E-TEST – Geological Field Investigations, Drilling Programs and Geophysical Logging

Raphael Burchartz, Marius Waldvogel, Nils Chudalla, Jonathan Zinser, Pooya Hamdi, Florian Amann

E-TEST Einstein Telescope EMR Site & Technology

Interreg Euregio Meuse-Rhine European Regional Development Fund

EUROPEAN UNION

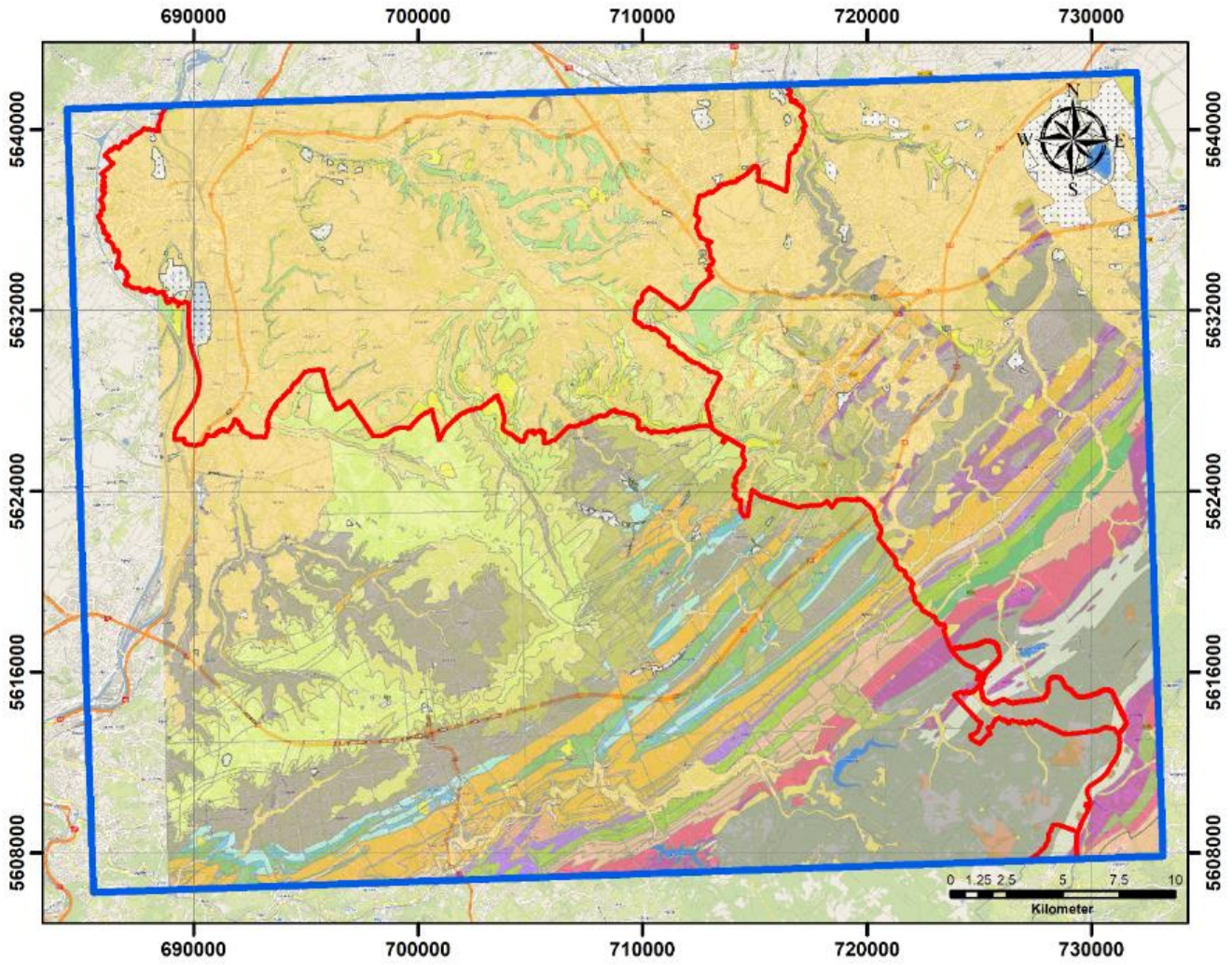
Main Objectives - WP T4

- **3D Cross-Border Open Geological Model**
  - Evaluation and incorporation of existing geological data sets
  - Implementation of new boreholes
  - Active and passive seismic survey
- **ET-Design**
  - Feasibility study and optimal positioning of the ET triangle
  - Extensive multi-disciplinary in-situ and laboratory testing campaign
  - Assessment of regional fracture characteristics by outcrop analogue studies

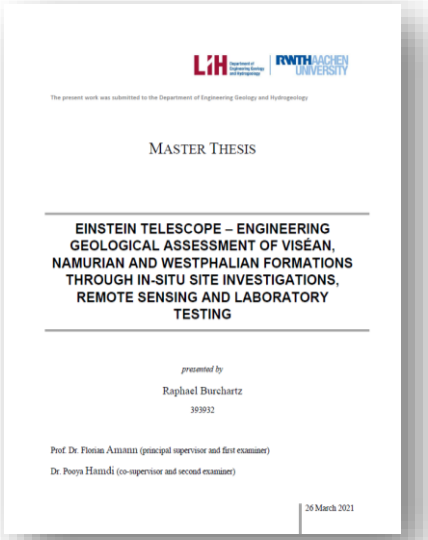
Rocks in the EMR Region

- Rocks of Paleozoic age
  - Carboniferous (361-300 Mio. years)
  - Upper Devonian (383-361 Mio. years)
- Rocks of Upper Cretaceous age
  - 85-66 Mio. years
- Distribution of rocks varies throughout EMR region

- General information from literature and outcrop studies
- Local subsurface information from drill cores



Geological Assessment of Representative Rocks within ET-Project



MASTER THESIS

EINSTEIN TELESCOPE – ENGINEERING GEOLOGICAL ASSESSMENT OF VISÉAN, NAMURIAN AND WESTPHALIAN FORMATIONS THROUGH IN-SITU SITE INVESTIGATIONS, REMOTE SENSING AND LABORATORY TESTING

presented by

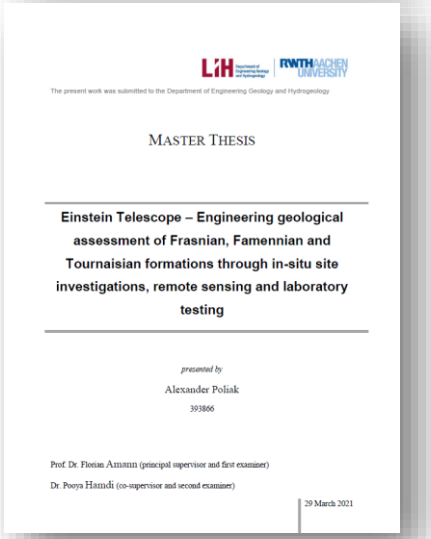
Raphael Burchartz

393932

Prof. Dr. Florian Amann (principal supervisor and first examiner)

Dr. Pooya Hamdi (co-supervisor and second examiner)

26 March 2021



MASTER THESIS

Einstein Telescope – Engineering geological assessment of Frasnian, Famennian and Tournaisian formations through in-situ site investigations, remote sensing and laboratory testing

presented by

Alexander Poliak

393866

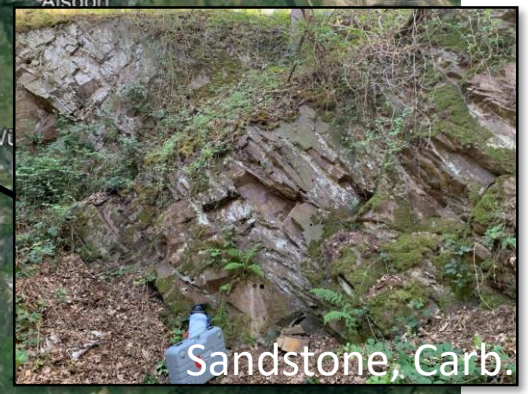
Prof. Dr. Florian Amann (principal supervisor and first examiner)

Dr. Pooya Hamdi (co-supervisor and second examiner)

29 March 2021

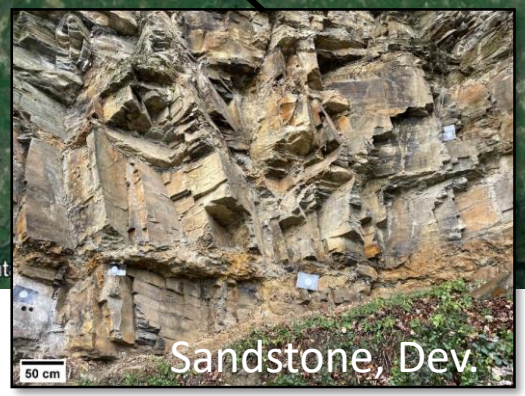
Limestone, Dev.

Siltstone, Carb.

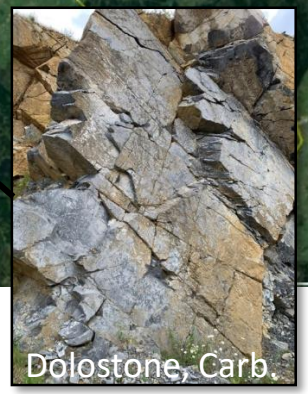


Sandstone, Carb.

Limestone, Carb.

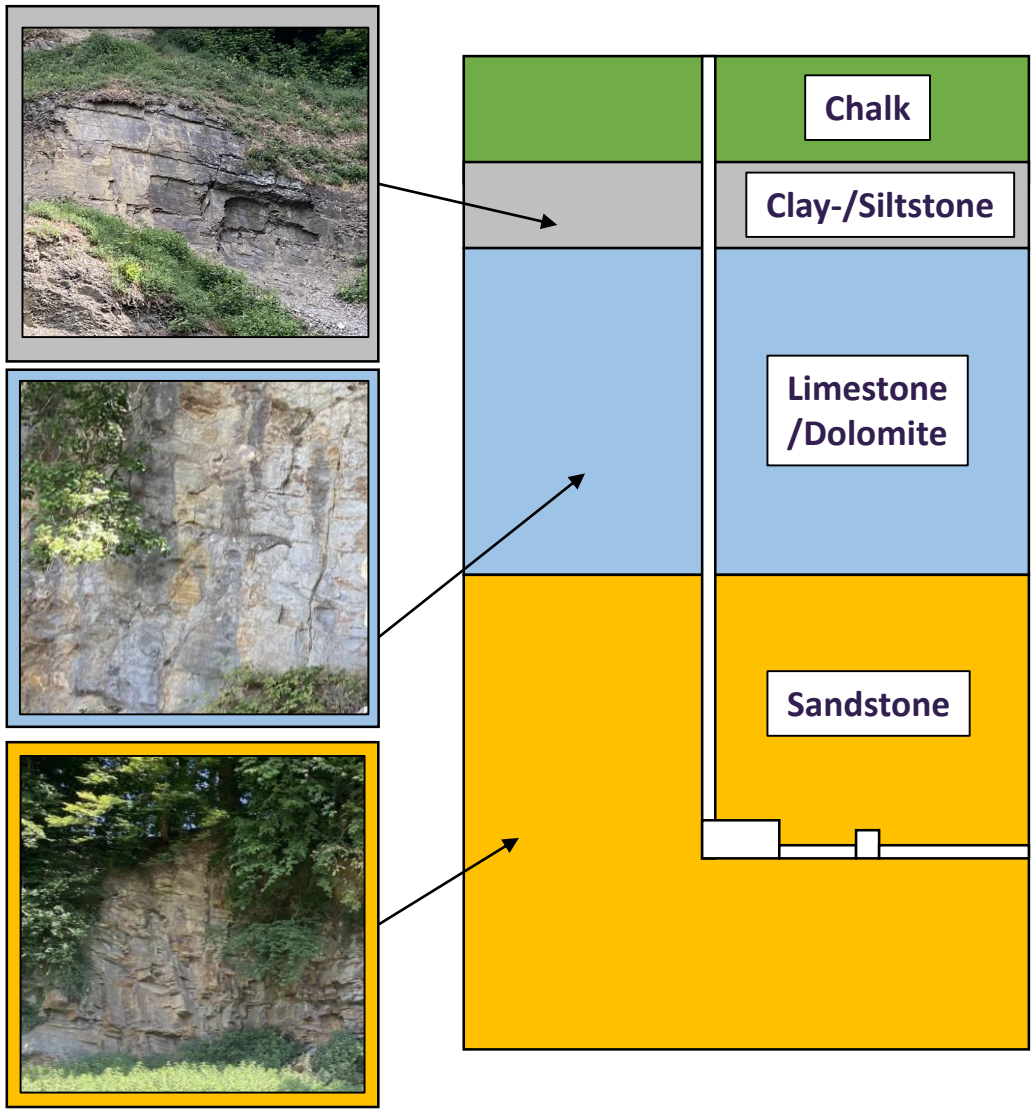


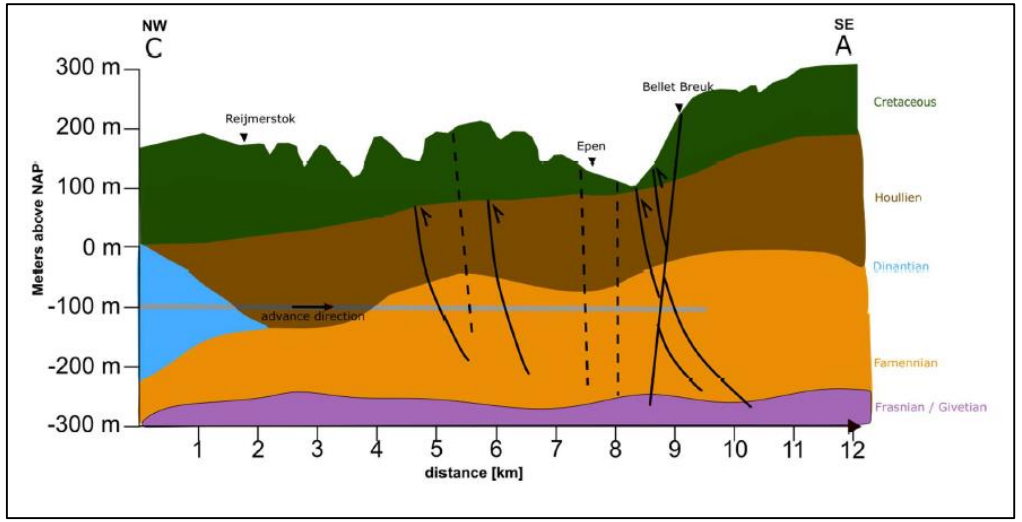
Sandstone, Dev.

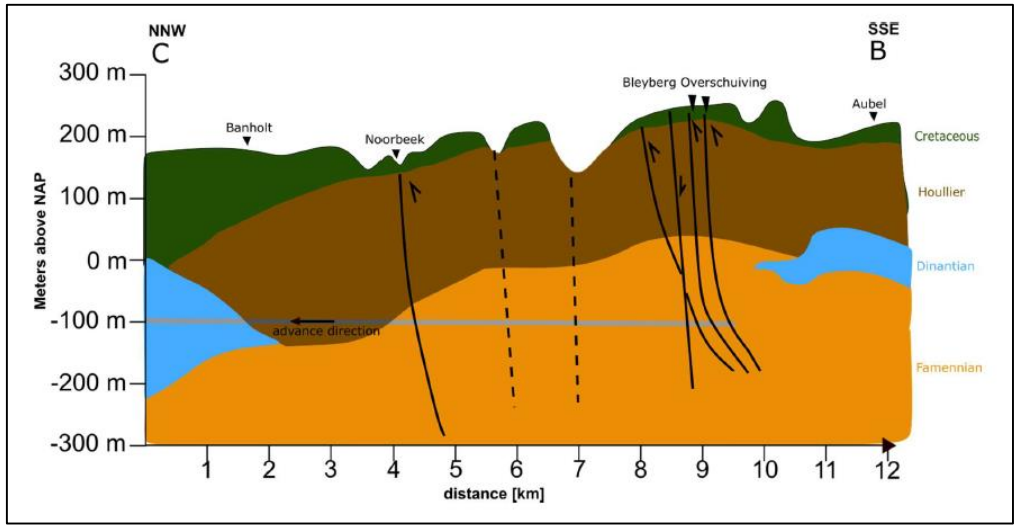


Dolostone, Carb.

Ideal vs Real Rock Column in the EMR Region



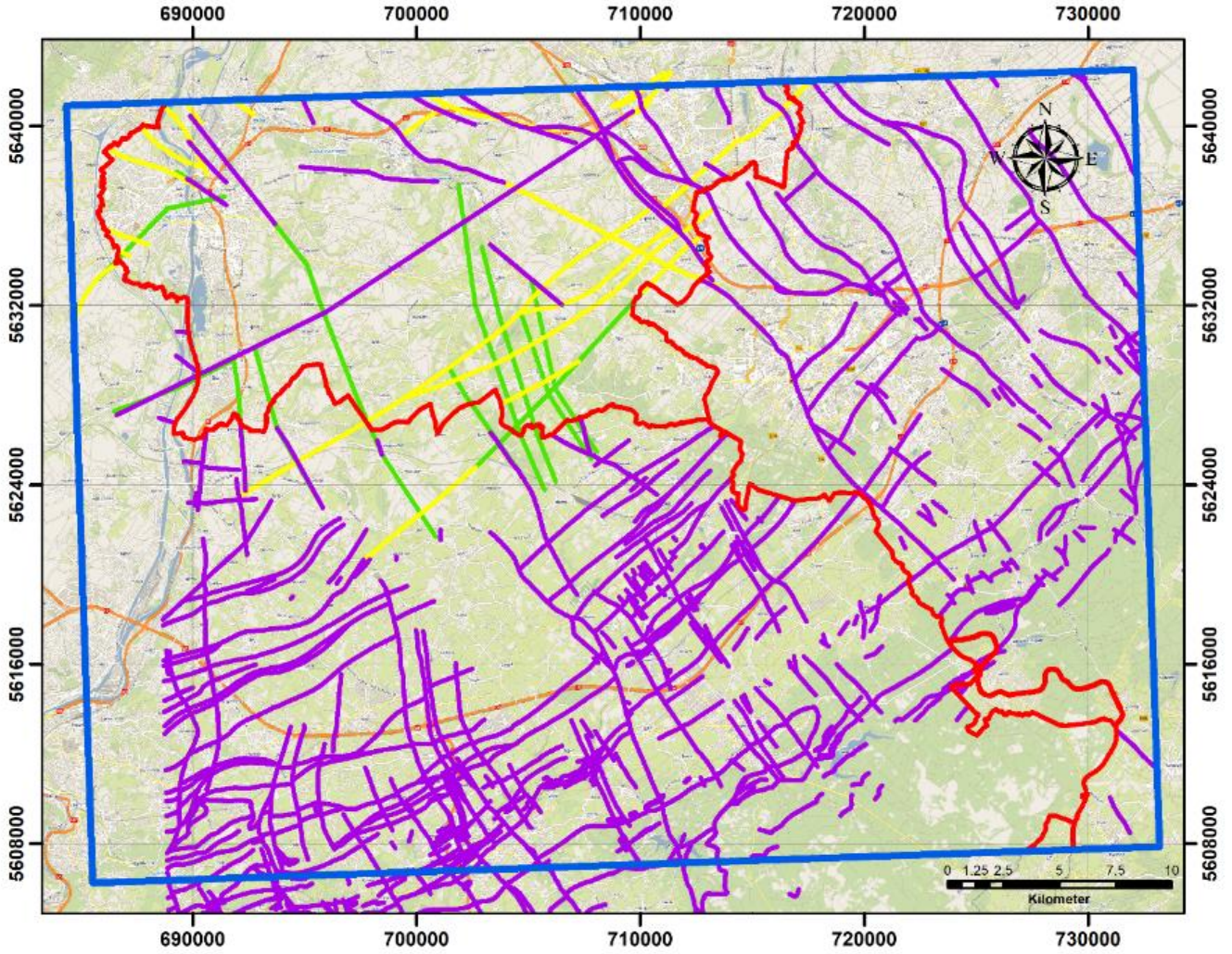




(Ott, 2021)

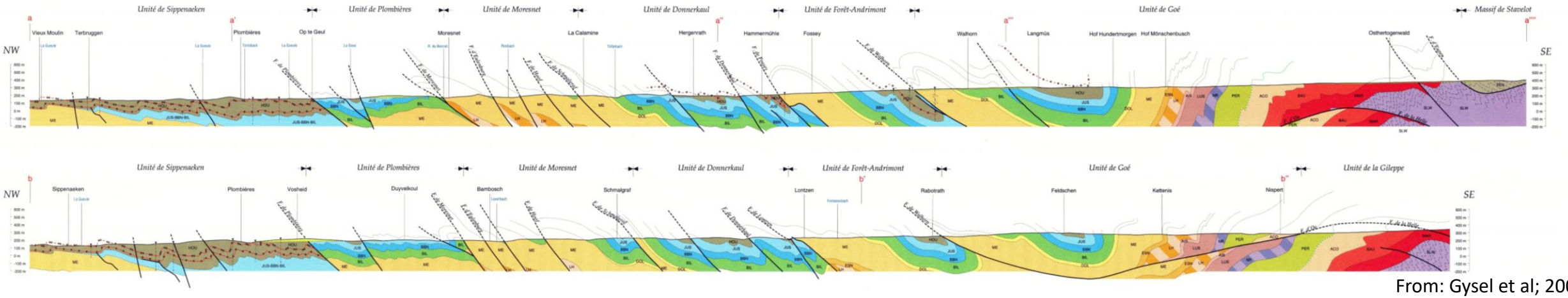
Geological Structures in the EMR Region

- Structure set A
  - Running NE – SW
  - Originate from Late Paleozoic orogeny
  - Affects only Paleozoic rocks
- Structure set B
  - Running NW-SE
  - Origin in Devonian, reactivated several times
  - Affects all rocks
- Information about large-scale structures from literature & maps
- Local information on small-scale features by outcrops & drill-core data



Structure Set A: Running NE-SW

- Folds and thrust faults on large scale
- Fractures on small-scale: Open and closed

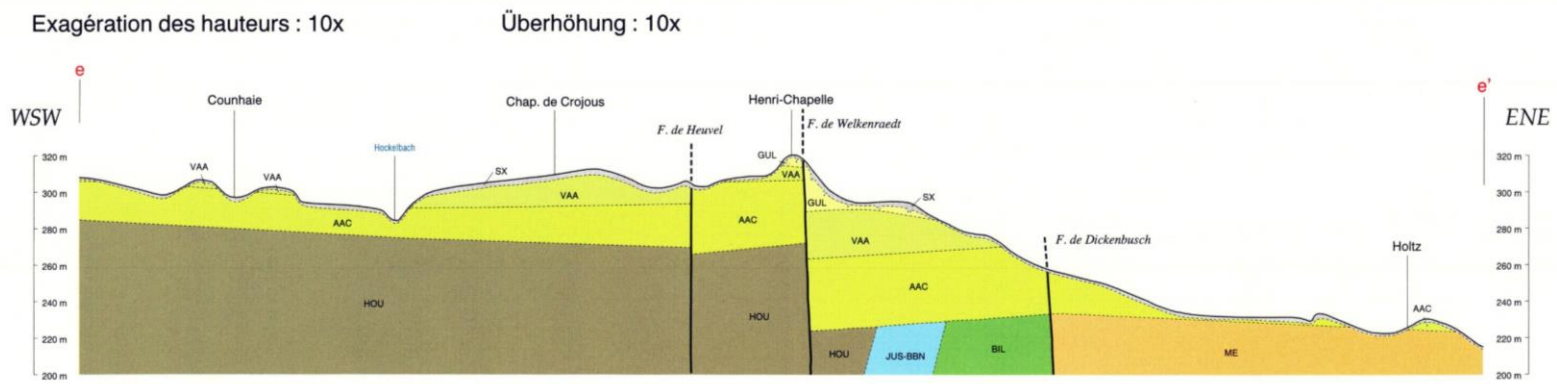


From: Gysel et al; 2000

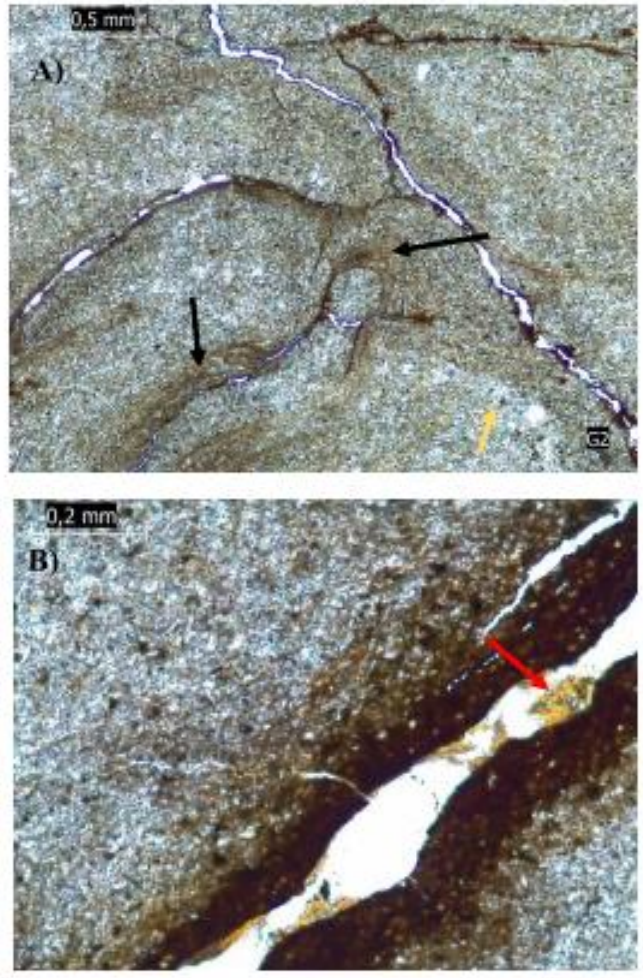
- Orientation unfavorable to recent stress field
  - Not active
- Water may circulate in open fracture

Structure Set B: Running NW-SE

- Normal and strike-slip faults on large scale
- Fractures on small-scale: mainly open



From: Gysel et al; 2000

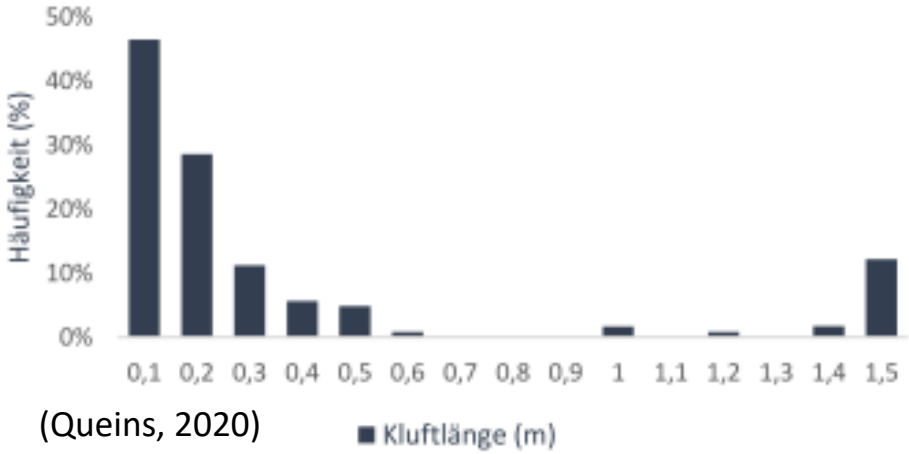


(Queins, 2020)

- Orientation favorable to recent stress field
  - Active in Lower Rhine Embayment
- Water very likely to circulate in open fracture

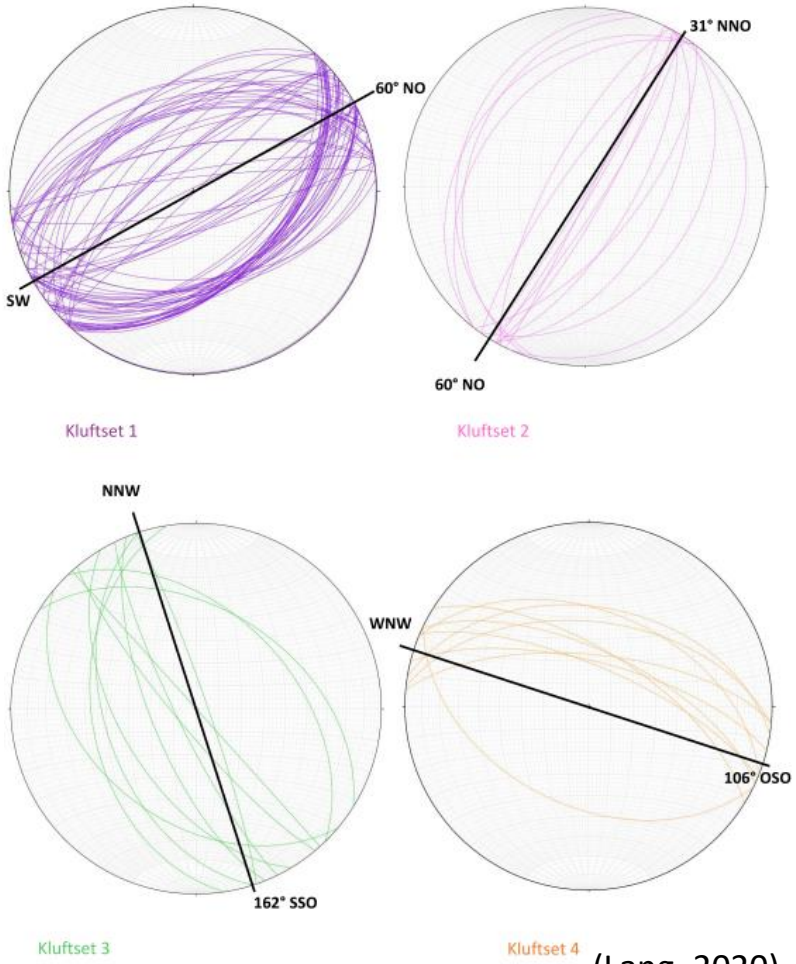
Fractures and Potential for Water Flow

- Water can flow easily along open fractures
- Connected open fractures enhance possible flow
- Field study on orientation, length and connectivity of fractures



(Queins, 2020)

Identified fracture orientations



(Lang, 2020)

Mapping of fracture connections

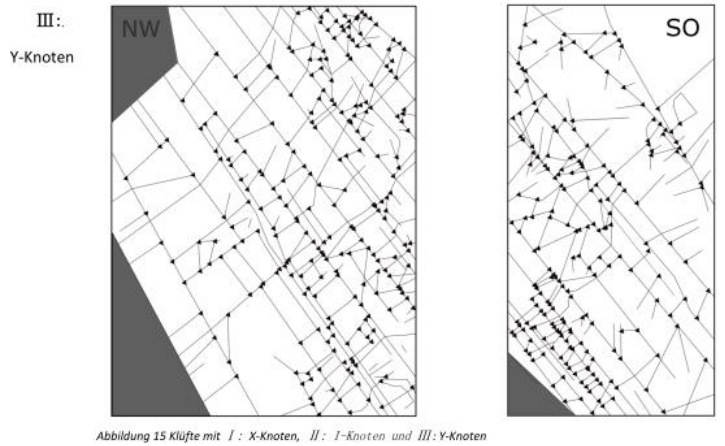
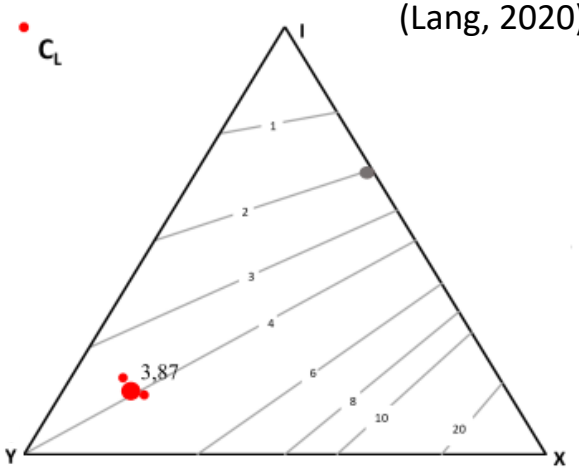


Abbildung 15 Klüfte mit I: X-Knoten, II: I-Knoten und III: Y-Knoten

Classification of fracture connections

(Lang, 2020)



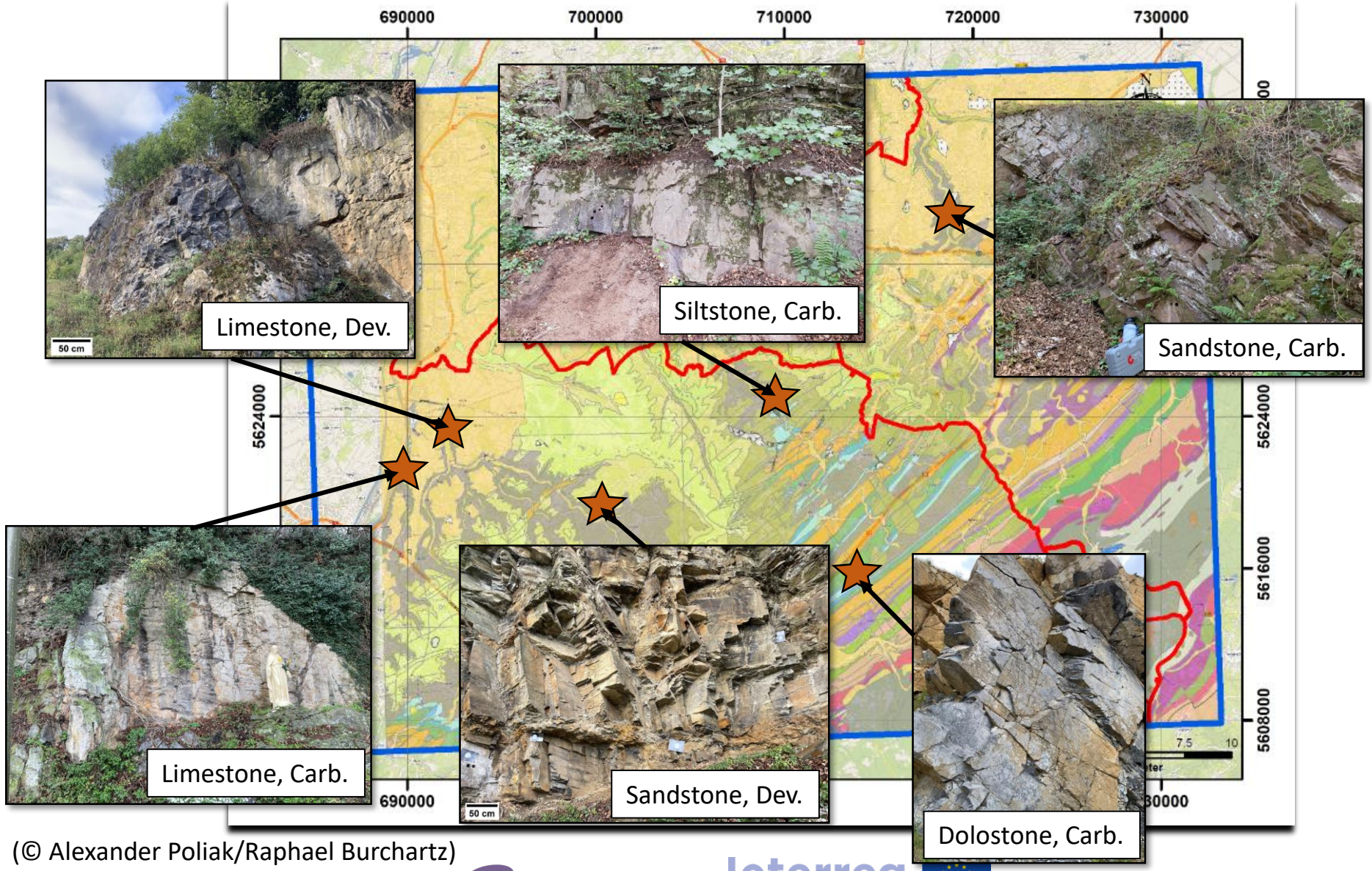
(Lang, 2020)

First Step - Surface Investigations

- Surface investigation of outcropping rocks provides
  a. The possibility to get a first approximating technical data source by in-situ and laboratory testing
  b. derive possible formations of special interest for further investigation

(© Raphael Burchartz)

Surface Investigations



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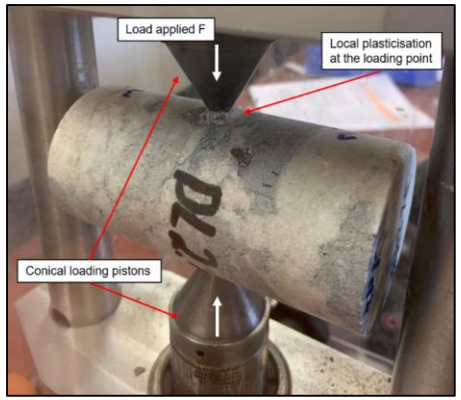
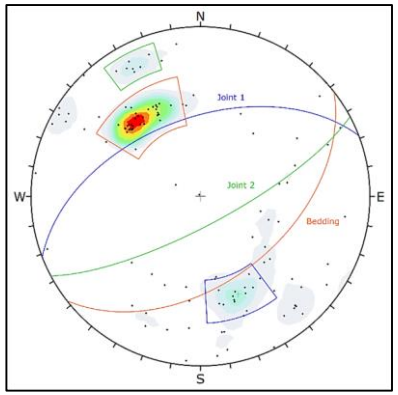
Surface Investigations

In-situ tests	Laboratory tests
• Photogrammetry • Point-load tests • Scan-line mapping	• P-wave velocity measurements • Brazilian Tensile Strength (BTS) • Uniaxial Compression Strength (UCS)





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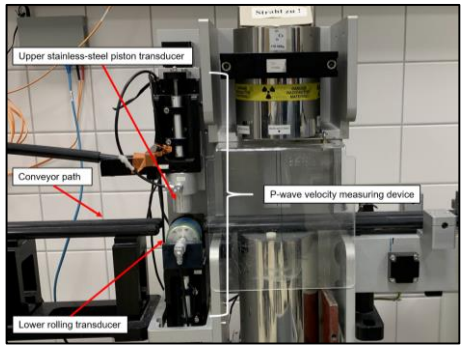

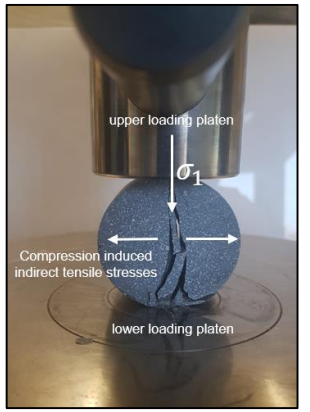

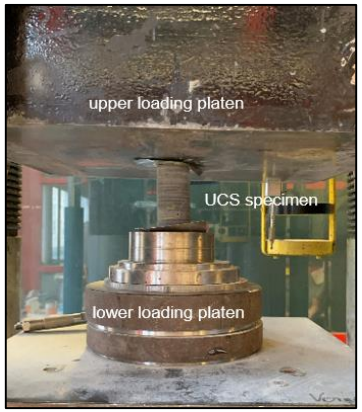

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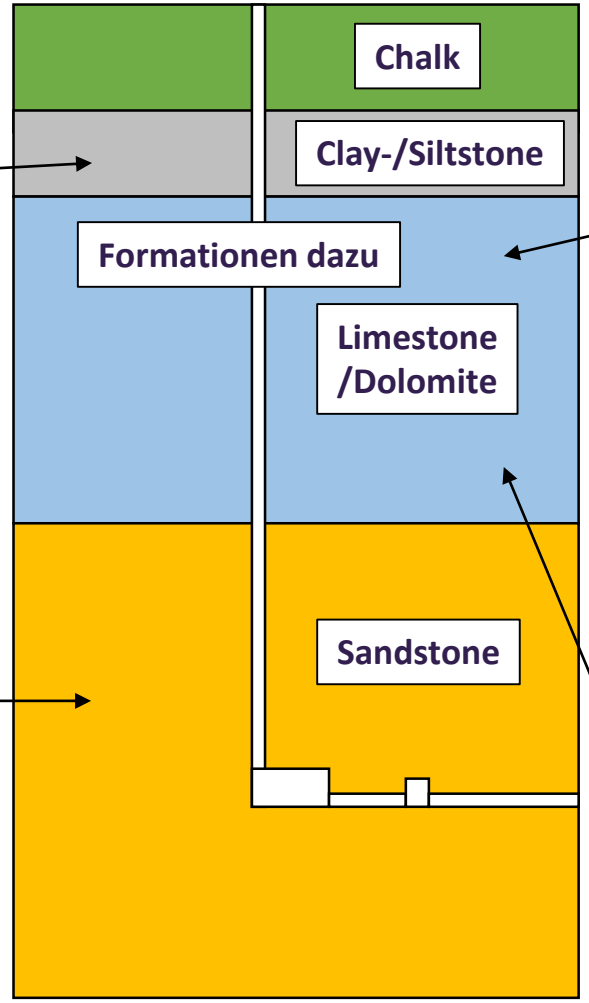
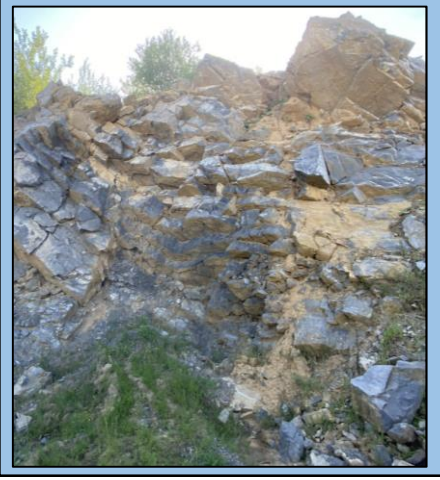
Geological Assessment of Representative Rocks within ET-Project

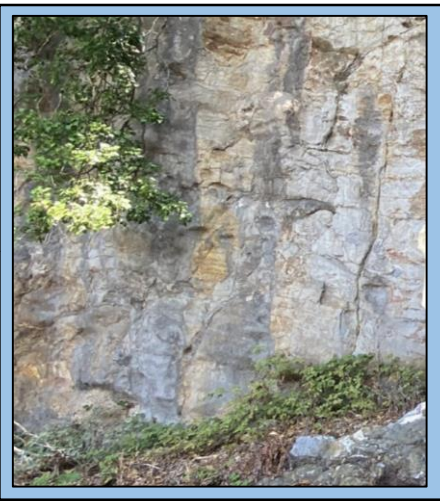
Density	2.32 g/cm³
Porosity	18.7 %
E-Modul	23 GPa
UCS	104 MPa
BTS	9 MPa
P-Wave-V.	4309 m/s

Density	2.64 g/cm³	UCS	119 MPa
Porosity	4.5 %	BTS	15 MPa
P-Wave-V.	5160 m/s	E-Modul	25 GPa





Density	2.76 g/cm³
Porosity	3.2 %
E-Modul	29 GPa
UCS	143 MPa
BTS	10 MPa
P-Wave-V.	4276 m/s

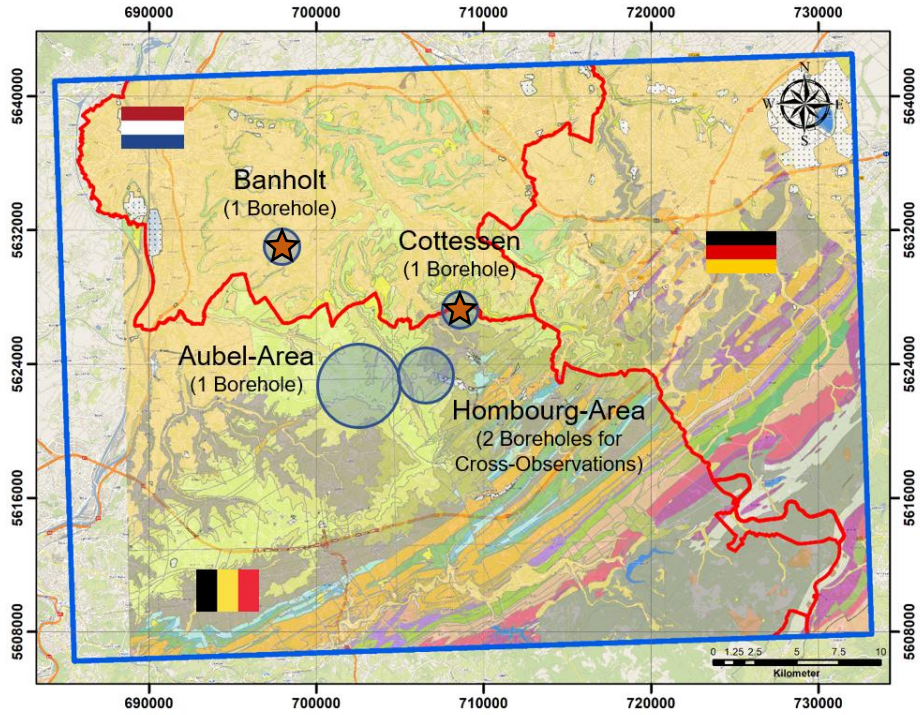


Density	2.68 g/cm³
Porosity	1.6 %
E-Modul	25 GPa
UCS	107 MPa
BTS	6 MPa
P-Wave-V.	5620 m/s

(Zinser, 2021)

Second Step - Drilling Campaigns

- Two currently ongoing drilling campaigns shall give information about the actual rock conditions/properties down to a target depth of 250 m
- Different borehole tests will be performed as well as core logging and mechanical tests on the core material



	October 2021					Nov-21				December 2021					
	27.09.-03.10.	04.10.-10.10.	11.10.-17.10.	18.10.-24.10.	25.10.-31.10.	01.11.-07.11.	08.11.-14.11.	15.11.-21.11.	22.11.-28.11.	29.11.-05.12.	06.12.-12.12.	13.12.-19.12.	20.12.-26.12.	27.12.-02.01.	03.01.-09.01.
Drilling Cottessen															
Logging Cottessen															
Hydraulic testing Cottessen															
Drilling Banholt															
Logging Banholt															
Hydraulic testing Banholt															

Drilling | Possible time adjustment | Logging | Hydraulic testing/fracturing

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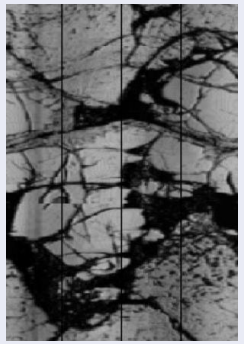
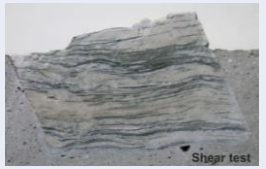
Borehole Geophysics/Logging

Geophysical Borehole Investigations		Hydraulic Testing & Fracturing		Laboratory Tests	
 	• Optical Televiewer Scan • Acoustic Televiewer Scan • 3-Component Magnetometer Log • Natural Gamma Log • Spectral Gamma Log • Full-Wave Velocity Log • Inflow/Outflow measurements • Formation Resistivity Log		• Pump-/Slug-/Pulse-Tests (~ 5-10 tests/borehole) • HF/HTPF-Tests + Impression-Packer-Tests (~ 5-10 tests/borehole in 3 boreholes)	  	• Uniaxial Compression Tests • Triaxial Compression Tests • Indirect Tensile Tests • Shear Tests • Cerchar-Test • P-Wave Velocity Measurement • Porosity Measurement

(Zinser, 2021)

Drilling Cottessen

- Started at 4th of October
- Drilling currently at 151 m
- Reached carboniferous hard rock at 2.5 m
- Previous ERT and GPR measurements were executed

(© Jonathan Zinser)

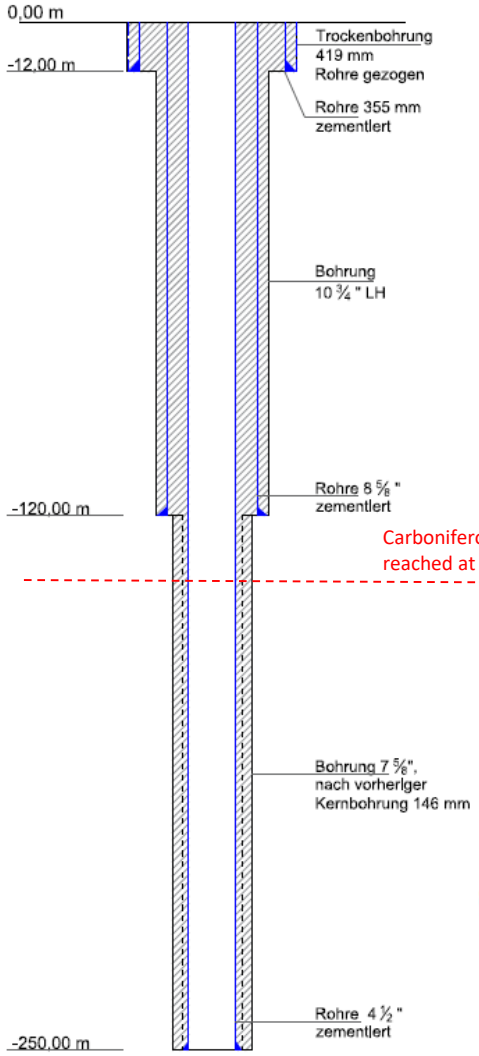
(© Raphael Burchartz)

Drilling Banholt

- Started at 9th of August
- Passed Cretaceous: Karstified lithologies and Sands of Vaals
- Drilling currently at a depth of 137 m

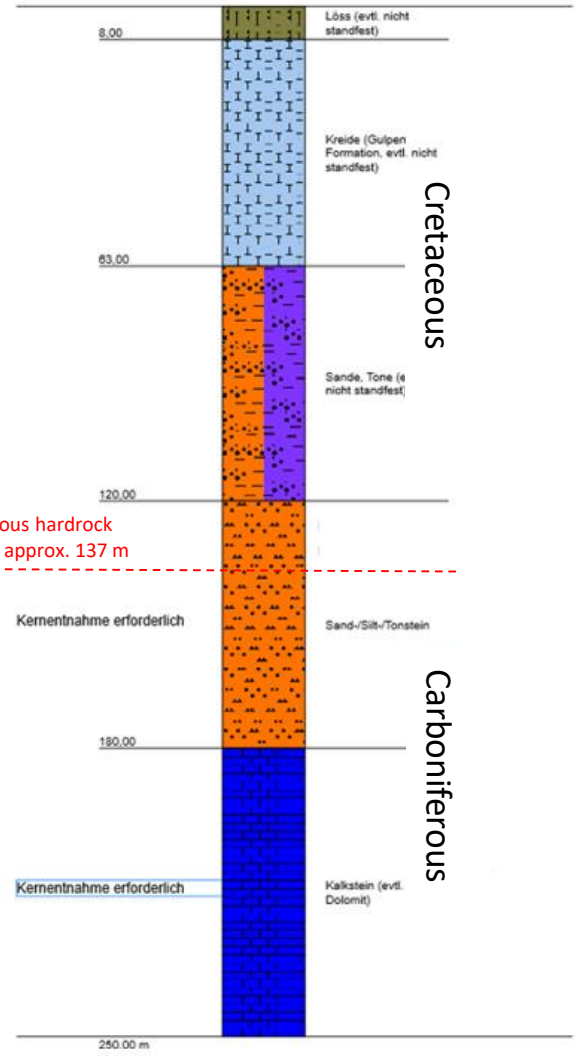
(©Bjorn Vink)

Technical concept



(Daldrup & Söhne AG, 2021)

Geological forecast

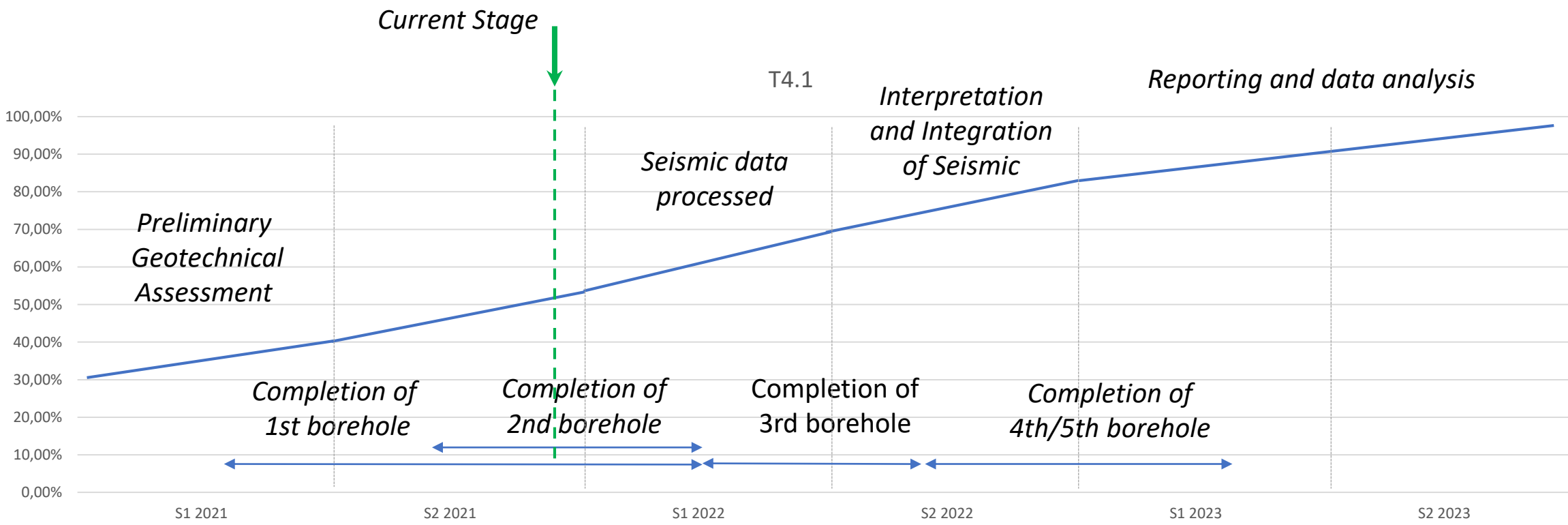


(©Bjorn Vink)

Geological Challenges during Field Work and Drilling

- Complex distribution of rock type in EMR region
  - Prediction of rocks in the subsurface in one specific location is difficult
- Understanding of fracture network is difficult
  - Water circulates in open fractures
- Technical problems during drilling
  - Fluid losses and additional cementation needed
- Access to outcrops
  - Closed borders due to COVID
  - Bringing equipment to outcrops

Preliminary Forecast of T4.1 Cross-border Open Geological Model



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Vlaanderen is ondernemen

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Ministerie van Economische Zaken en Klimaat

Ministerium für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen

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Nikhef

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Ministerie van Infrastructuur en Waterstaat

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