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# Compositional diversity at Theophilus Crater: Understanding the geological context of Mg-spinel bearing central peaks

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[1] Analysis of high resolution Moon Mineralogy Mapper ($M^3$) data reveals the presence of a prominent Mg-spinel-rich lithology in the central peaks of Theophilus crater on the lunar nearside. Other peak-associated lithologies are comprised of plagioclase, olivine, and pyroxene-bearing materials. A consistent spatial association of Mg-spinel with mafic-free anorthosite is recognized. Documentation of Theophilus central peaks brings the global inventory of Mg-spinel-rich lithology to two widely separated occurrences, namely Theophilus on the lunar nearside and Moscoviense basin on the farside. The Theophilus crater target region lies on one of the inner rings of the Nectaris basin, indicating that the Mg-spinel-bearing lithology source was deep in the lunar crust. **Citation:** Dhingra, D., C. M. Pieters, J. W. Boardman, J. W. Head, P. J. Isaacson, and L. A. Taylor (2011), Compositional diversity at Theophilus Crater: Understanding the geological context of Mg-spinel bearing central peaks, *Geophys. Res. Lett.*, *38*, L11201, doi:10.1029/2011GL047314.

## 1. Introduction

[2] The complexity of the lunar crust, both laterally and vertically, is manifested in numerous ways such as the nearside-farside crustal thickness difference [e.g., *Wieczorek and Phillips*, 1998], diverse lithologies occurring in the central peaks of complex craters [e.g., *Tompkins and Pieters*, 1999] as well as the geographically concentrated occurrence of lithologies such as KREEP [e.g., *Lawrence et al.*, 2000]. All these variations represent clues to further understand lunar evolution in space and time. The recent discovery, of a new Mg-spinel-rich lithology excavated from deep within the lunar crust, was made at Moscoviense basin on the lunar farside using Moon Mineralogy Mapper ($M^3$) data [*Pieters et al.*, 2011]. This new rock type has expanded the knowledge of existing crustal composition. The presence of spinel on the Moon has been well-known from lunar samples, where it is typically found to be a minor phase occurring with other mafic minerals [e.g., *Prinz et al.*, 1973; *Marvin et al.*, 1989]. The $M^3$ data reveal something much more fundamental, however; namely that the new Mg-rich spinel lithology 1) occurs without detectable presence of other mafic minerals and 2) is exposed on scale of hundreds of meters to kilometers. Here, we report on a new detection of the Mg-spinel-rich lithology at Theophilus crater.

## 2. Data and Methods

[3] The primary data used in this study include the high spatial and spectral resolution data from Moon Mineralogy Mapper ($M^3$) instrument onboard Chandrayaan-1, India's first mission to the Moon [*Goswami and Annadurai*, 2009; *Pieters et al.*, 2009]. $M^3$ is an imaging spectrometer operating in the wavelength range of ~500–3000 nm and is designed to identify and map lunar mineralogy. Most $M^3$ data were acquired in the low resolution "global mode" at a spatial resolution of 140–280 m and in 85 spectral bands (R. O. Green et al., The Moon Mineralogy Mapper ($M^3$) imaging spectrometer for lunar science: instrument description, calibration, on-orbit measurements, science data calibration and on-orbit validation, submitted to *Journal of Geophysical Research*, 2011). The spectral data used in this analysis were acquired during the imaging period Op1b [*Boardman et al.*, 2011]. The calibrated radiance dataset version R4 (Green et al., submitted manuscript, 2011) was converted to apparent reflectance after dividing by solar irradiance and the cosine of incidence angle. For this analysis, spectra have been limited to <2.5 $\mu$m to avoid thermal emission effects. Reflectance spectra relative to a standard region near Apollo 16 landing site were also prepared to minimize systematic instrumental artifacts. They were scaled to unity at 750 nm for ease of comparisons. Most of the sampled spectra are 3 × 3 pixel averages while some are 1 × 1 due to smaller targets. We use these data to assess the nature, distribution and associations of the various lithologies at Theophilus.

## 3. Theophilus Crater

### 3.1. Regional Setting

[4] Theophilus (11.4° S 26.4° E) is a complex impact crater ~100 km in diameter and located north-west of Nectaris basin on one of its inner rings (Figure 1). It was originally mapped as Copernican in age [*Milton*, 1968] but was reassigned to an Eratosthenian-age by *Wilhelms* [1987] on the basis of superposed crater populations. The western rim of Theophilus is superposed on the older Imbrian-aged crater Cyrillus. This complex setting with multiple excavation events (Nectaris basin, Cyrillus and then Theophilus) indicates exposure of deep seated material at Theophilus (estimated to be ~30 km based on Nectaris basin event alone [*Whitford-Stark*, 1981]). The diversity of this region is observed in the central peaks, walls and floor of Theophilus. Earlier remote sensing studies [e.g., *Spudis et al.*, 1989; *Tompkins and Pieters*, 1999] suggest that the local highlands are dominated by anorthositic

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