OLD TIGER STRIPES AND THE SOUTH POLAR DICHOTOMY ON ENCELADUS.
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Introduction: Enceladus stands out from the other icy moons of Saturn because of its regions of young, warm, and active crust near the south pole [1, 2]. Using crater counts and other geological features, the moon can be divided into many terrains with vastly differing ages [1, 3, 4]. Near 55°S, separating the mostly older terrains from the highly fractured and very young south polar terrain (SPT), lies a dichotomy (Fig. 1) resembling a compressive terrestrial fold belt [1, 5]. The belt encircles the moon's youngest terrain and the four prominent fractures known as tiger stripes [1]. The tiger stripes are the sources of water vapor plumes and are likely the youngest features within the SPT [1, 2].

Stereo images from the Cassini spacecraft have shown the dichotomy to be hundreds of meters higher than the surrounding region [1], but the belt is not uniform along its length. The belt is segmented with some regions composed of numerous parallel folds at the edge of the youngest terrain in the SPT, most prominently seen in the southeast and northwest (Fig. 1). The rise in topography and deformation are consistent with compression driven by spreading across the SPT [6]. Other points along the dichotomy are interrupted by Y-shaped cusps from which long fractures, extending to the north, emanate and are believed to be tension features [1, 7]. At a sub-kilometer scale, the shape of the dichotomy is difficult to define. Most regions of the dichotomy are interrupted by fractures and ridges, contain numerous interactions between it and other geologic features, and lack high resolution images that would enable more detailed mapping. At the tens of km scale, individual components of the dichotomy consist of chains of arcuate scarps pointing to the south until reaching the Y-shaped cusps where they reverse their shape. The overall trend of the dichotomy is nearly parallel to the lines of latitude pointing to a compression source originating near the south pole [8]. The overall shape of the dichtomy is roughly rectangular with the longest set of folds located parallel to the tiger stripes in region 3 of Fig. 1.

The relationship between the dichotomy and the tiger stripes could be attributed to crustal spreading in the SPT. However, unlike a terrestrial spreading center, multiple sources in time and space are thought to contribute to the creation of new material on the surface [9]. The large amounts of heat coming from the SPT [2] imply an internal heat source powered in part by tidal forces. Getting the energy from depth to the surface suggests convection is occurring within the ice shell. If this is so, it could create a spreading region in the SPT [10]. Assuming a convection model, a spreading rate of a few tens of mm/yr is possible [11].

Fractures and Boundaries: The SPT contains at least four fracture sets that share a common orientation and relative age which suggest the moon has experienced nonsynchronous rotation [12]. The youngest set includes the tiger stripes and many other fractures that are parallel to them. Three additional sets have been identified with unique orientations and relative ages (Fig. 1). Most of the fractures within about 25° latitude of the south pole can be categorized into one of these four sets.

Within each of the three older fracture sets are individual fractures that share many physical characteristics to the tiger stripes. Some fractures are fairly long, 10s of km, and have a spacing similar to what the present day tiger stripes have. Table 1 compares three of the old tiger stripes with the present day tiger stripes. These long fractures also are frequently wider and more pronounced than other fractures within their set suggesting they once were similar in form and function to the present day tiger stripes.

The region surrounding the south pole, between Cairo and Damascus sulci, appears to have deformed in a more ductile manner with fractures smoothly changing from a set 1 to a set 2 orientation. In contrast, other fractures further from the pole change strike more abruptly than the central ones forming sharp angles, likely due to an interaction with an older feature. The smoother transition suggests a more ductile material, possibly due to the increased temperature in this area.

Regions 1 and 2 (Fig. 1) contain additional fracture terrains located away from the central, heavily fractured area of the SPT. Within these terrains are fractures that share a similar orientation to some of the fracture sets near the south pole. These terrains are separated from the other sets near the south pole, not by fold belts but instead by ridges and fractures which could mark additional dichotomy boundaries. Future mapping of these fractured terrains will determine if they match the four main sets near the south pole or if they belong to their own family.

Discussion: The most prominent belts of the dichotomy, regions 3 and 4 (Fig. 1), are parallel to the orientation of the tiger stripes. If Enceladus is being heated from within by tidal forces, the ice shell could be convecting creating a spreading center along the tiger stripes. The spreading around the south pole could be accommodated by the raised terrain in the dichotomy [9, 10] seen in regions 3 and 4 (Fig. 1).

The tiger stripes share a similar orientation to the fold belts in regions 3 and 4 of Fig. 1. Set 2 fractures (yellow in Fig. 1) share a similar orientation to the fold belts of the dichotomy between longitudes of approximately 270° and 290° (Fig. 1). Parts of the dichotomy, between approximately 230° and 250° as well as between 10° and 50° longitudes, appear to be nearly parallel to set 3 fractures. These belts associated with the older fractures are not as prominent as those that appear to be associated with the tiger stripes. However, the set 2 and 3 belts are located on lower resolution images (100s m/pixel) which makes defining their characteristics difficult. Despite the lack of good quality data, mapping shows a rough correlation between the fracture sets and fold belts along the dichotomy, indicating they may be contemporaneous features.

If the tiger stripes do contribute to the resurfacing of the SPT and influence the formation of the dichotomy, the older fracture sets likely influenced the formation of the dichotomy in the past when they were more active. As new fractures are formed and the spreading center changes, older parts of the dichotomy will be changed by the newer fractures and a new spreading center. Changing the spreading center orientation could create a more segmented dichotomy than Fig. 1 implies. We should see evidence of interactions in different parts of the dichotomy, possibly in the form of crosscutting relationships between fractures and the dichotomy. Parts of the dichotomy that are older, and were likely created in conjunction with the older tiger stripes, should be cut by fractures of younger sets. If this is true, it would indicate the dichotomy is not of uniform age but likely shares similar relative ages with the older fracture sets. These changes are predictable and should be reflected in the fracture patterns of the SPT. Our additional mapping of the dichotomy and fractures will determine if the segments share a common relative age to the fracture sets.

Conclusions: If the tiger stripes do contribute to the fold belts in the SPT dichotomy, older versions of the tiger stripes hidden within the fracture sets may have contributed to the creation of older fold belts around the dichotomy. These older belts should share similar ages and orientations to the fracture sets to which they are associated. Additional mapping of the dichotomy and fractures in the region will help determine the relationship.

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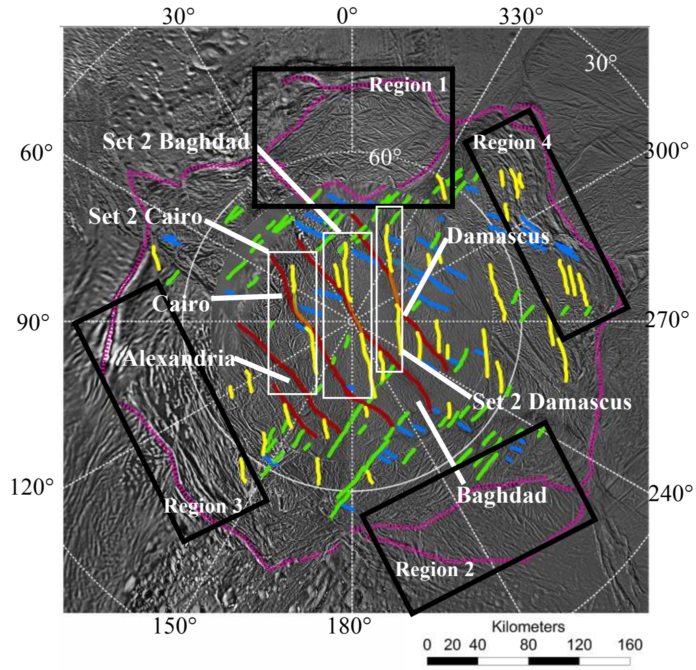

Figure 1: Dichotomy and fracture history. The dark red lines are the four named tiger stripes. Fracture sets 2, 3 and 4 are represented by the yellow, green and blue lines, respectively. Orange segments are where the current tiger stripes and old tiger stripes overlap. The purple line represents a rough outline of the south polar dichotomy. Fracture terrains separated from central region of the SPT are located in regions 1 and 2. Well defined fold belts are located in regions 3 and 4. This is a polar projection mosaic from [13].

Fracture Name	Length (km)	Spacing (km)
Damascus	128	35
Baghdad	158	35.5
Cairo	154	34.5
Alexandria	111	33
Set 2 Damascus	105	33
Set 2 Baghdad	126	37.5
Set 2 Cairo	90	42

Table 1: Fracture characteristics. The four main tiger stripes and three possible old tiger stripes within the set 2 fractures. Length refers to the straight line length from tip to tip and the spacing refers to the average distance between it and the two fractures on either side, when possible, or to the next fracture.