MORPHOLOGY OF GRUITHUISEN AND HORTENSIUS DOMES: MARE VS NONMARE VOLCANISM.

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Introduction: Digital elevation models (DEMs) (5 m/px) [1], derived from stereo image pairs acquired with the Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) [2], allow for a detailed comparison of the stratigraphy and morphology of Mons Gruithuisen γ (36.6°N, 40.5°W) and three of the Hortensius Domes, North of Crater Hortensius (6.5°N, 28.0°W).

The Gruithuisen and Hortensius domes represent two distinct varieties of extrusive volcanic features, nonmare and mare domes (respectively), which differ morphologically and spectrally [3-7]. The three Gruithuisen domes, γ, δ, and NW, are red spots, a type of spectral anomaly characterized by high albedo and strong absorption in the ultraviolet [3]. Evidence suggest that red spots may represent evolved highlands compositions (dacite, rhyolite, andesite) and highlands volcanism [3-5,8]. Gruithuisen γ and δ exhibit FeO values between 6% and 10% and TiO_2 values <1%, indicating low iron and titanium, a composition distinctly different from the mare [9]. Early morphologic studies found that lunar nonmare domes resemble terrestrial volcanic domes of silicic composition (rhyolite, dacite, or basaltic andesite) characterized by viscous lava and low extrusion rates [6,7]. In comparison, mare domes are similar to basalt in composition, and are generally flatter, smaller in diameter, often exhibit summit pits, and are more common in occurrence [7].

Stratigraphic Relationships: Previous studies show that the Imbrian age (3.7-3.85 G.y.) Gruithuisen domes are superposed on the edge of a plateau of highland material, and were subsequently embayed by mare basalt [6,10]. The morphology of the terminating edge of the dome's lava flow is covered by mare basalt, except along the contact with the texturally and spectrally distinct "peninsula" of highlands material (on the southeastern side of Gruithuisen γ), where the highlands predate the formation of the dome, as seen in figure 1 [10,11]. The LROC DEM confirms a gradual, smooth contact, with no lobate edge. The dome-mare contacts are distinct in albedo and texture where the smooth mare transitions to the approximately radial ridges found on the flanks of the dome. This contact is also slightly irregular, reflecting the morphology of the ridges. On the northeastern edge of Gruithuisen γ a small rille cuts through the mare and intersects with the dome. Here dome material fills portions of the rille, and appears to completely cover it to the west. The fill was likely mobilized by the impact event on top of the dome. At the southern end of the highlands "peninsula," there is a negative relief feature (pit) associated with a small rille that extends to the south. Due to its close association with the mare and the rille we interpret the pit to be a volcanic collapse feature, likely associated with a vent.

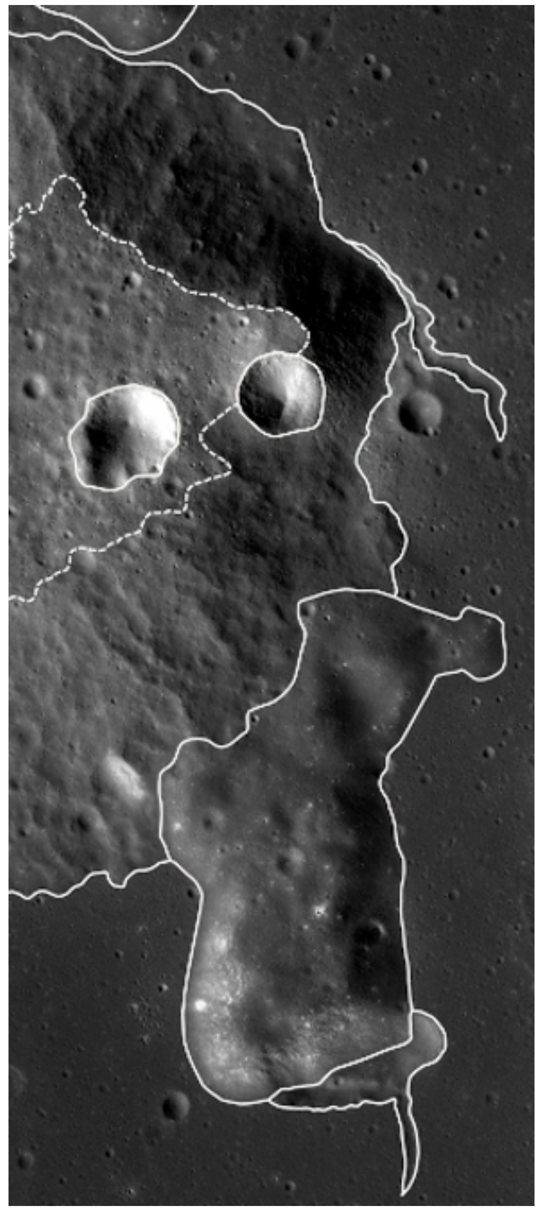

Figure 1. Sketch map of the eastern portion of Gruithuisen γ and immediate area. Solid white lines separate the major units: highlands, mare, and dome, as well as rille/volcanic collapse features and two ~ 2 km diameter craters. The dotted white line depicts the boundary of the plateau region at the summit of the dome. Image is 14.5 km across, LROC NAC M104783697, 1.62 m/px, incidence angle of 58.8°. The north-south diameter of the dome is ~24 km.

Morphology: Gruithuisen γ has asymmetric slope morphology, although the texture and topography of the dome flank (visible in the NAC frames) shows no clear boundaries, indicating no individual flows. Pre vious estimates suggested individual flows (based on Lunar Orbiter images) and that the overall slopes ranged from 15-30° [6], but radial profiles (n=50) from the new DEM show that the overall slope is 17-18° along the north- and northeastern-facing slopes, 14° along the eastern-most edge, 12° on the side facing the contact of the dome material and the peninsula of highland material, and 11° on the directly southern-facing slope. The summit of Gruithuisen γ is a plateau (~1500 meters above the mare surface), which extends across ~ 40% of the total area of the base of the dome. This relatively large plateau may indicate movement of the vent as the dome was formed.

Texture: The textures on Gruithuisen γ are remarkably distinct from the highlands and crater surfaces, with irregular furrows oriented radially downslope. The largest of these ridges are measured to be ~ 30-50 m in relief. The same furrowed texture is not seen on mare domes, which are generally much smoother in texture. The texture on Gruithuisen γ is a primary texture, despite the Imbrian age of the domes. Based on estimates of erosion caused by impacts that are small compared to the size of the rock (1 mm/10^6 years [12,13]) and "catastrophic rupture," caused by impacts resulting in a crater, it is reasonable to assume that the original volcanic texture would still be intact. After 3.8 billion years, only ~4 meters of erosion would occur due to small impacts. Estimates suggest that the median survival time for a boulder approximately 3 m across is on the order of 10^9 years [14]. Further characterization of the texture on nonmare domes is important to understanding the rheology of the magma.

Hortensius Domes: We analyzed the morphology of three domes within the Hortensius domefield: Phi (7.92°N, 27.58°W), Tau (7.59°N, 27.81°W), and Sigma (7.54°N, 37.56°W) [7]. The summit craters show no raised rims (see figure 2), and the depth to diameter ratios are all ~0.1. A comparison between our measurements of dome diameter, dome height, summit crater diameter, and crater depth and values measured for terrestrial shield volcanoes of various varieties as reported in [15] showed that there are no straightforward terrestrial shield volcano analogs for the Hortensius mare domes.

Conclusion: New DEMs derived from stereoscopic NAC images will continue to aid in our understanding of the morphology of lunar mare and nonmare domes [16]. The existence of non-mare volcanism has major implications for the thermal history and crustal evolution of the Moon. Understanding the morphology and stratigraphy associated at a detailed scale (5 m/px) will aid in developing theories of emplacement for nonmare domes. Further analysis of the ridge morphology of the ridges on Gruithuisien γ and rheological modeling based on further, higher resolution data is warranted.

References: [1] Tran, T. et al., this vol. [2] Robinson M. S. et al. (2009), *Space Sci. Rev.*, in press. [3] Whitaker, E.A. (1972) *Moon*, **4**, 348. [4] Malin, M.C. (1974) *Earth Planet. Sci. Lett.*, **21**, 331. [5] Wood, C.A. and Head, J.W. (1975) *Origins of Mare Basalts* (LSI), 189. [6] Head, J.W. and McCord, T.B. (1978) *Science*, **199**, 1433. [7] Head, J. W. and Gifford, A. (1980) *Moon and Planets, 22*. [8] Raitala, J. *et al.* (1999), *LPS XXX*, #1457. [9] Hawke, B. R. et al. (2003) LPSC XXXIV, #1545. [10] Wagner, R. J. et al. (2002) *JGR. 104*. [11] Wilson, L. and Head, J. W. (2003) *JGR. 108*, 5012. [12] Crozaz, G. et al. (1971) *Proc. LPSC 2nd* 2543-2558. [13] Gault, D. E. et al. (1972) *Proc. LPSC 3rd* 2713-2734. [14] Hörz, F. (1977) *Physics and Chemistry of the Earth.* 10:3-15. [15] Pike, R. J. (1978) *Proc. LPSC 9th*, 3239-3273. [16] Lawrence S. J. et al., this vol.

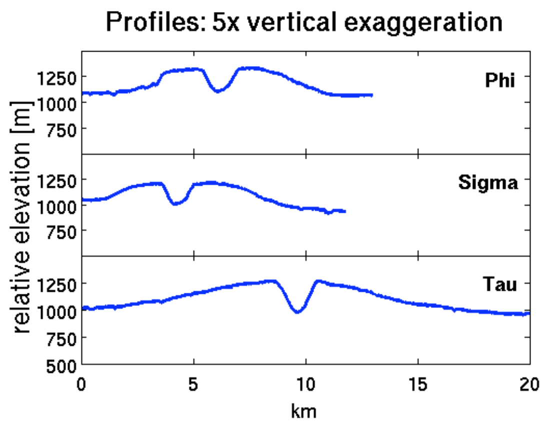

Figure 2. Profiles of three Hortensius domes across the summit craters. For all three summit craters, the bottom of the central crater is consistent with the approximate level of the surrounding terrain, indicating a non-impact origin.

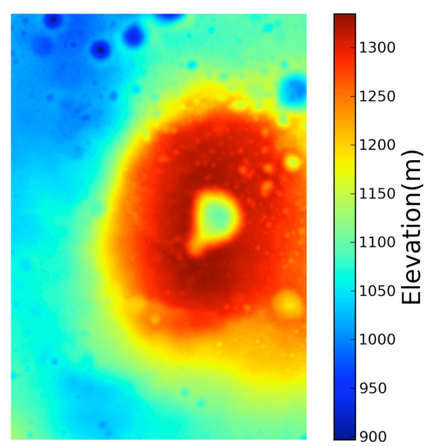

Figure 3. Color shaded DEM of Hortensius Phi, derived from LROC NAC frames M104691278 and M104698432. See similar figure for Gruithuisen γ in [1].