THERMOPHYSICAL PROPERTIES OF VOLCANIC FEATURES IN THE MARE VAPORUM REGION OF THE MOON L.M. Pigue[1], K.A. Bennett[1], J-P Williams[2], C.S. Edwards[3] | [1]U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ (lpigue@usgs.gov), [2]University of California, Los Angeles Department of Earth, Planetary, and Space Science, Los Angeles, CA, [3]Northern Arizona University Department of Astronomy & Planetary Science, Flagstaff, AZ.

Introduction: The lunar surface is covered with a wide variety of volcanic features including mare flows, lava channels, and pyroclastic deposits (remnants of explosive eruption). Here we evaluate the thermophysical properties of volcanic features within Mare Vaporum basin, focusing on potential relationships between an explosive eruption (as indicated by a remnant lunar pyroclastic deposit, "LPD") and effusive features (e.g., mare flows and features near a lava channel).

Temperatures can reveal information about surface textures, near-surface thermophysical properties, and regional variability of materials that we can use to evaluate geologic context. The range of daytime and nighttime temperatures can be used to characterize terrains. The maximum daytime temperature of a surface is most indicative of the albedo of the surface – high maximum daytime temperatures in a region are a result of the lowest albedo materials [1]. Minimum nighttime temperatures can be used to evaluate relative thermal inertia [1, 2]. A higher minimum nighttime temperature suggests a surface with a higher thermal inertia, which could be represented by a cohesive layer or large boulders that would be able to stay warmer throughout the lunar night [1].

For this study, we investigate features within the Mare Vaporum basin (central lat/lon: 13°N, 4°E) including the LPD, mare lavas, and a lava flow to the west (Fig 1), that we hypothesize will each exhibit different thermal properties. The volcanic features in this mare basin offer a comparison between explosive and effusive features and an opportunity to correlate these observations to eruption conditions and investigate their geologic context.

Methods: We use data from the multispectral thermal infrared Diviner Lunar Radiometer instrument (Diviner; ~0.3 – 400 μm, 9 spectral channels, ~200 m spatial resolution [3]) to map the Mare Vaporum region and calculate the effective surface temperature following the methods of [4, 5] to produce the surface bolometric brightness temperatures. We also investigate the rock abundance, modeled from observed anisothermality in the Diviner nighttime temperatures, [6] and H-parameter which is used to characterize variation in the rock-free regolith thermal inertia [2].

Results: *Pyroclastic deposit:* The Mare Vaporum pyroclastic deposit has the lowest albedo (Fig. 1) and the highest daytime maximum temperatures (Fig. 2). The shape of the pyroclastic deposit can be seen in the rock abundance map (Fig. 3) as a region of relatively lower rock abundance than surrounding materials, showing they are generally free of large (>~ 1 m) rocks with an average rock abundance ~0.004 areal surface fraction (well below the global average of 0.01 [6]). The LPD can't be differentiated from the mare regolith in the H-parameter map, but has an average H-parameter value of ~0.078 m, slightly higher than the mare at ~0.070 m suggesting the deposits are slightly lower thermal inertia than the mare regolith "rock-free" material.

Manilius crater: The lowest maximum daytime temperature in the study area surrounds Manilius crater – a crater that is mapped as Eratosthenian in age, but has also been thought to be Copernican due to the bright appearance of the ejecta blanket and crater rays [7], visible in Fig. 1. The crater floor of Manilius crater has a higher rock abundance (average of ~0.008). The ejecta blanket has a low average rock abundance of ~0.004 and a high H-parameter (i.e., low relative thermal inertia) of ~0.074 m, contrasting with the crater floor at ~0.057 m.

Mare basin: The mare basalts have a daytime maximum temperature that is higher relative to the surrounding highlands and the ejecta blanket of Manilius crater. The mare basalts have a low albedo relative to the bright highlands and ejecta blanket of Manilius crater, but a slightly higher albedo than the dark lavas from the lava channel in the west and the dark pyroclastic deposit. The mare exhibits relatively high rock abundance (average of ~0.005). The mare has an average H-parameter of ~0.070 m. A crater within the western lava channel has an anomalously high H-parameter halo with an average H-parameter of 0.101.

Lava channel: The lobate lava flow to the west of the Mare Vaporum basin can be observed as a lower albedo area on the floor of the mare basin in Fig. 1. The lava flow has slightly higher maximum temperatures, but these trends are not as significant as the maximum daytime temperatures of the pyroclastic deposit. The rock abundance of the lava flow is ~0.005. The H-parameter of the lava flow is ~0.074 m, similar to the values of the pyroclastic deposit and mare.

Initial Interpretations: As noted in [1], high maximum daytime temperatures in a region can be a result of the lowest albedo materials. This is consistent with our observations where the pyroclastic deposit has the lowest albedo (Fig. 1) and the highest maximum daytime temperatures (Fig. 2). Observations of Manilius crater also support this relationship as the ejecta blanket has the lowest maximum daytime temperatures and the highest reflectance. Relatively high maximum daytime temperatures can also result from low thermal inertia materials [8]. Similarities in the rock abundance between the ejecta blanket of Manilius crater and the pyroclastic deposit (both having a value around ~0.004) indicate that further investigation into the H-parameter map is needed to describe the relationship between thermal inertia and maximum daytime temperatures in Mare Vaporum. Rock abundance has been shown to correlate with crater age [9]. Manilius crater could be young as suggested by its high reflectance, but it does not exhibit high rock abundance as is observed around Copernican-age craters [9]. We will investigate whether it is more likely that the crater is Eratosthenian, or if it is possible that the crater impacted material that did not create blocks in the ejecta (i.e., regolith or other fine-grained material).

The visible shape of the pyroclastic deposit in the rock abundance map (similar to the shape of the deposit in Fig. 1) indicates a trend of the pyroclastic deposit having a low rock abundance ("regolith") relative to the surrounding materials (mare, highland, etc.). This potentially indicates a generally homogenous, fine-grained deposit. The relatively high rock abundance of the mare is more likely related to the presence of rocky impact craters.

The anomalously high H-parameter crater within the western lava channel in Fig. 4 is an identified "cold spot crater" in [10] (reported lon/lat/diameter: -0.1951°E, 14.5544°N, 446 m). Cold spot craters have anomalously low nighttime temperatures up to ~10–100 crater radii from the crater centers [10].

Future work: We will target thermophysical properties that can reveal geologic context and eruption conditions. This will include daytime maximum temperatures (at finer detail), daytime and nighttime temperature ranges (which can be used to evaluate rock abundance), and minimum nighttime temperatures (which can be used to evaluate relative thermal inertia of the surface). We will also refine the boundary extents of the Mare Vaporum pyroclastic deposit to further understand the relationship between the mare embayment and the pyroclastic deposit.

References: [1] Williams, J.P. et al., (2017) *Icarus, 283* (3), 300-325. [2] Hayne, P.O., et al., (2017) *JGR: Planets 122,* 2371-2400. [3] Paige, D.A. et al., (2010) *Space Sci Rev, 150*, 125-160. [4] Paige, D.A. et al., (2010) *Science, 330* (6003), 479-482. [5] Williams, J.P. et al., (2022) *Earth & Space Sci, 9,* 1-17. [6] Bandfield, J.L. et al., (2011) *JGR 116*, 1-18. [7] Wilhelms, D.E., et al., (1987) *USGS Prof. Paper, 1348*, 302. [8] Hardgrove, C., et al., (2009) *Earth & Planet Sci Letters, 285* (1-2), 124-130. [9] Ghent, R.R., et al., (2014) *Geology, 42* (12), 1059-1062. [10] Williams, J.P., et al., (2018) *JGR Planets, 123* (9), 2380-2392.

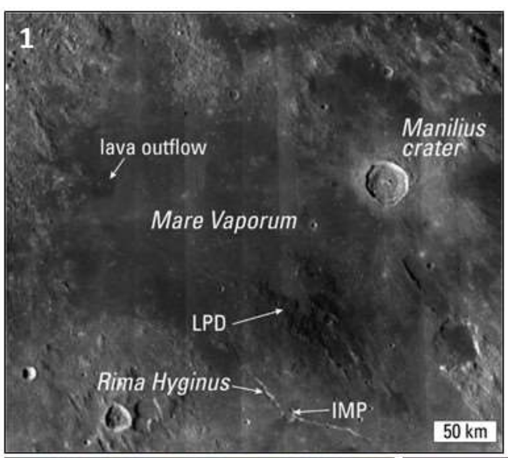

Fig 1*: Mare Vaporum region from Lunar Reconnaissance Orbiter Camera Wide Angle Camera (WAC) demonstrating variation in albedo. Highest albedo regions occur in Manilius crater rays and in the highlands; lowest albedo regions are in the pyroclastic deposit (labeled "LPD") and in the outflow of the lava channel.* ***Fig 2****: Maximum temperatures over the Mare Vaporum mare basin. Highest temperatures indicate lowest albedo areas (mare and pyroclastic deposit), lowest temperatures indicate highest reflectance areas (highlands and crater ejecta).* ***Fig 3****: Rock Abundance over the Mare Vaporum mare basin. Highest rock abundance areas are typically near craters and within the Rima Huygens graben. Low rock abundance areas occur most within the pyroclastic deposit ("LPD") and between craters in the mare basin. Color scale range is 0.00 – 0.01 surface fraction)* ***Fig 4****: H-Parameter. The color scale indicates the regolith H-parameter, in meters. A fresh crater within the lava channel to the west has anomalously high H-parameter and was identified in [10] as a cold spot crater.*