THE LCROSS IMPACT CRATER AS SEEN BY SHADOWCAM AND MINI-RF. C. I. Fassett[1], M. S. Robinson[2], G. W. Patterson[1], B.W. Denevi[1], P. Mahanti[2], E. Mazarico[3], E. Rivera-Valentin[1], F. S. Turner[2], [1]JHU-APL, [2]ASU, [3]NASA GSFC.

Introduction: The Lunar CRater Observations and Sensing Satellite (LCROSS) mission impacted a Centaur booster into a permanently shadowed region (PSR) in Cabeus crater on 9 October 2009 [1]. The objective was to use the impact to excavate volatiles in the regolith. The resulting ejecta plume had a substantial amount of water, ~6±3% (by mass), as well as other detectible volatiles [2]. Because the impact occurred in a PSR, fully resolving the crater formed by LCROSS was not possible until ShadowCam, hosted on the Korean Pathfinder Lunar Orbiter (Danuri) [3], acquired 2-meter scale images of the site.

The location of the LCROSS crater was initially estimated using images from the LCROSS shepherding spacecraft, Goldstone radar, and trajectory analysis with 1σ uncertainty E/W=115 m and N/S=44 m [4]. Additionally, the diameter of the crater was predicted prior to LCROSS from scaling [5] and computational modeling [6,7], to be within 17–25 m. Post-impact observations from the shepherding spacecraft led to a larger interpreted crater diameter of 25–30 m [8].

Mini-RF Analysis: The Mini-RF instrument [9] collected monostatic S-band radar observations of the impact location before and after the event. Initial change analysis saw a possible new bright spot near the LCROSS impact site, but the results were considered inconclusive [10]. However, processing techniques developed for the Mini-RF bistatic campaign [11] also provide a means to enhance the fidelity of Mini-RF monostatic data. As a result, we re-examined Mini-RF observations to detect differences pre- and post-impact.

We used the same before and after collects as Neish et al. [10], as they were acquired with similar radar geometries (Fig. 1). Both collects were reprocessed with the new techniques [11] and adjusted to ensure that they were accurately co-registered to the LOLA 30 m/px reference frame. We saw a significant new local maximum (Fig. 1) in the post-impact collect, at least ~4 dB (2.5×) higher in total backscattered power (S_1) than the pre-impact collect, close to the expected location of the LCROSS crater (~80 m from the point estimated by [4]; within 1σ uncertainty).

ShadowCam: Four ShadowCam images of the LCROSS crater location (M018618388S, M024514254S, M024521323S, and M033945243S) show a fresh crater ~22 m in diameter co-located with the Mini-RF temporal change (Fig. 2). The crater appears to have a slight rim, is crater formed on top of other small craters of similar size, and the surrounding terrain exhibits an equilibrium crater population [13].

There is no distinctive ejecta deposit or excavated blocks detected around the crater in the ShadowCam images, though other fresh craters of similar size also lack obvious ejecta or blocks. This may be normal for craters of this scale when seen with under secondary illumination geometry.

Context and age of the terrain impacted by LCROSS: Mini-RF observations (Fig. 1) show that the LCROSS crater formed on a radar-bright ray of a 900-m diameter crater [10]; such a ray is likely <500 My [14]. Illumination modeling shows that area became a PSR within the last ~900 My [15]. The ShadowCam data shows the LCROSS crater formed superposed upon a ~21 m diameter degraded crater. Lifetime estimates for a 21 m diameter crater are <~311 My [16], implying LCROSS impacted a surface substantially modified in the last few hundred Ma. The size of the LCROSS crater (~22 m) implies a maximum LCROSS excavation depth of ~2.2 m [17], though the low density of the projectile could reduce this estimate [5].

Taken together, this evidence implies that (1) the volatiles exposed by the LCROSS ejecta plume were emplaced in the Copernican (since the region was not permanently shadowed much earlier), and (2) the upper meters of regolith excavated by LCROSS were gardened within the last 100–500 My. The composition of the volatiles released by the Centaur impact have been interpreted as more consistent with a cometary origin than as a paleo-reservoir of an early volcanic atmosphere [18]. A young age for this volatile reservoir is consistent with this interpretation.

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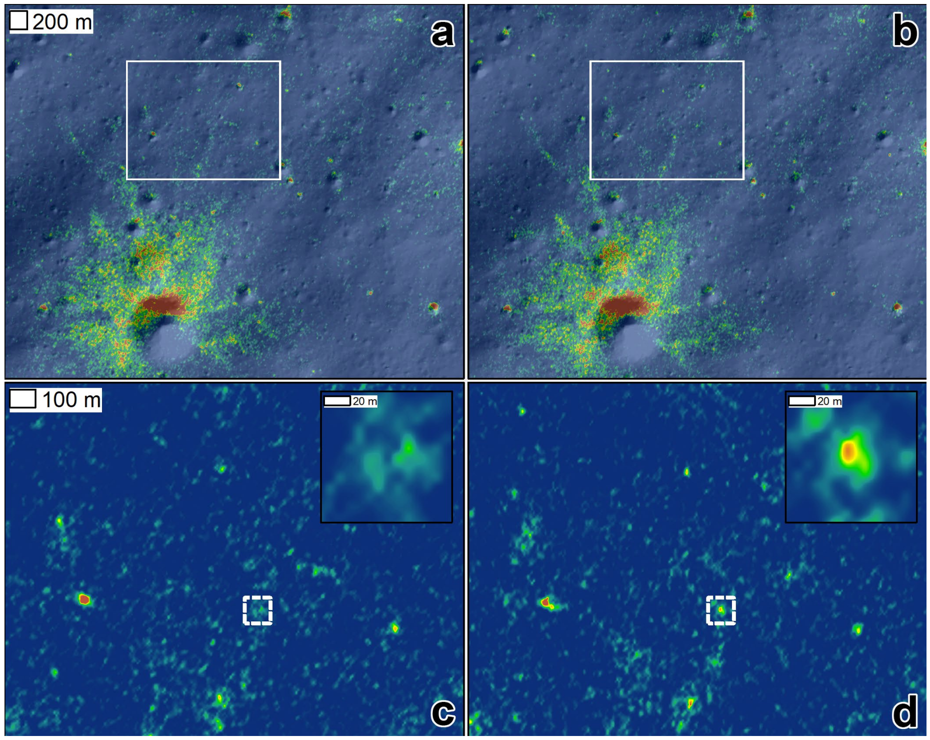

Figure 1. Mini-RF S_1 (total backscattered power) (a) before (lsz_00455_87s324) and after (lsz_03391_85s318) for the LCROSS centaur impact location, overlaid on LOLA hillshade. The D~900 m fresh crater near the LCROSS impact site has radar-bright rays that cross where the LCROSS impact occurred (also noted by [10]). (c) and (d) are zoom ins. Both the before and after collects were averaged to 7.5m/px, 3x3 Kuan speckle filtered [12], and stretched to a 0.1-99% range, and gamma corrected (γ=0.25). The spatial extent of (c) and (d) are the same as the Fig. 2 (a) and (b) below.

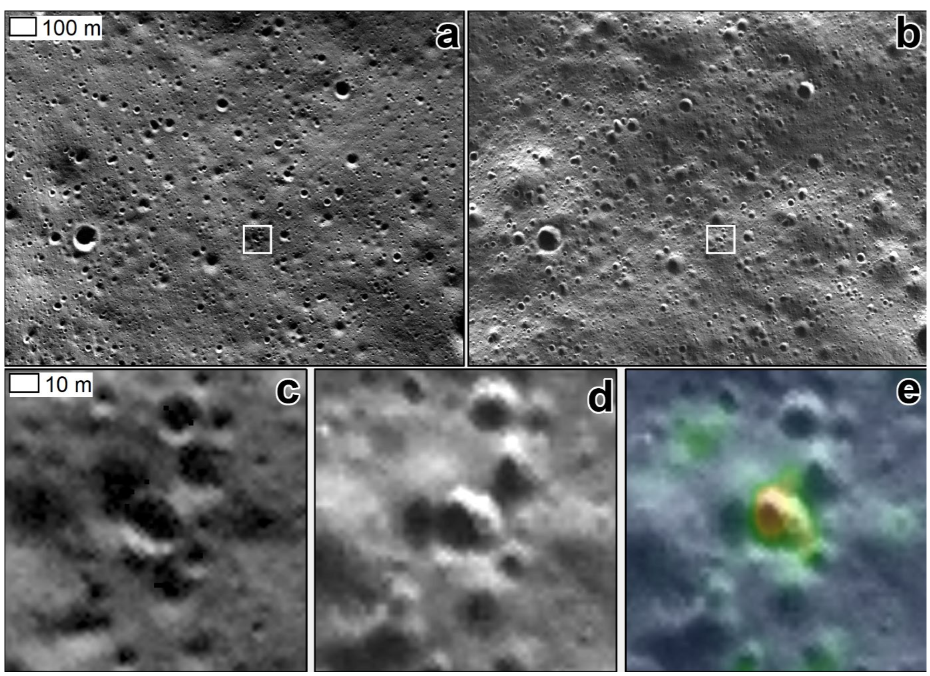

Figure 2. (a) ShadowCam image stack (average of M024514254S, M024521323S; most illumination from top/~east) (c: detail). (b) ShadowCam image stack (average of M018618388S, M033945243S; most illumination from bottom/~west) (d: detail). (e) Overlay of the after Mini-RF radar collect over ShadowCam. LCROSS crater is D~22m.