Use of water stable isotopes (^{18}O) for Hydraulic lift characterisation

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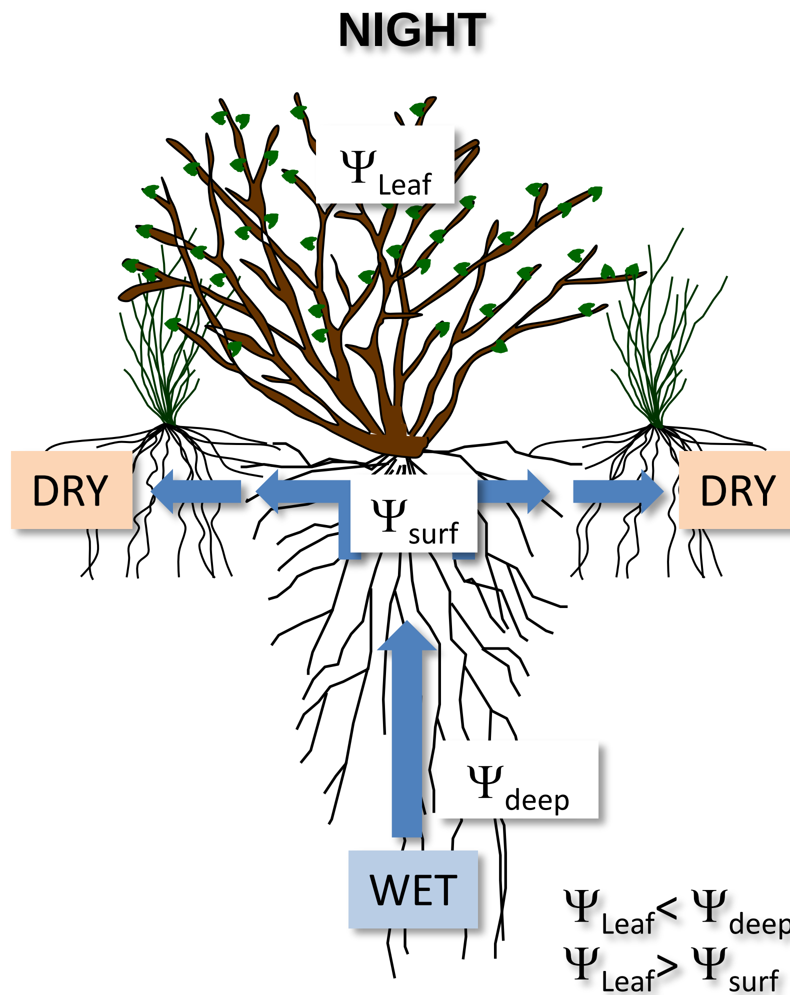
Session HS8.3.1
Soil-plant interactions from the rhizosphere to field scale

Introduction

- **Hydraulic Lift (*HL*) is the movement of water from wetter to dryer soil layers through passive root transport** *(Richards and Caldwell, 1987)*
- *HL* has been reported for a number of plant species but the volumes of water involved are **still controversial…**
- **What are the implications of *HL*** on water budgets at different time/spatial scales (e.g. *Jackson et al., 2000*)?
- **Water stable isotopes can help quantifying this phenomenon** *(Dawson, 1993)*



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Tools: water stable isotopes

- **Water stable isotopes** are **tracers** of occuring **processes** in ecosystems compartments (e.g. *Yakir and Sternberg, 2000*)
  - In **soils**:
    - Evaporation causes isotopic enrichment at soil surface
    - Root water uptake does not impact soil isotopic composition
  - In **plants**:
    - Transpiration causes leaf water enrichment
    - (*grasses*) Leaf input water isotopic composition is accessible through measurements of culm water (xylem sap) isotopic composition
- Isotopic compositions are expressed in **deltas** δ (‰) :

$$\delta_{sample} = \frac{R_{sample} - R_{SMOW}}{R_{SMOW}} * 1000 \qquad R_{sample} = \frac{n(H_2{}^{18}O)_{sample}}{n(H_2{}^{16}O)_{sample}}$$

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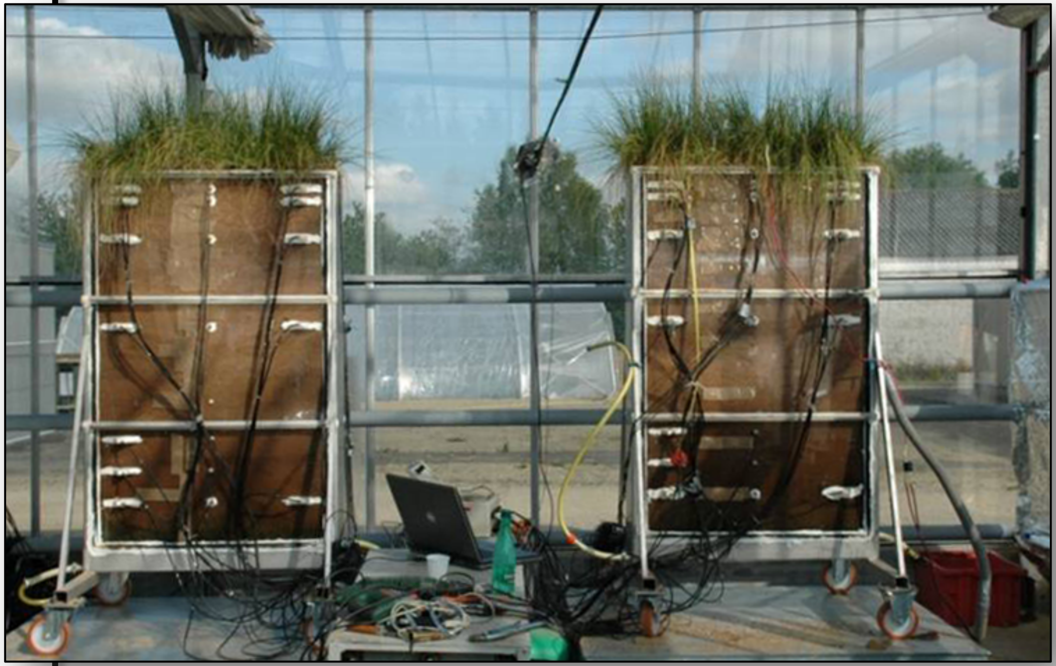
Materials and methods



Tall fescue rhizotrons setup installed in a glasshouse
Lusignan, INRA, France

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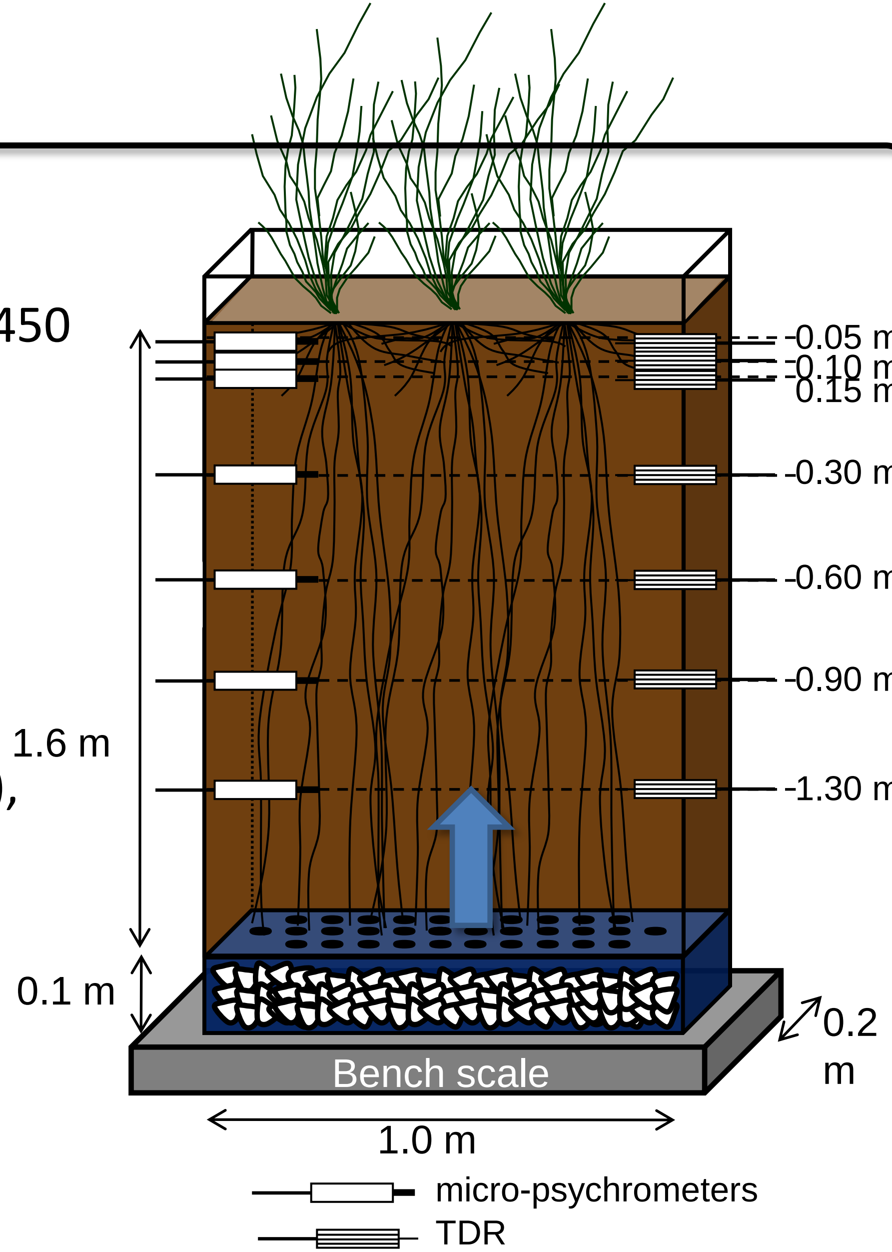
Materials

- Two macro-rhizotrons filled with 450 kg **silty-loam soil** placed on high precision **bench scales**
- **Supply of water** from the **bottom** only (gravel)
- Monitoring of **water contents** (TDR CS616n, Campbell Scientific), **potentials** (PST55, WESCOR), and **temperatures** (T107, Campbell S) at **7** different **depths**
- Plant cover: **tall fescue** (*Festuca arundinacea S.*)



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Methods

- **Semi-controlled conditions**: both macro-rhizotrons are placed in a glasshouse (Lusignan, INRA, France)
  - **Initial saturation** of the soil with water of known $\delta^{18}O_{input\ water}$
  - **Seeding** (Nov. 17th 2008) when field capacity is reached at soil surface
  - Observation of **root elongation**

- On **« intensive periods »** (May 3rd-5th and July 25th-27th 2009):
  - **Labelling** of input water ($\delta^{18}O_{input\ water}$ = 450 (+/- 0.15) ‰)
  - **Sampling** and **vacuum distillation of soil** (θ_S, $\delta^{18}O_S$)
  - **Sampling** and **vaccum distillation of leaves** (Ψ_L and $\delta^{18}O_L$) **and culms** ($\delta^{18}O_C$)

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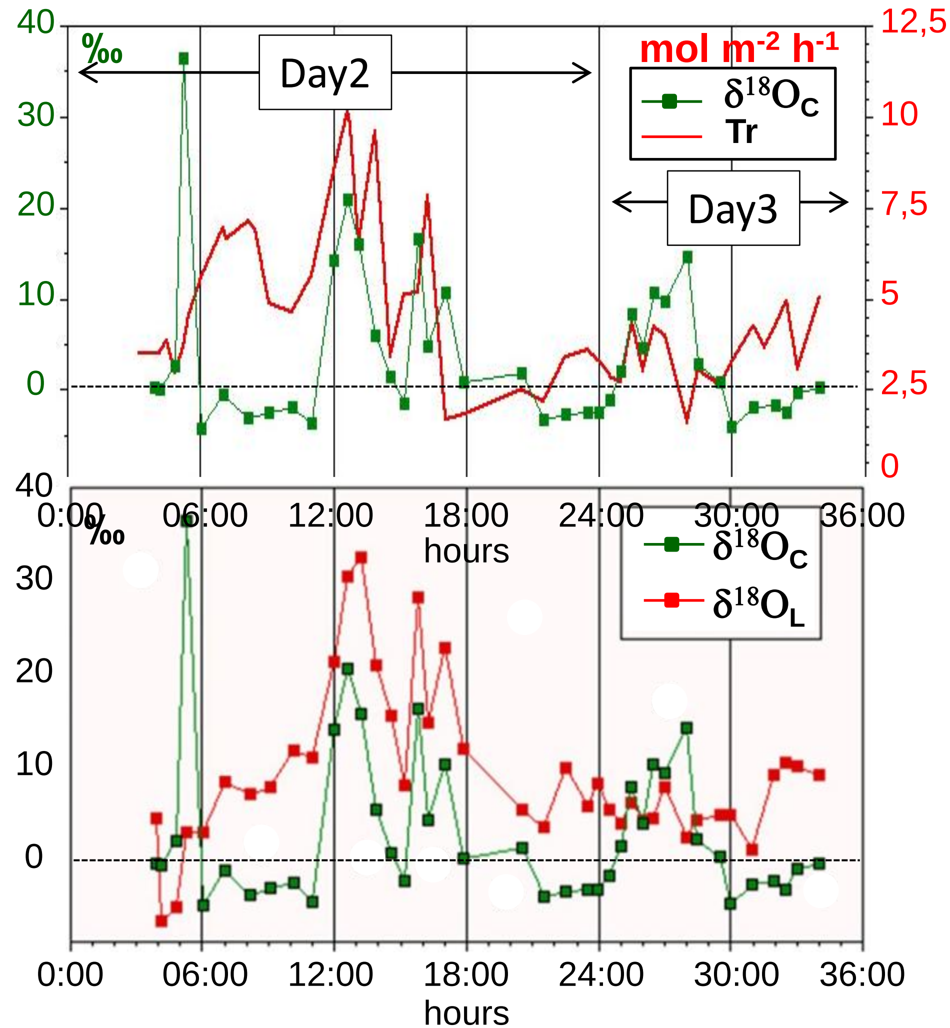
Results and discussion (1)

➢ **Intensive period 1** (May 3-5th 2010):

Plant results

- Labelling on Day1 17:00 (+437 ‰)
- During day time, **high values of T correspond to high values of $\delta^{18}O_C$ (deep water uptake)**
- Evolution of $\delta^{18}O_C$ and $\delta^{18}O_L$
  - **Correlated** (day) / **not correlated** (night)
- At night : **deep water uptake under low transpiration rate**

  →**Identification of a possible *HL* ?**



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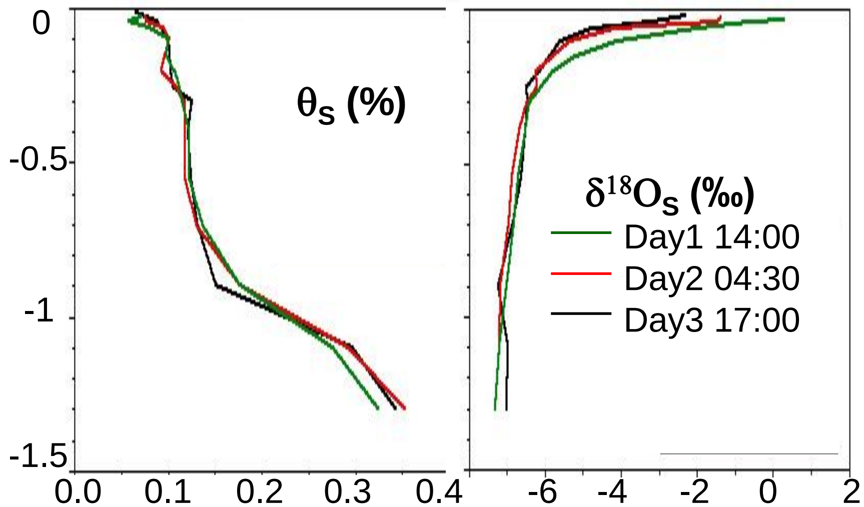
Results and discussion (2)

➢**Intensive period 1** (May 3-5th 2010) : **Soil results**



○ Much **stronger vertical discrepancies** of θ_S and $\delta^{18}O_S$ **than changes in time**

○ **Soil** very **dry at the surface** (5-10%) and **saturated at the bottom** (>43%)

○ **Evaporation** was noticeable at the surface (**isotopic enrichment**)

○ **δ^{18}O bottom value** was that of the reservoir water **before labelling**

○ ***HL*** was **not identified** here..

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Results and discussion (3)

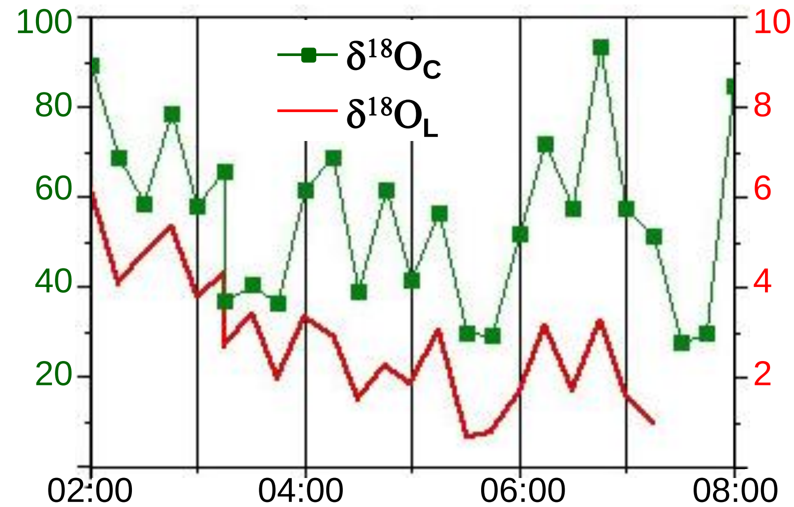
- **Intensive period 2** (July 25-27th 2010)

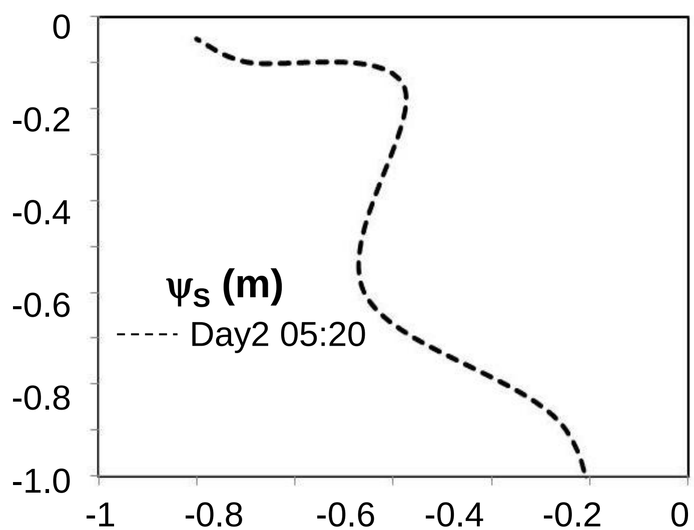
Plant results (from 2 to 8 am)

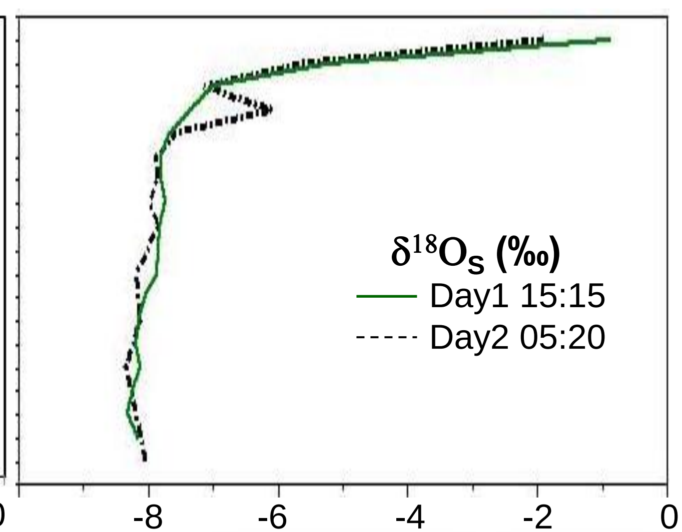
- Very low transpiration rate
- $\delta^{18}O_C > \delta^{18}O_L$

Soil results (Day2 05:20)

- ψ_S(-0.15 m) > ψ_S(-0.60m) at 05:20
- **Enrichment at 15 – 20 cm** (05:20)







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Results and discussion (4)

- **Intensive period 2**
  - What about x, the contribution of hydraulically lifted water to soil layer (15–20 cm) water?

$$\delta_{(15\text{–}20)5:20\_day2} = x\delta_{labelled\_water} + (1-x)\delta_{(15\text{–}20)17:15\_day1}$$

x = 5% (+/-1%)

(precision computed from Phillips and Gregg, 2001)

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Summary and perspectives

- HL estimated to account for **up to 81% of the water used during the following day by the vegetation** (Kurz-Besson et al., 2006). The local water balance could be in some cases deeply impacted by ***HL***
- **Evidence for *HL*** on intensive period 2, but contributing to **only 5%** of soil layer 10–25 cm
- **Perspectives** ..
  - **Another plant cover**? (e.g. maize)
  - **fully controlled** conditions (20 m^3 climatic chamber)
  - Modelling (SiSPAT-Isotopes)

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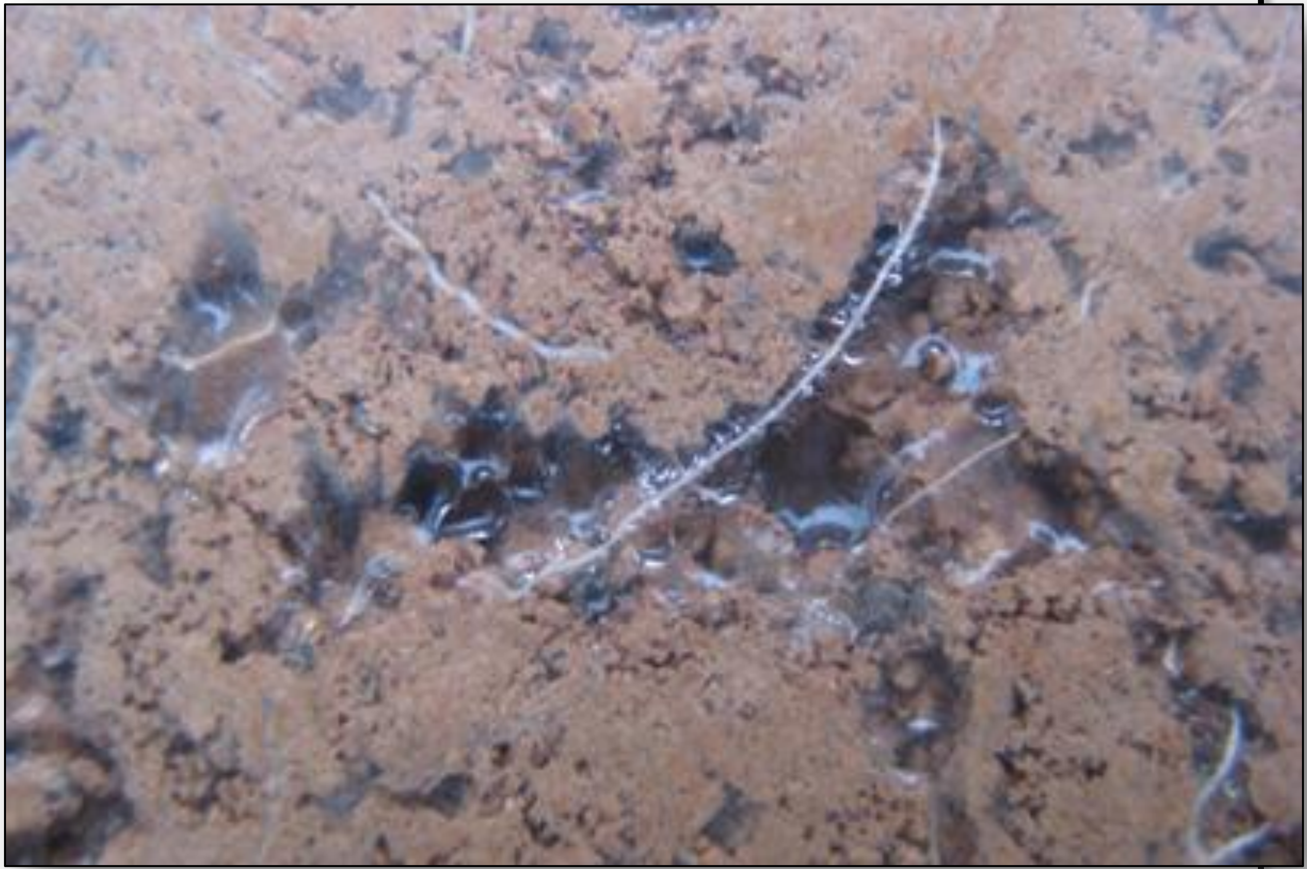
Thank you !

- Nocturnal condensation or Hydraulically Lifted water??



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