GEOMORPHOLOGIC SKETCH MAPPING OF A FRESH LUNAR CRATER EIMMART A.

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Introduction: Eimmart A (24.1°N, 65.7°E) is a 7.3 km-diameter simple crater on the NE rim of the Crisium basin (Fig. 1). It caught the eye of the infamous “observer” of lunar “changes”, W. H. Pickering, in 1913 [1]. Later it was being considered a potential source of the first known lunar meteorite ALHA 81005 [2–5], and spectral studies showed that Eimmart A exhibits the strongest 1 μm absorption feature observed on the Moon [3–5]. Thus, Eimmart A has amassed more interest than its size would suggest. This is due to its remarkable freshness. Indeed, no primary impact craters postdating Eimmart A have been identified in LRO NAC (Lunar Reconnaissance Orbiter Narrow Angle Camera) images inside the crater [6]. Here, we present the main results of geomorphologic sketch mapping of this unique crater, and discuss the opportunities it presents for lunar exploration and sample return.

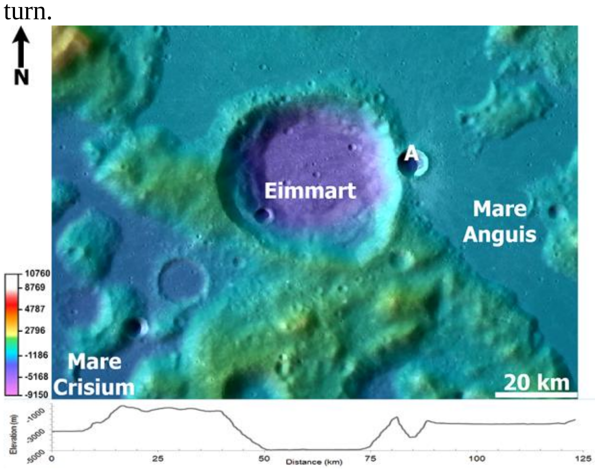


Fig. 1. Eimmart region on the NE rim of the Crisium basin. LRO WAC mosaic, digital terrain model (GLD100) and W–E-topographic profile from ASU/LROC/QuickMap.

Data and methods: The primary data sets were LRO NACs, accompanied by LRO wide angle camera (WAC) and Kaguya terrain camera images. In addition, digital elevation models created from NAC stereo pairs were used, accompanied by LRO Diviner radiometer Christiansen feature and rock abundance data.

Geology: The most relevant geologic events of Eimmart A region include the formation of Crisium basin during the Nectarian [7–9], followed by the formation of Eimmart, also during the Nectarian [10]. The surrounding Mare Anguis basalts are dated Imbrian and/or Eratosthenian [10]. Finally, Eimmart A impact occurred late in the Copernican [6, 10].

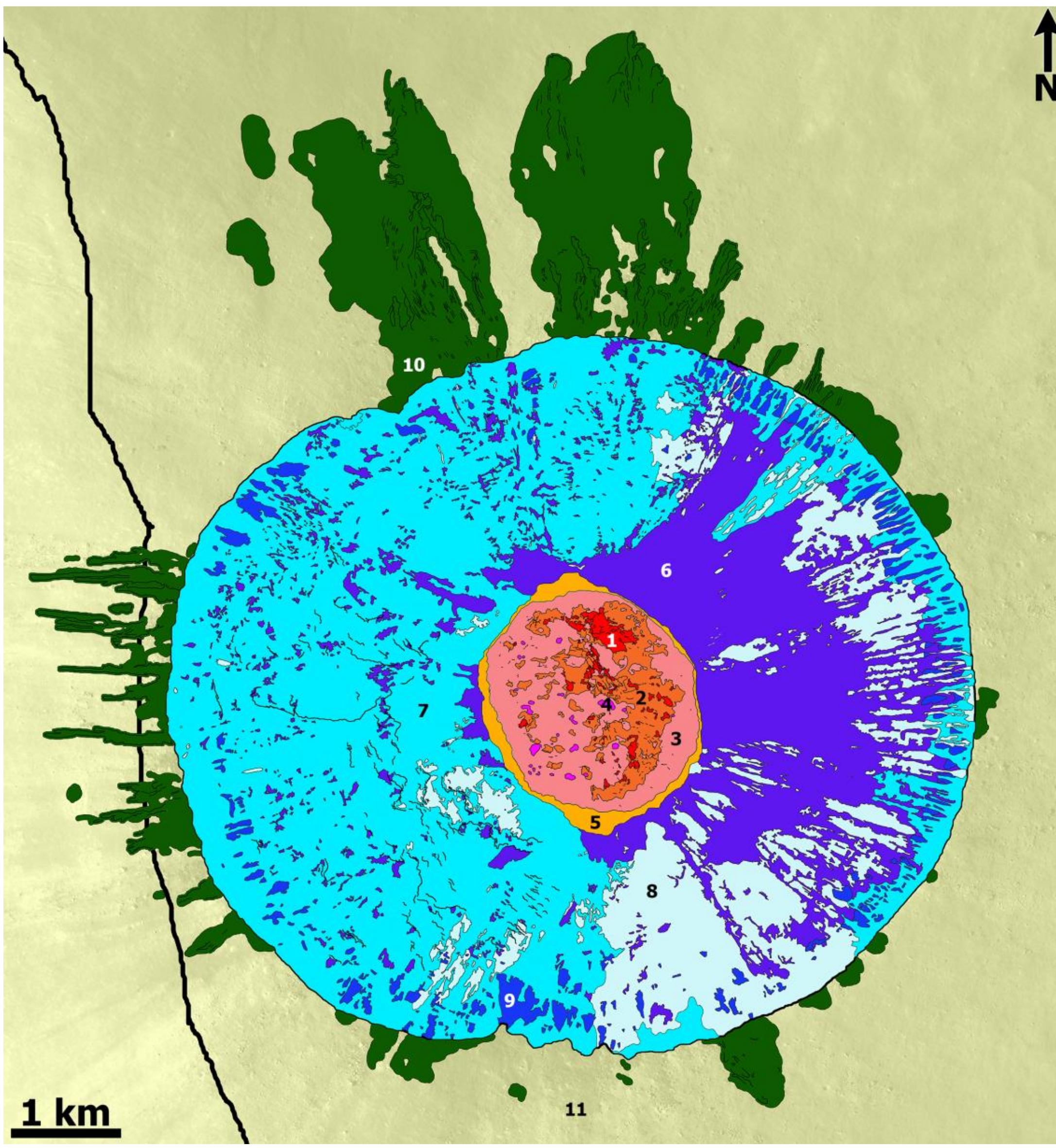
Geologic sketch mapping (Fig. 2) shows that E/W- and N/S-asymmetries are among the most notable features of Eimmart A. On the crater floor, impact melt-rich material (units 1 & 2) is concentrated on the E floor (downslope; see Fig. 1). However, ejected melt flows and ponds (unit 10) are abundant on the N and W flanks but virtually absent in the S and E, which is not readily explained by topography. Lobate, overlapping features imply presence of impact melt also on the W wall. The melt-poor S flank has substantially higher rock abundance than the rest of the flank. Dark wall material (unit 6) is found extensively on the E wall, but it is patchy elsewhere. The dark material is likely basalts of Mare Anguis that were excavated by the Eimmart A impact, while the W intermediate wall material is less mafic highland material brought to the surface by the Crisium and Eimmart impacts.

On the S rim and uppermost wall there is a remarkably massive outcrop (marked by unit number 9 in Fig. 2) protruding >600 m towards the crater center. This is larger than any outcrop we have seen on lunar craters in this size range. The outcrop may be composed of more competent rock than the surroundings, but its preservation may also be merely a reflection of the crater’s youthful age.

Exploration potential: Although lacking the well-known lure of the polar regions and not being able to provide answers to as many key questions as, e.g., Schrödinger crater [11], Eimmart A provides some interesting possibilities for lunar exploration. Dating its impact melt would give an important end point for the ages of the youngest large craters, crucial for estimating the Copernican impact flux. Being located on the rim of Eimmart, which is located on the rim of Crisium basin, Eimmart A sample suite would likely contain materials that could provide an age estimate for the Crisium basin formation. Crisium’s age is currently poorly constrained based on impact melt clasts in the small Luna 20 sample [7–9]. Mare Anguis basalts are excavated by the Eimmart A impact, so even stationary sampling on Eimmart A’s E rim could provide materials from previously unsampled basalt units. Eimmart A’s eastern, near-equatorial location would be suitable for a relatively low-cost sample-return mission, particularly one launched from the Earth’s eastern hemisphere (cf. Luna 20 and 24).

Summary and conclusions: 1) Factors other than pre-existing topography control the distribution of impact melt ejected around Eimmart A. 2) Melt distribution on the crater floor, however, is controlled by topography. 3) Mare Anguis basalts are excavated on the E wall. 4) Sampling Eimmart A would, among other benefits, be likely to provide the age of one of the youngest km-scale Copernican craters and one of the major Nectarian basins (currently poorly known Crisium), thus clarifying the impact flux through much of the lunar history.

References: [1] Pickering W. H. (1914), *Astronomische Nachrichten*, *196*, 413–418. [2] Treiman A. H. and Drake M. J. (1983), *GRL*, *10*, 783–786. [3] Pieters C. M. (1986), *Rev. Geoph.*, *24*, 557–578. [4] Pieters C. M. (1993), in Pieters C. and Englert P. (Eds.): *Remote Geochemical Analysis*, 309–339, Cambridge Univ. Press. [5] Blewett D. T. et al. (1995), *GRL*, *22*, 3059–3062. [6] Johnson K. E. and Kramer G. Y. (2014) *LPS XLV*, Abstract #2725. [7] Wilhelms D. E. (1987) *The Geologic History of the Moon*, USGS Prof. Paper 1348. [8] Swindle T. D. et al. (1991), *PLPSC*, *21*, 167–181. [9] Spudis P. D. (1993), *The Geology of Multi-Ring Impact Basins*, Cambridge Univ. Press. [10] Casella C. J. and Binder A. B. (1972), *Geologic Map of the Cleomedes Quadrangle of the Moon.* Map I-707 (LAC 44), USGS. [11] Potts N. J. et al. (2015), *Adv. Space Res.*, *55*, 1241–1254.



Map units
1: Smooth floor A. Dark, fractured, smooth. → Clast-poor impact melt rock. *2: Smooth floor B.* Dark, fractured, fairly smooth. → Clast-poor impact melt rock, more clasts and/or thinner than A. *3: Hummocky floor.* Brighter, few fractures. → Clast-rich impact melt rock. *4: Bright floor.* Bright small domes. → Very large breccia clasts not covered by melt. *5: Boulder ring.* Boulders between wall and floor. → Coarse talus. *6: Dark wall.* Streaky, dark. → Mixed talus, including mare basalts. *7: Intermediate wall.* Medium brightness, streaky, lobate features in W. → Mixed talus, probable impact melt lobes in W. *8: Bright wall.* Streaky, bright. → Freshest and/or least mafic talus. *9: Outcrops.* Wedge-shaped "bumps" near rim crest. → Exposures of bedrock. *10: Veneer, ponds, flows.* Dark, smooth, fractured. → Clast-poor impact melt rock. *11: Bright ejecta.* Rough, bright. → Continuous impact melt-poor ejecta.

Fig. 2. A geomorphologic sketch map of Eimmart A, based mostly on LRO NAC images M152451994LE & RE, M152445210LE & RE, M174841114LE & RE, M1098408548LE & RE and M192532183RE in simple cylindrical projection. Thick black line marks Eimmart's eastern rim crest. Black lines on W wall denote lobate features, likely caused by impact melt flows. Black lines on the floor denote cooling fractures, and black lines on the flanks (on unit 10) denote distinct flow features.