

LANDFORM EVOLUTION MODELING OF SPECIFIC FLUVIALLY ERODED PHYSIOGRAPHIC UNITS ON TITAN. J. M. Moore¹ A. D. Howard², and P. M. Schenk³, ¹NASA Ames, MS 245-3, Moffett Field, CA 94035 (jeff.moore@nasa.gov), ²Dept. of Environ. Sci., Univ. Virginia, Charlottesville, VA 22903 (ah6p@virginia.edu), ³Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (schenk@lpi.usra.edu).

Introduction: Several recent studies have proposed certain terrain types (i.e., physiographic units) on Titan thought to be formed by fluvial processes acting on local uplands of bedrock or in some cases sediment [e.g., 1-4]. We have earlier used our landform evolution models to make general comparisons between Titan and other ice world landscapes (principally those of the Galilean satellites) that we have modeled the action of fluvial processes [5]. Here we give examples of specific landscapes that, subsequent to modeled fluvial work acting on the surfaces, produce landscapes which resemble mapped terrain types on Titan.

Initial Terrain type Investigation: Crenulated Terrain and Isolated Ridges are commonly found in the equatorial latitudes of Titan, especially in the Xanadu region. Crenulated terrain generally occurs in discrete patches (sometimes closely spaced), often with significant linear elongation that might be associated with tectonic deformation [6]. Crenulated terrain has been interpreted by us and others to be mountainous relief that has been highly dissected by fluvial processes [1-6]. Some *crenulated terrain* is associated with dissected rims of large impact basins [3]. Such terrain may be analogous to eroded mountain belts on Earth. In the examples shown in Figure 1, crenulated uplands can be seen to range from nearly continuous in exposure to isolated belts surrounded and separated by increasing amounts of sediment infilling local lows. We investigate here whether the fluvial erosion of a region of tectonized terrain comprised of belts of ridge and trough (grooved) terrain separated from one another by regional lowlands might result in a landscape that resembles the crenulated and ridged terrains of Titan. Or alternatively would the erosion of a randomly-generated pseudo-fractal terrain of varying degree of small-scale roughness yield a closer match.

Landform Evolution Modeling: We use a landform evolution model (LEM) [7] to simulate fluvial and lacustrine modification to explore the degree to which strongly eroded landscapes retain information about their initial morphology. We utilized two types of initial conditions: (1) Digital elevation models (DEMs) of actual icy world landscapes not modified by fluvial processes (primarily tectonized landscapes of Ganymede and Europa) supplied by PMS; and (2) Randomly-generated pseudo-fractal terrain of varying

degree of small-scale roughness. For type 1 runs, we assumed complete runoff, so that depressions become lakes, and drainage exits somewhere along edges of simulation domain. Edges of simulation domain were fixed (non-erodible). For type 2 runs, edge boundaries were periodic and runoff was balanced by lake evaporation, resulting in small lakes within the simulation domain. Flow rates were scaled to Titan gravity. Rate of channel incision was set to be proportional to shear stress on bed (parameterized as a power function of discharge and gradient). Weathering in the model produced transportable debris. Sediment was deposited in low-lying areas, producing alluvial fans and infilling depressions from the edges inwards in deltaic deposits within lakes. We assumed little fine suspended sediment deposited in lakes. In LEMs, the spatial pattern of erosion does not vary much with different parameters but the rate of erosion is very affected. For the purposes of these initial trials, the *pattern* not the rate, was deemed most important.

Results: The pseudo-fractal landscapes have roughness expressed over multiple spatial scales, but no expression of systematic structural influence (Fig. 2a). When eroded, highlands are eroded by weathering followed by fluvial entrainment, whereas lowlands are infilled by bajada-like fans and deltaic deposits gradually encroaching on lacustrine depressions (Fig 2b). Because of the balance between lacustrine evaporation and runoff, persistent lakes are formed which deepen through time, but they may become inactive and infilled if drainage is subsequently integrated into larger basins. If deposition of suspended sediment were modeled, these depressions would feature infilling by fine lacustrine sediment. The landscape becomes bimodally segregated into steep, dissected uplands with abrupt but irregular lateral transitions into smooth, low gradient alluvial plains (Fig. 2b). The location of highlands and plains is dictated by the original topography. If the landscape is subjected to further erosion, the uplands shrink and lower, and the alluvial plains expand to cover a greater percentage of the landscape.

Simulated erosion of tectonized terrain from Ganymede (30°S, 185°W, Fig 3a) similarly results in three landform elements, steep eroded uplands, broad alluvial plains, and depressions gradually infilled by deltaic deposits, particularly evident in the interior of craters, which, in this simulation, are assumed to host

deep lakes due to the complete runoff and no assumed evaporation. Particularly noteworthy is the strong inheritance of initially elevated regions in the resulting eroded landscapes, which, in this case, features linear ridges inherited from the grooved initial surface (Fig. 3b).

Discussion and Conclusions: (1) Regarding the possible structural control of eroded ridges on Titan. A surprising result from this study is that eroded pseudo-fractal terrain produces a landscape broadly composed of belts of isolated somewhat aligned ridges. As noted above, the erosion of the Ganymede sample produces a landscape in with the individual ridges exhibiting a higher degree of alignment and similarity of scale than is observed on Titan. (2) Alluvial lowlands in fractal terrain, if partially flooded by increase in methane runoff, would resemble lakes on Titan – if shallowly flooded, would be like Ontario Lacus – if more deeply flooded, like the N polar lakes with some portions of shorelines transitioning to alluvial plains and others directly abutting

eroded highlands. Lakes could shallow, as observed [8], despite the abrupt, crenulated boundaries with eroded uplands. (3) If erosion is continued until few uplands remain, our models appear to produce possible analogs to dissected mottled terrain (allowing for some of this terrain to feature aeolian mantling as well). We are currently beginning runs to evaluate the original appearances of dissected mottled terrain, putative cratered terrain, and dissected plateau terrain [1].

References: [1] Moore, J. M., et al. (2014) *JGR*, 119 (9), 2060-2077. [2] Lopes, R. M. C., et al. (2010) *Icarus*, 205(2) 540-558. [3] Williams, D. A., et al. (2011) *Icarus*, 212, 744-750. [4] Aharonson, O., et al. (2014) in *Titan: Interior, Surface, Atmosphere and Space Environment*, pp. 63-101, Cambridge Univ. Press, NY. [5] Moore, J. M., et al. (2010) 41st *LPSC*, Abstract #1167. [6] Radebaugh, J., et al. (2011) *Icarus*, 211(1) 672-685. [7] Howard, A. D., et al. (2007) *Geomorphology*, 91, 332-363. [8] Aharonson, O., et al. (2009) *Nat. Geosci.*, 2, 851-854.

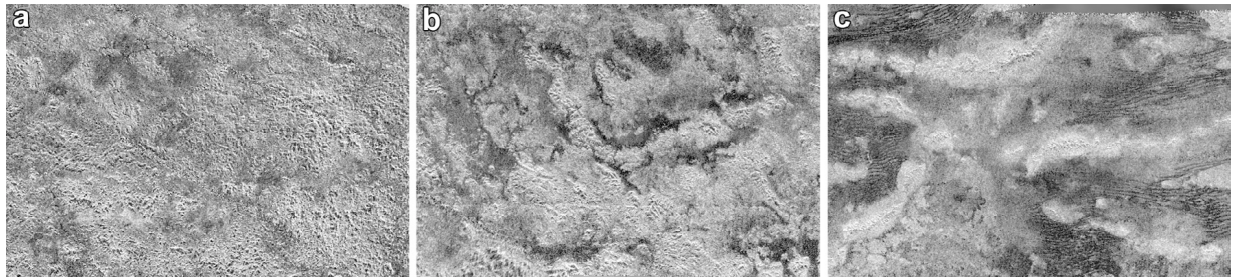


Fig. 1. Three views of equatorial Crenulated Terrain or Isolated Ridges [1] interpreted to be exposures of uplands bedrock, principally eroded by fluvial activity, showing increasing degrees of local sediment infilling of the local lows (left to right). Individual frames cover an area ~275 km across, N up. All at ~10°S. a. 115°W, b. 100°W, c. 205°W. (Excerpts from the latest USGS digital base map.)

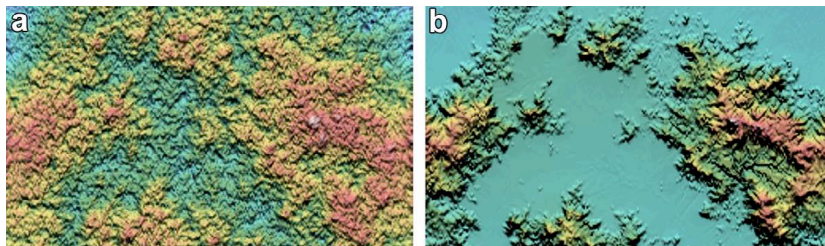


Fig. 2. The pseudo-fractal landscapes have roughness expressed over multiple spatial scales, but no expression of systematic structural influence. A surprising result from this study this that fluvial erosion of this terrain produces a landscape broadly composed of belts of isolated somewhat aligned ridges.

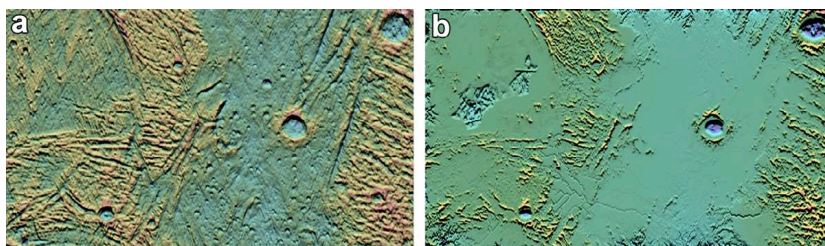


Fig. 3. Simulated fluvial erosion of DEM of Ganymede terrain (~300 km across). The erosion of the Ganymede sample produces a landscape in with the individual ridges exhibiting a higher degree of alignment and similarity of scale than is observed on Titan.