Left-slip Faulting along the Tiger Stripe Fractures: Implications for the Tectonic Evolution of the South Polar Terrain, Enceladus.
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Introduction: Although tiger stripes are the most prominent features on Enceladus in its South Polar Terrain (SPT), the nature of their post-formation fault kinematics remains controversial. Current models emphasize extension, shear or their combination as the main mode of fault motion [1–6]. To clarify this issue, we conducted a detailed photogeologic mapping of the tiger-stripe fractures and the surrounding SPT. Our results suggest that the current kinematics of the tiger stripes is left-slip, with faults terminating at hook-shaped fold-thrust zones at one end and horsetail fault zones at the other end. Our work also implies that distributed deformation dominates the SPT.

Methods. We determined the fault slip sense by examining (a) offsets of preexisting geologic features, (b) adjascent curvilinear patterns interpreted as drag folds, (c) structural geometry and kinematics of branching and termination structures, and (d) geometry of shear bends in fault zones. We also used cross-cutting relationships to establish sequential initiation of fractures related to the development of the tiger-stripe fault system. Finally, we mapped the relationship between the tiger-stripe fracture system and the boundary structures of the SPT. In concert, the mapped relationships allow us to develop a new tectonic hypothesis for formation of the SPT.

Tiger-stripe Fractures: As pointed out in [7], tiger-stripe fractures are linked with semi-circular "hooks" at one end and Y-shaped branching fractures at the other (**Fig. 1**). Our detailed mapping suggests that the main and branching fractures merge and/or terminate at obliquely oriented faults. This relationship requires left-slip motion on the tiger-stripe fractures for the hooks to be contractional structures, which is consistent with previous interpretation [3,7] that analogous curvilinear structures along the SPT margins are folds. In our interpretation, the Y-shaped termini are horsetail-like structures, where one branch of the Y is a splay off of the main strike-slip tiger-stripe fault.

The map-view pattern of the tiger-stripe fracture system is remarkably similar to the pattern of major active left-slip structures in Tibet (e.g., the Kunlun, West Qinling, and Haiyuan faults), each displaying hook-horsetail geometry [8] (**Fig. 2**). Our mapping supports the interpretation [3] that folds in fracture-bounded domains predate the formation of the tiger-stripe fractures.

SPT-bounding Faults: Building upon the work of [3,7, 9], we examined the kinematics of fault zones defining the SPT margins. The results lead us to infer a right-slip fault zone and a left-slip fault zone along its anti-saturnian and sub-saturnian margins, and a fold-thrust zone and an extensional breakaway zone along its trailing (western) and leading (eastern) margins, respectively (**Fig. 1**). This fault pattern suggests the SPT to have shifted from the leading toward the trailing hemisphere, in a direction nearly perpendicular to the tiger-stripe fractures. The terrain-bounding structures and tiger-stripe fractures are recently and currently active [7,10], so the above interpretation begs the question of how the two faults systems have been interacting.

Tectonic Model Involving Clockwise Rotation and Bookshelf Faulting: Following many previous workers (e.g. [1–3]), we consider the SPT to have been created by upwelling of a hot and low-density material. Polar flattening [7], plausibly from related polar wander [1], could have triggered radial extension to create the long and narrow wedge-shaped open cracks in the trailing (eastern) hemisphere and an extensional fault zone in the leading (western) hemisphere (**Fig. 1**). The maximum upwelling was probably centered closer to the 140°W edge, causing the SPT to "slump" toward the opposite direction. Possibly stronger terrains in the west blocked the movement of the SPT region, creating folds adjacent to the newly opened wedge-shaped cracks (**Fig. 1**). Uneven motion of the SPT (i.e., faster speed in the eastern/leading hemisphere side) may have induced a clockwise rotation of the SPT while it was translated. This rotation, in turn, may have been accommodated by left-slip bookshelf-style faulting along the tiger-stripe fractures (**Fig. 1**).

References: [1] Nimmo and Pappalardo (2006), *Nature*, *441*, 614-616. [2] Gioia et al. (2007), *Proc. Nat. Acad. Sci., 104*, 13578-13581. [3] Spencer et al. (2009), *Saturn from Cassini–Huygens*, pp. 683–724, Springer, New York. [4] Nimmo et al. (2007), *Nature, 447,* 289-291. [5] Hurford et al. (2009), *Icarus, 203*, 541–552. [6] Smith-Konter and Pappalardo (2008), *Icarus*, *198*, 435–451. [7] Porco et al. (2006), *Science, 311,* 1393–1401. [8] Taylor and Yin (1999), *Geosphere, 5*, 199-214. [9] Patthoff and Kattenhorn (2011), *GRL*, *38*, L18201. [10] Kirchoff and Schenk (2009), *Icarus, 202*, 656–668.

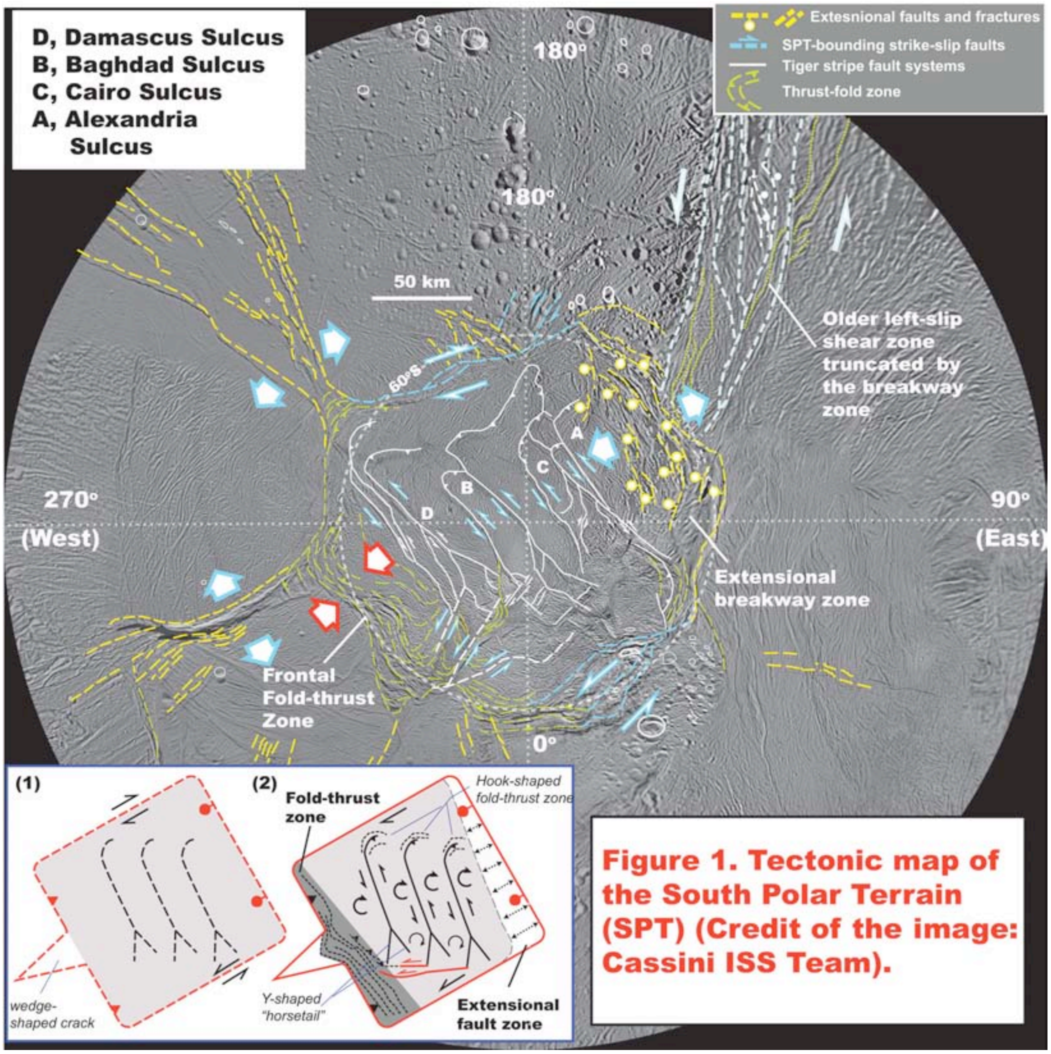

Figure 1. Tectonic map of the South Polar Terrain (SPT) (Credit of the image: Cassini ISS Team).

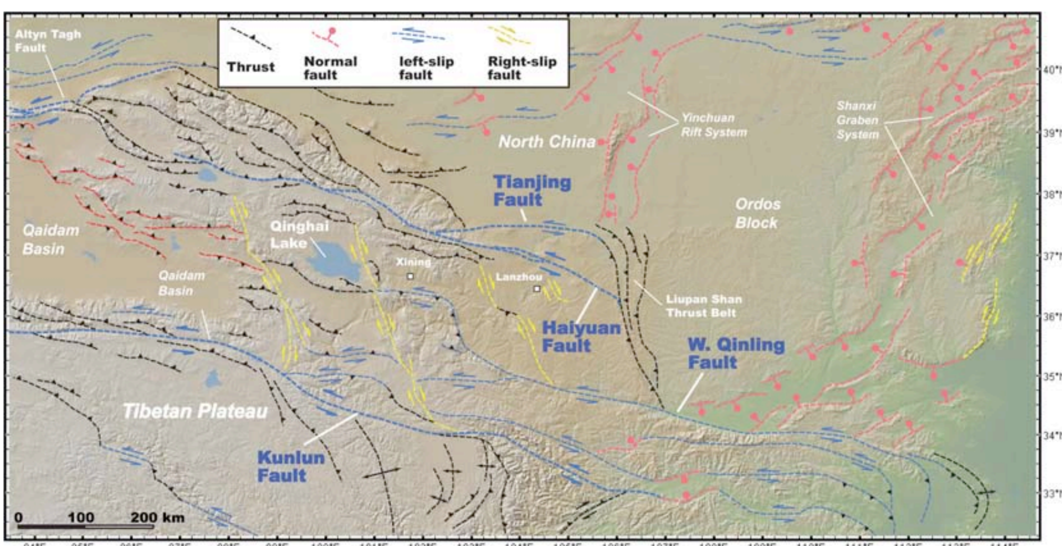

Figure 2. Active fault map of NE Tibet, modified from Taylor and and Yin (2009) in ref. [8].