VOLCANIC HISTORY OF MARE CRISIUM: A MULTIWAVELENGTH RADAR PERSPECTIVE.

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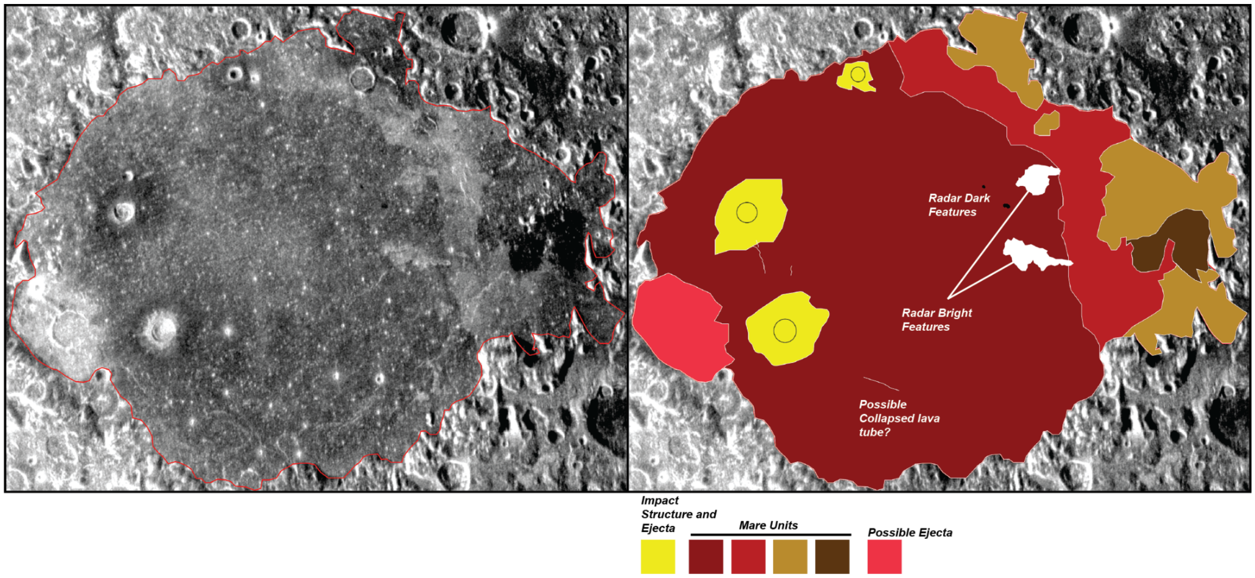

***Figure 1**. a) Same sense polarization Earth-based P-band radar image of Mare Crisium. Red line marks the mare boundary. b) Radar based map of main volcanic features.*

Introduction: Isolated from other mare deposits within the Nectarian-aged Crisium Basin, the 550 km wide Mare Crisium is host to a diverse range of volcanic structures and deposits. In addition to flood basalts, the basin also contains volcanic cones [1] and, as we will present, potential pyroclastic deposits and flow-like deposits not reported elsewhere on the Moon. This complex assemblage of volcanics suggests that a range of eruptive styles - from effusive to explosive - have occurred throughout the basin's history.

Previous investigations of Mare Crisium using albedo, spectral, and morphologic analysis suggest that there are four distinct mare units (based on TiO_2 and FeO_2 content) [1-3]. Corresponding age estimates from crater size-frequency distributions indicate the eruption of the mare basalts occurred over a 1.25 Gyr period, with the majority of the mare corresponding to an age of >3.5 Ga [1-2,4]. Kilometer-scale volcanic cones that are morphologically similar to edifices within the Marius Hills [5] and representative of episodes of explosive degassing that accompanied the eruption of effusive flows have also been identified. Eleven such features have been mapped, with the majority situated within the southeastern portion of the basin [1]. The mare units are also punctuated by other structures, some of which are interpreted to be impact melt sheets generated during the formation of the basin [6-7].

Radar analysis provides a highly complementary means to investigate and map lunar volcanic materials. Modeling work incorporating studies from Apollo sample returns found TiO_2 content to have a dominant influence on Earth-based P-band (70 cm) returns [9]. Tracking broad variations in the strength of the P-band backscatter across the surface of the lunar mare can therefore be used as a proxy for ilmenite content. [10] successfully applied this approach to map out mare units within Mare Imbrium, which was found to be effective even in regions mantled by distal crater ejecta (that would be prohibitive to the use of spectral analysis). Given the extensive ejecta deposits that cover large expanses of central, northern, and western Mare Crisium [1], radar-based mapping offers a new perspective with which to study the preserved volcanics.

We will discuss the results of integrating Earth-based, P, S (12.6 cm) and Mini-RF bistatic X-band (4.2 cm) data to map out volcanic deposits/structures within Mare Crisium.

Motivation: Characterizing the full extent of volcanic activity within Crisium will enable comparisons to be made with other lunar volcanic regions, thus providing a more complete picture of the thermal evolution of the Moon. The systematic identification of volcanic products within Crisium will also support previous and ongoing efforts to search for remnant impact melt deposits within the basin [6-7, 11]. Determining the age of the Crisum basin is critical to constraining the duration and intensity of the Late Heavy Bombardment epoch, and so choosing landing sites to collect samples for dating will depend on accurately distinguishing melt from volcanic material.

Radar Datasets: Earth-based radar images of the entirety of Mare Crisium were collected in both senses of circular polarization at both S and P-band. The data were acquired transmitting from the Arecibo Observatory (Puerto Rico) and receiving at the Green Bank Telescope (West Virginia) [e.g. 12]. **Figure 1** shows an example of the P-band data.

Mini-RF is a hybrid-polarized, dual-frequency Synthetic Aperture Radar (SAR) on the Lunar Reconnaissance Orbiter. Although designed as a monostatic radar system, due to a transmitter malfunction, Mini-RF is currently undertaking unique bistatic radar measurements in conjunction with the Goldstone (southern California) observatory. Operating in X-band, the radar images are complementary to the longer wavelength (fully) Earth-based data. To date, 14 observations have been made of Mare Crisium, with the majority of the coverage concentrated within the eastern section of the basin (**Figure 2**)

Initial Results: P-band based mapping reveals four/five possible mare units (**Figure 1**). The units show some agreement with the most recent mapping effort [1], especially in the east, but the radar data are able to pick up possible unit boundaries that were mapped as broad ejecta using UV-NIR datasets. We also identify multiple additional volcanic features/structures. Radar-dark lineal features, interpreted by [9] to be collapsed lava tubes, are present in multiple locations to the west. Radar-bright features that are elongated perpendicular to the broad, local slope (in an east-west direction) are also clearly identifiable. Inspection of the corresponding LROC NAC images reveal these features to have rough textures that appear broadly similar to platy terrestrial/martian lava flows. The elevated P-band backscatter could indicate a localized increase in blocky material on the surface and suspended within the regolith. Finally, two radar-dark features that correlate with the location of previously identified cones, may indicate the presence of small, previously unmapped, pyroclastic deposits.

References: [1] Lu et al., 2021, Remote Sens. 13(23), 4828. [2] Boyce & Johnson, 1977, Pro. LPSC, 3495–3502. [3] Head, et al., 1978, The View from Luna 24; Pergamon Press: New York, NY, pp. 43–74. [4] Hiesinger et al., 2011, Special Paper GSA, 477, 1-51. [5] Lawrence et al., 2013, J. Geophys. Res. Planets, 118, 615– 634. [6] Spudis and Sliz, 2017; Geophys. Res. Lett., 44, 1260– 1265. [7] Runyon et al., 2020, J. Geophys. Res. Planets, 125, e2019JE006024. [8]. [9] Campbell et al., 2014, J. Geophys. Res. Planets, 119, 313– 330. [10] Morgan et al., 2016, J. Geophys. Res. Planets, 121, 1498–1513. [11] Rivera-Valentín et al, 2023, this meeting. [12] Campbell et al [2007] IEEE Trans. Geosci. Remote Sens., 45(12), 4032– 4042.

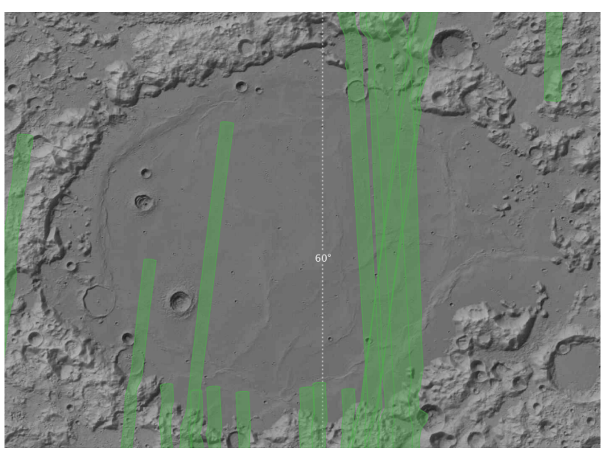

Figure 2. *Current X-band Mini-RF bistatic coverage of Mare Crisium.*