IMPLICATIONS FOR LUNAR MARE VOLCANISM INDICATED FROM RMDS-BEARING MARE DOMES IN TRANQUILLITATIS. F. Zhang[1,2], Y. Meng[1,2], and R. Bugiolacchi[1,2] [1]State Key Laboratory of Lunar and Planetary Sciences, Macau University of Science and Technology, Macau, PR China (fezhang@must.edu.mo), [2]CNSA Macau Center for Space Exploration and Science, Macau, PR China.

Introduction: Lunar domes, mainly referred to as mare domes, are low volcanic edifices that are similar to small and low shield volcanoes on the Earth [1]. Positive, nearly circular-shaped lunar domes are probably formed during the terminal phase of effusive (or intrusive) activities when the magma from the base of the crust or the mantle reaches the surface or the near surface. They are commonly characterized by a smooth surface featuring a pit or an elongated vent. For many domes, the presence of vents or pits is also associated with pyroclastic deposits [2, 3]. Their summit pits are commonly assumed to be the result of magma subsidence or collapse due to decreasing pressure [2].

Mare Tranquillitatis hosts many lunar mare domes, especially around the Cauchy and Arago craters [4-7]. The different morphologies of these domes suggest that they might have formed from lavas with different viscosity and erupting conditions with diverse effusion rates [8]. Our study aims to locate new mare domes taking advantage of the higher resolution images with favorable illumination conditions that have become available.

Several mare domes in Tranquillitatis feature ring-moat dome structures atop (RMDSs, [9]). The sub-km RMDSs are much smaller and lower than common mare domes and always occur in clusters. RMDSs are interpreted as a coherent part of the host lava resulting from small extrusions of pressured volatile-rich magmas beneath via crustal fractures during the emplacement of local basaltic lava flows [9-11]. Mare domes hosting RMDSs would suggest that they are effusive (rather than intrusive) in origin. In this work, we test the possibility of mare dome-forming magmas to form RMDSs and the dynamic processes related to the formation of RMDS-bearing mare domes.

Data and Methods: A global morphology basemap was produced using a collection of WAC frames acquired with incidence angles between 60°and 80° at a uniform resolution of 100 m/pixel [12], and the ~100 m/pixel WAC 643 nm mosaic of the lunar nearside taken at low-sun conditions [13]. Where necessary, the very high-resolution LROC NAC images (~0.5-2 m/pixel) and Kaguya TC maps (~10 m/pixel) were used to characterize very small features in details (e.g., dome flank craters and RMDSs).

To quantitatively measure the height, surface area, volume, and slope of mare domes, two sets of DTM data are currently available for constructing their three-dimensional profiles: (1) the SELENE and LRO Elevation model (SLDEM, ~60 m/pixel), which is constructed from a combined analysis of the measurements of Lunar Orbiter Laser Altimeter and the SELENE Terrain Camera [14]. The vertical accuracy of the SLDEM is about 3-4 m [14]; and (2) The Kaguya-TC derived DTMs (~10 m/pixel) [15].

Results: A total of 57 mare domes, which are topped with RMDSs (Figure 1), are identified and selected as the study targets of interest. We obtained their key morphometric parameters, such as dome height, diameter, volume, and slope. Based on the results, the rheologic properties of mare dome-forming magmas were estimated.

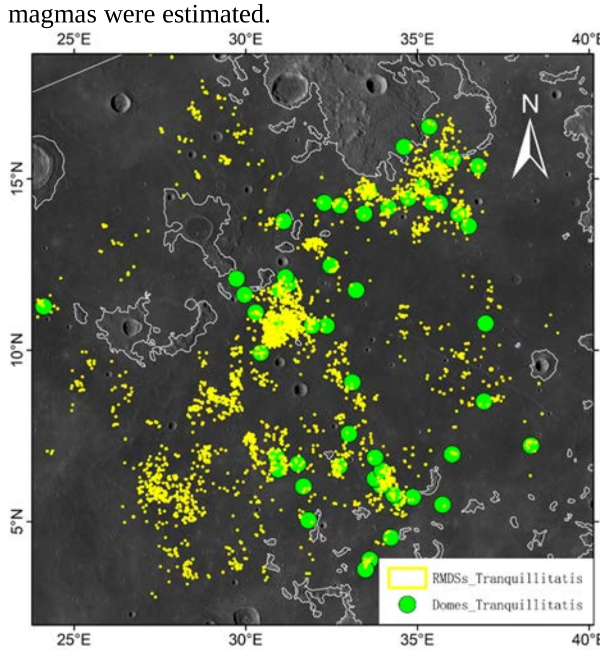

Fig. 1 LROC WAC mosaic showing the distribution of the 57 mare domes (green circles) and RMDSs (yellow points) identified in Tranquillitatis.

Morphometric properties of Tranquillitatis domes and RMDSs. Our results show that (1) the 57 Tranquillitatis domes have a diameter range between 2.4 and 19 km with an average value of 6.7 km; (2) the average height is 72 m, and the maximum and minimum heights are 210 and 24 m, respectively; (3) the volumes range from 0.06 to 16.5 km^3, but most < 5.0 km^3 with only one > 5.0 km^3. A striking contrast of the volumes of the domes is found, with the largest being two orders of magnitude larger than the smallest;

(4) the dome slopes are relatively small, between 3.97° and 1.40°. Most of them are less than 2°.

Based on the extensive search effort currently made by Zhang et al. [11], about 427 RMDSs associated with 57 mare domes were mapped (Fig. 1). Their heights and diameters were measured from Kaguya TC-based DTMs. The RMDSs have a diameter ranging from ~100 to 800 m with most between 100 and 500 m. Their heights are usually smaller than 16 m, consistent with previous statistic results by Zhang et al. [9, 11]. However, there is an unexpected exception of a case with a height of ~25 m. Generally, no clear correlation between the height and diameter is observed.

Rheologic properties of the dome-forming magma. Using a quantitative treatment of dome-forming eruptions of magma onto a flat plane [16], we used dome height and diameter to calculate the rheologic parameters which contain the yield strength, plastic viscosity, and the duration of the lava effusion process. For our data sets, we report lava viscosities between about 6.92×10^2 and 1.89×10^6 Pa s, effusion rates between 12 and 487.27 $m^3\ s^{-1}$, and durations of the effusion process between 7.5 days and 1.73 years. For comparison, we tested the effect of lava density with three values of 2000 kg m^{-3}, 2400 kg m^{-3}, 2800 kg m^{-3} on viscosities. Consistent with previous studies [1, 16], taking a density of 2800 kg m^{-3} only increase the viscosity by a factor of ~2.2, comparing with that using a density of 2000 kg m^{-3}.

Discussion: Mare domes have been interpreted to represent the last products of regional volcanism with a lower effusion rate and relatively low temperature of eruption [1]. Their formation is often controlled by tectonic structures (e.g., graben) linked to subsurface igneous processes (e.g., shallow dike intrusion [3]). The distribution of Tranquillitatis domes displays a relationship with tectonic and impact-caused structures, such as domes aligned along the inner and/or outer rim of a buried impact crater, and some mare domes that are spatially related to wrinkle ridges. Some domes are organized in a line along the extension of the Rupes Cauchy. This is further demonstrated by their summit vents/pits showing an elongation shape dominated by an NW-SE trending, suggesting that the formation of the Tranquillitatis domes might have a close relationship with tectonic structures at a regional or even a global scale.

According to the measured viscosity-composition relationship, the 57 mare domes can be divided into two types: (1) lower titanium-iron content, indicative of high viscosity, relative to the surrounding mare; (2) comparable titanium content to the mare. The first type domes would have formed at a time independent of the emplacement of their surrounding flows, whereas the second type domes may represent the late-stage products of regional volcanism. However, this interpretation will be further assessed in our future work. Further, we found no clear relationship between the estimated viscosity and TiO_2 contents derived from remote observations.

Conclusions: By analyzing the relationships between the distribution of mare domes in Tranquillitatis and other geological features/structures, we conclude that the formation of domes is closely linked to tectonic structures at either a regional or a global scale, or both. The dominant NW-SE direction mainly controls the elongation of summit vents of some mare domes, as well as often representing the general dome alignment. The relationship between the viscosity of the dome-forming magma and the compositional variation of TiO_2 abundances suggest that some domes were formed at a time independent of the emplacement of the surrounding flows, whereas some others may represent late-stage products of the regional volcanism. Crucially, our results support the hypothesis that late-stage basaltic lava flows (to form mare domes) with a viscosity between 10^2 to 10^6 Pa s could have contributed to the formation of RMDSs.

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