SHAPING TITAN'S LANDSCAPES BY DISSOLUTION AND EVAPORATION: THE CASE OF ONTARIO LACUS, A HIGH-LATITUDE SEMI-ARID KARST-PLAYA LANDSYSTEM. T. Cornet[1], O. Bourgeois[1], S. Le Mouélic[1], S. Rodriguez[2], C. Sotin[1,3], A. Lefèvre[1], J. W. Barnes[4], R. H. Brown[5], K. H. Baines[3], B. J. Buratti[3], R. N. Clark[6], P. D. Nicholson[7], [1]*Laboratoire de Planétologie et Géodynamique, Nantes, France.* [2]*Laboratoire AIM, CEA Saclay, Gif/Yvette, France.* [3]*JPL, Pasadena, USA.* [4]*University of Idaho, Moscow, USA.* [5]*Department of Planetary Sciences, University of Arizona, Tucson, USA.* [6]*USGS, Denver, USA.* [7]*Department of Astronomy, Cornell University, Ithaca, USA. (thomas.cornet@univ-nantes.fr).*

Introduction

Ontario Lacus (72°S, 180°E) is so far the largest feature of Titan's whole southern hemisphere interpreted as a lake [1] or a playa [2]. It has been imaged by the Imaging Science Subsystem (ISS) in June 2005 (rev09) and March 2009 (T51) [1, 3], by the Visual and Infrared Mapping Spectrometer (VIMS) in December 2007 (T38) [4, 5] and March 2009 (T51) [6], and by the RADAR instrument in June-July 2009 (T57-58) and January 2010 (T65) [6, 7, 8, 9].

From all these data, we compiled a geomorphological map of Ontario Lacus and its surroundings (Fig. 1). In accordance with Lorenz et al. [2], we suggest that Ontario Lacus is a partially liquid-covered flat-floored depression (playa). This depression displays many geomorphological similarities with karstic/evaporitic terrestrial ephemeral lakes encountered under arid/semi-arid climates, such as the Etosha pans in Namibia [6]. We discuss here the implications of this analogy on the role of dissolution and evaporation on land-shaping processes at Ontario Lacus and, perhaps, on Titan as a whole [10, 11, 12, 13, 14].

Mapping of Ontario Lacus

The geomorphological map we compiled using all the imagery datasets available on Ontario Lacus is shown in Fig. 1 [6]. Ontario Lacus is a shallow flat-floored depression located in the lowest part of a sedimentary basin composed of an alluvial plain (Unit F) drained by a poorly developed channel network and surrounded by small mountain ranges (Units G and I). In the southern part of Ontario Lacus, channels running on the floor of the depression are visible at the same location in the VIMS T38 (December 2007) infrared data and in the RADAR SAR T57-58 (June-July 2009) and T65 (January 2010) data [6]. Their constancy in location over a 2-years interval, in 3 different datasets acquired using 2 distinct sensors, and their location in a part of Ontario Lacus appearing brighter than the rest of the depression in RADAR images, suggests that the southern part of Ontario Lacus was not covered by liquids at the time of these observations. Only the darkest portions of Ontario Lacus on RADAR images, representing 53 % of its surface area and mostly located in the northern part of the depression, would be covered by liquid hydrocarbons (Unit A). The rest of the depression would rather correspond to a liquid hydrocarbon saturated substratum (Unit B).

According to this interpretation, the contour of Ontario Lacus as imaged so far by ISS and VIMS would be the topographic margin of the depression rather than the border of its liquid fill. As such, it should remain at the same location through time. To test this hypothesis, we are currently analyzing the position of this contour on all ISS, VIMS and RADAR images from 2005 to 2010, using a classical automatic gradient-based edge detection method [15]. An example of gradient-based edge detection applied on the VIMS T38 image is shown in Fig. 2, using several edge detector operators, to illustrate the efficiency of this technique in detecting contours in images.

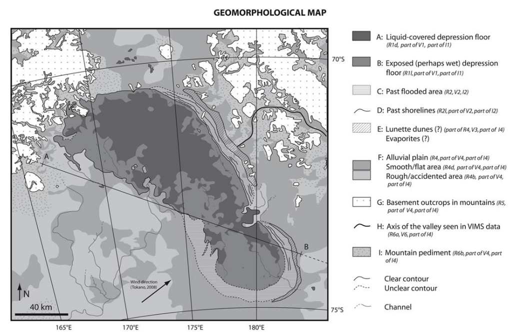

Figure 1: Geomorphological map inferred from the cross-comparison of VIMS, ISS and RADAR data.

Comparison with terrestrial karst-playa landsystems under arid/semi-arid climates

Titan is characterized by an active hydrocarbon cycle, involving methane and ethane, two compounds able to be liquid and probably to evaporate at the surface [16]. This cycle is closely similar to the water cycle on Earth [17]. Catastrophic rainy events may occur sporadically on the surface and lead to rapid and striking surface changes [18]. However, estimated global year-averaged precipitation rates [16, 19] are largely lower than estimated global year-averaged evaporation rates [16]. This suggests that, in some regions of Titan, the climate is probably similar, though with longer timescales, to terrestrial arid/semi-arid climates where occasional heavy flooding events are followed by months of droughts.

The Etosha region (Namibia) is one of those regions of the Earth, where year-averaged potential evaporation rates greatly exceed year-averaged precipitation rates [20]. Dissolution and evaporation acting under the semi-arid climate of this region are responsible for the development of specific karst-playa landsystems. These include the Etosha Pan (Fig. 3), a playa located in a shallow flat-floored karstic depression similar to Ontario Lacus in size, shape and geomorphological setting [11, 6]. This karstic depression developed by dissolution at the expense of a thin calcrete surface layer lying on a porous sedimentary substratum [21], thanks to vertical motions of the groundwater table and with only minor contribution from surface water runoff. Given the strong similarities between the

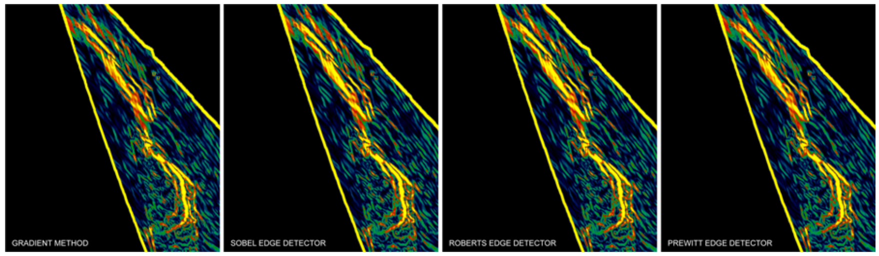

Figure 2: Gradient-based edge detection technique applied to the VIMS T38 image. Contours show up at the same location with different edge detecting operators. Contour thicknesses are confidence strips reflecting the inaccuracy of determined contour locations due to the image resolution.

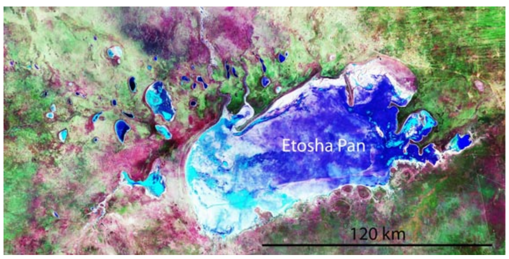

Figure 3: Landsat image of the semi-arid karst-playa Etosha landsystem in Namibia.

Ontario Lacus and Etosha Pan landsystems (climate, topography, geomorphological setting, size and shape), dissolution of a surface layer and vertical motions of an underground alkanofer (controlled by evaporation and precipitation of liquid hydrocarbons) could pertain to the formation of Ontario Lacus' depression, to temporal changes in its surface liquid coverage and to the development of its putative sedimentary fill [6].

Discussion: dissolution and evaporation as land-shaping process(es) on Titan

Ontario Lacus is not the only example of Titanian morphologies suggesting that dissolution and evaporation can shape Titan's landscapes. In the southern hemisphere, several morphological features in the Sikun Labyrinthus region are reminiscent of karstic morphologies [13, 14], while in the northern hemisphere evaporitic deposits located in and around lakes have potentially been identified [22]. Since Titan's North Polar region is spangled with numerous lakes, much more examples documenting dissolution processes on Titan's lakes are potentially present in the northern hemisphere [10, 11, 12]. The presence of a soluble surface layer on Titan, similar to the Namibian calcrete layer, is required to explain these dissolution processes and the observed morphologies. Among all hydrocarbons that are supposedly synthesized in Titan's atmosphere and potentially falling onto its surface, several compounds can be dissolved in liquid [23]. Some of these are even more soluble in liquid methane/ethane than calcareous rocks are in water on Earth [14].

To form the soluble surface layer on Titan, two mechanisms at least can be considered. First, solid hydrocarbons synthesized in the atmosphere can fall and accumulate onto to surface, thus building over geological timescales a layer up to several tens of meters in thickness [14]. Alternatively (but not exclusively), a formation mechanism similar to that of calcrete layers on Earth can be proposed. Under terrestrial semi-arid climates, surface calcrete layers are built on geological timescales by progressive crystallization of dissolved calcium carbonates ontop their porous substratum during evaporation of calcium-charged groundwaters [21]. The soluble surface layer on Titan could therefore be fed thanks to the crystallization of solutes during evaporation of underground liquid hydrocarbons. Laboratory experiments investigating the behavior of various hydrocarbons with respect to dissolution and evaporation [24, 25, 26] will help constraining the development mechanisms of this surface layer and of the associated landforms.

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