# MEASURING TECTONIC STRAIN: FROM GANYMEDE TO ENCELADUS AND DIONE.

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**Introduction:** Many satellites of the outer solar system exhibit prominent tectonic features. These cracks, ridges, and other terrain features are indicative of a dynamic past that we wish to further understand. Strain measurement quantifies the magnitude of tectonic movement, and may be used for models of internal evolution. It is also a way to compare tectonic behavior among the icy satellites and terrestrial planets.

In previous work, we have used three different methods of strain measurement to understand the tectonics of Ganymede grooved terrain [1, 2]. For our current project, we are using the same tools we have developed on Ganymede to better understand the tectonics of two of the Saturnian satellites: Enceladus and Dione.

**Methods:** Accurate strain analysis depends on knowledge of the image geometry. The first step in any of our strain measurement methods is to process the images. For the Saturnian satellites, we have been processing available Cassini data through ISIS. We are searching for images at high resolution that exhibit impact craters cut by faults. By reprojecting the images into Lambert azimuthal projection, centered on the centers of cut craters, we can minimize the geometric distortion on the images that would compromise our measurements. There are three strain measurement methods that we will be using in parallel to estimate strain on Enceladus and Dione.

*Method 1: Split Craters:* If faults transect a pristine crater, they will distort the shape of the crater rim so that it is no longer a perfect circle. By comparing the shape of a deformed crater with that of a circle, one can calculate strain and therefore estimate the amount of stress caused by the faults. In the split crater method, the zone of faults that cuts the crater is narrower than the diameter of the crater, and as a result the crater will split apart so that there are two partial-circle segments remaining (Fig. 1). To calculate strain, we will measure approximately 10-20 points on the rims of each of these segments. We then feed this data into a circle fitting program that will approximate (by minimizing the error) the original rim shape for each half of the crater. Strain can then be derived by finding the difference in circle centers.

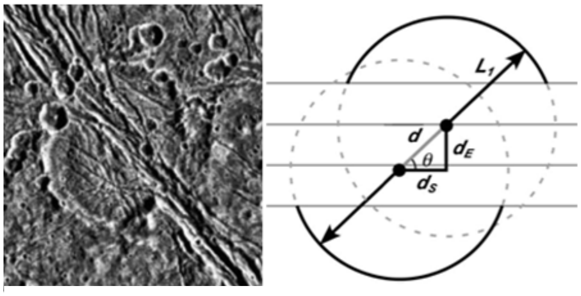

*Figure 1: An unnamed crater in Marius Regio on Ganymede demonstrates the split crater geometry that can be used for strain measurement [1]. This crater is 23 km in diameter and has undergone both extension and left-lateral shear. Methods 1 and 3 both estimate over 50% extensional strain in the fault zone that cuts this crater.*

*Method 2: Distributed Deformation:* If faults are distributed across the diameter of the crater, the rim will be stretched and take on the appearance of an ellipse (see Fig. 2). As in to the split crater method, 10-20 points along the crater rims will be recorded, but the data is then put into an ellipse-fitting program, which has more free parameters than the circle fitting program. Strain can be calculated from the ratio between the major and minor axes of each ellipse, as well as the orientation of the major axis.

Both methods 1 and 2 assume an initially circular geometry for the crater rim, which is a valid assumption for impactors striking the surface at more than a 10 degree angle [3]. However, for craters smaller than about 10 km in diameter on Ganymede, irregularities in the rim (probably from post-impact modification) become significant and cause too much error in the circle fitting routine [1].

*Method 3: Fault Geometry:* A method of strain estimation which is independent of any assumptions about crater geometry, instead looks at the fault geometry. If we assume that the faults cutting the craters are normal faults that cause grabens or tilt-blocking, we can measure the widths of the fault scarps. After correcting for the spacecraft look direction and making assumptions for the fault dip angle, we can calculate the extensional strain. It is important to note that this method can be applied to areas without faulted craters on Enceladus and Dione. The fault geometry method will be used as a check for our other two techniques in areas where craters are cut by faults. Checking strain measurements this way on Ganymede produced similar results, giving us confidence in all three of the methods outlined here. Inconsistencies between the fault geometry method and the two strained crater methods may arise due to secondary faulting or the difference in geometry between planar and listric faulting.

**Discussion:** With our strain measurements we will be able to place quantitative constraints on the tectonic histories of Enceladus and Dione. Our previous strain measurements on Ganymede have helped to determine a global strain value, which would be important in distinguishing between interior evolution models for the Saturnian satellites as well. It is important to be able to provide observational constraints for interior models such as those by Castillo *et al.* [4]. More broadly, the data may be used to compare tectonic features on other satellites in the outer solar system as a means of further understanding tectonic activity on these icy bodies.

At the meeting, we will be presenting the results of work performed during a summer internship to compare tectonic strain on Enceladus and Dione to the strain we have already measured on Ganymede.

**References:** [1] Pappalardo and Collins, *J. Struct. Geol.* (2005); [2] Michaud and Collins, *LPSC 38* (2007); [3] Gault and Wedekind, *Proc. 9 LPSC* (1978); [4] Castillo *et al.*, *LPSC 37* (2006).

**Acknowledgments:** This work is being supported by CDAP grant NNX07AJ70G to GCC and RTP, and the 2007 Caltech SURF program for RLM.

*Figure 2: Craters cut by extensional faults on Dione. The geometry of these craters and fault scarps are the subject of this summer's research.*