CHARACTERIZATION OF PROPOSED IMPACT MELT FACIES IN MARE CRISIUM.

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Introduction: Understanding the impact history of the Moon has important consequences for Earth's earliest history, including the time around the emergence of life ~4 Ga [e.g., 1], as well as the larger bombardment history of the inner Solar System. The Nectaris and Crisium basins, in particular, are important anchor points in understanding this history, and dating their formation times is thus a priority. Toward this end, Spudis and Sliz [2] mapped 10 locations of putative impact melt outcrops (high-standing kipukas embayed by mare basalt flows) around the periphery of Mare Crisium. If these outcrops are impact melt from Crisium, they provide an opportunity to measure the crater size-frequency distribution (CSFD) and derive absolute model ages (AMAs) for the Crisium-forming impact event [e.g., 3]; future in situ measurements or returned samples would provide an absolute age and important constraints for lunar chronology [1].

Here, we present high-resolution mapping (~1:50,000) of these proposed Crisium impact melt sites identified by Spudis and Sliz [2], describe relevant regional geology, and further assess their likely origin(s).

Methods: Our data sets include the global Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) monochrome basemap (100 m/px); both low and high incidence angle LROC Narrow Angle Camera (NAC) images (~1 m/px); a WAC color ratio composite mosaic [4]; the combined 59 m/px global Digital Elevation Model (DEM) from the Lunar Orbiter Laser Altimeter (LOLA) and Kaguya Terrain Camera (TC); and a photometrically normalized high-sun WAC mosaic. Map projection for the DEM and NACs was done through the USGS's online Planetary Image LOcator Tool and Projection on the Web interfaces [5,6]. Using NAC images, the DEM, and the derived slope information, we mapped the boundaries of kipukas in Mare Crisium at a scale of 1:50,000 and somewhat finer in certain places (typically 1:15,000) in ArcMap. We mapped fracture dimensions using the LOLA/Kaguya DEM.

Results and Discussion: *Kipuka Mapping*. Examples of our kipuka mapping, refined from the work of Spudis and Sliz, are shown in Figure 1. Of the previously mapped ten deposits, we omit one located in far-eastern Crisium (15.5°N, 69.0°E), which apart from a field of secondary craters and herringbone ejecta, is essentially level, disqualifying it as a kipuka. This area also features occurrences of craters with low-reflectance ejecta, suggesting it may be a region of mare basalt covered with highland ejecta (i.e., cryptomare) [see also 3]. As described by Spudis and Sliz [2], the kipukas display a range of morphologies, from apparently domed and fractured (e.g., the western Crisium Kipuka, WCK, and an eastern Crisium kipuka, ECK) to more subdued and hilly, e.g., in the north (Figure 1).

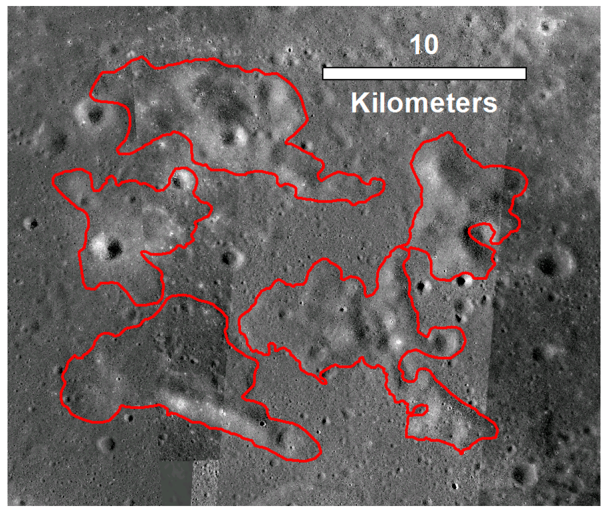

Figure 1. Refined mapping of the Northern Crisium kipukas (24.1°N, 61.2°E), outlined in red.

Composition. We examined high-resolution NAC images with low incidence angles to evaluate the reflectance properties of each of the mapped deposits. Spudis and Sliz [2] report that the kipukas, especially the WCK, have a depressed FeO content relative to the rest of Mare Crisium basalts (~8.3 vs. >15 wt% for the WCK), interpreted as evidence favoring a Crisium impact melt interpretation. Photometrically normalized high-sun imaging shows the WCK to be overprinted by highland ejecta from Proclus Crater to the west, suggesting the depressed FeO values may simply be a result of Proclus contamination (Figure 2). Impact craters superposed on both the WCK and surroundings also have low-reflectance ejecta, indicating a likely excavation of mare basalt from beneath Proclus ejecta (i.e., post-Crisium formation volcanic deposits, cryptomare), as opposed to melted feldspathic target rock (i.e. impact melt) (Figure 3). Reflectance values on the low-reflectance ejecta are 0.08, similar to surrounding mare, compared to > 0.1 for the rest of the WCK.

Fracture Morphometry. Some of the candidate melt sites mapped by Spudis and Sliz (WCK and ECK) exhibit fractures reminiscent of similar features in the Maunder Formation (MF) [2], the melt sheet of Orientale Basin [7]. However, fracturing is not unique to melt sheets, and floor fractured craters (FFCs) can have similarly morphologies [e.g., 8], thought to originate due to subcropping dikes, sills, and laccoliths [e.g., 9] that cause doming and fracturing of the surface. Initial measurements of fracture dimensions of the MF and kipuka fractures show MF fractures to be wider with more steeply-sloping walls (approaching 45˚). We continue to investigate morphometric comparisons between the Crisium deposits, the Maunder Formation, and FFCs.

Gravimetry. In the future, we will also analyze Bouguer gravity data to further aid in distinguishing between impact melt formation and possible intrusive magmatic origin [9] for the Crisium kipukas.

Conclusions: We find the strongest evidence for an impact melt origin for the northwestern and northern kipukas and the ECK first mapped by Spudis and Sliz [2] (18.0˚N, 50.5˚E; 19.4˚N, 51.5˚E; 24.0˚N, 61.4˚E). While not definitive, the morphology and composition of these kipukas, as interpreted through analysis of high-resolution NAC images (both low- and high-Sun), as well as their locations within the basin, are consistent with an impact melt origin, concordant with the work of Spudis and Sliz [2]. At the WCK, the identification of numerous superposed impact craters with low-reflectance ejecta suggests that this deposit is basaltic in nature and has been masked by Proclus ejecta. The basaltic composition suggests the WCK may represent early volcanism within Crisium, uplifted in a manner similar to FFCs, rather than as impact melt. Even in the conservative scenario in which the kipukas result from post-Crisium volcanics (especially the WCK), they are still stratigraphically lower than the maria [10] and can thus provide a lower limit on the age of the Crisium-forming impact [3].

Because the connections between Luna and Apollo 17 samples and a Crisium origin are not clear [3], sample return or in situ radiometric dating will be needed to definitively determine the basin's age. This underscores the need for a rigorous lunar surface exploration program to tightly constrain the impact history of the Moon, and, by extension, that of Earth. A future lander could be sent to the northern or northwestern Crisium kipukas to perform in situ age dating [1] or return samples; geologic field work could provide further context and understanding of their origin.

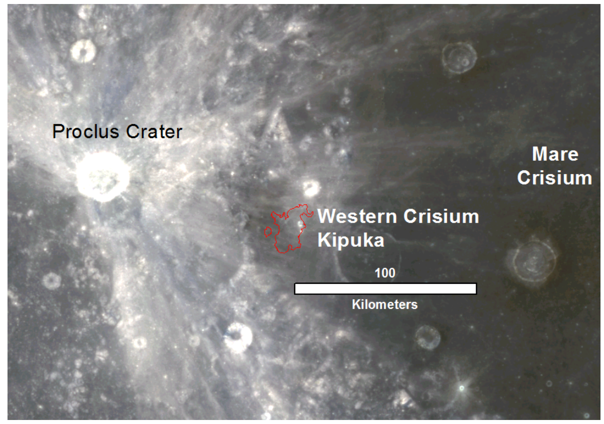

Figure 2. High-Sun photometrically normalized WAC mosaic showing highlands ejecta from Proclus Crater overprinting the WCK (centered at 15.0˚N, 50.3˚E).

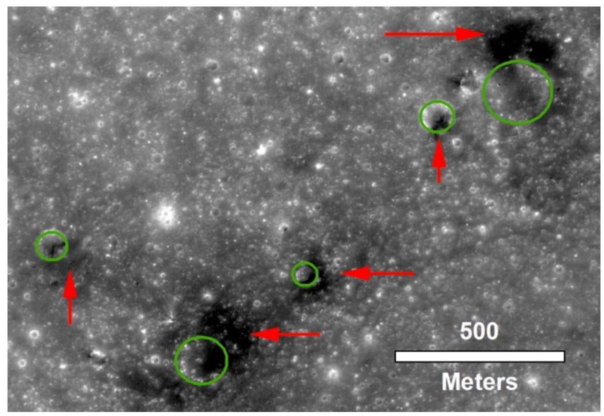

Figure 3. Example of impact craters (green circles) with low-reflectance ejecta (red arrows) found on the WCK (15.48˚N, 50.35˚E), interpreted as excavating basaltic material from beneath a surficial deposit of highland material. This interpretation is consistent with a mode of formation similar to that of floor-fractured craters for the WCK.

References:
[1] Cohen, B.A. et al. (2018) LPSC, this conference.
[2] Spudis, P.D. and Sliz, M.U. (2017) GRL, 44, 1260–1265, doi:10.1002/2016GL071429.
[3] van der Bogert, C.H. et al. (2018) LPSC, 1028, this conference.
[4] Denevi, B.W. et al. (2014) JGR: Planets, 119, 976–997, doi:10.1002/2013JE004527.
[5] Bailen, M.S. et al. (2013), 44th LPSC, Abstract #2246.
[6] Hare, T.M. et al. (2013), 44th LPSC, Abstract #2068.
[7] McCauley, J.F. (1977) Physics of the Earth and Planetary Interiors, 15, 2-3, 220-250, doi:https://doi.org/10.1016/0031-9201(77)90033-4.
[8] Jozwiak, L.M. et al. (2015) Icarus, 248, 424-447, doi: http://dx.doi.org/10.1016/j.icarus.2014.10.052.
[9] Jozwiak, L.M. et al. (2017) Icarus, 283, 224-231, doi: http://dx.doi.org/10.1016/j.icarus.2016.04.020.
[10] Hiesinger, H., van der Bogert, C.H., Reiss, D., Robinson, M.S. (2011), LPSC Abstract #2179.