THE ROLE OF TIDES IN FORMING THE TIGER STRIPE FRACTURES ON ENCELADUS. A. R. Rhoden[1], T.A. Hurford, J.N. Spitale, W.G. Henning, E.M. Huff [1]School of Earth and Space Exploration, Arizona State University, 781 E. Terrace Mall, ISTB4–795, Tempe, AZ 85287–6004.

Introduction: Enceladus' south polar region displays active plume eruptions emanating from four long, roughly parallel fractures, dubbed Tiger Stripes [1][2]. Much work has been done to understand the nature of the plumes, but the formation of the Tiger Stripe Fractures (TSFs) themselves, has not received as much attention. Here, we address the question of whether tidal stresses controlled the formation of the TSFs and, if so, what their formation implies about the strength, thickness, and rheology of Enceladus' ice shell. We then construct a model for the formation and evolution of the TSFs from cracks that formed in a vanishingly thin shell that is thickening over time.

Background: The eruptive output of the plumes varies over Enceladus' orbital period [3], evidence that tidal stresses play a key role in controlling the eruptions [4][5]. However, the details of this relationship are still poorly understood. Eruption timing does not match the timing of peak stress across the TSFs, and the models that provide the best fits require either a very thick ice shell at the south pole or a regional sea rather than a global ocean [6]. Interpretations of Enceladus' gravity, shape, and liberations [7][8][9] strongly support a global ocean with a thin ice shell (<10 km and perhaps much less). In addition, tidal stress magnitudes in these models are extremely low (max tensile stress of <14 kPa), making it challenging to open a fracture all the way through the ice shell. Initiating the TSFs, and restricting tectonic activity to the south pole, and not the north pole, is even more challenging for such low stresses.

The region also displays generations of older tectonic features at a variety of orientations [10], which are not associated with plumes. The complete lack of craters in this region implies a very young age, suggesting a relatively rapid change from widespread fracturing to only four main fractures as well as changes in the prevailing fracture orientation in the region.

Methods: We measure local orientations along the TSFs at 6391 individual points. We then calculate the magnitude and orientation of the principal tidal stresses throughout one Enceladus orbit in increments of 1°. This allows us to predict an orientation associated with a particular stress magnitude throughout an orbit. We then conduct a statistical analysis in which we calculate the likelihood of forming the observed orientations from tidal stress.

To make this determination, we must first decide how failure occurs. We test two criteria for failure: 1) failure is more likely to occur as stress increases, such that failure at peak tensile stress is most likely or 2) failure occurs at a consistent threshold, which may be lower than the peak stress. Although the second option sound more physical, it has been proposed that tidal stresses are too low to initiate failure in ice, and thus, an additional source of stress combines with tidal stress to achieve failure [e.g. 11]. As the other source of stress increases with time (e.g. cooling stresses), the combined stress eventually breaks the shell at peak tidal stress.

The magnitude and direction of the tidal stress is sensitive to the interior structure of the body. Hence, we calculate stresses for more than 20 interior structure models, based on the approach of [12], in which we vary the thickness of Enceladus' ice shell, the portion of the shell that is brittle, and the viscosity of the ductile portion of the shell. Parameters are chosen to be consistent with the constraints implied by past work [7][8][9].

For each interior model and failure criterion, we calculate the likelihood of forming all of 6391 measured orientations. We also determine the likelihoods associated with points along the main branches of the TSFs and ancillary fractures, separately. This enables us to distinguish fractures that are more likely to have formed from tidal stresses versus ones that formed in response to localized deformation.

Results: Our preliminary results indicate that the main branches of the TSFs are well matched to tidal stress orientations while ancillary fractures are not. We also find that failure most likely occurred at a particular stress threshold, rather than at the daily peak tensile stress, which argues against a background stress amplifying tidal stresses to achieve failure. Interior structure models with the thinnest shells and warmest ductile layers provide both the best fits and largest peak tensile stresses (>200 kappa). We will discuss the implications of these results and present a model for the formation and evolution of the TSFs.

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