The question is why, and especially so for accretionary Si. The other major issue is co-deposition of other more dangereous contaminants.. The Al in features A and B along with the Ge+white paint in C3 (**Figure 2)** are clear examples of co-deposition, but many other submicron particles are not necessarily associated with accretionary Si. 62073 suggests a two stage sequential deposition: accretionary Si (plus some Al?) followed by a dusting of other materials, but the results of Welten et al. [6] are best described by "chemical" deposition from a warm (hundreds of deg. C) gas dust cloud in which co-deposition of different contaminants would be the norm.

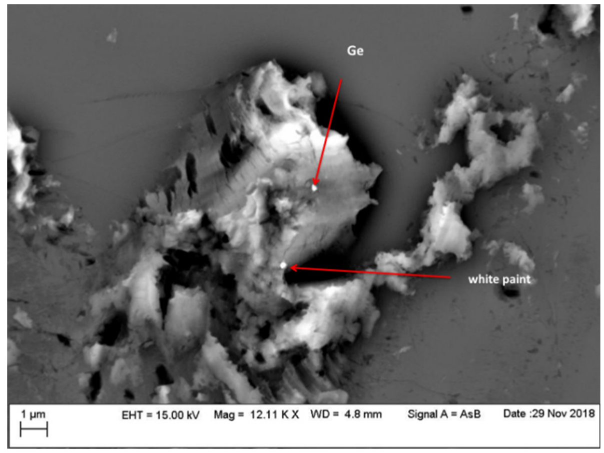

Fig. 2 High magnification BSE image of area C3

We will now proceed to produce a quantitative inventory of the amounts of accretionary Si on 62073. A specific target is to compare the volume of the deposits in Feature A with the volume of the large pit. It is quite possible that the amounts of deposits in **Fig. 1** are much larger than the volume of the pit. We can then proceed with an estimate of the amounts of Fe contamination, followed by targeted acid etching to remove as many of the documented submicron particles as well. The rarity of pits of similar size coupled with the ubiquity of accretionary Si deposits (on sapphire collectors as well) means that the possibility of the **Fig. 1** pit could be meteoritic, possibly even from a beta meteoroid.

References: [1] Kuhlman K. et al. (2013) 44th LPSC, abstract #2930 e-poster. [2] Goreva Y. et al. (2015) 46th LPSC, abstract #2533. [3] Kuhlman K. et al. (2016) 47th LPSC, abstract #2460. [4] Allton J. et al. (2016) 47th LPSC, abstract #1896. [5] Calaway M. et al. (2009) *NIM B* **267,** 1101. [6] Welten K. et al. (2018) 49th LPSC, abstract #2660.