ANCIENT RIDGES AND TROUGHS ON ENCELADUS. E. S. Martin[1] T. R. Watters[1] and D. A. Patthoff[2], [1]Center for Earth and Planetary Studies, National Air & Space Museum, Smithsonian Institution, Washington, DC 20560 (martines@si.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA.

Introduction: The diverse range of tectonic features on the surface of Enceladus and can be divided into five broad structural classes: troughs, scarps, chasmata, ridges, and bands [1]. Within the cratered terrains on the Saturnian and Anti-Saturnian hemispheres, the dominant tectonic features are fractures *pit chains* [2,3]. We identify an older group of structures, we term *ancient tectonic features,* that predates the pit chains and craters. Detailed fracture mapping of the underlying tectonic structures within the cratered terrains may reveal fracture patterns that can be compared with theoretical stress fields produced by different stress mechanisms (i.e. nonsynchronous rotation (NSR), diurnal tidal stress, polar wander, ice shell thickening, despinning, orbital migration). The geologic record within the South Polar Terrain (SPT) suggests the fractures and fissures within that region were formed by global stress fields driven by diurnal and NSR [3,4,5,6]. Thus, agreement between observed and theoretical ancient tectonic fracture patterns may identify likely stress mechanisms relevant to the earliest stages of Enceladus's geologic history. These structures can thus help provide clues into early stage tectonic activity on Enceladus. Developing an early tectonic history for the moon will provide a context for the SPT and recent tectonic activity in the tectonized and cratered terrains.

Enceladus's early environment was likely influenced by impacts, a changing orbit, ice shell thickening or thinning, despinning, early short-lived internal heating, diurnal tides, NSR, or a combination of some of these. Whatever driving mechanism was responsible for this early stage tectonic deformation on Enceladus, it would have had to produce stresses that exceed the tensile strength of the ice (~1-3 MPa [7]). We may also begin to elucidate why a moon as small as Enceladus is geologically active, and how the mid-sized icy satellites evolved in a nascent Saturnian system.

Morphology of Ancient Tectonic Features: These features are broad, muted, curvilinear, and typically form in ~10 km long segments (Fig. 1). Less frequently, ancient tectonic features can be very long (>30km), and linear. We find that ancient tectonic features are crosscut by both pit chains and craters.

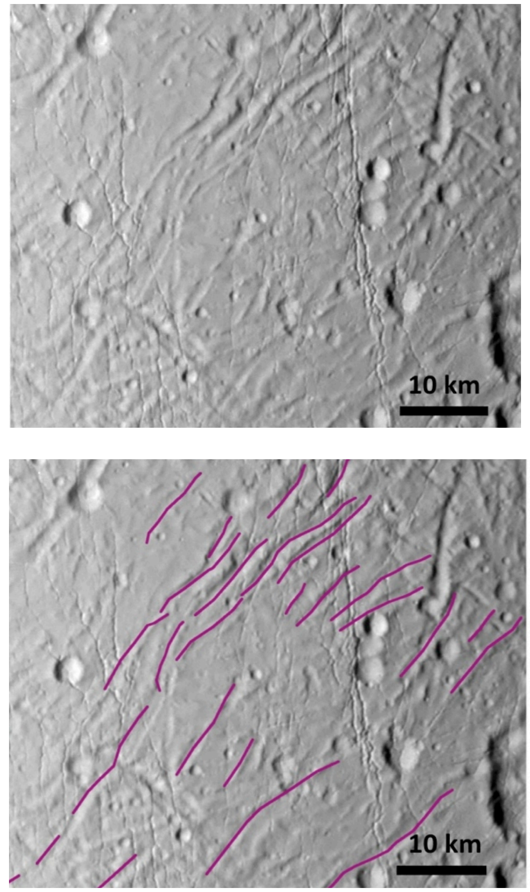

Figure 1: Example of ancient tectonic features interpreted in purple. Image from basemap by [8].

Additionally, ancient tectonic features can be broken up into two primary groups: *ancient ridge-like* features and *ancient trough-like* (Fig. 2) features. Ridge-like features on Enceladus have been described previously [1,9,10,11]. Recent ridge-like features Cufa Dorsa and Ebony Dorsum, are interpreted by [9] as contractional features accommodating late-stage loading based on compressional tectonics. Positive relief features are also found within the SPT funiscular plains [10] and the SPT leading hemisphere boundary [11].

Mapping Results: A preliminary map of ancient tectonic features (between 60°N and 60°S) reveals that structures are isolated within the cratered terrains centered near 0° and 180°. However, it is unlikely that they formed only within the cratered terrains, rather the recent deformation of the tectonized terrains did not preserve ancient tectonic landforms. Approximately

9% of the mapped ancient tectonic features are ridge-like, and appear to be randomly distributed (Fig. 3).

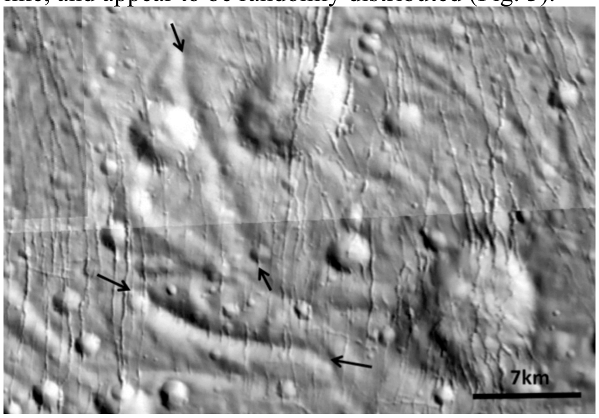

Figure 2: Two ancient ridge-like features in Enceladus's anti-Saturn cratered terrains, each bound by black arrows. Image numbers N1489050254 & N1489050475.

Analysis of fracture patterns within an icy shell is a robust technique for resolving the stress mechanism responsible for their formation [e.g. 4, 12-14,]. We grouped fractures into sets based on similar orientations, morphologies, and locations. Location was considered in order to distinguish possible locally controlled fracture patterns, from fracture patterns formed by global scale stress mechanisms. Mapped fractures fell into two broad groups: grouped (57%) and ungrouped (43%). Grouped fractures fall into systematic sets of fractures with distinct orientations suggestive of a tidally driven stress mechanism (Fig. 4). Ungrouped fractures appear randomly orientated suggestive of a stress mechanism that does not produce systematic sets. Tidal stresses are likely driving the active tectonics in the SPT [4,15,16,17,18] and the recent formation of pit chains [3] in the cratered terrains. It is possible therefore, that ungrouped fractures are evidence of a period of tectonism not dominated by tidal stresses.

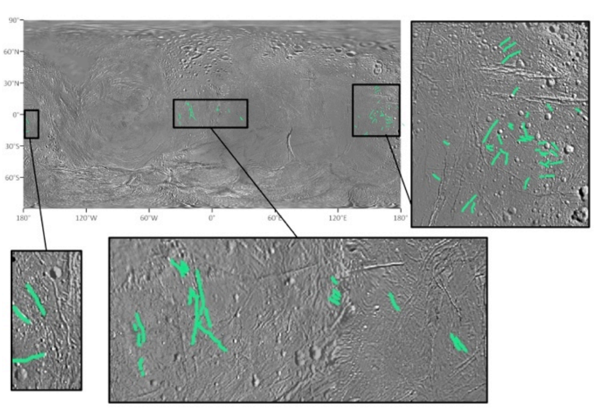

Figure 3: Global distribution of ancient ridge-like features, highlighted in green. Basemap by [8]

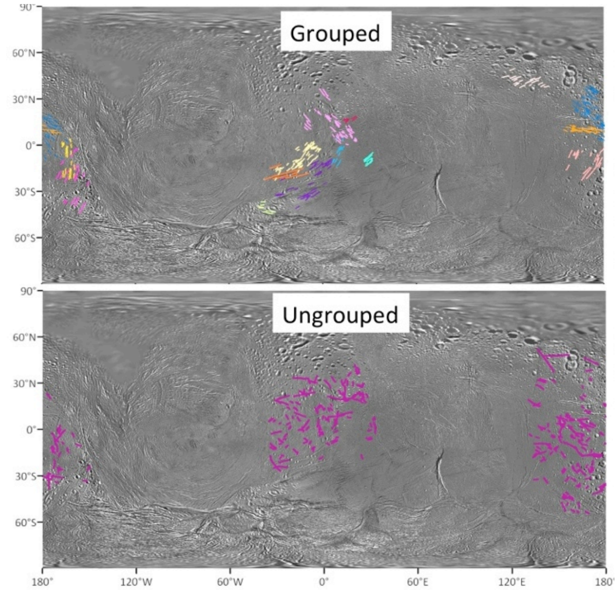

Figure 4: Preliminary maps of ancient tectonic terrains. Basemap by [8].

Ongoing Work: Additional details about the early tectonic history of Enceladus may be revealed with further detailed mapping of the ancient tectonic features in the polar regions. We will compare our completed maps of ancient grouped trough-like fractures to modeled global stresses produced by NSR and diurnal tidal stresses using SatStressGUI [19,20,21] to produce a theoretical stress fields which can predict the location and orientation of tectonic features. These stress fields will be compared with the grouped fractures. Additionally, cross cutting relationships between individual groups of ancient tectonic features will be investigated, as well as the manner in which grouped features interact with ungrouped features.

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