FLUVIAL FLOW ON TITAN: CONTEXT FOR GEOMORPHIC INTERPRETATION. D. M. Burr[1], [1]Carl Sagan Center, SETI Institute (515 N. Whisman Rd, Mountain View, CA, 94043, USA, dburr@seti.org).

Introduction: Previously hypothesized on the basis of Titan's volatile-rich atmosphere and surface conditions [e.g., 1], fluvial flow now appears confirmed by Cassini-Huygens imagery of Titan's surface at multiple wavelengths. Data from the Titan Radar Mapper, the Imaging Science Subsystem (ISS), the Visual and Infrared Mapping Spectrometer (VIMS) and the Hugyens Descent Imager/Spectral Radiometer (DISR) have all been interpreted as showing fluvial channels [e.g., 2,3,4,5]. In support of such interpretation, this abstract first reviews the theoretical basis for morphological similarity between terrestrial and Titan fluvial features, then discusses an approach for estimating discharge for fluvial channels on Titan.

Theoretical work: Fluvial channels and channel networks result from erosion of sediment or bedrock and subsequent transport of this eroded material. Eventual deposition of this sediment can also furnish evidence of fluvial processes. Comparing each of these three processes under terrestrial and Titan conditions lays out a theoretical basis for fluvial channel and network formation on Titan.

Erosion. Erosion occurs in terrestrial channels through multiple processes. Quarrying is the plucking of blocks of material from the channel floor, and requires preparation of the bedrock through hydraulic wedging of sediment into pre-existing discontinuities [6]. Abrasion is the gradual removal of material from the channel rock surface through forcible impact by sediment in the flow [6], and effected by material traveling as bedload on the channel floor; experiments show that fine-grained sediments traveling in suspension make poor abrasive tools [7]. Lastly, cavitation results when sufficiently high local flow velocities produce low pressure resulting in bubbles; the advection and subsequent collapse of these bubbles produce a micro-hammering effect [8, 9, 6].

Each of these processes depends on external circumstances, such as the pre-existence of discontinuities and the availability of appropriately sized sediment. For similar flow conditions of slope, discharge, and sediment supply, basic theoretical considerations and simple laboratory experiments show that these processes should operate at similar rates on Titan as they do on Earth [10]. An integrated model of precipitation, open-channel flow, and sediment transport [11] supports the interpretation of features at the Hugyens landing site [5] as being formed by rainfall and overland flow.

Transport. Sediment is transported by flowing liquid in three modes [e.g., 12]. Bedload moves by rolling, sliding, or saltating along the channel floor. Suspended load is material keep aloft in the water column by turbulence. And washload is the finest fraction of sediment, which is evenly distributed in the water column. These categories are distinguished by ratioing the settling velocity of the particle to the flow shear velocity (a proxy for the upward forces on a particle) [13, 14]. Threshold values of this ratio are derived experimentally for each category [see 15 and references therein]. Because the settling velocity of a given size particle changes with gravity, particle density, and fluid viscosity, threshold curves must be re-calculated for these parameters.

Following work by [15] on Martian fluvial sediment transport, such calculations have been presented for Titan fluvial sediment transport [16]. The results show that flow velocities and minimum flow depths on Earth and Titan (Fig. 1) are within an order of magnitude of each other for a given grain size.

Deposition. The Hjulström curve shows that sediment deposition occurs at lower flow velocities than does sediment erosion [e.g., 12]. To be recognizable from orbit as fluvial, sediment deposits must form distinct, coherent structures such as subaqueous dunes, streamlined bars, or deltas. Such bedforms are composed of bedload (and, to a much lesser degree, suspended load); washload is not deposited except as a thin layer in very quiescent lakes (e.g., as varves). The Huygens data are interpreted as showing large, water-ice rich sediment rounded during transported [5], of a size that would reasonably move as bedload on Titan. In comparison, organic sediments are orders of magnitude smaller [5], of a size that would reasonably move as washload. This difference in size and therefore transport category between water ice and organic sediment grains implies that on Titan bedforms within fluvial channels and deltaic deposits at channel mouths should be comprised primarily of water ice [17]. In contrast, organic sediment should be carried through the channel system and, where deposited in terminal seas or lakes due to infiltration or evaporation, should form a drape. This provides a criterion for identifying fluvial deposits.

Summary. For all other conditions being equal, erosion and sediment transport processes should operate at similar rates on Titan as on Earth. Fluvial deposits are expected to be composed primarily of water ice sediment, not organic material.

Discharge estimation: Given that fluvial processes are physically similar on Earth and on Titan, we can expect a similar morphology between terrestrial and Titan fluvial channels for similar inputs (e.g., precipitation rate and amount). This similarity provides a handle for calculating discharge from Titan channels using terrestrial empirical relationships.

Instantaneous or volumetric discharge is a fundamental parameter in fluvial geomorphology, and of great interest for its usefulness in quantifying the hydrologic cycle on Titan. It refers to the volume of liquid and sediment moved per time and is estimated as the product of flow width, depth, and velocity. The same discharge on a lower gravity body requires a greater width and depth than on a higher gravity body, in order to account for the lower flow velocity due to the smaller driving force [18]. Given a similarity of process, empirical data of terrestrial river width and discharge [19] may be scaled for extraterrestrial gravity [20]. Following this approach, the proportionate increases in flow width for any given discharge value may be calculated for Titan [see 21 for results].

As discussed by [20], distinguishing the true flow dimensions is necessary for valid application of this approach. Flow channels commonly sit within alluvial valleys, as can be seen in terrestrial examples, and application of this technique to the valley instead of the inset flow channel would proportionately overestimate the discharge. The importance of this distinction is demonstrated by [11], who estimate a flow width of only 1-30 meters for the Huygens channels.

Thus, an accurate discharge calculation using this approach requires determination from imagery of an inner channel. Although such a discovery has not yet been widely published, inner channels, bedforms, or other features indicating true flow width may well be discernable in high-resolution Radar images. In addition, the combined use of multiple datasets has revealed information about the morphology of inferred fluvial features that was not distinguishable in either dataset alone [e.g., 4]. Such cross-data correlations will contribute to untangling the fluvial geomorphology of Titan, and making subsequent inferences into Titan fluvial processes.

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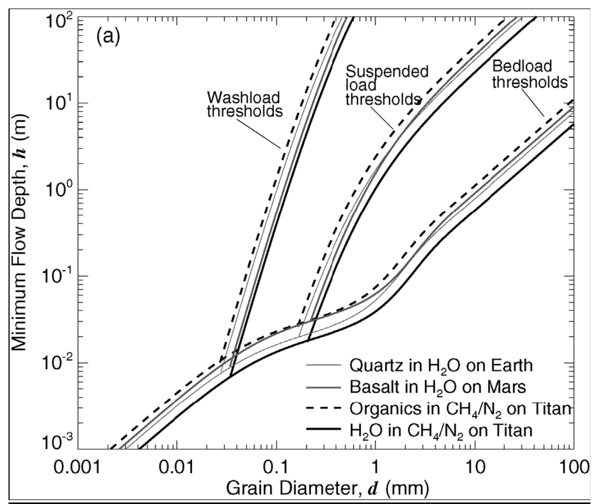

Figure 1: Plot showing similar minimum flow depths required to carry quartz on Earth, basalt on Mars, and organic material and ice on Titan over an arbitrary slope of 0.001 m/m. (from [16])