DEPTH-DIAMETER RATIO OF CORINTO SECONDARY CRATERS. Ingrid J. Daubar[1], M. P. Golombek[1], A. S. McEwen[2], L. L Tornabene[3], F. J. Calef III[1], R. Fergason[4], R. Kirk[4], R. Beyer[5].
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Introduction: The rim-to-floor depth to diameter ratio (d/D) is commonly used to describe crater morphology: small, simple primary craters commonly have d/D~0.2 [e.g. [1,2] (but can be as low as ~0.1 for small craters in regolith [3,4]); while secondary craters commonly have d/D~0.1 [5–7]. However, some secondaries have been found to have d/D as high as 0.15-0.20, with an apparent positively correlated relationship with distance from the source crater (deeper secondaries farther away) [7,8]. Secondaries from the young rayed crater Corinto (13.9 km diameter, 141.72°E, 16.95°N) [6,9–11] extend all the way to the proposed InSight landing site region [12,13] ~800-850 km away (see also Fig. 1A in [14]) (Fig. 1A). These secondaries were investigated regarding any potential hazard to the InSight lander [15]: their morphology was studied in order to assess the possible presence of steep slopes. These data on Corinto secondaries can thus be used to test the relationship found by [7,8] between d/D and distance from the primary.

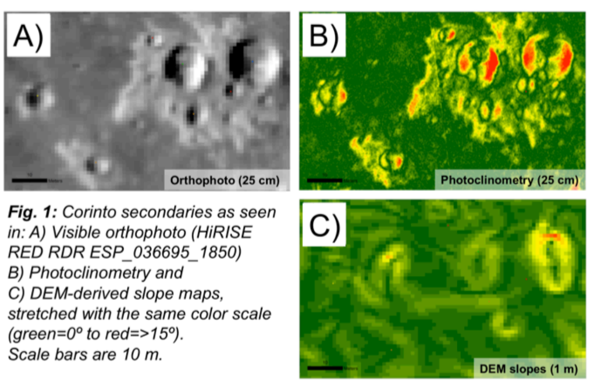

Fig. 1: *Corinto secondaries as seen in: A) Visible orthophoto (HiRISE RED RDR ESP_036695_1850) B) Photoclinometry and C) DEM-derived slope maps, stretched with the same color scale (green=0º to red=>15º). Scale bars are 10 m.*

Methods:

DEM profiles: We first measured d/D manually using profiles taken over HiRISE Digital Elevation Models (DEMs) (Fig. 1C). This method involved taking two transects each over 97 different craters located in different areas across the InSight landing site region. Profiles were taken across the highest rim points, at azimuths where craters appeared most well-resolved in elevation. This is typically in the roughly east-west direction, where the crater rim is most visible [16]. The highest points in the elevation profiles were manually identified and used as the location of the rim; their average elevation was taken as the rim height, thus minimizing regional slope effects. The difference between the average rim elevation and that of the lowest point between them was taken as the crater depth. Measurements were restricted to craters that could be confidently resolved in the DEMs, >~10 m diameter.

Automated script: To allow measurements over many more craters, an automated script was created in ArcGIS to use previously measured crater diameters. Those crater outlines were buffered outward radially by 3 m. Within that area, the difference between the highest and lowest points was taken to be the depth. There are obvious possible issues with this method that could yield erroneous measurements, including regional slopes and irregular crater shapes. However, it is an efficient way to gather statistics on large numbers (835) of these craters, and the results could be calibrated with the manual measurements described above. Considering the vertical precision of the DEMs used was ~0.1-0.5 m (calculated using the method of [17]), craters with diameters <~10 m were excluded, leaving 236 craters.

Photoclinometry profiles: To examine the Corinto secondaries at a finer spatial scale, we used photoclinometry slope data (25 cm/pixel) that had been tuned to match the DEM bulk slope statistics to account for haze effects [18] (Fig. 1B). Relative elevations were derived by integrating the slopes along profiles parallel to the illumination direction to capture the steepest slopes. These results were compared to DEM elevations (1 m/pixel), from which we derived 1 m slopes. A qualitative comparison between the photoclinometry data and DEM-derived slopes indicate that photoclinometry resolves craters <10 m diameter, a lower minimum D than DEMs (Fig. 1). Taking profiles over selected secondaries allowed us to quantify the resulting difference in measured d/D.

Results:

DEM profiles: The results of the manual DEM profile method gave an average d/D of 0.04 (Fig. 2A).

Automated script: The results of the automated script contained more scatter, but show an average d/D~0.06 with a mode ~0.04 (Fig. 2B). This average was slightly higher than that using the manual method, so we conclude that the script yielded a conservative estimate of the d/D of these craters on average.

Photoclinometry profiles: Using methods as described above to take profiles and measure the d/D, we calculated an average d/D for five craters of 0.052±0.0017 using photoclinometry, compared to

0.030±0.0041 using DEMs. Thus the photoclinometry yielded higher d/D than DEMs, as expected due to the higher resolution. However, the d/D values were still all very low (maximum 0.06).

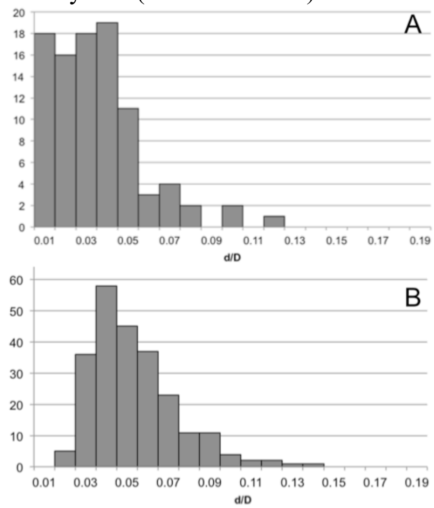

Fig. 2: *Histograms of depth to diameter ratio (d/D) values of Corinto secondaries as measured using manual DEM profiles (A) and an automated script (B).*

Discussion: The d/D values for Corinto secondaries, measured using three different methods, tend to be much lower than expected for secondary craters. This could be due to several reasons.

First, the craters could have been made shallower by processes of degradation and/or infill. Corinto is constrained to be older than Zunil (0.1-1 Ma) but younger than Cerberus lavas in the Western Lava Basin (2.5±0.5 Ma) [19 and references therein]. In the intervening time, it is possible that these secondaries have undergone significant degradation via erosion and/or infilling, although not enough to completely remove the bright ejecta. However, the secondaries are observed overlying eolian bedforms in the region, and there is little evidence of eolian fill inside the craters, other than very thin layers of dust.

Target material strength has also been shown to affect d/D [*e.g.*, 20], however no unusual strength properties have been detected in this area using the limited data available from remote sensing [15].

Another possibility is that the low d/D is related to a lower impact velocity. At a distance of ~850 km from the primary, these secondaries would be expected to have impacted at ~1.7 km/s using the range equation for a ballistic trajectory with a 45º ejection angle used by [21] and others. This is only somewhat farther and higher velocity than the maximum measured by [8], but we find d/D at this distance is ~4 times smaller than [8] found. So if impact velocity alone were determining the d/D, the velocity must have been lower than predicted by the standard ballistic equation. This perhaps could have been caused by deceleration in a thicker atmosphere or by entrainment in the originating primary ejecta curtain.

A lower impact velocity could also help explain the light-toned ejecta around these secondaries, which has been hypothesized to be indurated, low thermal inertia material such as sintered dust [6,19]. The bright ejecta around Corinto secondaries that is absent from nearby Zunil secondaries [19] indicates that something was different about the circumstances of impact in order to have caused this difference. It could be explained by differing impact velocities. This may have resulted in differing degrees of trapping and/or indurating material – material which could have been either pre-existing surface dust, or fines present in the ejecta cloud. Alternatively, a layer of surface dust could have been present at the time of the Corinto impact, which was later removed by the time of the Zunil impact.

Conclusions: Distal secondary craters located ~850 km from the primary Corinto crater have low depth/diameter ratios ~0.04-0.06. This is lower than typical for secondary craters, and lower than other fresh rayed craters' distal secondaries [8]. Unfortunately we cannot yet directly test the relationship with distance found by [8] because the required density of data (HiRISE coverage, derived DEMs, and photoclinometry) is currently only available at this location thanks to InSight landing site reconnaissance. However, given their remote distance of ~850 km from the primary, our results argue against increasing d/D with distance, at least in this case.

The morphology of Corinto's secondaries may also contain clues as to the formation of their bright ejecta. Both features may be related to lower than typical impact velocities, or a layer of dust present at the time of impact, sintered to form bright ejecta.

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