LUNAR CRATER INA: ANALYSIS OF THE MORPHOLOGY OF INTERIOR LANDFORMS.

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Introduction: Ina is a 2.9×1.9 km planimetrically D-shaped depression approximately 60 m deep near the center of the lunar nearside in Lacus Felicitatis (Fig. 1). It was first identified in photos taken from the Apollo-15 and -17 orbital modules [1, 2], but the best images of it are from the LROC NAC camera [3] and thus the most detailed studies of Ina were made using these images [4–7]. These studies showed that crater Ina is on the top of gentle-sloped shield basaltic volcano. Inside Ina there are low (5–25 m) flat-topped hills with steep slopes, separated by rough terrain with meter-scale relief. Ina and the landforms within it were considered by all these research teams to result from basaltic volcanism.

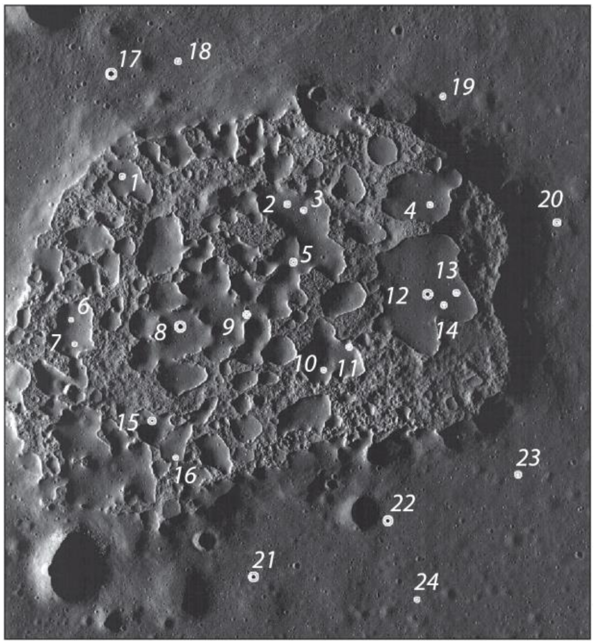

Figure 1. Ina Crater with morphologically fresh small craters indicated on the interior hills (1–16) and on the adjacent slopes of the shield volcano (18–24). Image: LROC NAC M116282876LE and RE.

The small crater population on the slopes of the shield volcano was found to correspond to an absolute age of ~3.5 Ga [7]. In contrast, the crater density on the hills interior to Ina was found to be much lower, corresponding to an age < 100 Ma [6]. Similar low crater densities were found on so-called *irregular mare patches* (IMP) [6] so that both crater Ina and other IMPs have been considered to be examples of very young lunar volcanism. To reconcile the difference, it has been suggested [7, 8] that the hills inside Ina may be composed of a magmatic foam – a massive pumice with porosity >75 % – rather than of normal basalts. Based on some experiments [9] and model calculations [10] it was suggested that meteorites impacting magmatic foam should produce craters of larger depth but smaller diameter, thus explaining the significantly lower apparent ages. In this manner, the authors conclude that the formation of Ina was contemporaneous with the shield volcano on which it occurs. In this study [11], we consider the morphologic freshness of the Ina interior landforms, comparing the morphologies of small craters superposed on the Ina interior hills with those on the shield volcano slopes, to determine whether they are different and thus establish whether the hills are composed of magmatic foam or normal basalts.

Morphologic freshness of Ina interior landforms: The eastern edge of Ina crater and the adjacent gently sloped surface of the shield volcano are seen in Figure 2. The volcano slopes look like normal mare: a smooth plain peppered with small craters. The lunar surface is a place of lateral material exchange: ejecta from newly-forming craters are dispersed in all directions while ejecta from neighboring and distant craters may arrive at any point. On sub-horizontal surfaces, which typify the lunar maria, the balance of incoming and outgoing material is close to neutral. Depressions are zones of positive balance, receiving more material from outside than they return. Adjacent to depressions are zones of negative balance, which lose more ejecta than they receive from the depression [12, 13]. The Apollo-15 and Lunokhod-2 teams observed that the effective range of lateral material exchange on the Moon varies from tens to hundreds meters, and a layer of regolith of decimeters to a few meters is involved [14, 15]. We may therefore expect that crater Ina, close to its interior boundary, should have received a surplus of up to several meters depth of crater ejecta from the adjacent mare-like terrain. This material is expected to be present at the foot of Ina inner slopes and should soften the relief of the Ina interior rough terrain and diffuse the boundaries of the Ina interior hills. We observe no such accumulation nor softening of the interior landforms (Fig. 2), which appears to indicate that the feature is indeed young.

Crater morphology on Ina interior hills and adjacent mare: Small morphologically fresh craters located on the Ina interior hills and on the adjacent mare-like shield volcano slopes are shown in Figure 3.

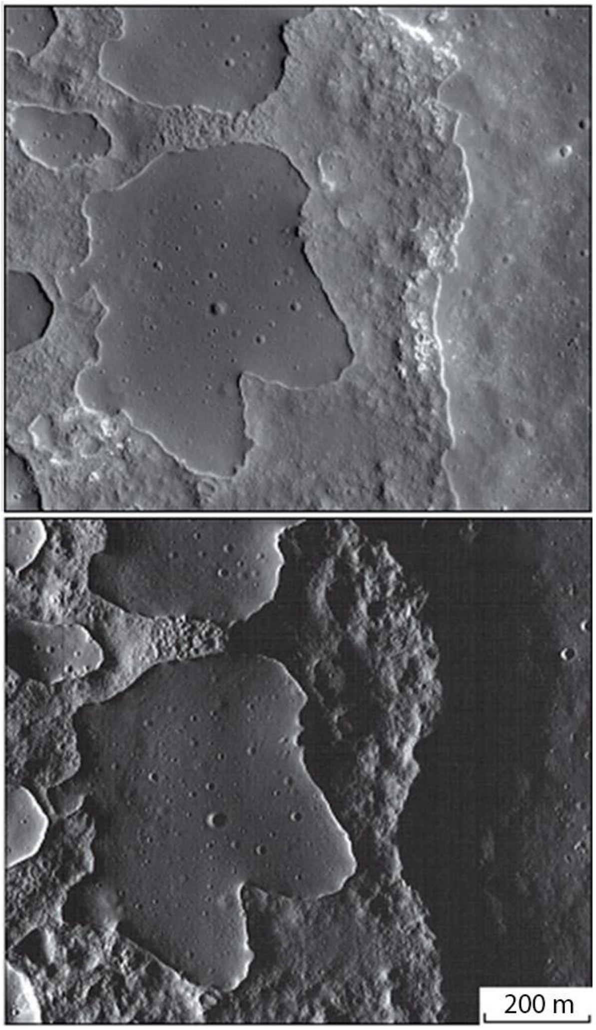

Figure 2. High (36°) and low (6.5°) sun images of eastern part of Ina. Images: M119815703LE, RE and M116282876LE, RE (original: 0.55 m/pix)

We compare only morphologically fresh craters because the potential differences between craters formed in magmatic foam and in normal basalts would likely diminish as the craters degrade. We see that craters formed on the two different terrains are morphologically very similar at comparable sizes. Both show an elevated rim that, possibly, should be suppressed for craters formed in magmatic foam.

Regolith accumulation model: We simulated the regolith accumulation that should occur over 3.5 Ga from the ejecta of craters forming in a) typical mare material, and b) magmatic foam, where craters are hypothesized to occur 3x smaller, finding a) 10–20 m b) ~1 m, using the methods of [16]. That the morphology of craters of similar size within and outside Ina does not differ observably suggests that the post-compression crater formation is similar, so we assume that the volume of excavation remains proportional to the final crater volume. The reduction in regolith thickness is less than estimated from scaling the excavated volume, because of the reduction of ejecta recycling over an equivalent area.

Conclusion: The boundaries of Ina Crater and its interior landforms are morphologically very fresh, suggesting that it is a product of very young (< 100 Ma) lunar volcanism. The morphology of small impact craters superposed on the Ina interior hills is very similar to that on the neighbouring mare-like surface, indicating that a magmatic foam structure is unlikely [11].

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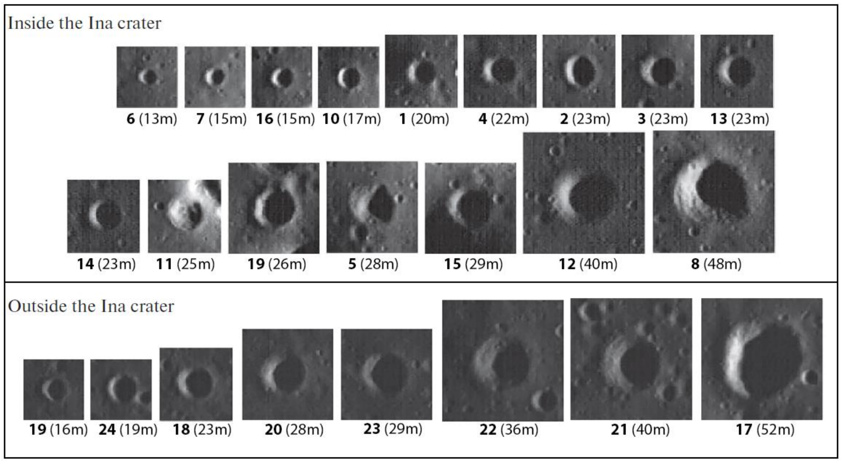

Figure 3. LROC NAC images of craters formed on the Ina interior hills and on the adjacent mare-like surface. Labels reference the craters shown in Fig. 1 with their diameters.