

INVESTIGATION OF LUNAR SPINELS AT SINUS AESTUUM. C. M. Weitz¹, M. I. Staid¹, L. R. Gaddis², S. Besse³, and J. M. Sunshine⁴, ¹Planetary Science Institute, 1700 E Fort Lowell, Suite 106, Tucson, AZ 85719 (weitz@psi.edu), ²Astrogeology Science Center, U. S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001; ³Camino Bajo del Castillo s/n, Ur. Villafranca del Castillo, 28692 Villanueva de la Canada, Madrid, Spain; ⁴Dept of Astronomy, University of Maryland, College Park, MD.

Introduction: Recent remote sensing observations by the Moon Mineralogy Mapper (M³) on the Chandrayaan-1 spacecraft and the Spectral Profiler (SP) on the SELENE Kaguya orbiter have identified spinels in numerous locations across the Moon [1-3]. SP data analyzed by [3] was used to identify a visible-wavelength absorption feature around 0.7 μm along with a strong 2 μm absorption only at Sinus Aestuum (SA). They attributed the 0.7 μm feature to the presence of a Fe- or Cr-bearing spinel rather than the Mg-spinel more commonly identified on the Moon [2]. The Fe- or Cr-rich spinels in the SA region are associated with widespread, dark pyroclastic deposits [1,3,4].

In this study, we analyzed M³ data for spinel locations at SA, and then examined visible images from the Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) and Wide Angle Camera (WAC), as well as the Kaguya Terrain Camera (TC) and Multi-band Imager (MI) images to correlate these spinel signatures to surface morphologic features. We extracted M³ spectra of several spinel locations and attempted to understand what was creating the signatures throughout SA. Finally, we examined the locations where SP data showed visible-wavelength features in the spinel spectra and compared them to locations where M³ data showed a 0.7 μm feature.

Observations: We examined 128 of the strongest and largest spinel signatures in widespread sites across the highlands and some mare of Sinus Aestuum. In all cases, we identified an impact crater in association with the spinel signature. The crater diameters ranged from ~100 m to ~4 km, which corresponds to transient crater excavation depths of ~25-1000 m [5,6], although for the larger craters (i.e., >1 km diam.) the spinels were observed along the upper crater walls rather than in the ejecta, suggesting shallower depths for the spinels. The majority of spinel deposits are associated with DMD on the highlands.

We identified several larger (>1 km diameter) highland impact craters that exhibit spinel signatures along the interior crater rim. The spinel is best identified in fresh exposures of the regolith, such as along the crater interior walls where mass wasting on the steeper slopes exposes immature regolith containing the spinels. For all these craters, there is no obvious source layer for the spinel observed along the crater walls.

We identified nine larger spots where we found a spinel signature in the highlands but outside of the

mapped DMD. Examination of NAC and TC images for these nine locations showed a small (100-400 m diameter) impact crater correlated to the spinel signature. The remaining spinel spots are associated with four larger (3.5-11 km diameter) impact craters (Gambart B, Gambart G, Gambart L, and Schroter D) and one smaller crater (350 m diameter) in the mare. All four larger craters have low reflectance debris along portions of their interior walls that corresponds to the spinel signatures. The dark spinel-bearing materials are observed starting near the top of the walls and spread down towards the crater floors. Spectra taken from the crater surroundings show small remnant highland materials are present within or beneath the mare, and it appears that the spinel signatures actually occur in highland materials rather than in the mare.

Discussion: Our new M³ results indicate that Fe- or Cr-spinels with 0.7 μm absorptions are mixed into most of the DMD across the Sinus Aestuum highlands. The discrepancy between spinel detections made by SP and M³ is simply a function of the more limited spatial distribution of the SP data compared to M³ data across the SA region. Consequently, our M³ analysis provides a more comprehensive understanding of the spinel distribution at SA. The M³ spectra extracted from spinel-rich locations show a visible-wavelength absorption, consistent with the SP results. Not all spinel spectra exhibit a strong visible-wavelength absorption, however, especially those spectra taken from slightly older craters.

The spinel deposits are strongly correlated to the distribution of pyroclastic deposits, indicating the two materials were most likely emplaced together as part of an explosive volcanic eruption. Although the spinels and pyroclastics may have once existed as a homogeneous deposit on the highlands, mixing by craters and regolith development over billions of years has created a heterogeneous distribution of both spinels and pyroclastics within the highlands of SA, and buried the deposit beneath younger lava flows on the mare.

References: [1] Sunshine J. M. et al. (2010) *LPSC 41*, Abstract #1508; [2] Pieters C. M. et al. (2011) *JGR* 116, 1-14. [3] Yamamoto S. et al. (2013) *Geophys. Res. Letts.* 40, 4549-4554. [4] Sunshine J.M. et al. (2014) *LPSC 45*, Abstract #2297. [5] Melosh J. (1989) *Impact Cratering, A Geologic Process*, Oxford Univ. Press. [6] Gaither T.A. et al. (2014) *LPSC 45*, Abstract 1933.