GEOLOGICAL INVESTIGATION OF MARE NUBIUM, MOON USING MULTIPLE DATASETS FROM RECENT LUNAR MISSIONS. Nupur Adarsh[1], Mamta Chauhan[2] and Prakash Chauhan[2]. ([1]School of Earth Sciences, Banasthali Vidyapith, Rajasthan and [2] Indian Institute of Remote Sensing (IIRS), Dehradun.) mamtachauhan@iirs.gov.in

Introduction: Mare Nubium is a Pre-Nectarian basin (~4.5 by to ~3.9 by) and represents one of the most ancient circular basin located at 21.3° S to 16.6° W towards the near side of the Moon. It is having diameter of about 750 km [1] and surrounded by Mare Humorum and Mare Cognitum basin towards its eastern and northern boundaries, respectively. This basin possesses vast morphological and structural diversity that includes mafic as well as silicic volcanic units, recent mare patches (Irregular Mare Patches, IMP), faults (Rupes Recta), rilles, wrinkle ridges and complex craters. The present work is an attempt to explore and understand the geology of Mare Nubium basin of the Moon. It has been carried out by analyzing the surface composition and mineralogy of various basaltic units and other morphological features of the basin in a spatial context using very high-resolution data mainly from ISRO's Chandrayaan-1 mission. Detail compositional mapping of the basin have been carried out by investigating the pyroxene variability with hyperspectral Imaging sensors, HySI and M^3. It has been further analyzed for its various morphological and structural features along with their spatial distribution and stratigraphic relationships. The results have been interpreted to understand the source, nature and extent of pyroxene variability within the various basaltic units and determine their age, delineate various other lithounits in order to understand the possible underlying petrological implications related with the formation and evolution of the basin.

Data and Methodology:

Datasets from Hyperspectral Imager (HySI) and Moon Mineralogy Mapper (M^3) from Indian Space Research Organization (ISRO) Chandrayaan-1 (Ch-1) Mission, has been used for mineralogical characterization of the study area as they provides high-resolution data in terms of different spectral as well as spatial range. HySI works in spectral range of 421-964 nm with 64 continuous spectral bands with a spatial resolution of 80 m from 100 km altitude [2] while M^3 works in the spectral range of ~450-3000-nm having a spatial resolution of ~140-280 m in two different modes [3]. ISRO's Ch-1 Terrain Mapping Camera (TMC) (5m/pixel) [2] and JAXA's Kaguya-SELENE Terrain Camera (TC) (10m/pixel) [4] data were used for the crater counting by CFSD method to determine the age of the studied basin. Besides, for morphological observations high-resolution TMC have been used alongwith NASA's Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) [5] wherever required.

Results and Discussions:

Mare Nubium is characterized by emplacement of vast expanses of various mare units that have been mapped by earlier remote observations [1,6,7]. In the present study mineralogy of these basaltic units were analyzed using HySI and M^3 data. Various lithounits were delineated and their spectra have been analyzed using various spectral parameters given by [8] from the available HySI strips for the region. The mosaic generated using M^3 was used to redefine the mare units based on reflectance and crater density. M^3 data was also used for generating colour composite images by assigning colours to bands of interest or integrated band depth [9] for mineralogical characterization. The lithological heterogeneity reflected by these images as manifested in the form of colour variations was further analyzed by acquiring spectra from fresh craters present within the lithounits. These spectra were analyzed to characterize the individual mafic mineral constituents based on their diagnostic absorption features [10,11,12] and band parameter analysis to obtain the compositional variability of basalts at Mare Nubium. The technique of crater size-frequency distribution (CSFD) measurements based on the [13] lunar chronology and production functions was utilized for determination of the age of the various basaltic units and other volcanic features present within Mare Nubium basin. The craters were identified using both TMC and TC data and compared with earlier obtained results [7]. The various morphological and structural features present within the basin were analyzed using TMC data along with NAC strips. A detailed geological map have been prepared based on morphological observations and identification and analysis of structural features. Some of the results are presented in form of figures 1-5.

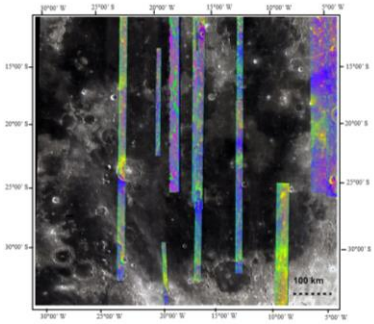

Figure 1: Ch-1 M^3 Mosaic of Mare Nubium basin, Moon overlain by band ratio images of HySI strips.

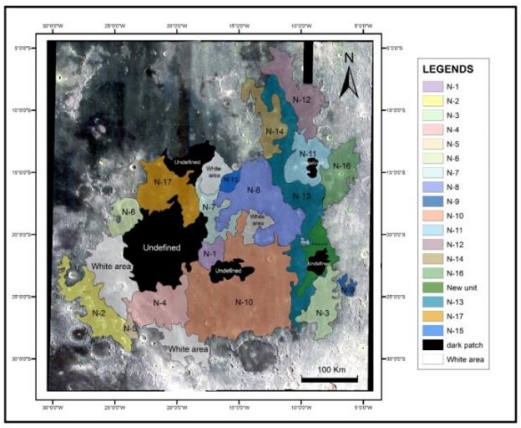

Figure 2: Redefined basaltic unit of Mare Nubium on the basis of visual observation in RGB image of its M^3 mosaic.

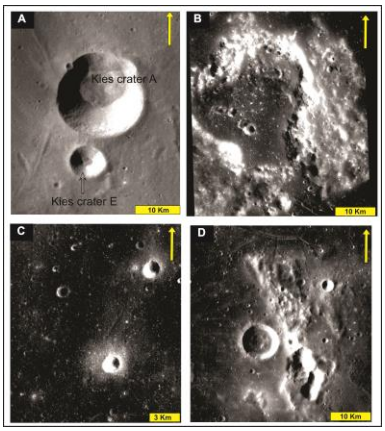

Figure 3: The various geological features as observed using TMC data A: Kies crater present towards SE of Bulliadus crater, here spinel were detected from M^3. B: Silicic volcanic construct, Wolf crater present at the center of Mare Nubium basin. C: Crater present within basaltic unit 16, here olivine was detected D: Lassell massif present in NE region of Mare Nubium basin

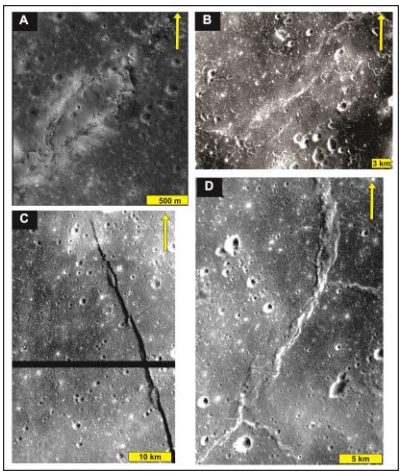

Figure 4. A. LROC-NAC image of Irregular mare patch indicative of recent volcanic activity in Mare Nubium. TMC image of B. Sinuous rilles C. Rupes Recta "straight wall"/ fault D. Wrinkle ridges present in the Mare Nubium basin.

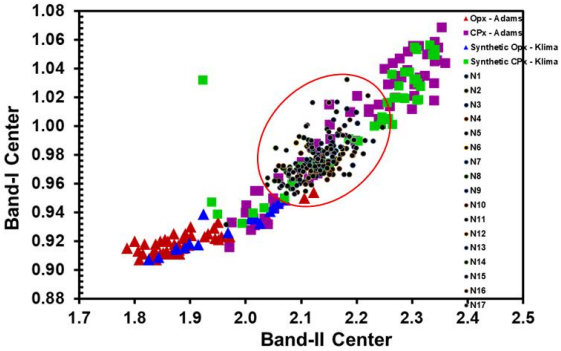

Figure 5. Band-I v/s Band-II Centre ratio data showing plots of basalts of different ages of Mare Nubium region along with data for pure ortho-and clino-pyroxenes of [14] and [11] data for comparison.

Conclusions: The present work utilized high-resolution data to map the various mare units present at Mare Nubium basin and analyze them for their composition. These were further correlated with their age to determine the time of eruption so as to integrate them stratigraphically. This Pre-Nectarian basin is unique in preserving volcanic units that shows variability in composition and eruptive styles (basaltic to silicic). The region has undergone a prolonged volcanic evolution as indicated by presence of mare basalts and young Irregular mare patches. Morphological observations and presence of various structural features suggest the role of both endogenic and exogenic geodynamic processes in evolution of the basin.

Acknowledgments: We duly acknowledge and thanks Department of Space, Indian Space Research Organization (ISRO), India for financial support provided under the Chandrayaan-1 AO (Ch-1/ISRO/SSPO/2016-2017) to carry out this research.

References:

[1] Whitford-Stark J.L. and Head III J.W. (1980), *JGR*, 85, B11, 6579-6609 [2] Goswami J. N. and Annadurai M. (2009), *Curr. Sci.* 96, 4, 486-491. [3]. Green R.O. et al., (2011), *JGR*, 116. E00G19. [4]Haruyama J. et. al., (2008) LPS, *XXXIX, Abstract #* 1391. [5] Robinson M. S. et al. (2013) *Space Sci. Rev., 150, 1-4,* 81-124.[6] Hiesinger H. et. al. (2000), *JGR*. 105:29,239-29,275 [7] Hiesinger H et al (2003), *JGR*, 108, 7, 5065 *XXVII*, 1344-1345 [8] Bhattacharya S. (2011), *Icarus*, 212, 470-479. [9] Mustard J. F. et al. (2011) *JGR* 116, E00G12. [10] Burns R. G. (1993) 2nd ed., *Cambr. Univ. Press*, New York [11] Klima R. L. (2007) *Meteorit. Planet. Sci.* 42, 235-253. [12] Klima R. L.(2011) *Meteorit. Planet. Sci.* 46, 3, 379-395.[13] Neukum G. et. al. (2001) *Space Sci. Rev.*, 96, 55-86. [14] Adams J. B. (1974) *JGR*, 79:4829-4836.