SURFACE EROSION OF TITAN.
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Introduction: The surface of Titan has been revealed globally by the Cassini observations in the infrared and radar wavelength ranges as well as locally by the Huygens instruments. Sand seas, recently discovered lakes, distinct landscapes and dendritic erosion pattern indicate dynamic surface processes. During Cassini's T20 flyby the Visible and Infrared Mapping Spectrometer (VIMS) [1] observed an extremely eroded area at 30° W, 7° S with resolution better than 350 m. Analyses of the drainage dynamics and comparison with the drainage systems at the Huygens landing site yield high discharge values of the associated channel systems and extreme runoff production rates of 10 to 50 cm/day. In addition, large sandur-like alluvial fans covering ten thousands of square kilometres are discovered at the boundary between high-standing bright and low-laying dark regions. To account for the estimated runoff production and widespread alluvial fan deposits of fine-grained material both frequent recurrence intervals and sudden release of area-dependent large fluid volumes are required. Frequent equatorial storms with heavy rainfall of methane and related hydrocarbons might explain this catastrophic erosion. High-energy flow will cause mechanical weathering and large accumulations of sand in alluvial fans that is picked up by winds to form Titan's vast equatorial sand seas and dune fields.

Bohai Sinus Region and Pacman Bay: During Cassini's 20th Titan flyby on 24 October 2006, VIMS observed the bright to dark boundary at about 30°W and 7°S. In the Quivira-Aztlan region a deep incision called Bohai Sinus was imaged with a resolution of about 1 km/pixel. Within the Bohai Sinus area an indentation called Pacman Bay is covered by the highest resolution image with a 330 m/pixel (Fig. 1).
Bohai Sinus is one of the most prominent disintegration areas between bright and dark materials and is expressed as an indentation tending northwards into the bright material about 100 km deep and 90 km wide. At the eastern end of the sinus a bright spot, called Marajo Facula, of about 60 km by 40 km occurs which is clearly isolated from the main bright area by a dark channel 2 km to 8 km wide. At the northern end of Marajo Facula, Pacman Bay, a 25 km wide protrusion, separates the island from the northern bright terrain. VIMS wavelengths ratios at 1.29/1.08 µm, 2.03/1.27 µm and 1.59/1.27 µm have been composed to a color image (RGB) in order to enhance the overall contrast of the observations (Fig. 2). As water absorptions are strongest in the 1.6 µm and 2 µm wavelength region, blue color indicate relative water ice-rich materials. Brownish colors coincide with regions that occur as dune material in radar images [2,3]. Bohai Sinus and the southern border of the bright terrain are relatively rich in water ice and mark a transition zone between the bright material and the equatorial dune material. Weathering and erosion are suggested to be responsible for transforming the state of surface materials. However the related geologic processes are not completely understood so far.

Erosional processes: Surface conditions on Titan are different from that on Earth. However discharge of fluids are also driven by the gravity and to a first order estimate we can model flows and discharges on Titan based on Earth-analogues for surface runoff. Liquid methane (CH_4) is suggested to be the main fluid on Titan. Its viscosity at surface temperature (95° K) is 1.8 10^{-4} Pa s which is approximately five times smaller than water at 298° K (1.8 10^{-4} Pa s) [4,5]. Thus, liquid methane will produce turbulent flows on Titan's surface that have significant erosional power. On Earth an empirical function relates channel width W to discharge Q in a first order approach, for alluvial unconfined sand-bedded channels with sand or silt banks carrying bankfull floods with relative short recurrence intervals [6]:

$$Q = 1.9\ W^{1.22} \qquad (1)$$

Although the conditions on Titan are different of that on Earth the equatorial vast sand seas and dunes [7] requires enormous production and sedimentation of small particles that have comparable mechanical properties of terrestrial gravel and river sands. In order to scale the empirical discharge equation to Titan's gravity, we have to adopt depth, width, and velocity of 1.39, 1.61 and 0.46 times that of unconfined erosional channels on Earth, respectively.

According to the measured channel widths in the backyard of Bohai Sinus, discharges should be in the order of 2000 m^3/s to 22500 m^3/s with a mean value of 8600 m^3/s, which are comparable to discharges in large river systems on Earth and Mars. If we assume a drainage area that directly feeds Bohai Sinus with a maximum radius of 50 km behind the bay, the production rates (P = Q/area) will range between 2.2 cm/day and 24 cm/day with a mean of 9.3 cm/day. The much better resolved drainage pattern at the Huygens landing site [8] yield first order channel widths of about 250 m that result, according to the above model, in discharges of about 900 m^3/s. However, due to the much smaller drainage areas at the landing site [8] of about 7 km radius the runoff production rates reach 50 cm/day. Runoff production rates on Titan seem to be one to two magnitudes higher than those typically for river systems on Earth [9]. Such runoff production rates will induce high erosion power to Titan's high standing bright areas causing intense mechanical weathering and production of fine-clastic debris that is rapidly transported along the local gradient.

To account for the estimated high runoff production rates and observed widespread alluvial fan deposition of fine-grained material both frequent recurrence intervals and sudden release of area dependent large fluid volumes are required.

References: [1] Brown, R.H. et al. (2005) *SSR*, *115*, 115–18. [2] Soderblom, L. et al. (2007) *PSS*, in press. [3] Barnes, J.W., et al. (2007) *Icarus*, *186*, 242-258. [4] NIST (2005) *Chem. Web Book, Stand. Ref. Data Base*, *69*. http: webbook.nist.gov./chemistry. [5] Lorenz, R.D., et al. (2006) *Science*, *312*, 725-727. [6] Hanley, H.J.M., et al. (1977) *J. Phys. Chem. Ref. Data* 6, 597-601. [7] Osterkamp, W.R., and Hedman, E.R. (1982) *U.S.G.S. Prof. Paper*, *1242*. [8] Tomasko, M.G., et al. (2005) *Nature*, *438*, 765-778. [9] Irwin, R.P.R., et al. (2005) *Geol. 33*, 489-492.

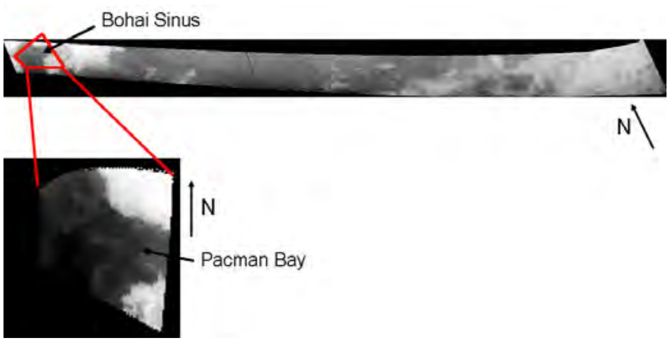

Fig. 1: High resolution VIMS observations during orbit T20 including the Bohai Sinus Region (top) including the Pacman Bay (bottom).

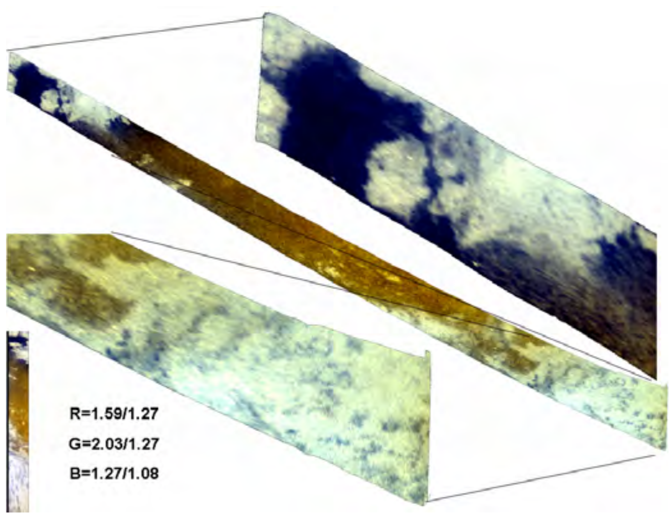

Fig. 2: VIMS color composite using ratios at 1.59/1.27 μm (red), 2.03/1.27 μm (green), and 1.29/1.08 μm (blue).