A HISTORY OF PIT CHAIN FORMATION WITHIN ENCELADUS'S CRATERED TERRAINS SUGGESTS A NONSYNCHRONOUS ROTATION STRESS FIELD. E. S. Martin[1] and S. A. Kattenhorn, [1]Department of Geological Sciences, University of Idaho (875 Perimeter Drive MS 3022, Moscow, ID 83844-3022, mart5652@vandals.uidaho.edu, simkat@uidaho.edu).

Introduction: Large-scale tectonic deformation in icy shells can manifest itself as fractures that form in response to stresses caused by a range of mechanisms including true polar wander, despinning, changes in volume caused by freezing or thawing of a subsurface ocean, orbital recession/decay, diurnal tides, and nonsynchronous rotation (NSR) [1,2]. Icy shells often preserve this record of tectonic deformation as patterns of fractures, in this case pit chains, which can be used to identify the sources of stress.

For example, pit chains are linear troughs comprised of circular to elliptical depressions [3], and are unique to Enceladus in the outer solar system [4] (Fig. 1). Pits are distinguishable from impact craters, because they lack raised crater rims, impact ejecta, or other flow features [3,4]. Formation of pit chains on Mars is closely associated with regions of extension [3,4]; motion along high-angle normal faults causes drainage of overlying loose regolith into the resultant dilational space along the fault plane, causing pit chains to form in the regolith [3]. Such dilational faults are common on Earth, Venus, and on small bodies like Phobos, Eros, Gaspra and Ida (review by [6]). Previously, [4] used high resolution Cassini ISS data to map pit chains on Enceladus. Isolated primarily within the old cratered terrains, [4] concluded that, like on Mars, pit chains on Enceladus are formed by drainage of loose material into a void formed through dilational faulting. A second possibility is that pit chains simply form above dilational cracks (like terrestrial joint sets) below an icy regolith.

We can use the extensive geologic record of tectonic deformation on Enceladus's surface [7,8] to identify the source of stress that produced these fractures. For example, the established geologic history of the South Polar Terrain (SPT) involves four systematic fracture sets suggestive of a relative change in the stress field through time caused by the rotation of the ice shell due to NSR [7]. The high heat production along the tiger stripes is attributed to geologic activity driven by diurnal tidal stresses [7, 9, 10]. It is fitting therefore that we test whether the pattern of pit chains in the cratered terrains is consistent with results from the SPT. We utilize the viscoelastic stress modeling program SatStressGUI [8,9] to produce a theoretical global NSR stress field by making reasonable assumptions about the rheological properties of the ice shell and the source of stress [9, 11, 12]. We test whether the predicted fracture patterns produced with SatStressGUI match the observed fracture patterns to thus infer the likelihood that NSR stresses were also responsible for fracture formation outside the SPT.

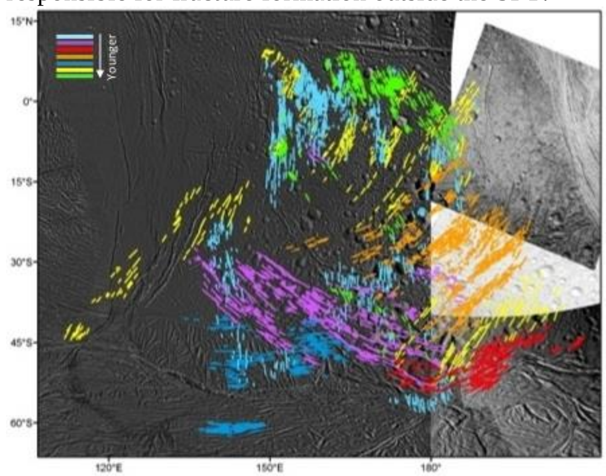

Figure 1: Systematic fracture sets of pit chains on Enceladus's anti-Saturn facing hemisphere.

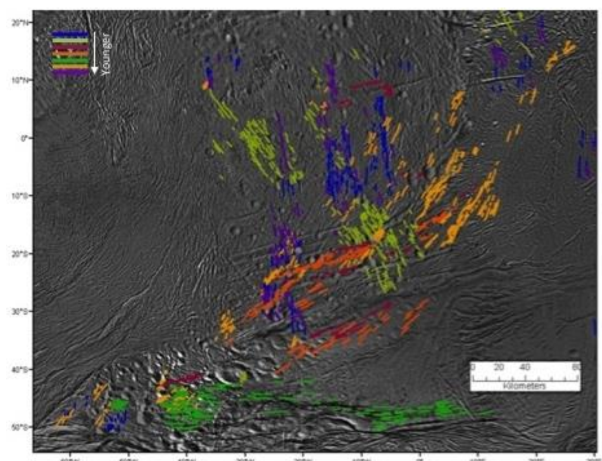

Figure 2: Systematic fracture sets of pit chains on Enceladus's Saturn facing hemisphere.

Establishing Fracture Histories: Pit chains have been suggested to be some of the youngest features on Enceladus outside of the SPT [4]. [8] used crosscutting relationships to demonstrate that they may, in fact, be the youngest features on Enceladus's surface other than the tiger stripes. Globally extensive fracture sets are mostly likely to form in response to a global stress field. If the stress field changes, new fractures may form in a different orientation dictated by the orientation and magnitude of the new stress field, and the strength of the ice shell. Rather than Enceladus's stress field changing with respect to Saturn, NSR changes the position of Enceladus's ice shell through faster than synchronous rotation relative to the solid interior, allowing for multiple fracture sets with distinct orientations to form within the same region at different points in time. Detailed fracture mapping can resolve the different sets, and their relative age relationships (Figs. 1, 2). Pit chains were found mostly within cratered terrains (see also [4]) but can also be found within the tectonized terrains of the trailing hemisphere. We used crosscutting relationships to determine the relative ages of adjacent fractures. Additionally, fracture orientation and morphology were used to place fractures within distinct fracture sets.

Results: Detailed fracture mapping of Enceladus's cratered terrains have resolved at least 6 pit chain sets on both the Saturn and anti-Saturn hemispheres (Figs. 1, 2). Both sets are offset from 0° and 180° longitude by ~30° to the west. There are a similar number of fracture sets on each hemisphere, producing similar fracture patterns. Moreover, sets with similar orientations on each hemisphere also share similar places within the relative age sequence. Fig. 3 shows the breakdown of pit chain sets. Black lineaments represent the expected orientations of theoretical extensional fractures based on SatStressGUI [13, 14]. To produce all fracture sets, Enceladus's ice shell must have rotated a minimum of 115° ([7] suggest a minimum of 153° of rotation in the SPT during the observable fracture sequence).

Conclusion: In agreement with [7], we find that the patterns of pit chains in Enceladus's cratered terrains show systematic changes in fracture orientation through time. The mapped fracture patterns are consistent with NSR of a floating ice shell over a global liquid ocean.

References:

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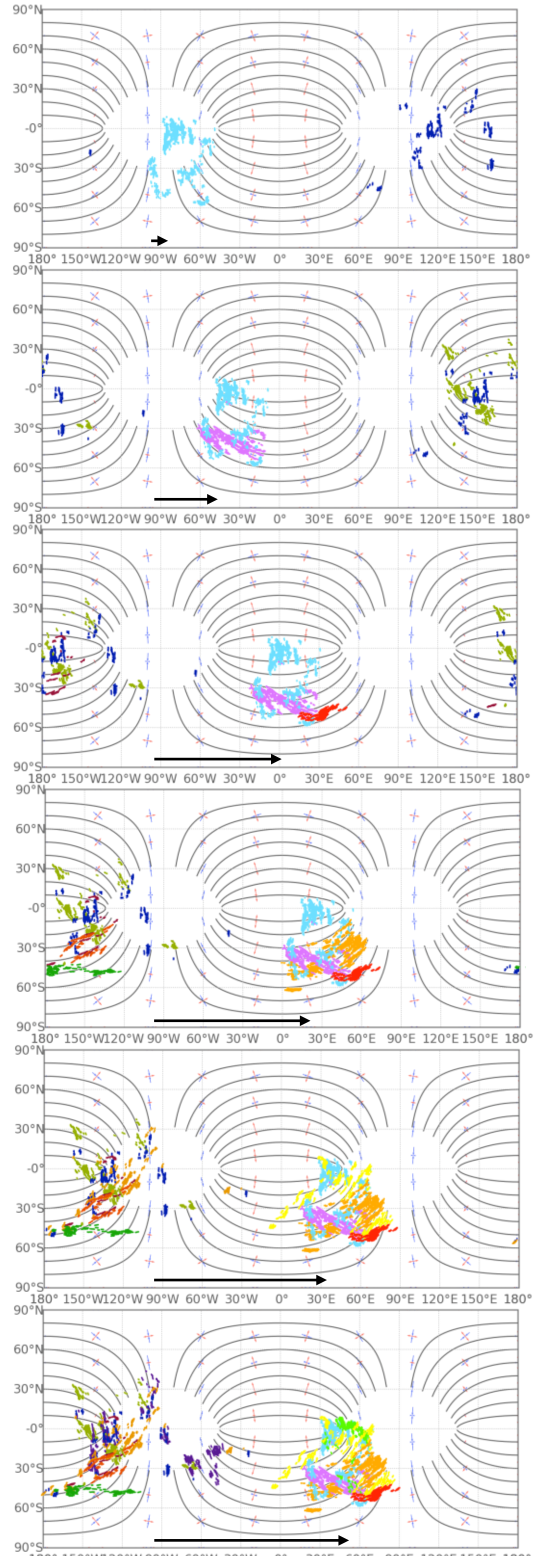

Figure 3: The position and orientations of the position of the NSR stresses remain fixed with respect to Saturn. The ice shell will rotate slightly faster than synchronous causing a progressive eastward migration.