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Effects of Salt Precipitation on Evaporation Rate in Porous Media

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Background and motivation

Salts in porous rocks;

- Widely occur in porous rocks such as sandstone
- Derive from various sources such as:
  - Groundwater
  - Dissolution and weathering of the rock
  - Atmospheric deposits (rain and coastal spray)
- Can be destructive for the material due to the growth and expansion of various salts crystals within pores
- Can effect the water flow/vapor flux due to the clogged pores after crystallization

Background

- Salt precipitation in porous media has two different forms (Rodriguez-Navarro and Doehne, 1999):
  - Efflorescence (on surface)
  - Subflorescence (subsurface, in porous medium)
- Some salts dominantly precipitate as efflorescence/subflorescence
- This may affect the evaporation rate from media in different order of magnitudes depending on (Shahidzadeh-Bonn et al. 2010; Nachshon and Weisbrod, 2015):
  - Type of salts
  - Concentration
  - Pore structure of the media

Objective

To reveal the effects of halite and epsomite precipitation on evaporation from porous media in selected aspects. In particular:

- To describe the role of halite and epsomite salt solutions on evaporation rate from identically same porous media
- To describe the role of the concentration of halite solution on evaporation rate from identically same porous media
- To describe the role of pore structure on evaporation rate and precipitation pattern of halite salt solution from two structurally-different porous medium

Materials and methods

- Cylindrical glass columns are packed with the material and are fully saturated with solution
- Each column is weighted and visible changes on both columns are photographed during the experiment periodically
- Wind speed over surface is kept constant during experiments (av. wind speed is 2.7 m/s)
- Average temperature and relative humidity during experiments are measured as 22 °C and 42%

Porous media:

- Naturally-loose sand (0.8 - 1.2 mm)
- Well-rounded glass beads (0.8 - 1.2 mm)

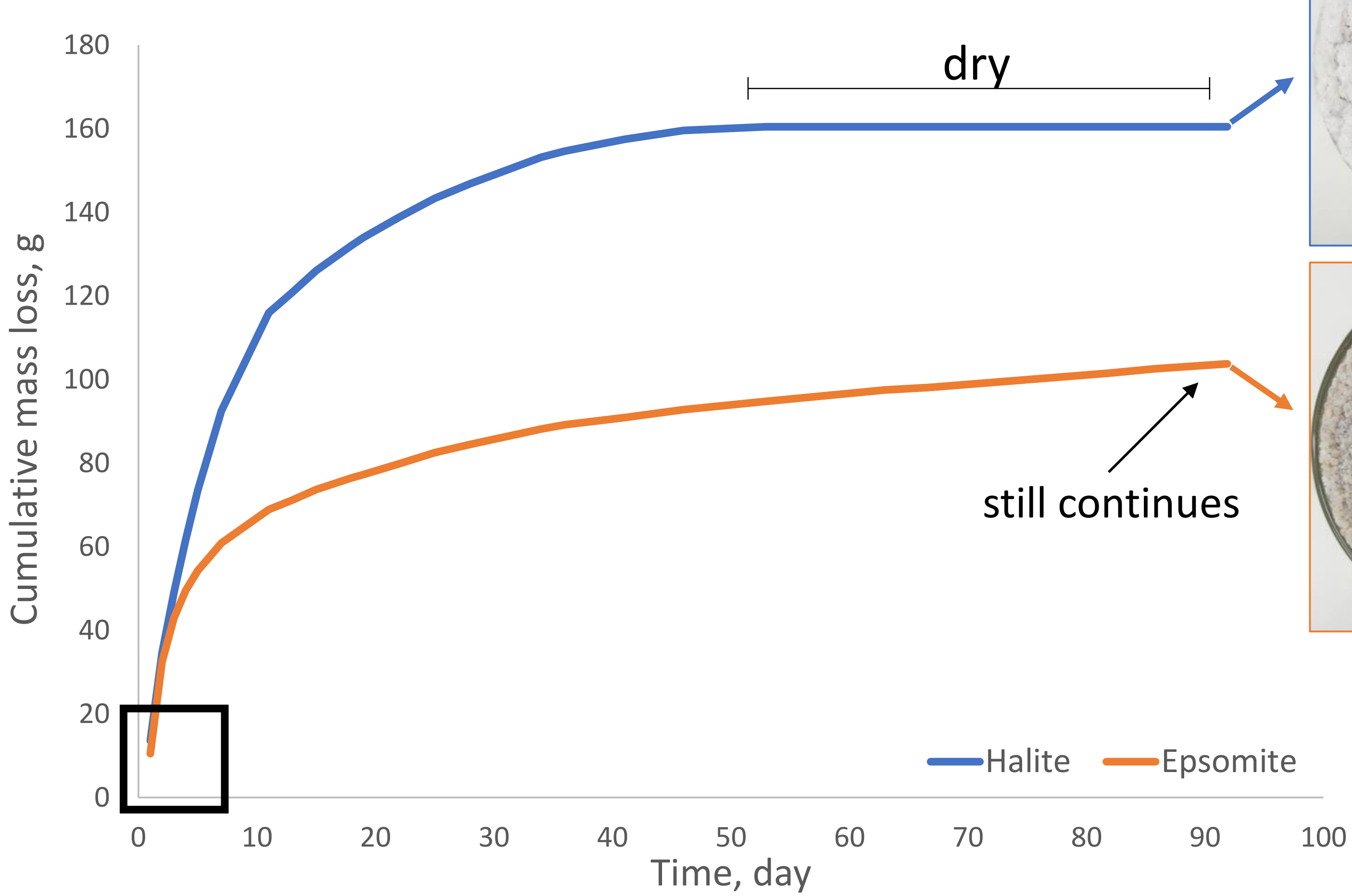
Salts:

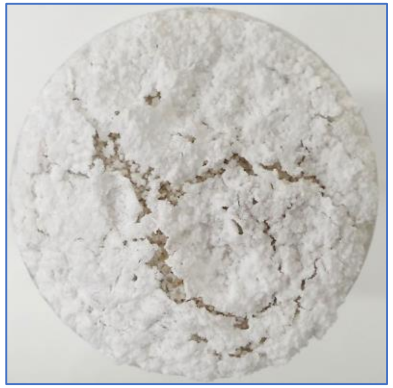
- Halite [NaCl] (0.2 Molar, 1 Molar, and 3 Molar)
- Epsomite [$MgSO_4$ $7H_2O$] (1 Molar)

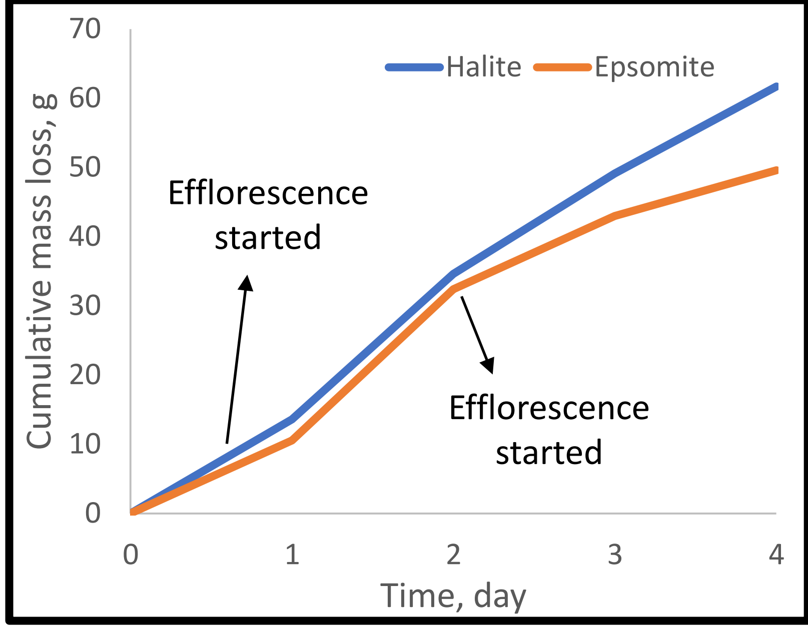
Experiments are divided in three modules as follows;

1. 1 Molar halite and 1 Molar epsomite solution, in sand
2. 1 Molar halite and 3 Molar halite solution, in sand
3. 0.2 Molar halite, in sand and glass beads

Results 1. Comparison of 1 Molar Halite and 1 Molar Epsomite solution in sand







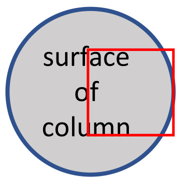
2)

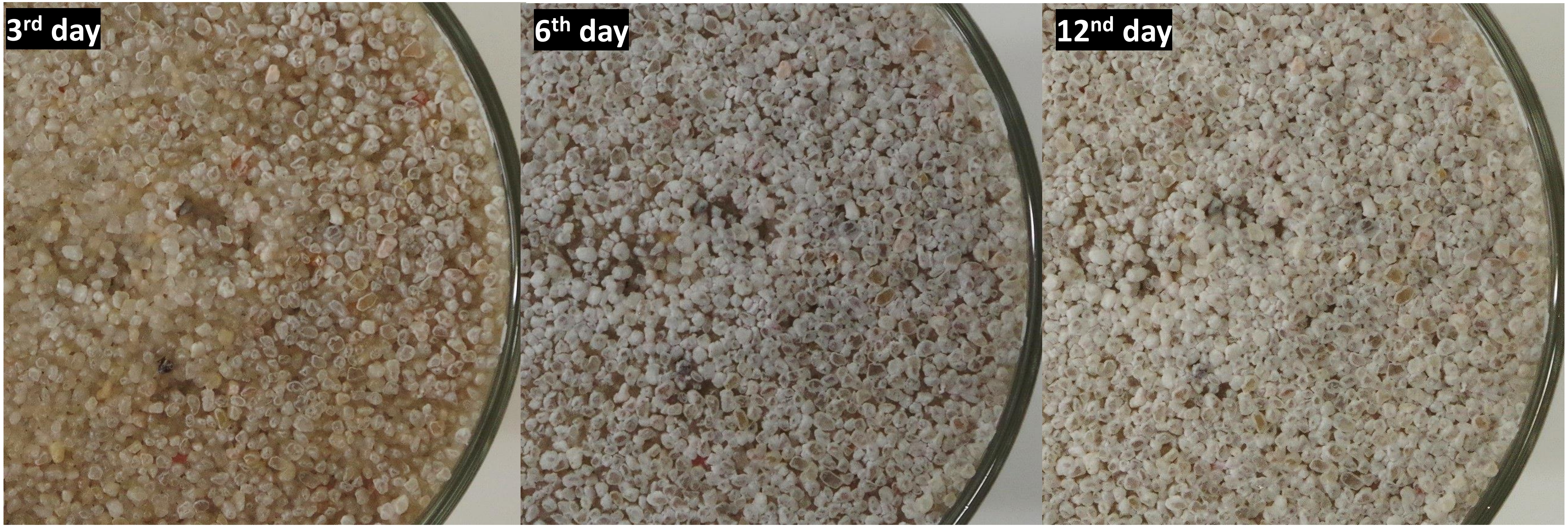
- Abrupt decrease of evaporation rate once efflorescence occurs in epsomite solution
- No any effect of efflorescence observed on halite solution

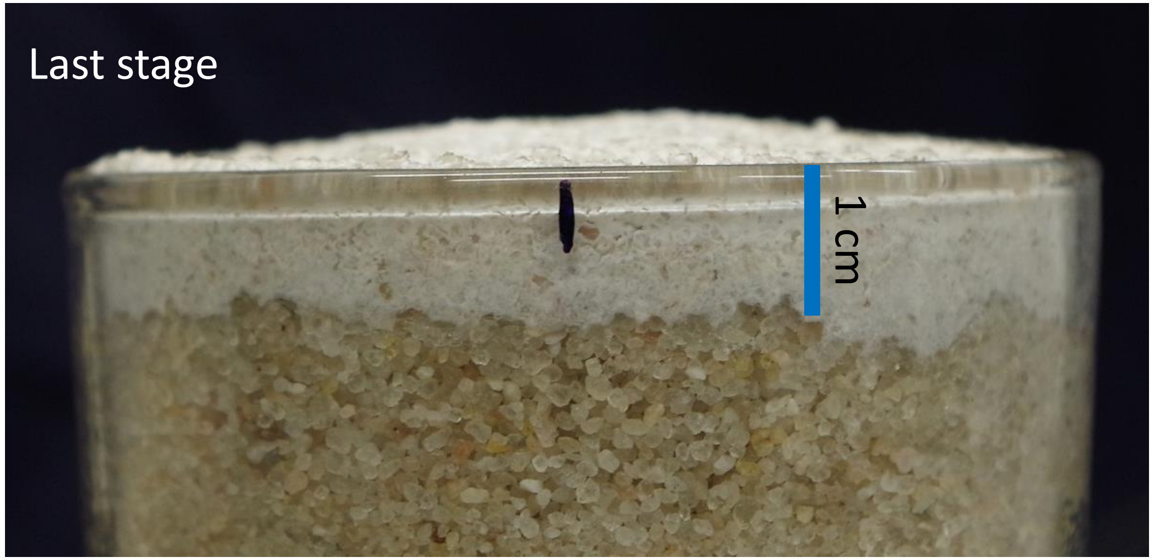
1)

- A **significant difference** between evaporation rates of 1 Molar halite and 1 Molar epsomite solution from sand is observed as it is showed on cumulative mass loss over time diagram above
- Starting from 2nd day of the experiment, evaporation from epsomite solution started to an **abrupt decrease**
- Halite-solution saturated column gets dry on 53rd day of experiment whereas epsomite solution still continues the evaporation after 100+ days

1M Epsomite close-up





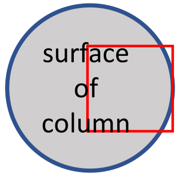


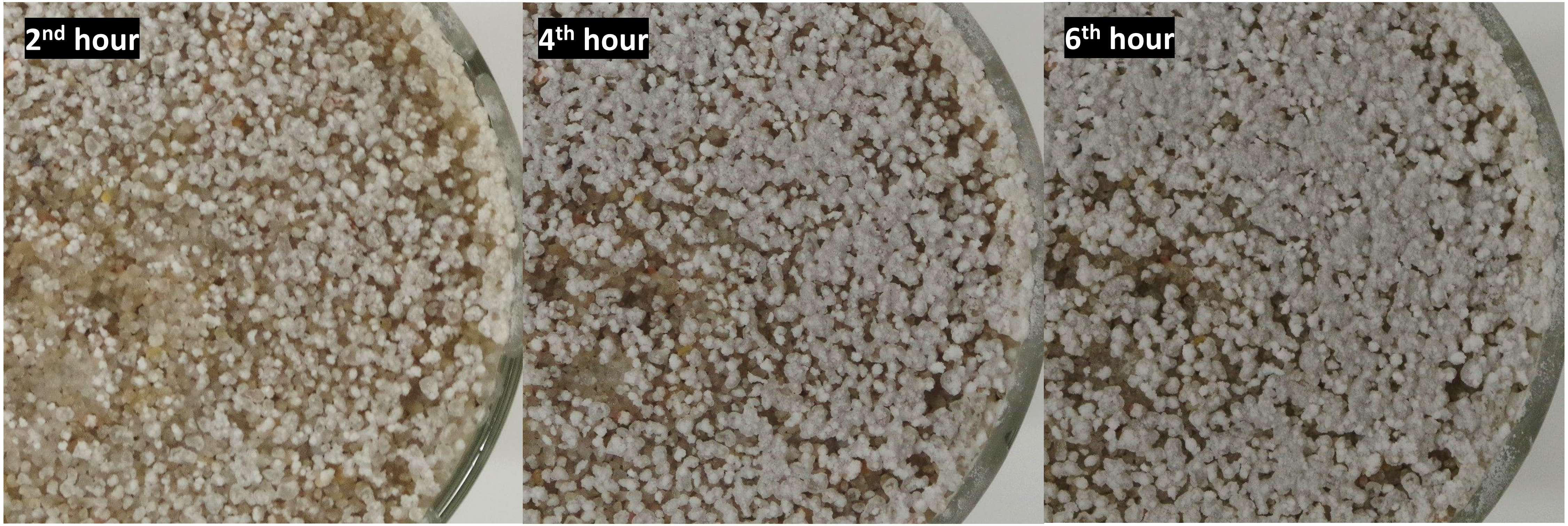
3)

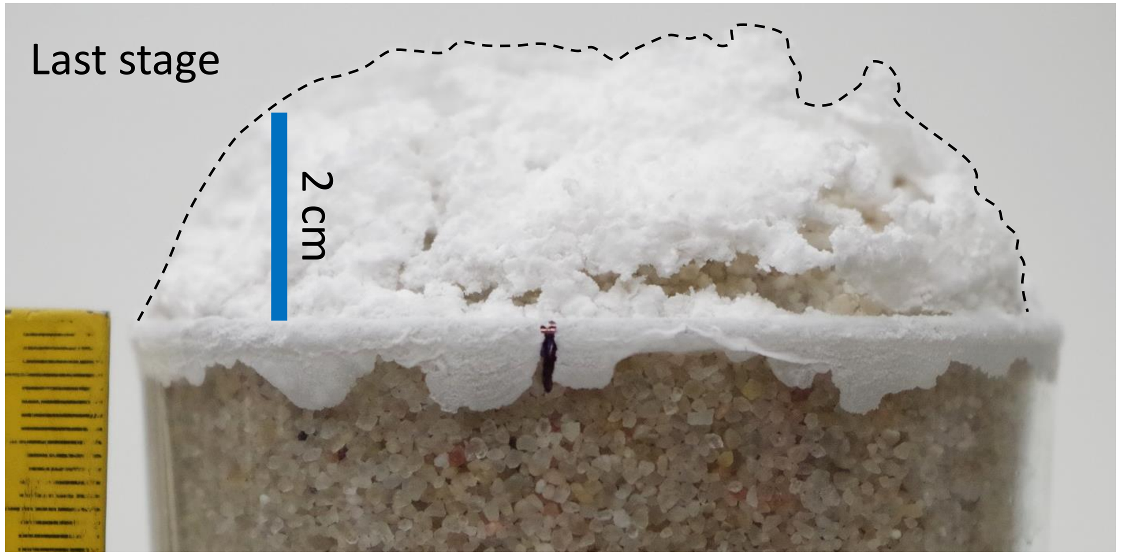
Epsomite precipitation progress on surface

- At first, precipitation coats the sand grains
- Precipitation progresses downwards from the surface level
- At the last stage, fine and dense epsomite precipitation reaches to 1 cm depth from surface into the media

1M Halite close-up







4)

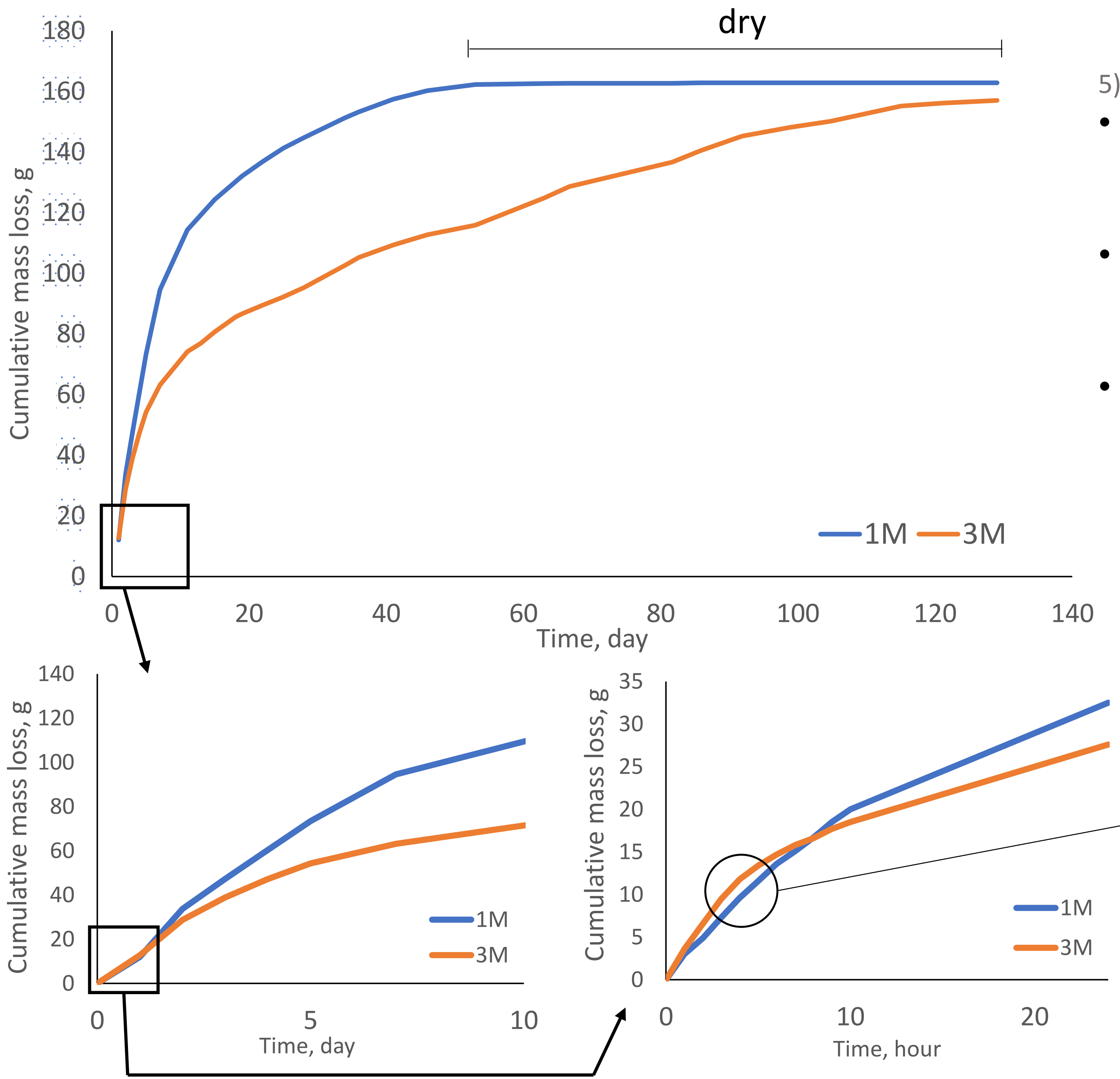
Halite precipitation progress

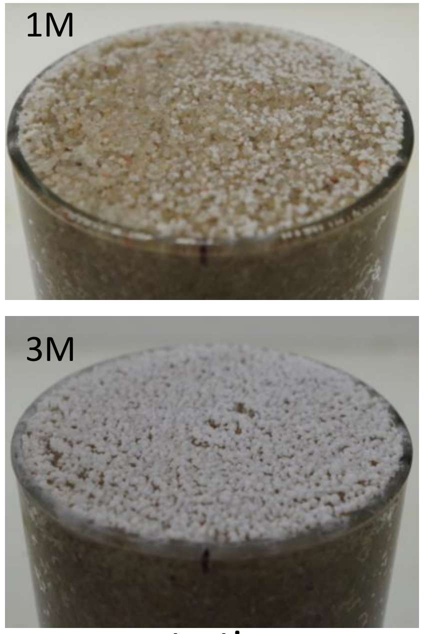
- At the beginning, halite precipitation form on top of sand grains
- Precipitation progresses upwards and sideways forming continuous crust which covers surface
- Part of the grains from the surface are uplifted by the heave of the crust

Results 2. Comparison of 1 Molar halite and 3 Molar halite in sand

5)

- 1 Molar halite solution saturated column gets dry in 53 days whereas 3 Molar halite solution took 130 days
- 3 Molar halite solution **shows a higher evaporation rate during first 6 hours of evaporation**
- At the last stage, 3 Molar halite solution formed a thicker, denser crust comparing to the 1 Molar halite solution



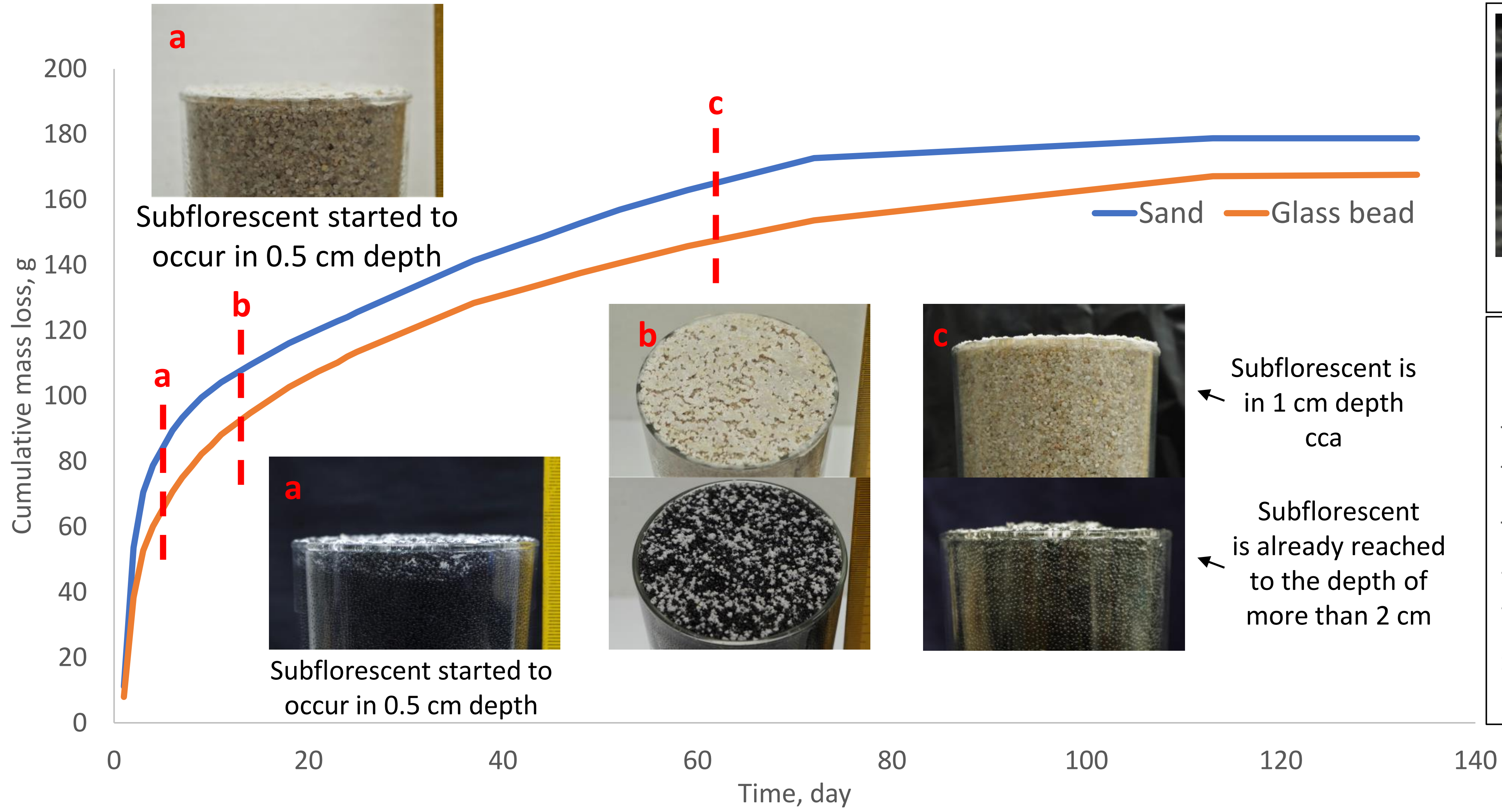


Higher concentration causes faster evaporation at the beginning

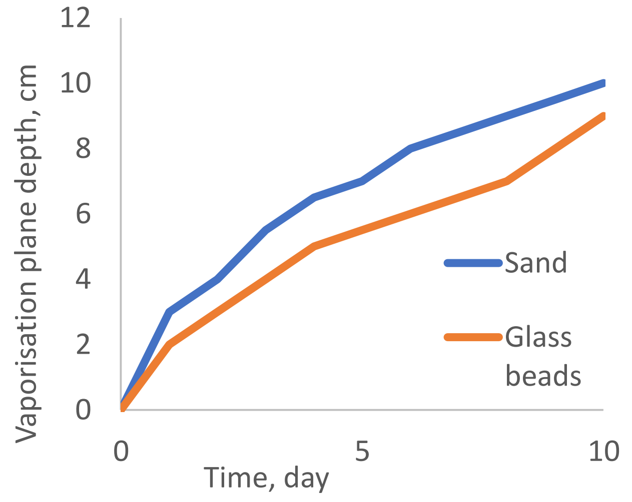
Results 3. Comparison of 0.2 Molar Halite solution in natural-loose sand and well-rounded glass beads

6)

- Higher evaporation rate in sand than similar size of glass beads (seemingly due to the rough grain surfaces)
- Subflorescence reaches larger depth in glass beads
- After both columns get dry, a wide and well-covering crust forms on the sand surface whereas discrete salt lumps form on the surface of the glass beads



Last stage



Results and discussion

1 Molar halite and 1 Molar epsomite

- Due to the downward growing pattern of precipitation, epsomite precipitation clogs the pores and blocks the pathways for vapor flow, whereas halite precipitation grows upwards uplifting part of the sand grains from the surface.
- As a consequence, epsomite precipitation on the surface causes a decrease in evaporation rate compared to halite.

1 Molar halite and 3 Molar halite

- Higher concentration of halite solution provides an effective pathway for capillary water and enhances the evaporation rate at the beginning of the evaporation.
- However, when capillary water loses contact with the surface and evaporation continues in form of water vapor, thicker crust on the surface then acts as a barrier, decreasing the evaporation rate.

0.2 Molar halite; in natural-loose sand and in well-rounded glass beads

- Evaporation rate is faster from natural sand compared to round glass beads. This is likely caused by rougher grain surface of the natural sand.
- Grain shape also likely influences salt precipitation pattern as salt crust covered most of the surface area of the natural sand, whereas the precipitation pattern on the glass beads was non-continuous and discrete on.

Conclusion

- Subflorescent precipitation (characteristic for epsomite) clogs the pores, causes decreasing of the evaporation rate.
- Halite dominantly causes efflorescent crust formation and its subsequent heaving which has lower effect on evaporation rate than subflorescence.
- Halite crust provides effective pathway for capillary water - not for vapor, for which it acts as a barrier.
- Grain shape influences salt precipitation causing the evaporation rate to be faster from natural sand compared to round glass beads.
- **Salts may strongly affect evaporation by various processes and effects of single salt in different evaporation stages may be even opposite.**

Thank you for your attention

Acknowledgement

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References

Rodriguez-Navarro C., and Doehne E. (1999), Salt Weathering: Influence of Evaporation Rate, Supersaturation and Crystallization Pattern, Earth Surface Processes and Landforms, 24, 191-209

Shahidzadeh-Bonn N., Desarnaud J., Bertrand F., Chateau X., Bonn D. (2010), Damage in Porous Media due to Salt Crystallization, Physical Review E, 81, 066110