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Analysis of mineralogy of an effusive volcanic lunar dome in Marius Hills, Oceanus Procellarum.

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Abstract

Domes are analogous to the terrestrial shield volcanoes and are among the important volcanic features found on the lunar surface indicative of effusive vents of primary volcanism within Mare regions. Marius Hills Complex (MHC) is one of the most important regions on the entire lunar surface, having a complex geological setting and largest distribution of volcanic constructs with an abundant number of volcanic features like domes, cones and rilles. The mineralogical study of an effusive dome located in the south of Rima Galilaei, near the contact of Imbrian and Eratosthenian geological units is done using hyperspectral band parameters and spectral plots so as to understand the compositional variation, the nature of the volcanism and relate it to the rheology of the dome.

1. Introduction

Volcanism in a planetary body is very important for wide ranges of implications in terms of its geologic, compositional, and thermal history, including contributions to variations in the magnetic and gravitational characteristics [1]. Moon, a one-plate planetary body, the volcanism apparently resulted from melting of mantle rocks that was unlikely to be contaminated by recycled crust. Highly silicic composition is reported in the Gruithuisen (highland) domes, Aristarchus regions [2] and also global silicate mineralogy [3]. These findings of silicate mineralogy not only gives a new dimension to the exploration of lunar mineralogy, but also in understanding the nature of lunar volcanism and their genesis. In this context, Marius Hills Complex (MHC) is also one of the most important regions in the entire lunar surface for having a complex setting and largest distribution of volcanic constructs with an abundant number of volcanic features like domes, cones and rilles [4]. Domes, an analogue of the terrestrial shield volcanoes are one of the important volcanic features found on the lunar surface. As a part of initiation of the study of mineralogy of MHC, an effusive dome located in the south of Rima Galilaei, near the contact of Imbrian and Eratosthenian geological units is taken up for the present study. The morphology, rheology and the possible dike parameters have already been studied and reported [5].

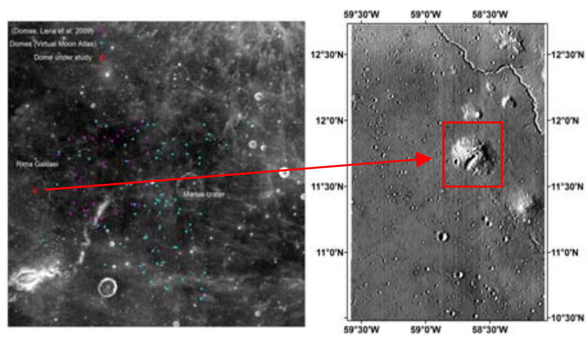


Fig. 1: Distribution of dome in MHC (Red-the dome under study, Green- from Virtual Moon Atlas, Magenta [6]) and the Study area showing the dome under study on M3 reflectance 2.9 µm image.

2. Data used and Methodology:

The data used here is Chandrayaan-I Moon Mineralogy Mapper data (M3), level 1B radiance data (orbit number 1130) which was acquired at an orbital height of 100 km. The data is having 140 m sampled spatial resolution with 20 nm and 40 nm spectral resolution, imaged in push-broom mode in the spectral band of 0.46–3 µm [7]. The radiance data is converted to apparent reflectance [8]. Thermal and photometric corrections are not applied for this analysis, but the data is de-striped (column de-striping) so as to reduce the noise data due to striping in the data. The wide spectral range of M3 enables analysis of both the 1 µm and the 2 µm regions, which are important wavelengths for the study of mafic minerals such as those on the surface of the Moon.

2. Discussion and Results

The first identification of different compositional units in MHC was made using the Galileo multi-spectral images [9]. Two units were identified based on the brightness differences and ratios in the visible and near infrared region. Then, Weitz and Head [10] identified two units with mixed boundaries: a high-titanium basalt unit and a low-titanium basalt unit, using Clementine multi-spectral data. Six main units of lava flows were mapped using Clementine multi-spectral data according to the UV/VIS slope, the strength of the 1 μm band and TiO_2 content [11]. Recently, MHC was analysed using M3 (Chandrayaan– I) data using various band parameters (1 μm and 2 μm) and spectral analysis of the different volcanic features [12]. The above study aimed at defining the mineralogical composition of the mare basalts and the spatial variability of the different mineralogical units and concluded that MHC is composed of two main mare units that may represent different volcanic episodes of the MHC: 1) a high-calcium pyroxene mare unit that covers a large portion of the plateau and has a weaker IBD1000 compared to the other mare unit, 2) an olivine-rich mare unit that is more localized and has a strong IBD1000.

1 μm Integrated Band Depth (IBD1000) is useful for mapping different units of MHC [12]. The IBD1000 can vary due to the abundance of mafic minerals, which will affect the strength of the absorption band or due to mineral composition, which will affect the shape of the band. An olivine composition will increase the band depth towards longer wavelengths. However, the IBD1000 can be the same for a stronger low calcium-pyroxene composition because the absence of absorption at longer wavelengths is compensated by a stronger absorption at short wavelengths.

The IBD1000 is shown (Fig. 2). The different grey levels correspond to the strength of the 1 μm band depth; darker areas have a weaker 1 μm band depth. The dome under study can be distinguished from its surroundings by a relatively weaker 1 μm band depth. The relatively darker regions are olivine poor regions having Pyroxene as dominant constituent and vice versa. The dome under study is poor in olivine and rich in Pyroxene. An FCC is also generated assigning IBD1000 as red, IBD2000 as green, 1.58μm reflectance image as blue [13].

An analysis of apparent reflectance spectra of the study area is also attempted. Since the data is not photometrically and thermally corrected, so a detailed and accurate analysis can not be made, however an overall idea can be made observing the nature of the absorption features in the spectra. A total of 29 spectra each from the outside and inside the dome are examined, and selected spectral plots are shown separately. It can be inferred that the spectra of the regions inside the dome are relatively homogeneous in nature, while variations in the spectre due to the varying amounts of mafic mineralogy of the regions outside the dome can be seen (Fig. 3). Absorption features at 1 um, around 0.95 um and towards longer wavelengths as well as longer wavelengths at 2 um, signifies the dominance of high calcium pyroxene lithologies/regolith.

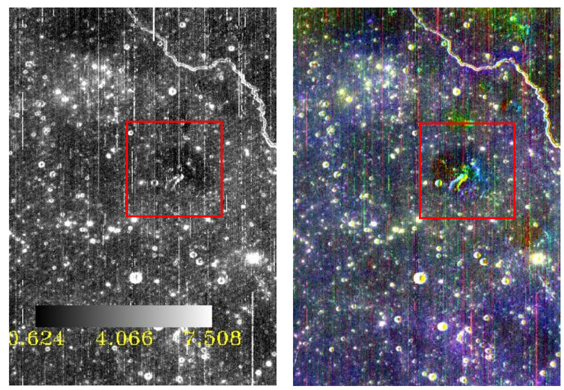
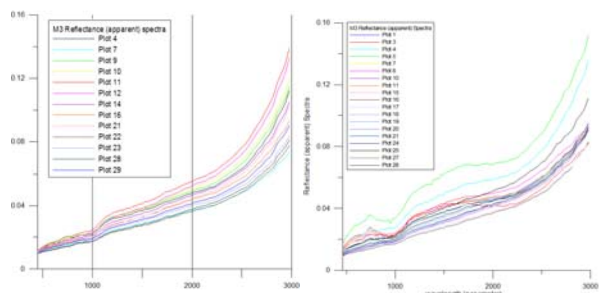


Fig.2: a) IBD1000 and b) RGB (IBD1000 as red, IBD 2000 as green, 1.58 μm reflectance image)

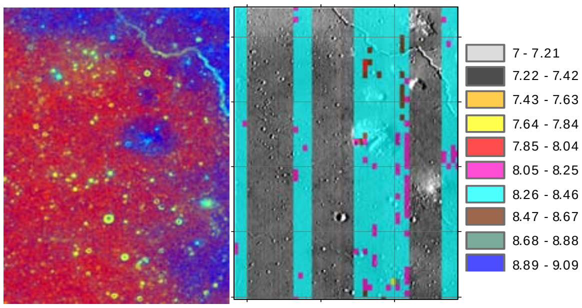


a) b)

Fig.3: Reflectance (apparent) spectra (a) inside the dome and (b) outside the dome.

Further, Christiansen Feature (CF) from Gridded data record (GDR) level 3 data product (approx. 950m/pixel) of Diviner Lunar Radiometer Experiment/Lunar Reconnaissance Orbiter (DLRE / LRO) data is used for further analysis. The Christiansen Feature (CF) is directly sensitive to silicate mineralogy and the bulk SiO_2 content. Silicic minerals and lithologies exhibit shorter wavelength positions at 8 µm channel [2]. For the study area, CF values of 8 µm are towards longer wavelength which signifies less silicic composition/lithologies (Fig. 4b).

An FCC is also generated using Clementine UVVIS reflectance image, assigning R750/R415 as red, R750/950 as green, R415/750 as blue, which are sensitive to mapping of plagioclase/ejecta, iron and titanium respectively. The dome under study is enriched in titanium with less iron (High Ti, Low Fe Basalts), embayed by a plagioclase/ejecta dominant mare unit (Fig. 4a).



(a) **(b)**

Fig. 4: (a) RGB image from Clementine UVVIS data with 750/415 as red, 750/950 as green, 415/750 as blue (b) DLRE (LRO) data overlying on M3 image, showing the Christiansen Feature (CF) values with the captions on right hand side.

6. Conclusion and Future scope

From this initial study, it can be inferred that the dome under study is enriched in Titanium with lesser iron, having a mafic lithology with high calcium pyroxene and less olivine. However, there is no significantly different bulk composition with respect to the surrounding mare. This is supportive of the deeper source of the nested magma (160 km depth) i.e. from the lower mantle older age of the dome (3.36 Ga), with respect to the surrounding mare (3.17 Ga) [5]. This further consolidates the multi-phase volcanism in Mare basalts. A detailed compositional study with a quantitative approach of the volcanic features in MHC is in progress in order to understand the genesis and chronology of effusive events within MHC, in a holistic manner.

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