DISTRIBUTION AND ORIGIN OF IMBRIUM EJECTA IN THE CLEOMEDES QUADRANGLE, NORTH AND NORTHWEST CRISIUM BASIN.

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Introduction: High-resolution LROC and LOLA imagery reveals a variety of Imbrium ejecta features on the northwest and north margins of the Crisium Basin. More than 70 of these ejecta features, which include radial valleys, asymmetric secondary craters, and crater chains, in order of decreasing abundance, are recognized and portrayed on a modified version of the geologic map of the Cleomedes Quadrangle (Fig. 1) [1]. Although ejecta on the northwest and north margins of the basin are dominated by southeast-trending Imbrian-age ejecta, north- and northeast-trending Crisium ejecta of Nectarian age are also present [2, 3]. In contrast, Serenitatis ejecta are confined primarily to limited areas ~200 km east and southeast of the Serenitatis Basin, where dominant ejecta are also Imbrian in age [3, 4, 5].

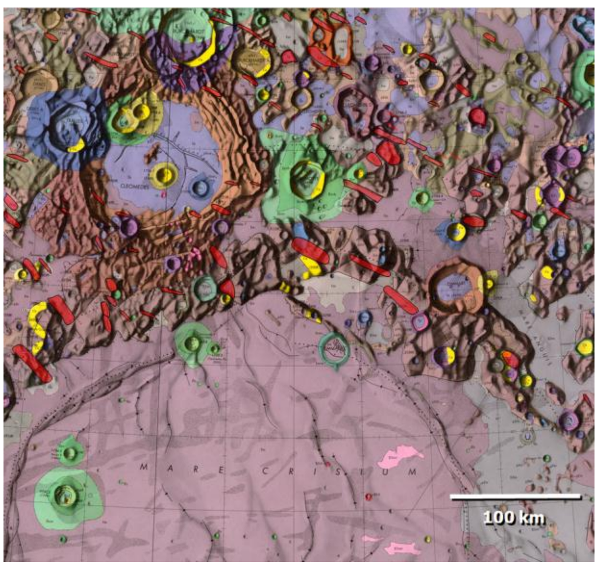

Figure 1. Imbrium ejecta (red) superimposed on main part of geologic map of the Cleomedes Quadrangle [1]. Crisium ejecta not shown are mapped in [2, 3].

Radial Valleys: Southeast-trending radial valleys on the northwest and north margins of the Nectarian-age Crisium Basin [6] are part of an extensive Imbrium ejecta field with a dominant orientation of azimuth 245 (azimuth 0 defined as due north). This ejecta field extends from the east rim of the Imbrium Basin to at least 500 km northeast of the northeast rim of the Crisium Basin [3]. These radial valleys range in scale from long (>30-km) and wide (5-km) basalt-flooded valleys that impinge on the north rim of the Crisium Basin (for example, the radial valley east of the crater Delmotte), to narrow, subparallel scours 5 to 10 km long and <2 km wide (Fig. 2).

Asymmetric Secondary Craters: Asymmetric secondary craters, typically 15 to 20 km long, occur within Imbrium ejecta fields on the margins of the Crisium Basin (Fig. 2). They are shallow floored (commonly <1.5 km deep) with many, such as Eimmart TB (Fig. 3), being teardrop or acorn shaped and elongate, reflecting low-angle impacts. Similar morphologies for low-angle impacts have been demonstrated experimentally [7, 8]. The trajectory and source area of asymmetric secondary craters are inferred from the orientation of their teardrop-shaped and tapering rims, which point away from the basin center. Minor asymmetry also occurs in small-complex primary craters, which have been ascribed to postimpact rim subsidence [9, 10]. Asymmetric secondary craters are differentiated from these small-complex, primary craters by narrow rims and an absence of significant slumps [11, 12].

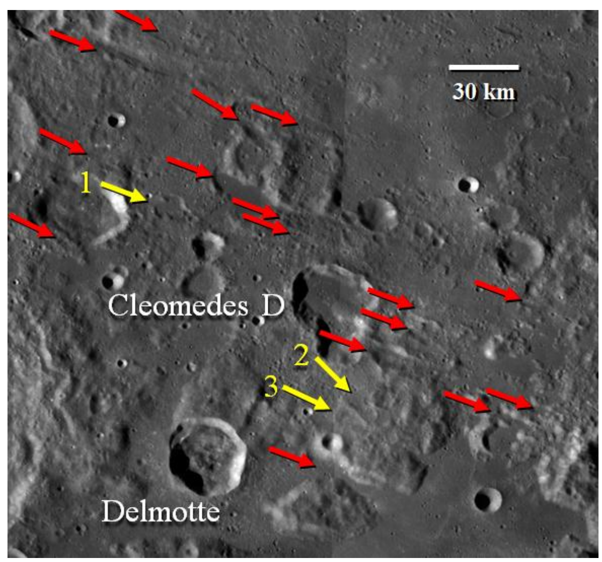

Figure 2. Imbrium ejecta northeast and east of Cleomedes. Radial valleys are red, and selected asymmetric secondary craters 1–3 are yellow. Craters 2 and 3 also shown in Fig. 4. Photograph from LROC mosaic.

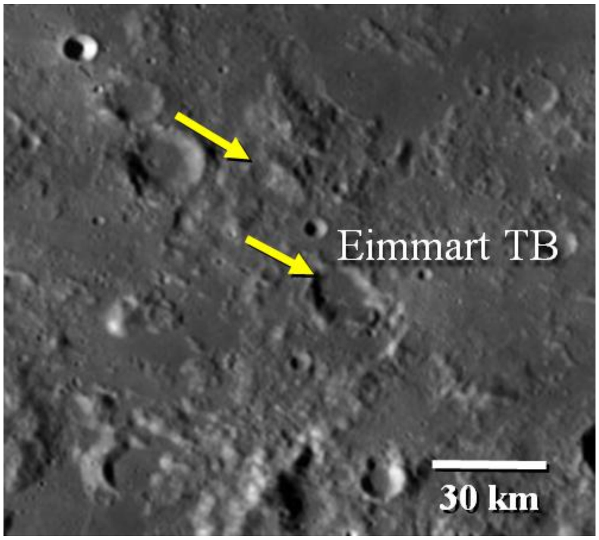

Figure 3. Imbrium asymmetric secondary craters Eimmart TB and unnamed crater to the northwest, indicated by yellow arrows. Photograph from LROC mosaic.

Chronostratigraphy: Radial valleys and asymmetric secondary craters associated with the Imbrium impact event can be used to refine the chronostratigraphy of surficial features on the northwest and north margins of the Crisium Basin, owing to overlapping relationships between ejecta and other terrain. For example, Cleomedes D, composed of two degraded and overlapping, low-relief craters northeast of Delmotte, has been interpreted as Imbrian in age [1]. However, a Nectarian interpretation may be more appropriate, owing to Cleomedes D being overlapped by multiple, southeast-trending and overlapping radial valleys (Fig. 2). In addition, the asymmetric secondary crater northwest of Cleomedes D (1 in Fig. 2) overlaps two types of terrain (Imbrian smooth terra material and Pre-Imbrian hilly terra material [1]), which together may be Pre-Imbrian (Nectarian?) in age, owing to these terra materials being overlapped by the same ejecta feature. In contrast, other Imbrium asymmetric secondary craters such as Eimmart TB (Fig. 3) have been correctly interpreted as Imbrian in age, although the smaller asymmetric crater northwest of Eimmart TB has not been previously differentiated from Pre-Imbrian rugged terra material [1]. A pair of asymmetric, shallow-floored craters southeast of Cleomedes D (Figs. 2 and 4), interpreted in this study as Imbrium secondary craters, overlap terrain previously mapped as both Imbrian and Pre-Imbrian in age (Fig. 4). Although asymmetric crater 3 in Fig. 4 was not recognized in the map of the Cleomedes Quadrangle [1], the outline of asymmetric crater 2, which overlaps Imbrian plains-forming and crater-floor material, as well as Pre-Imbrian rugged terra material, is clearly defined in the map. The outlines of other possible Imbrium secondary craters are suggested in many other areas in the Cleomedes Quadrangle [1], including a small (8 × 12 km), southeast-trending oval depression at 24.1ºN, 54.4ºE, overlapped by the Eratosthenian-age Cleomedes L, a simple, bowl-shaped crater south of Cleomedes. Although mapped originally as Pre-Imbrian (Nectarian) Cleomedes crater-rim materials [1, 6], this oval, shallow-floored crater is likely Imbrian in age, having no genetic relationship to Cleomedes.

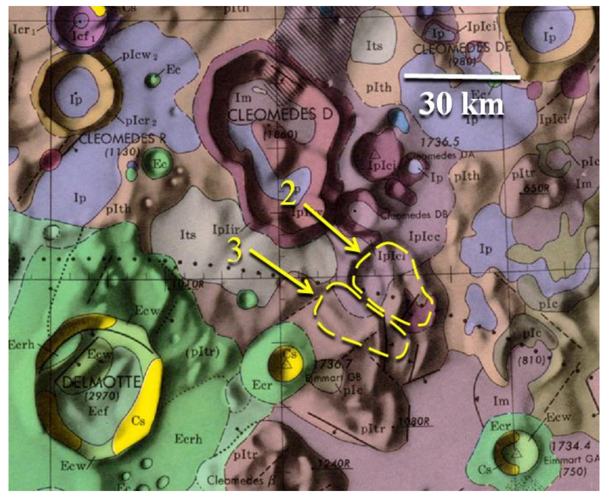

Figure 4. Imbrian-age asymmetric secondary craters southeast of Cleomedes D, indicated by dashed yellow lines. These secondary craters also shown in Fig. 2. Modified from map of Cleomedes Quadrangle [1].

References: [1] Casella C. J. and Binder A. B. (1972) *Geol. Map Cleomedes Quad.*, http://www.lpi.usra.edu/resources/mapcatalog/usgs/I707/. [2] Ambrose W. A. (2010) *LPS XLI*, Abstract #1061. [3] Ambrose W. A. (2012) *LPS XLIII*, Abstract #1048. [4] Spudis P. D. (2011) *LPS XLII*, Abstract #1365. [5] Spudis P. D. et al. (2011) *Jour. Geophys. Res., 116*, E00H03, 9 p. [6] Wilhelms D. E. (1987) *USGS Prof. Paper 1348*, 302 p. [7] Gault D. E. and Wedekind J. A. (1978) *LPS VIII*, 3843–3875. [8] Forsberg N. K. et al. (1998) *LPS XXIX*, Abstract #1691. [9] Melosh H. J. and Ivanov B. A. (1999) *Ann. Rev. Earth Planet. Sci. 27*, 385–415. [10] Melosh H. J. (1980) *Ann. Rev. Earth Planet. Sci. 8*, 65–91. [11] Clark M. (2006) *The Lunar Observer*, *June*, 4–10. [12] Ambrose W. A. (2008) *LPS XXXIX*, Abstract #1019.