SPACE WEATHERING OF INTERMEDIATE-SIZE SOIL GRAINS IN IMMATURE APOLLO 17 SOIL 71061. S. J. Wentworth,[1] G. A. Robinson[2], and D. S. McKay[3], [1]Lockheed Martin, Mail Code C23, 2400 NASA Parkway, Houston, TX, 77058 (susan.j.wentworth@jsc.nasa.gov), [2]Baytech, Houston, TX, 77058, [3]NASA-JSC, Houston, TX, 77058.

Overview: Understanding space weathering, which is caused by micrometeorite impacts, implantation of solar wind gases, radiation damage, chemical effects from solar particles and cosmic rays, interactions with the lunar atmosphere, and sputter erosion and deposition, continues to be a primary objective of lunar sample research. Electron beam studies of space weathering have focused on space weathering effects on individual glasses and minerals from the finest size fractions of lunar soils [1] and patinas on lunar rocks [2]. We are beginning a new study of space weathering of intermediate-size individual mineral grains from lunar soils. For this initial work, we chose an immature soil (see below) in order to maximize the probability that some individual grains are relatively unweathered. The likelihood of identifying a range of relatively unweathered grains in a mature soil is low, and we plan to study grains ranging from pristine to highly weathered in order to determine the progression of space weathering. Future studies will include grains from mature soils. We are currently in the process of documenting splash glass, glass pancakes, craters, and accretionary particles (glass and mineral grains) on plagioclase from our chosen soil using high-resolution field emission scanning electron microscopy (FE-SEM). These studies are being done concurrently with our studies of patinas on larger lunar rocks [e.g., 3]. One of our major goals is to correlate the evidence for space weathering observed in studies of the surfaces of samples with the evidence demonstrated at higher resolution (TEM) using cross-sections of samples. For example, TEM studies verified the existence of vapor deposits on soil grains [1]; we do not yet know if they can be readily distinguished by surfaces studies of samples. A wide range of textures of rims on soil grains is also clear in TEM [1]; might it be possible to correlate them with specific characteristics of weathering features seen in SEM?

Samples and Techniques: For the first phase of our single grain studies, we chose Apollo 17 soil 71061, an immature (bulk $I_s/FeO = 14$) mare soil [4] for the reasons given above. This soil was also one of the soils recently studied in a comprehensive way by the Lunar Soil Characterization Consortium (LSCC), so a lot of pertinent data from the fine (<45 micrometer) fractions are available [e.g., 5, 6] for comparison to the results we obtain for larger grains. We are studying individual plagioclase grains from intermediate size fractions (150-200 µm and 250-500 µm) using both standard and field emission scanning electron microscopy (JEOL 5910LV and JEOL 6340F for SEM and FE-SEM, respectively). Some of the individual grains will be prepared for transmission electron microscopy (TEM) using focused ion beam (FIB) sectioning. The locations of the FIB sections will be precisely known and, therefore, subsequent TEM results can be exactly correlated with the surface weathering features documented during the earlier SEM work.

Results and Discussion: A few grains of 71061 plagioclase contain trace to moderate amounts of weathering features. Most grains examined thus far show little or no evidence of space weathering, as expected. Two features are known to be characteristic of materials that have been exposed directly to space: microcraters and glass pancakes (flat, circular glass accretions). Examples of these features on 71061 grains are shown in Figs. 1-4; in general, the features on these plagioclase grains are very small. The microcraters generally do not have spall zones; the absence of spall zones, which are characteristic of larger microcraters, is typical of microcraters <5 micrometers in diameter. Figures (Figs. 1, 2, 4) demonstrate that microcraters (and nanocraters) are identifiable at sizes down to the limits of resolution of the images, as are glass pancakes. Other accretionary features seen on the 71061 grains include glass splashes (e.g., Fig. 3), glassy spherules, and tiny mineral fragments, all of which also range down to the limits of resolution (Figs. 1-4); such features are not indicators of direct space weathering but are ubiquitous to most lunar soil grains.

Summary and questions. Space weathering features on 71061 plagioclase grains appear to be the same as those found on finest lunar soil grains and/or those on large lunar rocks. The range of weathering intensities in the 71061 grains suggest that they represent a broad range of weathering intensities, and they will provide a good range of samples for future FIB and TEM studies. In general, the unanswered questions for the 71061 feldspars are similar to those for other space-weathered materials. For example, how closely can the abundance and types of space weathering features on individual grains be correlated with the overall maturity of each lunar soil? Are most space weathering features on the 71061 feldspars the result of vapor deposition? Can vapor deposits eventually be distinguished from splash glasses in SEM studies? What are the fundamental differences between glass pancakes, spherules, and other glass splashes? Did reduced iron seen in TEM studies of other space weathered samples [1] form at the same time(s) as the other features, and what is the source of the iron? What are the sources of all of the accretionary materials (including vapor deposits, glass splashes, and accreted mineral grains)? Are they the result of deposition from nearby regolith, or do they (especially glass spherules) travel long distances? Why are glass pancakes only found on surfaces that also contain micro-craters? Do micro- and nano-scale craters contain any record of the impactors from which they formed? Is any of the impactor material implanted into the soil grain?

References: [1] Keller and McKay (1997) *GCA* **61**, 2331-2340; [2] Wentworth et al. (1999) *MAPS* **34**, 593-603; [3] Wentworth et al. (2004) *LPS XXXV*, Abstract #2078; [4] Morris et al. (1983) *Lunar Soil Handbook*; [5] Taylor et al. (2000); [6] Pieters et al. (2000) *MAPS* **35**, 1101-1107.

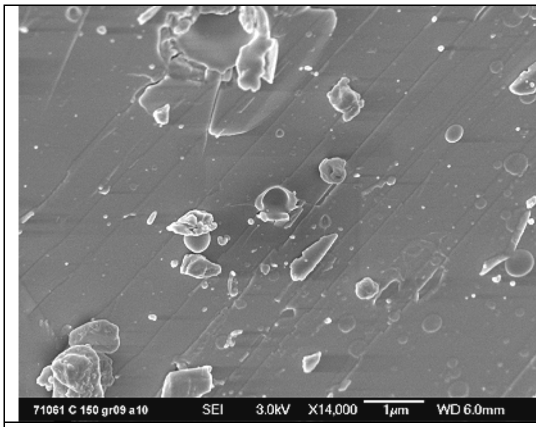

Fig. 1: Surface of 71061 plagioclase grain showing microcrater (at center), glass spherules, accretionary mineral grains, and glass pancakes; pancakes mostly visible at middle and lower right.

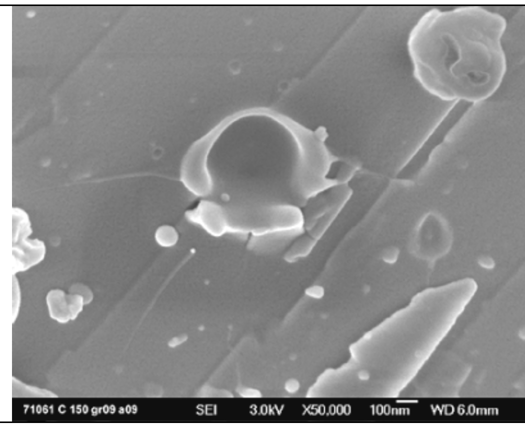

Fig. 2: Closeup of microcrater at center of Fig 1. Note even smaller crater to its right (~200 nm across). Accretionary spherules and mineral grains are ubiquitous on most lunar soil grains.

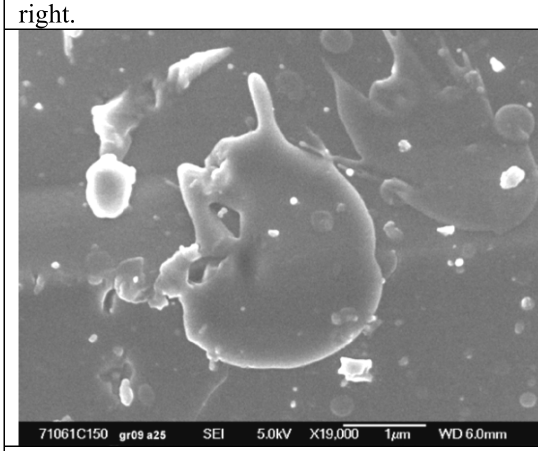

Fig. 3: Splash glass (large grains at center and center right) on 71061 plagioclase and smaller pancakes (to limits of resolution) characteristic of direct exposure to space, along with mineral accretions.

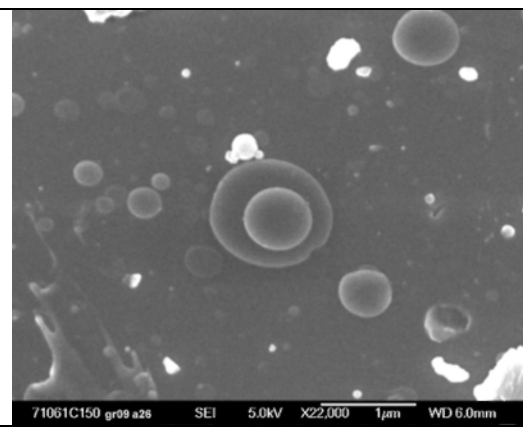

Fig. 4: Glass spherules and possible glass pancakes on 71061 plagioclase; tiny crater with partly raised rim at lower right.