

CHARACTERIZATION OF ISRO-JAXA LUPEX LANDING SITE NEAR SHACKLETON-DE GERLACHE RIDGE (SDR) REGION BASED ON OBSERVATIONS FROM CHANDRAYAAN-2 IMAGING INFRARED SPECTROMETER (IIRS) INSTRUMENT. Satadru Bhattacharya^{1, 2}, Aditya Kumar Dagar¹, Sumit Pathak², R. P. Rajasekhar¹, Sugali Sekhar Naik¹, A. S. Kiran Kumar³, N. M. Desai¹, Saibal Gupta² and M. K. Panigrahi². ¹Space Applications Centre, ISRO, Ahmedabad – 380 015, India; ²Dept. of Geology & Geophysics, Indian Institute of Technology, Kharagpur – 721 302, India; ³Indian Space Research Organisation, HQ, Bengaluru, India (satadru@sac.isro.gov.in).

Introduction: The Shackleton-de Gerlache ridge (SDR) has been considered one of the prospecting localities for future crewed and robotic landing/roving missions [1], including the ISRO-JAXA Lunar Polar Exploration (LUPEX) mission [2]. The primary goals of most future lunar missions are the characterization of polar volatiles concentrated in and around the permanently shadowed regions (PSRs) [2]. The SDR region is chosen for its proximity to the PSRs, having the potential of hosting water-ice deposits and also due to the extended Sun and Earth visibilities that are key to the surface operations [3]. Spectrometer instruments onboard Chandrayaan-1 and other recent lunar missions have mapped the surface mineralogy and hydration features of both exogenic and magmatic origin on the Moon. Here we present a preliminary study of the SDR region based on the observations from the Chandrayaan-2 Imaging InfraRed Spectrometer (IIRS) instrument. IIRS is designed with an extended spectral range of up to 5.0 μm as compared to the previously flown Moon Mineralogy Mapper (M^3) spectrometer onboard Chandrayaan-1 mission and is presently mapping the lunar surface at a Ground Sampling Distance (GSD) of ~ 80 m in ~ 250 spectrally narrow and contiguous channels from a ~ 100 -km polar circular orbit [4].

Results and discussions: Two IIRS Scenes (in E1G2 mode) capturing Shackleton crater and the proposed landing site of the ISRO-JAXA LUPEX mission have been analyzed to gain insight into the overall mineralogy and hydration that exist in and around the landing site. IIRS scenes have been stitched together, and the locations of the proposed landing sites are marked on the IIRS mosaic (CR-1 and SR-1). It is evident from figure 1 that a major part of the IIRS mosaic is covered by shadows, including the permanently shadowed floor of the Shackleton crater. It is also seen that both the CR-1 and SR-1 sites of the LUPEX lander/rover mission fall within complete to partially shadowed regions. We have obtained regions of interests (ROIs) (Fig. 1) from across the IIRS mosaic that also includes the PSR of the Shackleton crater and the CR-1 and SR-1 regions. Figure 1 shows the locations of the ROIs from which representative spectra have been collected, whereas figure 2 presents the mean representative reflectance spectra

corresponding to the ROIs in the spectral range of ~ 0.85 - 3.30 μm covering completely the 3 - μm lunar hydration feature. The vertically dotted black line is a guide for the 3 - μm hydration feature. The CR-1 and SR-1 regions are mostly under shadow or at contact region of dark and illuminated areas, and the ROIs around these two regions show overall featureless matured highland spectra. However, the overall albedo of the ROI corresponding to the CR-1 region is relatively higher than its SR-1 counterpart up to ~ 2.5 μm , followed by a broad and moderate absorption around 3 μm having a band minimum centered on ~ 3.02 μm . Interestingly, the mean spectra from the SR-1 region do not show any observable 3 - μm feature and is located at the Shackleton rim with a very narrow and restricted illumination, IIRS could only cover a very few relatively less illuminated pixels, and the majority of the region is under the shadow.

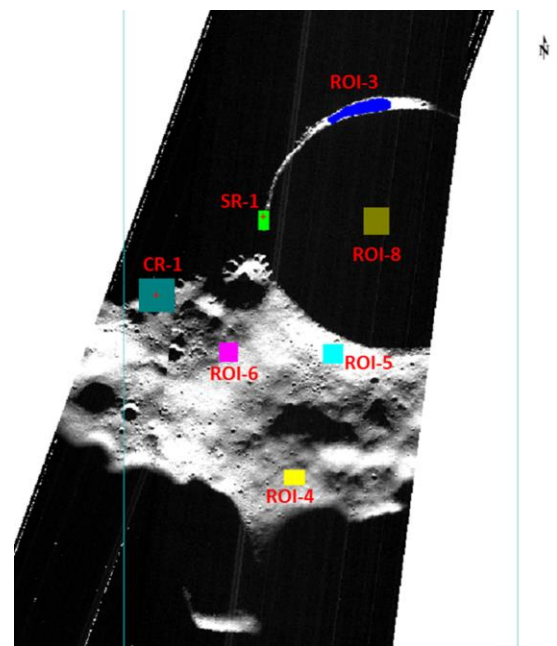


Figure 1. Locations of ROIs corresponding to the proposed LUPEX landing sites and immediate surroundings that include Shackleton crater floor, sunlit inner rim and bright to moderately illuminated regions south of Shackleton crater as seen in the IIRS mosaic.

In addition, we have obtained spectra from across the mosaic having regions that can be categorized as brightly illuminated, moderately illuminated and completely dark areas, as is presented in figure 2. The mean spectra of ROIs - 3, 4, 5 and 6 show an almost non-existent feature near 1 μm and a relatively weak to non-existent 2- μm feature suggesting optically matured lunar highland lithology. However, all these spectra are accompanied by a broad and moderate absorption around 3- μm arising primarily due to the solar proton-induced hydroxylation (Fig. 2). The band center of the 3- μm feature is centered on $\sim 3.02 \mu\text{m}$, indicating the presence of water at this studied site.

Future Scope: IIRS data have successfully captured the presence of hydration at the lunar south pole near the LUPEX landing site from the bright to moderately illuminated surfaces. A detailed spectral analysis will be carried out subsequently to come up with a quantitative hydration map of the SDR region following the method described by [5]. Even though IIRS can detect the hydration signatures from the sunlit surfaces near the pole, it is not designed to study the very cold PSR regions of the Moon that remain permanently under shadows. As the temperature of the PSRs range from $\sim 60\text{--}120 \text{ K}$, it is therefore not feasible to receive any meaningful signal from these extremely cold lunar traps, which are being speculated to host a large deposit of lunar water ice. However, considerable

improvements in the SNR of IIRS data over the PSRs can be made through spectral and spatial binning and through multiple acquisitions over the PSRs. In future, systematic pole-to-equator long acquisitions of IIRS data in E1G2 mode should continue to have a complete lunar polar coverage, and that should continue across the optical periods to depict the diurnal and viewing-geometry related variations. Future lander/rover missions that are being planned for lunar polar exploration, therefore, require high-resolution IR spectrometers with an active illumination source (in PSR regions) for complete characterization of the 3- μm lunar hydration feature and also to infer the nature and quantity of the hydration species. These measurements will act as “ground truth” and an independent source of hydration estimation validation for the orbiter-based spectrometers. Thus, in the ISRO-JAXA LUPEX mission, a high-resolution imaging spectrometer having a spectral range of $0.8 - 5 \mu\text{m}$ in passive (for Sun illuminated regions) and a range of $2.6\text{--}3.4 \mu\text{m}$ in active (with illumination source in shadow regions) mode has been proposed.

References: [1] NASA. (2020) Artemis III science definition team report. Report No. NASA/SP-20205009602. [2] Bickel et al. (2022) *GRL* 49, e2022GL099530. [3] Bernhardt et al. (2022) *Icarus* 379, 114963. [4] Roy Chowdury A. et al. (2020) *Curr. Sci.* 118(3),368-375. [5] Milliken and Li (2017), *Nat. Geosci* 10, 561-565.

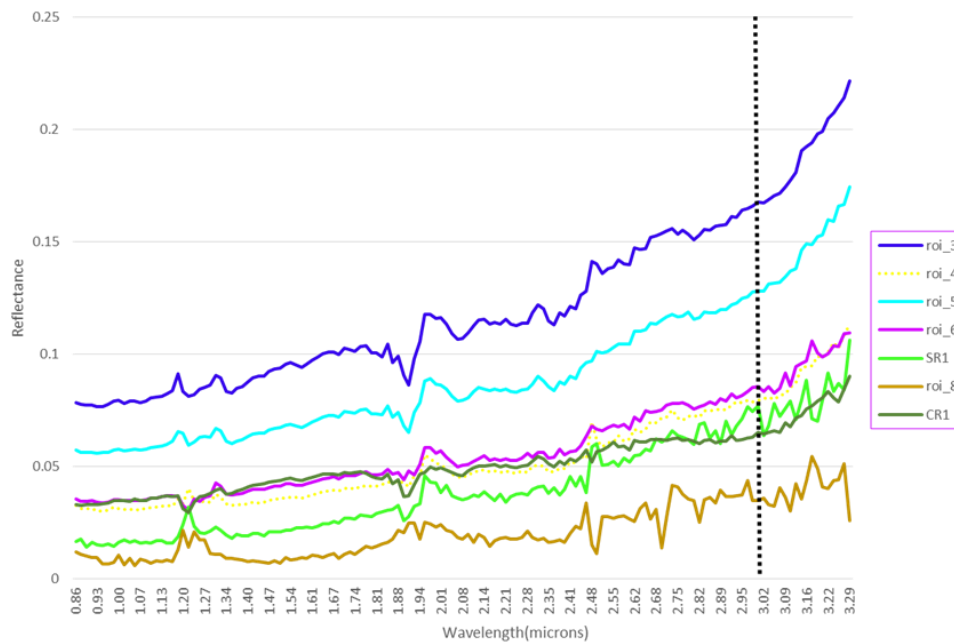


Figure 2. Mean representative reflectance spectra corresponding to the ROIs showing in figure 1.