LACCOLITH MODEL FOR LUNAR RING-MOAT DOME STRUCTURES. I. Garrick-Bethell[1,2] and M. R. K. Seritan[1], [1]Earth and Planetary Sciences, University of California, Santa Cruz (igarrick@usc.edu), [2]School of Space Research, Kyung Hee University, Republic of Korea.

Introduction: Some of the most numerous geologic features on the Moon are low-lying circular domes of several hundred meters diameter, surrounded by shallow depressions (moats). These features are known as ring-moat dome structures (RMDS) [1,2]. Here we propose that RMDSs are related to buried impact craters. Magma intruded at these craters was guided into a circular plan form by either a crater-lining paleosol, or by the brecciated rock beneath the crater, analogous to proposed mechanisms at floor-fractured craters. Magma pressure deformed the overburden producing the characteristic dome (Figs. 1 & 2). We model this process with analytical and finite element models of elastic plate deformation. We suggest the moat forms from subsidence of the overburden into high-porosity crater floor materials as they compact over billions of years. An elastic plate sagging under its own weight is successful in modeling the subsidence with reasonable parameters.

Model: The model starts with the assumption that buried craters exist within the maria between extrusive events (Fig. 1a). Paleosols and loose debris lined the floors of these craters. Pressurized magma intruded beneath these craters and may have followed one of two possible paths in our model: i) movement along a paleosol/debris decollement layer, or ii) stalling beneath the crater floor (Fig. 1b). The pressure from these intrusions elastically deformed the overburden, forming the characteristic dome as a laccolith.

The crater's axisymmetric shape symmetrizes and guides the distribution of intruded magma and the pressure exerted on the overburden. For magma intruded into the crater floor paleosol, the resulting geometry is similar to cone sheet intrusions on Earth. For magma intruded beneath the crater, the geometry is similar to the intrusions proposed to form lunar floor fractured craters [3-5]. In either case, the resulting overburden deformation is highly circular in plan form compared to terrestrial laccoliths, which are usually elliptical [6].

After laccolith formation a more complex phase of subsidence forms the surrounding moat (Fig. 1d). We propose the subsidence is due to the gradual compaction of the high porosity brecciated rock at the buried crater, driven by the weight of the overburden and billions of years of adjustment time.

We model the formation of the dome as the upward deformation of a circular elastic plate with its edges clamped, loaded from below by a uniform pressure P_m (Fig. 1e). The deformation $w(x)$ in this case is [7]:

$$w = \frac{\rho g h - P_m}{64D}\left(\left(\frac{L}{2}\right)^4 - 2\left(\frac{L}{2}\right)^2 x^2 + x^4\right) \qquad (1)$$

Where ρ is the density of the overlying plate, g is the lunar gravity (1.62 m/s), h is the effective elastic thickness of the plate, and D is the rigidity, equal to $E_o h^3/(12(1-\nu^2))$, where E_o is Young's modulus and ν is Poisson's ratio (0.25), and L is the plate diameter.

The appearance of the moat suggests flexural deformation from the load of the dome might be responsible for its formation (e.g. [2]). Furthermore, a positive amplitude circumferential ridge found in many RMDSs (X labels in Fig. 2) has a similar appearance to a forebulge found in terrestrial lithosphere loading problems. However, our attempt to model the moat and circumferential ridge in this manner was not successful without implausible parameters. Instead, we model the moat as the downward deflection of a hanging circular plate (Fig. 1g), sagging under its self-weight.

We approximate the plate's self-weight as a uniform pressure $P_s = \rho g h$ acting over a plate of radius R_p (and diameter D_p, Fig. 1f). The deflection in this case is:

$$w = \frac{P_s}{64D}\left(\left(\frac{5+\nu}{1+\nu}\right)R_p^2 - x^2\right)\left(R_p^2 - x^2\right) \qquad (2)$$

where here $D = E_p h^3/(12(1-\nu^2))$, E_p is the Young's modulus of the plate, and h is the same h value as obtained from the dome topography, above.

Results: Figure 2 shows results for two domes. The models can explain the topography profiles rather well, with elastic parameters that are reasonable in this context. However, the circumferential ridge seen in some RMDSs is difficult to explain. Further examples will be discussed, and we will also present a finite element model to explain flat-topped domes.

References: We thank [2] for making their topography data publicly available. [1] Zhang et al. (2017) *GRL* 44, 9216. [2] Zhang et al. (2020) *JGR 32*, e2019JE005967. [3] Jozwiak et al. (2015) *Icarus* 248, 424. [4] Michaut et al. (2020) *EPSL* 530, 115889. [5] Schultz, P. (1976) *The Moon* 15, 241. [6] Corry, C.E. (1988) *GSA SP* 220. [7] Pollard, D. & As. M. Johnson (1976) *Tectonophysics* 18, 311.

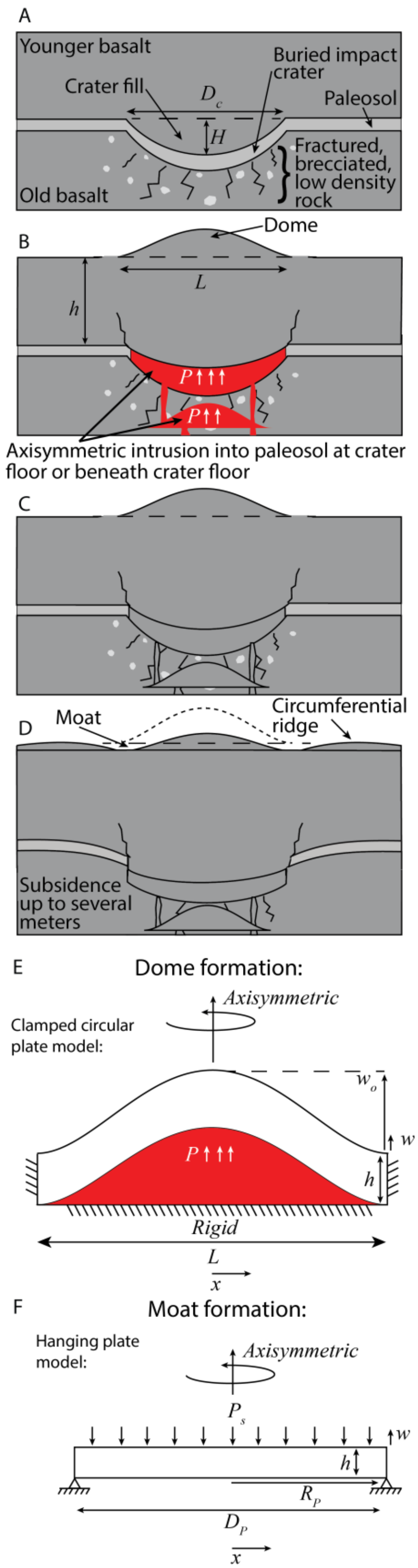

Figure 1. Concept illustration (time evolves from A to D) and mathematical representation (E and F).

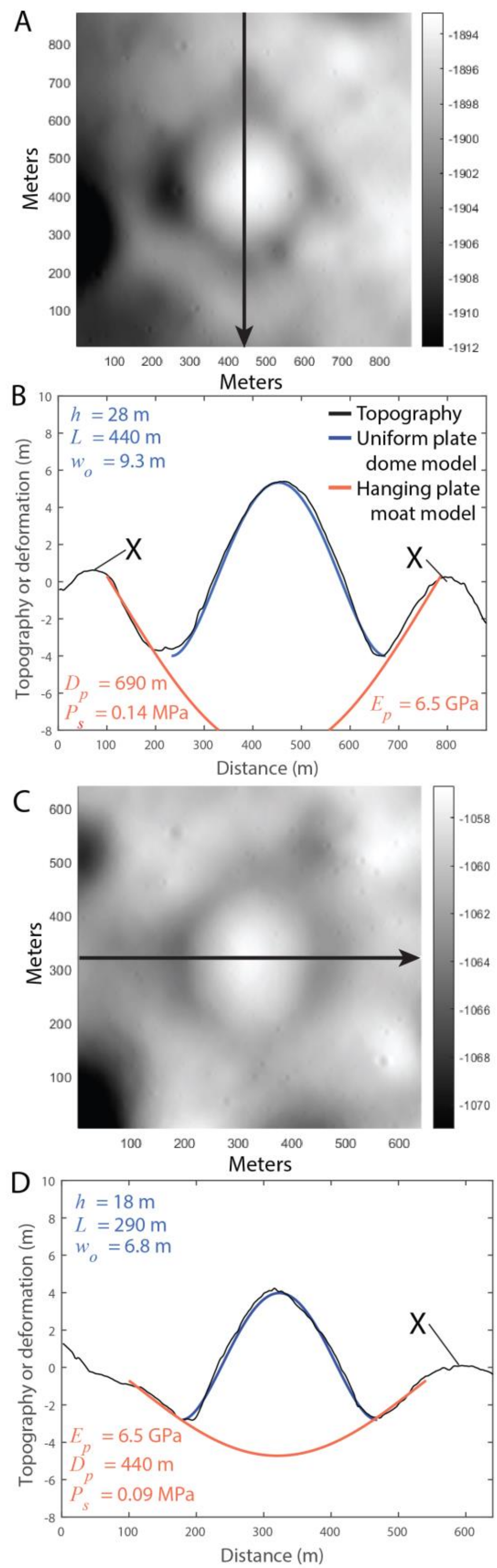

Figure 2. Results for two RMDSs.