LAVA FLOW INFLATION FEATURES ON THE MOON?: A COMPARISON OF INA WITH TERRESTRIAL ANALOGS. W. B. Garry[1,2], J. R. Zimbelman[1], J. E. Bleacher[3], S. E. Braden[4], L. S. Crumpler[5], and the LROC Team, [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, MRC-315, PO Box 37012, Washington, DC 20013, garryw@si.edu, [2]Planetary Science Institute, Tucson, AZ, wbgarry@psi.edu, [3]Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD. [4]School of Earth and Space Exploration, Arizona State University, Tempe, AZ. [5]New Mexico Museum of Natural History and Science, Albuquerque, NM.

Introduction: The enigmatic lunar volcanic feature, Ina (18.65° N, 5.30° E), has a distinct morphology and complex origin **(Fig. 1A)**. Imaged and observed from orbit by the Apollo astronauts **[1-3]**, the D-shaped feature measures ~3 km x 2 km and forms a caldera-like depression on top of a regional dome. Previous work compared the morphology of Ina to terrestrial lava pillars in Dimmuborgir, Iceland and suggested the mounds in Ina are extrusive features fed by individual sources from below **[4]**. Here, we propose a lava flow inflation model for the formation of Ina based on our field observations of lava flow inflation features in Hawai'i, Idaho, and New Mexico.

Ina: Lunar Reconnaissance Orbiter (LROC) Narrow Angle Camera (NAC) images of Ina, at resolutions up to 0.5 m/pixel, allow for detailed remote sensing observations of the lunar surface. Topography for Ina is derived from a 2 m/px Digital Terrain Model (DTM) created from two LROC NAC pairs **(Fig. 1B)**.

Morphology. Three key units are observed in Ina: the higher elevation, smooth bulbous mounds, the lower elevation, hummocky and ridged terrain, and the higher albedo, blocky material. The irregular shaped mounds are dispersed across the depression with some extending from the mare unit along the caldera margin. The mottled and ridged terrain surrounds the mounds and has a moderately higher albedo than the mounds. This change in albedo is also noticeable where the edges of mounds transition into the mottled and ridged unit. The lower unit is comprised of hummocky areas and narrow, convoluted ridges **(Fig. 1C)**. The higher albedo, blocky material appears to be the lowest stratigraphic unit observed on the floor and along the caldera wall. Craters are more prominent on the surface of the mounds than in the lower units **[5]**. This morphology is also observed at Hyginus crater **[6]**.

Topography. Measurements from the LROC NAC DTM show the overall relief from the edge of the margin to the central floor of Ina is ~80 m. The mounds are 100s of meters across and up to 18 m in relief. The tops of the mounds only change in relief a few meters (~1 to 5 m). The slopes along the margins of the mounds are up to 40°. At some locations along their margins, the mounds are observed to grade out into the lower elevation, mottled and ridged unit. The relief varies from 1 to 3 m across the lower unit between the mounds **(Fig. 1D)**.

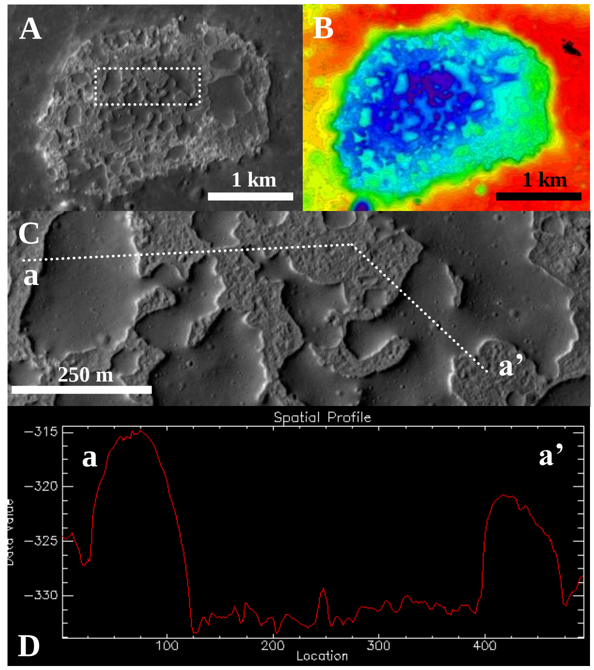

Figure 1. (A) LROC NAC mosaic of Ina (M113921307, 0.5 m/pixel, incidence angle 57.7°) (NASA/GSFC/ASU). Box shows close up in C. **(B)** LROC NAC DTM with 2 m contours. Range of elevation covered by color scale: red (-268 m) to purple (-334 m). **(C)** Close up of mounds and hummocky-ridged unit. Dashed line marks topographic profile. **(D)** Topographic profile across the floor of Ina. Derived from the 2m LROC NAC DTM in ENVI. Units are in meters.

Terrestrial Analogs: Lava flow inflation can occur when lava is injected underneath a solid crust in a stalled section of the flow causing it to rise and thicken on the order of centimeters to meters **[7,8]**. The idea of inflation was first applied to the 1859 Mauna Loa flow in Hawai'i **[7,9,10]** and has been observed in active flows **[8]**. We have documented the surface textures and dimensions of inflation features (e.g. platforms, hummocky-ridged terrain, terraced margins, tumuli, inflation-rise pits) at the 1859 flow and lava flows in New Mexico (McCarty's, Carrizozo) and Idaho (Sunset Pāhoehoe **(Fig. 2)**, Cerro Grande) through field mapping and the use of a Trimble R8 Differential GPS which provides a horizontal and vertical precision of ±4 cm; we have also applied our observations to Mars **[11-15]**. The flows we have investigated are monogenetic basaltic lava flows and occur on low underlying slopes (<1°). These flows exhibit platforms 100s of meters in length, up to 20 m in relief, with the change in relief across the tops changing on the order of 10s of centimeters to ~2 m. The margins of the platforms are tilted sections of crust and exhibit a range of slopes typically within 20° to 50°, but up to near vertical. Cracks, typically on the scale of 1 to 3 m wide and 4 to 10 m deep form along the upper margins of the platforms and are distinguishable in remote sensing images **(Fig. 2A)**. The hummocky and ridged terrain is a convoluted terrain of coalesced breakout flows from along the margins of the platforms. This terrain type is at a lower elevation than the platforms **(Fig. 2B)** and changes in relief on the order of 1 to 5 m **(Fig. 2C)**. Source locations of the breakouts along the margins are identified in the field.

Discussion: Based on our field observations of terrestrial inflated lava flows, we find a striking morphologic similarity with Ina, along with some differences.

Similarities. First, the overall morphology of broad, odd shaped mounds and platforms dispersed across the flow field surrounded by a lower elevation, hummocky and ridged terrain. Second, dimensions of the platforms (100s meter wide, <20 meter relief, tops change in relief only a few meters) and lower terrain (change in relief of a few meters) are on the same order of magnitude. Third, slopes of the platform margins are consistent, and both show transitions from the platforms and mounds to the lower terrain, indicating a link between the two units and not individual sources.

Differences. One of the key differences on Ina is the lack of observed cracks along the margins of the mounds that are typically observed in the terrestrial platforms. Did cracks not form due to properties of the lava or could they have been filled in by regolith? Another difference is that while the change in relief across the mounds is similar, the mounds in Ina appear more domical shaped than 'flat' like the platforms in the terrestrial flows. A few mounds in Ina also exhibit a slight 'sag' towards their centers. Inflation-rise pits **[7]** are also not readily observed on the mounds in Ina, where they are common on the terrestrial flows. We also note that Ina forms within a caldera-like depression and does not appear to emanate from a central source or contained within a flow field as the terrestrial flows.

Conclusion: Terrestrial inflation platforms are not fed from individual sources, but from horizontal flow of the lava through preferred paths in the flow field. We propose that the mounds in Ina could be fed through similar pathways during drain back of lava into the depression, which can explain why some of the mounds connect with the surrounding mare terrain, or from a single source (not visible) within the depression, though individual sources cannot be ruled out **[3,4]**. As mounds in Ina are fed through pathways, breakouts form along their margins to feed the mottled terrain unit, influenced by the topography of the blocky unit.

References: **[1]** Whitaker, E.A. (1972) *Apollo 15 Prelim. Sci. Rep., NASA SP-289,* 25-84 - 25-85. **[2]** Evans, R.E., El-Baz, F., (1973) *Apollo 17 Prelim. Sci. Rep., NASA SP 330,* 28-1 - 28- 32. **[3]** El-Baz F. (1973) *Apollo 17 Prelim. Sci. Rep., NASA SP 330,* 30-13 - 30-17. **[4]** Strain P.L. and El-Baz F. (1980) *LPS XI,* 2437–2446. **[5]** Robinson M.S. et al. (2010) *LPS XLI,* Abs. 2592. **[6]** B.R. Hawke and C.R. Coombs (1987) *LPS XVIII*, 407. **[7]** Walker, G.P.L. (1991) *Bull. Volcanol*., 53, 546-558. **[8]** Hon, K. et al. (1994) *GSA Bull., 106,* 351-370. **[9]** Rowland, S.K. and Walker, G.P.L. (1990) *Bull. Volcanol., 52,* 615-628. **[10]** Anderson, S.W. et al. (1999) *EPSL, 168,* 7-18. **[11]** Bleacher J.E. et al. (2007) *AGU Fall Meeting,* Abs. P34A-05. **[12]** Garry, W.B. et al. (2008) *LPS XXXIX,* Abs. 1734. **[13]** Bleacher, J.E. et al. (2008) *GSA Annual Meeting,* Abs. 133-6. **[14]** Zimbelman, J.R. et al. (2009) *GSA Annual Meeting,* Abs. 95-4. **[15]** Zimbelman J.R., et al. (2010) *LPS XLI*, Abs. 1826.

Acknowledgements: This work was funded the NASA LRO-PS (NNX08AM74G), PG&G (NNX09AD88G), and MMAMA (NNX09AW15G) programs. Thanks W.J. Clancey and M. Sierhuis.

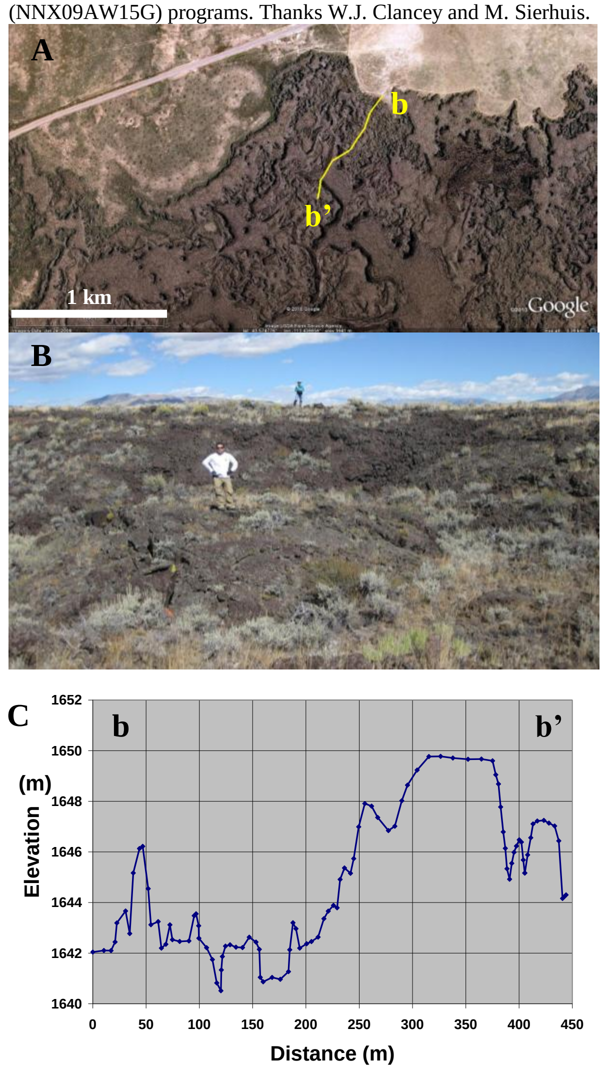

Figure 2. Sunset Pāhoehoe flow, Craters of the Moon, Idaho. **(A)** Remote sensing image (Google Earth). DGPS traverse (yellow line). **(B)** Field view of a platform and breakout in the hummocky ridged terrains. Photo is at the 380-400 m point along traverse. **(C)** DGPS topographic profile.