THE MICROSTRUCTURE OF A MICROMETEORITE IMPACT INTO LUNAR OLIVINE. S. K. Noble[1] L. P. Keller[2], R. Christoffersen[2,3] and Z. Rahman[2,3], [1]NASA Headquarters, 300 E St SW Mail Code 3D75, Washington DC 20546, sarah.k.noble@nasa.gov, [2]NASA JSC, Houston TX 77058, [3]Jacobs Technology Inc, Houston TX.

Introduction: The peak of the mass flux of impactors striking the lunar surface are particles ~200 µm that erode rocks, comminute regolith grains, and produce agglutinates. The mechanisms by which these micro-scale impacts form nanophase Fe metal ($npFe^0$) in the lunar regolith are still not fully understood. Current efforts are focused on simulating the physical and optical effects of micrometeorite impacts on lunar and meteoritic material using hypervelocity impacts and pulsed lasers [e.g. 1, 2]. Here we provide some ground-truth for those studies from a natural lunar sample. Through TEM analysis of the cross-section of a ~20 µm diameter crater into an olivine single crystal we can see first-hand the effects of a single impact, including the creation of $npFe^0$ in the melt.

Sample: Lunar rock 12075 is an olivine basalt with large olivine phenocrysts (1-2 mm). The surface contains numerous micrometeorite impact craters ranging from 100 µm down to 1 µm. The solar flare track density in olivine (~$10^{11}/cm^2$) indicates a minimum surface exposure of ~10^6-10^7 years.

Methods: A small chip of 12075 was examined by SEM to locate an impact crater into olivine of appropriate size for FIB sectioning and analytical TEM characterization. A FIB cross-section was prepared using the FEI Quanta 3D600 FIB at JSC (Fig. 1). TEM work was done using a JEOL 2500SE 200 keV field-emission scanning-transmission electron microscope.

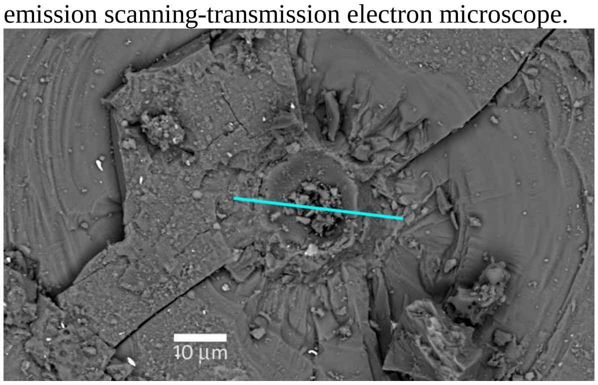

Fig 1. Micrometeorite impact into olivine crystal. The line represents the approximate location of the FIB sample.

Results: Extending from the crater cavity outward into the host olivine grain, the crater walls are composed of a shock-melted lining ~0.5 – 2 um thick of glassy olivine that sharply transitions to an underlying layer of polycrystalline olivine with recrystallization textures. The recrystallized olivine becomes progressively finer-grained as it transitions to the underlying olivine single-crystal.

An extensive zone of shocked and deformed olivine containing radial fractures and numerous defects and dislocations extends outward 15-20 um from the melt recrystallized zone. Unshocked areas of the host olivine contain a high density of solar flare particle tracks (~$10^{11}/cm^2$), but closer to the crater, the tracks are erased.

$NpFe^0$ is present throughout the melt and recrystallized layer; it is remarkably consistent in size, ~3-7 nm. The upper ~70 nm is vesiculated, likely the result of implanted solar wind gases, and the top surface is highly enriched in $npFe^0$. A small amount of Ca and Al is present at the uppermost surface, indicating a very thin layer of post-event vapor-deposited material.

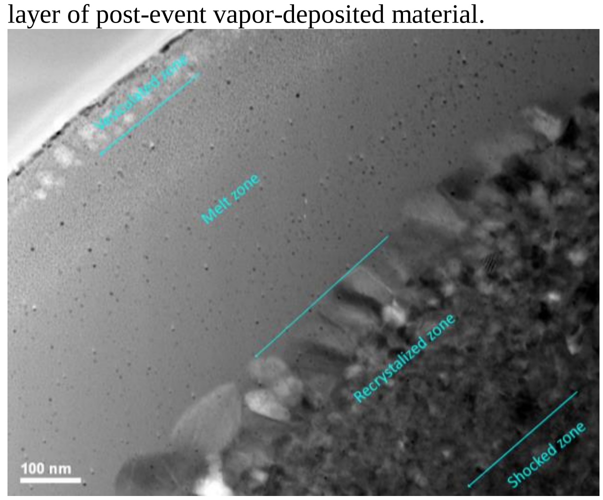

Fig 2. TEM bright field image of the impact melt lining.

Discussion: This sample clearly demonstrates that a natural micrometeorite impact into an Fe-bearing olivine single-crystal can produce glassy olivine with abundant $npFe^0$ inclusions. It does not, unfortunately, inform us whether solar wind H^+ is required in the impacted surface for $npFe^0$ formation, since most exposed lunar surfaces are saturated with solar wind ions. The size distribution and narrow range of the $npFe^0$ is most similar to that in grain rims rather than the much larger sizes and wider size range observed in agglutinitic glasses. This suggests that sequential impact processing is required for $npFe^0$ to coarsen to the sizes seen in lunar agglutinitic glass.

Future work: Future work will focus on analyzing additional craters in olivine as well as other phenocrysts in the 12075 (e,g, pyx and ilm) and comparing the results to laboratory impact experiments.

References: [1] Sasaki et al. (2001) *Nature, 410,* 555-557. [2] Brunetto R. et al. (2006) *Icarus, 180,* 546-554.