NEW CRATER ON THE MOON AND A FIELD OF SECONADRIES. M. S. Robinson[1], A. K. Boyd[1], B. W. Denevi[2], S. J. Lawrence[1], D. E. Moser[3], R. Z. Povilaitis[1], R. W. Stelling[1], R. M. Suggs[3], S. Thompson, R. V. Wagner[1]. [1]Arizona State University, Tempe, AZ 85287, [2]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, [3]Meteoroid Environment Office, Marshall Space Flight Center, Huntsville, AL 35812.

Introduction: Amateur and professional observatories monitor the Moon for flashes, interpreted to represent impact events. The NASA Lunar Impact Monitoring Program includes a dedicated telescope facility at Marshall Space Flight Center [**1**]. The Marshall group recorded over 300 flashes (meteoroid impacts); their brightest recorded flash occurred on 17 March 2013 (20.599±0.172°N, 336.078±0.304°E). Subsequently, a series of Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) images [**2**] were acquired over the period of June through November 2013 to investigate the nature of this flash.

Fortunately, NAC images acquired before 17 March 2013 in the area of flash coordinates exist. The first set of post-impact flash images (21 May) were targeted on the Marshall-reported coordinates and numerous small (<6 m diameter) changes of surface brightness (hereafter, "splotches") were found by directly comparing the pre- and post-flash images, but no resolved crater was found. A second set of NAC images was acquired on 1 July, and more splotches were found. However, three faint ray-like features and several chains of splotches and asymmetric splotches generally pointed to a common area west of the Marshall coordinates, and a NAC pair was targeted on that convergence point for 28 July. Analysis of this third set of images with pre-existing coverage revealed a new 18 m diameter crater (20.7135°N, 335.6698°E) and more associated splotches.

Crater and Ejecta: The 17 March crater is circular with an asymmetrical ray pattern, both in shape and reflectance values (**Fig. 1**). The interior of the crater is not sharply seen at the meter scale of the images, however there is a small ~2 m diameter low reflectance (-10% relative to surrounding crater floor) zone in the crater center that may be a small deposit of impact melt. High reflectance (+25% to +50%) ejecta extends to the southwest 10 to 20 m, and to the northeast <10 m. A low reflectance zone (-5% to -10%) extends beyond the high reflectance ejecta in a more symmetrical pattern about the crater 50 m (west-south-west) to 80 m (east-north-east). A subtle high reflectance zone (3% to 5%) extends beyond the low reflectance zone in a ragged hemispherical pattern about up to distances of 1 km, centered to the northeast (**Fig 2**). The high reflectance ejecta is likely relatively immature material excavated from the deepest portion of the crater (~5 meters) or excavated locally as the ejecta impacted. The proximal low reflectance material may be ejecta from shallower portions of the crater. However, the low-reflectance zone extends far beyond one crater radius, the typical extent observed for continuous ejecta deposits [**3**], and we instead propose that it represents an area of regolith disturbance (rather than a layer of ejecta), likely the result of ballistic sedimentation. In the case of the far field ejecta from the 18 m crater, mixing of the regolith occurred within the mature surficial layer only, and the decrease in reflectance is due to increased surface roughness. Similar decreases in reflectance are observed at Apollo landing sites, where the regolith disturbed by astronaut activities is rougher

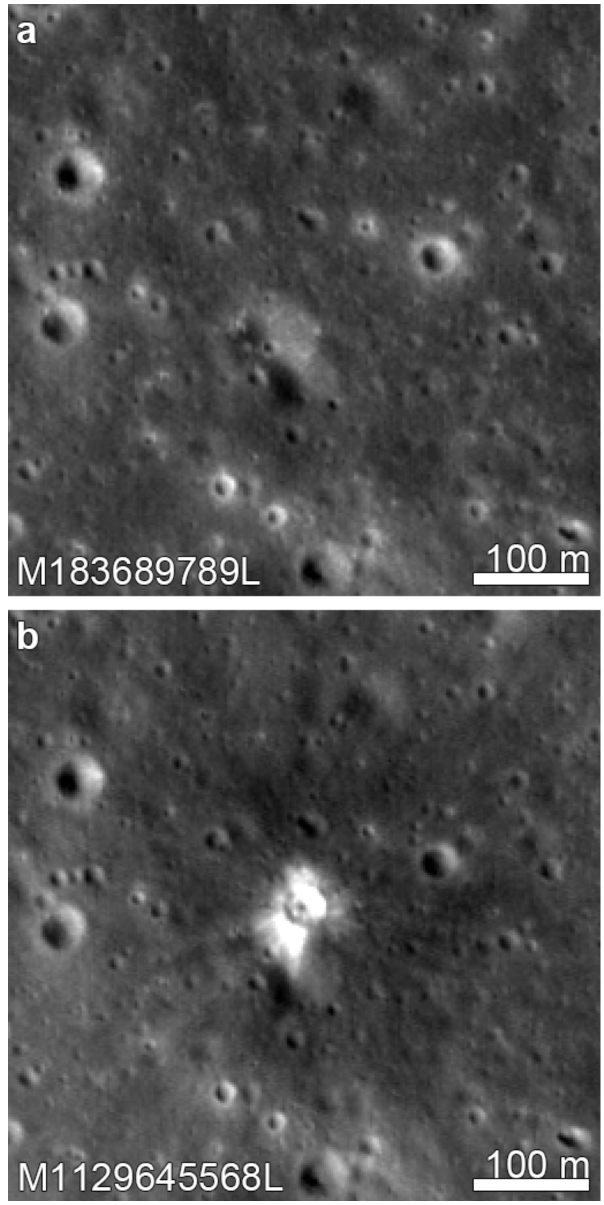

Figure 1. a) Pre-impact NAC image of the 17 March event, b) post impact image showing newly formed 18-m diameter crater and associated regolith changes.

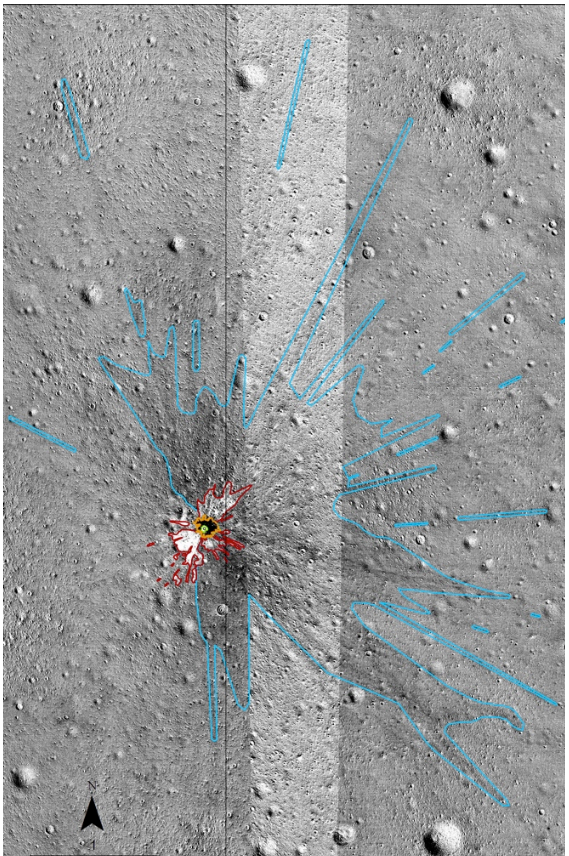

Figure 2. Temporal ratio (before M183689789L / after M1129645568L) orange outline delimits proximal high reflectance ejecta, red line is the boundary of low reflectance ejecta, blue outline shows boundary of high reflectance outer continuous ejecta, scale bar is 1000 meters.

at the mm–cm scale [**5**] and shows a decrease in reflectance of 4–5%.

Examination of all the relevant temporal pairs revealed 248 splotches within 30 km of the 17 March crater. These splotches are circular to irregular in planform, 2 to 14 meters in diameter (median 6 m); none are seen as resolved craters. Of the splotches, 239 exhibit reflectances lower (median -4%) than unaffected nearby regolith, and three have reflectances greater (4 to 12%) than their surroundings (the remainder are mixed reflectance). The abundance of low reflectance splotches indicates that significant quantities of immature regolith was not excavated during formation, and the splotch decreased reflectance is likely related to increased roughness, as seen in the near-crater low-reflectance zone.

Energy of the main impact event: Physical parameters of the 17 March impact event (resolved crater) were assessed using the impact-scaling model of [**6**]. Impact events into representative lunar regolith using appropriate impactor densities for iron-nickel (6 g/cm^3), cometary (1 g/cm^3), and chondritic impactors (3.4 g/cm^3 [**7**]) were modeled over a range of plausible impact velocities (5-60 km/sec). The measured crater rim (also termed outer diameter; 18 m) and inner diameter (measured from level of pre-existing terrain inside the crater; 15 m) was used as a constraint to generate model estimates of the impactor diameter and mass and the energy released by the impact. The measured physical properties of the 17 March impact crater are consistent with an impactor between 0.3-1.3 m in diameter and a mass between 33-566 kg, dependent on model assumptions. Assuming a 15 km/sec velocity, the impactor would have released 1.49-2.05 × 10^7 kJ depending on its density.

Secondary vs. primary: The nature of the swarm of splotches associated with the 17 March event is a key question in terms of understanding current impact rates and associated hazards. Splotches may have formed as a swarm of associated high velocity and relatively small simultaneous primary impacts, or low velocity secondary impacts from the 18 m crater. We interpret the latter case to be true due to the aligned nature of many splotches and their geographic association with rays emanating form the 18 m diameter crater.

The volume of ejecta from the 17 March primary required to create splotches was examined by assuming an even layer of ejecta was emplaced over each splotch. The 18-m crater has a volume of ~450 m^3. The volume of the 17 March crater continuous ejecta blanket is estimated to be ~100 m^3 using the delta function for ejecta thickness from [**8**]; the estimated volume of the distal ejecta is about 150 m^3. Assuming 0.1 mm to 1 mm of ejecta was scattered over each splotch, results in a total volume of 0.54 m^3 – 5.4 m^3. Energies required to emplace the splotches were calculated using ballistic trajectory velocity estimates [**8**]. For ejection angles of 45° impact velocities range from 30 m/s to 250 m/s for all the splotches. With velocities in this range we assume no crater was formed at each splotch, but rather a simple turbation of the surface. Total energy required to emplace the 0.1 mm – 1 mm thick layer of ejecta for all splotches ranges from 1.4 × 10^4 kJ to 1.4 × 10^5 kJ, two orders of magnitude less than the estimated total energy of the primary impact. If the thickness of the material that formed the splotches was increased by an order of magnitude (10 mm), the energy required to emplace all of the splotch ejecta is still an order of magnitude less than the primary impact. Thus from an ejecta volume and energy stand point it is likely that the splotches are distant secondary features of the new 18 m diameter crater.

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