The effects of pore space modification on multiphase flow dynamics and salt precipitation within natural building stones

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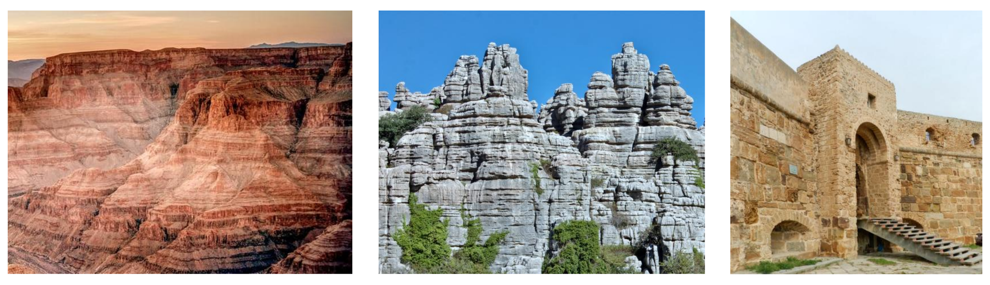
Drying-induced salt precipitation is governed by pore-scale properties

Sedimentary rocks

Sandstones and limestones are used extensively in modern and ancient buildings



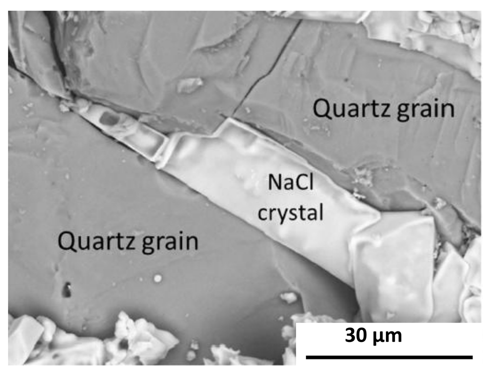
Zornoza-Indart et al., 2019

Salt crystallization

Macroscopic

Image courtesy of Zhaoyuan Zhang

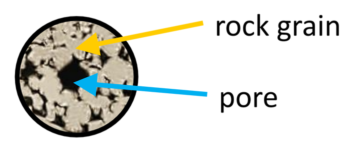
Microscopic



Desarnaud et al., 2016

Pore-scale properties influencing drying

- Pore structure



- Connectivity

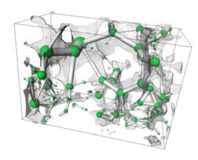
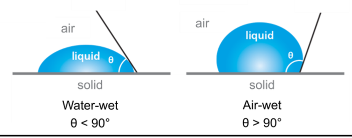


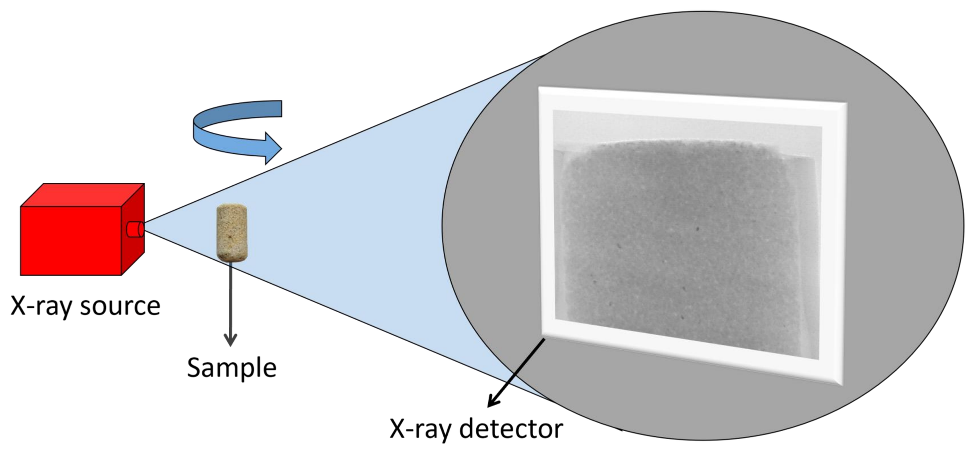
Image courtesy of Tom Bultreys

- **Wettability**



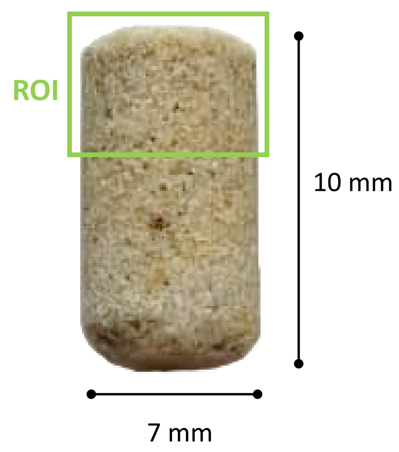
Our approach to investigate the effect of wettability change on drying

4D non-destructive X-ray imaging

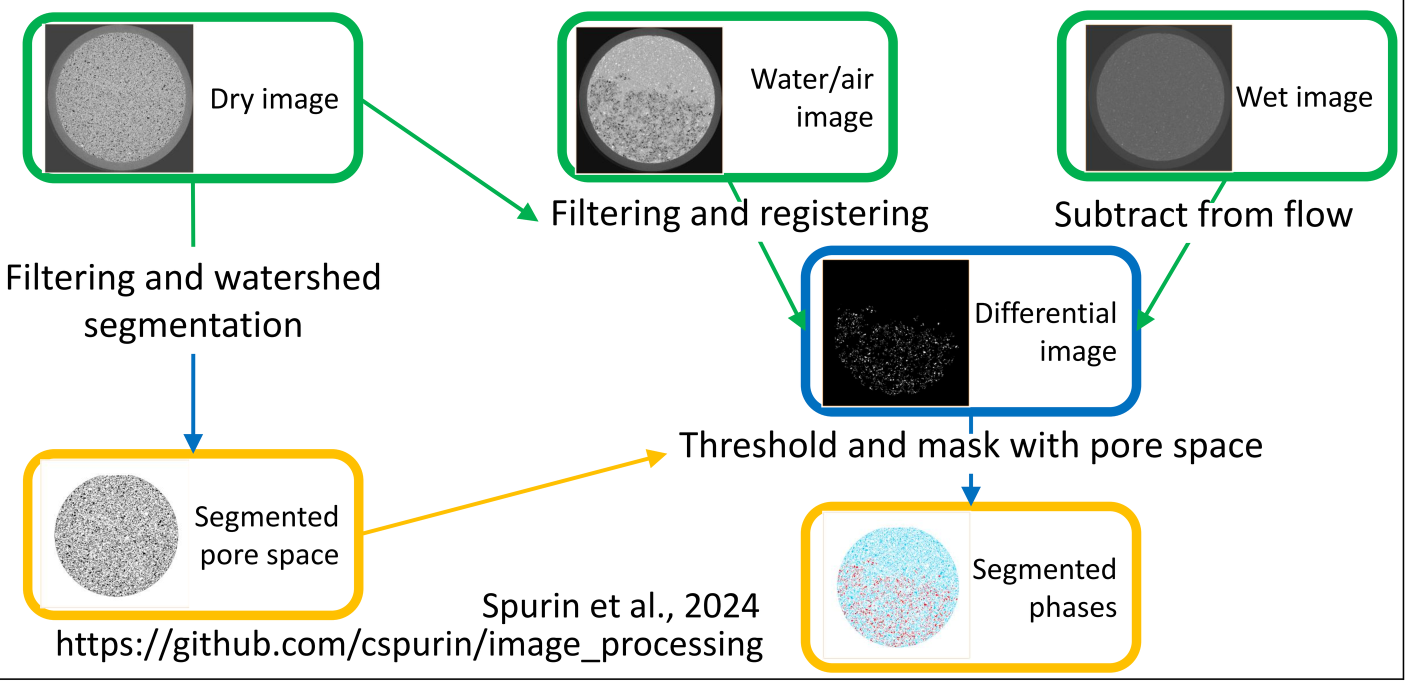


Sample conditioning

1. Seal sides and bottom to ensure drying only from top surface
2. Saturation with DI water under vacuum
3. Drying at 24°C and 40 %RH
4. Treat sample with nano-silica and repeat



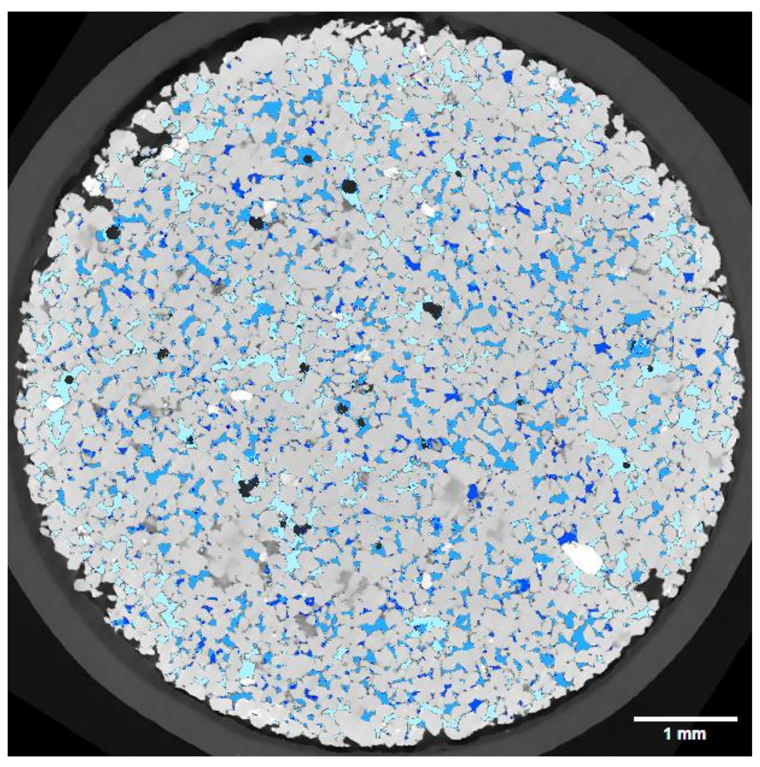
Advanced image processing workflow



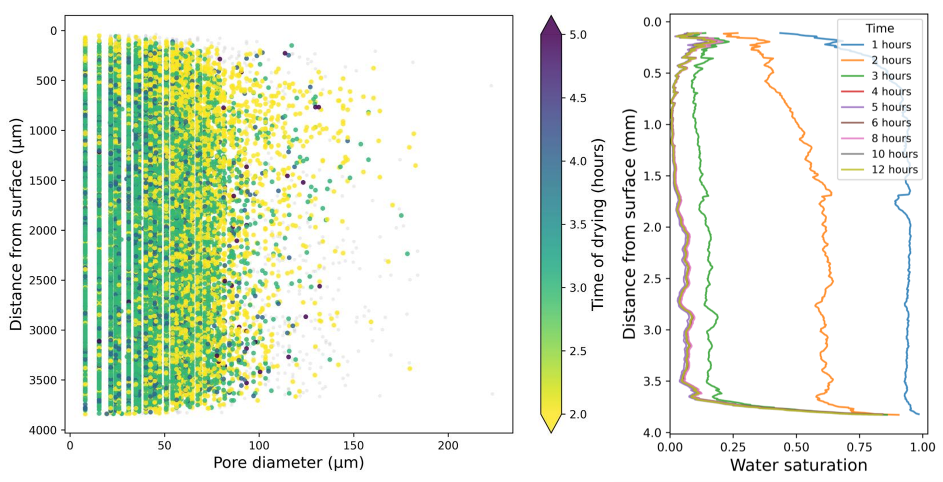
Spurin et al., 2024
https://github.com/cspurin/image_processing

Preliminary results – drying of DI water

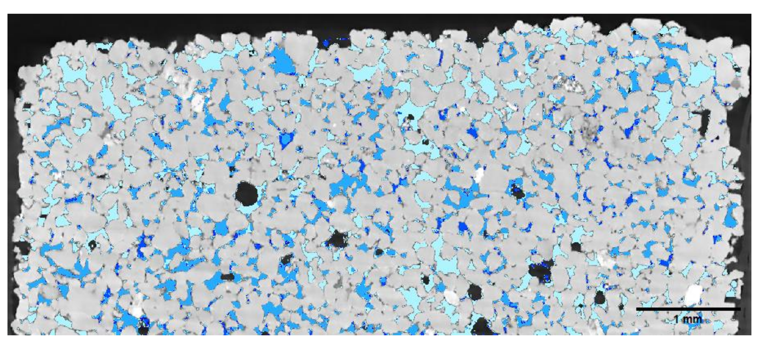
Bentheimer



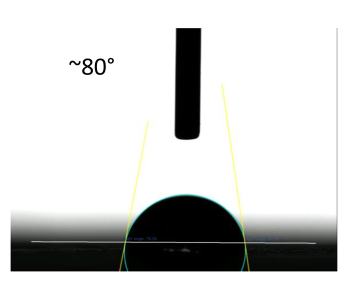
- Large pores dry out first
- No clear relationship with distance from surface → highly connected pore space



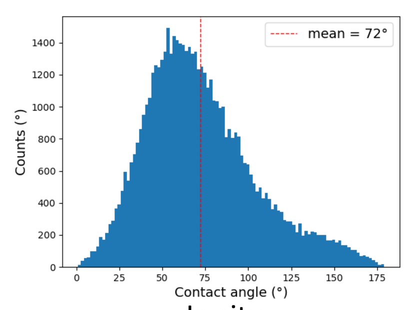
Drying time
2 hours | 4 hours
3 hours | >12 hours



- Water-wet
- Differences between contact angle measurement methods are likely due to hysteresis, roughness and scale

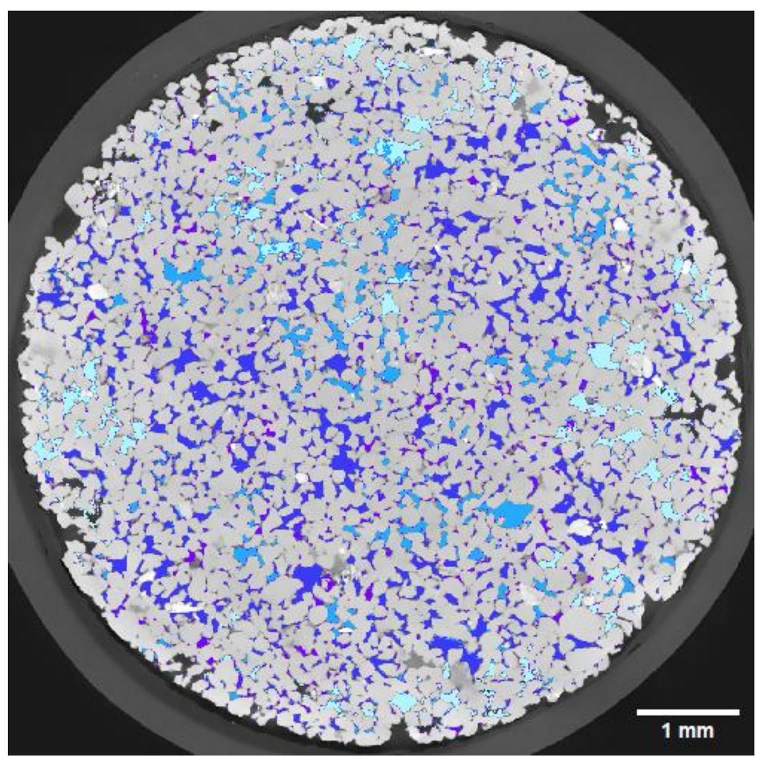


Sessile drop

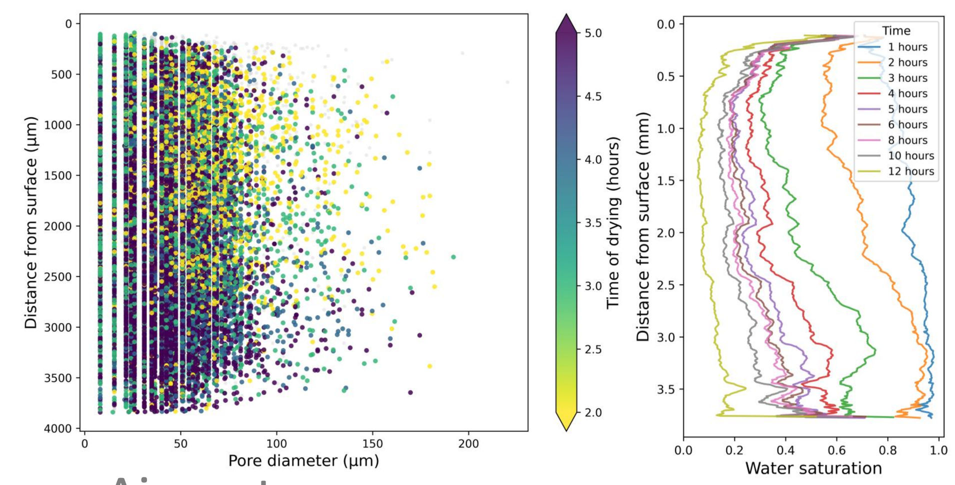


In situ

Bentheimer treated with nano-silica



- Drying speed is much slower than for untreated Bentheimer
- Dries in function of height → wettability change results in diffusion-driven drying



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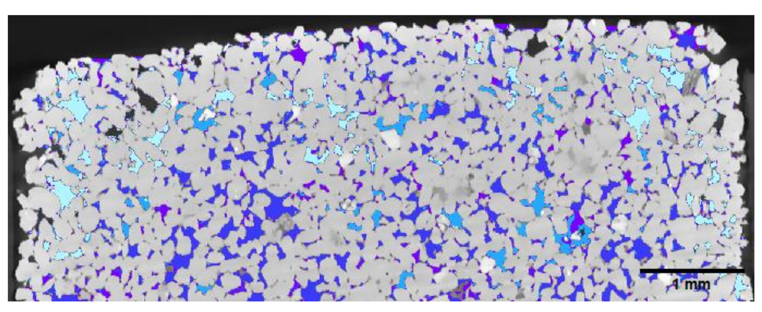
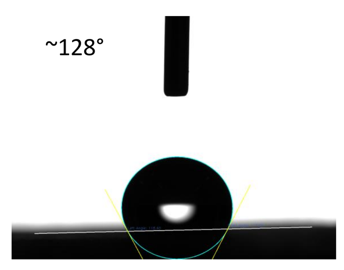
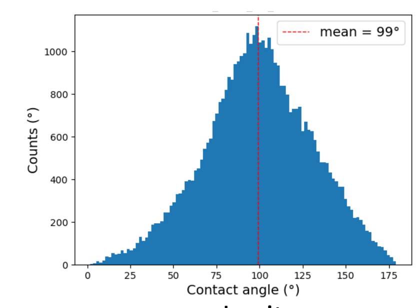


- Air-wet
- In-situ shows less change as it is an average, including regions with less contact with product



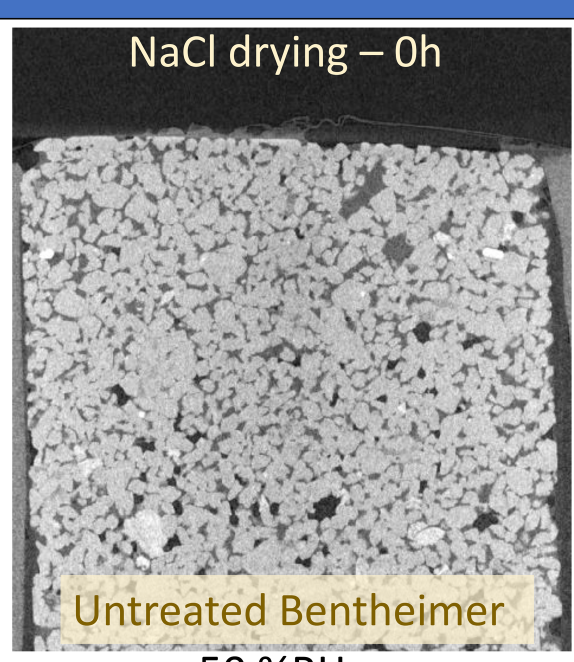
Sessile drop



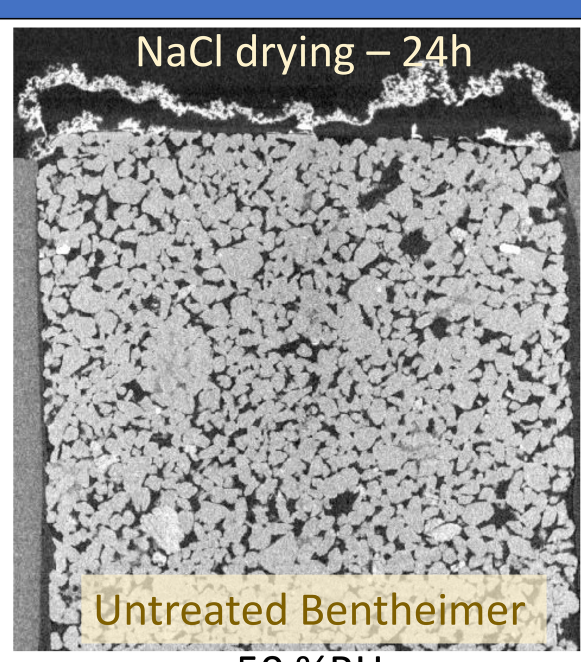
In situ

Future work

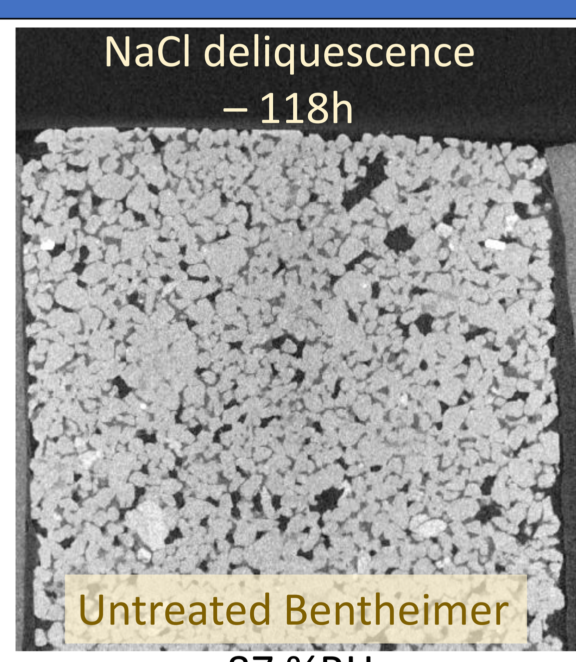
- Rain simulation
- Active relative humidity and temperature control
- Drying/deliquescence cycles with salt solutions
- Samples with more complex pore space (e.g. Savonnières limestone)



50 %RH



50 %RH



87 %RH

50 %RH

Desarnaud, J., Bonn, D., & Shahidzadeh, N. (2016). The Pressure induced by salt crystallization in confinement. Scientific Reports, 6. https://doi.org/10.1038/srep30856
Spurin, C., Ellman, S., Sherburn, D., Bultreys, T., & Tchelepi, H. A. (2024). Python Workflow for Segmenting Multiphase Flow in Porous Rocks. Transport in Porous Media, 151(15), 2819–2834. https://doi.org/10.1007/s11242-024-02136-2
Zornoza-Indart, A., Lopez-Arce, P., Zoghlami, K., Leal, N., & Simão, J. (2019). Marine Aerosol Weathering of Mediterranean Calcarenite Stone: Durability of Ethyl Silicate, Nano Ca(OH)2, Nano SiO2, and Nanostructured Consolidating Products. Studies in Conservation, 64(2), 73–89. https://doi.org/10.1080/00393630.2018.1477654

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