NANOPHASE IRON GLOBULES IN LUNAR SOIL. C. L. James[1] S. L. Letsinger[1] A. Basu[2] S. J. Wentworth[3] and D. S. McKay[3], [1]Indiana Geological Survey, Bloomington, IN 47405, cjames@indiana.edu, [2]Indiana University, Bloomington, IN 47405, NASA JSC, Houston, TX 77058.

Introduction: Micrometeoritic impacts on lunar soils produce melt and vapor [1]. A patina of condensed vapor is deposited on lunar grains [2], the melt forms agglutinitic glass [3]. In lunar soils, agglutinitic glass and rinds of grains host submicron-sized globules of pure Fe^0 (Fe-rich globules larger than 1 micron usually contain other elements such as Ni, P, and S). Observation and measurement of such small size requires either back scattered electron (BSE) imaging with a high-resolution SEM or transmitted electron imaging with a TEM. The two techniques impose different limitations on the size-range of measurements.

Resolution of BSE imaging of polished thin sections or grain mounts of lunar soils is at best around 4-5nm (JEOL 6340F field-emission (FE)-SEM at JSC). Therefore, Fe^0 globules below 10nm in cross-sectional diameter are not truly measured. The upper limit of a millimeter or so is not a hindrance. In fact, it is an advantage because whole grains can be observed and mapped at varying magnifications. Angstrom-scale resolution of TEM images is more than sufficient to observe and measure the smallest of Fe^0 globules that are about 1nm in cross-section. Microtoming edges of lunar grains; however, puts an upper size limitation of 50nm, at best, on the wafer, which more or less limits measuring Fe^0 globules up to 30nm or so [4].

Clearly, SEM and TEM techniques complement each other in obtaining the complete range of size distribution of Fe^0 globules in lunar soils. Below we describe, in brief, our method of determining the size distribution of Fe^0 globules in agglutinitic glass using BSE-SEM imaging and size-measurement. Although our work is incomplete, we also include a table of results obtained so far, which understandably would be refined as we collect more data.

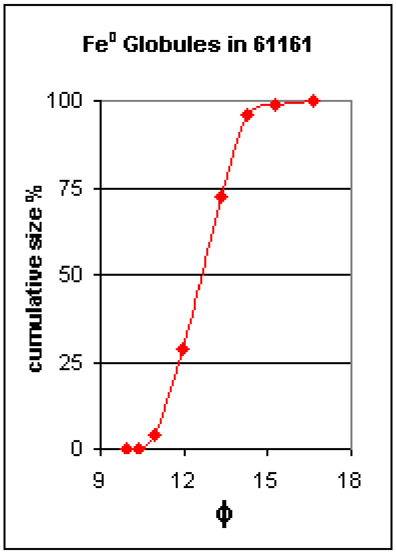
Method: *Imaging and Counting:* The back scattered electron images are obtained using a JEOL analytical FEG-SEM with a 15kv beam at 12 nanoamp sample current. The majority of our images are at x30,000 magnification imprinted with a scale bar of 1nm for reference. The image analysis is done using ArcView software (ESRI). Once the image is brought into ArcView, the measuring tool is used to measure the scale bar in arbitrary units. The units are then put into an ArcView extension, Coordinate Grid Maker (Christoph Feldkotter). The grid maker produces a grid covering the entire image with square grid cells corresponding to the 1nm scale bar and the arbitrary units measured previously. Once the grid is overlaid onto the image, the image can be enlarged and the globule size can be measured accurately. We have counted the numbers of Fe^0 globules in eight size intervals between 1500nm and below 25nm. The resolution of BSE-SEM imaging allows easy measurement of globules larger than 25nm. We have, therefore, counted all smaller globules in the size interval defined simply as <25nm and the midpoint of the size interval was arbitrarily fixed at 10nm for plotting and calculations. When the smallest resolvable globules are viewed as images, the pixels representing the edges of the globules have reflectance values that represent both $npFe^0$ and matrix glass, this being known as a mixed pixel effect in geospatial analysis. Approximately 300 to 3500 globules were measured in each soil (see table below).

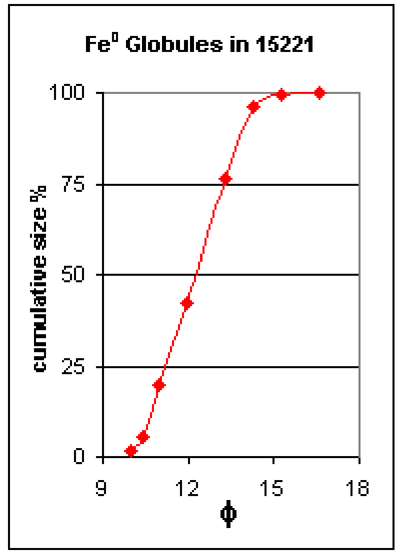
Size Distribution: Because this study was designed to provide details about the grain-size distribution of the 10-1500nm $npFe^0$ globules that represent the coagulated or fractured agglutinates, we present statistical measures in addition to the cumulative frequency distribution for each lunar soil studied. All agglutinate grain measurements were combined to obtain the grain-size distribution of Fe^0 globules in each lunar soil. The cumulative particle-size distribution for eight size fractions was plotted based on percentage frequency per size interval. A script was written to interpolate the size fractions at ¼ ϕ intervals for the entire size distribution, and statistical parameters were calculated for the size distribution. The range of grain sizes observed in the agglutinate grains was realistically between 10nm and 1500nm, with a mean of 137.89nm

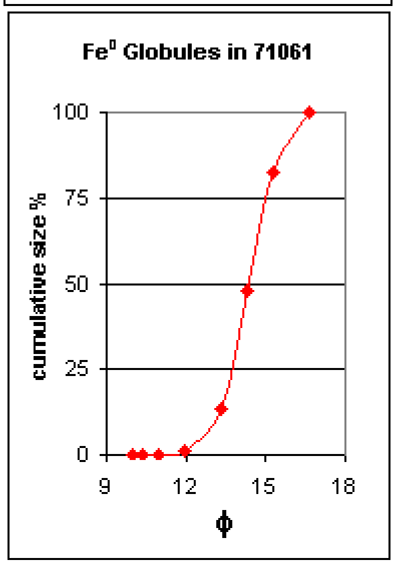
Discussion: In closing we note that not only the proportion of metallic Fe but also the nature of their occurrence and dispersion in lunar soils affect remote sensing signals (e.g., albedo, reflectance spectra, gamma and x-ray spectra, magnetism). Therefore, a thorough characterization of Fe^0 in lunar soils and understanding their origin is important in planetary exploration of atmosphere-free bodies.

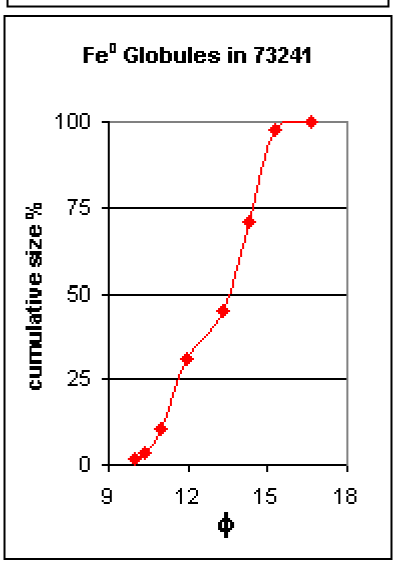
Sample	#Globules	Mean(nm)	I_s/FeO	FeO(wt%)
15221	1744	183.62	63	11.5
15601	1120	116.53	29	19.2
61161	930	142.97	82	5.4
61181	2526	83.15	82	5.5
61221	463	171.08	9.2	4.9
63501	1010	77.79	46	4.7
64501	653	88.13	61	5.2
67941	64	543.66	29	4.2
71061	1440	44.37	14	17.8
72150	269	84.78	82	14.5
73241	1610	103.94	18	8.8
75081	681	140.61	40	17.1
76321	1230	141.98	93	9.8
78421	3505	98.47	92	12.0
79221	1178	47.20	81	15.4

I_S/FeO and FeO% data from Morris 1978 [5]









References: [1] Cintala M. J. (1992) *JGR, 97,* 947-973. [2] Keller L. P. and McKay D. S. (1993) *Science., 261,* 1305-1307. [3] Heiken G. H. et al. (1991) *Lunar Sourcebook*. [4] Keller L. P. and Clemmet S. J. (2001) *LPS XXXII,* Abstract #2097. [5] Morris R. V. (1978) *LPS XIIII,*2287-2297

Acknowledgements: This research was supported in part by NASA Grant NAG5-9396.