FEATURES ANALOGOUS TO ICE STREAMS AND ICE RISES ON ENCELADUS' LEADING HEMISPHERE: INDICATIVE OF SUBSURFACE WATER? C. B. Beddingfield[1] and A. S. Yoshinobu[2], [1]University of Tennessee, Knoxville, TN (cbeddin1@utk.edu), [2]Texas Tech University, Lubbock, TX (aaron.yoshinobu@ttu.edu)

Introduction: The leading hemisphere of Saturn's ~504 km diameter satellite, Enceladus, is characterized by a region of resurfacing and less densely cratered terrain than the surrounding Saturn- and anti-Saturn facing regions. The resurfaced area is centered near the equator at about 92° longitude and is partially overprinted by the South Polar Terrane below 52° south latitude. The ice making up the terrain of the leading hemisphere is characterized by sub-parallel trending bands separated by extensive ridges and grooves that surround at least 5 'islands' of cratered terrain, the largest of which is approximately 50 km in long-dimension (Fig. 1). The ridge and groove structures trend circumferential to a point located near the equatorial region of the hemisphere. These arcuate structures generally trend subparallel to each other, although they become chaotic at length scales below about 5-10 kms. In one well-imaged region, concentric fractures 10 > 50 km in length, overprint areas of the resurfaced ridge and groove terrain and offset older, more northerly-trending fractures. These offset fracture segments display progressively increasing amounts of counterclockwise apparent displacement away from the center of the terrain.

The margin of the 'leading hemisphere terrane' (LHT) is transitional along the cratered terrane, with ancient craters being partially overprinted by younger fractures. In some places, particularly along the southern boundary with the SPT, the margin is a discreet discontinuity represented by a graben system with at least 1 km of relief. This graben is locally defined by an outward-dipping (with respect to the LHT) scarp (Fig. 2). The transition zone is defined by a series of parallel, small (100's of meters to kms in length), apparently Mode I fractures that surround and encompass the 'leading hemisphere terrane'. These fractures appear to extend, or grow into the cratered terrane. The fractures trend sub parallel to the inner grooves within the resurfaced area. Based on the morphology and nature of displacement of the terrain on the leading hemisphere, we proposed that terrestrial ice streams and ice rises may be analogous to the observed ice ridges and grooves and 'islands' of cratered ice, respectively.

Terrestrial Ice Streaming: Ice streams are present in many areas in Antarctica and Greenland [3-5] and represent ice sheets that migrate at significantly faster rates than the surrounding ice, up to several hundered meters per year [6,7,10]. The rapid motion of ice streams relative to the surrounding ice have been explained to occur due to the presence of underlying fluvial systems which provides a localized decouplement between the ice sheet and the underlying rock. A subsurface layer of either water, or water-saturated till is required to provide an appropriate decouplement to allow the base of the glacier to slide at higher velocities than the surrounding frozen based glacier [8-10]. This decouplement allows the entire vertical extent of the ice stream to flow at a consistent rate resulting in the formation of subparallel trending bands of ice separated by fractures. These bands trend subparallel to the direction of displacement and exhibit brittle, stick-slip behavior [1]. Crevasses commonly occur along ice stream margins due to the differing migration velocities of the ice. Sticky spots at the base of the glacier commonly occur within ice streams. Surface manifestations of sticky spots are ice rises, which are patches of stagnant or relatively slow moving ice, where the base of the glacier is frozen to the rock below [2]. This may be due to the interaction of the ice stream with topography so that a patch of ice remains stagnant above the asperity in the underlying rock. Ice rises are sometimes associated with a series of crevasses forming a tail of deformed ice, indicating the flow direction of the surrounding ice stream [2].

Evidence for Enceladean Ice Streaming: The leading hemisphere contains a variety of terranes that appear analogous to terrestrial ice streams. We suggest that the morphology of the radially trending grooves and ridges may have been produced by ice-streaming mechanisms. Flow of the ice about a pole of rotation centered near the equator occurred. The presence of ice 'islands' (Fig. 1) which may be analogous to terrestrial sticky spots (Fig. 1), supports the occurrence of ice streaming and the direction of fracture displacement is consistent with the migration direction expected for an ice stream (Fig. 1 and 3) as well as offset direction indicated by drag on craters along the LH terrane margin (Fig. 4). These cratered 'ice islands' may indicate that topography exists on the rocky core of Enceladus (Fig. 3), or that the amount of water or saturated till is very thin and non-existant in areas below the patches of stagnant ice. The offset fractures in Figure 1 do not appear to have undergone much internal deformation, suggesting that the grooves between the ice bands are brittle in nature and likely represent throughcutting strike-slip faults. This is also consistent with that of terrestrial ice streaming.

Future work includes further mapping of continuous ice bands and ice islands throughout the leading hemisphere to better understand the lateral extent of possible subsurface water and topography along Enceladus' rocky core.

References: [1] Douglas A. W. et al (2008) Nature 453, 770-774. [2] Stokes C. R. (2007) Earth-Science Reviews*, 81,* 217–249. [3] Hughes T. (1977) Reviews of Geophysics, 15, 1-46. [4] Bentley, C. R. (1987) JGR, 92, 8843-8858. [5] Joughin I. et al (2001), 106, 34021-34034 [6] Clarke, G. K. (1987), JGR, 92, 8835-8841. [7] Edhelmeyer, K., Harrison, W. D. (1990), Journal of Glacioligy, 36, 82-88. [8] Tulaczyk S. (2000), JGR, 105, 463-481. [9] Blankenship, D. D. (1987) JGR 92, 8903-8911. [10] Bell, R. E., et al. (1998), Nature 394, 58-62.

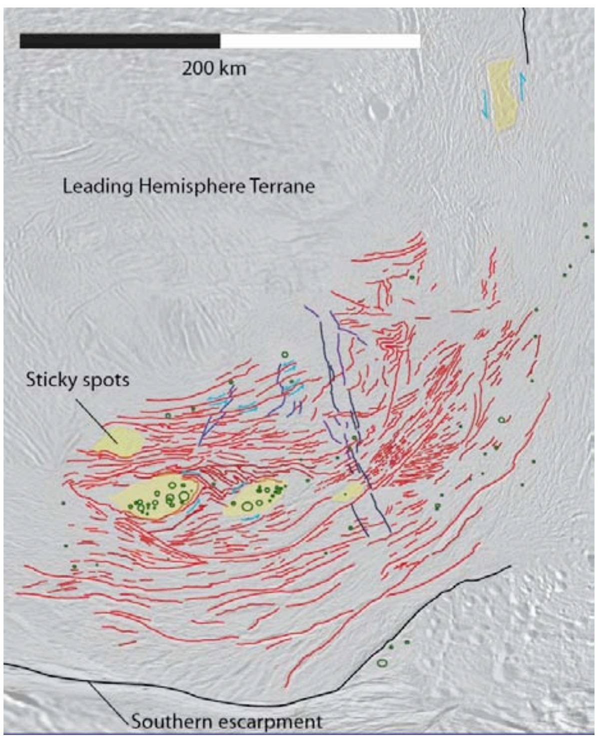

Figure 1. Map of fractures and faults in the LHT. Yellow regions are ice rises/sticky spots. Note apparent sinistral offset along concentric faults.

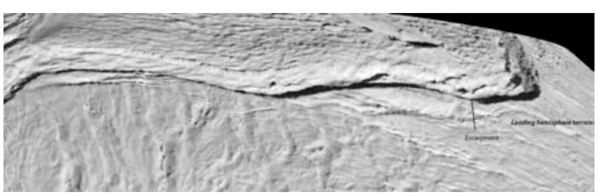

Figure 2. Oblique view of outward-dipping escarpment that separates the LHT from the SPT. LHT is to the right in this image.

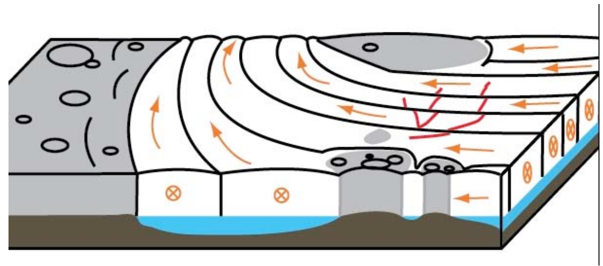

Figure 3. Sketch of ice streams and ice rises/sticky spots on Enceladus. Grey regions are ice rises, or sticky spots, that are adhered to the rock substratum.

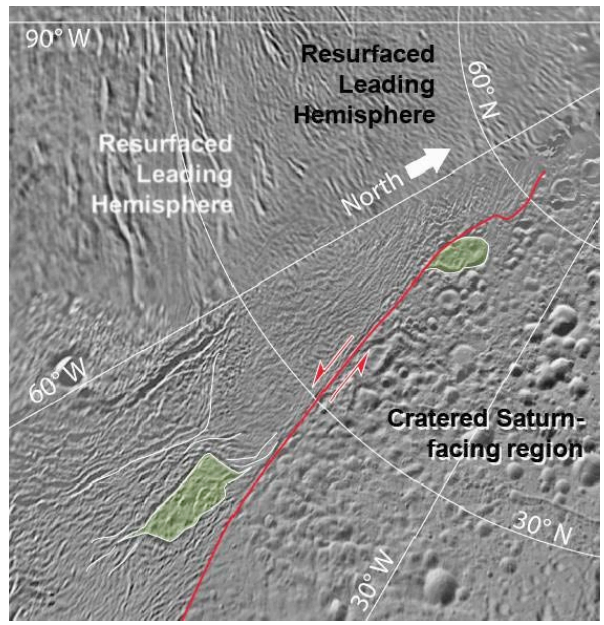

Figure 4. Boundary between LHT and the cratered Saturn-facing hemisphere. Note asymmetric sinistral offset of interpreted 'sticky spot'.