MORPHOLOGIC CLASSIFICATION AND GEOLOGIC IMPLICATIONS OF TITAN FLUVIAL FEATURES.

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Introduction: Images of Titan's surface gathered by an array of instruments onboard the Cassini-Huygens spacecraft have revealed fluvial features [1-4]. These features are likely formed by precipitation and runoff of liquid hydrocarbons [5-6], although sapping has also been proposed as a potentional formation mechanism [4]. Mapping of these features has been conducted covering various geographic regions of Titan [7-10]. In previous work [11], we delineated fluvial networks using data gathered by Cassini's Titan Radar Mapper (RADAR; res. 350m-1.7 km/px; [1]), acquired through July 2010. Networks were delineated using the criteria of tone, RADAR shadowing, and fluviatile morphology [8, 11]. Here we present an updated analysis and interpretation of drainage patterns on Titan, and their implications for surface stress mechanisms.

On Earth, drainage network patterns reveal geologic controls that influence fluvial network morphology such as tectonic structures, regional slope, bedrock resistance, and ancient topography [12-13]. Network attributes such as the network link lengths, tributary junction angles, and right-angle bends are diagnostic of network patterns. Specific combinations of these attributes form the basic drainage patterns, summarized by Howard [13]: dendritic, parallel, rectangular, trellis, radial, annular, multibasinal, and contorted. The recognized basic drainage patterns are each attributed to a type of geologic control [12-13]. Dendritic networks imply a gentle regional slope or bedrock of uniform resistance. Parallel networks are formed on moderate to high regional slopes or in areas of elongate, parallel landforms. Rectangular networks are controlled by tectonic structures, typically faults or joints, at or near right angles [13]. An algorithm developed by Ichoku and Chorowicz [14] from terrestrial drainages can be used to determine drainage pattern from measured network attributes. This algorithm was modified for Titan and used to analyze fluvial features mapped through radar swath T44 [8].

Methods: Using our network delineations [11], values for network attributes were collected using the Jennessent Graphic Tools and Shapes plug-in for ArcMap. This tool was used to acquire lengths and azimuths (for junction angle derivation) of network links for use in the terrestrial drainage pattern classification algorithm modified for Titan [8]. Possible network classifications generated by the modified algorithm are dendritic, rectangular, parallel, and unclassified classifications. The original algorithm [14] includes trellis and pinnate classifications, but those classifications cannot be derived with our simplified algorithm, given the limits of our data resolution (see Interpretations below). Analysis was performed to assess whether the classification results are sensitive to the number of links in the network. For networks of 10 or more links, the clalssification results are insensitive to network size. Thus, all networks consisting of 10 or more links were analyzed.

Results:

Classification: Analysis of 46 networks yields a majority (~60%) as rectangular, ~20% as dendritic, ~7% as parallel and 13% as unclassified. The mapped networks cover a wide range of sizes, and ~75% of them are not large enough to analyze; indeed, these features account for more than four times the total length of the features analyzed.

Geographic distribution

Figure 1 shows the geographic distribution of networks with colors indicating the pattern classification. Fluvial features are found in all areas of Titan where radar data are available.

Interpretations:

Titan rectangular networks: The predominance of rectangular networks suggests that tectonic structures are a dominant influence on fluvial networks on Titan. To investigate what type of tectonic structures these may be, we investigated three rectangular networks on Earth for which data on the associated tectonic structures were available.

Terrestrial analogs: The Yellowstone River, featuring straight reaches and sharp right-angle bends, is controlled by extensional joints in the bedrock formed by the doming of the building caldera [16]. The Ausable River in New York features sharp, right-angle bends due to joints in the Potsdam sandstone [12], although the tensional mechanism that produced these joints is not known to us. The Zambesi River in Zimbabwe, characterized by right-angle bends, drains a fractured basaltic plateau, where the flow is channeled along the cooling fractures [12]. In these examples, the structures resulting in rectangular networks are tensional in origin. By analogy with Earth, we hypothesize that the rectangular networks on Titan are also controlled by extensional or possible transtensional structures.

Crustal tension occurs on icy outer Solar System bodies as a result of tidal forcing, orbital evolution, despinning or volume changes due to phase changes [17]. These different stress mechanisms produce different zones of extension, compression, and shear on the surface. These different stress mechanisms are modeled as producing zones of tension or transtension at characteristic latitudes [summarized in 17]. Thus, we can compare the locations of rectangular networks, as evidence for extension or possibly transtension, with the model results to infer the most likely stress mechanism(s). Non-synchronous rotation and orbital recession result in extension or transtension at the poles and equator, where the majority of rectangular networks are located, whereas polar wander and despinning generally result in compression at the poles and equator. Thus, polar wander and despinning seem less likely crustal stress mechanisms than non-synchronous rotation and orbital recession for creating the structures that influenced the rectangular networks. These mechanisms are not mutally exclusive, however, and a combination of several could most accurately represent the stress field on Titan.

As mentioned in Methods, using the modified algorithm for Titan, we cannot detect trellis and pinnate drainage patterns. Trellis networks have very similar characteristics to rectangular networks but are distinguished by their overall short exterior links. The RADAR data resolution undoubtedly limits our ability to see short exterior links, so that in the rectangular networks group, there may be some trellis networks that were misdiagnosed. Trellis patterns commonly form on folded highlands. We can assess the classified rectangular networks for possible trellis morphology using a landscape scale brightness pattern. Radar-bright units connote mountainous highlands [18-19]. Thus, we will inspect the radar brightness pattern for each of the rectangular networks to assess if folded terrain, and hence a trellis drainage pattern, is possible.

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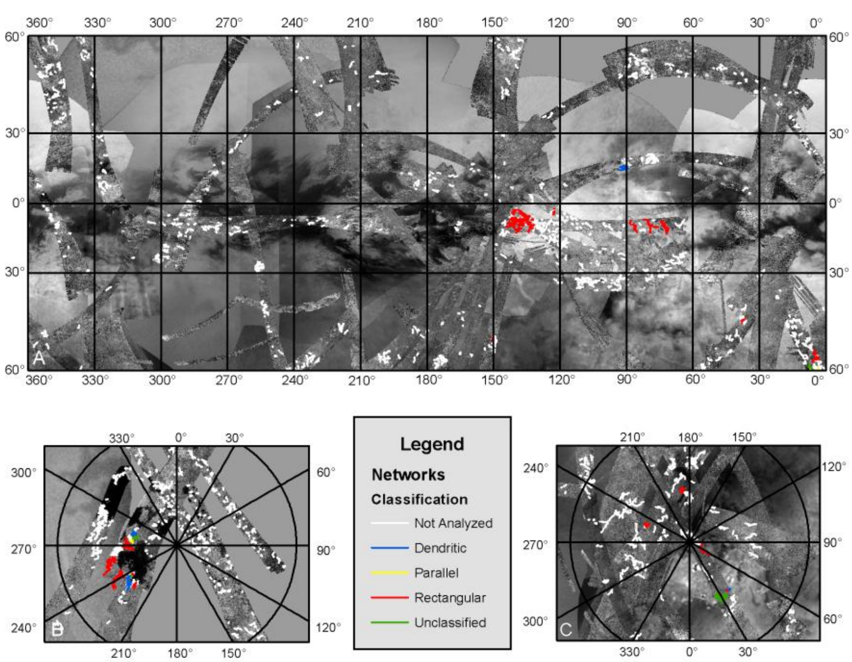

Figure 1. Geographic distribution of networks by drainage pattern classification.