

EFFECTIVENESS OF FLUVIAL INCISION PROCESSES ON TITAN: HOW WERE THE CHANNELS CARVED? G. C. Collins, Wheaton College, Norton Massachusetts (visiting LPL during spring semester 2005)

Sinuuous channels on the surface of Titan have been observed by DISR on Huygens, as well as the RADAR and ISS instruments on Cassini. The emerging consensus is that these channels are fluvial in origin, most likely carved by liquid methane running across the surface. The origin of this liquid could possibly be from atmospheric precipitation or from subsurface reservoirs. In either case, channels could be carved into the surface of Titan by moving loose regolith and/or wearing away the icy bedrock. In this presentation I attempt to show how the effectiveness of these stream incision processes scale from the Earth to Titan.

Sediment transport: The motion of sediment particles in a turbulent flow depends on the Shields parameter (τ_c), which is basically the ratio of lift forces from turbulent flow around the particle to the submerged weight of the particle [1]. At a critical value $\tau_{c,c}$, sediment particles at the bottom of a flow will begin to move. As τ_c increases, the particles will first slide and roll along the bottom, then begin to saltate, and finally become suspended in the flow. The fall velocity of a sediment particle on Titan, and the shear velocity required to move that particle, are about 30% of the equivalent velocities on the Earth, mostly due to the lower submerged weight of sediment on Titan. These velocities generally agree with those of Burr et al. [2], though they used a slightly different approach. Since gravity is lower on Titan than Earth, the slope required to achieve these flow velocities is fairly similar, so a stream valley at a certain grade will transport roughly the same sized sediments on Titan and the Earth.

Bedrock incision: Incision of stream valleys into bedrock may take place through the processes of abrasion, plucking, and cavitation [3]. I have modified a bedload abrasion model [4] to predict rates of incision by saltating sediment in Titan stream channels. The main factor which makes incision by abrasion slower on Titan is the lower kinetic energy imparted to the bedrock by moving sediment particles. However, initial (crude) experiments on water ice indicate that this is offset by an increased susceptibility of ice to abrasion relative to rock. Therefore stream incision rates by abrasion should be about the same as rates on the Earth, for the same combination of slope, discharge, and sediment supply.

Plucking loose blocks of bedrock from the bottom of streams on Titan should be more effective due to the lower velocities required to move large particles. However, the existence of such loose blocks depends on the existence of closely spaced joints, and is enhanced by layering in the bedrock [3].

Cavitation has been proposed as an effective agent of erosion on Titan due to the high vapor pressure of methane on the surface [5]. However, the inception of cavitation depends on the difference between the vapor pressure and the ambient pressure in the fluid [6]. Because of Titan's 1.5 bar surface pressure, cavitation is actually more difficult to induce than it is on the Earth. It is unknown whether cavitation occurs in natural streams on the Earth [3], and the higher velocity required to induce it on Titan poses a serious challenge given Titan's low gravity.

Discussion: Despite large differences in gravity and material properties of the liquid and sediment, streams on Titan should be remarkably similar to streams on the Earth, in terms of the slope required to transport sediment, and the rate of bedrock incision by abrasion. However, there are many unknown factors that we need to study in order to further constrain fluvial erosion on Titan, and determine whether it is truly "Earth-like." (1) How much sediment is available in highland areas of Titan, and how is new sediment created in these areas? Stream incision by abrasion is ineffective without sediment load. (2) Is the ice bedrock on Titan likely to be finely jointed? This will control the efficacy of plucking. (3) Does water ice have the same abrasion susceptibility at Titan surface temperatures? If the bedrock is an ammonia-water mixture, how does that change its susceptibility? (4) What is the typical precipitation profile of a rainstorm on Titan, and can methane infiltrate into a water ice regolith? This is essential for determining the typical discharge in streams on Titan.

References: [1] Julien, P.Y., *Erosion and Sedimentation*, Cambridge, 1995; [2] Burr, D.M., et al., *LPSC XXXVI* #2044, 2005; [3] Whipple, K.X., et al., *GSA Bulletin* 112, 490-503, 2000; [4] Sklar, L.S., and W.E. Dietrich, *Water Resources Res.* 40, W06301, 2004; [5] Lorenz, R.D., and J. Mitton, *Lifting Titan's Veil*, Cambridge, 2002; [6] Arndt, R.E.A., *Ann. Rev. Fluid Mech.* 13, 273-328, 1981.