CORINTO: A YOUNG, EXTENSIVELY RAYED CRATER THAT PRODUCED A BILLION SECONDARIES ON MARS.

M. Golombek[1], S. Hibbard[1,2], C. Bloom[3], M. Deahn[4], N. Warner[5], N. Williams[1], I. J. Daubar[6], C. Hundal[6], A. Lagain[7,8], S. Piqueux[1], C. Edwards[9], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [2]Desert Research Institute, Reno, NV, [3]Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, [4]Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN, [5]Department of Geological Sciences, SUNY Geneseo, Geneseo, NY, [6]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RU, [7]Aix Marseille Univ., CNRS, IRD, INRA, CEREGE, Institut ORIGINES, Aix en Provence, France, [8]Space Science and Technology Centre, School of Earth and Planetary Science, Curtin University, Perth, Australia, [9]Department of Astronomy and Planetary Science, Northern Arizona University, Flagstaff, AZ

Introduction: Corinto crater is a fresh impact crater in Elysium Planitia that produced one of the most extensive systems of thermal rays and secondary craters on Mars, extending ~2000 km to the south and covering a nearly 180° arc on Mars. Orbital thermal and visible imaging datasets are used to describe the crater, ejecta blanket, four facies of rays and secondary craters, and to estimate the age of the impact and the total number of secondary craters.

Regional Setting: Corinto crater is located at 16.95°N, 141.72°E, approximately 500 km south-southwest on lava flows from the summit of Elysium Mons. The size-frequency distribution of 200 m to 1.3 km diameter craters on the volcanics indicates an Early Amazonian model age of ~1.7 Ga.

Crater and Ejecta Blanket: Corinto crater is a slightly elliptical ~13.9 km diameter, 1 km deep complex crater (Fig. 1). It has a sharp elevated rim, a steep interior slope, and elevated blocky terraces. The interior floor is covered by a large number of pits <200 m diameter arranged around a 2 km diameter, roughly 100 m deep central pit; none of these pits have elevated rims or obvious ejecta. The continuous ejecta blanket is asymmetric in planform and is lobate with a distinct raised rampart edge. The rampart ejecta suggests impact into water or ice [1] and the pits on the floor are consistent with subsurface drainage or degassing of ice rich target materials [2]. The slightly elliptical shape of the crater, the asymmetric shape of the continuous ejecta, the predominance of rays to the south, and the lack of rays or secondary craters to the north, are all consistent with a moderately oblique impact (30°-45°) [3] from the north-northeast.

Age: Counts of small primary craters on Corinto's continuous ejecta blanket indicate an impact age of 2.34±0.42 Ma (2-9 Ma) [4,5]. Secondary craters from Zunil are superposed on Corinto secondaries in the InSight landing ellipse indicating that Corinto is older than Zunil (0.39 Ma or 0.1-1 Ma) [4,5]. Corinto secondary craters are found on young volcanics in central Elysium Planitia, estimated to be 2.5±0.2 Ma [6] indicating Corinto is younger than these volcanics. Because the age of Corinto is similar to the recurrence interval for craters of this size on Mars (3 Myr), Corinto is likely the youngest crater of its size on Mars.

Rays: We have identified four ray facies (0-3) based on their thermophysical contrast, location, radial distance, and the size and morphology of secondary craters (Fig. 2). Of these, three facies are distinguished by the degree of thermophysical contrast, and two facies are distinguished by their crater and ray morphology

Facies 0 rays are composed of radial dense concentrations of low relief semi-circular or scalloped depressions/pits with subdued/indistinct rims with no obvious ejecta, and are similar to pits on the floor of the crater. They radiate from Corinto in all directions but are longest and densest to the southeast.

Facies 1a and 1b rays include irregular depressions similar to facies 0, but also include bowl-shaped secondary craters with raised rims, the outermost of which have distinct herringbone structure and begin to show thermophysical contrast with the surroundings.

Facies 2 rays are composed of dense clusters of sharp-crested, circular, bowl-shaped secondary craters with distinct light-toned lobate ejecta blankets. Facies 2 (and 3) rays have lower thermal inertia than background surfaces. Facies 2 rays are longer and wider and secondaries are generally larger (0.5-66 m) than facies 3 rays or secondaries, respectively, and show up prominently in CTX images.

Facies 3 rays are long and narrow with the greatest thermophysical contrast. They are composed of dense clusters of small (<30 m), fresh craters with distinctive bright, lobate ejecta blankets. They extend the farthest from Corinto (260 km to 1850 km) and show up in HiRISE images. The THEMIS thermal inertia of facies 3 rays is moderately

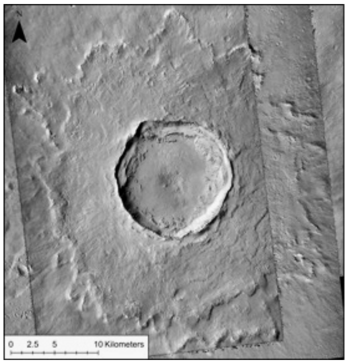

Fig. 1. CTX Mosaic of elliptical Corinto crater and asymmetric ejecta blanket.

low and corresponds to unconsolidated or poorly consolidated surface materials dominated by fine sand.

Factors Controlling Crater Rays and Secondary Crater Morphology. The observed variations in thermal rays and secondary crater morphology around Corinto are likely related to the impact velocity, size, and material properties of the ejecta and the physical properties of surface materials. The large number of secondary craters formed by Corinto are consistent with most of the ejected material being strong, competent basalt. The observed differences in ray facies and secondaries with distance from the crater likely result from variations in impact velocity and size of ejecta. Material properties of the impacted material are indicated by the presence of thermal rays on surfaces with moderate thermal inertia and moderate to moderately high albedo, arguing that thermal rays require cohesionless or poorly cohesive sandy surface materials or soils to form. The characteristic bright lobate ejecta of most facies 2 and 3 Corinto secondaries also likely requires sandy surface materials to form.

Number of Secondary Craters: To quantify the total number of secondary craters produced by Corinto, the size-frequency distribution of secondary craters within and in between the facies (i.e., zones) was characterized, the maximum size of secondaries with distance was determined, and the mapped area of the facies and zones was measured. We used a machine learning database of all craters measured in a global CTX image mosaic [4] to create size-frequency distributions of craters $\geq$25 m in diameter. We also measured the size-frequency distribution of secondaries in HiRISE images $\geq$5 m diameter.

We separated primary from secondary craters in the CTX database in 28, 100 km^2 samples (10 km by 10 km) from the mapped facies and adjacent zones with increasing distance from the crater rim. In sampled areas, the slope of the cumulative number of craters per km^2 is ~-4 at diameters <60 m and steepens to ~-5, approaching the slope measured in HiRISE images for smaller crater diameters (~-5). Using a plot of the 5 largest secondaries versus distance, we removed all larger craters in the CTX database in ten annuli defined to capture the different facies with distance mapped around Corinto. The cumulative number of craters >50 m diameter from the CTX distribution is extrapolated along a power law slope from HiRISE to estimate the cumulative number of craters $\geq$25 m, $\geq$15 m and $\geq$10 m diameter.

The cumulative number of craters $\geq$50 m diameter varies from 0.5/km^2 to ~9/km^2 and the power law slope varies from -4 to -7 among the different facies. The extrapolated cumulative number of craters were then multiplied by the total area in each facies and zone and then summed to estimate the total number of secondaries around Corinto. For a power law slope of -4.5 for all facies and zones, the total number of Corinto secondaries $\geq$10 m diameter is estimated to be ~2 billion.

For nine variations in slope and measured cumulative number of craters in each facies and zone, the total number of secondary craters around Corinto $\geq$10 m diameter varied from ~10^9 to $7\text{x}10^{10}$, with most estimates of the total number of secondary craters around Corinto $\geq$10 m diameter between 1.3 and 3 billion. This is factor of 10 times higher for $\geq$10 m diameter secondaries than estimated from crater counts in MOC images of Zunil (10.1 km diameter) [8]. Of order a billion secondaries is the largest number of secondaries yet estimated for a crater on Mars.

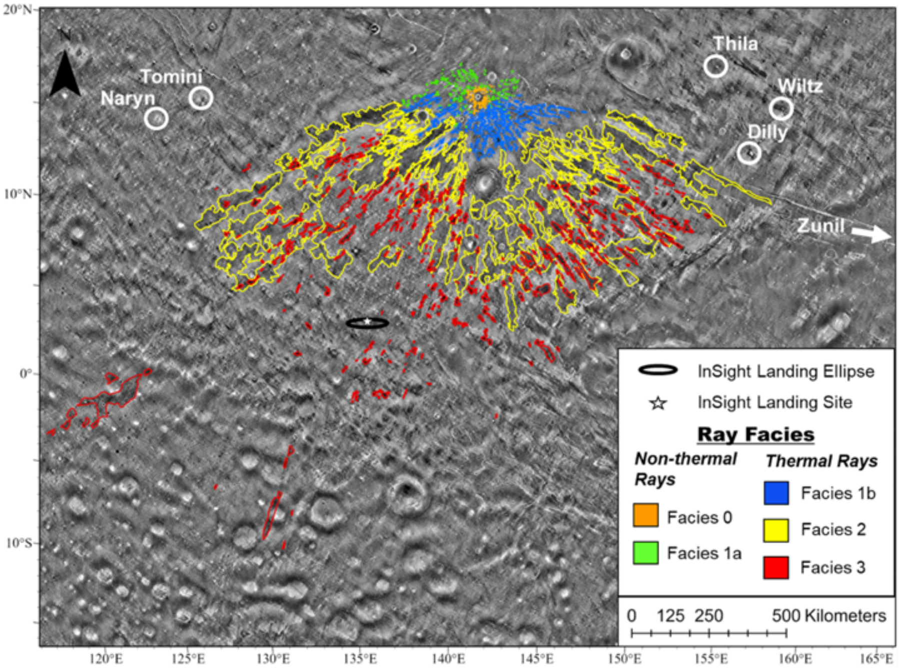

Fig. 2. Map of Corinto crater ray facies in Elysium Planitia on THEMIS nighttime infrared mosaic. Locations of other nearby young rayed craters [7] are identified with white circles or, pointed to for Zunil crater (white arrow).

References: [1] Carr M. et al. (1977) *JGR 82*. [2] Boyce J. et al. (2012) *Icarus, 221*. [3] Gault D. & J. Wedekind (1978) *PLPSC 9th*. [4] Lagain A. et al. (2021) *Nature Comm. 12, 6352*. [5] Hartmann W. et al. (2010) *Icarus, 208*. [6] Vaucher J., et al. (2009) *Icarus 204*. [7] Tornabene L. et al. (2006) *JGR, 111*. [8] Preblich B. et al. (2007), *JGR, 112*.