**MARE DOMES IN MARE TRANQUILLITATIS: IDENTIFICATION, DISTRIBUTION, CHARACTERISTICS, AND IMPLICATIONS FOR THEIR ORIGIN AND THE OLDEST LUNAR VOLCANISM.** L. Qiao[1], J. W. Head[2], L. Wilson[3] and Z. Ling[1], [1]Inst. Space Sci., Shandong Univ., Weihai, Shandong, 264209, China (LeQiao.GEO@Gmail.com), [2]Dep. Earth, Env. & Planet. Sci., Brown Univ., Providence, RI, 02912, USA, [3]Lancaster Env. Centre, Lancaster Univ., Lancaster LA1 4YQ, UK.

**Introduction:** Volcanism is one of the major geological process on the Moon, directly reflecting the composition and thermal state of lunar interior and its evolution, and serves as an important window into the geological and thermal evolution of the Moon. Mare domes, small (<~30 km diameter) and generally circular structures with convex-upward shapes [1], are among the most common volcanic landforms on the Moon. Over 300 mare domes have been previously identified, using mainly telescope and orbital photographs [e.g., 1-4]. However, due to the very gently-sloping topographic nature of lunar mare domes (generally <5°), many of them are not easily identified or are otherwise obscured, especially for areas where images obtained at very low Sun illumination (for example near terminator and in earthshine [5]) are not available. Newly-obtained global lunar topographic data, like the Kaguya/SELENE-TC (Terrain Camera) + LRO-LOLA (Lunar Orbiter Laser Altimeter) merged topography (SLDEM2015) with ~60 m spatial sampling and ~3–4 m vertical altimetric accuracy [6]), provide an unprecedented tool for identifying and characterizing low-amplitude gently-sloping geomorphic features on the Moon, including mare domes.

Lunar mare domes are generally interpreted to be analogues to small terrestrial shield volcanoes and to be built up through multiple phases of flows erupted from a common pit crater source, dominated by accumulating low-effusion rate, cooling-limited flows (e.g., [7]), though other formation mechanisms have also been proposed, for instance, laccolithic intrusions [8].

We initiated a global search campaign for mare domes, plotting their distribution, modes of occurrence, local and regional clustering, range of characteristics (diameter, height, shape, presence of pit craters) and associations (terrain, volcanic, structural, mineralogic, and age). As the first step of this project, we focus on Mare Tranquillitatis, which has one of the greatest concentrations of mare domes (e.g., [1,4]) and is an area identified by [9] as a lunar large shield volcano. We employ the SLDEM2015 topography, with assistance from other multi-source topography (e.g., Kaguya TC DTM, LOLA) and images (e.g., LROC WAC and Kaguya TC low-sub mosaic) to (1) evaluate each mare dome identification in previous investigations and (2) search for new mare dome features. We then characterize each catalogued mare dome further by examining the detailed surface morphology and structure.

**General Characteristics and Identification Criteria of Mare Domes.** A preliminary survey of previously-catalogued mare domes [1-4] reveals some of their fundamental characteristics. A typical well-developed mare dome is characterized by a domical raised structure with a generally convex-shape and low-slope (<5°) profile and a (quasi-)circular or elliptical outline. Some domes have summit pit craters, while many lack them, possibly being filled up by the last eruptions. The development of the circular mound shape of mare domes is sometimes affected by pre-existing topography; in these cases, the outline of the dome at the side near the pre-existing topography will be poorly defined, while at the side distal to the pre-existing topography, the circular mound shape will be relatively well developed, forming an arc-shaped shield baseline.

**Evaluations of Previous Mare Dome Identifications in Mare Tranquillitatis.** There are three prior dedicated mare dome identification contributions in this region, and each is re-visited as follows:

(1) Head and Gifford [1] identified 36 mare domes in Mare Tranquillitatis using telescopic (Consolidated Lunar Atlas) and orbital photographs (Apollo). Of these domes, all but one (Cauchy 3) are confirmed in our new data-based investigations (Fig. 1).

(2) Tye and Head [4] identified 67 "new" (other than those in [1]) domes in Mare Tranquillitatis using LOLA topography. Of these "new" domes, 54 are confirmed, three are poorly defined and 10 are of questionable existence (Fig. 1).

(3) Wöhler et al. [2,3,10] identified seven additional mare domes in Mare Tranquillitatis using Earth-based telescopic photographs. Among these, four are confirmed in our investigation, one is poorly defined and two are of questionable existence (Fig. 1).

**Newly-Identified Mare Domes in Mare Tranquillitatis.** Using the new SLDEM2015 topography and other new data sets, we conducted a systematic search for mare dome features in this region. We identify 81 new domes in Mare Tranquillitatis (Fig. 1), which brings the number of confirmed domes in this region to 174. We also find possible evidence for 50 additional mare domes (Fig. 1). These observations show that Mare Tranquillitatis contains one of the highest densities of mare domes among the entire lunar maria. Crater count dating has shown that Mare Tranquillitatis is one of the oldest maria on the Moon, with ~90% of mare units emplaced between 3.5 and 3.8 Ga ago [11], indi-

cating that shield-building eruptions may be a prevalent volcanic eruption style in the earliest stage of lunar volcanism, a very important constraint on lunar thermal evolution history.

Our updated inventory of mare domes shows that their regional spatial distribution is highly inhomogeneous, with nearly 90% of the domes (155/174) located in the eastern half of Mare Tranquillitatis. Eastern Mare Tranquillitatis is characterized by a large broad rise, ~560 km across and up to 2.2 km above the surrounding mare [4,9], and has been interpreted as a large shield volcano by [9]. Our detailed characterization of hundreds of mare domes in the region will shed light on the emplacement model of this rise structure.

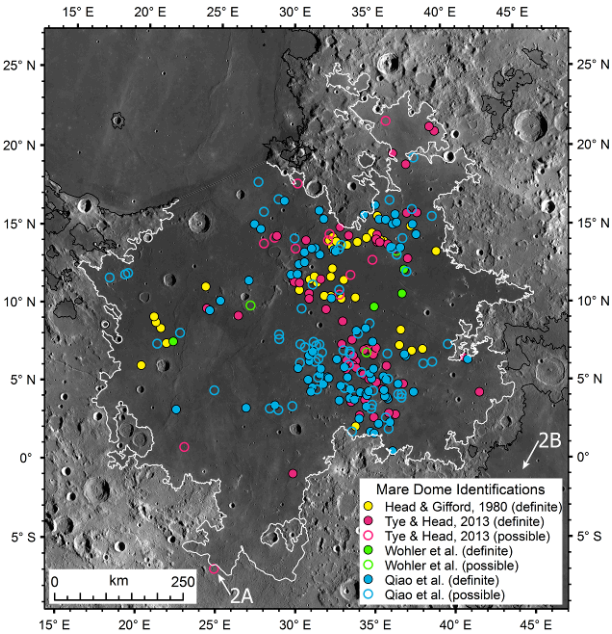


**Fig. 1.** Identifications of mare dome in Mare Tranquillitatis by prior and this studies. The locations of the two identified intermediate-scale volcanic rises shown in Figs. 2A and 2B are marked with white arrows.

**Intermediate-Scale Volcanic Rises.** We have also identified two intermediate-scale volcanic rises (Fig. 1): one at the SW margin of Mare Tranquillitatis, with a diameter of ~70 km (Fig. 2A) and another at the NW margin of Mare Fecunditatis, with a diameter of ~160 km (Fig. 2B). These rises are much larger than typical mare domes on the Moon (typically up to ~ 30 km) and have associated near-summit volcanic structures that may represent volcanic constructs intermediate between classic small shield volcanoes and the larger structures of [9]. All of the mapped features lack large collapse calderas typical of terrestrial and martian shield volcanoes, an absence consistent with the low-frequency and deeper sources of lunar eruptions, and lack of buildup of shallow reservoirs [7]. We interpret these features to represent construction from one (small shield) to multiple (large shield) dike emplacement and eruption events above an active upwelling diapiric source region in the mantle.

**On-going and Future Work:** We have developed criteria for the definition and documentation of small shield volcanoes as a basis for their global mapping, and assessment of their contributions to large volcanic accumulations such as those seen in Mare Tranquillitatis and these efforts are currently underway.

**References:** [1] Head & Gifford (1980) *Moon and the Planets* 22, 235-258. [2] Wöhler et al. (2006) *Icarus* 183, 237-264. [3] Wöhler et al. (2007) *Icarus* 189, 279-307. [4] Tye & Head (2013) *LPSC XLIV*, #1319. [5] Head & Lloyd (1973) *NASA SP-330*, 4-33–4-39. [6] Barker et al. (2016) *Icarus* 273, 346-355. [7] Head & Wilson (2017) *Icarus* 283, 176-223. [8] Wöhler et al. (2007) *Icarus* 204, 381-398. [9] Spudis et al. (2013) *JGR-Planets* 118, 1063-1081. [10] Pau et al. (2008) *LPSC XXXIX*, #1107. [11] Hiesinger et al. (2011) *GSA-SP* 477, 1-51.

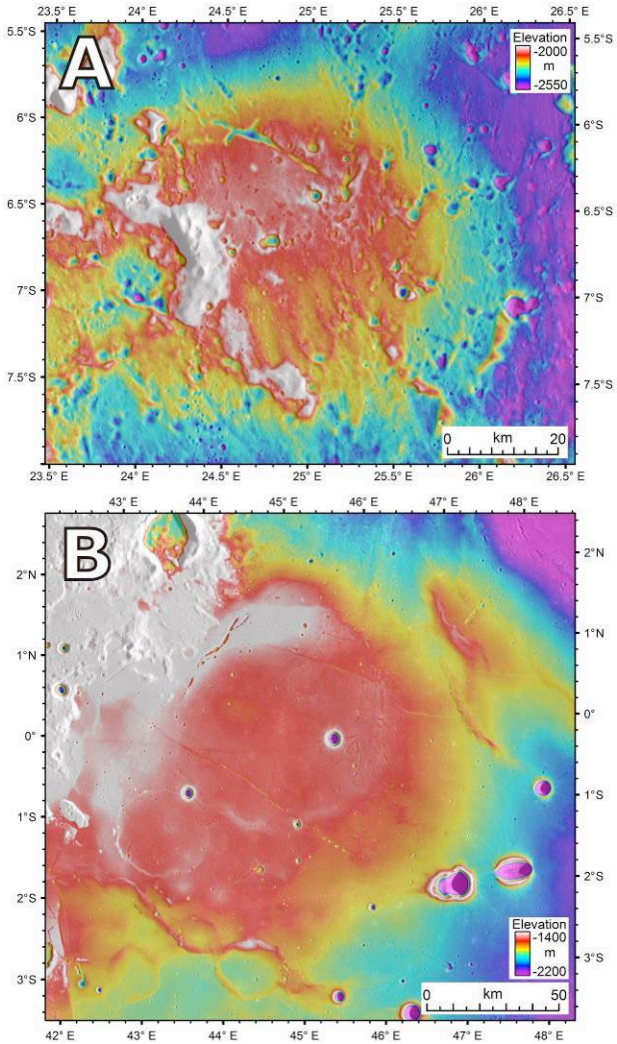


**Fig. 2.** Intermediate-scale volcanic rises identified at the (A) SW Mare Tranquillitatis and (B) NW Mare Fecunditatis.