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A SURFACE DISSOLUTION/PRECIPITATION MODEL FOR THE DEVELOPMENT OF LAKES ON TITAN, BASED ON AN ARID TERRESTRIAL ANALOGUE: THE PANS AND CALCRETES OF ETOSHA (NAMIBIA). O. Bourgeois[1], T. Lopez[1], S. Le Mouélic[1], C. Fleurant[2], G.Tobie[1], L. Le Corre[1], L. Le Deit[1], C. Sotin[3] and Y. Bodeur[1], Laboratoire de Planétologie et de Géodynamique, UMR 6112, CNRS, Université de Nantes, Faculté des Sciences et Techniques, 2 chemin de la Houssinière BP 92208, 44322 Nantes Cedex 3, France. [2]UPSP Paysages, Institut National d'Horticulture, 2 rue André Le Nôtre - 49045 Angers Cedex 01, France. [3]JPL, Pasadena, USA. olivier.bourgeois@univ-nantes.fr

Introduction: Images collected by the Synthetic Aperture Radar (SAR) onboard the Cassini spacecraft revealed the existence of closed, smooth and flat depressions above northern and southern latitudes of 60° on Titan, Saturn's largest moon [1,2]. Due to the very low radar backscatter of these depressions and their association with networks of ramified channels, they have been interpreted as lakes of liquid hydrocarbons and dissolved nitrogen, resting on the icy crust that covers this moon [1,2,3].

These lakes include large (over 100,000 square kilometers) seas with dendritic or poorly defined contours, small (1-10 km wide) circular steep-sided depressions, and medium-sized (20-50 km wide) depressions, the contours of which are composed of adjacent circular segments (Fig. 1). Some lakes are completely filled with radar-dark material, while others are partially filled and some are empty [1,2]. Most of these depressions are surrounded by plains flat and smooth, some of which are covered by extensive fields of parallel linear dunes [4].

By comparison with a terrestrial analogue located in the Etosha Basin (Namibia), we introduce here a dissolution/precipitation model for the development of these lakes at the expense of a superficial soluble layer.

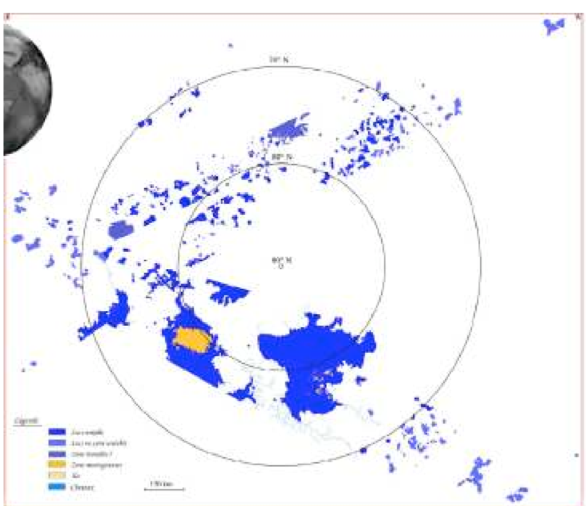

Figure 1: Map of Titan's northern lakes, interpreted from a mosaic of Cassini SAR images.

Pans and calcretes of Namibia: The Etosha Basin is an extremely flat sedimentary basin located at the western border of the Kalahari desert in northwestern Namibia. The climate is semi-arid (average annual precipitation rate: 300 mm/yr; average annual potential evaporation rate: 2000 mm/yr). Sediments in the basin include Cretaceous to Tertiary clays and silts, covered by a layer of calcrete a few meters in maximal thickness [5,6]. The calcrete has formed by precipitation of dissolved calcium carbonate at or near the surface, due to the average annual dominance of groundwater evaporation on precipitation [5,6,7].

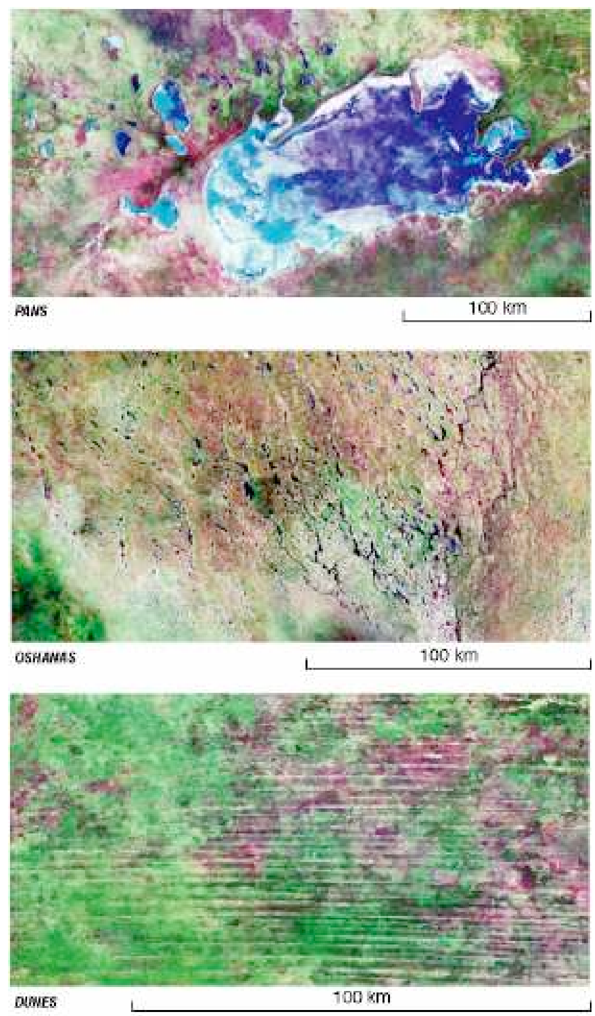

Figure 2: Landsat images showing the morphology of pans, oshanas and dunes in the Etosha Basin (Namibia). The development of pans and oshanas is typical of surface dissolution/precipitation processes occurring in extremely flat, semi-arid regions.

Fields of parallel linear sand dunes, several hundred kilometers in length, cover some parts of the basin (Fig. 2). Other parts are covered by dozens of so-called pans: these are closed, steep-sided, extremely flat and smooth depressions, 1 to 200 km wide and a few meters deep. Relict rounded boulders of calcrete rest on the silty, clayey and evaporitic floors of the pans and provide evidence that the pans grow by radial regressive dissolution of the calcrete layer.

The pans are or are not connected to each other by shallow channels named oshanas. During rainstorms, rainwater floods the oshanas, infiltrates the calcrete layer and fills completely or partially some or all of the pans. Water stored in the pans subsequently evaporates within a few days or weeks, leaving thin accumulations of fine-grained evaporitic sediments on their floor [5,6].

Growth model: The morphology of lakes on Titan and of pans in Namibia suggests that both kinds of landforms develop by lateral growth and coalescence of individual seeds initially circular and distributed more or less regularly on the topographic surface (Figure 3).

We have developed a quantitative geometrical model of this growth process. Inputs for the model are the surface distribution and radial growth rate of the seeds. The model then computes the shapes, perimeters and surface areas of the lakes at any stage of their development. Shapes, perimeters and surface areas of landforms produced by the model are comparable to those of small and medium-sized lakes of Titan and to the pans of Namibia.

On the basis of this geometrical simulation, and by comparison with the development of pans at the expense of the calcrete layer of Etosha, we infer that the small and medium-sized lakes of Titan grow by regressive radial dissolution, during flooding episodes associated with rainstorms, of a superficial soluble layer. The formation of this layer can be explained, as for the superficial calcrete layer of Namibia, by precipitation at or near the topographic surface of non-volatile materials, during evaporation of liquids accumulated in the ground after rainstorms.

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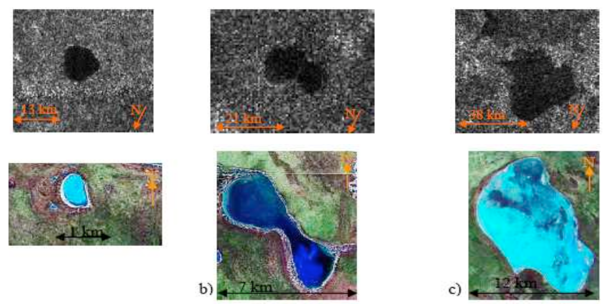

Figure 3*: Compared morphology of lakes on Titan (above, Cassini SAR images) and pans in Namibia (Landsat images). Our favored hypothesis for the development of these landforms is that isolated circular seeds (left) increase in diameter by radial dissolution, then coalesce with nearby seeds (center) and eventually form wider lakes, the contours of which are composed of adjacent circular segments (right).*

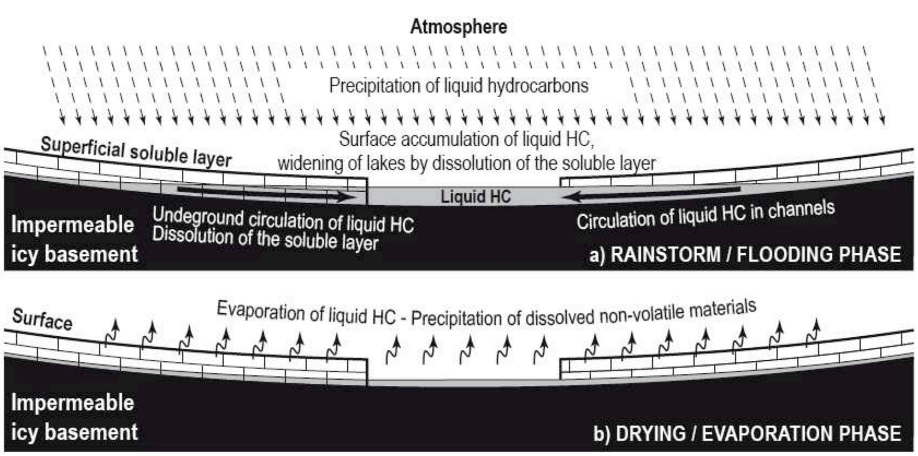

Figure 4*: Conceptual model of development of the lakes of Titan, based on processes observed in Namibia. a) During rainstorms, liquid hydrocarbons flood the lakes and channels network, and dissolve the superficial layer. b) During dry seasons, the hydrocarbons evaporate and non-volatile dissolved materials precipitating at the surface form the soluble layer.*