GASPRA'S CRATERS: IMPLICATIONS FOR PRODUCTION FUNCTIONS & SURFACE PROCESSES.
K. D. Runyon[1], O.S. Barnouin[2] [1]Johns Hopkins University Department of Earth & Planetary Sciences (kirby.runyon@jhuapl.edu); [2]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD.

Introduction: Measuring the size-frequency distribution (SFD) of impact craters on small asteroids may provide an opportunity to interrogate the small impactor population in a microgravity environment. "Contamination" from secondary craters [1] would be removed if modification by other known surface processes are not significant (e.g. seismic shaking [2]; slope failure). Using asteroids such as Gaspra as test plates, we can separate out the effects of small primary versus secondary cratering on major planetary bodies for crater diameters under 2km.

951 Gaspra, encountered by the *Galileo* spacecraft is an S-type asteroid in the inner Main Belt [3]. Gaspra's dimensions are 18.2 x 10.5 x 8.9 km with a mean radius of 6.1 km. [4]. Imaged at a best resolution of 54 m/pix [1], the imaged portions of Gaspra do not reveal a large crater that may have either deposited significant ejecta or resurfaced the asteroid. However, surface lineaments are visible [5], which, as on other asteroids, could indicate [6,7,8] a large individual crater on the un-imaged portion. Together with Gaspra's small craters and low self-gravity, impact ejecta and secondary craters should be absent. Gaspra's cratering record might therefore accurately record the impactor population of the inner Main Belt within the time constraints of Gaspra's surface age, although we cannot rule out that the small impactor population may be collisionally-evolved as ejecta from previous impacts [1].

This study re-visits the crater SFD on Gaspra by undertaking our own crater counts using the Small Body Mapping Tool (SBMT) developed at The Johns Hopkins University Applied Physics Laboratory (JHU/APL). We explore whether we can reproduce others' [1,9] SFDs and if a primary impactor population is indeed a reasonable assumption.

Methods: The SBMT was developed at APL [10] specifically to address the challenges of viewing and manipulating spatial data on irregularly-shaped bodies. SBMT allows users to map with polygons, circles and ellipses from PDS imagery draped over shape models. It thus offers easy and robust planetary GIS functionality. SBMT can also be used to improve the registration of individual images relative to an asteroid shape model, each other, and a basemap. This was required in the case of Gaspra images before our analysis could begin.

Two highest-resolution images from *Galileo's* Solid State Imaging System (SSI) were draped over a shape model of Gaspra [4]. Individual craters were mapped (Figure 1) within a polygon-defined search area. We measured 712 craters in 119.6 km^2.

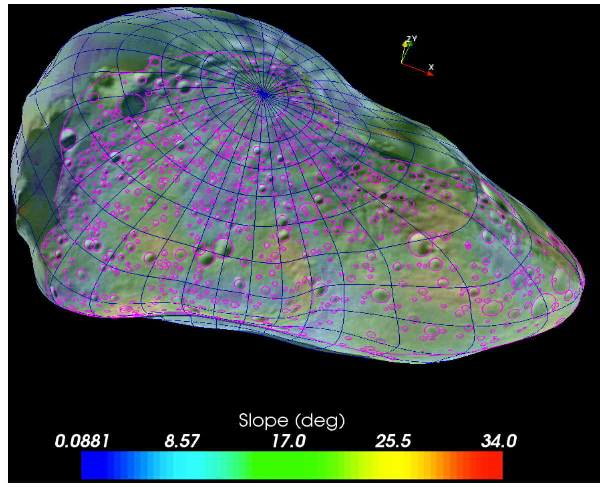

Figure 1. Images, craters (pink circles), search area (pink outline), and slope map overlaid on shape model in APL's SBMT. For scale, Gaspra is 18.2km long. The featureless area was not imaged at high resolution.

Results: Figure 2 shows the basic unbinned crater SFD. It also highlights the two domains for the crater SFD: the unambiguously linear "large" crater population and the rollover based on the limits of camera resolution. Figure 3 is an R-plot [11] indicating the degree of crater equilibrium and saturation showing craters around ~150 m in diameter to be near equilibrium. In the study, we use the R-plot equation of [12] as

$$R(D) = \frac{2^{3/4}}{-1+\sqrt{2}} D^2 \left[N - ND\sqrt{2}\right]$$

where N is the cumulative number of craters with diameter D or larger.

Our investigation shows smaller craters than previously reported. However, the rollover seen in Figure 2 indicates that craters <170m are probably not completely counted due to limitations of image resolution, and the SFD slope measured for these smaller craters is not meaningful.

Discussion: The -2.578 slope for craters larger than ~170m is slightly shallower than [3]'s value of -2.7, but it is within their uncertainty of ±0.5 despite their slope-fitting including only craters >400 m in diameter.

[1] estimated a crater retention age of Gaspra's surface of 210 Myr, indicating that a large impact event and seismicity likely reset the surface age by erasing craters. Surface age resetting impact events like this are estimated to occur every 550 Myr, indicating Gaspra's age is ~40% of its collisional lifetime [1].

Several sets of sublinear grooves cross the surface in several orientations suggesting faulting younger than the collisional lifetime. Experience from Eros [6], Vesta [7], and Lutetia [8] indicate that faults are usually the result of surface craters, which in the case of Gaspra may not be visible. These indicate that an unseen crater might have locally altered the crater SFD distribution of Gaspra. As a consequence, the -2.578 slope of the log-linear portion of Gaspra's SFD, which has been attributed to the production function of impactors in the inner Main Belt [1], may need to be considered with caution. A primary production function with a steeper slope than this could be a possibility, as suggested by [13].

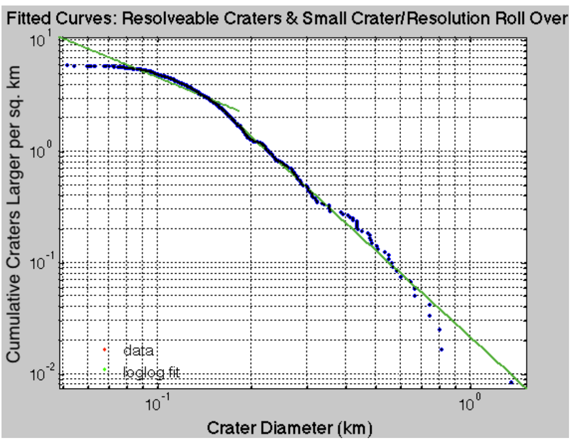

Figure 2. The small-crater rollover has a slope of ~-1.154 while the larger crater population follows a -2.578 (R^2 = 0.991) power law decay in agreement with Chapman et al.'s (1996) value of -2.6 and Belton et al.'s (1992) value of -2.7. All crater degradational states are included. Note the resolution-induced rollover is at $D \sim 170$ m.

Figure 3. R-plot for Gaspra, where the red line indicates small crater equilibrium (R = 0.22) and the green line indicates geometric saturation (R = 3.12) (Melosh, 2011). The only craters near equilibrium are those around $D \sim 150$m. Gaspra's R-plot is qualitatively similar to that of Mimas (Chapman et al., 1996), possibly indicating similar catastrophic age-resetting impacts across the solar system. The non-equilibrium of large craters may indicate a youthful surface, with implications for Gaspra's collisional evolution and history.

To evaluate such modification, we have begun to explore whether the crater distribution has been influenced by geologic processes. Qualitatively, no such correlations are immediately apparent (Figure 1). We will present more quantitative results of any such regional changes using [2]'s method for ascertaining the influence of Shoemaker Crater on Eros. We will search for any changes in crater distribution and size as a function of surface elevation, slope, gravity, and location to link to potential source craters.

Conclusion: We extended the crater counts on Gaspra to include craters as small as 50m, producing a SFD slope of -2.578, consistent with past studies. The R-plot (Figure 3) indicates possible crater equilibrium near 150m confirming the view that Gaspra's larger craters (>150m in diameter) are not significantly modified by subsequent cratering. So far, we see no evidence for modification of the smaller crater population as seen on other asteroids and so in general concur with current views that the SFD seen on Gaspra is representative of the crater production in the Main Asteroid Belt [e.g. 1]. However, we still plan to explore if a modification of the craters by surface processes can be identified using quantitative approaches used in other studies [e.g. 4].

References: **[1]** Chapman, C.R., Veverka, J., Belton, M.J.S., Neukum, G., Morrison, D., (1996) *Icarus*, 120, p. 231-245. **[2]** P. C. Thomas and M. S. Robinson, (2005) *Nature*, vol. 436, pp. 366–369. **[3]** Belton, M.J.S., et al., (1992) *Science*, 257, p. 1647-1652. **[4]** P. C. Thomas, J. Veverka, D. Simonelli, P. Helfenstein, B. Carcich, M. J. S. Belton, M. E. Davies, and C. R. Chapman, (1994) *Icarus*, vol. 107, p. 23. **[5]** J. Veverka, P. Thomas, D. Simonelli, M. J. S. Belton, M. Carr, C. Chapman, M. E. Davies, R. Greeley, R. Greenberg, and J. Head, (1994) *Icarus*, vol. 107, p. 72,. **[6]** D. L. Buczkowski, O. S. Barnouin, and L. M. Prockter, (2008) *Icarus*, vol. 193, pp. 39–52. **[7]** R. Jaumann, et al., (2012) *Science*, vol. 336, no. 6, pp. 687. **[8]** S. Besse, M. Kuppers, O. S. Barnouin, N. Thomas, and J. Benkhoff, (2014) *Planetary and Space Science*, pp. 1–10. **[9]** M. H. Carr, R. L. Kirk, A. McEwen, J. Veverka, P. C. Thomas, J. W. Head, and S. Murchie, (1994) *Icarus*, vol. 107, p. 61. **[10]** Kahn, E.G., Barnouin, O.S., Buczkowski, D.L., Ernst, C.M., Izenberg, N., Murchie, S., Prockter, L.M., (2011) LPSC 42, Abstract #1618. **[11]** Crater Analysis Techniques Working Group, R. E. Arvidson, et al., (1979) *Icarus*, vol. 37, p. 467. **[12]** Melosh, H.J., (2011) *Planetary Surface Processes*: Cambridge University Press, ISBN: 978-0-521-51418-7. **[13]** Neukum, G., Ivanov, B.A., Hartmann, W.K., (2001) *in* Chronology and Evolution of Mars, 96, p. 55-86.