HIGH RESOLUTION IMAGING OF INA: MORPHOLOGY, RELATIVE AGES, FORMATION.

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Introduction: Since its discovery, the feature known as Ina (**Fig. 1**) has intrigued lunar geologists, while knowledge of its origin has remained elusive [1-4]. Generally, this depression is thought to have formed relatively recently as a collapse pit, or caldera, atop a low relief volcanic dome [1-5]. Its interior consists of two broad units, usually discriminated by differences in elevation and texture [5]. The *lower unit* is described as relatively rough with few preserved superposed impact structures. The discrete elements that make up the *higher* unit are described as smooth, flat to slightly arched or bulbous with lobate and topographically steep boundaries, and a greater population of impact craters. Most workers propose that the elevated unit was formed as extrusive volcanic material, perhaps similar in nature to the surrounding mare materials [reviewed in 5, 6]. The rough floor materials are proposed to have formed as collapse rubble as magma evacuated from the subsurface [2, 3] or an unusual (texturally and compositionally) volcanic deposit [5]. Albedo and color differences [1-4, 6] within Ina are attributed to maturity contrasts, grain size variations, compositional variations with depth, and sublimate deposits. Recent work by [6] reached the conclusion that Ina is one of the youngest features on the Moon, and may still be evolving through discontinuous volcanic outgassing events. Key evidence cited for the young age included the paucity of impact craters within Ina, and the spectral immaturity of the higher reflectance material [6]. Key questions that remain concerning Ina include: 1) ages of surrounding mare, rough interior unit, and smooth interior unit, 2) nature of color and albedo variations within and around, and 3) topography of interior elements.

LROC NAC Observations: New Narrow Angle Camera (NAC) images returned by the Lunar Reconnaissance Orbiter (LRO) reveal the morphology of Ina with pixel sizes of 0.5 to 1.1 meters. NAC images were obtained under both high and low Sun conditions, useful for discriminating albedo variations from differential reflectance due to topographic facets. Since the resolution of the lowest altitude NAC images is close to a factor of ten higher than those previously available [6] we are able to test existing interpretations of surface morphology and reflectance as well as more accurately identify and determine crater number densities.

The higher unit, sometimes referred to as mounds [5,6], has a noticeably smoother texture at scales greater than a few meters (**Fig. 2A**). However the NAC images reveal a large number of superposed craters (n >3000; **Fig. 2**) indicating an age greater than 1 by. Previous workers [1-6] noted a steep drop off along the margins of these occurrences and noted a moat surrounding some.

The lower unit shows a range of morphologies from rough at the few pixel scale, linear troughs, curvilinear raised arcs, curved depressions, isolated lobate knobs, and circular features that may represent buried or degraded craters. This range of morphologies is hard to reconcile with a simple collapse mode of formation. The narrow moats that surround some of the higher unit may be where relatively thin viscous flows of the lower unit terminated due to topographic obstacles. There are far fewer preserved impact craters than on the higher unit (**Fig. 2C**) and the surrounding mare indicating a relatively young age. However the NAC images reveal more craters on this unit than reported in [6] and thus it is not likely that this unit as a whole formed in past 10 my.

The patchy high reflectance areas are associated with steep slopes and boulder fields in most cases. The boulders are seen down to the limit of resolution and mostly likely grade into cobble and smaller size fractions. The larger boulders were seen in the Apollo Pan photography [5] and perhaps are responsible for the deeper 1-micron band and higher maturity index reported in [6].

Summary: NAC-based crater counts indicate that both major morphologic units within Ina are not recent; the higher unit may be contemporary with the surrounding mare materials. The high reflectance areas appear to be associated with blocky material and there is no compelling evidence of contemporary condensate deposits. Topographic relations between the floor material and higher unit are ambiguous and await stereo analysis of NAC data to be obtained in the near future. We note that Kaguya [7] topography confirms the presence of the broad low-relief dome associated with Ina.

References: [**1**] Whitaker, E. A. (1972) NASA SP-289. [**2**] El Baz, F., Worden, A. W. (1972) NASA SP-289. [**3**] El-Baz, F. (1973) NASA SP-330. [**4**] Evans R. E., El-Baz F. (1973) NASA SP-330. [**5**] Strain, P., El Baz, F. (1980) PLPSC. XI, 2437–2446. [**6**] Schultz et al. (2006) Nature, doi: 10.1038/nature05303. [7] Araki, H. et al. (2009) Science 897, DOI: 10.1126/science.1164146.

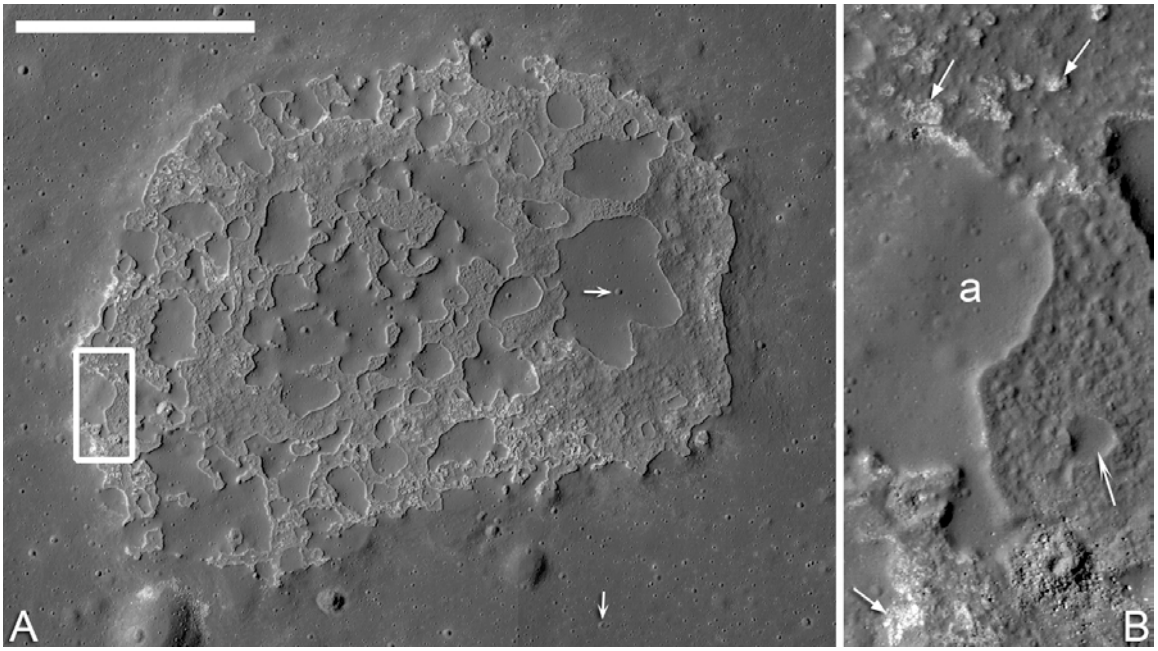

Fig. 1. (**A**) Ina interior exhibits bulbous smooth elevated terrain surrounded by rougher lower floor materials. Horizontal arrow locates largest crater visible in Fig. 1A, vertical arrow indicates irregular crater truncated in bottom of Fig. 2B. Scale bar 1 km, north is up [M113921307L/R], Sun is from the right, location of B indicated by white box. (**B**) Detail from (A) showing higher smooth material “a” and surrounding lower rough material. Single sharp arrow points to small-scale smooth elevated ground commonly seen in the rough floor materials down to the limit of resolution. Three arrows with triangular points indicate boulder fields that appear as enigmatic white patches in lower resolution images. Image width 205 m.

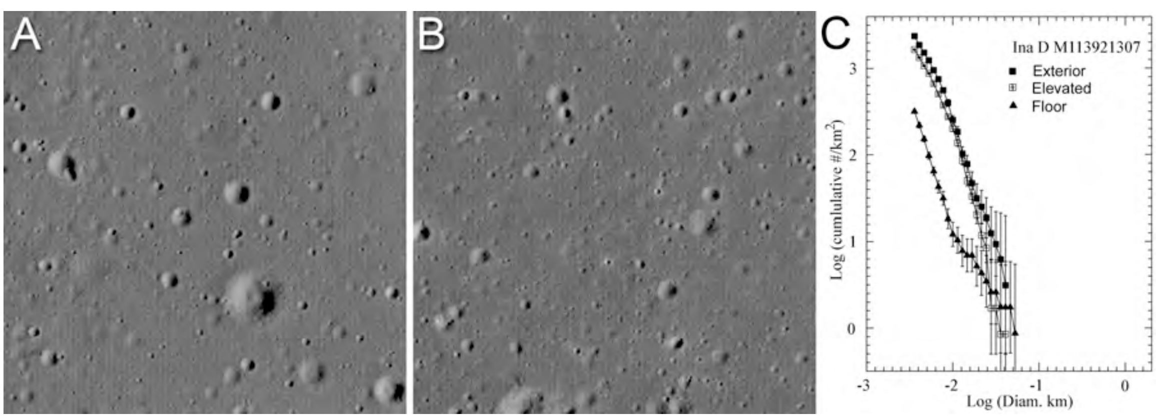

Fig 2. Surface morphology of smooth deposit within Ina (A) and surrounding mare (**B**). Panel A is from the center of the largest lobate elevated deposit, and B is ~500 m SE of Ina (see arrows in Fig. 1A). Each panel is 250 m wide. (**C**) Cumulative crater densities in and near Ina. “Exterior” includes two areas north and south of Ina depression (see B). Elevated unit (A) and the rough floor of Ina (lower unit) are approximately 50% covered by these counts.