On the Formation of a South Polar Basin in the Ice Shell of Enceladus. C. C. Walker and J. N. Bassis, University of Michigan Atmospheric Oceanic and Space Sciences, Ann Arbor, Michigan, 48109 U.S.A. (catcolwa@umich.edu)

Introduction: The South Polar Terrain (SPT) of Enceladus is the youngest region on the surface and features the long, thin fractures called the "tiger stripes". This region is surrounded by topography suggestive of an ovoid-shaped chain of mountains, which upon closer inspection appear to be lower in elevation than the older, cratered plains to the north, which surround the region [1]. This topography is suggests that the SPT region could have formed in the style of a basin on the Earth.

An interesting comparison point presents itself in a few rift basins on the Earth. The North Fiji Basin in the south Pacific Ocean is an evolved back-arc basin and example of the complex plate tectonics that occur on the Earth. The basin, which used to be called the 'North Fiji Plateau' due to its relatively shallow depth, overlies a high-temperature anomaly in the upper mantle, and features parallel spreading ridges as part of a back-arc basin system of tectonic activity [2]. Enceladus' basin, similarly shallow, features notable parallel fissures and is also situated atop a heat anomaly.

The McKenzie Model for basin formation [3] on the Earth is applied to the Enceladus setting. Additionally, we use our knowledge of terrestrial ice sheets and sea ice to further model and constrain the formation mechanisms of the SPT basin.

On Basin Formation: Warm ice underlying the elastic layer, or "mantle" in this case, expands, causing crustal thinning. Tidal bending and stress contribute to weakening of crust, which may lend itself to an increasingly brittle top layer and calving of ice blocks within the thinned plate. Isostatic adjustment of the ice blocks may cause a drop in dip-slip fashion; and bending of the plastic crustal plate leads to horizontal stresses and possible Coulomb failure (fractures). In this manner, a half-graben is formed, which would be similar in topographical appearance to the bordering wrinkle-ridge-like structures surrounding the SPT.

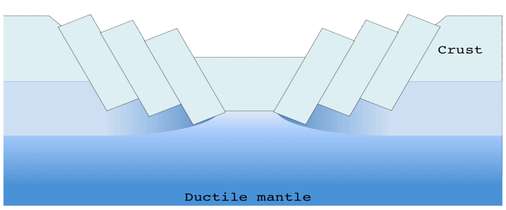

Figure 1. Basin formation at the south pole. The brittle crust is weakened and may fault in a fashion similar to both graben formation and the iceberg calving process on Earth.

The McKenzie Model for Basin Formation. McKenzie (1978) described a model for the formation of the terrestrial basin that includes two phases: first, instantaneous lithospheric stretching; second, long-term cooling with the fading and/or changing nature of the original heat source. The instantaneous stretching of the lithosphere contributes to the initial subsidence, while the longer-term, cooling phase contributes to the thermal subsidence of the basin. This simple model is based upon three assumptions: thickness of lithosphere affected by stretching, i.e., elastic thickness T_e, uniform stretching of this layer, and a geothermal/ density gradient in underlying mantle layer. [4,5]

In an initial calculation, total ice shell subsidence at the south pole of Enceladus would range between 0.39 km and 0.95 km, dependent upon a range of elastic thicknesses of the ice shell. Subsequently modified, the model includes considerations and constraints due in part to models of terrestrial sea ice.

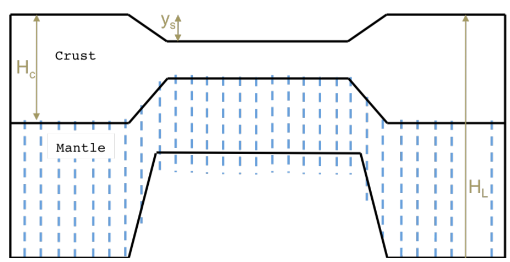

Figure 2. A schematic approach to the McKenzie formation model. Thinning occurs in the crust of thickness H_c as a result of heating in the mantle (total lithospheric thickness is H_L). Y_s is the depth of the resulting basin.

Interpretations of south polar and global topography. Grabens at the boundaries of the SPT with the northern plains are induced collapse features, likely originating from the high-heat temperature anomaly below that location. These features have a similar topographic appearance, and can possibly be studied in comparison, to terrestrial ice falls or ice slides. Graben formation at the border is related to the isostatic sinking of the center section of the basin. In the center of the basin, horizontal forces could cause additional rifting, e.g., the 4 main "tiger stripes".

Continued heating in the subsurface and weathering contributes to the flattening and/or rounding of tectonic features (rounded ridges, lower elevations, etc.).

If and when heat source fades, crustal refreezing (i.e., thickening) causes a renewed process of isostatic compensation, which leads to uplift of the basin floor. This sequence may serve as a possible explanation for relic basins and/or active regions found elsewhere on the surface.

Summary: At a global temperature of 70 Kelvin, surface and subsurface ice can be regarded as somewhat different to that of Earth. Likewise, the geological models that are employed were originally intended for Earth materials, i.e., rocky materials. Since Enceladus' crust is made of ice rather than rock, it is necessary to combine current knowledge of terrestrial ice sheets and sea ice dynamics to supplement the geological models and further model the formation of a basin at the south pole. Since the formation mechanisms that have contributed to the SPT are not well understood, it is highly important to apply our better-constrained knowledge of Earth-bound tectonics and cryospheric processes to those of the icy satellites.

References: [1] Schenk, P. and McKinnon, W. (2009), *One-hundred-km-scale basins on Enceladus: Evidence for an active ice shell*, Geo. Res. Letters, Vol. 36, L16202, pg. 5. [2] Ruellan, E. and Lagabrielle, Y. (2005), Subductions et ouvertures oceaniques dans le Sud-Ouest Pacifique, Geo. Rev., 307, pg. 121-142. [3] McKenzie, D. (1978), *Some Remarks on the Development of Sedimentary Basins*, EPSL 40. [4] Watts, A. B. (2001), *Isostasy and Flexure of the Lithosphere*, Cambridge University Press. [5] Allen and Allen (2005), *Basin Analysis: Principles and Applications (2nd Ed*ition), Blackwell Publishing.