OOS LITHOLOGY AND DETECTION OF MAGMATIC WATER AT THE RIM OF SINUS IRIDUM IN ASSOCIATION WITH OLIVINE OF POSSIBLE MANTLE ORIGIN. Satadru Bhattacharya, Mamta Chauhan and Prakash Chauhan, Space Applications Centre (ISRO), Ahmedabad – 380 015, India (satadru78@yahoo.co.in).

Introduction: Olivine, orthopyroxene and spinel are the important constituents of lunar mantle representing the early product of Lunar Magma Ocean (LMO) crystallization [1]. The presence of these mafic minerals, as well as their occurrence and distribution in lunar feldspathic crust thus, provide important clues to understand magma ocean composition and crust-mantle interaction. The association of orthopyroxene-olivine-spinel (OOS) bearing lithology is rare on the Moon and so far have been reported only from two regions, namely Mare Moscoviense and crater Endymion [2, 3]. It is therefore important to identify and map similar exposures of OOS lithology from different parts of the Moon in order to constrain the bulk composition of the lunar mantle as also the lithologic make up of the lunar crust more accurately.

In this study, we report the presence of yet another OOS suite of rocks from the rims and the terraces of Sinus Iridium based on Chandryaan-1 Moon Mineralogy Mapper (M^3) observations. Also, we have observed a prominent hydration feature near 2800 nm associated with olivine-rich exposures occurring along the northern rims of Sinus Iridum. It is a crescent shaped basin characterised by extensive basaltic plain of upper Imbrian age and is situated northwest of Mare Imbrium on the near side of the Moon. The area is being recently explored by China's lunar exploration mission, Chang'e 3 and therefore, significant for new research findings from the area.

Data and Methods: M^3 is NASA's imaging spectrometer onboard Chandrayaan-I. It measured reflected solar radiation in 85 spectral channels between 460 to 3000 nm at a spatial resolution of ~140 m [4]. Photometrically and thermally corrected Level-2 (Global Mode) data [5] were used for the present study.

Observations: The major compositional variations in the area can be observed in the false colour composite (FCC) image of area (Figure 1). Several small mafic exposures have been observed along the rims and the terraces of Sinus Iridum. Olivine, orthopyroxene and Fe-Mg spinels were detected from these edges and terraces that correspond primarily to the basin rings of Imbrium. We have collected representative spectra of the specific minerals from the locations as marked in Figure 1. In other areas, these minerals are present as mixures with varying proportions. Reflectance spectra of Fe-Mg-spinel were collected from Location 1 near the southern edge of Sinus Iridium as shown in Figure 2a. The area marked by location 2 hosts orthopyroxene exposures (see Figure 2b). Pure olivine signatures were detected from location 3. The olivine spectra as shown in Figure 2c are characterized by the presence of prominent OH/H_2O absorption feature near 2800-3000 mm with 4-6% band strength. The continuum-removed spectra of these olivine (Figure 2d) show varying 1000-nm band depth, with the highest being ~23%. Location 4 marks the detection of Fe-Mg-spinel signatures along the northern edge of Sinus Iridum alongwith crystalline plagioclase (Figure 2e). Location 5 is a small crater named Maupertuis A from where spinel along with olivine and plagioclase (spinel troctolite) was detected and its representative reflectance spectra are displayed in Figure 2f.

Discussions: The rings of large basins are likely to preserve uplifted deep crustal rocks in relatively pristine form as they are least affected by melting and heating. At such locations the primary olivine can survive. Previously Kaguya Spectral Profiler (SP) detected the presence of pure olivine on the Northern rim of Sinus Iridium basin and the researchers argued that the olivine was possibly of mantle origin [6]. Considering the diameter of Sinus Iridum basin and the refined crustal thickness of ~25-30 km for Sinus Iridum as revealed by GRAIL mission [7, 8], we argue that the basin forming event probably had excavated materials directly from the crust-mantle interface and therefore OOS suite of rocks possibly represents the magnesium-rich cumulates of upper mantle, the early differentiated products of lunar magma ocean. The other possibility includes excavation of Mg-rich pluton intruded into the lower crust in which case the olivine-rich exposures should be similar to troctolite. Interestingly, we have observed pure olivine spectra having band strength of the 1000-nm composite feature as high as ~23% from the northern rim of Sinus Iridum. We could also see the presence of spinel-troctolite from the inner flank of a steep-sloped small crater situated in the anorthositic highland close to Sinus Iridum. The M^3 spectra of the olivine-rich exposures further indicate the presence of hydroxyl and/or water, which could be attributed to the presence of melt inclusions within olivine crystals that were trapped during crystallization and therefore these melt inclusions represent samples of primitive lunar magma.

Conclusions: At Sinus Iridum, the OOS lithological suite in general and the olivine-rich exposures, in particular, reflect a range of mafic components from dunitic to noritic to troctolitic and at places, we have also observed the presence of Fe-Mg-spinel-bearing troctolite. We hypothesize that the basin formation event must have excavated the lunar upper mantle giving rise to OOS suite of rocks. However, the spinel-troctolite exposures at Maupertuis A crater also points towards lower crustal composition formed by the interaction of Mg-rich pluton and anorthositic highland crust. In this study, we have also seen prominent hydration feature in association with pure olivine-rich exposures of possible mantle origin [6] along the northern rim of Sinus Iridum that could possibly be attributed to the olivine hosted melt inclusions and therefore, we argue that the observed hydration feature along the northern terraces of Sinus Iridum could be of endogenic origin. We propose that hydroxyl bound to olivine were excavated from depth by the impact that formed Sinus Iridum. This is perhaps the third report on the possible occurrences of endogenic water on the Moon based on remote orbital observations after its discovery from the silicic volcanic constructs at Compton-Belkovich, Gruithuisen Domes, Hansteen Alpha [9] and central peak of crater Bullialdus [10]. The results presented in this study are thus important as addition of newer locations of endogenic water occurrences on the Moon will help in better constraining the water budget of the lunar mantle.

References: [1] Warren P and Wasson J.T. (1980) *Proc. Conf. Lunar Highlands Crust*, 81-99. Pergamon Press, New York. [2] Pieters C. M. et al. (2011) *JGR*, *116*, E00G08. [3] Bhattacharya S. et al. (2012) *Curr. Sci*., *103(1)*, 21-23. [4] Pieters C. M. et al. (2009) *Curr. Sci*,. *96(4)*, 500-505. [5] Clark R. N. et al. (2011) *JGR*, *116*, E00G16. [6] Yamamoto S. et al. (2010) *Nat. Geosci*., *3*, 533-536.[7] Zuber M. T. et al. (2013) *LPS XXXXIV*, Abstract #2037. [8] Zuber M. T. et al. (2013) *Science* doi:10.1126/science.1231507. [9] Bhattacharya S. et al. (2013) *Curr. Sci*., *105(5)*, 685-691. [10] Klima R. et al. (2013) *Nat. Geosci*. Doi:10.1038/ngeo1909.

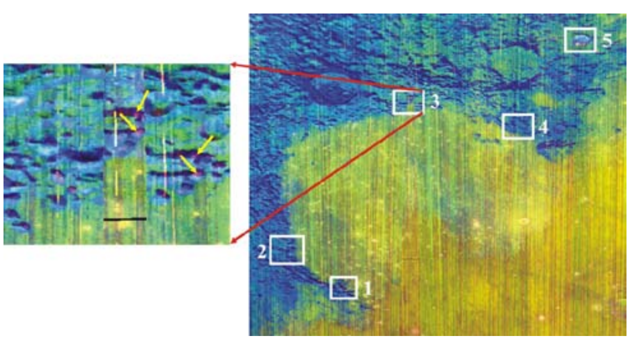

Figure 1. IBD-Albedo FCC image (R: 1000-nm integrated band depth, G: 2000-nm integrated band depth, B: M^3 1578-nm albedo band) showing the compositional variations in and around Sinus Iridum with feldspathic region appearing in blue and embaying basalts in yellow. The white boxes mark the pixel locations of the spectra collected along the rims and terraces of Sinus Iridum. In the inset close up view of the pure olivine exposure (dark red coloured pixels marked by arrows).

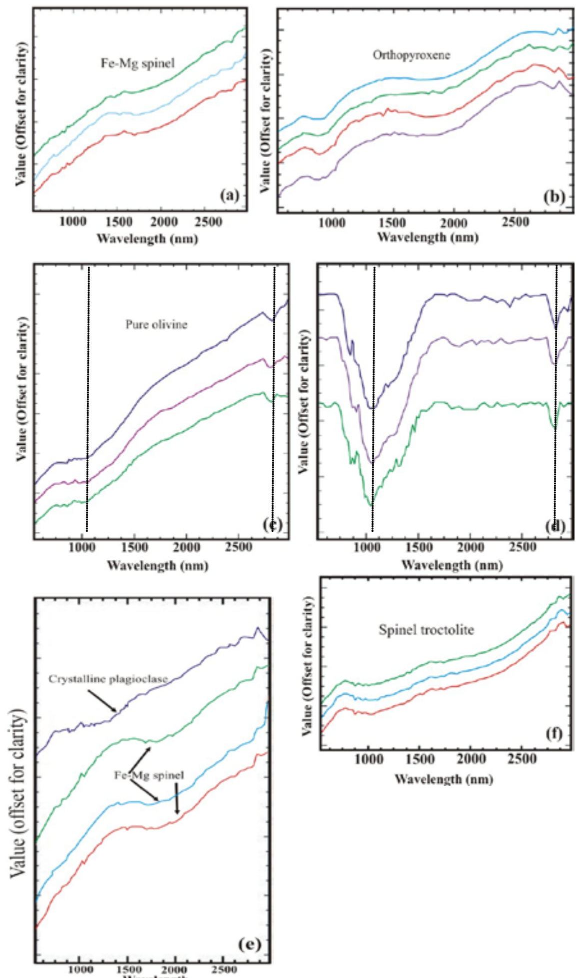

Figure 2. a. Spectra of Fe-Mg-spinel from location 1 of Figure 1; b. Spectra of low-Ca pyroxene from location 2; c. Spectra for Pure olivine and (d) its continuum removed spectra from location 3, (e) Spectra for Fe-Mg spinel and crystalline plagioclase from location 4 and (f) Spectra for spinel troctolite from location 5.