DISCOVERY OF IMPACT CRATERS FORMED DURING LRO OPERATIONS

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ABSTRACT:

Recent impacts on the lunar surface are known from Earth-based observations (Rabinowitz, et al., 2000; Stuart and Binzel, 2004; Nemtchinov et al., 1997) and the Lunar Reconnaissance Orbiter Camera (LROC) temporal image comparisons (Thompson and Robinson, 2013; Robinson et al., 2013; Robinson et al., 2014; Thompson et al., 2014). Detecting changes in the lunar surface with LROC Narrow Angle Camera (NAC) (Robinson et al., 2010) observations is carried out by examining ratios of the same terrain acquired with similar lighting conditions acquired at different times (>6 months). The "before-and-after" image pairs are referred to as Temporal NAC Pairs (TNP).

As of 15 January 2014, 138 TNPs were searched for evidence of surface changes. Out of the near 27,000 km^2 searched, 657 features were found in 93 TNPs (67%), which are globally distributed. These numbers include the 17 March 2013 crater (see below), but do *not* include splotches associated with that event. Based on the relative reflectance change of the disturbed area, the crater or "splotch" (obvious disturbances in the regolith lacking a resolved crater) is classified as a low reflectance change (LRC) or a high reflectance change (HRC), where LRC is a decrease in the relative reflectance and HRC is an increase (604 LRCs and 53 HRCs have been documented with 19 (mostly HRCs) expressing an identifiable crater rim). Splotch diameters average 6.0 m (std. 7.5); resolved crater diameters average 3.9 m (std. 4.0).

The NASA Lunar Impact Monitoring Program includes a dedicated telescope facility at Marshall Space Flight Center (Suggs, et al., 2007) and they have recorded over 300 flashes (meteoroid impacts); their brightest recorded flash occurred on 17 March 2013. A series of Lunar Reconnaissance NAC images were acquired over the period of June through November 2013 to investigate the nature of this flash (Robinson et al., 2014). 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 but no resolved crater. 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.

The 17 March crater is circular with an asymmetrical ray pattern, both in shape and reflectance values. 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.

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.

The nature of the of the splotches is a key question for evaluating the current impact rate and associated hazards for future lunar exploration assets. Splotches may have formed as a swarm of associated high velocity and relatively small simultaneous primary impacts, or low velocity secondary impacts from a single crater. Based on the LROC observations of the 17 March crater and associated splotches it is possible (likely?) that a significant portion of the LRC splotches (found globally) are low velocity

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secondary events. Currently the LROC operations team is targeting temporal pairs (areas where pre-existing images exist) around regions with clusters of LRCs to search for nearby resolvable primary source craters.

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