CRATER INDUCED FRACTURE REORIENTATION ON ENCELADUS. E. S. Martin and S. A. Kattenhorn, Department of Geological Sciences, University of Idaho, Moscow, ID 83844-3022, mart5652@vandals.udaho.edu, simkat@uidaho.edu.

Introduction: There are a variety of ways in which fractures disrupt craters on planetary surfaces (Fig. 1) including those on Ganymede [1], Venus, and Dione. The way in which fractures interact with impact craters on Enceladus however, appears to be a unique style of deformation in the solar system. On Enceladus, the mutually parallel trend of some fractures appears to change with increasing proximity to a crater, converging towards the crater in a somewhat radial pattern [2, 3, 4]. Fractures then cut through and continue beyond the crater, returning to the original orientation of the fracture set at some distance past the crater. Both simple and complex craters have been observed to perturb fractures [4,5]. There appears to be no dependence of fracture reorientation due to the relaxation state of the crater [4]. Fractures that experience reorientation by a crater appear relatively young, and many of them are pit chains, thought to be some of the youngest features on Enceladus [6].

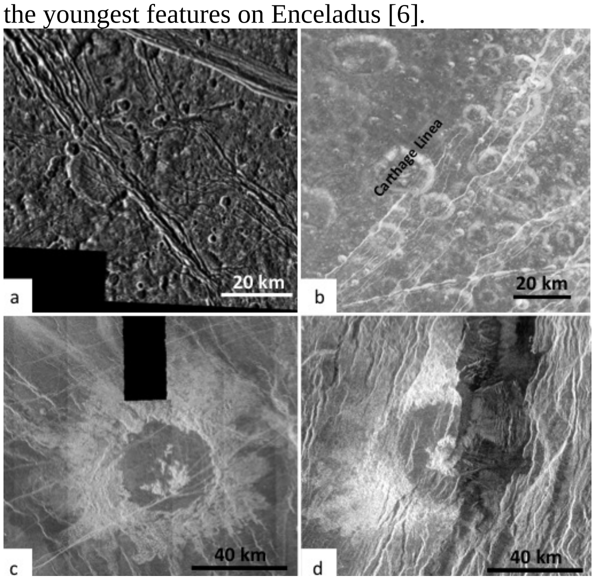

Figure 1: Crater-fracture interactions in the solar system. a) strained crater on Ganymede. Image No. G8GSANSHAR01. b) Craters disrupted by fault scarps. Image no. PIA07638 on Dione. c) Tubman crater, a heavily fractured crater on Venus. d) Balch crater, a greatly disrupted crater on Venus.

Several mechanisms have been proposed for crater-induced fracture reorientation [2,3,4]. Reorientation of fractures may be due to topographic loading by the crater rim [2]. This is not our favored mechanism, as we observe craters that perturb fracture growth over large distances, and rim topography may not be sufficient to influence local stresses at such a distance. Crater depth, controlled by relaxation, may play a role in frature orientation; only craters of a certain depth relative to the depth of the fracture may cause a fracture to reorient [4]. We explore the possibility of a source of internal pressure underneath the crater, such as thermally mobilized ice due to an impact, which would cause parallel fracture sets to reorient radially to the crater. Measuring the amount of reoirentation that has occurred, and the maximum distance at which a crater can reorient fractures, is necessary for further examination of this hypothesis.

Characterization of these interactions is important for understanding what is driving a crater's ability to reorient fractures. Understanding local heterogeneities of fracture and terrain types is also critical for gaining perspective on Enceladus's global geologic history.

Previously, [7] reported a possible crater size dependency on fracture reorientation. We present here continued analysis of fracture reorientations by presenting initial measurements of the change in average fracture orientation with increasing distance from the crater. We also introduce a new possibility that some apparently reoriented fractures are the result of intertwined fracture sets overprinting older craters which warrents further examination.

Radius of Influence: Craters of all sizes were found to reorient fractures; however, craters greater than 7 km in diameter in particular always reorient fractures [7]. It follows therefore, that larger craters might also influence fracture orientations at greater distances. It is also expected that average fracture orientation will converge on the orientation of the background fracture set with increasing distance from the crater. We refer to the maximum distance at which a crater influences fracture orientation as the Radius of Influence (Fig. 2).

Five craters previously determined by [7] to induce fracture reorientation were selected for preliminary analysis. 1 km long fracture segments within a single fracture set were mapped around each selected crater. Average fracture orientations were measured within buffer zones concentric about each crater at increasing distances scaled to crater size. For each of the five craters, there is no pattern of change in average fracture orientation with increasing distance from the crater. There is no constant change of azmith converging on the orientation of the background fracture set as initially hypothesized. An increased sample size of craters is needed to verify this result. Additionally, the average fracture orientation within each buffer zone must be compared with the average orientation of the background fracture set to determine the radius of influence for each crater.

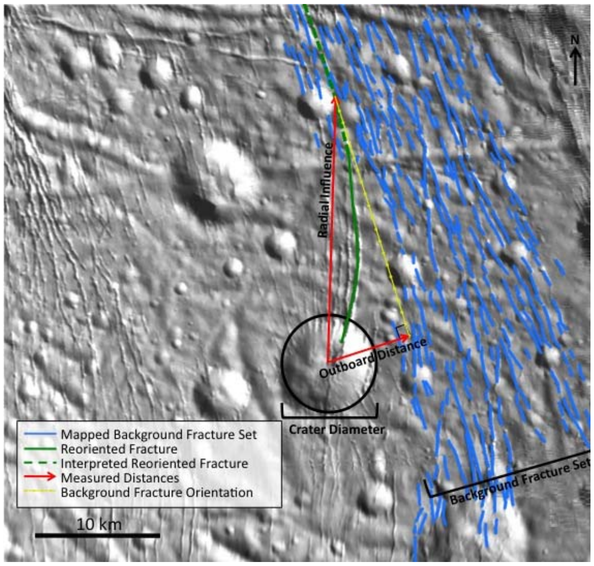

Figure 2: The spatial relationships between measured parameters. Image No. N1489050254 & N1489050409.

Detailed Fracture Mapping: Enceladus's cratered terrains, which are commonly overlooked as being extensively fractured, are dominated by fractures and pit chains that appear very young. Detailed fracture mapping has been carried out in a variety of locations within the cratered terrains (Fig. 3,4). Fractures are mapped based on crosscutting relationships, fracture orientation, and fracture morphology, resulting in identification of dominant fracture sets. In the absence of crosscutting relationships, fracture orientation and morphology become the next most important fracture characteristics used to determine which set a fracture belongs to. In the case of Fig. 3, it is possible that the apparently reoriented fractures are within two separate fracture sets that have formed after the crater. Fig. 4 shows a similar scenario but highlights the difficulties of fracture mapping. A fracture that appears to be reoriented towards the crater (arrowed), has no crosscutting relationships to help determine the set to which it belongs. Also, the fracture cannot be resolved to pass through the crater, and thus orientation and morphology are used to place it within the green fracture set. These fracture maps highlight the importance of measuring average fracture orientation within the same fracture set, but also brings to question crater-induced fracture reorientation in all apparent cases.

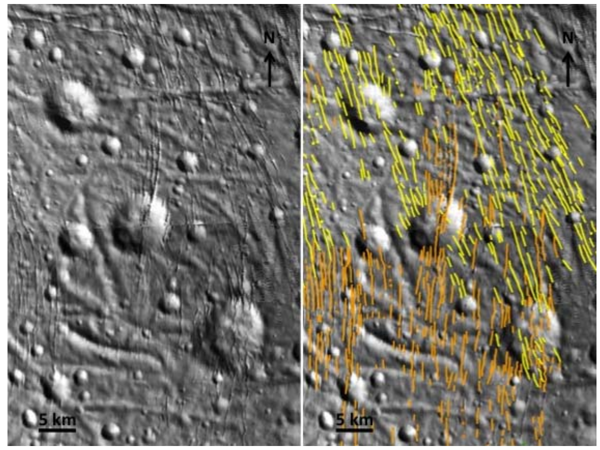

Figure 3: Fracture sets crosscutting an 8 km crater. Image No. N1489050254, N1489050442 centered at 2.7°N, 165.5°E.

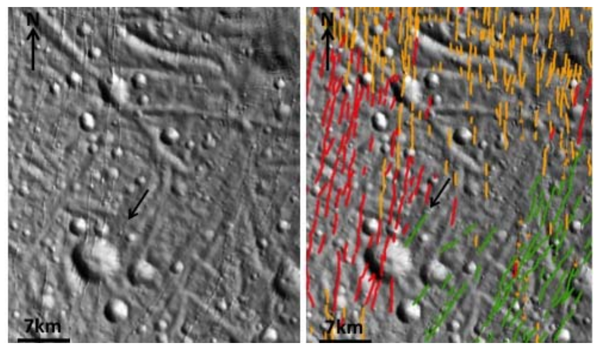

Figure 4: Fracture orientation and morphology are relied upon when crosscutting relationships are absent. The arrowed fracture was mapped based on orientation and morphology and so may not be a reoriented fracture in the red set. Image No. N1489050442 centered at -4.7°S, 161.9°E.

Discussion: Previous work by [7] determined reorientation by measuring the difference between fracture orientation and the average orientation of the background fracture set. We present here two examples where detailed fracture mapping suggests that fractures which have apparently undergone reorientation may belong to different fracture sets, which may postdate the crater. The inconclusive results from initial measurements of the radius of influence show that continued analysis is required.

References: [1] Pappalardo & Collins (2005) *J of Struc. Geol. 27*, 827-838. [2] Miller et al. (2007), *Ices, Oceans and Fire: LPI Contribution No. 1357*, p.95-96. [3] Barnash et al. (2006) *38th DPS* Abs. #24.06. [4] Bray et al. (2007) *38th LPSC*, Abs. #1873. [5] Kirchoff & Schenk (2009) *Icarus, 206*, 656-668. [6] Michaud et al. (2008) *39th LPSC* Abs. #1678. [7] Martin & Kattenhorn (2011), *42nd LPSC* Abs. #2666.

Acknowledgements: This work was funded by NASA OPR Grant #NNX08AQ94 and NESSF Grant #NNX11AP30H