Behaviour of montmorillonite at low ionic strength

Emelie Hansen, Magnus Hedström

Clay Technology AB

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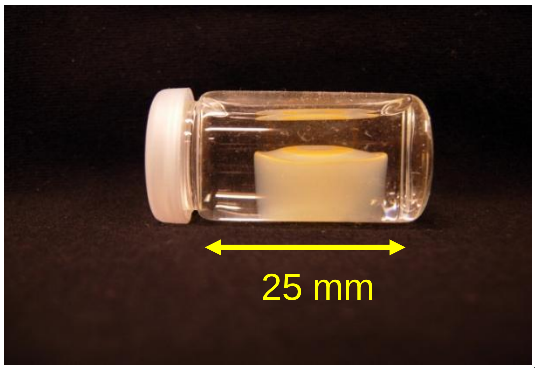
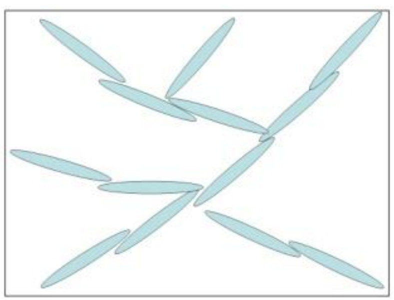
Why do we care about gels and sols?

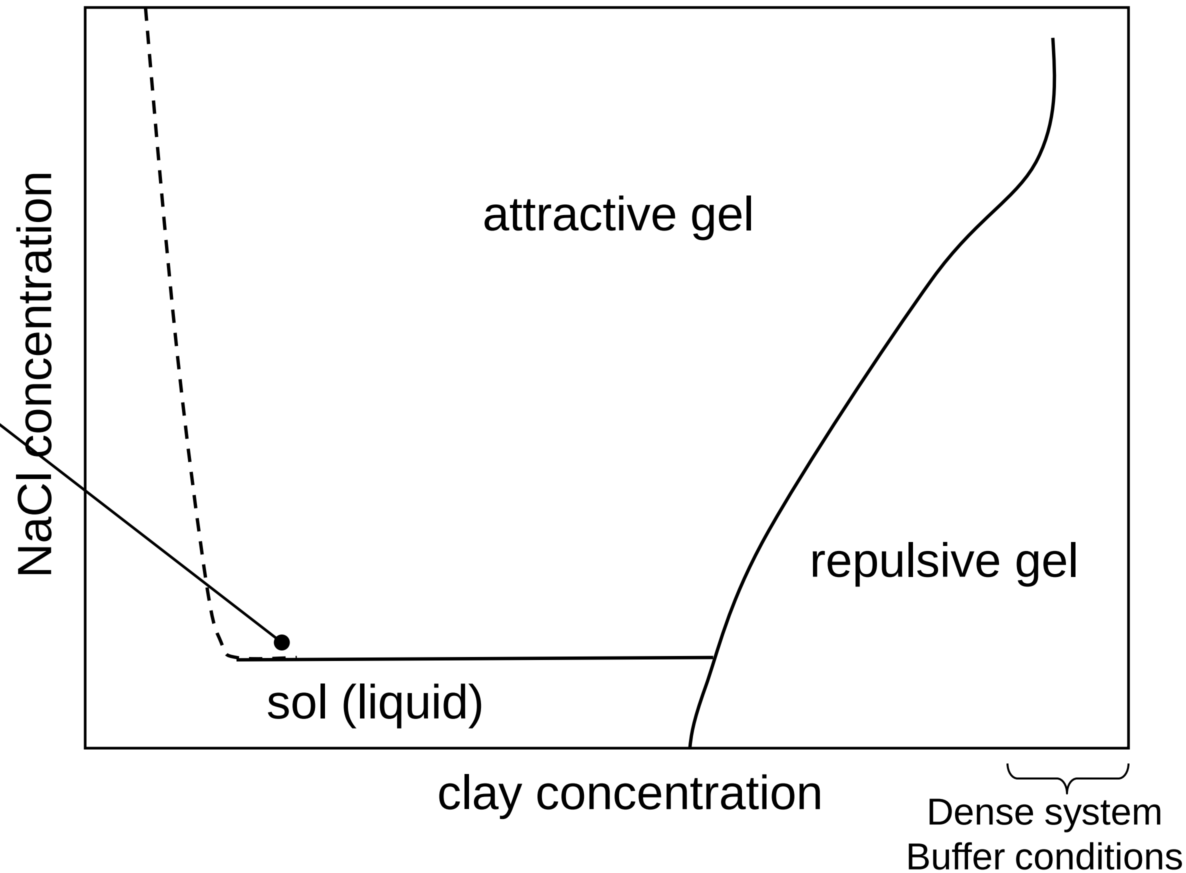
- Repository operational time may include several glaciations.
- Post-glacial meltwater is expected to be very dilute (low salinity).
- In contact with water of low salinity bentonite may swell extensively and turn into a sol at the swelling front.
- A sol is a liquid colloidal state and can thus easily be carried away by flowing water.
- Significant loss of bentonite may compromise buffer function.

Na-Montmorillonite phase diagram

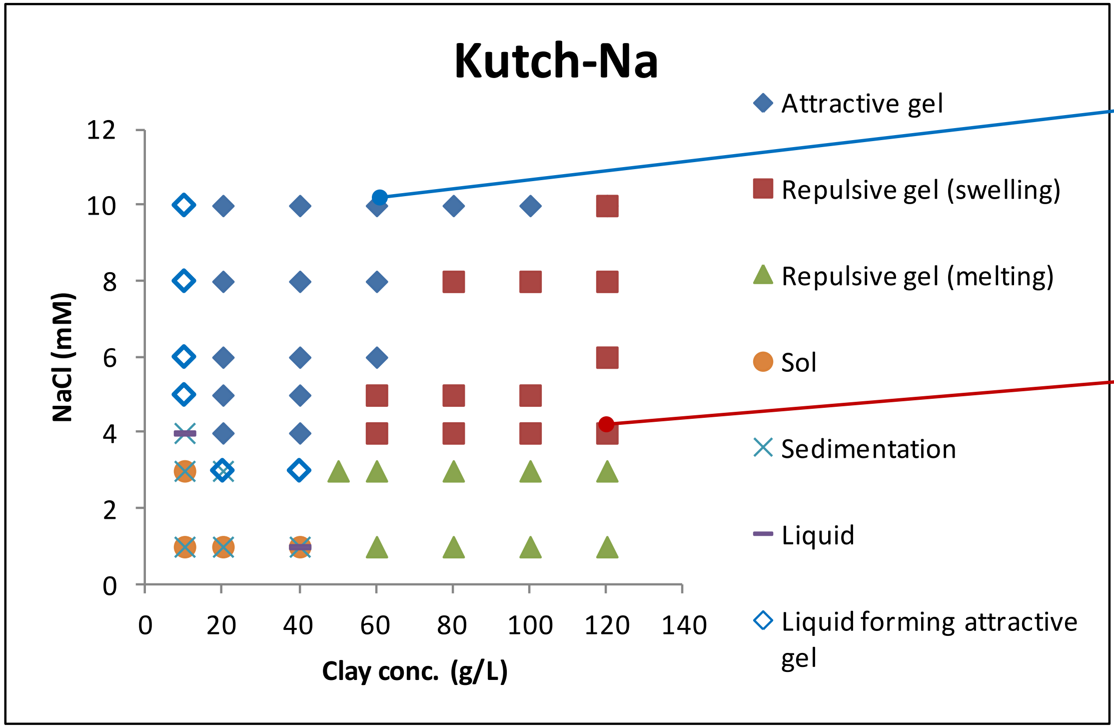


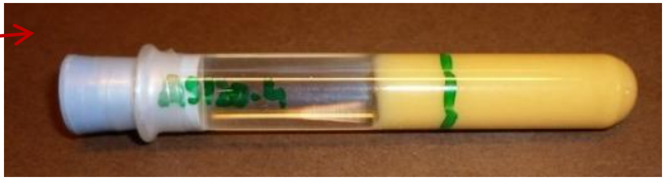
~1400 nm of water between clay layers
Diameter of typical clay platelet 100-500 nm



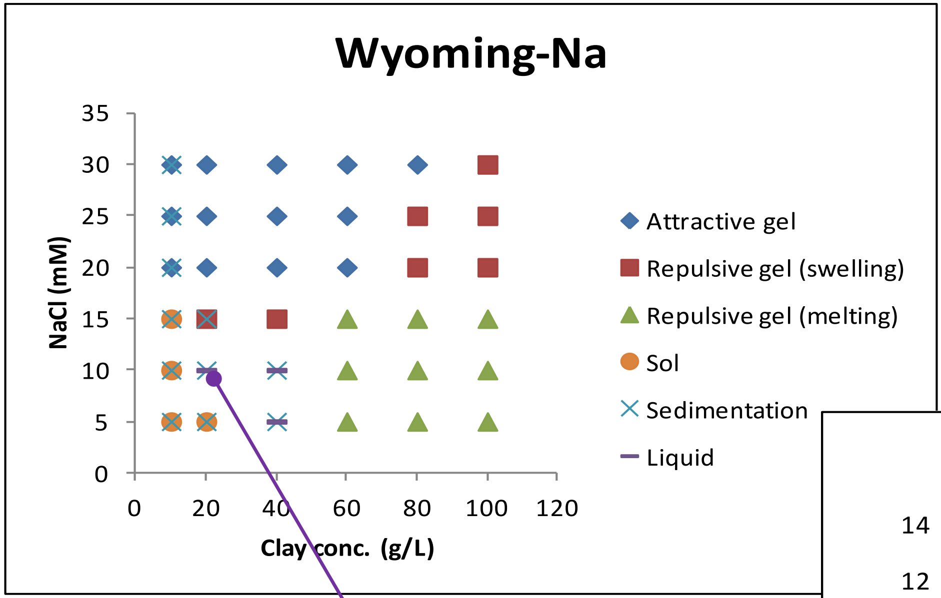


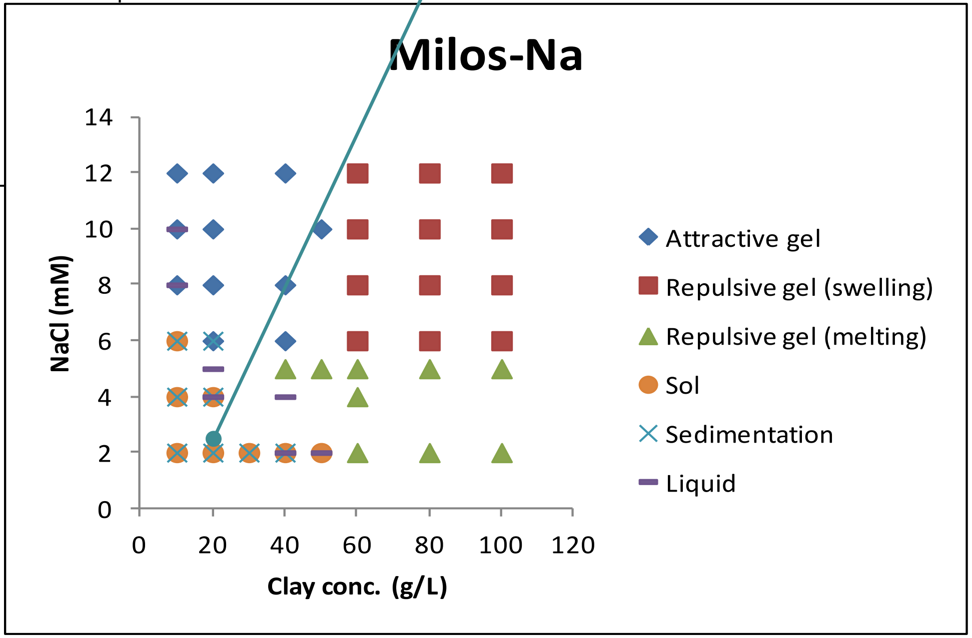
Phase diagram





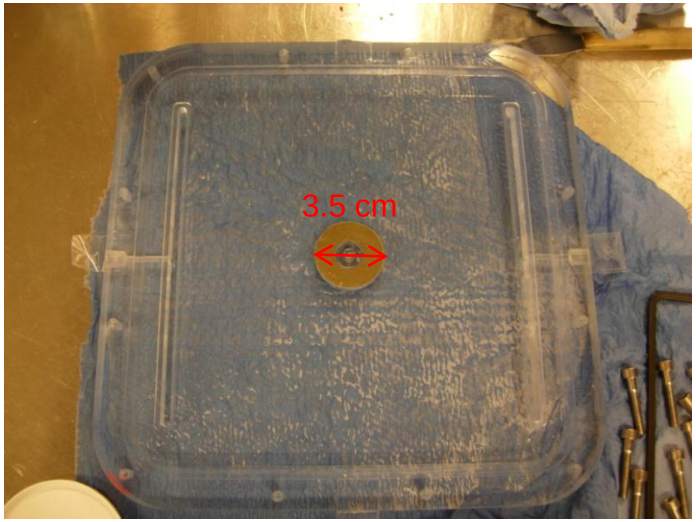
Phase diagram

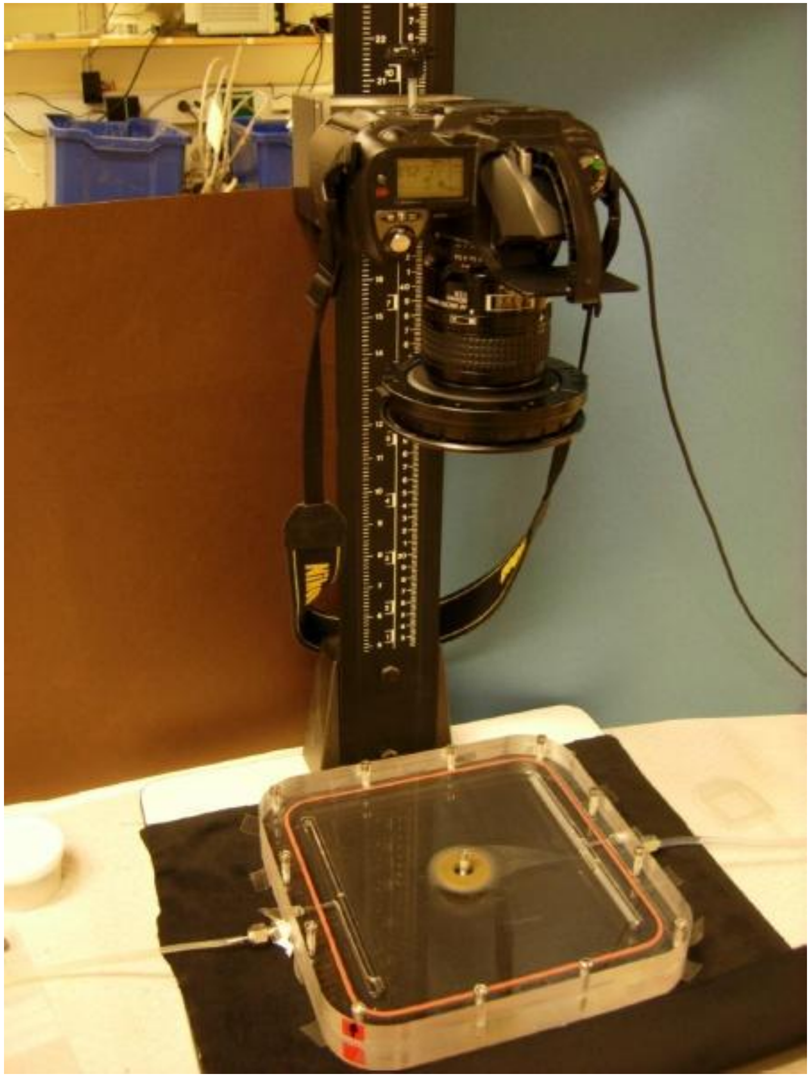




Artificial fracture

- Compacted bentonite/montmorillonite
- 100-120 µm fracture
- Changing flow rate, ionic strength, montmorillonite composition





Free swelling behaviour in an artificial fracture

- Wyoming-Na
- 1200 kgm^{-3} initial dry density
- 100 µm artificial fracture
- Deionised water

Free swelling behaviour

Free swelling behaviour

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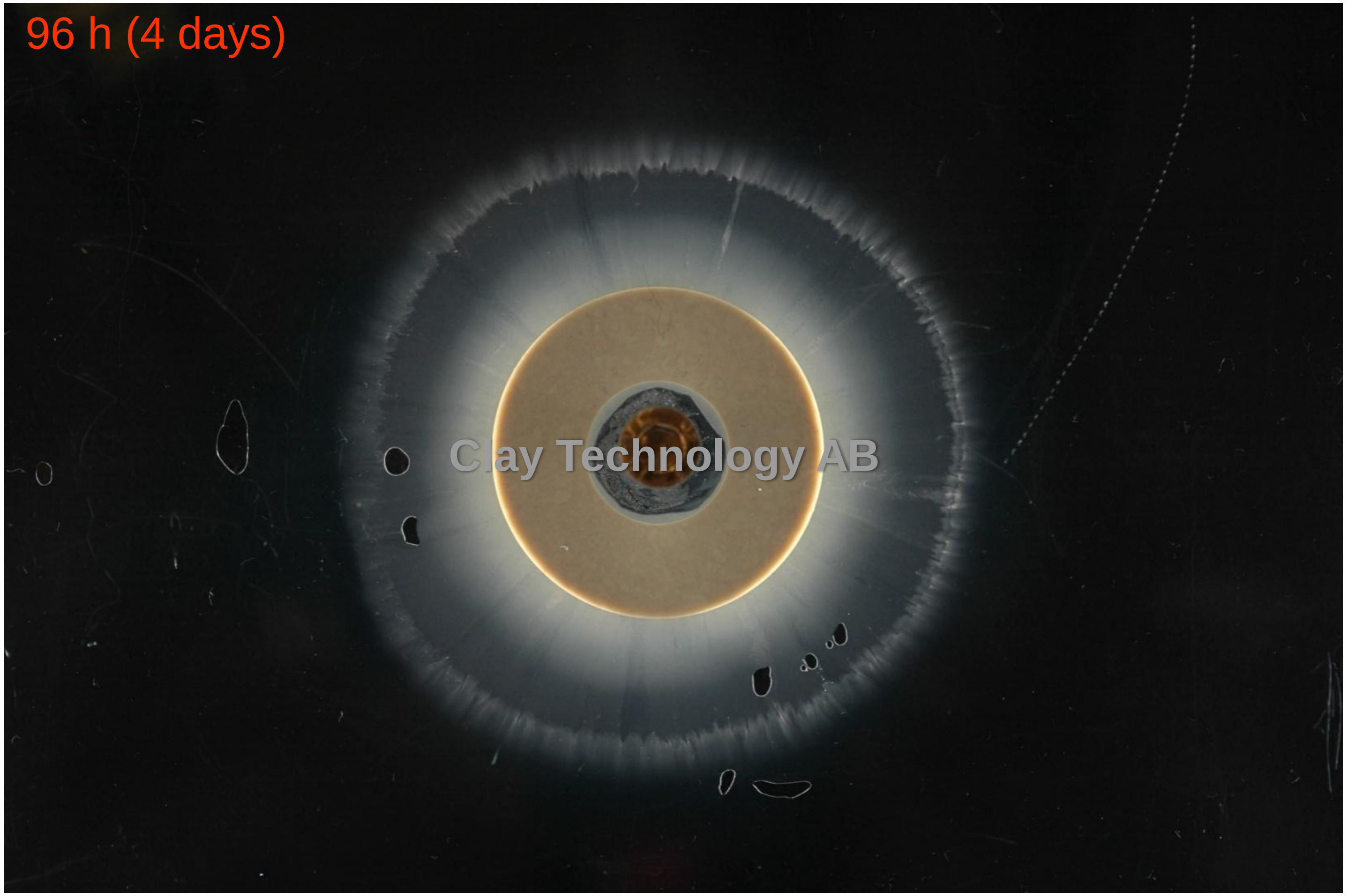
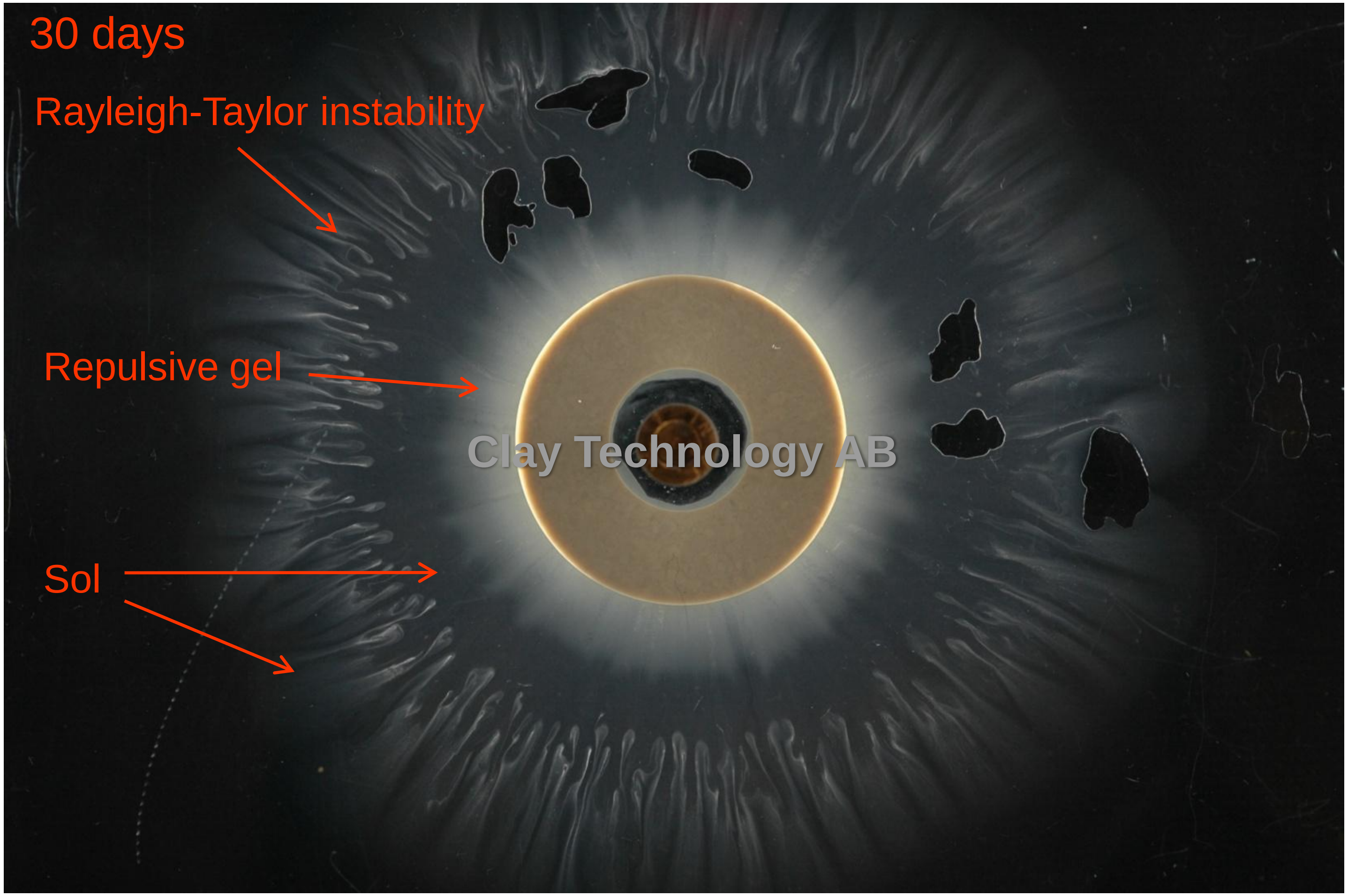
Free swelling behaviour



Free swelling behaviour



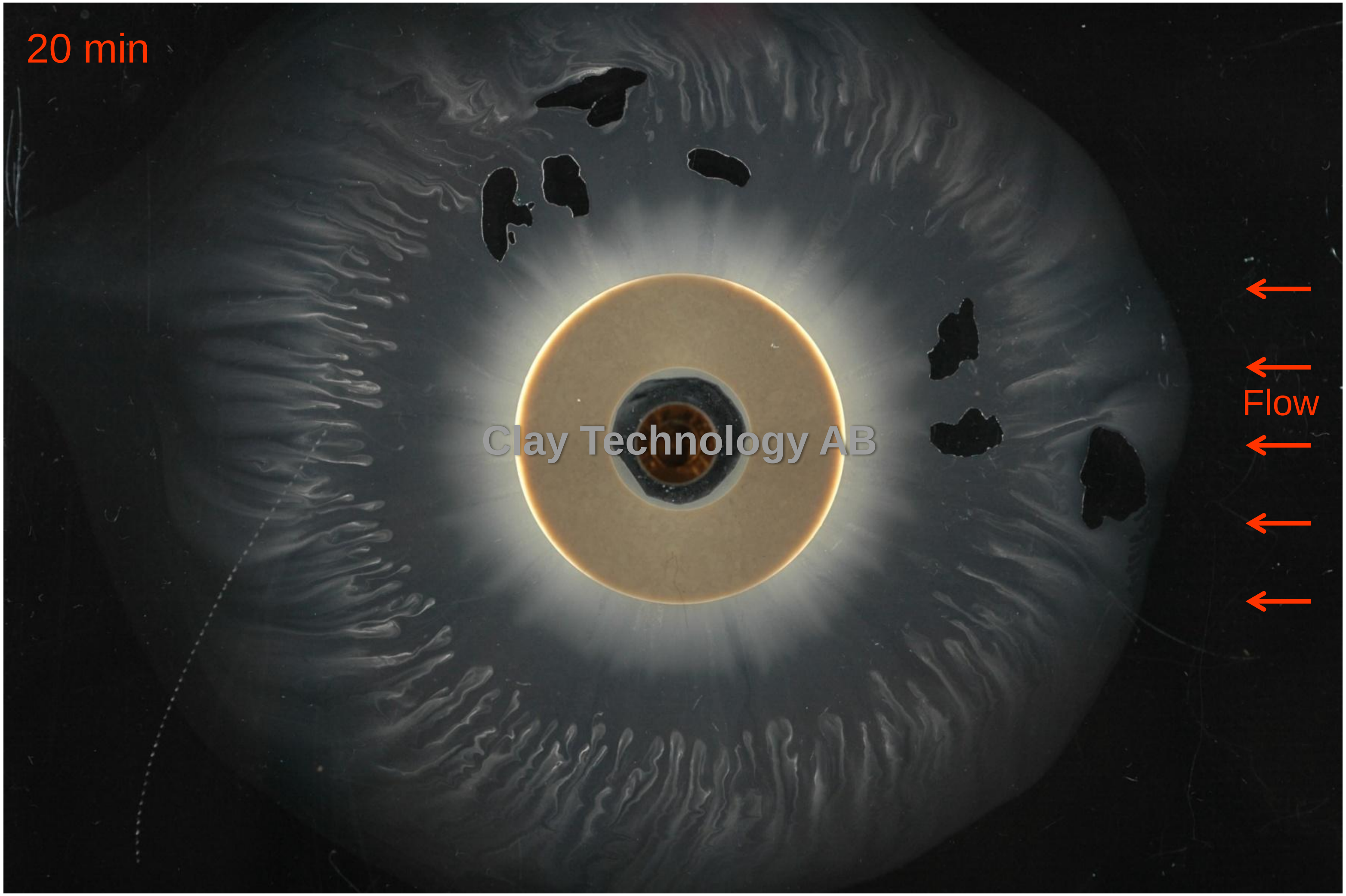
Flow after free swelling

- Wyoming-Na
- Flow with deionised water
- After 30 days of swelling in deionised water

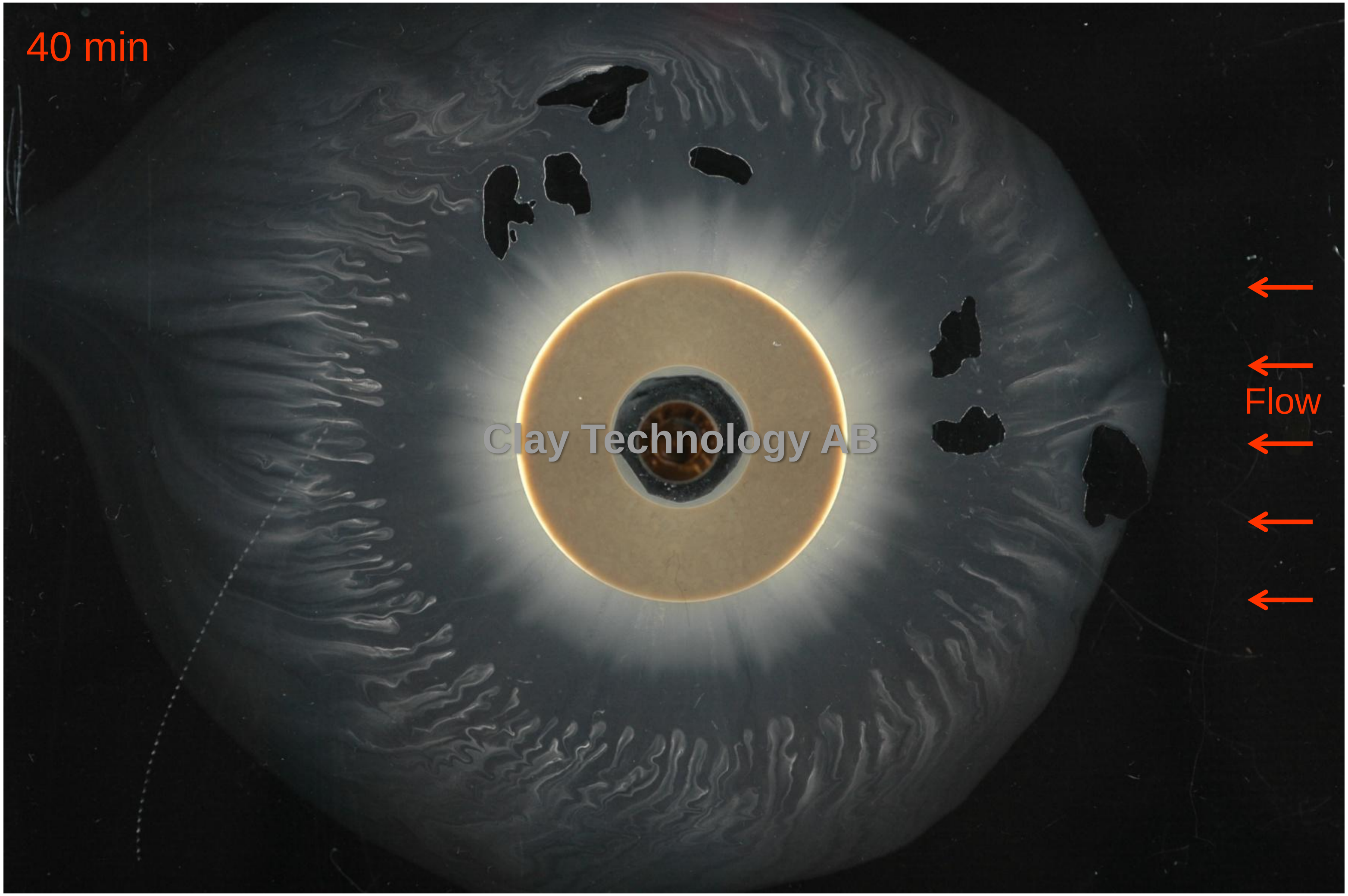
Flow after free swelling

Flow after free swelling

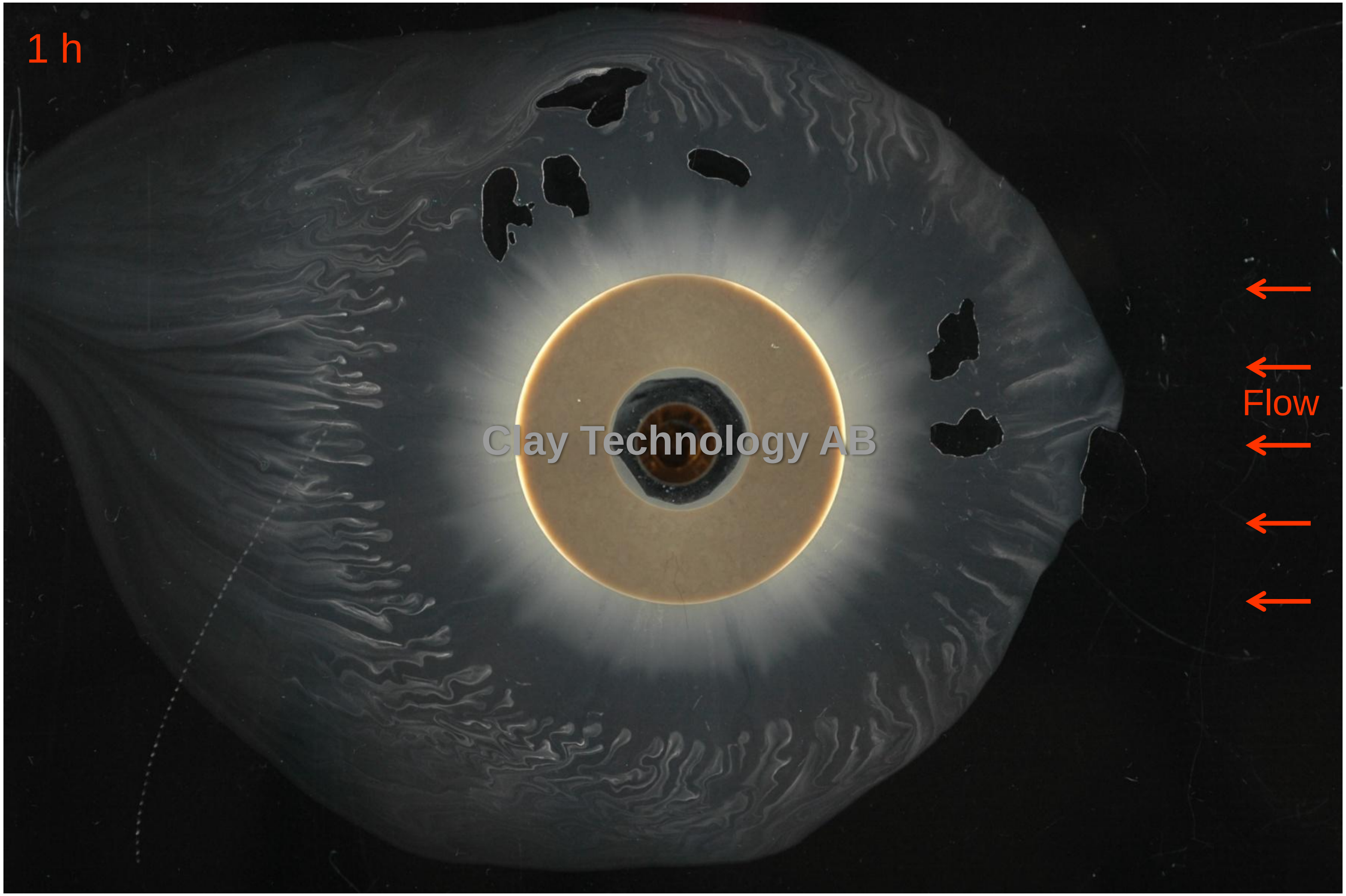
Flow after free swelling



Flow after free swelling



Flow after free swelling



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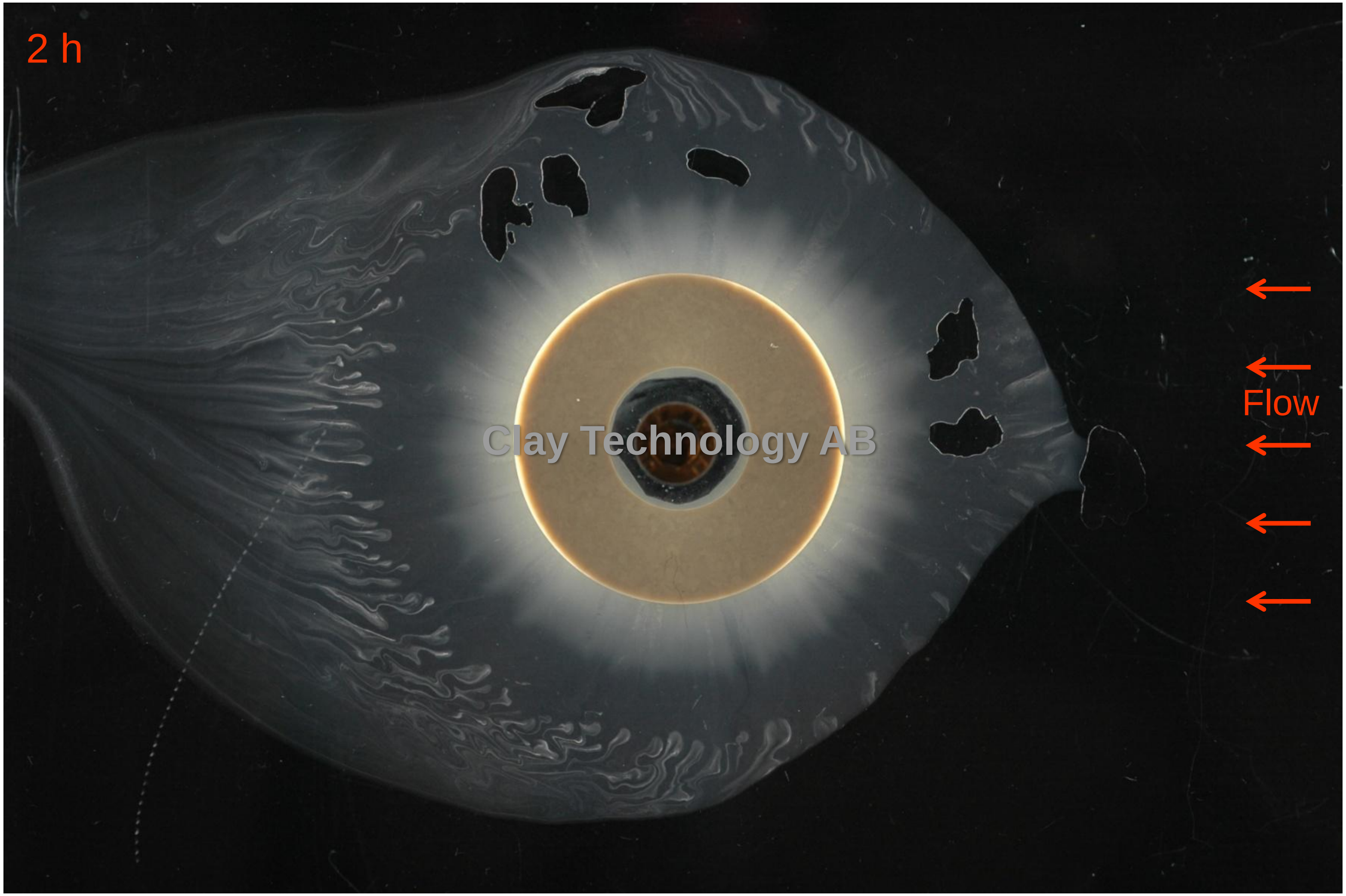

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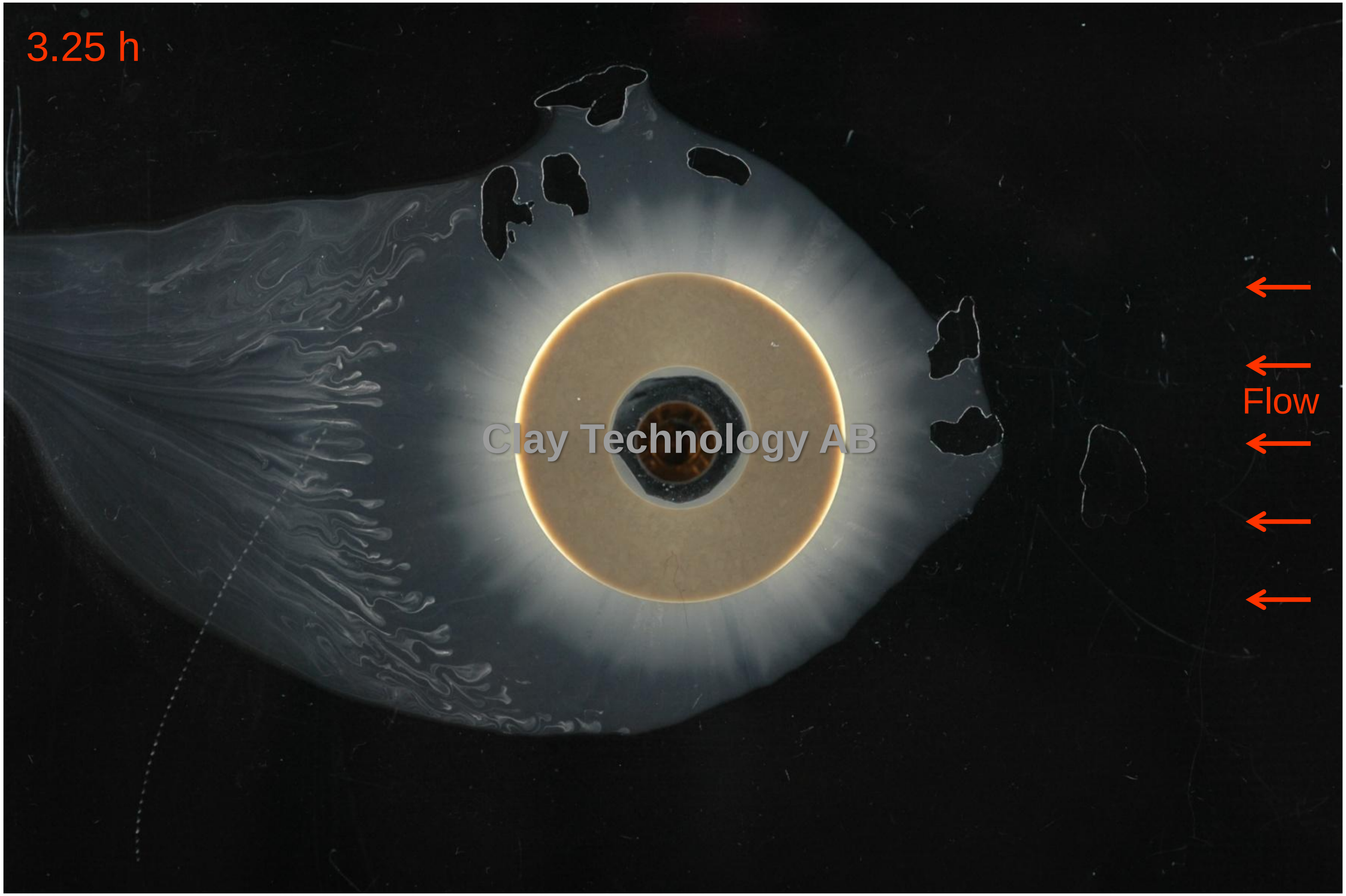
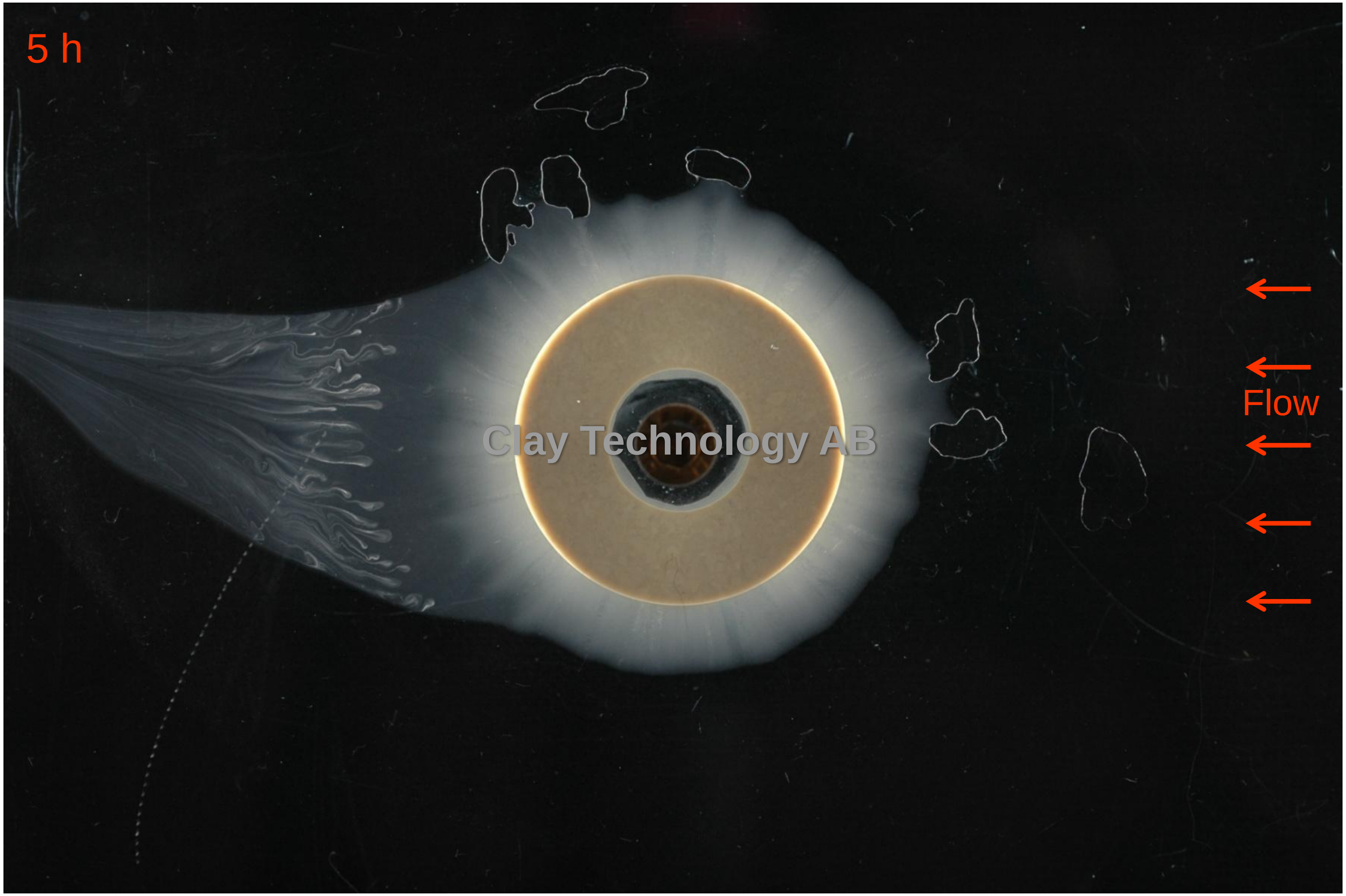
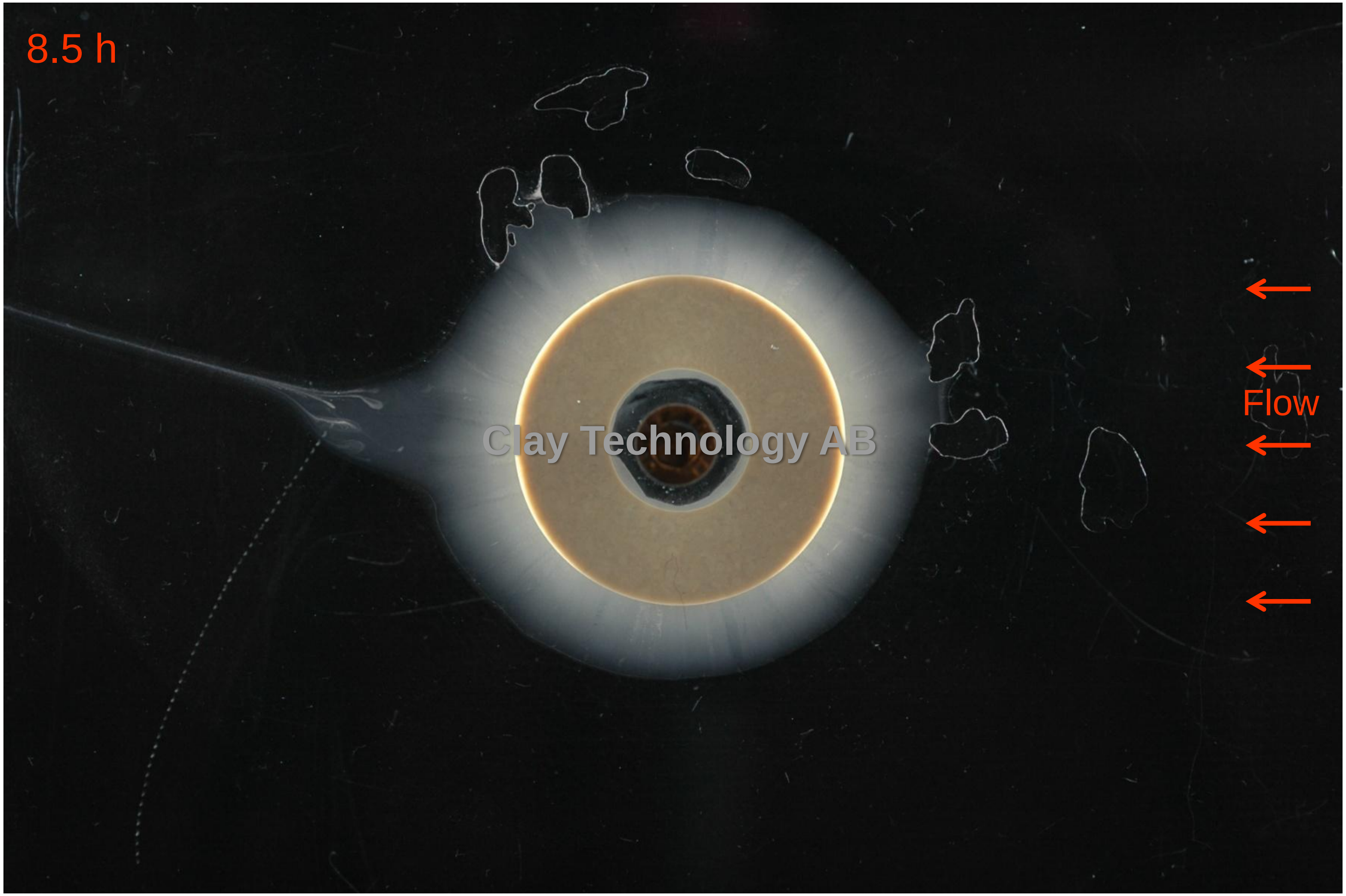


Flow after free swelling



Flow after free swelling



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Wyoming-50/50 – free swelling

- Wyoming-50/50 (i.e. 50% Wyoming-Ca mixed with 50% Wyoming-Na)
- Free swelling into fracture
- 120 µm fracture
- Deionised water

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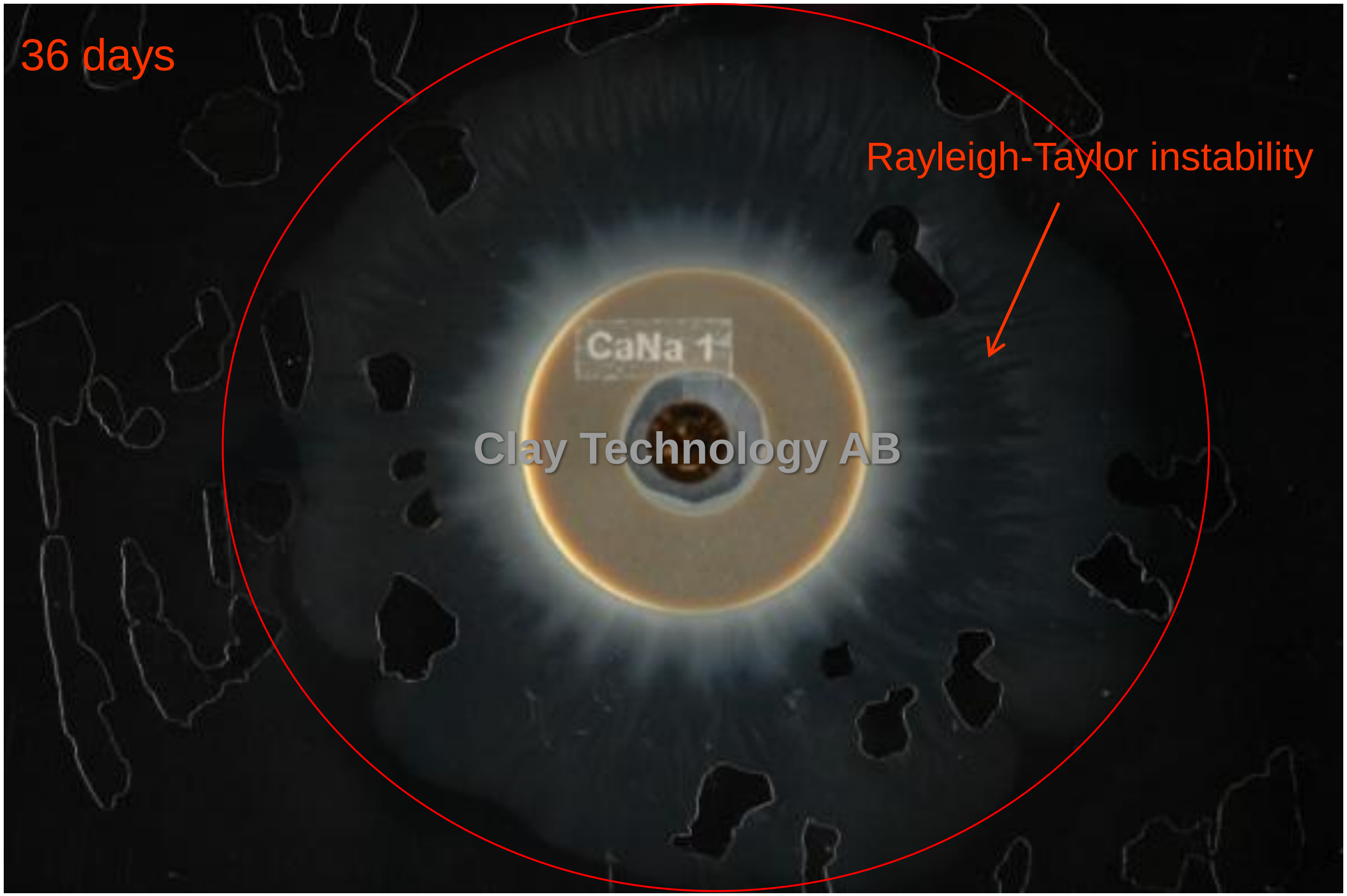
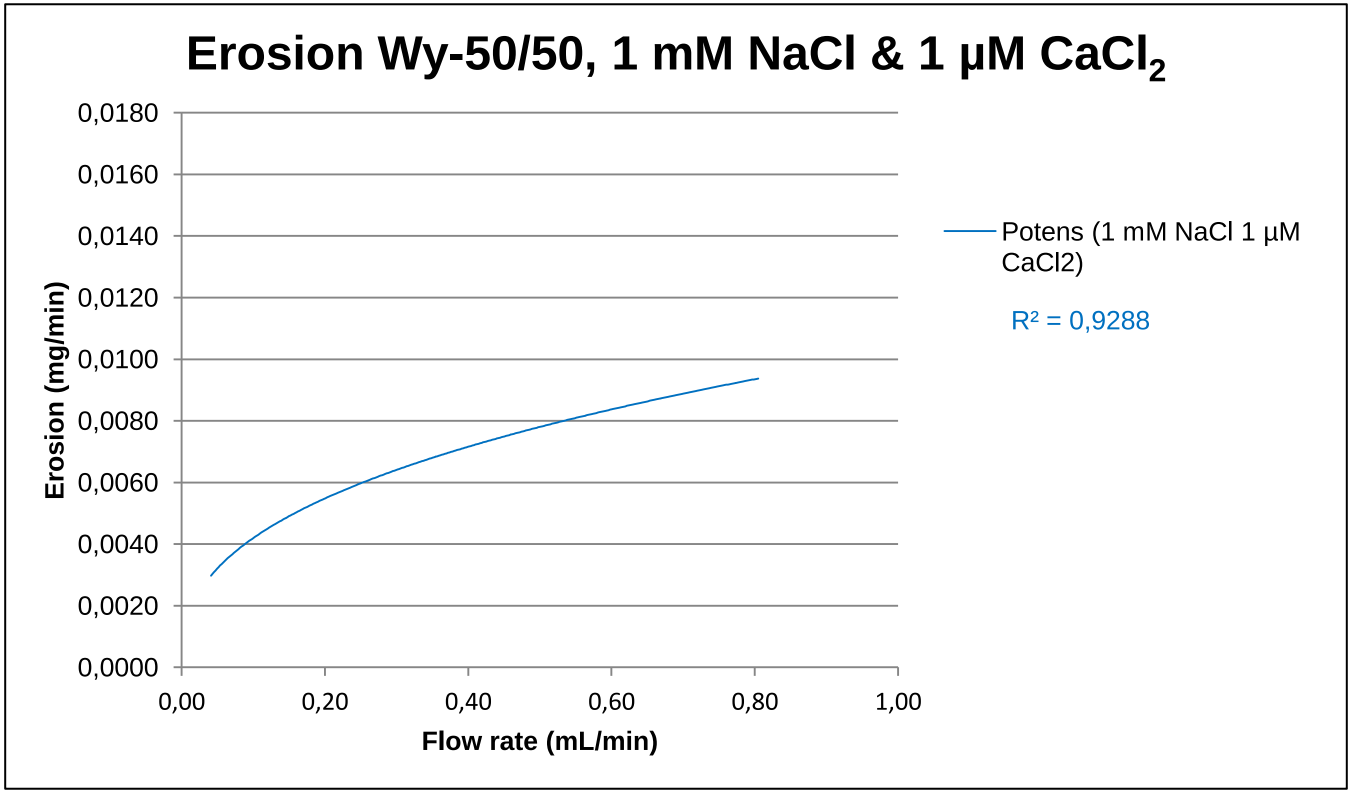


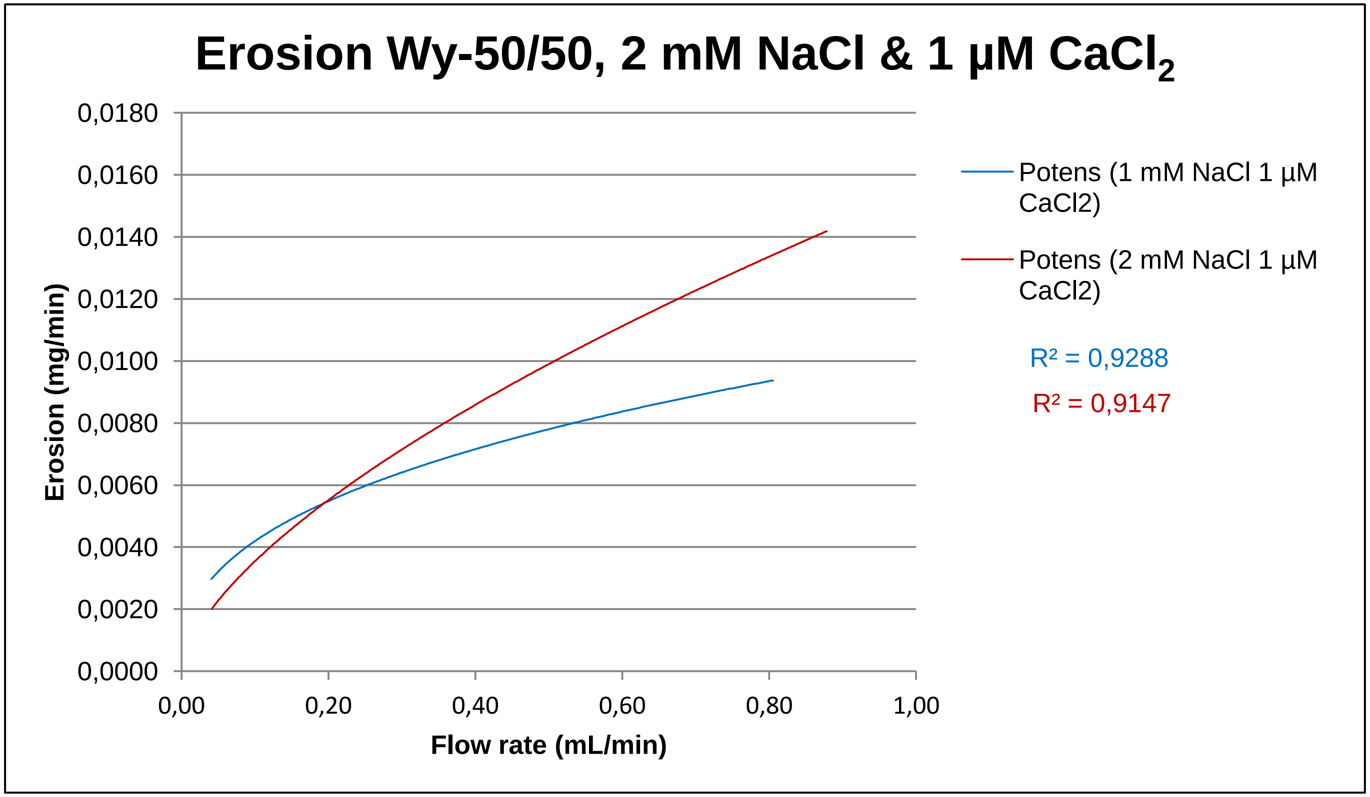
Erosion measurements

- Wyoming-50/50
- Compacted clay - 1200 kgm^{-3} initial dry density
- 120 µm fracture
- Constant flow
- Flow with solution of increasing salinity
- Erosion determined by turbidity measurements
- Addition of $CaCl_2$ to solution in order to prevent depletion of Ca-ions in the clay

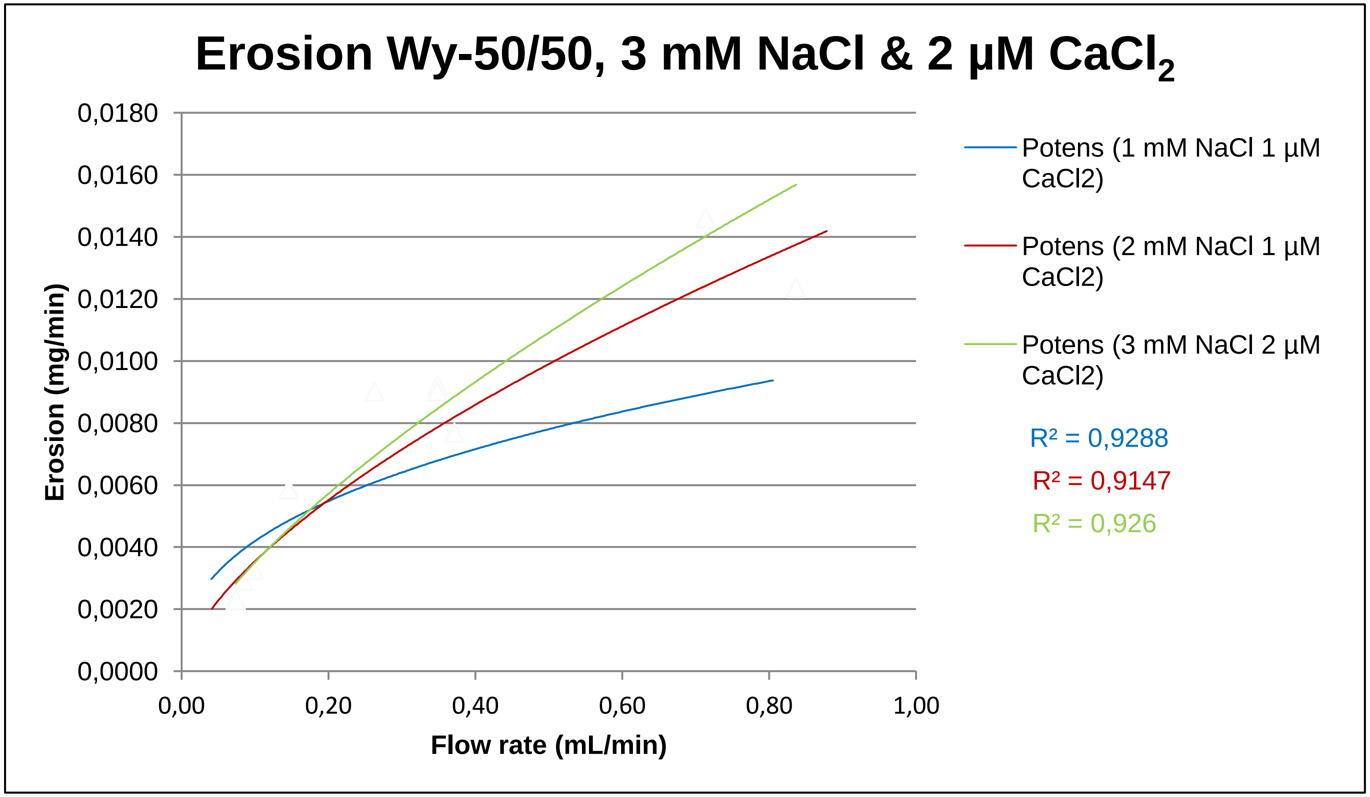
Erosion measurements



Erosion measurements



Erosion measurements



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Free swelling in NaCl-solution

- Wyoming-Na
- NaCl-solution, 25 mM, pH 9-10
- 100 µm fracture
- 1200 kgm^{-3} initial dry density

Free swelling in NaCl-solution

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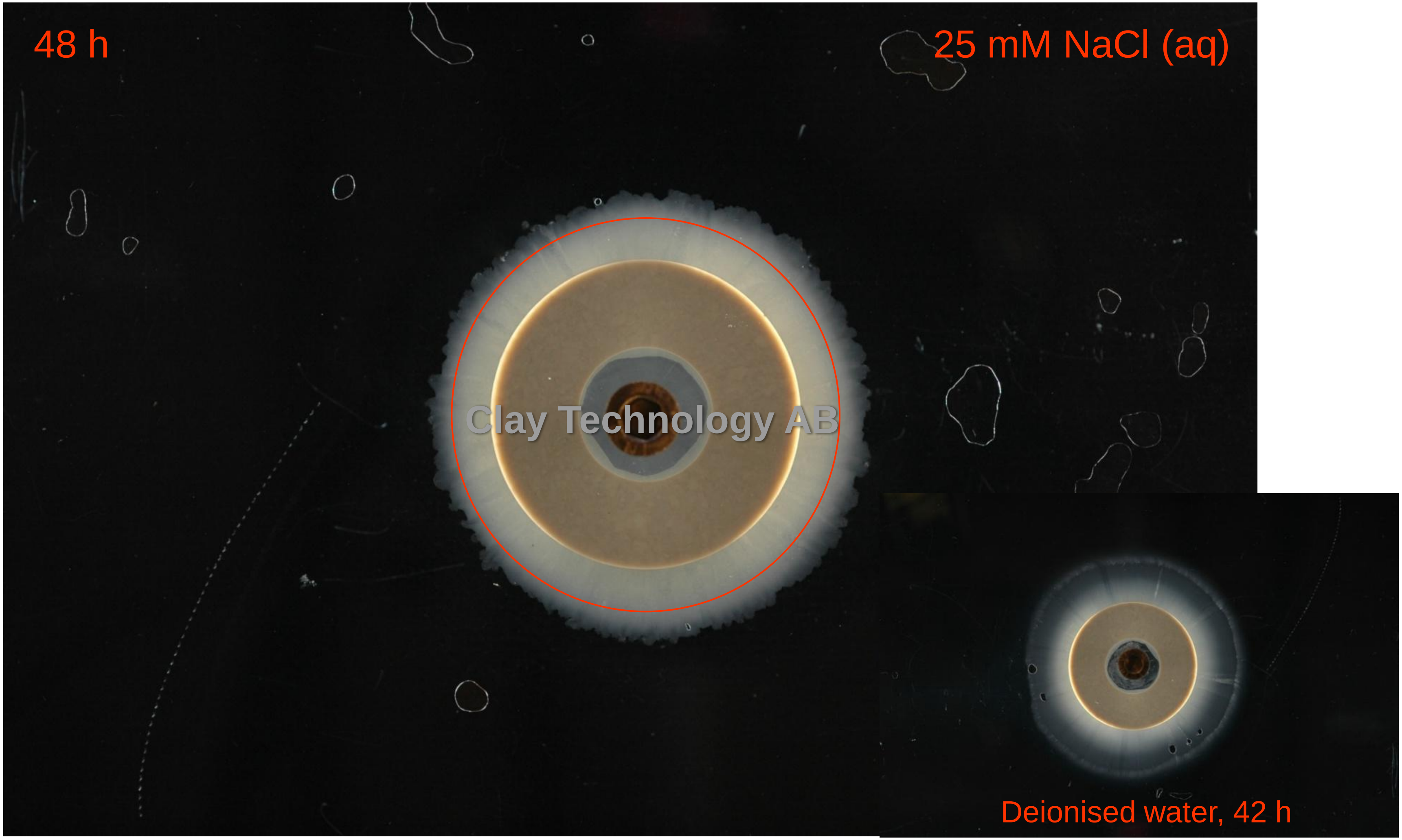


Free swelling in NaCl-solution

Free swelling in NaCl-solution

Flow after free swelling in NaCl-solution

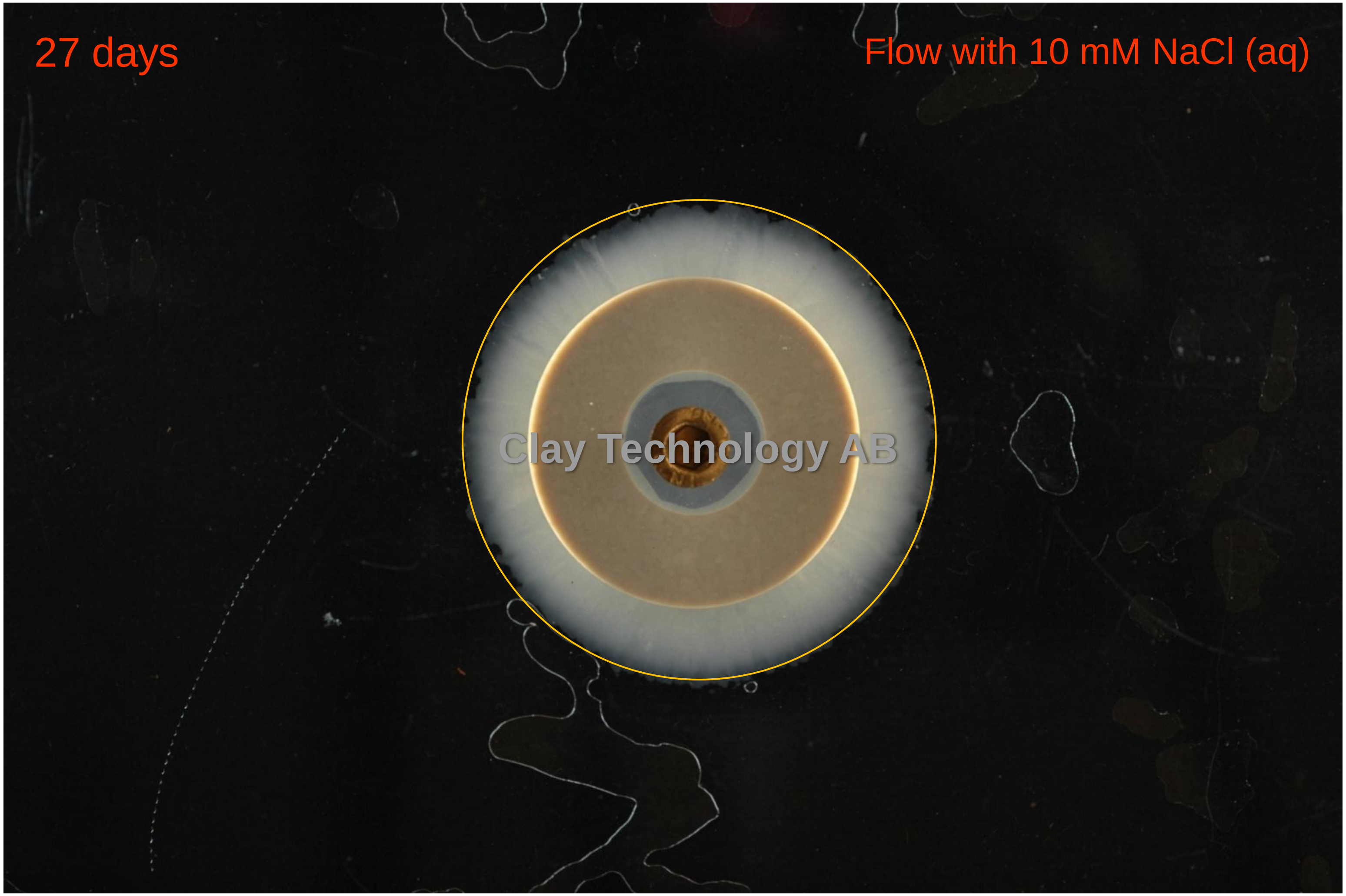
- Wyoming-Na
- NaCl-solution, 25 – 5 mM, pH 9-10
- 100 µm fracture
- 1200 kgm^{-3} initial dry density

Free swelling in NaCl-solution – Flow started

Flow after free swelling in NaCl-solution

Flow after free swelling in NaCl-solution

Flow after free swelling in NaCl-solution



Flow after free swelling in NaCl-solution

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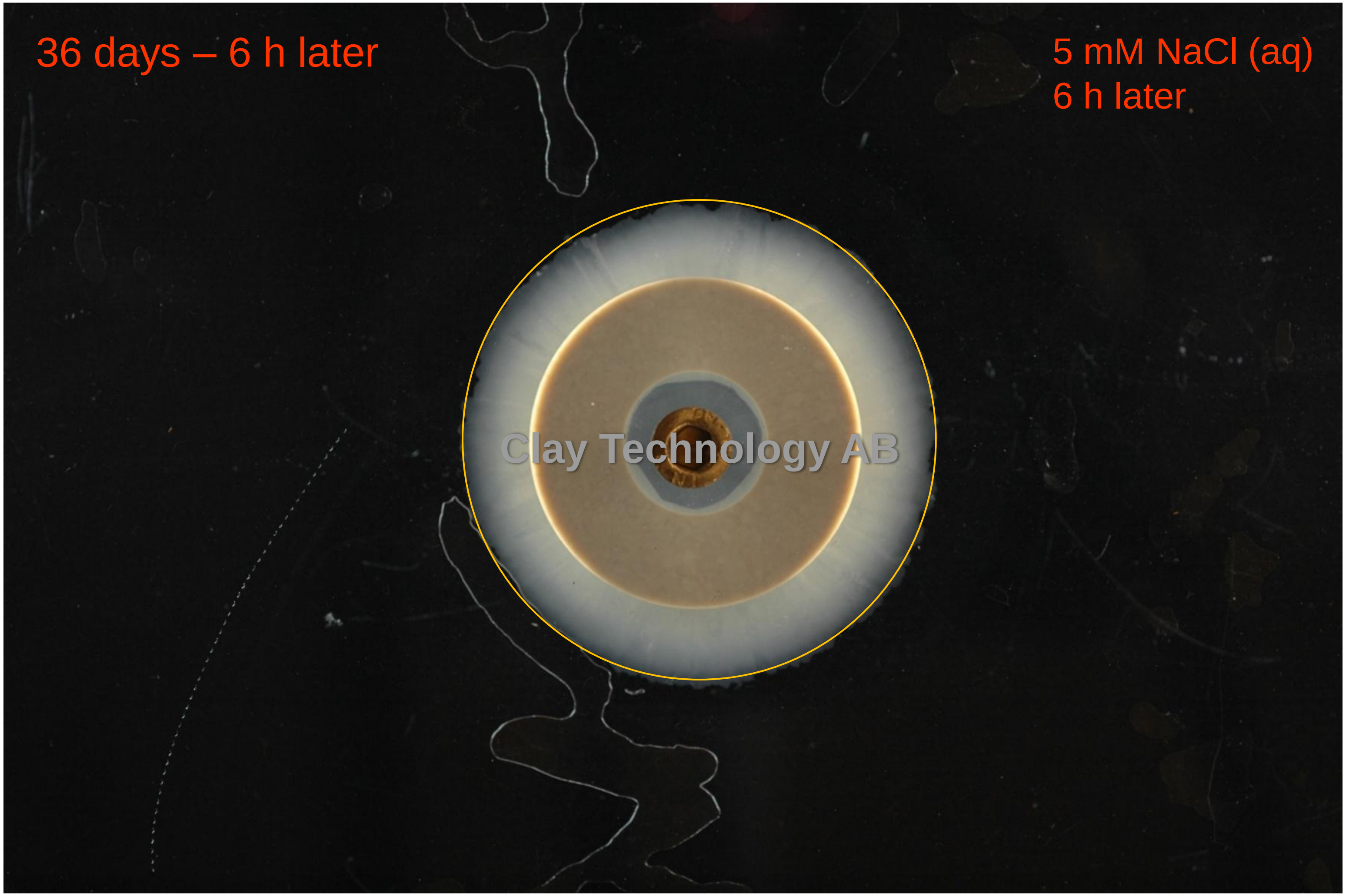


Flow after free swelling in NaCl-solution

Going the other way

- When commencing with 25 mM NaCl, no swelling or erosion was noticed even when the salinity decreased as far as to 5 mM NaCl.
- Possible hysteresis effect.
- What if we start with low salinity and then gradually increase the NaCl-concentration?

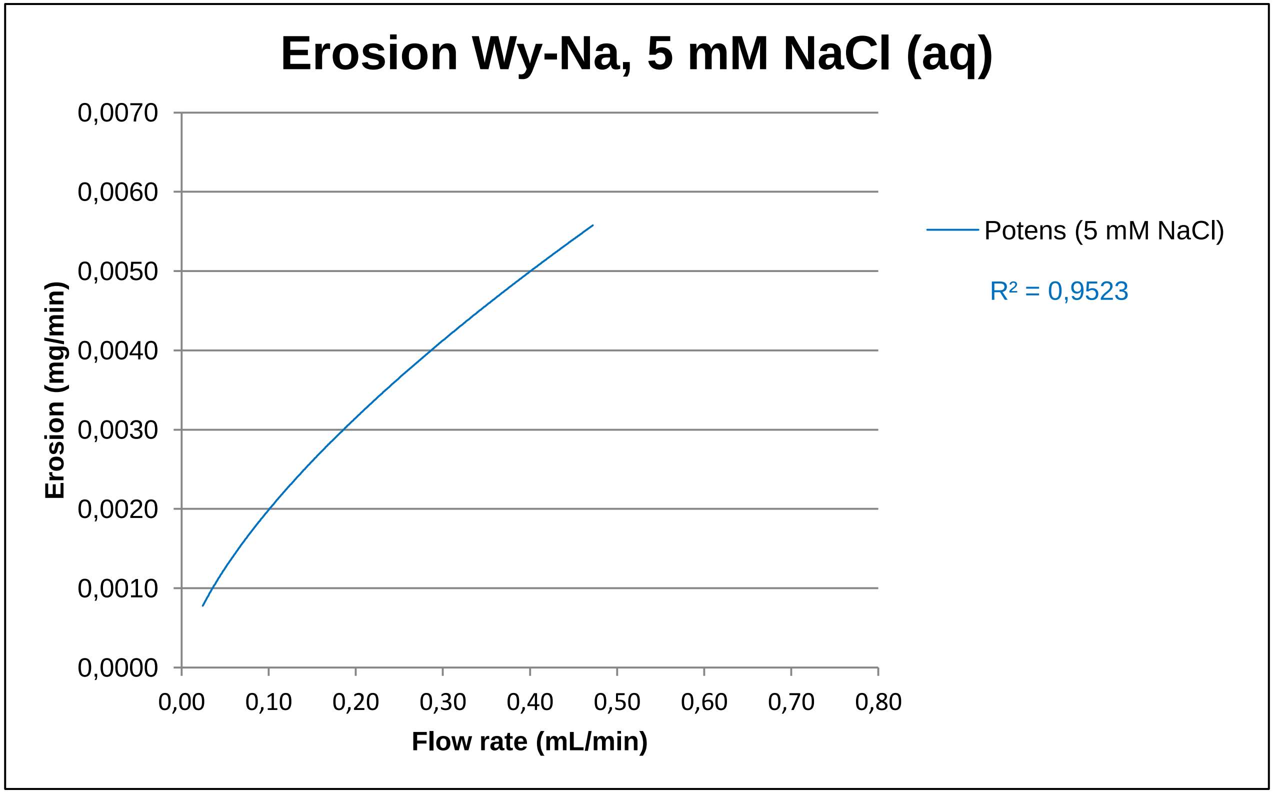
Going the other way

- When commencing with 25 mM NaCl, no swelling or erosion was noticed even when the salinity decreased as far as to 5 mM NaCl.
- Possible hysteresis effect.
- What if we start with low salinity and then gradually increase the NaCl-concentration?
- In 5 mM NaCl-solution, the clay does swell out into the fracture and during flow, we experience erosion.

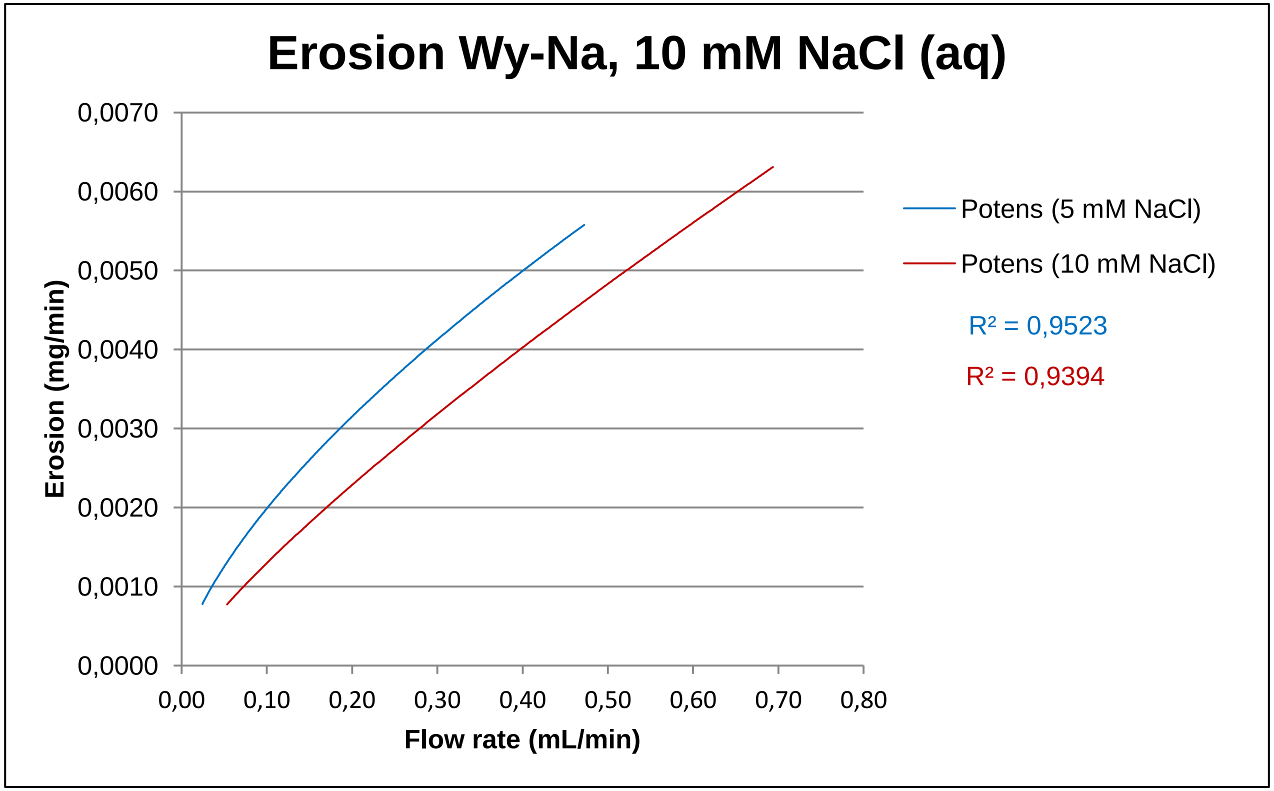
Erosion of Wy-Na in solution with increasing salinity

- Wyoming-Na
- Compacted clay - 1200 kgm^{-3} initial dry density
- 120 µm fracture
- Constant flow
- Flow with solution of increasing salinity
- Erosion determined by turbidity measurements

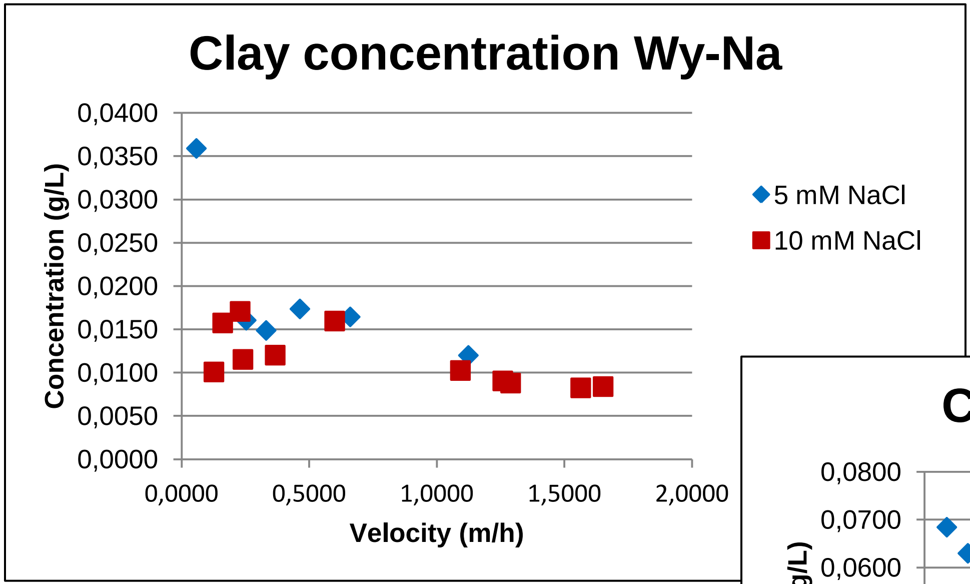
Erosion of Wy-Na in solution with increasing salinity

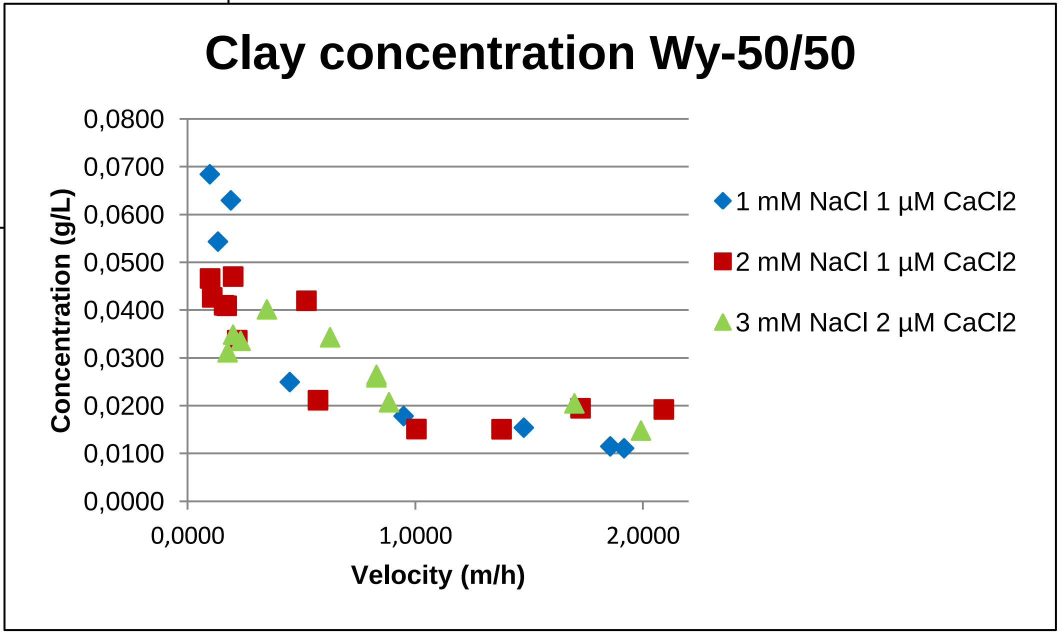


Erosion of Wy-Na in solution with increasing salinity



Clay concentration as a function of velocity





Conclusions

- Phase studies
- Swelling behaviour
- Difference between Na- and Ca/Na-clay
- Method for measuring erosion in artificial fractures
- Initial results show that erosion appears to be highly dependent on the salinity and the flow rate

Acknowledgements

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