THE POROSITY OF THE UPPER LUNAR REGOLITH. B. Hapke[1] and H. Sato[2], [1]University of Pittsburgh (hapke@pitt.edu), [2]Arizona State University.

Knowledge of the porosity P (or filling facor $\phi = 1\text{-}P$) of the uppermost portion of the Lunar regolith is important because P strongly affects the reflectance, thermal inertia, emissivity and mechanical properties. From a study of the lunar bidirectioinal reflectance prior to the Apollo missions Hapke and Van Horn [1] estimated that the mean particle size of the regolith is < 100 μm and its porosity is between 80–90%. Carrier et al [2] concluded from a study of the Apollo cores that the mean porosity of the upper 15 cm is about 52%. However, the upper few cm, which is the important portion for UV/VIS/IR and thermal remote sensing, is very compressible, implying a much higher porosity there. Hapke [3] derived a porosity-dependent reflectance model and suggested that the difference in reflectance between a Lunar regolith sample on Earth and its source region on the Moon [4] was because the porosity was different.

Ohtake et al [5] attempted to find the *in situ* Lunar regolith porosity by using a flight spare of the Multi-band Imager on the Japanese Kaguya Lunar orbiter to measure the spectral reflectance of Apollo 16 soil sample 62231 in a laboratory on Earth. They also measured the porosity of the sample . Using the Kaguya imager they then measured the reflectance of the area on the Moon from which the sample was taken. They assumed the reason for the difference between the reflectances of the sample and its Lunar site was caused by a difference in porosity and used the porosity-dependent model [4] to conclude that the *in situ* porosity is between 74-87%.

However, the agreement between the measured and modeled reflectances was not particularly good, and the authors gave no details of their calculations. The reflectance is affected by several parameters in addtion to P, including photometric roughness angle θ, and particle single-scattering albedo w and phase function p(g) (where g = phase angle). We have revisited the analysis of Ohtake et al in an attempt to obtain better agreement and reduce the prosity uncertainty by systematically varying all the parameters to ascertain their effects on the modeled reflectances and regolith porosity.

We make the following asumptions: (1) The relectance of 62231 on the Moon would be the same as its source region. (2) In particular, its *in situ* value of θ would be the average Lunar value, $\theta = 23.4 \pm 2^{o}$ [6], but in the laboratory $\theta = 0$. (3) The particle scattering properties are the same on the Moon and Earth. With these assumtions the ranges of the parameter values were found to be strongly constrained by the measured reflectances and laboratory P.

The results of our modeling are given in Fig. 1, which shows the reflectances at several wavelengths of sample 62231 in the lab and its Lunar source site, along with the model spectrum. Except at 410 nm, an excellent fit was obtained by slimply increasing the surface roughness of 62231 from $\theta = 0$ to 23.4^{o} and decreasing the filling factor from the laboratory value of $\phi = 0.26$ to $0.17 \pm .02$. Assuming this is represntative, the average porosity of the upper Lunar regolith is $P = 83 \pm 2\%$. The major source of uncertainty in P is the uncertainty in θ.

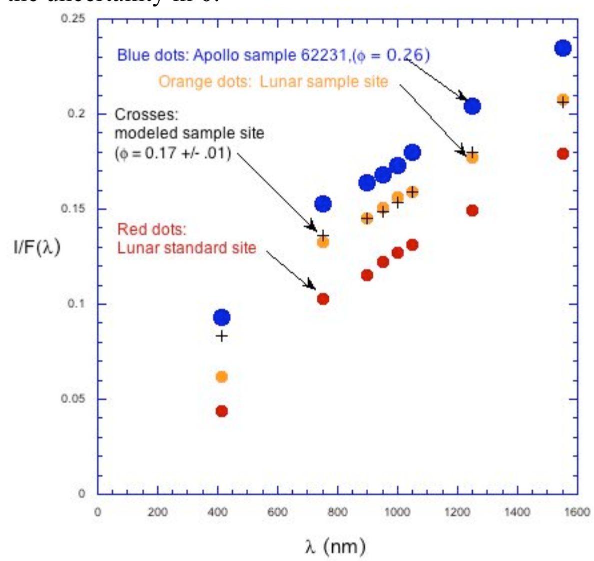

Figure 1

Fig. 1 also shows the spectral reflectance of a nearby Lunar site, located about 10 km west of the sample site, that is widely used as a standard, and was also measured by Ohtake et al [5]. We found that it was not possible to convert the reflectances of 62231 or its sample site to those of the standard site by any combination of parameters, except by changing the average particle single scattering albedos w. This inplies that the two sites have different compositions and/or maturities.

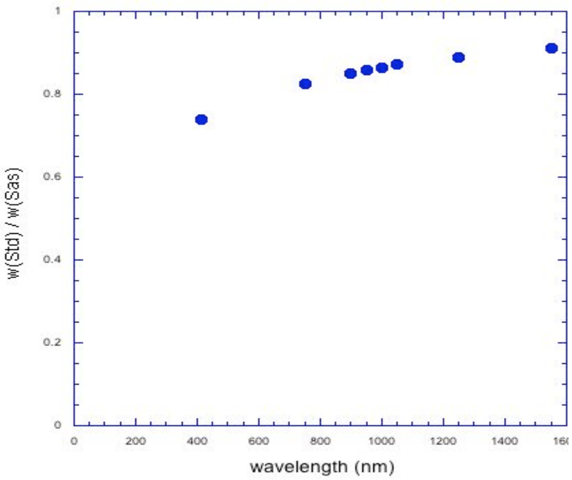

Figure 2

Fig. 2 shows the ratios of the single scattering albedos of the standard site to those of the sample site. This is the relative amount by which the *in situ* w's of 62231 must be reduced to match those of the standard site. The amounts increase as wavelength decreases. This behavior is a hallmark of space weathering [7]. Thus, the differences can be explained if the sample and its source site are less mature than the standard site. This is consistent with Lunar Reconnaissance Orbiter images of the sample site, which shows that it is located on a system of rays (Fig. 3). Maturity effects may alo account for the inablility to obtain a good match at 410 nm.

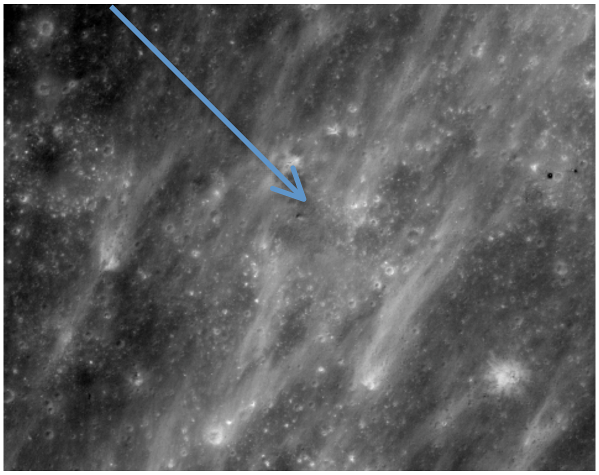

Figure 3. The arrow shows the 62231 sample site.

Refernces: [1] Hapke & Van Horn (1963), J. Geophys. Res. 68, 4545- 4570. [2] Carrier et al (1991), in *Lunar Sourcebook*, ed. by Heiken et al, Cambridge Univ. Press, pp 475-494. [3] Hapke (2008), Icarus, 195-918. [4] Hilier et al (1999), Icarus 141, 205-225. [5] Ohtake et al (2010) Space Sci Rev, 154, 57-77.[6] Sato et al (2014), J. Geophys. Res. Planets, 119, 1775-1825. [7] Hapke (2001), J. Geophys. Res. Planets, 106, 10039-10073.