EROSION ON TITAN.

Ralf Jaumann[1,2,*], Robert H. Brown[3], Katrin Stephan[1], Larry A. Soderblom[4], Christophe Sotin[5], Stephane Le Mouélic[5], Stephane Rodriguez[5], Roger N. Clark[6], Jason Barnes[3], Bonnie J. Buratti[7], Tom B. McCord[8], Kevin H. Baines[7], Dale P. Cruikshank[9], Caitlin A. Griffith[3], Phil D. Nicholson[10], Roland Wagner[1] and Mirjam, Langhans[1]
[1]DLR, Institute of Planetary Research. Rutherfordstrasse 2, 12489 Berlin, Germany; [2]Dept. of Earth Sciences, Inst. of Geosciences, Freie Universität Berlin, Germany; [3]Lunar and Planetary Laboratory, University of Arizona, TucsonAZ 85721, USA; [4]U.S. Geological Survey, Flagstaff, AZ 86011, USA; [5]University of Nantes, 44072 Nantes Cedex 3, France; [6]U.S. Geological Survey, Denver Federal Center, Denver CO 80225, USA; [7]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109, USA; [8]Planetary Science Institute, 22 Fiddler's Rd., Winthrop WA 98862-0667, USA; [9]NASA Ames Research Center, 245-6, Moffett Field, CA 94035-1000, USA; [10]Department of Astronomy, Cornell University, Ithaca, NY 14853, USA; [*]Corresponding author (Fax :+493067055 402 ; Email address: ralf.jaumann@dlr.de

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. Extended dune fields, 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 500 m/pix.. 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 up to 220 cm/day. In addition, large dune free plains covering ten thousands of square kilometers are discovered at the boundary between high-standing bright and low-laying dark regions. To account for the estimated runoff production and widespread plain deposits of fine-grained material both frequent recurrence intervals and sudden release of areadependent 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.

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 500 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 40 x 60 km bright spot occures, called Marajo Facula, 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 channels carrying bankfull floods with relative short recurrence intervals [6].

Although the conditions on Titan are different of that on Earth the equatorial vast dune fileds [7] require 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 of 200 to 1000 m in the backyard of Bohai Sinus, discharges should be in the order of 130 m^3/s to 1,600 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 area of about 320 km^2, the production rates (P = Q/area) will range between 4 cm/day and 40 cm/day. The much better resolved drainage pattern at the Huygens landing site [8] yield for first order channel widths of about 30 - 100 m that result, according to the above model, discharges of 4 m^3/s – 30 m^3/s. However, due to the much smaller drainage areas at the landing site [8] the runoff production rates are in the same order. 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 (Fig. 3) 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, 55,* 2025-2036. [3] Barnes, J.W., et al. (2007) *Icarus, 186*, 242-258. [4] NIST (2005) *Chem. Web Book, Stand. Ref. DataBase, 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.

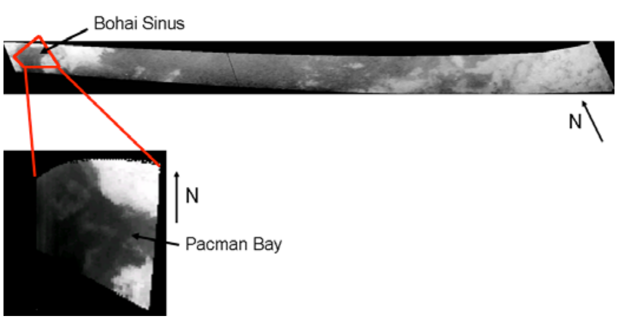

Fig. 1: High resolution VIMS observations during orbit T20 including the Bohai Sinus Region (top) including the Pacman Bay (bottom).

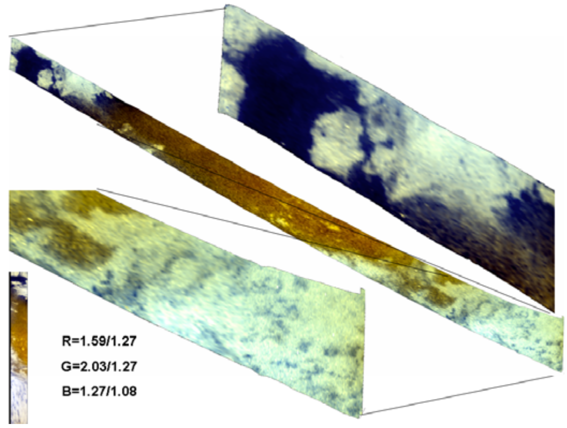

Fig. 2: VIMS color composite using ratios at 1.59/1.27 µm (red), 2.03/1.27 µm (green), and 1.29/1.08 µm (blue).

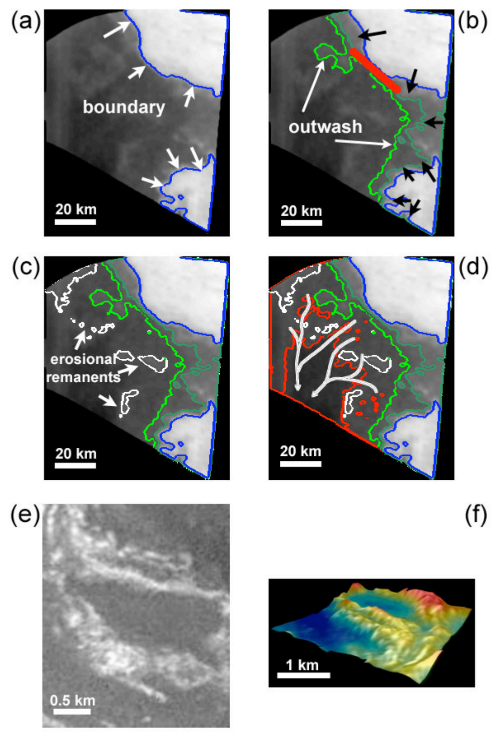

Fig. 3| Geologic Map of the Pacman Bay Region. Bright material is separated by dark materials through a distinct boundary (a). A zone of relatively bright outwash material borders the bright to dark transition (b), which vanish at a presumably tectonically controlled cliff (red bar). Input (black arrows) to the outwash regions came from the bright backland. Outside of the outwash zone are bright spots, which seem to be remnants left over from retreating erosion (c) that can also found at the Huygens landing site (e and f). (d) materials from behind the ostacles might have been washed out catastrophically into the fan sedimentation area after reaching a critical mass. Remnants that surround such depressions are also exposed at the Huygens Landing site (e, f) (DISR image 14/01/2005 and stereo topographic model).