TECTONIC ORIGINS FOR TITAN'S EQUATORIAL MOUNTAIN BELTS AND IMPLICATIONS FOR INTERIOR STRUCTURE. J.W. Miller[1] (juliawmiller@g.ucla.edu), M.J. Malaska[2], R.M.C. Lopes[2], and A. Yin[1], [1]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, Los Angeles, CA, USA, 90095. [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, 91109.

Introduction: Titan's linear mountain chains have been a topic of interest since observed by the Cassini spacecraft over a decade ago. However, limited topographic data and low-resolution images mean that a consensus on their origins has yet to be reached, with mountain formation attributed by various researchers to compression[1], extension[2], and strike-slip faulting[3]. Previous work on these regions has largely focused on global measurements of mountain ridge orientation and understanding the planetary-scale mechanisms for their formation[1,4]. We expand the early work by characterizing the morphology of individual ridges in mountain chains and conducting morphometric comparisons with terrestrial analogues. Our goal is to understand the mechanisms that build mountains on Titan, which would in turn provide better insight into the moon's interior structure. Furthermore, morphometric parameters can be used to determine the brittle and elastic thickness of ice shells with implications for the nature of the mountain-bounding basins.

Data: Cassini SAR, SARTopo, and altimetry data were used in our examination of mountain belts on Titan. Visible image data from SPOT 6/7 and WorldDEM4Ortho elevation models were used to map ridges used as analogues on Earth.

Methods: We chose the mountain belt in Adiri (Fig 1.) as our region of interest based on the availability of both high-resolution SAR topographic data. We began by using the Cassini altimetry dataset[5] to confirm that the long curvilinear radar-bright features in the area were topographic highs. We used ArcGIS (ESRI) to map the ridge lines and measure the widths and peak-to-peak ridge distances.

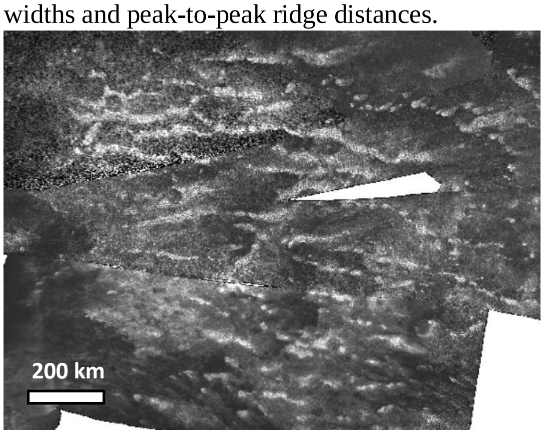

Figure 1: Linear mountain belt in Adiri (10°S, 145° W).

The measured ridge wavelength data are used to estimate the physical properties of Titan's ice shell, such as the brittle and elastic thickness of the crust under extension and compression. These estimates can be made using the model of Fletcher and Hallet (1983) for unstable extension and the model of Yin (1991) for 3-D buckling of a thin elastic plate with finite dimensions.

Morphometric parameters were then quantified for potential Earth analogues, using the Basin and Range province in the SW United States as an example of an extensional system and the Zagros fold belt in Iran as an example of a compressional system. Key parameters include ridge spacing, ridge length-width ratios, and ridge curvature as determined by variation in segmental orientation. For the last metric, we wrote a python script to determine ridge orientations by breaking each ridge into ten equally-spaced segments and averaging the angles of each segment. We additionally performed Fourier transforms on each ridge to isolate the dominant wavelengths of ridge curvature.

Results: Our preliminary measurements of ridge orientations did not show significant differences between the two terrestrial examples. However, preliminary inspections show that the dominant wavelength of terrestrial ridge curvature is much higher in compressional fold-thrust systems that for extensional systems. When using both structural models, we found a significant difference in the estimated thickness for the brittle layer (20 km) under extension and the elastic layer (~1 km) under compression using the ridge spacing obtained from our study area on Titan. The thin elastic layer would imply the presence of shallow (a few km) decollements below the folds that formed the mountain chain in the study area. This case is shown in Fig. 2.

Discussion: Relatively high length-to-width ratios and little short-wavelength curvature for the ridges in Adiri favor a compressional origin, with one potential formation scenario involving ice-sheet underthrusting and decollement folding as depicted in Figure 1. Frictional heating together with the presence of ammoniated water ice could lead to local melting. However, we have not yet explored the dependence of the measured metrics on gravity (Earth vs. Titan) and material properties (e.g., rock vs. ammoniated water ice). We also plan to study additional Earth analogues to determine the uncertainties associated with our metrics.

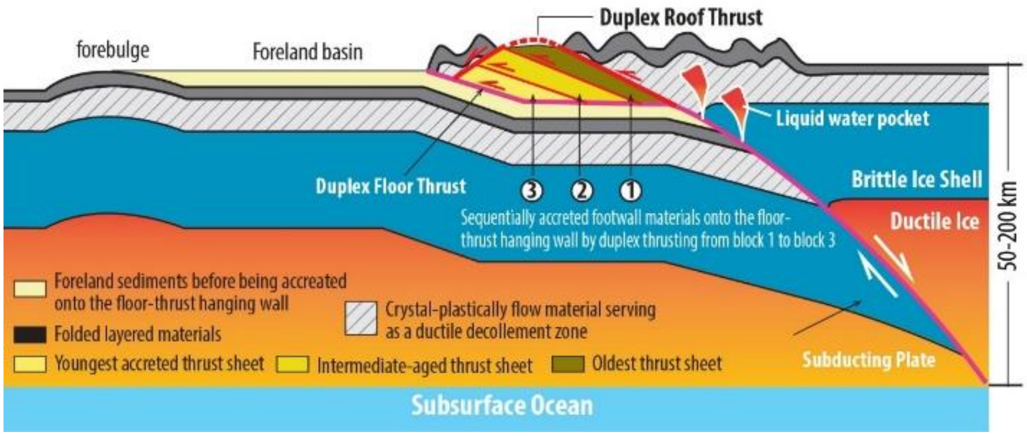

Figure 2: An end-member tectonic model for the formation of a linear mountain belt on Titan.

Potential reasons for equatorial contraction include changes in global volume and spin rate, which have been discussed by Cook-Hallet et al. (2015). An in-depth treatment of volume change and its effect on the moon's global stress field was conducted in 2010 by Mitri et al., but refinements since made to models of Titan's interior mean that revisit these concepts would be helpful. Specifically, revised estimates of ocean density and ice shell thickness from Vance et al. (2018) mean that a narrower range of parameters would have resulted in global contraction (Fig. 3). A morphometric determination of the origin of Titan's mountain belts might eventually be used along with more comprehensive models of global volume change to place additional constraints on ice shell thickness.

Conclusions: Based on comparisons with Earth analogues, we suggest that the linear mountain belts in Adiri are the result of equatorial contraction. However, we are expanding our study to better determine scaling relationships between ridge geometries on Titan and the Earth and to more accurately constrain thresholds for different tectonic settings.

References: [1] Liu et al. (2016), *Icarus* **270**, 14-29. [2] Matteoni et al., (2020). [3] Burkhard, et al. (2021), *Icarus*, 114700. [4] Cook-Hallet et al. (2015) *JGR: Planets* **120**, 1220–1236. [5] Corlies et al. (2017), *GRL* **44,** 11,754-11,761. [6] Fletcher and Hallet (1983), *JGR* **80**, 7457-7466. [7] Yin (1991), *JGR* **96**, 14,577-14,594. [8] Mitri et al. (2010), *JGR* **115**, E10002. [9] Vance et al. (2018), *JGR: Planets* **123**, 180–205.

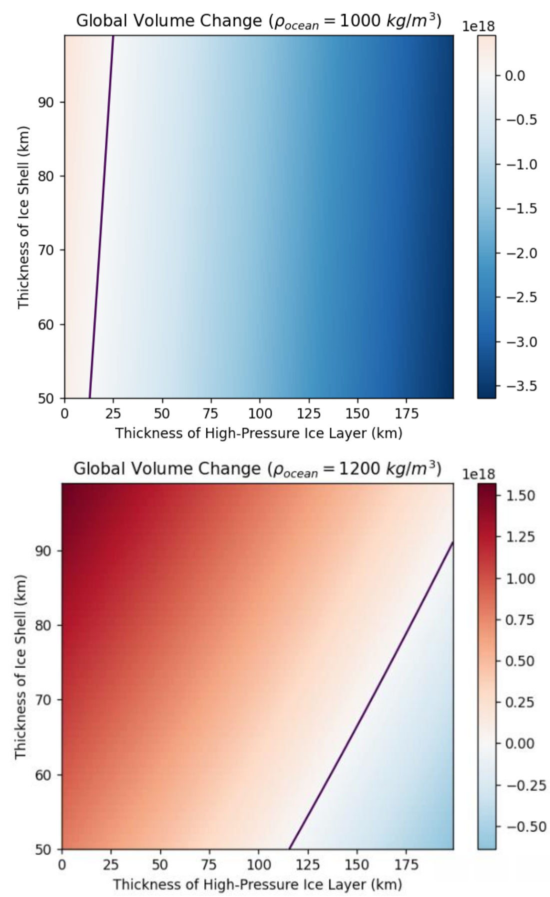

Figure 2: Global volume change resulting from the formation of Titan's high-pressure and ice-I shells, as a function of each shell's thickness. Red is expansion and blue is contraction. Top: ocean has density of pure water. Bottom: ocean has higher density, consistent with Vance et al. (2018).