DETECTION OF Mg-SPINEL EXPOSURES FROM THE ANORTHOSITIC TERRAIN SURROUNDING MARE INGENII ON THE FAR SIDE OF THE MOON P. Kaur, P. Chauhan and Ajai, Space Applications Centre, (ISRO), Ahmedabad-380015, India (prabhjotk@sac.isro.gov.in).

Introduction: Mg-Spinel exposures on the lunar surface were detected first time on the central peak crater Theophillus [1, 2]. The discovery of this new mineral has initiated new ideas about the crustal evolution of the Moon. On the lunar surface, Spinel minerals apparently associated with three distinctly different igneous rock types: anorthosites/troctolites of highlands, gabbro-norites and mare basalts having variation in TiO_2 contents [3]. Large scale exposures of spinel have been detected in the past recent years using Moon Mineralogical Mapper (M^3) data onboard Chandrayaan-1 from several locations [1, 2, 4, 5]. The recent detection of Mg-Spinel from several locations of the lunar surface suggest that Mg-Spinel bearing lithologies are not very rare and may hold a considerable percentage of the lunar crust.

Mare Ingenii represents one of the lunar swirls that are high albedo, curvilinear surface features and located in the deepest South Pole Aitken basin [6, 7]. Ingenii basin is partially filled with basalt flows. The two adjacent large craters Thompson (~120 km) and Thompson M (~100 km) flooded with Ingenii basalts, both of which fit neatly with the basin. The lunar swirls are considered to be optically immature features as compared to their surroundings and are known to be associated with magnetic anomalies [8]. Mare Ingenii have been studied in terms of spectral properties or the immaturity characterization using spectral information of Clementine UVVIS data [9]. This study brings out new information on the detection of Mg-Spinel exposures from the Mare Ingenii basin.

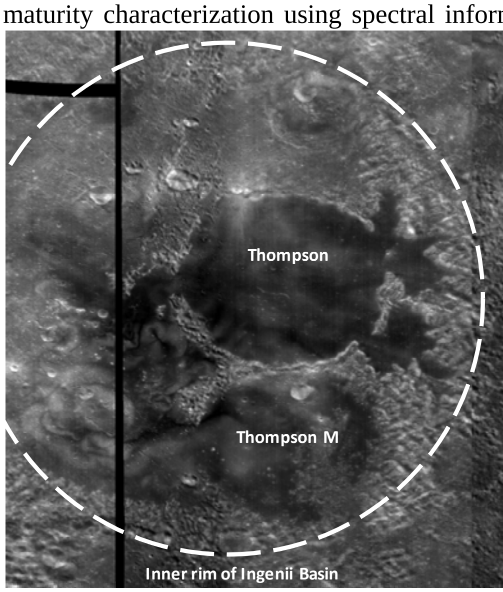

Figure 1. Albedo mosaic of Mare Ingenii basin generated using images from OP2C optical period imaged from 200 km orbit. Black color represents gap in the data coverage.

Data and Methods: We used data from the Moon Mineralogical Mapper (M^3) onboard Chandrayaan-1 which was operated until August 2009 [10]. M^3 is an imaging spectrometer covering the 0.43-3.0µm wavelength region with 85 spectral bands and a global resolution of ~140m/pixel from 100 km altitude [11]. The other mode of the data was obtained at a raised orbit of 200 km with a spatial resolution of ~260m/pixel which corresponds to optical period OP2C [12]. The available reflectance images were mosaiced together to obtain the full geographic extent of the basin. The images used in this study were from 200 km altitude at a resolution of ~260m/pixel. Figure 1 represents the mosaic of Mare Ingenii generated using M^3 images imaged during optical period OP2C. To facilitate a quick overview of the subtle variation in the composition a RGB composite of integrated band depth at 1- and 2-µm along with R1309/1938 nm is presented in Figure 2 which brings out an optimal compositional variation.

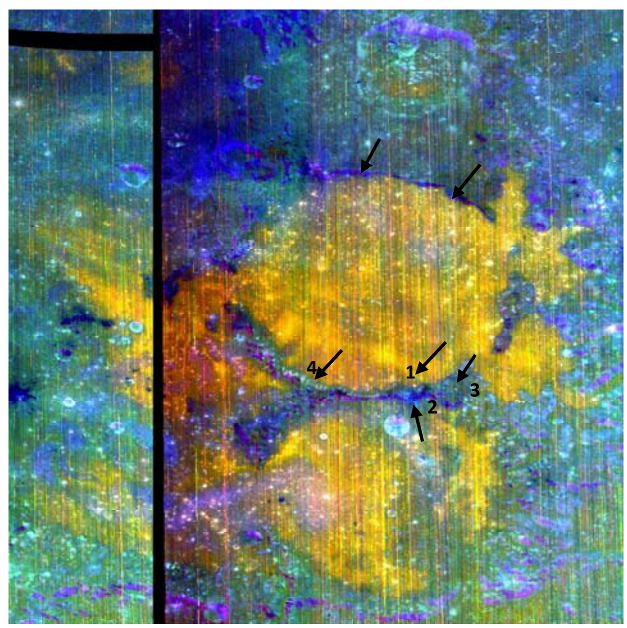

Figure 2. RGB composite of the study area generated to depict the mineralogy of the basin (R - Integrated 1µm band depth, G - Integrated 2µm band depth and B = 1309/R1938). Arrows indicate Mg-Spinel rich exposures which are concentrated on the Anorthositic hills surrounding the Thompson and Thompson M crater.

Mg-Spinel rich exposures on Mare Ingenii: Anorthositic hills following Mare Ingenii basin rim exhibits some small Mg-Spinel rich exposures characterized by strong 2µm absorption feature and lack of 1µm absorption dip (Figure 3). An overall view of the mineralogy of Mare Ingenii is presented in figure 2 where Mare Ingenii basalts appear yellow to orange due to presence of high-Ca pyroxenes. Pink color represents fresh bright swirls having strong 1µm absorption. Greenish blue tone represents strong 2µm absorption which is due to spinels or pyroxene-spinel mixture. Example spectra is shown in figure 4 from the Anorthositic hills appearing in greenish blue tone and from the basalt appearing yellow in figure 2. Spectra from Anorthositic terrain exhibits strong and broad 2µm absorption feature and band II center at lower wavelength (spectra b & c, fig. 4) more consistent with Mg-Spinel mixed spectra as compared to blue spectrum (fig. 4) obtained from Mare Ingenii basalt, characteristic of high-Ca pyroxene spectra. Mg-Spinel rich exposures are of small areal extent and appear in strong greenish blue tone (Figure 3a). Mg-Spinel exposures occur as small patches anorthositic terrain surrounding the basin. The exposures are prominent on the anorthositic hills surrounding the Thompson crater and the ridge dividing the two craters (Thompson and Thompson M, marked in the figure 1).

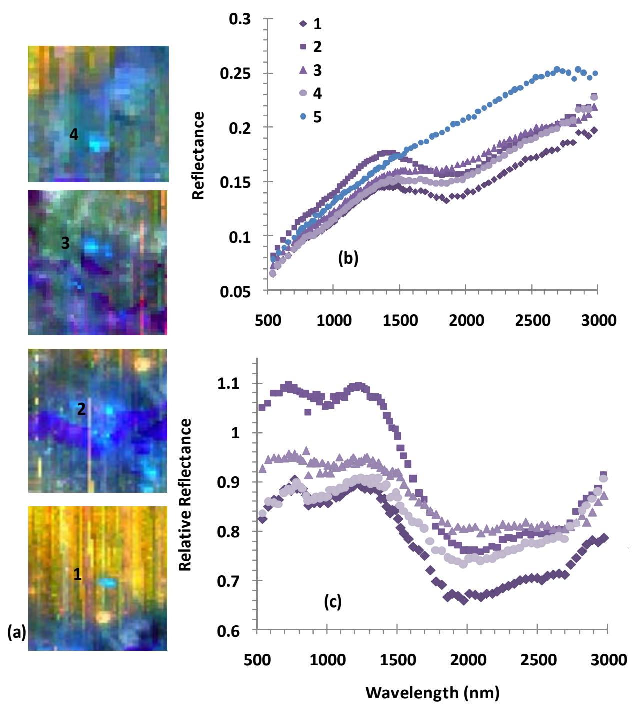

Figure 3a. Close view of the Mg-Spinel rich sites exposed along the anorthositic ridge following the Thompson crater rim. The locations of the close-ups are marked in the figure 1. Mg-Spinel exposures appear as greenish blue in IBD composite image (b) Example spectra collected from the marked locations showing characteristic strong absorption at 2µm and are lack of 1µm absorption. Spectrum 5 represents featureless spectrum from the nearby region used for generating relative reflectance. (c). Relative reflectance spectra of the Mg-Spinel derived after dividing the original spectra in (b) by the corresponding featureless spectrum.

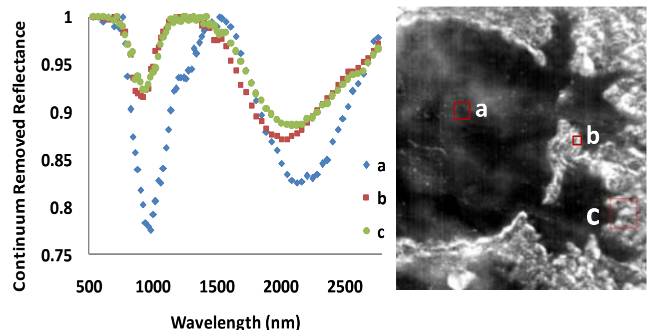

Figure 4. Continuum removed spectra presented for comparison of pyroxene dominated regions appearing yellow (spectrum 'a' collected from Mare Ingenii basalt) and spinel dominated regions appearing greenish blue in fig. 2 (spectra 'b and c' collected from surrounding anorthositic terrain).

Discussion: The prime objective of the M^3 sensor was to map the lunar surface mineralogy. The sensor has successfully detected and discovered some new and unexpected aspects regarding the crustal evolution of the Moon. Discovery of Mg-Spinel exposures from the various geological settings has opened new aspects of the geology and petrology of the Moon. Here again, M^3 data has has detected Mg-Spinel bearing rocks in an anorthositic terrain. Pink-Mg spinels occur in Troctolites formed after the initial Ferroan anorthositic (FAN) crust as a minor phase [3]. Mg-Spinels which would sink during crysrtallization due to their higher density can later on, be a part of the highland intrusive formed by the deep serial magmatism within the anortositic crust with upward intrusion. Detailed studies with the high spatial and spectral resolution data are underway to determine the formation and nature of the Mg-Spinel exposures on the lunar surface.

References: [1] Lal, D. et al. (2011) *LPSC XXXXII*, Abstract #1339. [2] Dhingra, D. et al. (2011), *Geophys. Res. Lett.*, *38*, L11201. [3] Taylor, L.A. et al., (2009), *AGU Fall Meeting*, Abstract #P34A-07. [4] Kaur P. et al. (2012) *LPSC XXXXIII*, Abstract # 1434. [5] Bhattacharya, S. et al., (2012) *Curr. Sci.*, 102, 12. [6] El-Baz, F. (1972), *NASA Special Publication*, 315. [7] Schultz, P.H. and Srnka, L.J., (1980), *Nature*, 284, 22-26. [8] Hood, L.L, and William, C.R. (1989), In *Proc. Lunar Planet. Sci. Conf. 19*, 99-113. [9] Kramer, G.Y. et al. (2011), *JGR*, 116, E00G14. [10] Goswami J. N. and Annadurai M. (2009) *Curr. Sci.*, *96*, *4*, 486-491. [11] Pieters, C.M. et al. (2009) *Curr. Sci.*, *96*, *4*, 500-505. [12] Boardman, J.W. et al. (2011), JGR, 116, E00G14.