PROGRESS ON A 1:2M GLOBAL GEOLOGIC MAP OF ENCELADUS. G. W. Patterson[1], G. C. Collins[2], M. J. Kinczyk[3], A. D. Patthoff[4], R. P. Perkins[1], R. T. Pappalardo[5], M. T. Bland[6], T. L. Becker[6], [1]The Johns Hopkins University/Applied Physics Laboratory, Laurel, MD (Wes.Patterson@jhuapl.edu), [2]Department of Physics and Astronomy, Wheaton College, Norton, MA, [3]Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695, [4]Planetary Science Institute, Tucson, AZ, [5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [5]U. S. Geological Survey, Astrogeology Science Center, Flagstaff AZ.

Introduction: The unusual geology of the Saturnian moon Enceladus was first recognized in images of the satellite returned by the Voyager spacecraft during their encounters with Saturn [1]. Those images revealed a surface with evidence of tectonic activity and episodic partial resurfacing [2] suggesting a geologic history that was remarkably complex for a moon with a mean radius of ~250 km. The Cassini mission to Saturn has provided a wealth of additional information regarding the diverse geology of Enceladus. Most notable has been the detection of an active plume containing water vapor, dust, and other materials erupting from fractures near its south pole [3, 4]. The fractures, along with the terrain that surround them, are bound by a circumpolar chain of south-facing scarps and confined mountain chains that together define a geologic province referred to as the South Polar Terrain (SPT) [3]. Analyses of this region have revolutionized our understanding of the evolution of icy satellite surfaces [e.g., 4-8]. However, Enceladus' SPT tells only the most recent part of the story of this unique icy body. The rest of the story is buried in and, to some extent, obscured by: 1) the complex geological relationships between the SPT and other recognized geologic provinces on Enceladus, 2) the distribution and density of observed craters on the surface, and 3) the distribution, orientations, and cross-cutting relationships of tectonic features across the surface of Enceladus.

Distinct geologic provinces on the leading and trailing hemispheres of Enceladus that share characteristics with the SPT have been recognized [cf. 9, 10]. Analyses of these provinces, and their relationship to each other, have provided insight into the thermal evolution of the satellite [11, 12], the potential for reorientation of its spin-pole axis [5, 6], and the potential for variability in the rheological and mechanical properties of its icy shell [7, 13]. The conclusions drawn from these analyses each provide a piece to the puzzle that represents the geologic history of Enceladus' surface. Understanding that history requires integrating these insights (and others) into a self-consistent picture of the surface evolution of this unusual moon. The most fundamental means of doing so is through geologic mapping.

Current Progress: The creation of a global geologic map requires a global image basemap, constructed with as robust a control network as possible. A global control network that includes 577 Cassini ISS images with a resolution better than 500 m/pixel and phase angle < 120° has been produced for this mapping effort. It includes image data in four filters: UV3 at 338 nm, green at 569 nm, clear at 651 nm, and IR3 at 930 nm. Tie points (control points) are distributed with sufficient density to ensure complete coverage across each image. Each tie-point ties together multiple images (i.e., "measures"), resulting in a combined network that consists of 10,362 tie points and 131,142 individual measures. Ninety percent of the tie points in the basemap have more than two measures (the minimum), and eighty percent have at least four. The average tie point has ~12 measures - a substantial increase over previous networks [e.g., 14]. The basemap now also includes high-quality images of Enceladus' north pole from the fall of 2015 and 2016, permitting truly global mapping of the satellite.

A global basemap that has a consistent image resolution, and that is geometrically constrained, provides an ideal dataset for compiling crater statistics of Enceladus. We have counted craters across the surface of the icy satellite down to diameters < 1 km and have used that data to create areal crater density maps using $N(D)$ measurements, where D is crater diameter [15] (similar to a previous crater density study) [16]. As with that study, we observe a dearth of large craters near the equator, with the number of craters increasing at progressively higher latitudes. This observation was noted in areal density maps where $D \geq 2$ km. A previously proposed explanation for this observation suggested a combination of burial and viscous relaxation of craters at these diameters [16]. However, these processes do not fully address the latitudinal dependence that we find of the crater size-frequency distributions of large craters. Our observations also revealed that an equatorial absence of craters is not present on the anti-Saturnian hemisphere where $D <$ 2 km. Further investigation will be necessary to explain this observation.

Previous work mapping the global geology of Ganymede has also shown that a global basemap that has a consistent image resolution, and that is geometrically constrained, is crucial for accurate structural mapping of the satellite surface [17, 18]. Current progress on the structural mapping of the surface of Enceladus has now includes the ancient cratered terrains and portions of the northern leading and trailing hemisperes.

The ancient cratered terrain of Enceladus stretches from the sub-Saturn hemisphere, over the north pole, to the anti-Saturn hemisphere. At least three generations of tectonic features cross-cut the ancient terrain. The most recent are open fractures and parallel, linear chains of pits that appear to be associated with deformation of the south polar terrain. The next oldest are apparent normal faults and graben-like structures that are perhaps associated with deformation of terrain in the leading and trailing hemispheres. The oldest tectonic features are subdued, widely-spaced ridges and troughs of unknown origin. Current mapping efforts are finalizing the locations and distribution of these features.

Structural mapping of the northern leading and trailing hemispheres has revealed a complex network of young ridges and fractures. On the trailing hemisphere, a series of dorsa, long (~50 km) and linear ridges, have been identified. Features similar to these are not found elsewhere on the satellite. Ridges of the leading hemisphere are similarly long (>50 km) but appear in a more inosculating pattern. Several groups have been identified based on ridges with similar orientations. Numerous fractures extending from the boundary of the SPT are found through both of these terrains [19].

References: [1] Smith, B.A., et al. (1982) *Science* 215, 504–537. [2] Squyres, S.W., et al. (1983) *Icarus* 53, 319–331. [3] Porco, C., et al. (2006) *Science* 311, 1393–1401. [4] Spencer, J.R., et al. (2006) *Science* 311, 1401–1405. [5] Nimmo, F. and Pappalardo, R.T. (2006) *Nature* 441, 614–616. [6] Collins, G.C. and Goodman, J.C. (2007) *Icarus* 189, 72–82. [7] Barr, A.C. (2008) *JGR* 113, doi: 10.1029/2008JE003114. [8] Patthoff, D.A. and Kattenhorn, S.A. (2011) *GRL* 38, doi:10.1029/2011GL048387. [9] Spencer, J.R., et al. (2009) *in* Saturn pp. 683–724, Springer, New York. [10] Crow-Willard, E. and Pappalardo, R.T. JGR 120, doi: 10.1002/2015JE004818. [11] Bland, M.T., et al. (2007) *Icarus* 192, 92–105. [12] Giese, B., et al. (2008) *GRL* 35, L24204. [13] O'Neill, C. and Nimmo, F. (2010) *Nature Geosci.* 3, 88-91, DOI:10.1038/NGEO731. [14] Roatsch, T. et al. (2013) *Planet. Space Sci., 77,* 118-125. [15] Kinczyk, M.J., et al. (2017) 48th LPSC, #2926. [16] Kirchoff, M. R. and Schenk, P. M. (2009) *Icarus, 202,* 656–668. [17] Patterson et al. (2010) Icarus 207, 845-867. [18] Collins et al. (2013) USGS Science Investigations Map Series #3237. [19] Patthoff et al. (2016) 47th LPSC #1772.