Comparative spectral analysis approach: The study of Lunar Mineralogy using two Hyperspectral data from Chandrayaan-1

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Introduction: Hyperspectral remote sensing is an advanced approach to study the compositional variability of a planetary surface [1]. Hyperspectral data gives number of contiguous spectral band in the VIS-NIR region [2] which gives an opportunity to study the absorption features in minerals that arises due to the Fe^{+2} electronic charge transition in the crystallographic site of the mineral crystal [3]. In this work, we have studied compositional variations of Mare Tranquillitatis, located towards eastern near side (7°N, 30°E) of the Moon using two Hyperspectral data from India's Chandrayaan-1 mission. Mare Tranquillitatis is a nonmascon [4], Pre-Nectarian age basin [5] and is known for Apollo 11 landing site. It shows characteristic two basin ring structure [6] with diameter of 800 km from east to west. The mare shows irregular boundary and is well known for its high titanium bearing basalts from both, ground-based Apollo 11 samples and remote sensing based analytical results [7],[8],[9]. Location of Mare Tranquillitatis is given in Fig. 1.

Data set and Calibration: Data from Hyperspectral Imager (HySI) and Moon Mineralogy Mapper (M^3) instrument onboard Chandrayaan-1 have been used in this study. HySI operating in VNIR (421 - 964 nm) spectral region, on board Chandrayaan-1 complements the M^3 VNIR spectral region (540-3000 nm) by extending the spectral coverage in the lower range up to 400 nm and better resolution of 80 m/pix to that of 140 m/pix of M3 M^3 instrument. The visible part of the spectrum is less reliable in M^3 data due to calibration artifacts [10]. Vice versa M^3 compliments HySI with extended NIR region up to 3000 nm. We have acquired the HySI Level-4 Band to Band Registered (BBR) data products from the ISRO Science Data Archive (ISDA) from (https://issdc.gov.in/CHBrowse/index.jsp) and M^3 Level 2 data product of OP1A and OP1B optical period which contains pixel located, thermally corrected, photometrically corrected, reflectance data from PDS Geoscience Node (https://ode.rsl.wustl.edu/moon/index.aspx). In this study we have acquired data of 100 km altitude and of same Coordinated Universal Time (UTC) from both the hyperspectral instruments. HySI data has been converted from radiance to reflectance by dividing it with solar flux and cross calibrated with the Apollo 11, 10084 bulk soil sample data, selected from the RELAB spectral library.

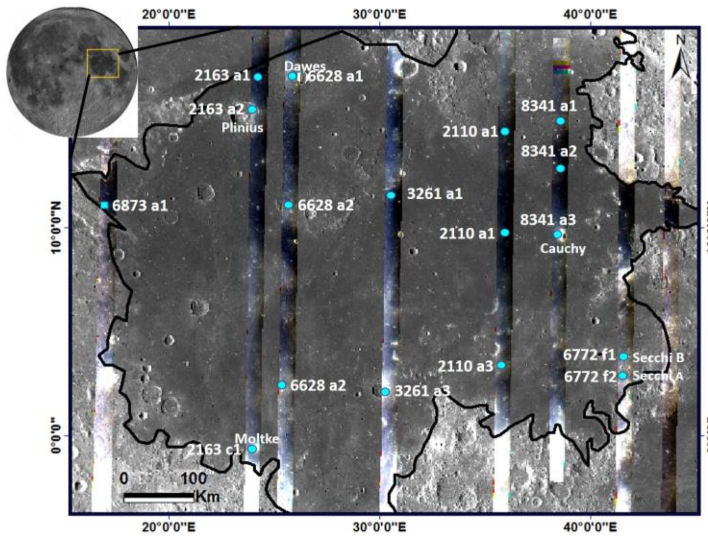

Figure 1: Location Map of Mare Tranquillitatis. HySI data coverage is shown by overlaying the HySI image strip on LROC WAC data. Marked Cyan circles shows location of the spectra collected from the fresh surface of the area (as labelled white).

HySI image strips has been georeferenced and overlaid on LROC-WAC mosaic as the coverage of HySI data is not contiguous. The corresponding M^3 data has been taken and subset according to the area, georeferenced and mosaiced.

Methodology: Comparative spectral analysis approach is used to study the mineralogy of area. Average reflectance spectra of 4 to 6 pixel were calculated from each location presented in Fig. 1. To study the spectral variability from both the data small fresh craters from homogeneous Mare surface as well as from the rim of large crater which exposes fresh surface were selected. To identify the freshness of the surface, mature area was avoided by marking the densest cloud on 950/750 nm vs 750 nm plot [12]. We collected average reflectance spectra of the same location from both the data to know the exact variability in the VIS-NIR spectral region. The spectral Plot acquired using HySI data is shown in Fig 2A. The extended spectral range of M^3 was cut down up to 970 nm i.e. up to HySI spectral range (Fig. 2B) to observe the spectral variability in both the data. Full spectral range of M^3 reflectance spectra is presented in Fig. 2C.

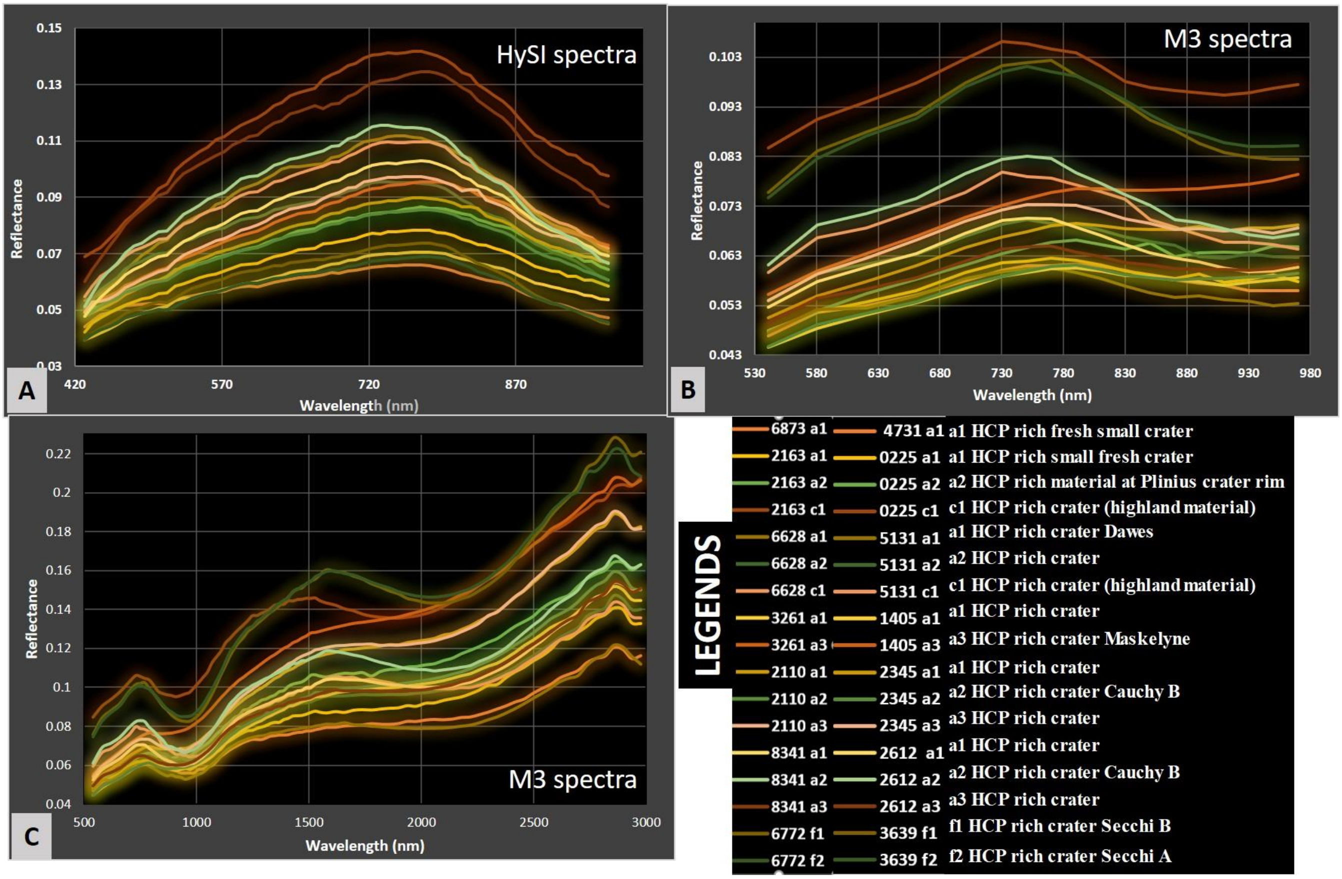

Figure 2: A. HySI average reflectance spectra from selected location as given in Fig. 1. B. M^3 spectra presented up to 970 nm for the comparison. C. M^3 full spectral range of the corresponding location.

Results and Discussions: Reflectance spectra and their location in the image are represented with last four digit of their Image ID. We have cut down spectral range of M^3 spectra up to HySI spectral range to study the variation in the particular region. HySI data with limited spectral range serves high spectral and spatial resolution. HySI data with correct calibration can be used to identify minor absorption that arises in the visible spectral region due to presence of transition element in the mineral such as V, Ti, Mn, and Cr [13]. In the Mare, fresh surface exposes basalt rock type. Lunar basalt contains major four minerals pyroxene, plagioclase, olivine, and ilmenite. Pyroxene mineral is detectable with prominent spectral signature at band I and band II that arise due to Fe^{+2} charge transfer in the M1 and M2 crystallographic site in the mineral crystal [3]. All the spectra show presence of High Calcium pyroxene (HCP) bearing material within Mare Tranquillitatis. Crater rim of Dawes and Plinius crater shows presence of HCP rich basalt material. Maskelyane, Cauchy B, Secchi A and Secchi B crater shows presence of HCP rich material.

Conclusion: These comparative spectral analyses from both the hyperspectral data confirms presence of HCP rich material within Mare Tranquillitatis. HySI data with correct calibration gives an opportunity to study the absorption feature present in the VIS-NIR region with higher spatial resolution.

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