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Supporting Online Material for

Temporal and Spatial Variability of Lunar Hydration as Observed by the Deep Impact Spacecraft

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This PDF file includes:

Materials and Methods

Table S1

References

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Materials and Methods

The Deep Impact HRI-IR spectrometer *(S1)* is a double-prism design providing spectra from 1.05 to 4.5 µm with variable resolving power ranging from >700 at 1.05 µm, down to 200 at 2.5 µm, and increasing to 350 at 4.5 µm. Although this design was driven by considerations relevant to comets, it provides an ideal instrument for measuring the hydration features in the 3-µm region on solid surfaces *(e.g., S2)*.

Observations

As part of on-going calibration efforts, the Deep Impact spacecraft observed the Moon on three occasions. A small area along the equator was imaged as part of a calibration in December 2007. The Moon was also observed over the north pole on both June 2nd and June 9th, 2009 (**Table S1**). Conditions were such that the HRI-IR instrument was near its coldest possible operating temperature (138K in December 2007 and 137K in June 2009), minimizing the instrumental background signal.

Data Reduction

The observations were reduced using the standard procedures developed during the Deep Impact prime mission *(S3)* in conjunction with the contemporaneous calibration data, to produce spectra in calibrated radiance units. The thermal contribution was then removed from each spectrum (each pixel) by independently fitting and subtracting a blackbody function using data beyond 4 µm, which also provides an estimate of the temperature at each location *(S4)*. Emissivity was assumed to equal one at all wavelengths. Since the actual emissivity must be <1, this simplification results in an underestimate of the temperature by ~5K. After thermal removal, apparent reflectance spectra were produced by dividing by the solar radiance *(S5, S6)* and dividing by the cosine of the incidence angle to account for photometric effects.

Estimating Water Content

It has been shown that the strength of the 3 µm feature can be used to estimate of the amount of H_2O in hydrated phases *(S7, S8)*. Using Hapke radiative transfer theory *(S9)*, reflectance spectra are converted to single scattering albedo and an effective single particle absorption thickness (ESPAT) parameter was calculated. The ESPAT parameter calculated at ~2.9 µm exhibits a linear relationship with absolute H_2O content for a wide variety of hydrated materials, allowing one to quantify hydration based on observed reflectance spectra *(S7, S8)*. Although this method was originally derived for H_2O-bearing phases, the linear trend also holds true for certain OH-bearing materials *(S7)*. Here we estimate the water content using the linear trend with ESPAT parameter derived from laboratory data of synthetic OH and H_2O-bearing basaltic glasses *(S7)*. Similar results are obtained when using trends derived from laboratory data of other hydrated phases [*e.g.*, clay minerals, zeolites; *(S7)*].

Table S1. Geometry of the Deep Impact Lunar Observations

Acquisition Date	Time (UTC)	Spacecraft Range (km)	Phase Angle	Sub-S/C Lat, Lon	Sub-Solar Lat, Lon	Spatial Scale (km/pixel)	Scan Size (pixels)
29 Dec 07	19:20	1.00×10^6	98.8	4S, 33E	1S, 66W	10.0	64 x 64
2 Jun 09	02:08	7.88×10^6	93.6	75N, 37W	1N, 72E	78.8	64 x 100
9 Jun 09	02:20	5.88×10^6	94.6	77N, 129W	1N, 14W	58.8	64 x 100

Supporting References and Notes

S1. D. L. Hampton *et al., Space Sci. Rev*. **117**, 42-93 (2005).

S2. J. M. Sunshine *et al., Science* **313**, 635-640 (2006).

S3. K. P. Klaasen *et al., Rev. Sci. Instrum.* **79**, 091301 (2008).

S4. O. Groussin *et al., Icarus* ***187***, 16-25 (2007).

S5. G. P. Anderson *et al., Proc. SPIE* **4049**, 176-183, (2000).

S6. R. L. Kurucz, *Proc. 17th Ann. Rev. Conf. Atm. Trans. Models* **1**, 333-334, (1995).

S7. R. E. Milliken, Ph.D. thesis, Brown University, (2006).

S8. R. E. Milliken *et al., J. Geophys. Res* **112,** doi: 10.1029/2006JE002853 (2007).

S9. B. W. Hapke, *Theory of Reflectance and Emittance Spectroscopy* (Cambridge Univ. Press, Cambridge, UK, 1983).