

DETECTION OF MG-SPINEL BEARING CENTRAL PEAKS USING M³ IMAGES. Y. Sun¹, L. Lin¹, Y. Z. Zhang², ¹Indiana University- Purdue University at Indianapolis, Indiana, USA (yingsun@iupui.edu), ²Institute of Space and Earth Information Science, the Chinese University of Hong Kong, China (yuanzhizhang@cuhk.edu.hk).

Introduction: Mg-spinel bearing lithologies, lacking abundant olivine and pyroxene, have been discovered with images acquired by the Moon Mineralogy Mapper (M³) aboard Chandrayaan-1 in four regions on the Moon [1-4] (Fig. 1). One Mg-spinel bearing location is along the innermost ring of the Moscoviense impact basin on the lunar farside, and another three regions are located in the lunar nearside craters (Theophilus, Tycho, Copernicus). Mg-spinel lithologies are characterized by an unusual composition (high Mg-Al, but low Fe) [5]. Currently, the petrogenesis of Mg-spinel bearing lithology is still a mystery. The first step to resolve this mystery is to figure out global distribution of Mg-spinel rocks on the Moon. To achieve this objective, we have been conducting a systematic screening of lunar crater central peaks for the presence of Mg-spinel bearing lithologies.

Lunar crater central peaks originate from deep crustal layers or mantle, and offer an informative window for the detection of lunar crustal variations in lateral and vertical dimensions. Several studies about the lithology of lunar crater central peaks have been completed [6, 7]. In this study, we reexamine 109 lunar crater central peaks investigated in [6] for the presence of Mg-spinel lithology. Among the 109 crater peaks, five are not covered by M³ data and seven don't exhibit significant peak topography based on M³ images and Lunar Orbiter Laser Altimeter (LOLA) elevation data. Therefore, only 97 crater central peaks are examined in this study. The corresponding craters are from 40 km

to 185 km in diameter (D), and the excavation depth (d) ranges from ~5.85 km to ~30.61 km based on $d=0.109*D^{1.08}$ [9].

Dataset and Method: M³ is an imaging spectrometer that provides high spatial (140 m) and spectral (20-40 nm) resolution data in the global mode [8]. The newest reflectance data (level 2), corrected for thermal and photometric effects and released in Dec. 8, 2011 by NASA, were used in this study.

M³ images covering 97 craters were downloaded from the NASA PDS website. These images were geometrically corrected, and smoothed for noise reduction. For geometric correction, the original reflectance images were warped based on latitude and longitude values of each pixel recorded together with image spectra. During noise reduction, pixels with negative digital number or in shadow were eliminated, and moving average was used to smooth the image spectra. After spectral smoothing 72 bands from 540 nm to 2537 nm, which is sensitive to mineral diagnostic absorption, were retained for further analysis.

Continuum removal was applied to each image spectrum to isolate mineral diagnostic absorption features from the spectral continuum. Mg-spinel has a significant absorption near 2000 nm but no detectable absorption near 1000 nm [10]. This spectral characteristic was used to identify Mg-spinel lithology with the constraint that the deepest absorption is located near 2000 nm and absorption depth less than 0.05 near 1000 nm.

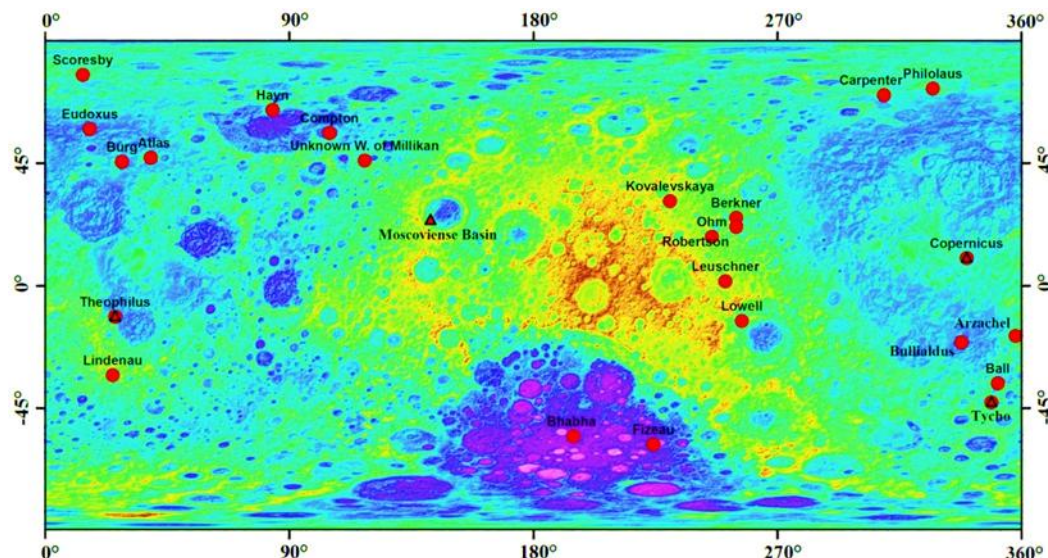


Fig 1. Distribution of Mg-spinel bearing crater central peaks overlaid on a LOLA DEM image of the Moon. Red solid circle represent the results obtained in this study, and black triangle with red background show the results from previous studies [1-4].

Results and Discussion: Based on spectroscopic analysis, Mg-spinel has been identified in 24 out of 97 investigated crater central peaks (Fig. 1). A typical spectrum of Mg-spinel from each crater central peak shows strong absorption near 2000 nm but very weak absorption around 1000 nm (Fig. 2). Globally, Mg-spinel bearing central peaks are sparsely distributed on the Moon, and are identified in all three distinct provinces (FHT, PKT, SPAT). The number of Mg-spinel bearing central peaks in the northern hemisphere is nearly as twice as in the southern hemisphere. According to the origin depth of crater central peaks, Mg-spinel bearing lithologies should be present in the lunar crust from ~5.85 km to ~26.53 km. One half of central peaks were excavated from depth less than 10 km, and the other half from larger than 10 km. That rather than appear to exist only in lower crust based on previous studies. Besides Mg-spinel, most of these spinel bearing central peaks also contain mafic materials (olivine and pyroxene) except for 3 crater central peaks (Berkner, Lindenau and Unknown W. of Millikan).

Our results clearly show that the presence of Mg-spinel is by no mean limited to four areas investigated in previous studies; rather it is more common in the lunar crust than expected before. Here we detect Mg-spinel existence for 109 crater central peaks, Mg-spinel bearing crater central peaks account for about 20%. Assuming this is an appropriate proportion for the presence of Mg-spinel in lunar crater central peaks, it is expected that more Mg-spinel bearing crater peaks could be identified. If the detection area includes crater wall, crater ring, or ejecta, rather than just crater central peaks, the distribution of Mg-spinel bearing lithologies could be dramatically different.

The presence of spinel commonly indicates high formation temperatures in intensely metamorphosed rocks and igneous mafic and ultramafic rocks in terrestrial magmatic systems [11]. Although high Fe spinel originates from rapid crystallization of magma at low pressure [12], this process cannot explain the petrogenesis of Mg-spinel with low Fe. The observation of this study suggests that the origin of Mg-spinel detected on the Moon appears to be linked to large-scale magmatic intrusions near the crust-mantle interface, later excavated by impacts and then settled on the central peaks. Prissel T. C. (2012) suggested that Mg-spinel originates from a reaction product between Mg-suite parental magmas and the anorthositic crust [5]. Our results demonstrate that this reaction should be widely distributed in the lunar crust. However, this does not rule out the possibility that the production of Mg-spinel is due to one or more small plutonic events or plutonic bodies that are disrupted by the basin forming event [1]. To put constraints on the origin of Mg-

spinel bearing materials, more crater central peaks and other regions (e.g. crater wall) need to be analyzed for Mg-spinel. Meanwhile, the existence of other major minerals (plagioclase, pyroxene, and olivine) will be determined with M^3 data.

References: [1] Pieters C.M. et al. (2011) *JGR*, 116, doi:10.1029/2010JE003727 [2] Dhingra D. et al. (2011) *GRL*, 38, doi:10.1029/2011GL047314 [3] Dhingra D. and C. M. Pieters (2011) *LPSC*, XXXXII, 2024 [4] Kaur P. et al. (2012) *LPSC*, XXXXIII, 1434 [5] Prissel T.C. et al. (2012) *LPSC*, XXXXIII, 2743 [6] Tompkins S. and C. M. Pieters (1999) *Meteorit. Planet. Sci.* 34, 25-41 [7] Cahill J.T.S. et al. (2009) *JGR*, 114, E09001, doi:10.1029/2008JE003282 [8] Pieters C.M. et al. (2009) *Curr. Sci.* 96, 500-505 [9] Cintala, M.J. and R. Grieve (1998) *Meteorit. Planet. Sci.* 33, 889-912 [10] Cloutis E.A. et al. (2004) *Meteorit. Planet. Sci.* 39, 545-565 [11] Dyar M.D. (1989). *Am. Mineral.* 74, 969-980 [12] Gross J. and Treiman A.H. (2011) *JGR*, 116, doi:10.1029/2011JE003858.

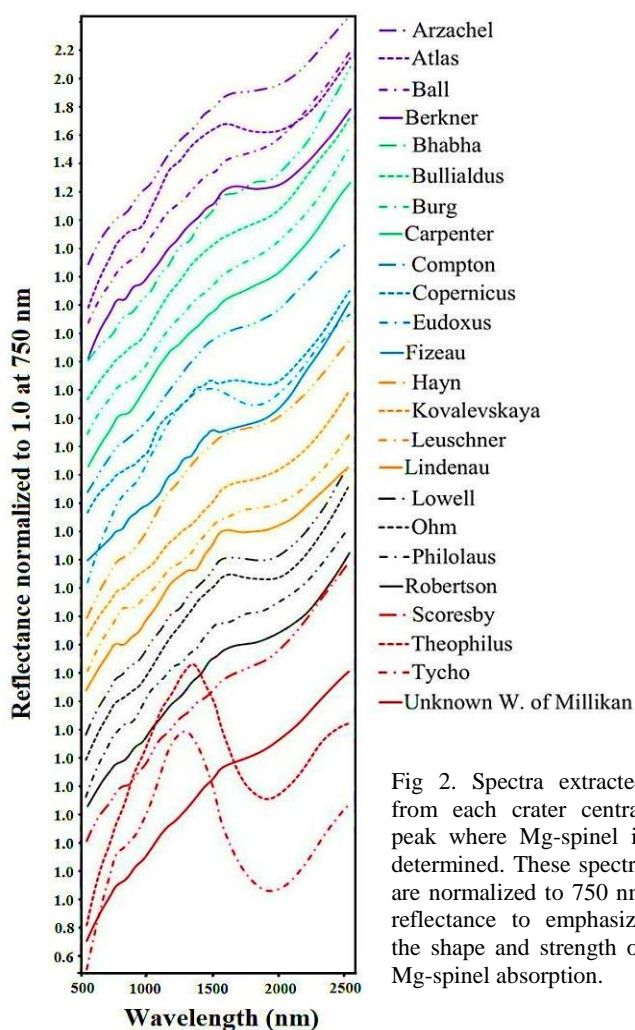


Fig 2. Spectra extracted from each crater central peak where Mg-spinel is determined. These spectra are normalized to 750 nm reflectance to emphasize the shape and strength of Mg-spinel absorption.