VOLCANISM ON THE MARIUS HILLS PLATEAU  D. J. Heather, S. K. Dunkin and L. Wilson

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Introduction: The Marius Hills region of Oceanus Procellarum comprises a plateau with an area of around 35,000 km², rising several hundred metres from the surrounding plains. The plateau contains one of the highest concentrations of volcanic features on the lunar surface, with 262 domes, 59 cones and 20 sinuous rilles [1]. Recent studies using the Galileo [2] and Clementine [3] multispectral data have indicated a wide range of volcanic activity and eruption styles to have occurred in the region, with a similar variation in basalt composition.

In this study, we used the Clementine multispectral data to map the different mare basalts on the plateau for the first time. Detailed spectral analyses of the volcanic constructs were also completed and tied in with the mapping results to investigate the way in which eruption styles and volcanic activity have changed through time. Work is now continuing in order to produce theoretical models from these results, looking at the likely nature and depth of source regions and the rise and eruption mechanisms required to develop the plateau and its associated structures.

Data Reduction: The Clementine data for the Marius Hills region were reduced using the ISIS software and the standard techniques developed by the USGS Astrogeology Team [4]. As Marius Hills is near to the lunar equator (∼9°N to 17°N), some additional photometric corrections were required to account for the variation in phase angle between orbital strips. For details of the photometric coefficients and additional procedures used during data reduction, please contact the authors or see [5]. Abundance maps for FeO and TiO₂ were also produced from the data using the Lucey method and the algorithms given by [6] and [7].

Mapping Technique: The basalts in Marius Hills were mapped using the Clementine data as an analytical tool to identify spectral (compositional) boundaries. The techniques used to complete this study are outlined in [5] and detailed in [8]. The Clementine UVVIS camera data provide information regarding the steepness of the UV/VIS continuum (from 415 to 750 nm), albedo (reflectance at the 750 nm point), and the shape and structure of the 1 μm absorption band (seen in the 900, 950 and 1000 nm bands) as well as abundance maps for FeO and TiO₂. In combination, these products and analyses can be used to quantitatively identify boundaries between different basalts in the surface flows of a region. The Flamsteed region, previously mapped using UVVIS and NIR data from ground-based telescopes [9], was successfully used to test the viability of this mapping technique [8]. In addition to helping map the flow boundaries, the UV/VIS slope and 1 μm absorption criteria also represent some of the key spectral characteristics of basalts and can be used to help identify discrete units of similar properties and place them correctly within their regional context.

The FeO map produced using the Lucey method also provides the means to search for evidence of an impact crater having excavated through the mare flows to expose highland units beneath. The calculated excavation depth of an impact crater provides an upper or lower limit for the thickness of the basalts at that point, depending on whether the impact has or has not exposed the sub-basalt highland units respectively. A combination of the FeO wt% map and five-point spectra were used to investigate all of the impact craters in Marius Hills that were large enough to provide a viable spectral measurement in the Clementine data. Limits for the thickness of the basalts on the plateau were derived using the 1:10 excavation depth:diameter ratio for simple craters [10].

Mapping Results: The flow boundaries across a large region of southern Oceanus Procellarum [5] were mapped from the Clementine data. Figure 1 shows the region relating specifically to Marius Hills and placed in the stratigraphic sequence of [11]. The area is quite complex, with 6 distinct units identified. The basalts on the plateau vary in age and composition, but are dominated by a young high titanium basalt, most likely from the same source as the young Flamsteed Basalt of the Sharp Formation, further south. The range of FeO and TiO₂ values is large, with unusually high FeO wt% values being found (up to 24 wt%) in some regions, and rarely having FeO values less than 18 wt%. Marius Basalt 1 is a newly identified unit which we place within the Hermann Formation of [11], representing a slightly earlier phase of volcanism than the Marius Basalt 2 units (identified as 3.3±0.3×10⁸ years by [11]).

The study of the impact craters in the region revealed none that had penetrated through to the underlying highland bedrock. This implies that the total
thickness of all basalts combined in this region is greater than 1 km.

**Studies of the Volcanic Features:** Marius Hills contains a high concentration of volcanic constructs, including domes, cones and rilles. These were all studied and placed into context with the surrounding mare units.

Most of the domes and cones in the area are truncated by younger mare flows, and hence represent the oldest visible volcanic features in the area. Analysis shows that the domes and cones in the region are not related to a specific basalt or volcanic episode, suggesting that they formed from several separate events throughout the history of the Marius Hills mare basalt formation. The cones in Marius are spectrally distinct in the Clementine data, dominated by a strong glassy signature and often with an associated microlitic structure. In some areas, these spectral signatures are seen where only poorly developed structures are present in the Lunar Orbiter data, and in many cases where no cone is evident in the photographic data. We propose that these features represent short-lived pyroclastic episodes that have deposited glassy and microlitic units on the plateau but have not been maintained for long enough to develop a cone.

The low effusion rates required to form the cones and domes at Marius Hills contrasts sharply with high effusivity required to develop the 20 sinuous rilles in the area. Some of the rilles appear to have sourced many of the Eratosthenian mare lavas in this area [11] and hence developed from a late phase of volcanic activity.

**The Volcanic Evolution of the Marius Hills plateau:** The volcanic history of the Marius Hills region is extremely complex, and most likely involved several separate episodes of volcanism with a large contrast in eruption styles and characteristics. Recent studies of the ascent and eruption of mare basalts suggest Marius Hills may be the result of a large number of small dikes rising from a large melt reservoir in the lunar mantle [12]. These suggest dike volumes up to the order of 100 million cubic metres, and a survey of the morphology/approximate volumes for the domes is underway to test these values. In addition, the stress state of the lunar lithosphere is likely to be important in assessing the volume of magma, both erupted and intruded [13] in the region. These studies are continuing in order to produce theoretical models to investigate the volcanic history of the Marius Hills, including the probable nature and depth of source regions and the rise and eruption mechanisms required to develop the plateau and its associated structures.

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