42 YEARS OF IMPACT CRATERING AT THE APOLLO 15 LANDING SITE.

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Introduction: The age of every planetary surface beyond the Earth-Moon system is ultimately derived from the lunar cratering record. Studying the size and density of impact craters on a planetary surface is the only technique to derive an age through remote sensing. The Moon, through samples returned by the Apollo and Luna missions, provides the critical calibration data for the chronology of impact craters throughout the Solar System.

Recent studies have used temporal images to identify new craters [e.g. 1], determine the present-day crater production rate [e.g. 2], and have even linked ground-based observations of lunar flashes to new impact craters [e.g. 3]. Previous studies have demonstrated that non-digital images can be used for change detection studies [e.g. 4, 5]. Here, we have carried out a pilot study of long-term imaging, to test whether new impact features are identifiable between Apollo-era and present-day data.

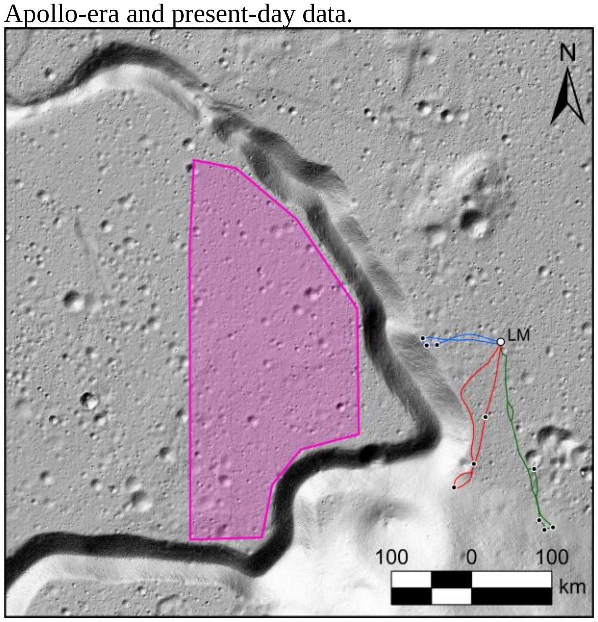

Figure 1. Context map of the Apollo 15 landing site study region. Shaded purple area shows the change detection area. Also shown is the Lunar Module (LM) location, and Extravehicular Activity (EVA) routes. Base image is a hillshade of USGS LRO NAC DEM (Apollo 15 26N004E 150cmp).

Method: We used an Apollo Panoramic camera image (AS15-P-9372) taken from orbit on 31 July 1971. We used the high resolution (200 pixels/mm) digital scans provided by the ASU Apollo Image Archive (http://apollo.sese.asu.edu/index.html), which have ground sample distances (GSD) of 2-30 m [4]. We georeferenced the central part of this image by hand to the orthorectified Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) image M1121224102 (GSD = 1.2 m), which also has an underlying stereo Digital Elevation Model (DEM; GSD = 5 m/px), provided by the LROC team as a Reduced Data Record (RDR). This after image was taken on 21 April 2013, offering a time gap of 15,240 days, or almost 42 years.

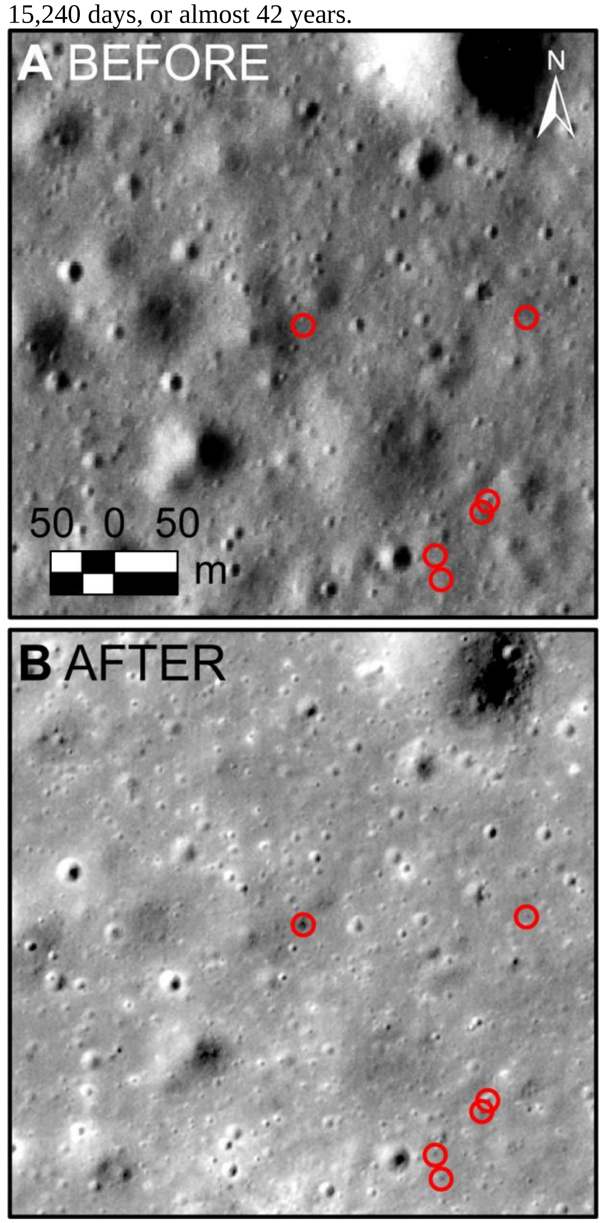

***Figure 2.** Example of new impact features (red circles). (A) Before: Apollo 15 Panoramic Camera image AS15-P-9372. (B) After: NAC orthorectified image M1121224102.*

We used 54 tie points with a spline interpolation to achieve georeferencing that was adequate for change detection. Following previous studies [e.g. 1], we ratioed the images to help identify changes, although differences in imaging conditions limited the use of this method. We systematically searched the study region (area = 30 km^2) by blinking images, and marking the location of any change. We took care to avoid possible false negatives due to shadow changes.

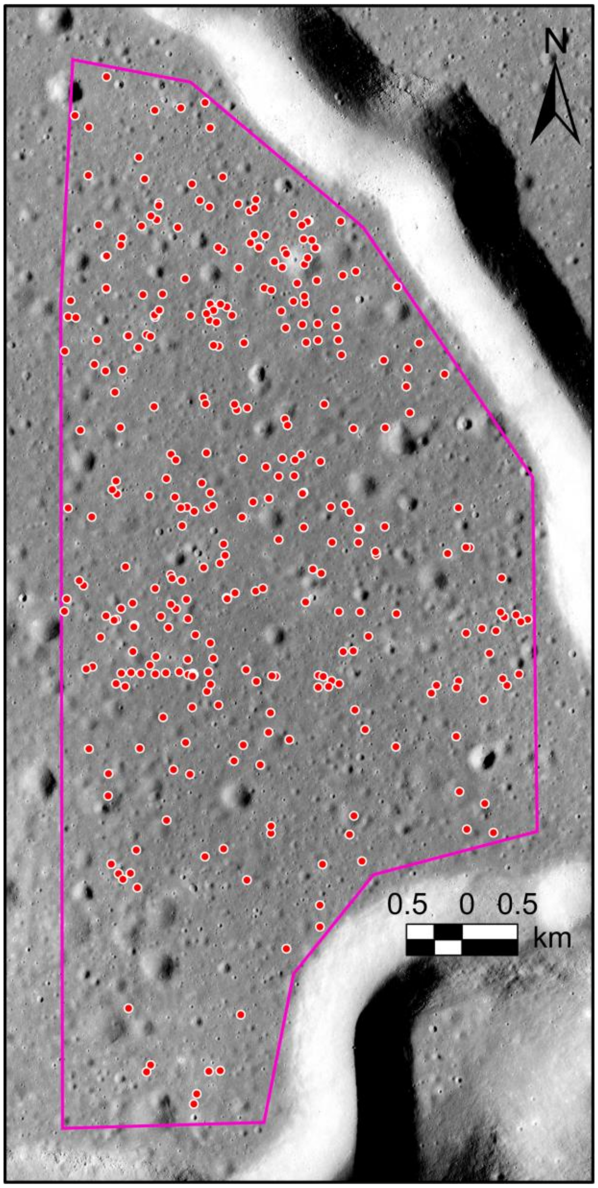

Figure 3. *The location of all 320 new impact features identified in our change detection area. Apollo 15 Panoramic Camera image AS15-P-9372.*

Results: We identified 320 new impact features (Figure 3). All but one of these features appeared as a new, dark feature on the surface (Figure 2). Only the largest (15.9 m diameter) feature had a discernible crater at the center of the dark feature (Figure 4). The median diameter of the features was 2.7 m. Areas with significant shadowing in either image were difficult to assess, and thus our work represents a likely minimum, even before considering resolution limitations.

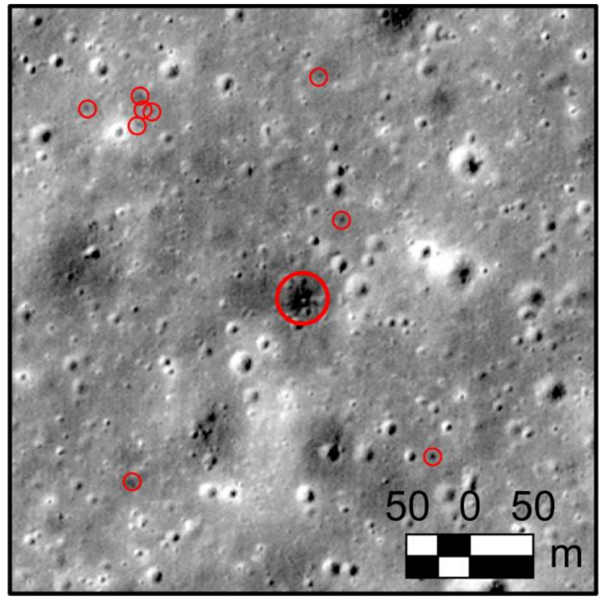

Figure 4. *Close-up of the largest new impact feature (large circle), and surrounding new impact features (smaller circles). NAC orthorectified image M1121224102.*

Conclusions and Future Work: We have demonstrated that it is possible to identify small-scale changes between Apollo Panoramic Camera and LROC images, enabling long baseline temporal imaging. Although we have identified a relatively large number of likely new impact features, further work is required to determine the proportion of primary to secondary cratering. We plan to use previous clustering methods to address this issue [e.g 6], as well as using more recent images to possibly refine the timing of new features. Recent efforts at photogrammetric control of Apollo Panoramic Camera images [e.g. 7] would allow much better application of this method.

References: [1] Robinson, M.S. et al. (2015) *Icarus* 252, 229-235. [2] Speyerer, E.J. et al. (2016) *Nature* 538, 215-218. [3] Sheward D. et al. (2022) MNRAS 514, 4320-4328. [4] Oberst, J. et al. (2012) *Plan. Space Sci.* 74, 179-193. [5] Bickel, V.T. & A. Valantinas (2021) *LPSC* 52, #1285. [6] Lagain, A. et al. (2021) *Earth Space Sci.* 8, e2020EA001598. [7] Edmundson, K.L. (2015) *LPSC* 46, 1350.