LABORATORY SIMULATION OF THE FORMATION OF DRAINAGE NETWORKS ON TITAN.
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Introduction: Drainage networks were among the first features to be observed on Cassini and Huygens imagery [1, 2]. They have been interpreted as having originated analogously to Earth drainage networks, *mutatis mutandis*: whereas on Earth catchment basins collect and distribute water atmospheric precipitation, precipitation on Titan is assumed to be composed mainly of liquid methane 'raining' from a much colder, denser atmosphere than the Earth's [3].

In 2017 we began a project to investigate the influence of a few variables (mainly related to soil composition and water saturation) in the formation of periglacial features [4].

Our laboratory simulations indicated another possibility for the formation of Titan's drainage networks: that they may collect liquid methane originated by the seasonal thawing of permafrost.

Materials and methods: We used a Teca AHP-1200CPV Peltier effect thermoelectric plate (Fig. 1), which can be easily programmed to cycle between -15 and 23°C every 40 minutes, thus simulating 36 freeze/thaw cycles per day [5].

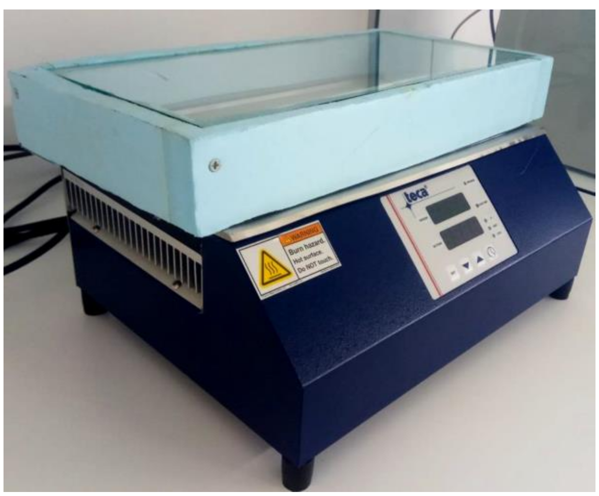

Fig. 1 – Thermoelectric plate

Atop the thermoelectric plate we placed a thin box built from extruded polystyrene foam to provide some insulation from the laboratory environment, thus allowing for shorter cycles.

Soil samples were constructed from milky quartz ground and sieved to 3 grain sizes (ϕ): ϕ<105μm; 150< ϕ <210μm; 210< ϕ <300μm.

All permutations of soil compositions were tested: single size; two sizes, mixed or stratified with coarser soil at the bottom or at the top; three sizes, mixed or stratified in all six possible orders.

Four different water saturations were tested: dry, moist, saturated, and with excess water.

The total number of possible arrangements of the three variables (soil grain, stratification, and saturation) thus amounts to 60, all of which were tested for a minimum of 70 and a maximum of 630 freeze/thaw cycles (essentially, until no change is noticeable).

Excess moisture inside the box atmosphere was captured with permeable bags of silica xerogel.

The setup was time-lapse photographed every 20 minutes, so that we had records of the colder and hotter phases on each cycle.

Results: The relevant results for modelling the formation of drainage networks on Titan occur with a saturated mixture of fine and coarse grains, the evolution of which is shown in figures 2 to 6.

After only 45 freeze-thaw cycles (Fig. 3) two 'lakes' are formed. After 90 cycles (Fig. 4) the lakes have coalesced and drainage channels began differentiating. After 135 cycles (Fig. 5) drainage networks seem to be already fully developed and reach maturity after 180 cycles (Fig. 6) with no further development visible thereafter.

Figures 5 and 6 are visually analogous to the scenes acquired by the Cassini spacecraft showing drainage towards Ligeia Mare [6].

Figure 7 shows the methane (CH_4) phase diagram.

The vapor pressure curve was obtained by application of Antoine's equation [7] with parameters gathered from [8]. In the same figure we mark the average conditions at the surface of Titan (T = 93.7 K; P = 152 KPa) [9].

Conclusions: In Fig. 7 we can see that the moon's average surficial temperature is just 3 K above the freezing point of methane. If we add to this the set of published observations on variations of surface temperature on Titan during one winter and one spring [9] it is reasonable to accept that extreme temperature variations between Titan's winter and summer can cyclically cross the phase diagram solidus curve in a process that is analogous to our laboratory simulation.

Fig. 2 – Initial setting.

Fig. 3 – After 45 cycles.

Fig. 4 – After 90 cycles.

Fig. 5 – After 135 cycles.

Fig. 6 – After 180 cycles.

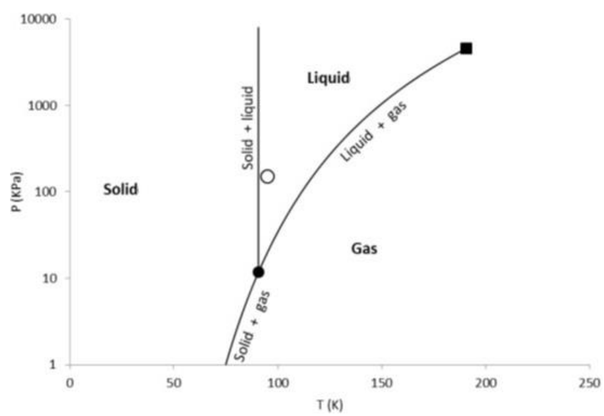

Fig. 7 – Methane phase diagram. Open circle represents the T-P conditions prevailing on the surface of Titan

References: [1] Porco, C. C. *et al*. (2005) *Nature*, 434(7030), 159-168. [2] Lebreton, J. P. *et al*. (2005) *Nature*, 438(7069), 758-764. [3] Turtle, E. P. *et al*. (2009) *GRL*, 36, L02204. [4] Silva, D. A. (2017), *Laboratory Simulation of Periglacial Features*, MSc Thesis, U. Coimbra (in Portuguese). [5] TECA (2017) *EasyLog Software for the TC-4300 Temperature Controller - Product Manual V01.3*. [6] NASA/JPL-Caltech/ASI/Cornell (2013) https://photojournal.jpl.nasa.gov/catalog/PIA17031 [7] Antoine, C. (1888) *Comp. Rend. Séances Acad. Sci.* 107, 681-684. [8] CHERIC (2017), *Chem. Eng. Mat. Res. Center*, https://www.cheric.org/research/kdb/hcprop/cmpsrch.php. [9] McKay, C. *et al*. (1991) Science 253(5024), 1118-1121. [9] Jennings, D. E. *et al.* (2016) *Astrophys. Jour. Lett.* 816(1), L17.

Acknowledgements: This work was supported by Portuguese and European Funds through FCT and FEDER – COMPETE 2020 – project POCI-01-0145-FEDER-006922.