MULTI SENSOR IMAGE FUSION TO STUDY LITHOLOGICAL VARIABILITY AROUND CENTRAL PEAK OF TYCHO CRATER ON THE MOON. P. Chauhan[1], Henal Bhatt[2] & Mamta Chauhan[3], [1]Space Applications Centre, (ISRO), Ahmedabad 380015, India; [2]M. G. Science Institute, Ahmedabad 380009, India, [3]Banasthali Vidyapith, Banasthali 304022, India. (prakash@sac.isro.gov.in)

Introduction: Crater Tycho is a Copernican age crater, having diameter of ~85 km, located at 43.40S, 11.10E. It is a unique dark haloed impact crater, with an excavation depth about 7 km in the southern highlands on the near side of Moon [1]. It represents well developed bright ray pattern in its surrounding and intact crater morphology exhibiting conspicuous central peak, wall, rim and ejecta blanket. Its central peak exhibits an interesting peculiar compositional assemblage, comprising of high-Ca pyroxene, bearing lithology [2,3,4,5,6]. Mineralogical analysis using Chandrayaan-1 M^3 data, have shown presence of high calcium pyroxene, crystalline plagioclase, olivine from the central peak and crater margin [7,8,9]. The average titanium content is >1wt% [10]. Observations from morphological analysis of high resolution data have confirmed the presence of melt flow and ponds associated with embedded clasts from floor of the crater Tycho [11,12,13]. However, the lithological details of the central peak of Tycho crater are not well studied using very high resolution multi-spectral remote sensing data sets.

In this investigation, we have used Multiband Imager (MI-VIS) data of Kaguya's SELENE (SELenological and Engineering Explore) spacecraft having five visible multispectral bands in 0.4, 0.75, 0.9, 0.95, 1.0 µm spectral region, with a spatial resolution of 20 m/px along with high resolution Terrain Mapping Camera (TMC) data from the Chandrayaan-1 mission, which contains one panchromatic band with spatial resolution of 5 meter. PAN Sharping algorithm of Intensity, Hue and Saturation (IHS) has been used to obtain multi-sensor fusion image of Central Peak of Tycho crater. For detailed compositional study we have also used hyperspectral data of Moon Mineralogy Mapper (M^3) from Chandrayaan-1 mission having spectral range from 430-3000 nm with 140 m/px spatial resolution. TMC sensor of Chandrayaan-1 has captured central peak of Tycho crater at 5 m spatial resolution using three different stereoscopic views separated by $\pm 26^0$. The three stereo triplets of orbit number 2877 of TMC data were further used to generate digital terrain model (DTM) of the lunar surface at 25m posting interval [14].

Methodology for Pan sharpening of MI and TMC data: Pan-sharpening is a technique that merges high-resolution panchromatic data with medium-resolution multispectral data to create a multispectral image with higher-resolution features. "Pan Sharpening" is termed as "Panchromatic sharpening". It means using a panchromatic (single band) image to "sharpen" a multispectral image. In this sense, to "sharpen" means to increase the spatial resolution of a multispectral image [15]. A pan sharpened image represents a sensor fusion between the multispectral and panchromatic images which gives the best of both image types, high spectral resolution and high spatial resolution. In this work, MI-VIS data and TMC data of the central peak of Tycho crater have been extracted from http://darts.isas.jaxa.jp/planet/pdap/selene/ and http://www.issdc.gov.in/CHBrowse/index.jsp, respectively. Both the data sets were co-registered using ~20 ground control points collected in both the images. We have used Intensity, Hue, Saturation (IHS) transformation to generate IHS image from MI data sets. The intensity image thus obtained was replaced by high resolution intensity image of TMC data of the central peak. Inverse IHS transformation was used to generate pan sharpen image using MI and TMC data sets.

Results and Discussions. Figure 1 shows TMC image of the central peak of Tycho crater, generated by draping the TMC panchromatic image over the DTM of the central peak. Figure 2 shows False colour composite image of MI-VIS SELENE data sets generated using 950 nm, 900 nm and 750 nm band assigned to Red, Green and Blue colour, respectively. Image shows two colours, purple colour shows mafic material and yellow colour represents impact melt material.

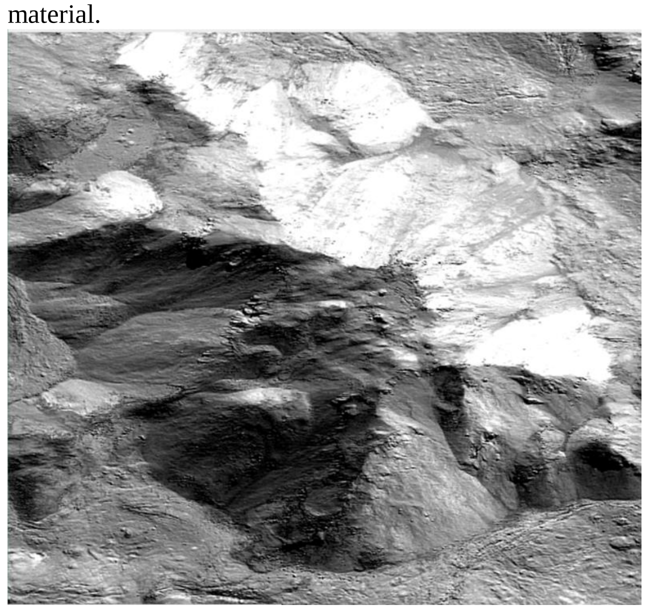

Figure 1: TMC image of the central peak of Tycho crater.

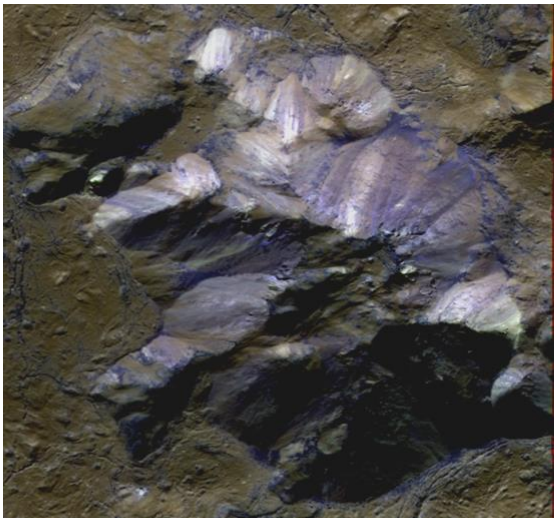

Figure 2: MI-VIS FCC image of central peak generated using 950 nm, 900 nm, 750 nm band assigned to corresponding Red, Green, Blue channel.

Figure 3 is the Fusion image generated using Pan sharpening technique by draping over DEM derived from TMC data. In this fusion image two major colour variations can be observed which represents two distinct lithological units. The yellow colour represents impact melt covering major area including central peak, its flanks, and the surrounding floor. While the purple colour represents mafic mineralogy mostly high calcium pyroxene rich material overlain at many locations on central peak and also exposed around fractures. The spectral analysis done using Moon Mineralogical mapper (M^3) data confirms the presence of high calcium pyroxene rich material at purple locations shown in fused image. The spectra from the Moon Mineralogy Mapper (M^3) data are shown in Figure 4.

Conclusion: Here we show that use of multisensory data fusion techniques improves the interpretation of high-resolution panchromatic data and provides detailed insight into the lithological variability present over central peak of crater Tycho at 5 meter spatial scale.

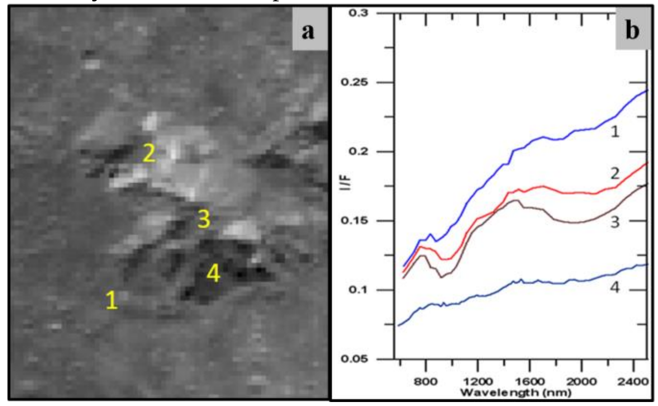

Figure 4: a. M^3 data set albedo image of central peak. b. Reflectance spectra of the corresponding location shown in 4a.

References. [1] Cintala M.J. and Grieve R.A.F., (1998), *MAPS* 33, 4, 889-912. [2] Hawke B.R., et al., (1986), *Spectral reflectance studies of Tycho crater*: Preliminary Results. LPI. [3] Lucey P.G. and Hawke B.R., (1988), *Proc. LPSC*, 355-363. [4] Pieters C.M., (1993), 309-336, *Cambridge Univ.Press*, Houston, Texas, USA. [5] Tompkins S. and Pieters C.M., (1999), *MAPS*, 34, 25-41. [6] Matsunaga T., et al., (2008), *GRL*, 35, L23201. [7] Ohtake M., et al., (2009), *Nature*, 461, 236-240. [8] Chauhan P., et al., (2012), *Curr. Sci.*, 102, 7, 1041-1046. [9] Kaur P., et al., (2012), *43rd LPSC*, 1434. [10] Srivastava N., (2008), 42, 281 -284. [11] Bray V.J., et al., (2010), *GRL*, 37, L21202. [12] Carter L.M., et al., (2012), *JGR*, 117, E00H09. [13] Dhingra D., et al., (2017), *Icarus* 283, 268-281. [14] Gopala Krishna et al., (2009), *Proc. LPSC*, 1694. [15] Gene Rose, Pan sharpening (istrat.ca/uploads/files/brochures/pan sharpening).

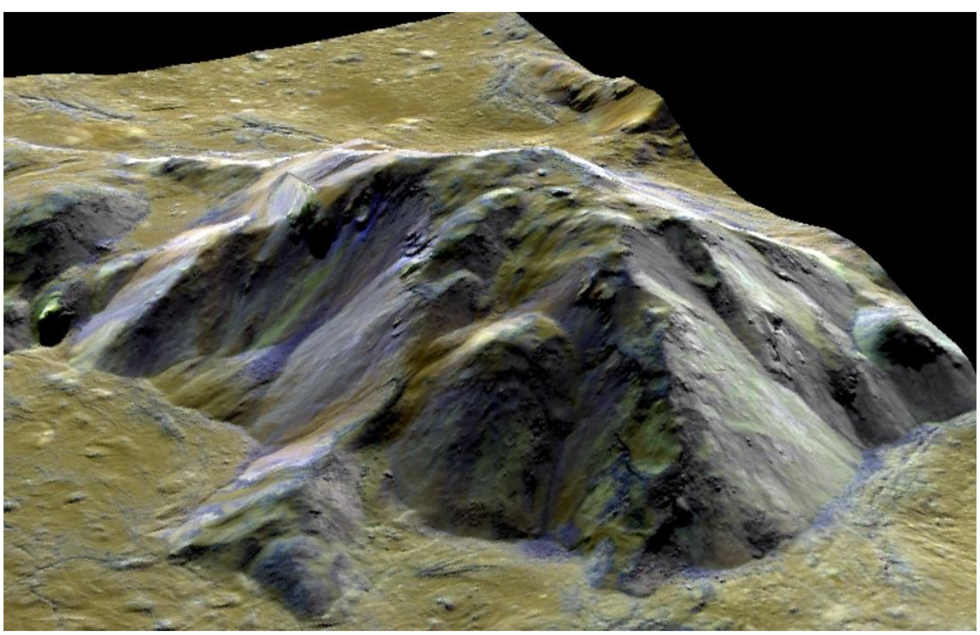

Figure 3: Fusion image of central peak of Tycho crater generated by draping MI FCC image over the DTM derived TMC image.