SHOEMAKER CRATER – GOING WHERE WE CAN "SEE".

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Introduction: The recommended impact site for LCROSS is Shoemaker crater, centered at 88.1 S, 45 E. This 51-km diameter crater is in permanent shadow. However, more than half of its floor has been imaged by Earth-base radar. This degree of target knowledge will strongly constrain impact models and significantly increase the confidence of data interpretation.

Crater Description: The 51-km diameter Shoemaker crater is centered at 88.1 S, 45 E. It is located in highlands terrain between Faustini and an unnamed 40-km crater, and just north of Shackleton. Lunar Orbiter IV [1] and Clementine [2] images show that the rim is illuminated by sunlight, but the crater floor remains dark.

The lunar poles have been imaged by the Goldstone radar, operating at a wavelength of 3.5 cm [3]. Radar interferometry was used to produce a digital elevation model (DEM) of the terrain at each pole, with 150-m spatial resolution and 50-m height resolution. The authors applied ray tracing techniques to this model and calculated permanently shadowed locations at both poles. Some areas, including portions of crater interiors, could not be imaged as intervening topography blocked the radar beam. This analysis of the south polar region highlights five craters in which a portion or all of each floor is in permanent shadow (Fig. 1).

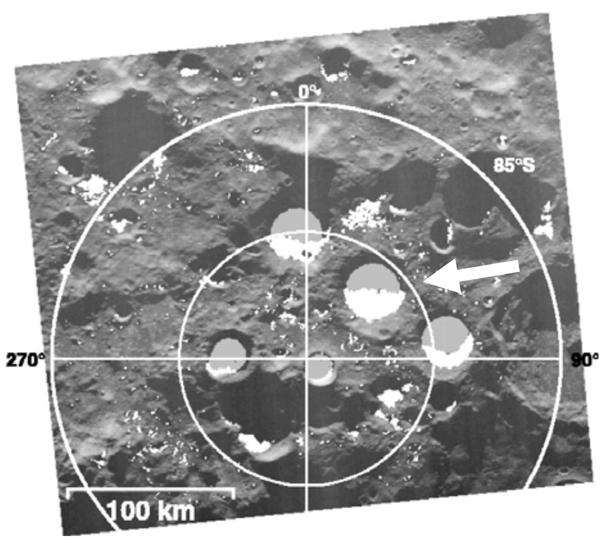

Figure 1. Radar DEM of south polar craters, Shoemaker crater indicated by arrow; white – permanent shadow (calculated), gray – no radar return; from [3].

The craters range in diameter from 51 km to 20 km, and all are centered south of 87 S latitude. The mean elevation of intercrater areas is approximately 1 to 2 km below the lunar datum, equivalent to a sphere 1378 km in radius (Fig. 2).

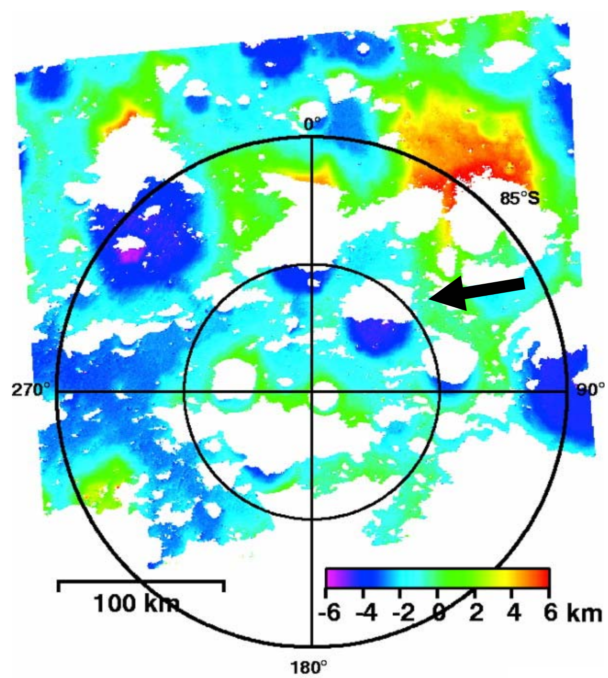

Figure 2. Radar DEM of south pole craters, Shoemaker crater indicated by arrow; from [3].

The radar DEM of Shoemaker crater shows an intact rim with numerous 1 to 10 km superimposed craters (Fig. 1). The ejecta blanked is totally subdued. This crater is more degraded than the adjacent craters Faustini and Shackleton, but less degraded than several unnamed craters of similar size in the region.

The radar DEM indicates that the floor of Shoemaker is approximately 3 to 4 km below the datum (Fig. 2). The morphometry of fresh lunar craters in this size range provides a calculated depth of 3.4 km below the rim, and a calculated rim height of 1.1 km above the original surface [4,5]. The DEM and morphometric calculations are thus in agreement that the crater floor should lie approximately 2 km below the surrounding intercrater areas. More detailed analysis may indicate whether the crater has been significantly infilled.

The Goldstone radar beam was returned from approximately half of the interior wall and floor of Shoemaker (Fig. 3). The radar DEM shows that the crater floor diameter is approximately 20 km, in accord with morphometric modeling [4]. The illuminated portion of the floor is flat and partially smooth, with scattered impact craters. The crater is simple in plan, with no evidence of a central peak. Detailed modeling of crater morphology, morphometry, and radar return should further constrain physical models of the floor material.

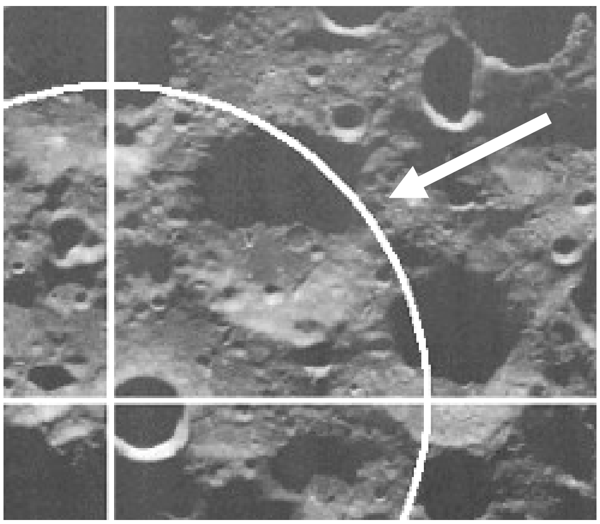

Figure 3. Radar DEM of south polar craters, Shoemaker crater indicated by arrow; from [3].

Previous Studies: Shoemaker crater lies within the latitude range where thermal and epithermal neutron counts measured by the Lunar Prospector spacecraft suggest concentrations of near-surface ice. The most recent calculations [6] indicate that “the average hydrogen abundance near both lunar poles is 100–150 ppm and is likely buried by 10 ± 5 cm of dry lunar soil, a result that is consistent with previous studies. The localized hydrogen abundance for small (<20 km) areas of permanently shaded regions remains highly uncertain and could range from 200 ppm H up to 40 wt% H_2O in some isolated regions.”

The floor of Shoemaker crater is, however, one of the areas in which radar observations showed no evidence for ice. Radar beams with wavelengths of 2.5, 12.6, and 70 cm have returned echoes that are typical of highland terrain, without the strong echoes attributable to ice [7].

Shoemaker crater has already been the site of one spacecraft impact. In 1999 the Lunar Prospector, carrying a small vial of Gene Shoemaker’s ashes, was deliberately crashed into the crater. Earth-based sensors observed the crater at the time of the impact, but detected no ejecta plume. The LCROSS experiment, however, could well produce significantly different results. The LCROSS spacecraft will impact the Moon with orders of magnitude more kinetic energy than Lunar Prospector, and the ejecta plume will be observed by from lunar orbit as well as from the Earth.

Basis for Recommendation: Many targets meet the LCROSS criteria: nearside; permanently shadowed; poleward of 70 degrees latitude; large enough to contain a 10 km landing ellipse. However, the actual material to be impacted in most of the candidates is unknown. Permanently shadowed areas, by definition, provide no reflected sunlight and thus no imaging data.

Shoemaker crater is unique among these candidates in that half of the floor has been imaged by radar. The physical properties of the floor material can be modeled. This target is known to be flat, providing simple geometry for understanding impact dynamics and the ejecta plume.

The importance of imaging the target area in a spacecraft impact experiment was demonstrated by the Deep Impact mission to Comet Temple 1 [8]. The plume dynamics and composition data indicated a complex, heterogeneous target. Close-up images of the impact point, revealing layered target material, strongly constrained the comet model.

Shoemaker crater also provides a unique opportunity to test the seemingly-contradictory neutron and radar results concening near-surface ice. The crater is large enough to cover a substantial portion of a Lunar Prospector neutron detector pixel [6], and so contributes directly to that ice “detection”. In addition, half of the floor is within sight of Earth-based radar and was probed as part of the null ice “detection” by that technique [7]. A LCROSS impact into Shoemaker crater will thus provide a direct test of these two results at the same surface location, and should significantly improve our understanding of lunar ice.

References: [1] Bowker D. E. and Hughes J. K. (1971) *Lunar Orbiter Photographic Atlas of the Moon*, NASA. [2] Bussey B. and Spudis P. D. (2004) *The Clementine Atlas of the Moon*, Cambridge. [3] Margot J. L. et al. (1999) *Science, 284*, 1658-1660. [4] Pike R. J. (1977) in *Impact and Explosion Cratering*, Pergamon, p. 489-510. [5] Pike R. J. (1974) *GRL, 1*, 291-

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