



Supplement of

From process to system understanding with multi-disciplinary investigation methods: set-up and first results of the CD-A experiment (Mont Terri rock laboratory)

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From process to system understanding with multi-disciplinary investigation methods: set-up and first results of the CD-A experiment (Mont Terri Rock Laboratory)

BGR:

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Federal Ministry of Economics and Technology













From process to system understanding with multi-disciplinary investigation methods:

set-up and first results of the CD-A experiment (Mont Terri Rock Laboratory)

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1.00

Saturation 0.75 0.800 0.850 0.900 0.950



Outline

- **Introduction CD-A Experiment**
- **Process understanding**
- System understanding

CD-A Experiment: Set-up



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Aim: Important for: Investigation of coupled HM-effects in the Opalinus Clay Stability and integrity of a potential repository

- 2 horizontal excavations
- perpendicular to strike of bedding
- no stabilization
- upper sandy facies
- influence of climatic conditions on HM behavior
- CD: "cyclic deformations"



CD-A Experiment: Set-up



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Open twin:



Closed twin:

Closed twin



Air lock

Open twin

"natural" niche containing coupled HM effects due to desaturation "air conditioned" niche avoiding desaturation effects as much as possible

CD-A Experiment: Climatic conditions







Closed niche: Constantly high relative humidity

Open niche: Seasonally influenced relative humidity

CD-A Experiment: Relevant effects



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Open twin:



Closed twin:



- Excavation (2019):
 - Stress redistribution
 - Pore pressure changes

- Climatization
 - Desaturation
 - Swelling/Shrinkage
 - Saturation dependent material parameters

Χ



Desaturation around the niches – numerical modelling



Numerical modelling (OpenGeoSys6) of the twin niches also indicates the differences of the desaturated zone (already) two years after excavation



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Desaturation around the niches: geophysical measurements



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Electric Resistivity Tomography ERT measurements at ring profiles: relative changes of the resistivity **Evolution of** desaturated zone



Furche (BGR)

Desaturation around the niches: geophysical measurements



Nuclear magnetic resonance measurements (NMR) provide information about the water content









Costabel (BGR)



Resistivity – water content – relation

Multi-disciplinary interpretation aiming on:

- Process understanding
- Work in progress
- Constitutive material modelsValidation of numerical approach

Characterization of Opalinus Clay



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Extensometer Geophysical mesurements Evapometer Minipiezometer

Method: Info:	Lith.	ERT	MSM	NMR/CCM	Taupe	Pulse test	Numerics
Subfacies type	+	+	-	-	-	-	(*)
EDZ	-	-	+	-	+	(+)	(*)
Fault zones	+	-	-	-	(+)	(+)	(*)
Water content	-	+	-	+	(+)	-	+

Table 2: Investigation methods and available information. [+: information available, -: no information available, *: may provide information about their impact on physical effects, (): limited information]. Lith. = Lithological investigations on drill cores. ERT: Electric Resistivity tomography

> MSM: Mini-Seismic

NMR: Nuclear Magnetic Resonance

CCM: Calciumcarbid-Method

Taupe: Time domain reflectometry (TDR)

Borehole investigations



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Geologic mapping

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Figure 32: N-S-striking fault in the Closed Twin, here in the ceiling. Displacement (A) and rotation (B) of the fault when crossing bedding parallel faults.

Figure 35: Open Twin, system of small flatly dipping (238/07) veins (red) showing drag folds (orange) and cm displacement of bedding planes (green).

Extensometer measurements in relation to detected fault zones

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Measurements indicate impact of some fault zones on convergence behavior

Further investigations needed!

Conclusion

CD-A Experiment:

- Increased process understanding of coupled long-term HM effects
- Geologic characterization + geophysical measurements + numerical modelling + visualization

- Multi-disciplinary approach + close collaboration
- Aiming on an increased system understanding
- Calibration/Verification of constitutive modelling approaches

Preliminary results:

- Measurements and numerical modelling illustrate desaturation and convergence around the twin niches
- Impact of heterogeneities such as sub-facies types and fault zones on coupled HM effects