Interpreting the small crater record of Tethys and the role of secondary craters. S. Ferguson[1], A.R. Rhoden[1], E. B. Bierhaus[2], [1] School of Earth & Space Exploration, Arizona State University, Tempe, AZ 85282 [2] Lockheed Martin Aerospace, Sierra.Ferguson@asu.edu

Introduction: We have mapped craters on Tethys in four regions that were imaged at high-resolution by the *Cassini* spacecraft [1]. Here, we assess whether and how secondary and sesquinary craters may be contributing to our crater counts, particularly in the region nearest to the Odysseus impact basin (R1). We use models of the formation of Odysseus that account for Tethys' low gravity to determine the likely spatial and size distribution of secondaries and sesquinaries. We then compare the predictions with our observations to determine whether the expected secondaries are present in our crater counts. Implications for the impactor flux and surface age of Tethys will also be discussed.

Background: Craters have been used for age dating of planetary surfaces throughout the solar system. For age dating, it is critical that counts include only primary craters (i.e. ones that form from a bolide impact onto the surface) and not secondary craters, though there different perspectives on measuring secondaries remain [e.g. Hartmann and Dauber 2017]. Secondaries are craters produced when debris that was excavated from the primary crater impacts the surface, creating an additional crater. On terrestrial planets like the Moon and Mars, some secondaries tend to form in chains that are near the primary crater and can be easily identified due to their proximity to the primary crater [3]; more distant and spatially random secondaries are harder to identify. Secondaries are kept out of the crater counts for age dating purposes because they are not a direct product of the initial bolide impact, and thus, do not record information about the impactor population and flux for that body. The presence of secondary craters can thus lead to inaccurate surface ages.

When looking at craters on low gravity bodies, secondaries can be distributed differently than on higher gravity bodies [4]. Icy moons like Tethys have a much lower escape velocity than say Mars (5.027 m/s vs 0.394 m/s on Tethys), increasing the amount of ejected mass that can reach greater ranges. In addition, debris fragments can be launched into orbit, re-impacting the body almost anywhere, and creating so-called sesquinary craters that are very challenging to distinguish from small primary craters [5]

The size of secondary craters is dependent on the diameter of the parent (primary) crater. The maximum diameter of a secondary crater is typically 5% of the parent crater diameter [2,6,7]. This relationship has been observed for the Moon, Mars, and Europa [2,3,4]. For the Odysseus impact basin, which has a diameter of 445 km, the maximum diameter of secondary craters (i.e. 5% of Odysseus' diameter) would be 22 km. Hence, the crater population below about 22 km should be contaminated by secondary craters from Odysseus. We would also expect regional differences at these sizes based on the proximity to Odysseus, although sesquinary craters (formed by ejecta launched into orbit) will complicate interpretations of the surface.

Methodology: We mapped and measured craters in four regions of Tethys, using Cassini ISS data [8]. We focused exclusively on regions that were imaged at higher resolution than the Tethys basemap in order to obtain information about smaller craters than were previously analyzed. The average resolution of our mosaicked images is 132m/pix which is high enough to resolve craters with diameters of 1 km and larger. The basemap used has a scale of 293 m/pix, which is not enough to resolve some of our smaller craters. Figure 1 shows the locations of the mosaics used for the mapping portion of this study. The mosaics are tied together using the Integrated Software for Imagers and Spectrometers (ISIS3) [9]. After the images are tied together, they are map projected and then mosaicked.

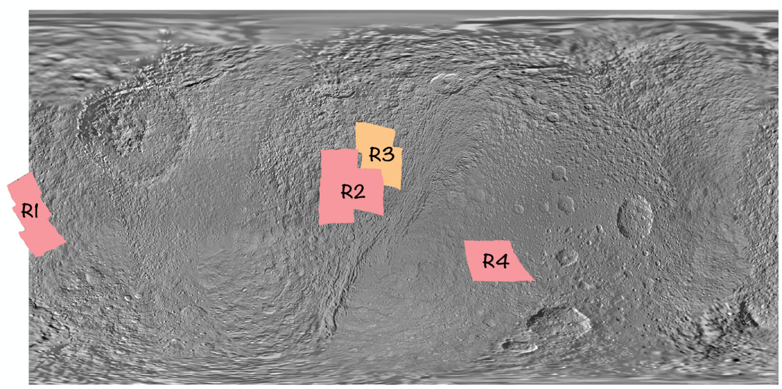

Figure 1. Mosaic locations on the Tethys globe.

To assess regional variability, and compare with the predictions of secondary crater formation we map features in four distinct regions. One is near the Odysseus impact basin, which we'll refer to as region 1 (R1), and the other is located on the other side of Ithaca Chasma, R2. Region 3 (R3) is located above region 2 (R2). Region 4 is located roughly antipodal to the Odysseys basin to investigate differences in the antipodal terrain.

Preliminary results: Table 1 shows the distribution of crater diameters in the mapped study regions. Based on this dataset, 99.3% of the craters we mapped have diameters below the 22 km cutoff for secondary craters from the Odysseus-forming event. We are currently comparing the populations in each region to the predictions of secondary and sesquinary crater formation to better constrain the impactor flux and surface age of Tethys. Figure 2 shows the crater size frequency diagram for the mapped regions. We do see an elevated population in R1, suggestive of secondaries, and continue to examine R2-4.

References:

[1] Ferguson, S.N et al. (2017), AGU Fall Meeting, Abstract 243922 [2] Hartmann and Daubar 2017. MAPS. V. 52, pp. 493-510. [3]Shoemaker, E.M. (1965), JPL Tech report ,in *The nature of the Lunar Surface,* No. 32-700, pp 23-77 [4] Bierhaus, E.B. et al. (2012), Icarus, 218, pp. 602-621 [5] Alvarellos et al. 2017. Icarus, v. 284, p. 70-89., [6] Bierhaus, E.B et al. (2001), *Icarus*, 153, pp 264-76 [7] Schultz P.H, Singer J. 1980, *Proc. Lunar Planet. Sci*. 11:2243–59 [8] Porco, C.C. et al. (2004), *Space Science Reviews*, 115, 363-497. [9] Anderson, J.A. et al. (2004), 35th LPSC , abstract 2039.

Diameter Bin (km)	**Region 1**	**Region 2**	**Region 3**	**Region 4**	**Total**
0-1	10	5	28	4	47
1-2	320	158	118	51	647
2-3	105	83	56	41	285
3-4	51	22	25	23	121
4-5	31	24	21	21	97
5-6	22	16	7	9	54
6-7	11	8	8	12	39
7-8	10	2	2	12	26
8-9	5	3	3	8	19
9-10	7	2	4	1	14
10+	14	13	10	10	47
Total	**586**	**336**	**282**	**202**	**1396**

Table 1. List of number of craters in diameter bins based on the mosaic maps.

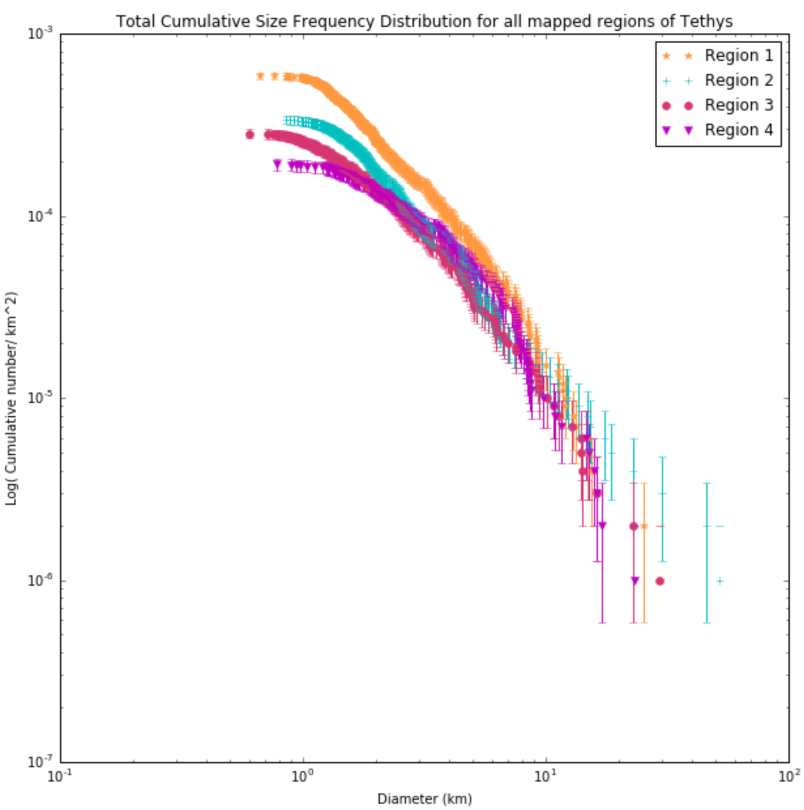

Figure 2. Cumulative size frequency distribution for our mapped regions of Tethys. Region one appears to have a distinct difference in impacts on the scale of ~1-4km.