STUDIES OF VISCOUS RELAXATION OF CRATERS ON ENCELADUS. D. E. Smith[1], V. J. Bray[2], E. P. Turtle[3], H. J. Melosh[1], and J. E. Perry[1], [1]Department of Planetary Sciences, University of Arizona, 1629 E. University Blvd, Tucson, Arizona 85721-0092 (dsmith@lpl.arizona.edu), [2]Imperial College London, Exhibition Road, London, SW7 2AZ, United Kingdom, [3]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, Maryland 20723-6099.

Introduction: Enceladus' icy surface displays evidence of a wide range of diverse terrains and geologic processes including fractures, ridges, active plumes, and variable crater density [e.g., 1, 2]. Considering Enceladus' lack of radiogenic heating (~500 km in diameter) and low availability of tidal heating [1], this amount of geologic activity is somewhat mysterious. There are heavily cratered areas and others almost devoid of craters, and the craters display a range of morphologies including both relaxed and unrelaxed forms. In some areas both relaxed and unrelaxed craters are present together. Such a heterogeneous surface raises many questions into the nature of Enceladus' subsurface and rheology. By studying craters that have undergone different degrees of viscous relaxation and the distribution thereof, we can constrain Enceladus' subsurface rheologic and thermal properties.

Observations: The Imaging Science Subsystem (ISS) aboard the Cassini spacecraft has observed Enceladus many times during encounters with the satellite. These images have revealed diverse terrains of ridges, fractures, and both relaxed and unrelaxed craters on Enceladus' surface. It has also been observed that there is an active plume erupting from an obvious heat source at the South Pole [2]. The observed plume activity gives evidence that the South Pole is a currently geologically active region. This is supported by the general lack of craters in the South Polar Terrain (SPT), which indicates that the surface is relatively young. Such a strong heat source may have a profound effect on the relaxation of geologic features, and we indeed observe a lack of craters in the southern latitudes. Figure 1 shows a good demonstration of a group of unrelaxed craters around 42°N, 344°W. In contrast, Figure 2 illustrates an example of an impact crater that has undergone a large degree of relaxation.

Crater morphology over time is known to respond to local heatflow. Therefore, the study of the impact craters on Enceladus can reveal variations of heatflow based on the change in relaxation state with latitude (Figure 3). Figure 3 demonstrates how these relaxed craters are distributed over most of the surface of Enceladus. We observe that the number and extent of relaxed craters is higher in the southern latitudes as well as a general increasing trend in the relaxation state moving toward the south [3, 4].

Modeling: For a material that obeys a Newtonian rheology, viscosity is independent of the state of stress and its behavior can be represented analytically [5]. Analytic solutions can be derived by decomposition of the crater topography into J_0 Bessel functions to illustrate basic first-order evolution of crater topography as a result of viscous relaxation [4]. However, the nature of ice is non-Newtonian [e.g., 6], which means that the viscosity is actually stress dependent. Analytical modeling, although good to first order, fails in this regime [4]. To more accurately model Enceladus' icy lithosphere, it is necessary to explore numerical modeling of our problem. For this, we will use finite-element analysis to explore crater relaxation on Enceladus using Tekton, a finite-element analysis tool [7].

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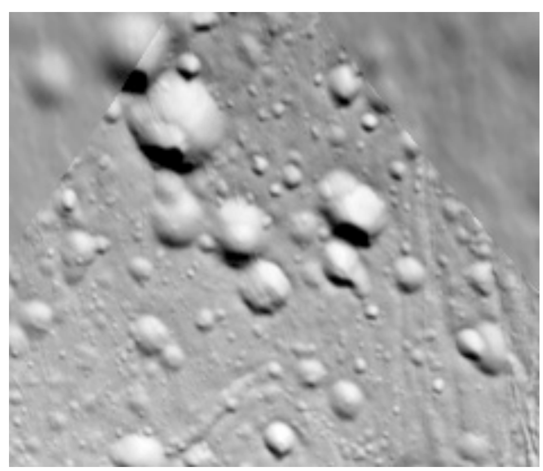

Figure 1. Group of unrelaxed craters in the northern latitudes centered at about 42°N, 344°W. The largest crater in this image is ~10 km in diameter. Relaxed craters are also present in the northern hemisphere, which is expected for old craters in ice that is warm enough to be mobile. These relaxed craters in the North represent somewhat larger and older craters when compared to craters in the South.

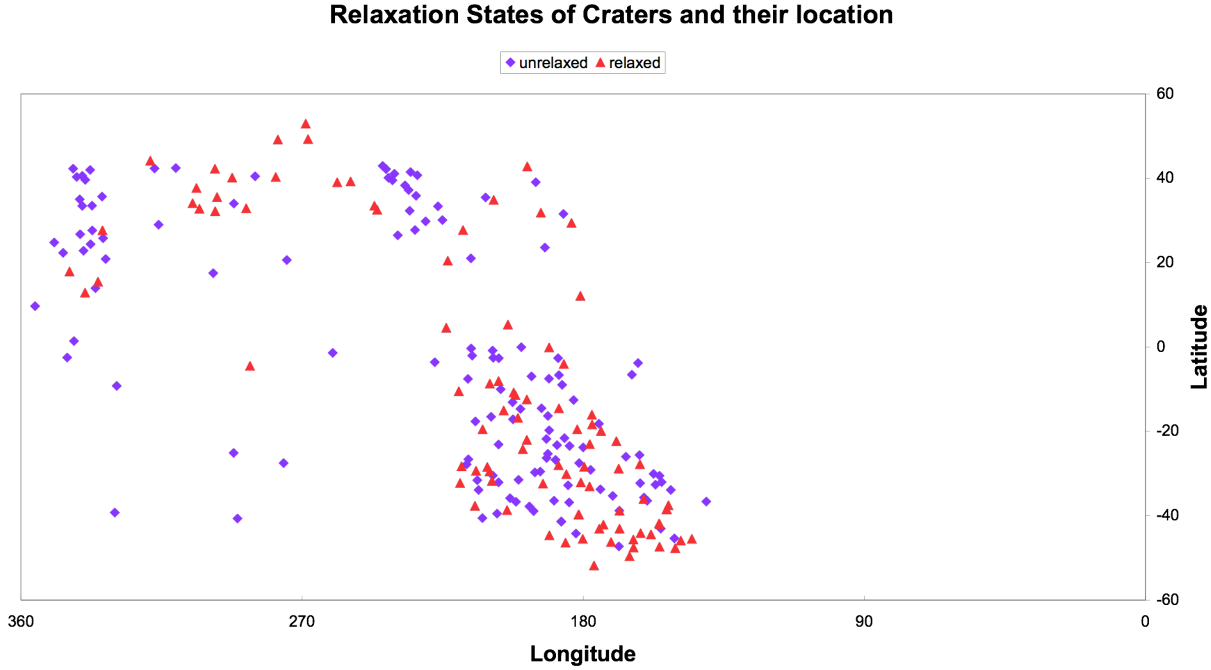

Figure 3. Crater relaxation as a function of latitude on Enceladus. The region between 0° and ~140°W has only been imaged at low resolution (~1 km/pixel) and was not included in this survey. This region or parts of it may be observed at higher resolution during the Cassini extended mission. Although the number of relaxed craters in the southern latitudes may not be statistically greater than those in the northern latitudes, the degree of relaxation exhibited by southern craters is, indeed, greater than for those observed in the north.

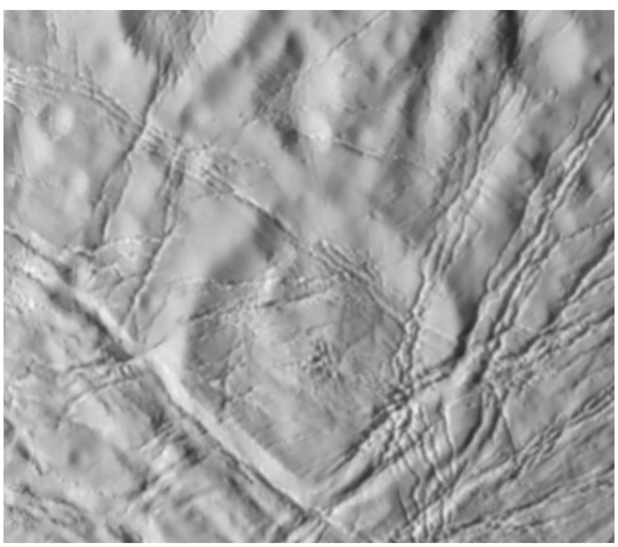

Figure 2. Example of a relaxed crater centered at approximately 52°S, 177°W. Note the upbowed floor and the persistent rim that is characteristic of crater relaxation. The rim-to-rim diameter of this crater was measured to be approximately 22 km.