HIGH-TITANIUM OLIVINE-RICH BASALTS FROM THE GRIMALDI BASIN ON THE NEARSIDE OF THE MOON: IMPLICATIONS FOR THE VOLCANIC HISTORY OF THE BASIN P. M. Thesniya[1], V. J. Rajesh[1,*] and J. Flahaut[2], [1]Department of Earth and Space Sciences, Indian Institute of Space Science and Technology, Thiruvananthapuram 695547, India. (E-mail: thesniyathesni91@gmail.com), [2]Centre de Recherches Pétrographiques et Géochimiques (CRPG) - CNRS/ Université de Lorraine, 15 rue Notre Dame des Pauvres, 54500 Vandoeuvre les Nancy, France (flahaut@crpg.cnrs-nancy.fr)

Introduction: Mare basalts on Moon are formed by the fissure-type eruption of the low-viscosity basaltic magma from the interior of the Moon [1]. Surface dating of the lunar mare basaltic units based on Crater size-frequency Distribution (CSFD) technique as well as radiometric ages of the returned lunar samples revealed that the mare volcanism on Moon begun at around ~3.9-4.0 Ga and continued until ~1.2 Ga, with a peak in the volcanic activity at ~3.6-3.8 Ga [2]. Understanding the origin, diversity, and ages of mare basalts on the Moon is key to better understand its volcanic history and thermal evolution. The present study investigates the spectral and chemical characteristics as well as ages of the nearside mare basaltic units from the Grimaldi basin (Fig. 1), Mare Grimaldi and Mare Riccoli, using orbital remote sensing data. The pyroxene group minerals, which are major components in basalts, form in all the stages of the crystallization of basaltic magma [3] and therefore, the chemical trend of pyroxenes in basalts should provide information about the crystallization history of basaltic magma [3]. The cooling and emplacement history of the Grimaldi basaltic units have been deciphered based on their chemical characteristics as well as pyroxene chemistry. The ages were also estimated from Crater Size Frequency Distribution Technique (CSFD). The chemical variation of these basaltic units with respect to their eruption at different periods have provided significant insights into the volcanic history of the Grimaldi basin. The origin and emplacement of the younger high-Ti basalts within Mare Grimaldi have also been discussed.

Data and Methods: M[3] (Moon Mineralogy Mapper) data has been utilized for determining the mineralogy of mare basaltic units. Detailed chemistry of pyroxenes in the Mare Grimaldi and Mare Riccoli has been analyzed further based on the M[3] absorption band characteristics. Moderate-high resolution spatial data from TMC, TC, LROC WAC (Wide Angle Camera), and topographic data from LOLA (Lunar Orbiter Laser Altimeter) have also been used to study the geological context and dating of the mare basaltic units by CSFD in the Grimaldi basin.

Results: The present study delineated distinct basaltic units of varying albedo, mineralogy and chemical nature within both Mare Grimaldi and Mare Riccoli. The mapped basaltic units were labeled as G1, G2, G3 and G4 in the Mare Grimaldi and R1 and R2 in the Mare Riccoli.

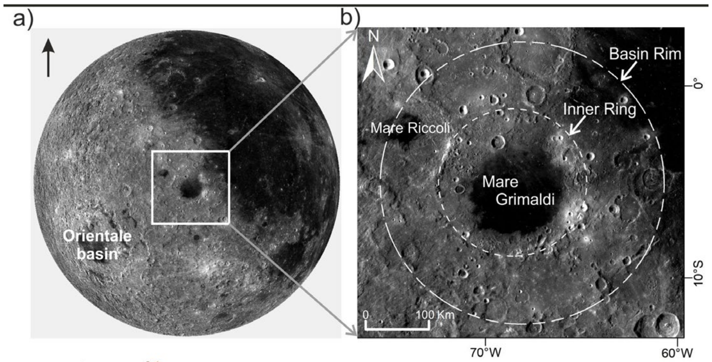

Figure 1 (a) LROC-WAC mosaic of the western limb of the Moon in stereographic projection, centered on the Grimaldi basin at 5ºS, 68ºW. (b) WAC grey-scale mosaic image of the Grimaldi basin.

Pigeonite and augite are the major pyroxenes identified in these basaltic units. The distinct basaltic units in Mare Grimaldi were showing varying TiO_2 and FeO abundances. In the Mare Grimaldi, the G1 unit exhibits exceptionally higher concentrations of high-Ti (>9 wt. %) basalts (Fig. 2). The G2 unit has medium to high-Ti contents. The G3 and G4 units possess lower Ti abundance values.

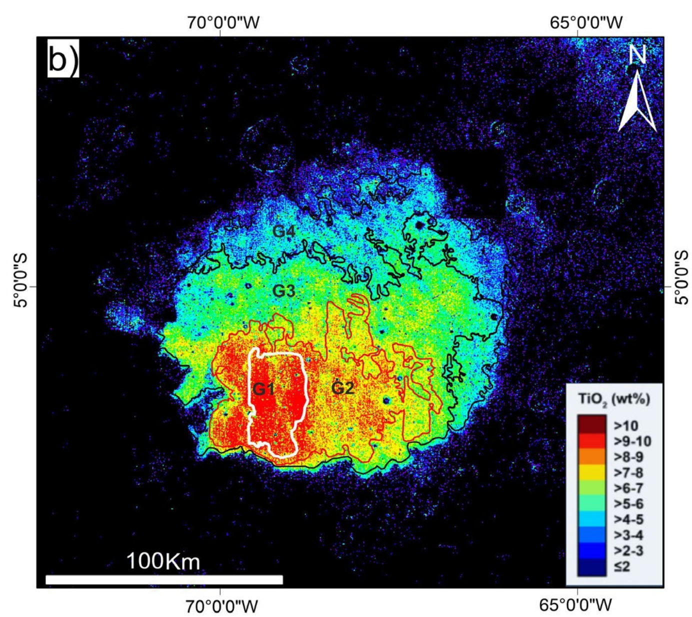

Figure 2 LROC WAC derived TiO_2 abundance map of the Mare Grimaldi.

In short, the high Ti basalts appear to be surrounded by the low-Ti basalts (Fig. 2). The high-Ti basalts also exhibit olivine-bearing mineralogy (Fig. 3). The high-Ti basalts revealed a much younger age of 2.05 Ga ±0.06 while the low-Ti basalts showed an older age of 3.47 Ga ±0.08/0.19 (Fig. 4 & 5). In the Mare Riccoli, the R1 unit has medium Ti contents while the R2 unit possesses low-Ti abundances. The age estimated for the Riccoli basaltic unit is 3.26 Ga ±0.14/0.44.

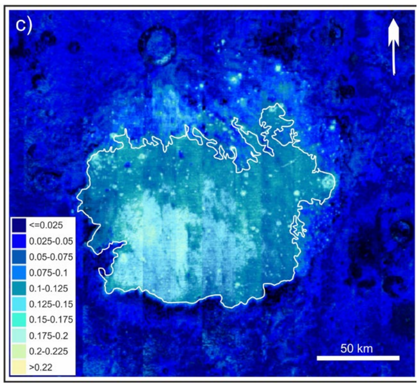

Figure 3 Kaguya MI derived olivine abundance map of the Mare Grimaldi and Mare Riccoli.

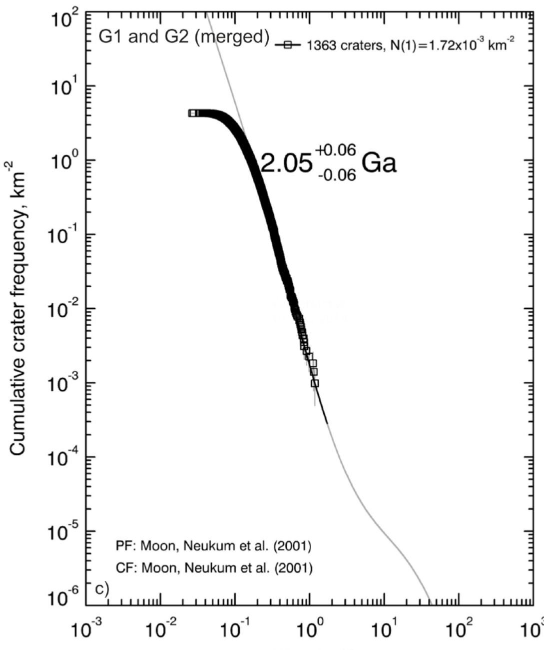

Figure 4 Cumulative frequency plots of the G1-G2 (merged) unit in the Mare Grimaldi along with isochron and error for the data points.

Discussions: Two distinct compositional trends of pyroxenes having different crystallization histories have been observed at both locations. This observation is consistent with the emplacement of distinct basaltic units that erupted at different periods in the Grimaldi basin (3.47 Ga-2.05 Ga).

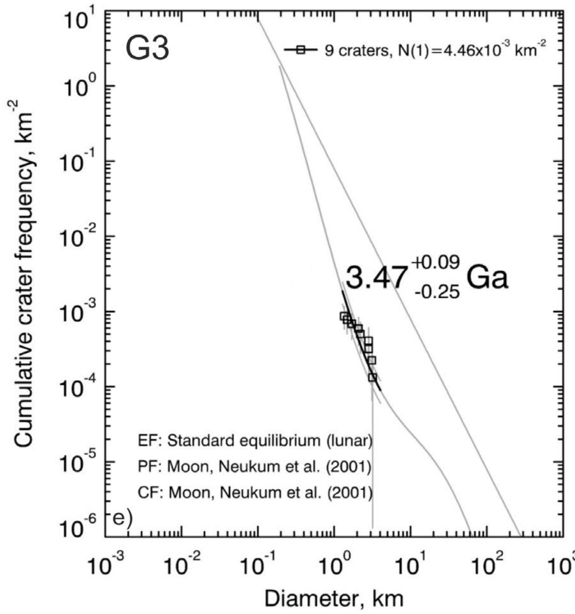

Figure 5: Cumulative frequency plot of the Mare Grimaldi Low-Intermediate Ti basaltic units (G3-G4) along with age isochron and error for each data point.

The low to intermediate-Ti basalts in the Mare Grimaldi and Mare Riccoli would have been erupted between 3.47-3.26 Ga ago from an olivine-orthopyroxene cumulate source region in the mantle, the younger high-Ti basalts could have been erupted from a clinopyroxene-ilmenite rich cumulate source region in the lunar mantle at around 2.05 Ga. Based on the results from Hiesinger et al. 2010, it was believed that the volcanic activity occurred at 3.48 Ga and 3.25 Ga ago and ceased soon after the eruption of Mare Riccoli. However, the results from the present study indicate that volcanism was active in the Grimaldi basin until 2.05 Ga ago.

Conclusions: The new evidence from the present study suggest that volcanism had not ceased in the Grimaldi basin at 3.26 Ga, rather it was active and fed by different mantle sources until 2.05 Ga for a period spanning ~1.2 billion years.

Acknowledgments: This work is supported by ISRO-project under the Chandrayaan-1 AO (Announcement of Opportunity) program, funded by DoS, India. The authors would like to thank the TMC, M^3 (Chandrayaan-1) and LROC team for making the datasets available in the public domain. J. Flahaut is supported by a LUE future leader grant, a CNRS Momentum fellowship and CNES.

References: [1] Head and Wilson (1992) *Geochem.Cosmochem.Acta,* 56, 2155-2175. [2] Hiesinger et al. (2000) *JGR*, 150 (E3). [3] Shearer et al. (2006) *Rev. Min. and Geochem.,* 60, 365-518.