Self–patterning of a thin clayey layer induced by condensation: Supplementary Material

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This Supplementary Material contains a detailed technical description of the experimental setups.

I. TEMPERATURE MEASUREMENTS

All the temperature sensors were Pt100 platinum resistances, with a sheath diameter of 3 mm. The sensor resistances were recorded with a Keithley 2002 multimeter ($10\,\mu\Omega$ resolution) at 0.05 Hz sampling rate. All the sensors had been calibrated against the same reference thermometer, with an accuracy better than 10 mK. In the steady regime, the standard deviation of the temperature fluctuations around the mean value typically ranged from 1 mK to 30 mK.

II. CONTROL OF THE HUMID AIR FLOW

The experimental setup used to control the mass flow rate and the dew point of the humid air is displayed in fig. 1. The air flow was provided by the compressed air network of the university. The air flowed through three filters, the last one having a porosity of 10 nm. A mass flow controller (Brooks, SLA5850S) was used to control and record the air mass flow rate ($0.215\,\mathrm{g/s} \pm 1\%$ in all experiments). The CO_2 partial pressure was that of the network without addition of CO_2, 35 ± 5 Pa (measured with a BCP Bluesens sensor). The air dew point was fixed by bubbling in bottles of deionized water enclosed in a thermostated water bath (Lauda RC 20 CP). The actual temperature of the bath, denoted T_0 in the following, was recorded via a Pt100 temperature sensor (see section I for details). The air flow was saturated with water vapor when it leaved the bath. Its dew point was thus T_0, equal to 14.92°C in all experiments.

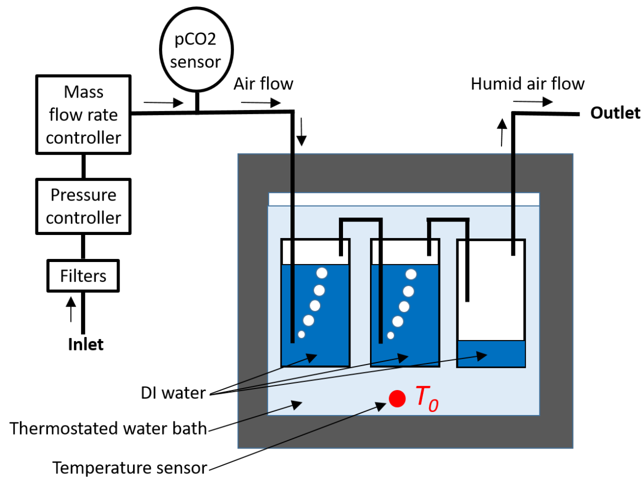

FIG. 1: Experimental setup used to control the humid air flow (volume of the thermostated bath: $8\,\ell$).

III. THERMOSTATED ENCLOSURE

The thermostated enclosure used to control the condensation rate on the sediment layer is displayed in fig. 2. After having been coated with a $(150\pm50)\,\mu$m thick layer of sediment, the parallelepiped rock ($80 \times 55 \times 20$ mm) was inserted in an enclosure made of an aluminium alloy (5083) selected for its high thermal conductivity ($120\,\mathrm{W.m^{-1}.K^{-1}}$) and good corrosion resistance. The cavity containing the rock was closed with transparent double glazing consisting of two Plexiglas plates. The humid air delivered by the setup described in Section II permanently flowed in the channel in between the sediment coating and the inner plate of the double glazing.

Temperature control is the crucial part of this experiment. It was performed as follows. Before entering the enclosure, the humid air flow was precooled at the enclosure temperature by flowing through a heat exchanger not shown in fig. 2. Water delivered by a thermostated bath (Lauda ECO RE 415) flowed first through the heat exchanger, and then at the lower side of the enclosure. A temperature sensor was inserted in the heat exchanger, and two temperature sensors in the aluminium body of the enclosure. One of the latter sensors was connected to the PID controller of the thermostated bath with a set–point of 15.05°C. We checked that, in the steady regime, the temperature measured by these three sensors ranged from 14.94°C to 15.08°C, slightly above the air dew point (14.92°C, see Section II).

Condensation on the sediment layer was triggered by

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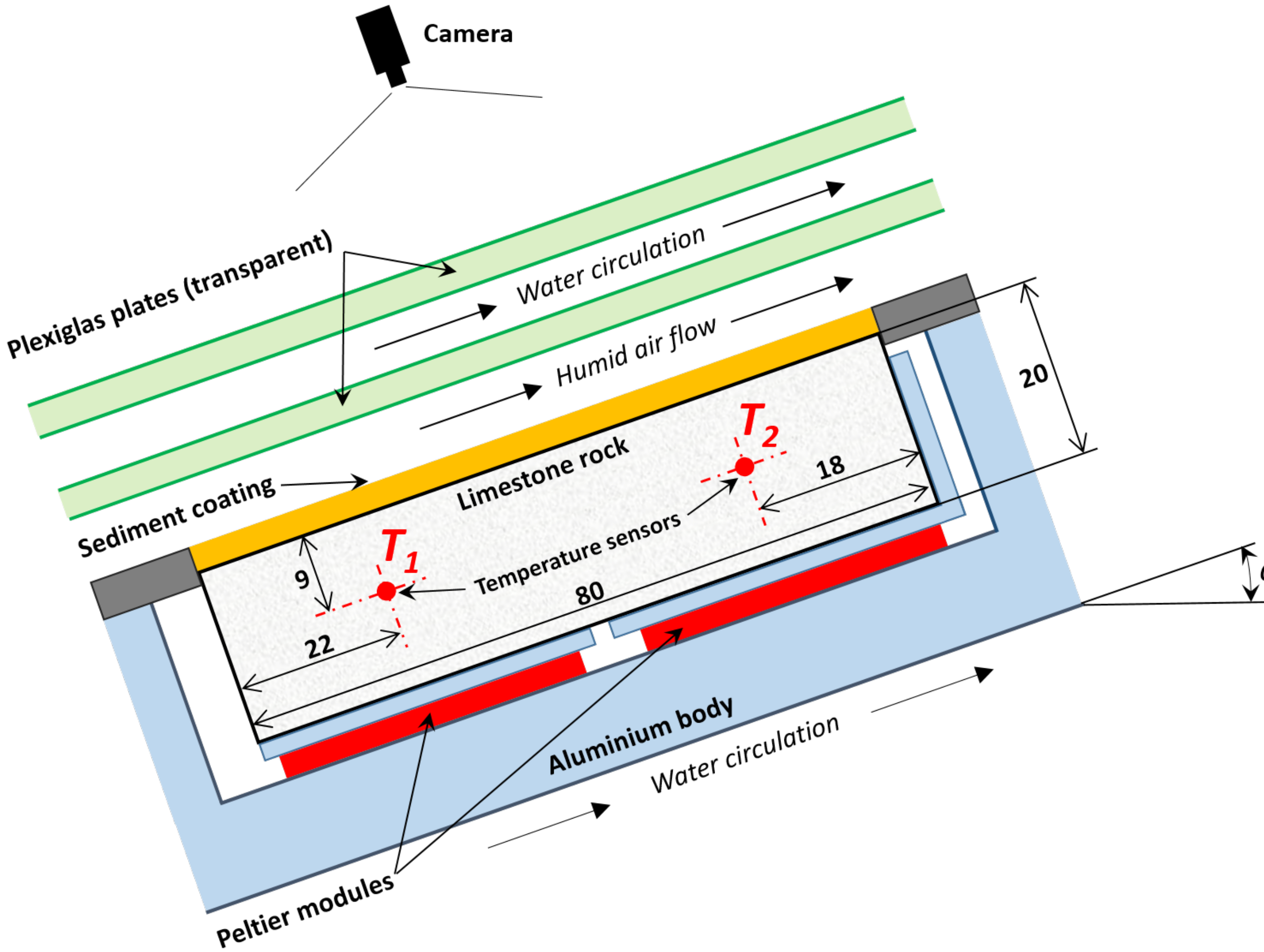

FIG. 2: Sketch of the thermostated enclosure (all dimensions are in millimeters).

decreasing the rock temperature below the dew point of the humid air flowing above the sediment layer. The temperature sensors T_1 and T_2 were inserted inside the rock (see fig. 2), which rested on two Peltier modules (small heat pumps in the form of 40×40 mm square plates, Laird Thermal Systems Ref. 430082-547). These Peltier modules could transfer heat from the rock to the aluminium body, and vice–versa, depending on the sign of the current. They were serially supplied by accurate DC power supplies (Keysight E36103A), driven by a PID controller to regulate the T_1 temperature. The set–point value was 15°C during step 1. It was decreased to a lower value during step 2 to enable condensation.

An instance of time evolution of the temperatures T_0, T_1 and T_2 is displayed in fig. 3. The initial time corresponds to the change of the set-point value, from 15°C to 12°C in this particular case. 3 min were required to get 90% of the full temperature drop. The presence of two temperature sensors in the rock allows the spatial variations of temperature to be assessed. The actual temperature difference ΔT between the air dew point and the rock was estimated from the relation

$$\Delta T = T_0 - \frac{T_1 + T_2}{2}\,, \tag{1}$$

where T_0, T_1 and T_2 are mean values in the steady regime of step 2. The temperature error bars in fig. 5 of the main text are equal to $\pm|T_1 - T_2|/2$.

Heat transfer through the double glazing was minimized by flowing cooled water in between the Plexiglas plates. This water flow was delivered by a third thermostated bath (Grant GR 150 Blue). The temperature set–point of this bath was determined to avoid condensation on the inner surface of the double glazing. The minimal temperature set–point with no condensation was determined from trial and error for each value of ΔT. With the exception of the double glazing, the thermostated enclosure was carefully insulated with expanded polystyrene (6 cm thick, not shown in fig. 2).

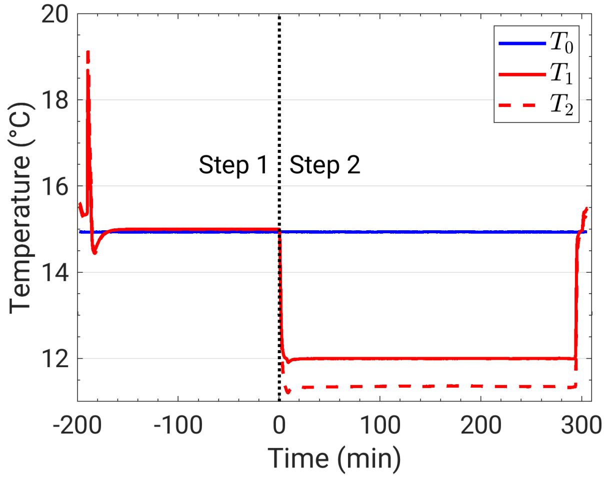

FIG. 3: Air dew point (T_0) and rock temperatures (T_1 and T_2) as a function of time for $\alpha = 85°$ and $\Delta T = 3.3°$C (same experiment as video 1 in Supplementary Material). The injection of the NaCl–$CaCO_3$ solution began at $t = -180$ min and was stopped at $t = 0$, when the rock temperature set–point was decreased from 15°C to 12°C.

IV. DATA ACQUISITION

The experimental setups displayed in figs. 1 and 2 were driven by two distinct PC computers, running the software Labview for the control of all the devices used in the experiment (multimeters, power supplies, air flow controllers, pCO_2 sensor and syringe pump). Images of the sediment layer were taken with a Nikon D300s camera (4288 × 2848 pixels) equipped with an objective AF–S Nikkor 16–85 mm and driven by the software digiCamControl.