THEOPHILUS CRATER : COMPOSITIONAL DIVERSITY & GEOLOGICAL CONTEXT OF MG-SPINEL BEARING CENTRAL PEAKS D. Dhingra[1], C. M. Pieters[1], J. W. Boardman[2], J. W. Head[1], P.J. Isaacson[1], L. A. Taylor[3] & M3 Team, [1]Geol. Sc., Brown Univ., 324, Brook St., Providence, RI, USA (deepak_dhingra@brown.edu), [2]Analytical Geophysics and Imaging LLC,CO, USA, [3]Univ. of Tenn., Knoxville, USA

Introduction: Theophilus (11.4° S 26.4° E) is an Eratosthenian age complex crater (~100 Km diameter) located on the north-western part of one of the inner rings of the Nectaris basin (~860 km diameter) on the lunar near side. It is partly superposed on older crater Cyrillus (~100 km diam.) to the south-west and along with crater Catharina (~104 km dia.), they form a well known triplet occurrence.

The geological diversity of this region is captured in the material excavated by the crater Theophilus and some is believed to be represented in the returned lunar samples from Apollo 11 and 16 landing sites [e.g. 1]. The region has also been extensively explored by several remote sensing studies [e.g. 2,3,4]. The highlands in this region are dominated by anorthositic norites & noritic anorthosites with several exposures of pure crystalline anorthosites [4]. Theophilus displays a rich diversity of mineralogical variation exposed in its central peaks, walls & floor coupled with occurrences of impact melt, both within the crater & outside.

New Results from M3: Here, we report the detection of 'Mg-spinel bearing lithology' (along with other mineralogies) at crater Theophilus based on our analysis of high spatial and spectral resolution datasets from Moon Mineralogy Mapper (M3) instrument onboard Chandrayaan-1, India's first mission to the Moon [5,6]. M3 is an imaging spectrometer operating in the wavelength range of ~400-3000 nm with spectral resolution of 10-20 nm & spatial resolution of 140 m in the global (coarse resolution) mode. Other mineralogies present on the central peak region include exposures of olivine, pyroxenes and crystalline as well as shocked plagioclase (Fig. 1) indicating the presence of a diverse suite. With the exception of the newly discovered spinel and crystalline plagioclase, the observed mineral assemblage compares well with earlier estimates carried out using Clementine data [7].

The occurrence of spinel-bearing lithology on the Moon in the form of relatively large exposures was not known until very recently [8,9,10] and has still been reported only for two other locations apart from the present report at crater Theophilus. Whether the occurrence of this newly discovered rock type is rare or common on the Moon is yet to be ascertained but the detection of spinel bearing lithology at these scales merits a better understanding of the origin of these lithologies and their stratigraphic position in the geological evolution of the Moon [11]. The present study is aimed at ascertaining the mineralogical association of the lithologies on the central peaks and understanding the geological setting under which the spinel is found to occur.

Nature of Spinel Exposures: Theophilus exhibits several small exposures (~400 m – 1 km) of Mg-Spinel characterised by the presence of a very strong 2 micron absorption band & an absence of 1 micron absorption [10,12]. Most of the exposures occur in various units of the central peak region but isolated exposures of spinel have also been detected on the floor & wall of the crater. The spinel spectra observed so far (Fig. 2) display variation in reflectance and may be grouped into two broad categories which are also spatially separated. As described below the spinel lithology currently is only observed in possible contact with mafic-free (plagioclase-rich) areas, although other lithologies may be near-by. At times, the spinel exposures end abruptly rather than displaying any lateral transition probably indicating discrete occurrence at those locations.

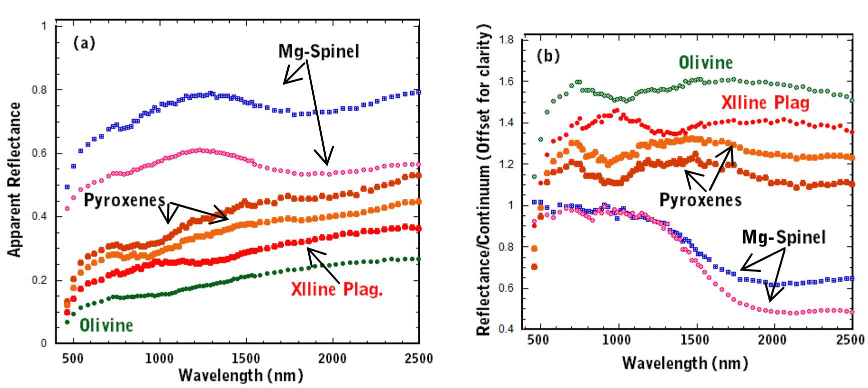

Fig. 1 Mineralogical diversity observed at the central peak of Theophilus. (a) Reflectance spectra of various mineralogies. Spinel spectra is offset for clarity. (b) Same spectra with continuum removed using straight line tangent across 1μm band. Spinel spectra are relative reflectance w.r.t. featureless spectrum. All spectra have been truncated at 2500 nm to avoid effects of thermal emission.

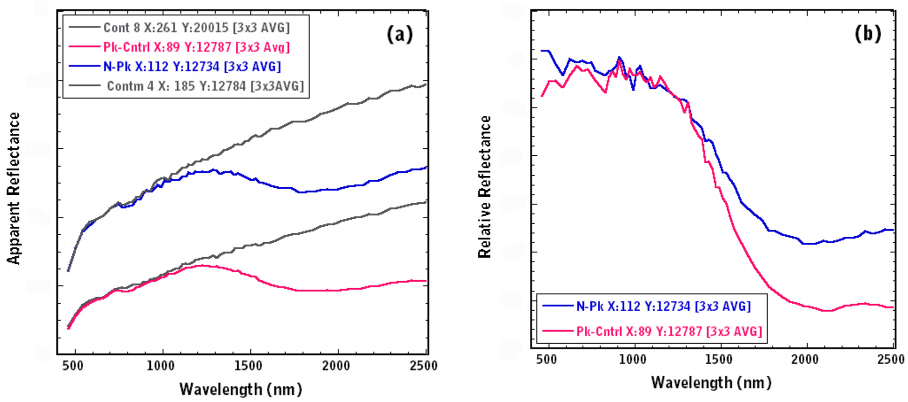

Fig. 2 (a) Representative spectra (in blue & magenta colors) from spinel bearing locations at Crater Theophilus. Also shown are featureless spectra from nearby region in gray used for generating relative reflectance. (b) Relative reflectance spectra derived by dividing original spectra in (a) by the corresponding featureless spectrum.

Geological Setting of the observed Exposures: In order to better undertand the geological context of the spinel occurrences, we carried out a coordinated study of M3 data with the high spatial resolution data from Kaguya Terrain Camera (TC) data which provides a spatial resolution of 10 m/pixel [13]. The figure below (Fig. 3) shows the results for the region on the central peak displaying strongest spinel absorption observed to date on the Moon.

A spatial profile of spectral variation across this region is marked by the yellow dots. Spectral variations across this profile (shown in 3c) contain spinel and mafic-free materials (shocked plagioclase) in close proximity. The bottom of the profile (bottom of the hillock) is represented by the blue spectrum while green spectrum marks the end point of the profile at the top of the hill near the bright patches where boulders are outcropping from the central peak. It can be observed that there are sharp boundaries a few 100 m on either side of the strong spinel absorption spectra (in magenta color). Detailed non-linear mixture modeling efforts [14] are required to derive estimates of relative abundances of the minerals present.

Detailed studies of the region on these lines are underway to determine the scale and context of the diverse lithologies observed.

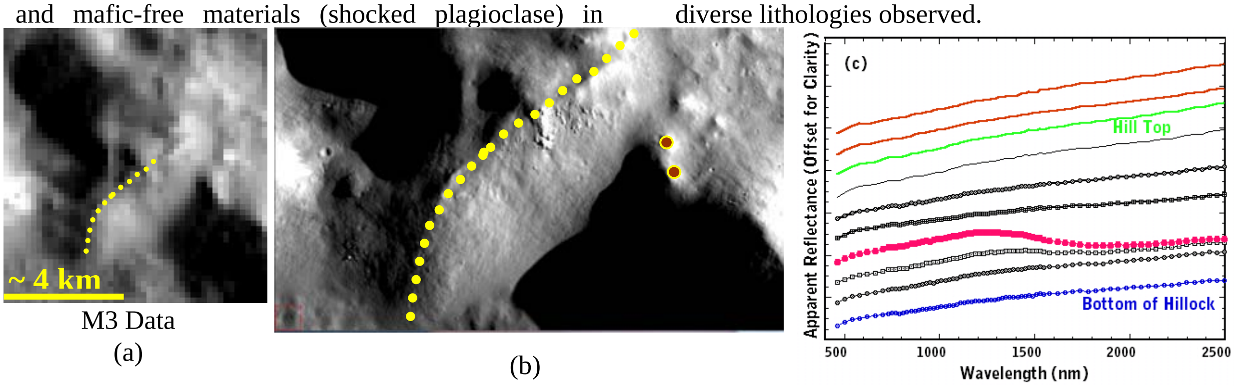

Fig. 3 Coordinated study of Theophilus central peak using M3 and Kaguya TC datasets. (a) M3 scene containing spinel exposures (b) Kaguya TC image (TC_MOR_02_S09E024S12E027SC.IMG) showing the geological setting of the same area. Yellow dots represent the spectral sampling traverse taken. (c) Spectral variation along the spatial traverse on the hill. Blue & Green spectra mark beginning and end respectively. Brown dots and spectra in (b) & (c) respectively represent another set of spectra showing shocked plagioclase. All the spectra are offset for clarity.

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