An unorthodox exploration and exploitation strategy for the development of an unconventional geothermal reservoir, the Göttingen University campus demo site

Bernd Leiss

Bianca Wagner, Katie Ford, Dmitry Romanov, Graciela Sosa, David Tanner, Axel Vollbrecht & MEET-partners

MEET Project – Geothermal Winter School – February 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

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Purpose of this lecture

- One of the objectives of **Enhanced (Engineered) Geothermal Systems** (and therefore also of MEET) is to make geothermal energy also available **in areas not suitable** in the classic approach

- Only if we are succesful with such an enhanced approach, geothermal systems are able to **contribute** to the overall renewable energy supply **in a significant proportion** on the long-term perspective

Purpose of this lecture

- **Exploration** and **Exploitation** strategy for an energy **consumer-driven** geothermal project – an approach on how to turn a geothermically unsuitable geological setting eligible, i.e. economically attractive feasable at a very early stage (transition pre-studies to research well)

- From the **perspective** of a **scientific project developer** (compare with the talk of John Reinecker: Exploration workflow for deep geothermal systems)

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Purpose of this lecture

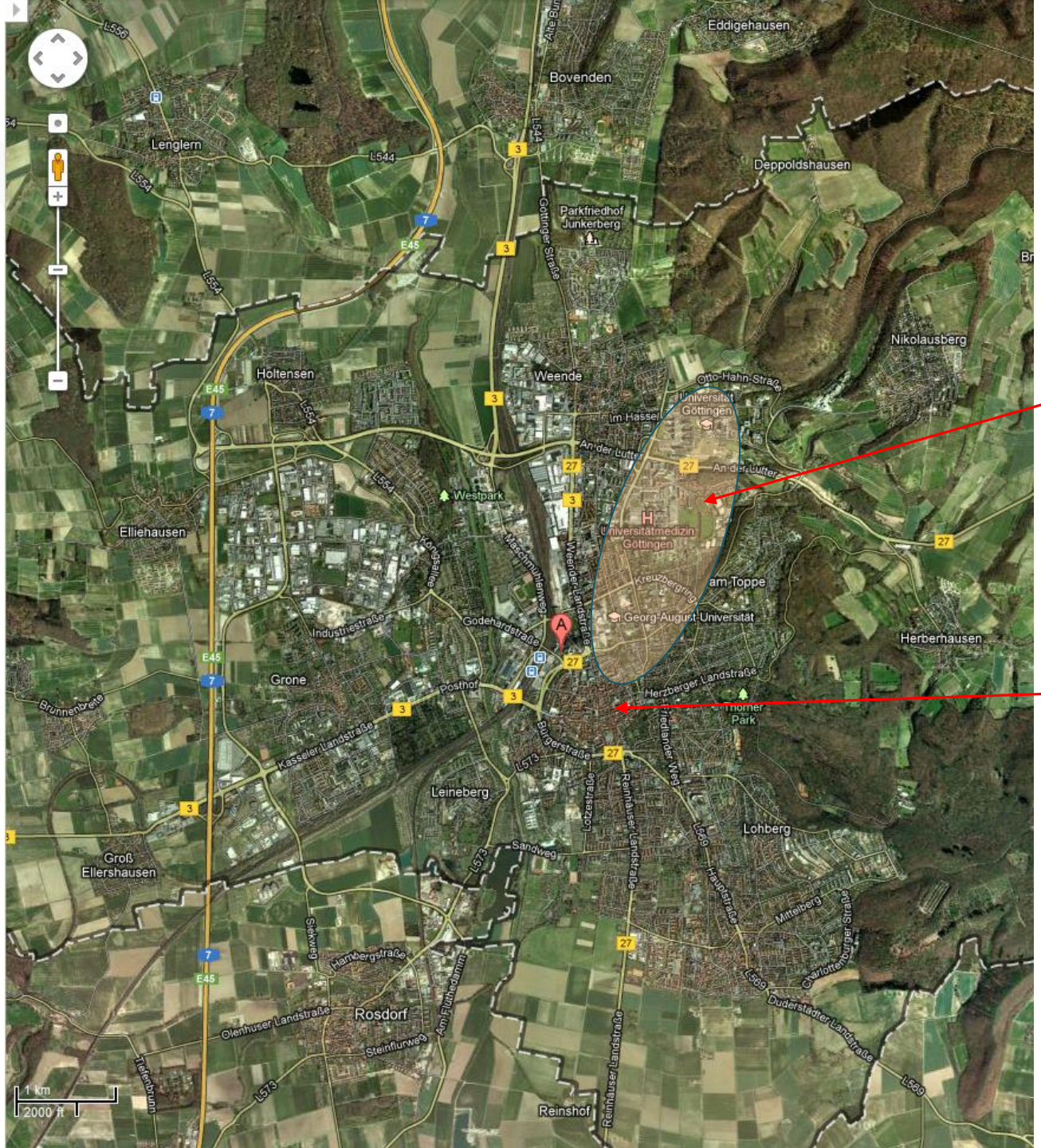
- **Excercise:** take a role as one of the stakeholders, i.e. scientist, project developer, administration, decision maker, investor, politician, citizen, climate change activist etc.

… and place your **questions from the different perspectives** for a discussion at the end of the lecture

1. Introduction
2. **Energy infrastructure setting of the University Campus**
3. Geological setting of the Göttingen region
4. Exploration strategies
    - MEET-project: analogue studies, reservoir modelling
    - Research well: strategy and public funding
5. Summary and Outlook

Energy infrastructure setting

Location of the city of Göttingen in Lower Saxony in Germany



Campus area

Historical City Center

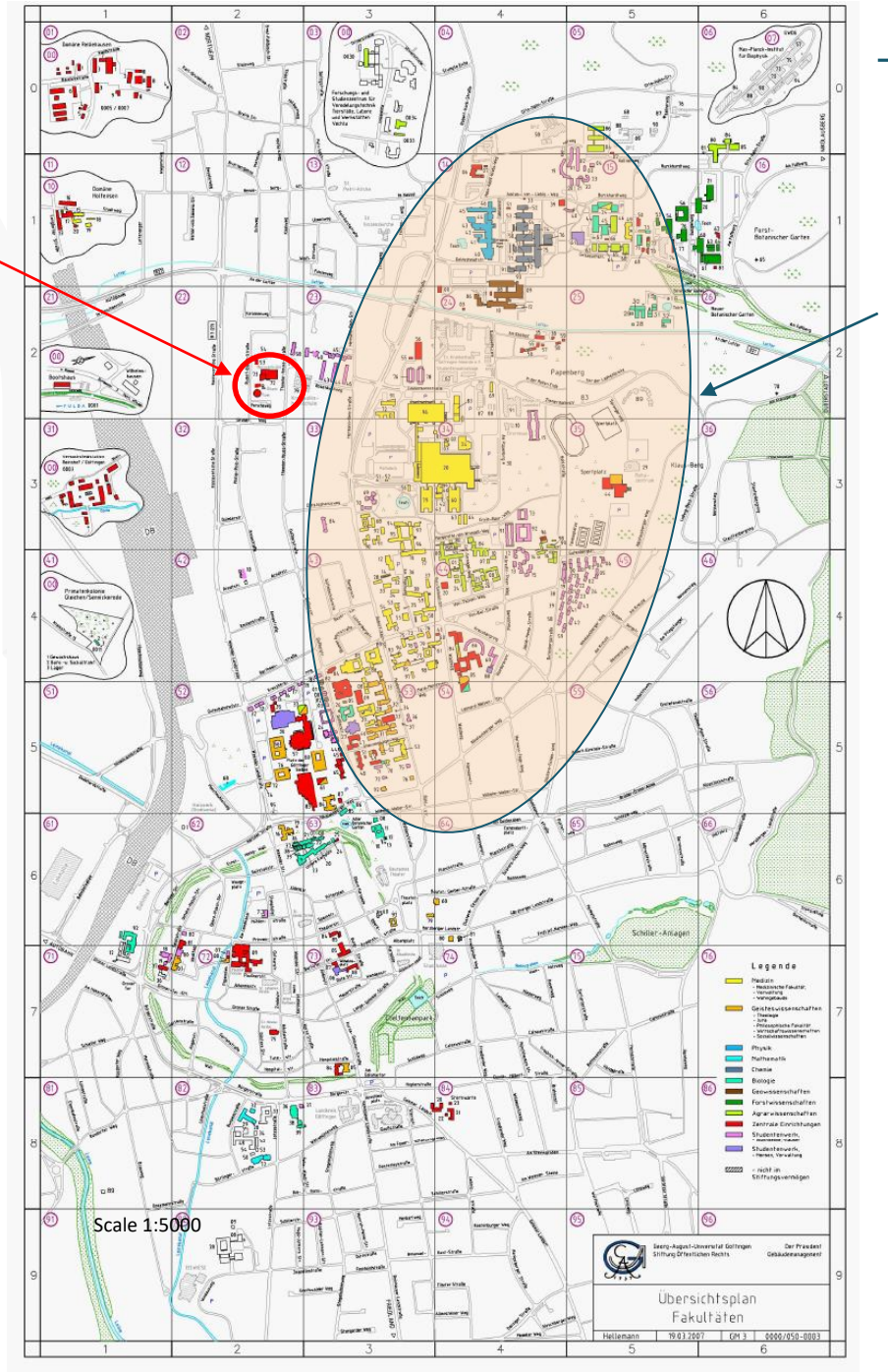
Population: ca. 120.000
Students: ca. 30.000

Energy infrastructure setting

Power station

Combined Heat and Power Generation
23 MW_{el}, 60 $MW_{heat\ input}$

(>30 mio Euros total costs per year)



500 m

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District heating of the University:

13 km heating pipe

supplying

ca. 250 building units

20-25% of the total natural gas consumption of Göttingen:

1693 GWh natural gas in total in Göttingen

392 GWh University

(7 mio Euros/year)

Energy infrastructure setting: Combined heat and power station

31 $MW_{heating\ power}$

Gas powered aircraft turbine

Steam and cooling production

Diesel railway engine as backup for supply guarantee

Energy infrastructure setting: Energy Balance 2018

Electrical power from renewables can be purchased

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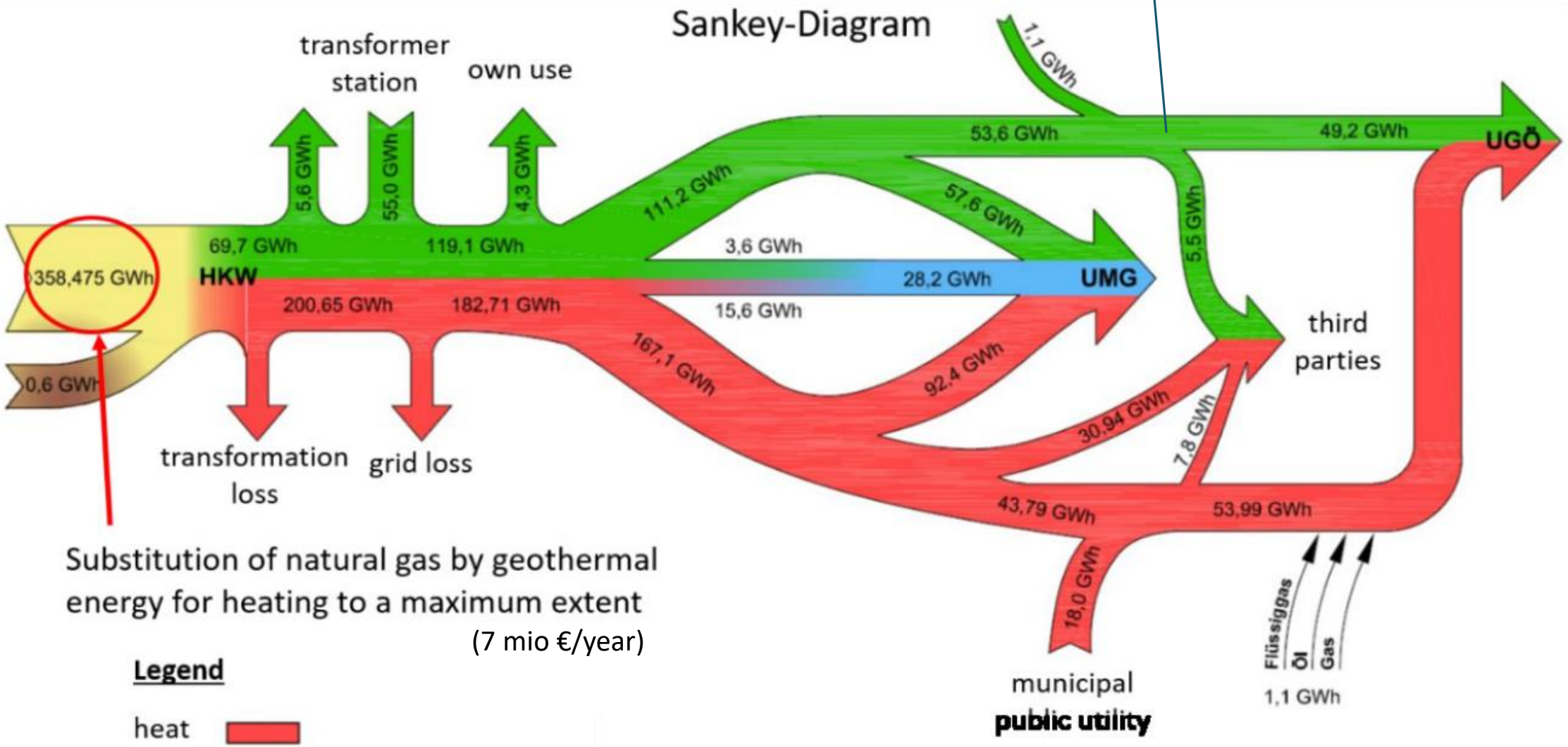


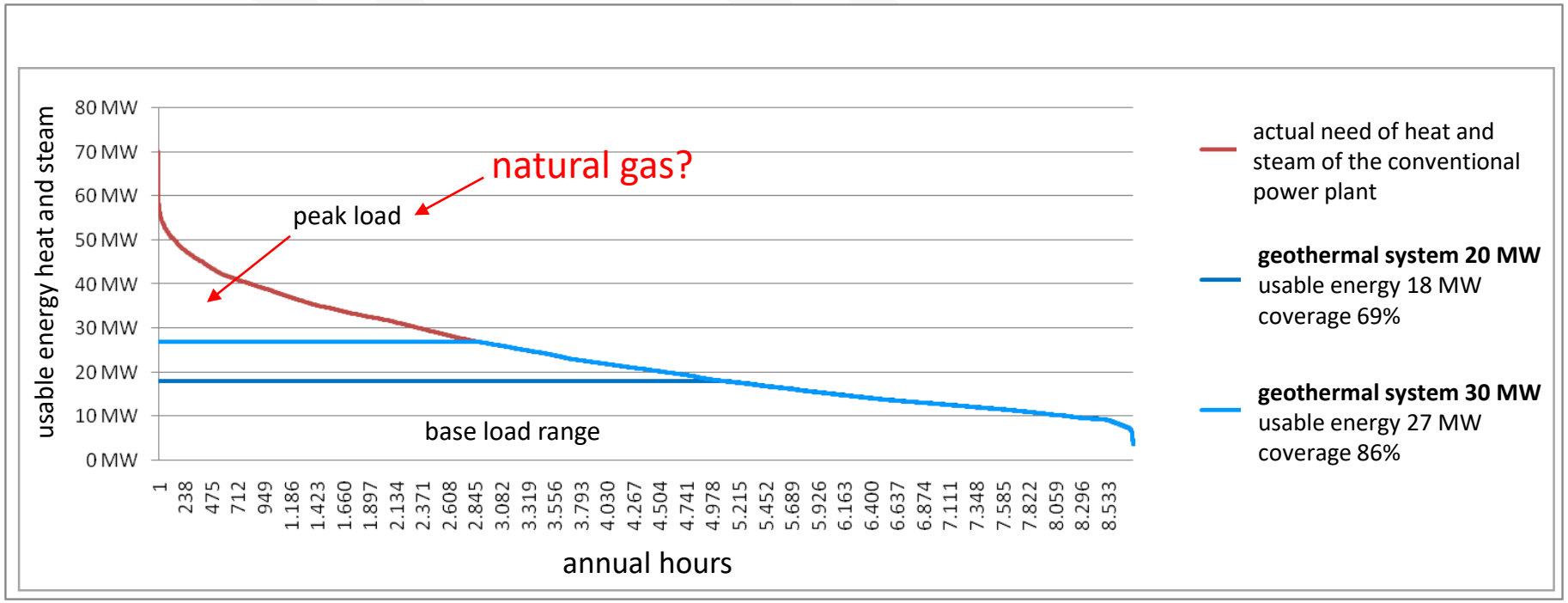
Substitution of natural gas by geothermal energy for heating to a maximum extent

(7 mio €/year)

Legend

heat
power
cold
natural gas
crude oil

Energy infrastructure setting: Heat demand



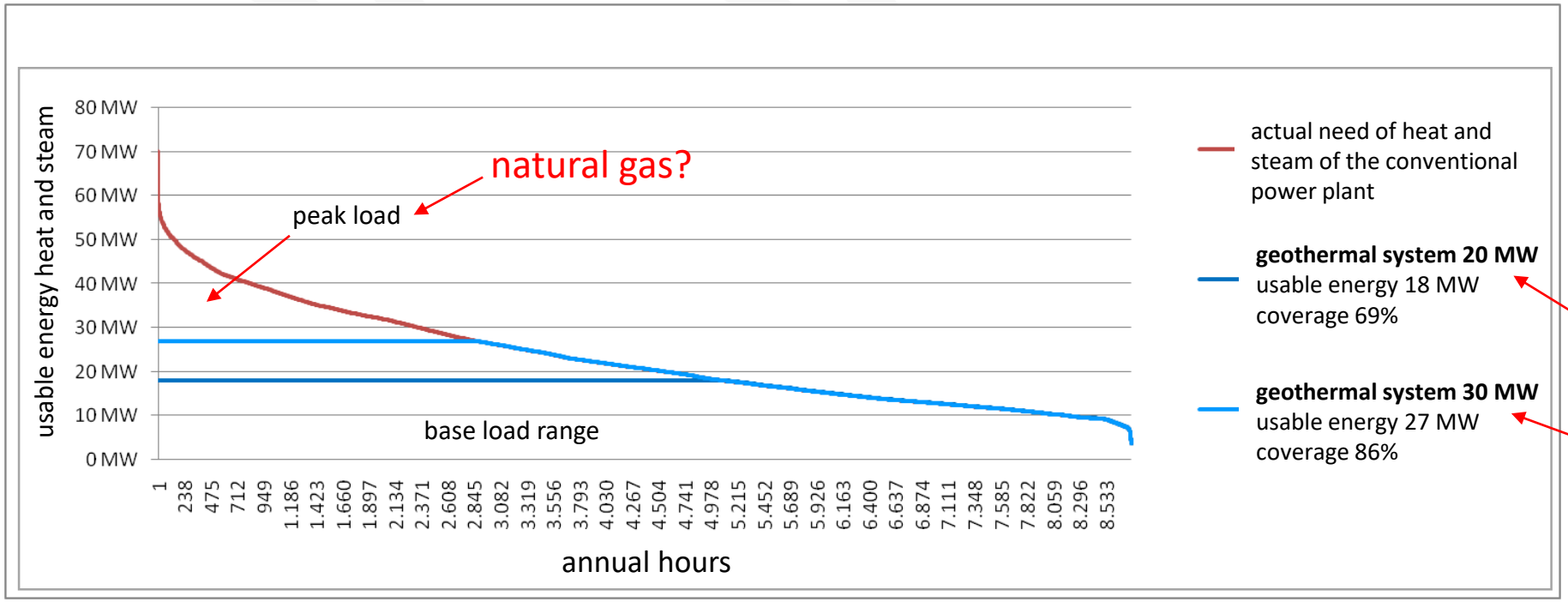
useable energy coverage

	heat+steam ab HKW/FW-Netz	Geothermie 20 MW Nutzenergie ab FW-Netz (18 MW)	Geothermie 30 MW Nutzenergie ab FW-Netz (27 MW)
Nutzenergie	203 GWh	140 GWh	175 GWh
Anteil Deckung	100%	69%	86%

Could the heat demand be covered by geothermal heat production (EGS)?

Wishful thinking for Göttingen:
Geothermal power plant Rittershofen, Alsace, France (24 $MW_{heat\ production}$)

Energy infrastructure setting: Heat demand



useable energy coverage

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Nutzenergie	203 GWh	140 GWh	175 GWh
Anteil Deckung	100%	69%	86%

- can the heat demand be covered by geothermal heat production?
- also other renewables cannot cover the full heat demand
- **what is the minimum amount of geothermal heat production to be economic?**

University Medical Center in 2019

UNIVERSITÄTSMEDIZIN GÖTTINGEN UMG

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New buildings are in a planning stage offering the oppertunity to integrate geothermal and other renewable energy systems in a flexible way

Interim summary on the surface structure:

-- existing consumption infrastructure

-- deep geothermal system only for heat production reasonable (around 120°C)

-- flexible infrastructure for energy supply/modular system

-- deep geothermal energy supply is first option for the University as the renewable heat source

-- extensive demand of cooling

-- mixture of building units to be newly constructed and to be restructured

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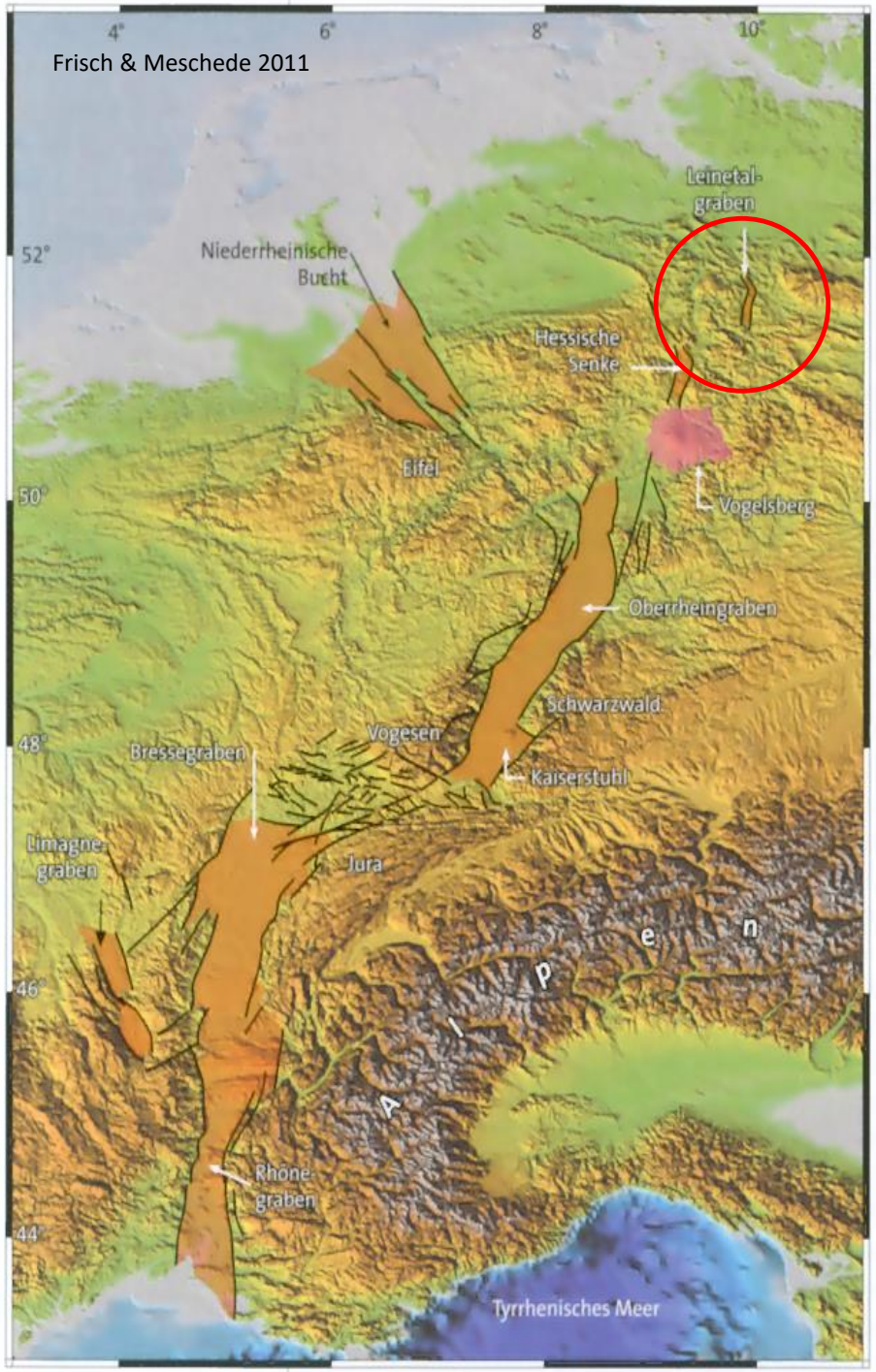
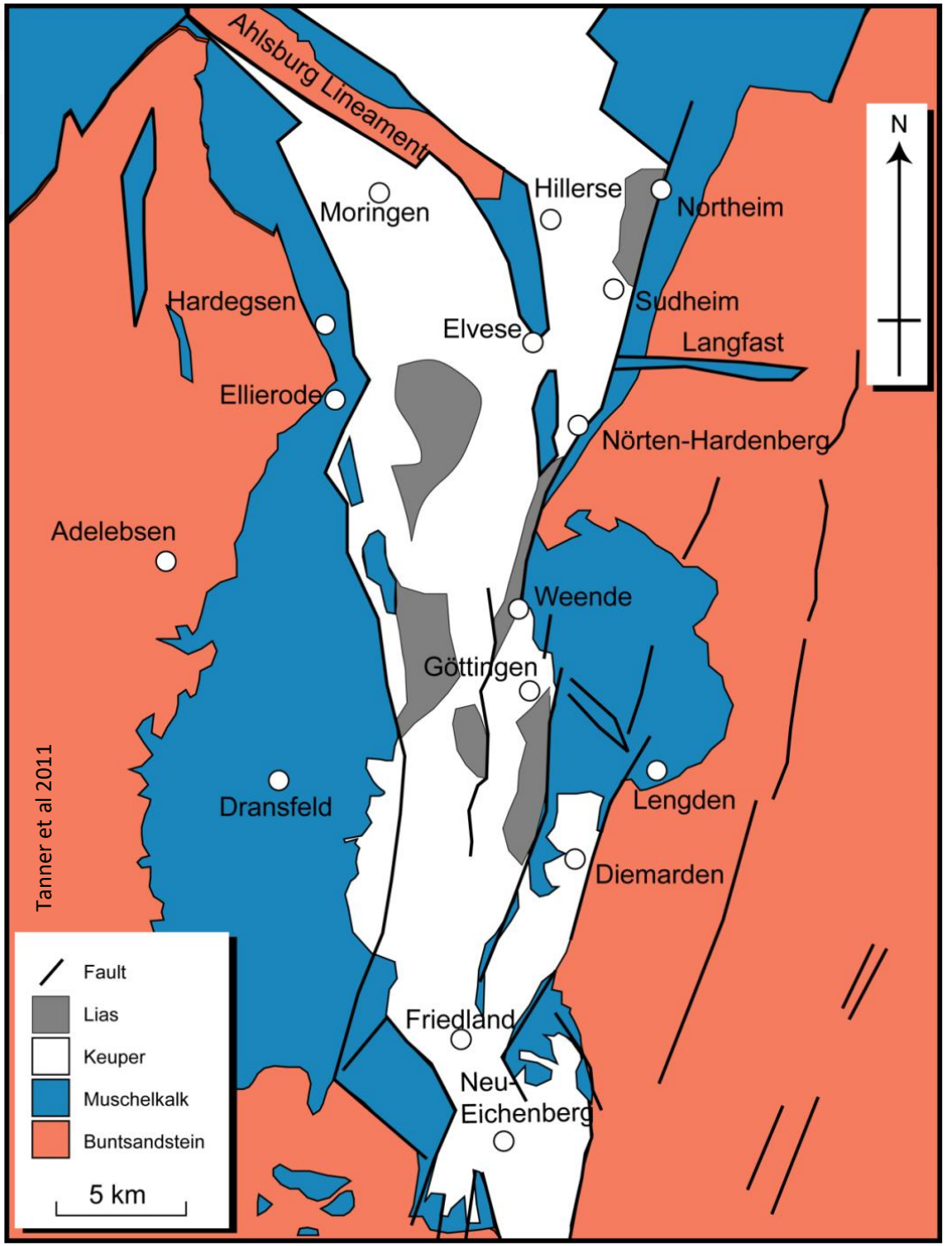
5. Summary and Outlook
6. Time for questions and discussion: 10 to 15 min





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Leinetal Graben structure:

Triassic lithologies,

Cenozoic to Tertiary extensional tectonics

Geological Setting: Models of the Leinetalgraben (salt vs. extensional tectonics)

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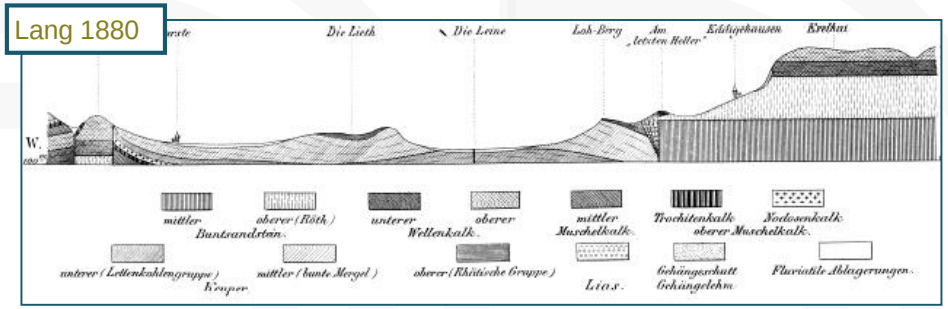
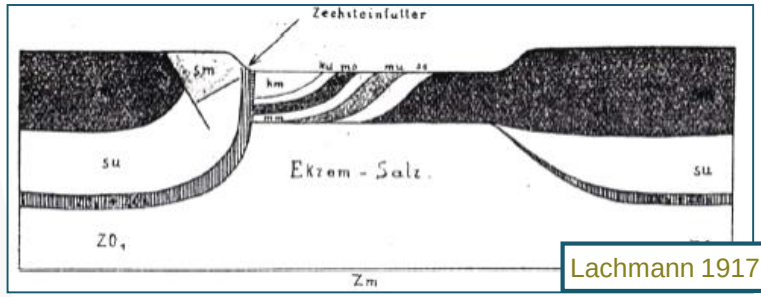
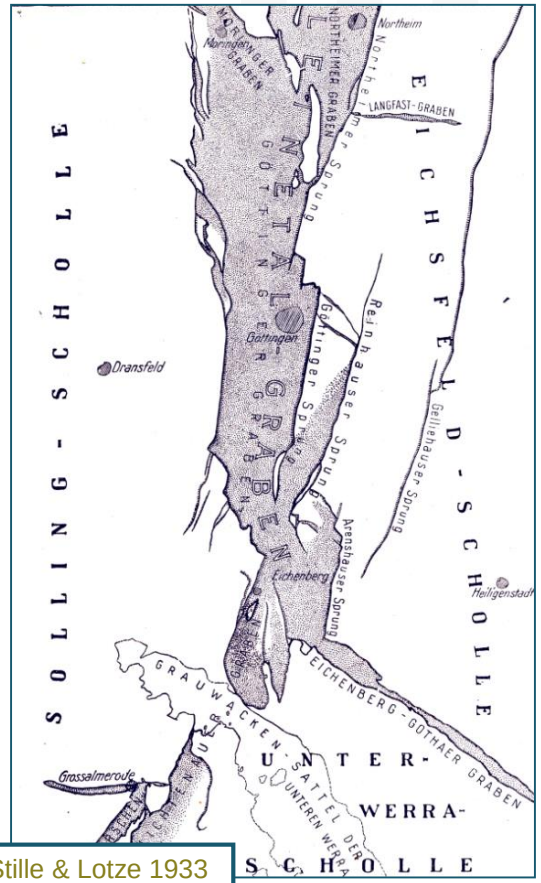
Lang 1880

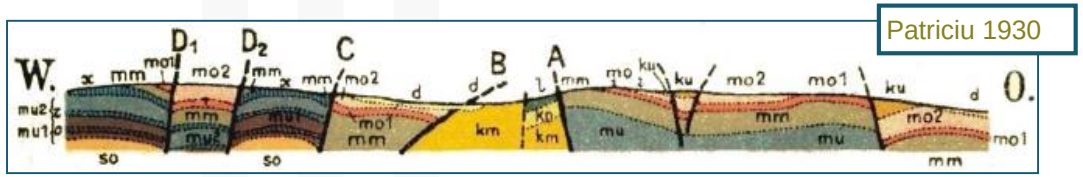




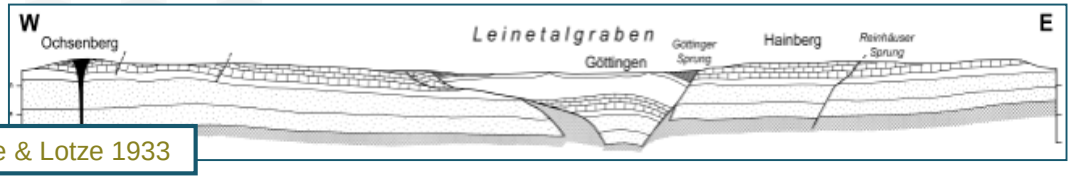
Lachmann 1917



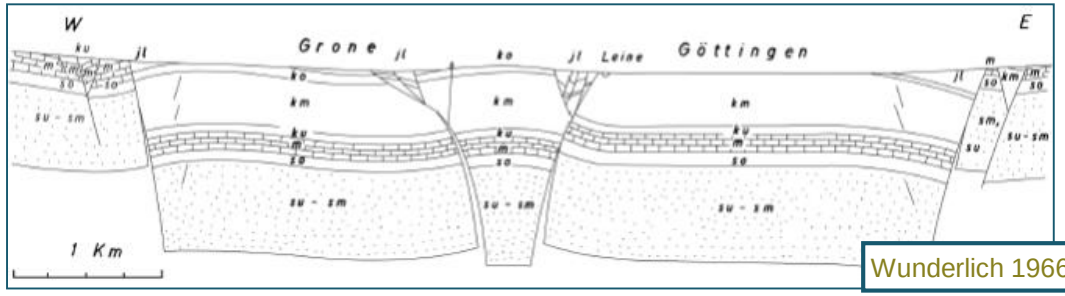
Stille & Lotze 1933



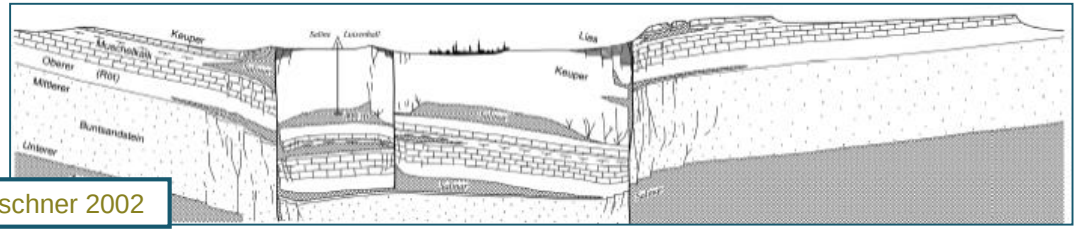
Patriciu 1930



Stille & Lotze 1933

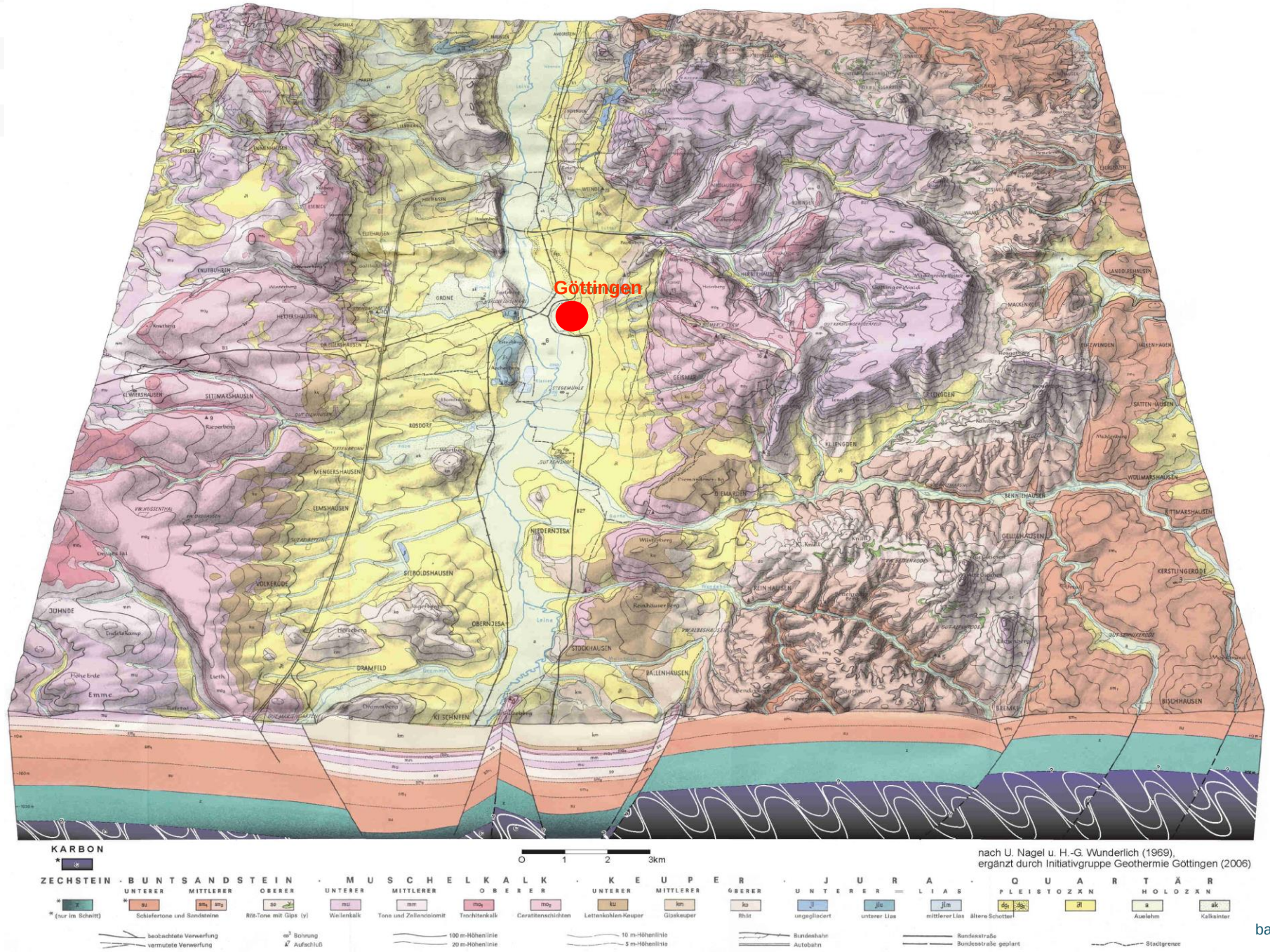


Wunderlich 1966



Meischner 2002

Geological Setting: Models of the Leinetalgraben (salt vs. extensional tectonics)



based on Nagel & Wunderlich 1976

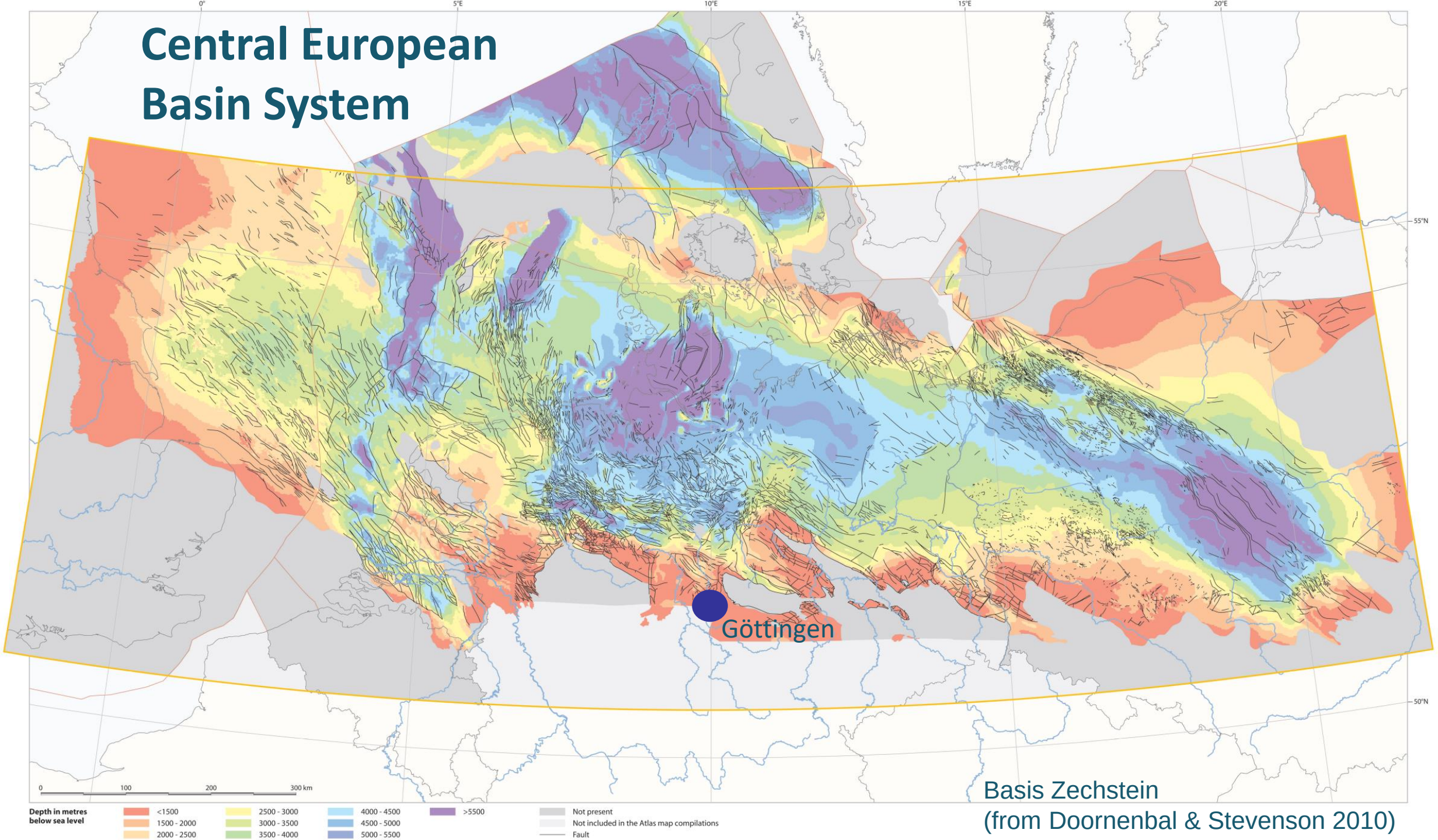
Geological Setting: Salt and potash salt of Zechstein age

Saline Luisenhall:
Brine production
from 400 m depth

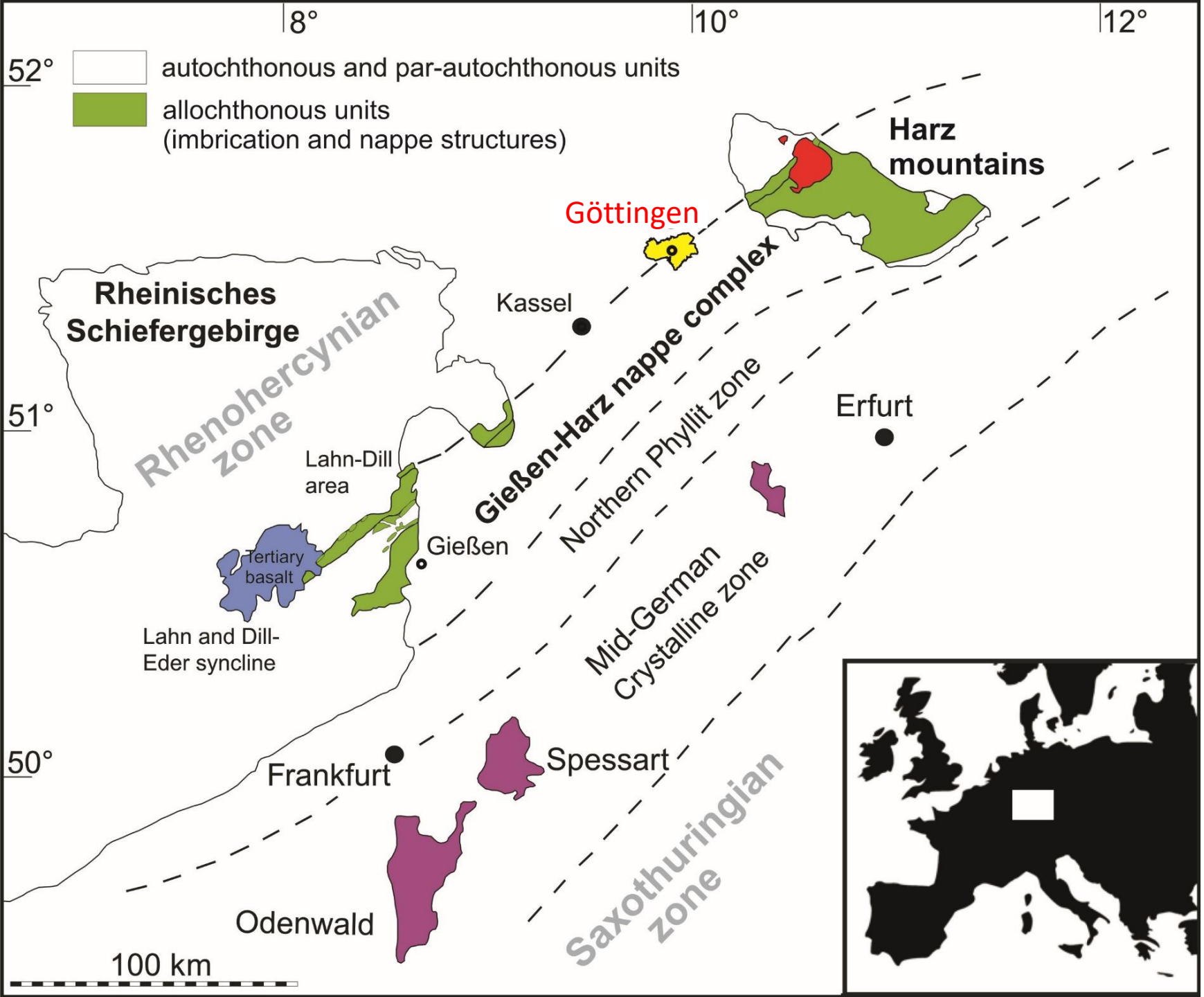
Potash salt mine Reyershausen (arond 1900 to 1974)
in about 800 m depth

Reyershausen, Kaliwerk Königshall-Hindenburg, Schachtanlage Königshall um 1930: Links die Fabrik, ganz rechts das Fördergerüst am Schacht Hindenburg; vorne das Fördermaschinenhaus am Schacht Königshall Slotta 1980

Central European Basin System



Basis Zechstein
(from Doornenbal & Stevenson 2010)



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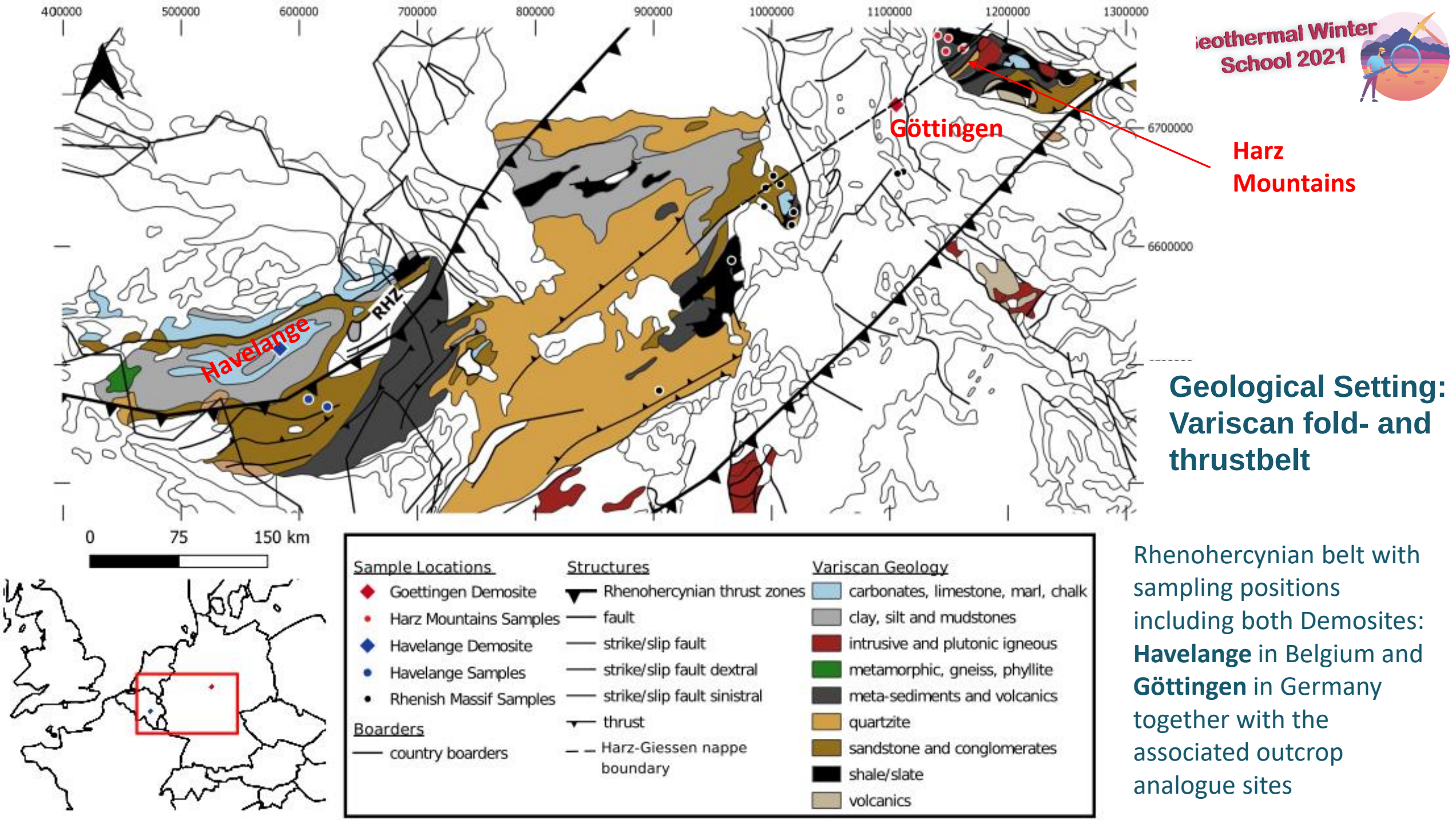
Geological Setting:

Variscan Basement

sequence of greywacke and slates, granites, reef carbonates, diabases

Eckelmann et al. (2014): Gondwana research



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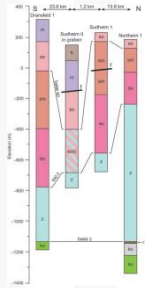
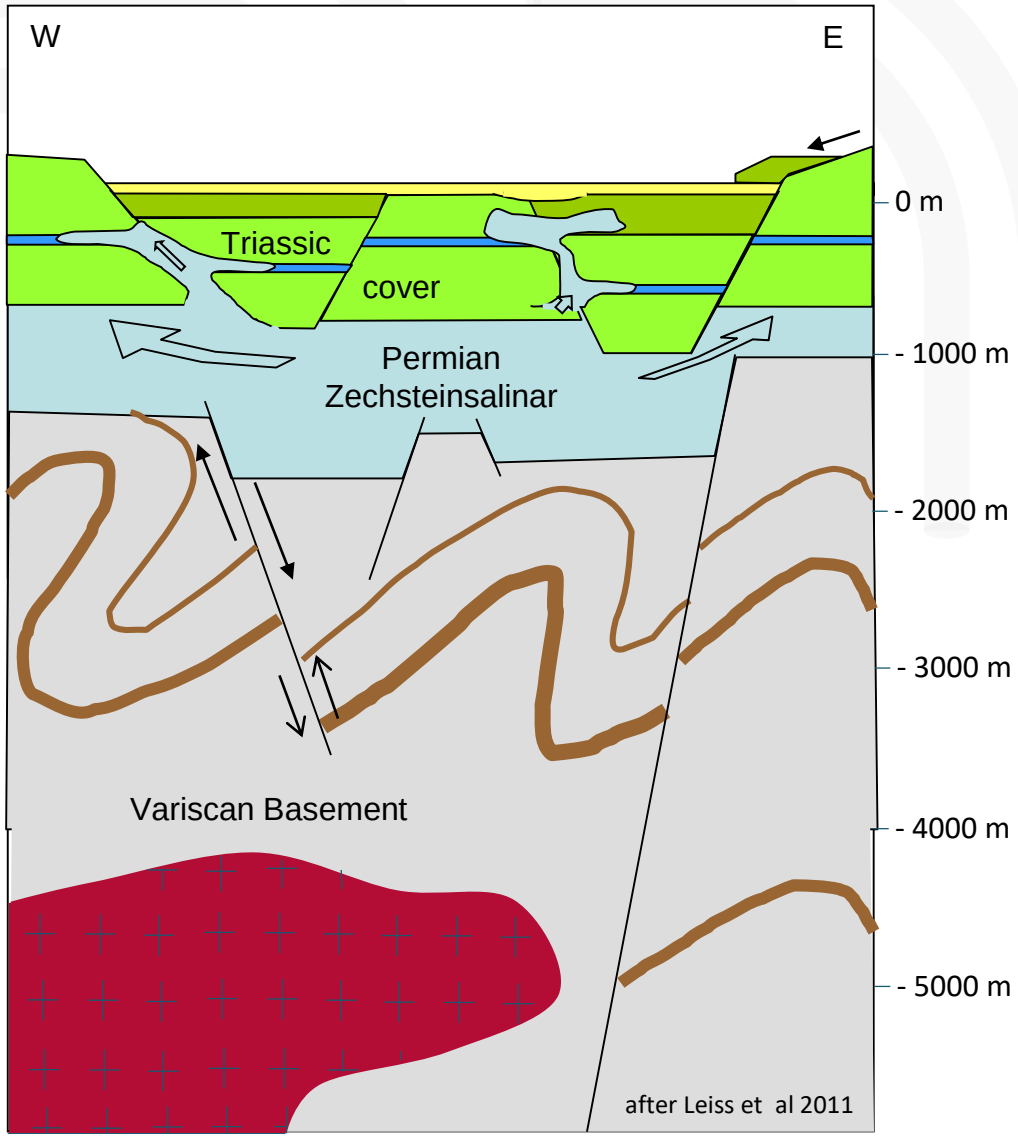
Geological Setting: Variscan fold- and thrustbelt

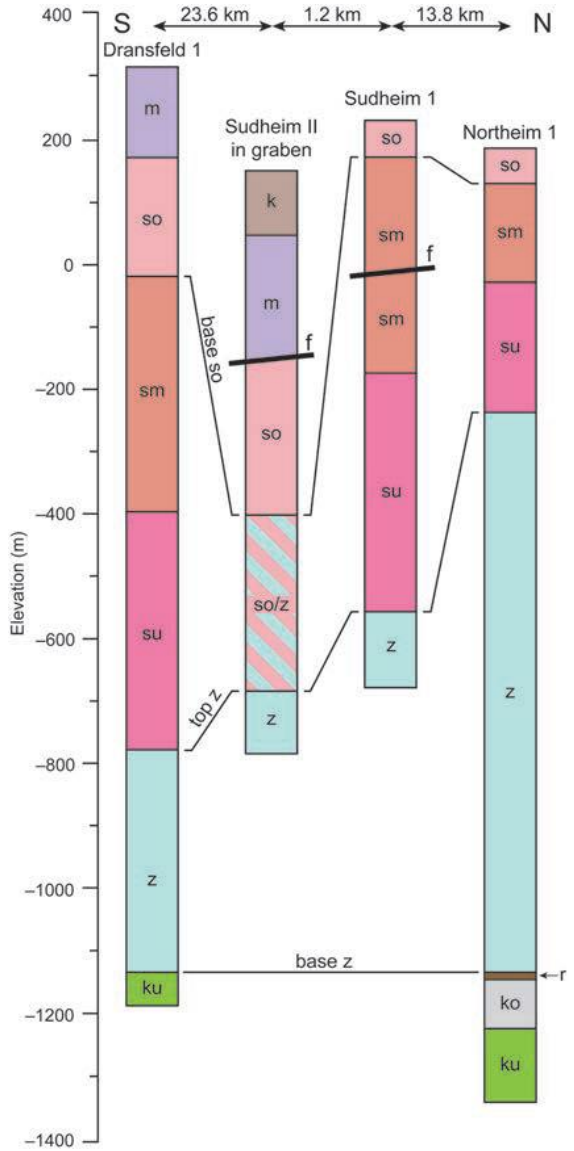
Rhenohercynian belt with sampling positions including both Demosites: **Havelange** in Belgium and **Göttingen** in Germany together with the associated outcrop analogue sites

Geological Setting: Simplified sketch of the Leinetal Graben structure





Lithological/structural units/fault systems



Wells of the Göttingen region

Geological Setting: Geological target horizons

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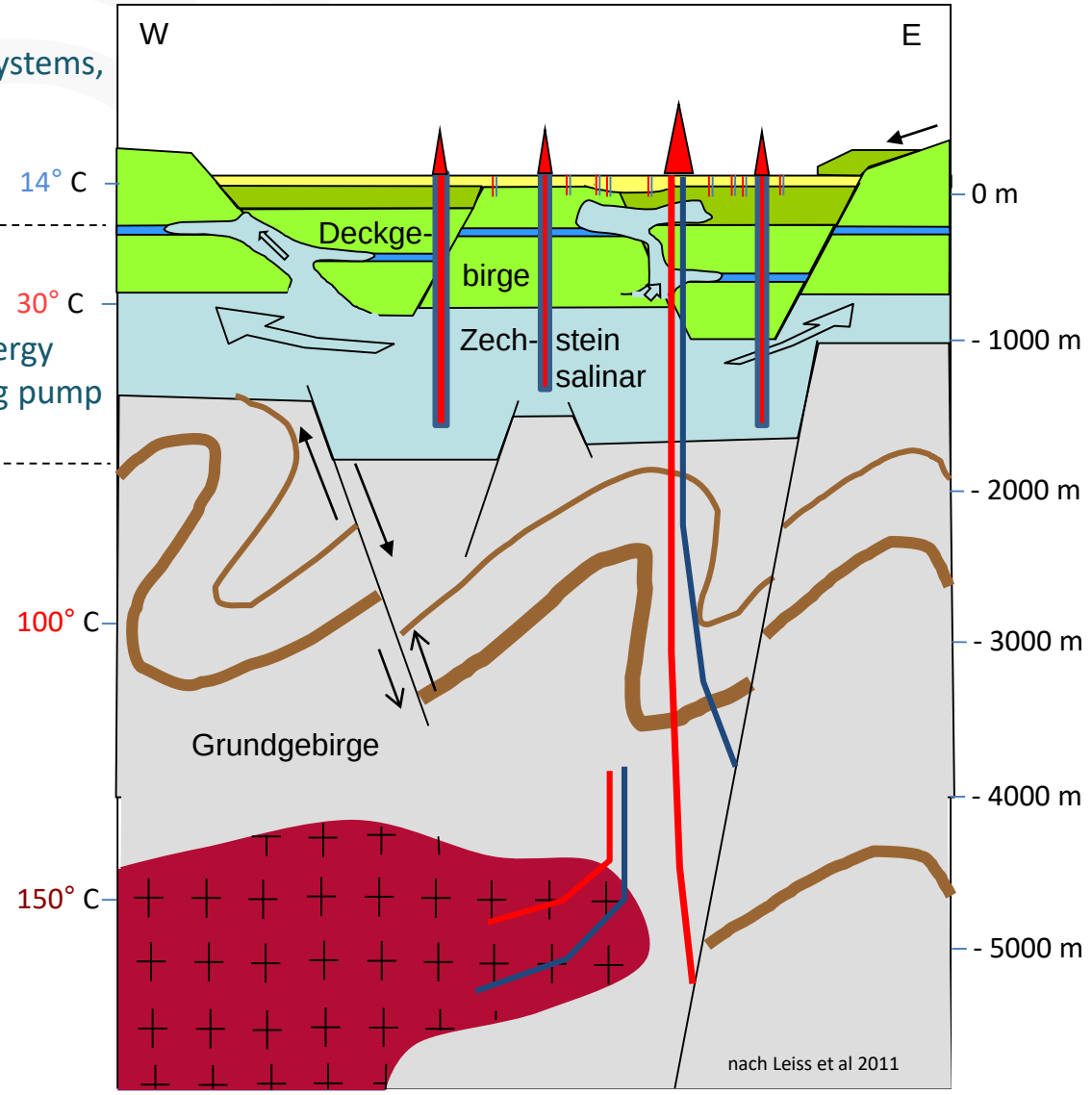
1 Shallow geothermal energy systems, especially for local cooling, ption for aquifer thermal heat storage systems

2 Medium deep geothermal energy systems, local heating, heating pump Needed, option for thermal heat storage systems

3 Deep geothermal energy systems, central heating



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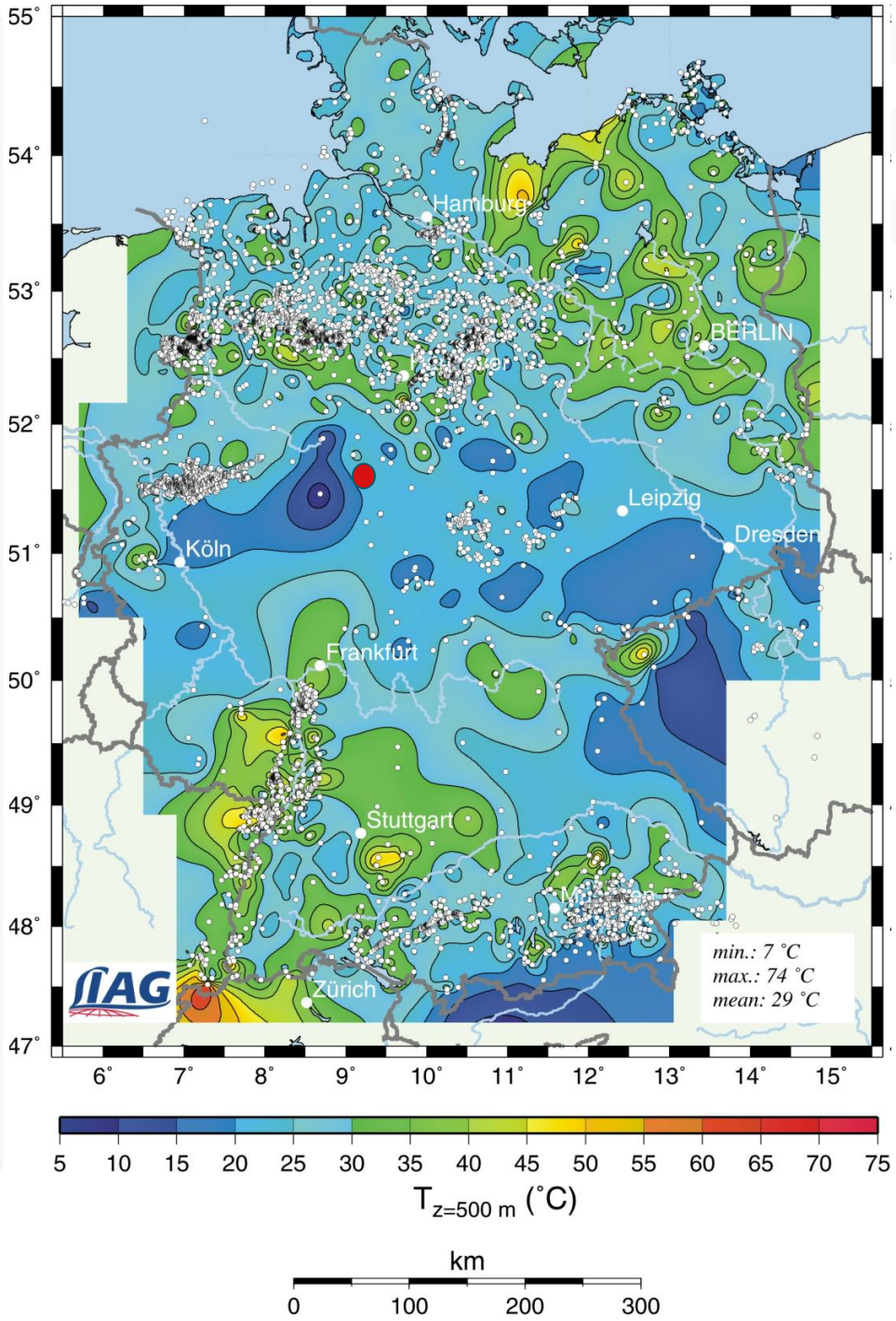
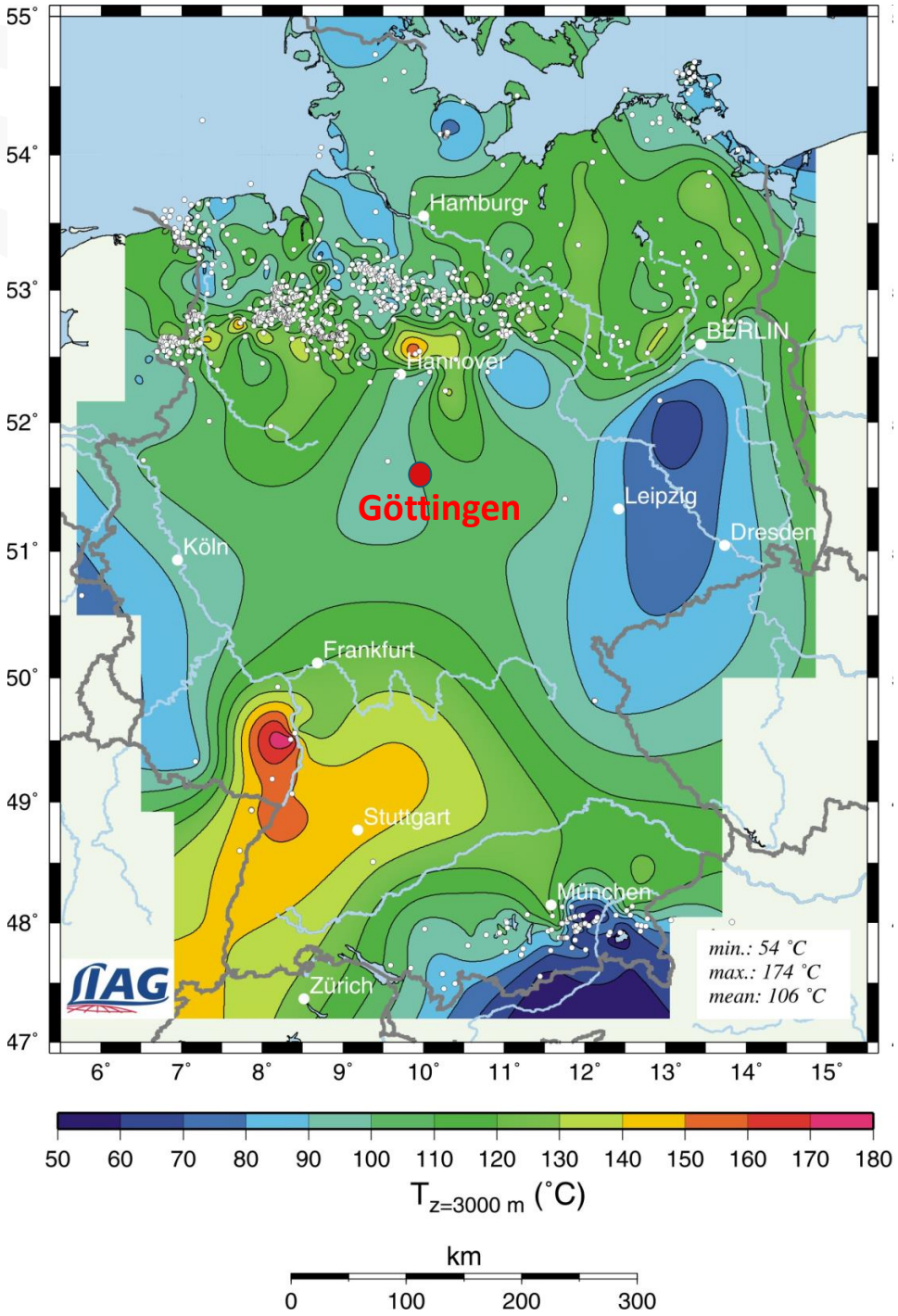
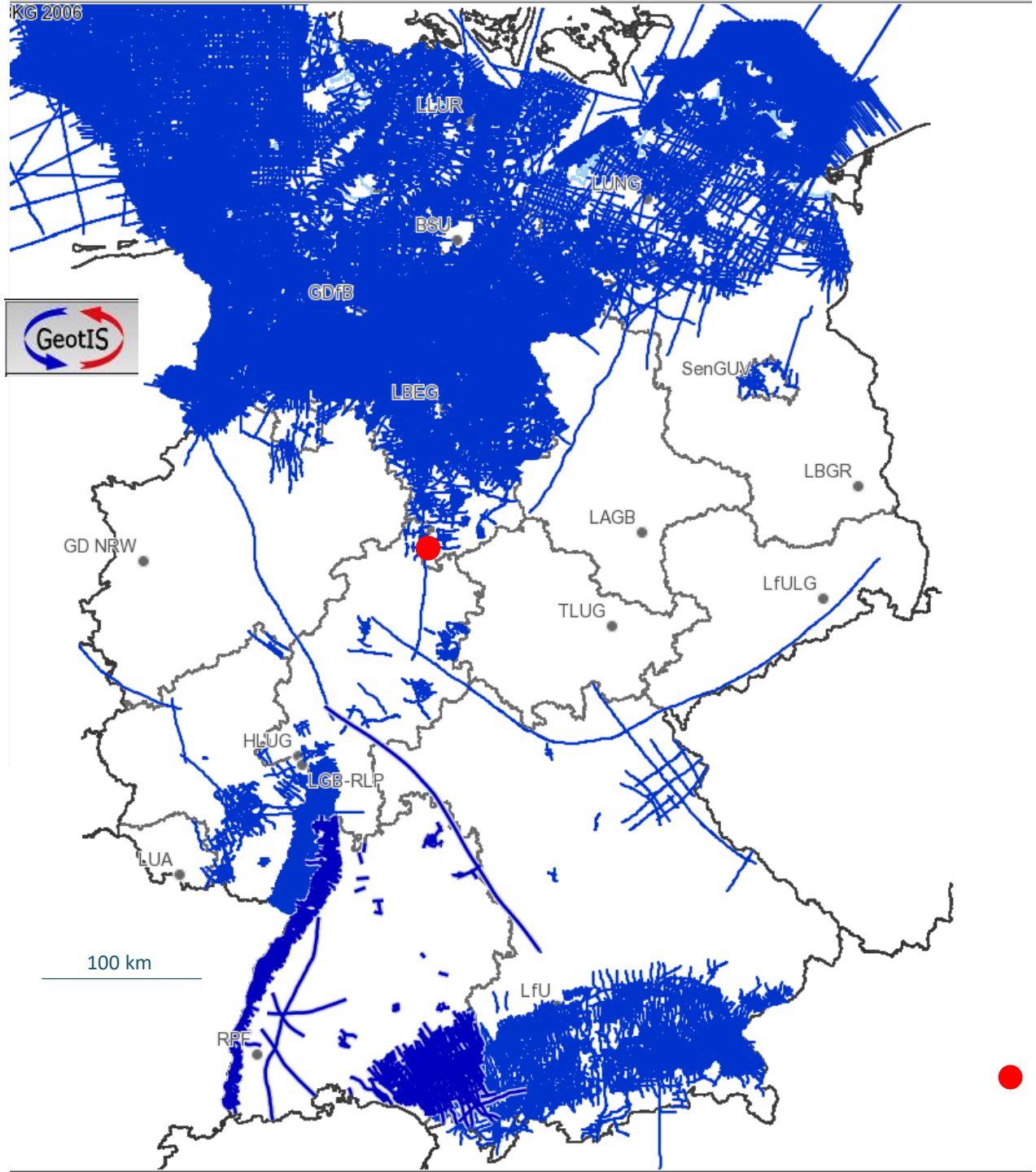
Geological Setting: Isotherms







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Geological Setting:

Seismic lines of Germany

● = Göttingen, Leinetalgrabensystem

Geological Setting: Seismic Campaign 2015

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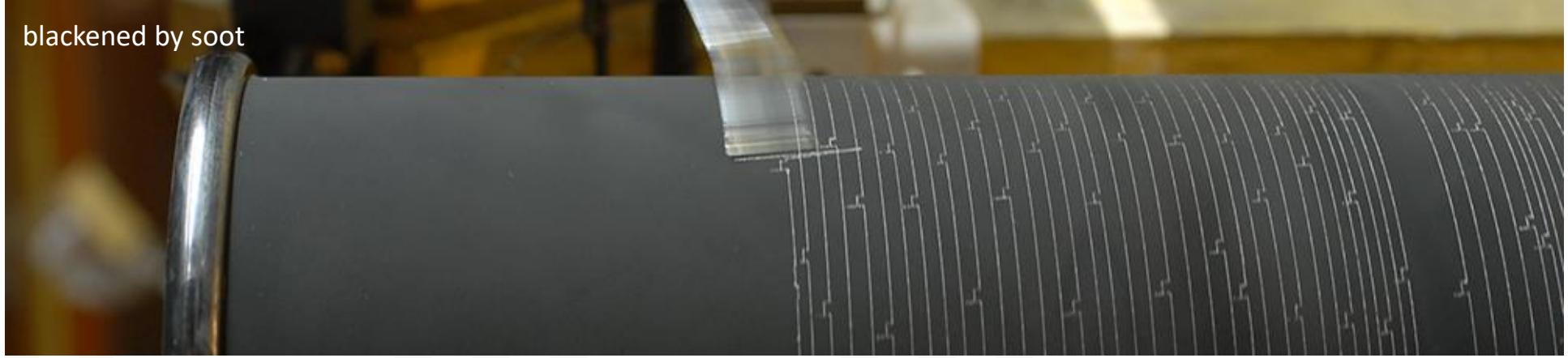
1898 fondation of the first Institute of Geophysics in Göttingen by Emil Wiechert



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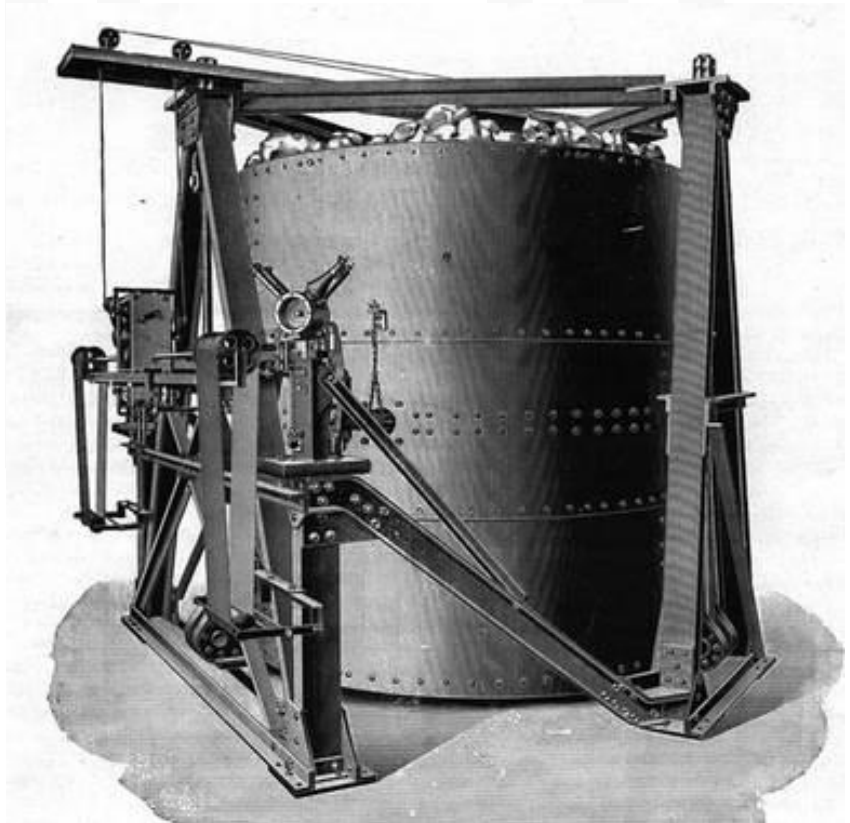
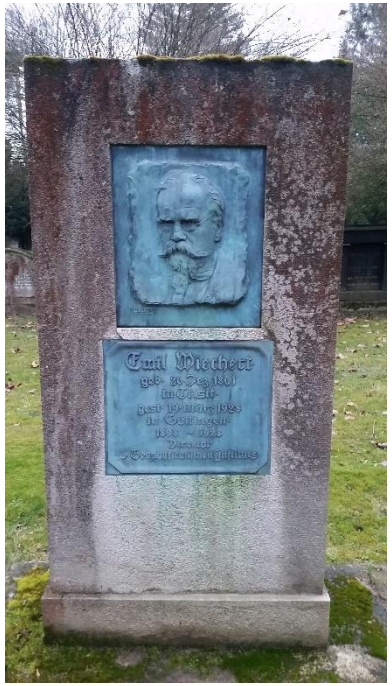
Wiechert Seismograph with 17-ton pendulum (barite)





Emil Wiechert
Cemetry Göttingen

Wiechert'sche Seismic Station Göttingen: Mintrop-Drop-Weight (4 t)

now maintained by Wiechert'sche Erdbebenwarte e.V.
(an association)

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Von Gerhard Keppner - Archiv Gerhard Keppner, CC BY-SA 2.0 de, Link

Geological Setting: Seismic Campaign 2015

Geological Setting: Seismic Campaign 2015

Lots of public relations work for societal acceptance done!

Geological Setting: Seismic Campaign 2015

Lot‘s of public relations work for societal acceptance done!

Accompanying research: **SOFI** | Soziologisches Forschungsinstitut Göttingen an der Georg-August-Universität

#geothermie #wissenschaft #UniGöttingen

Erdwärme - Energieprojekt mit Zukunft

1.128 Aufrufe • 18.04.2017

YouTube-Video: https://youtu.be/cRCsrywCoQw

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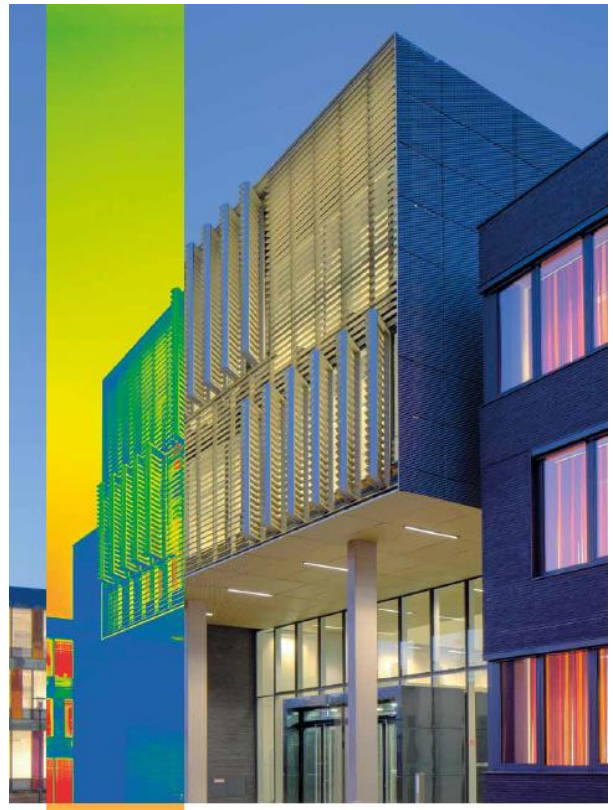
Flyer for households along the line



Erdwärme für den Universitätscampus?

Seismische Erkundung in Göttingen
Frühjahr 2015

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

UNIVERSITÄTSMEDIZIN GÖTTINGEN UMG

Geological Setting: Seismic Campaign 2015

Geological Setting: Seismic Campaign 2015

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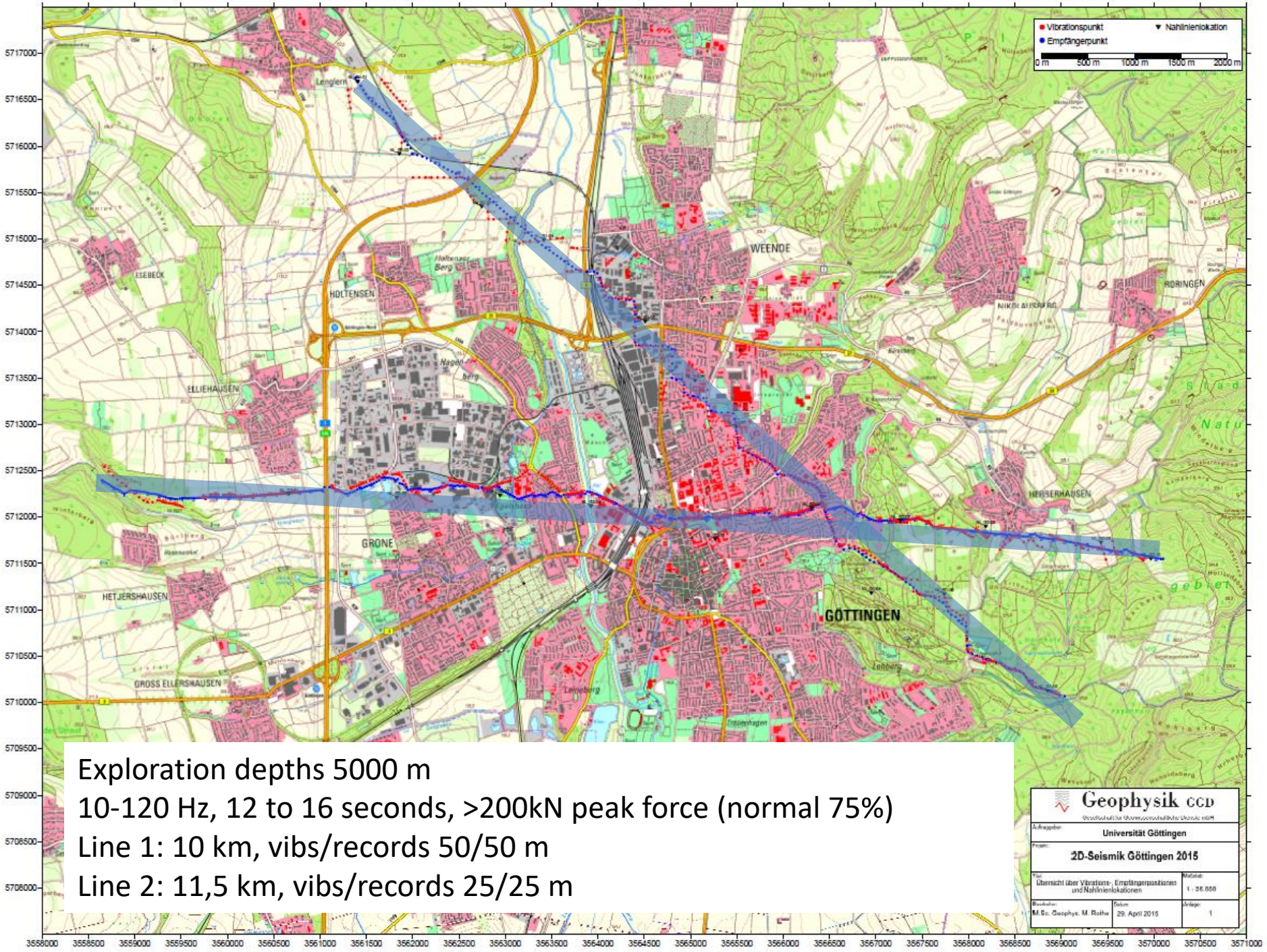
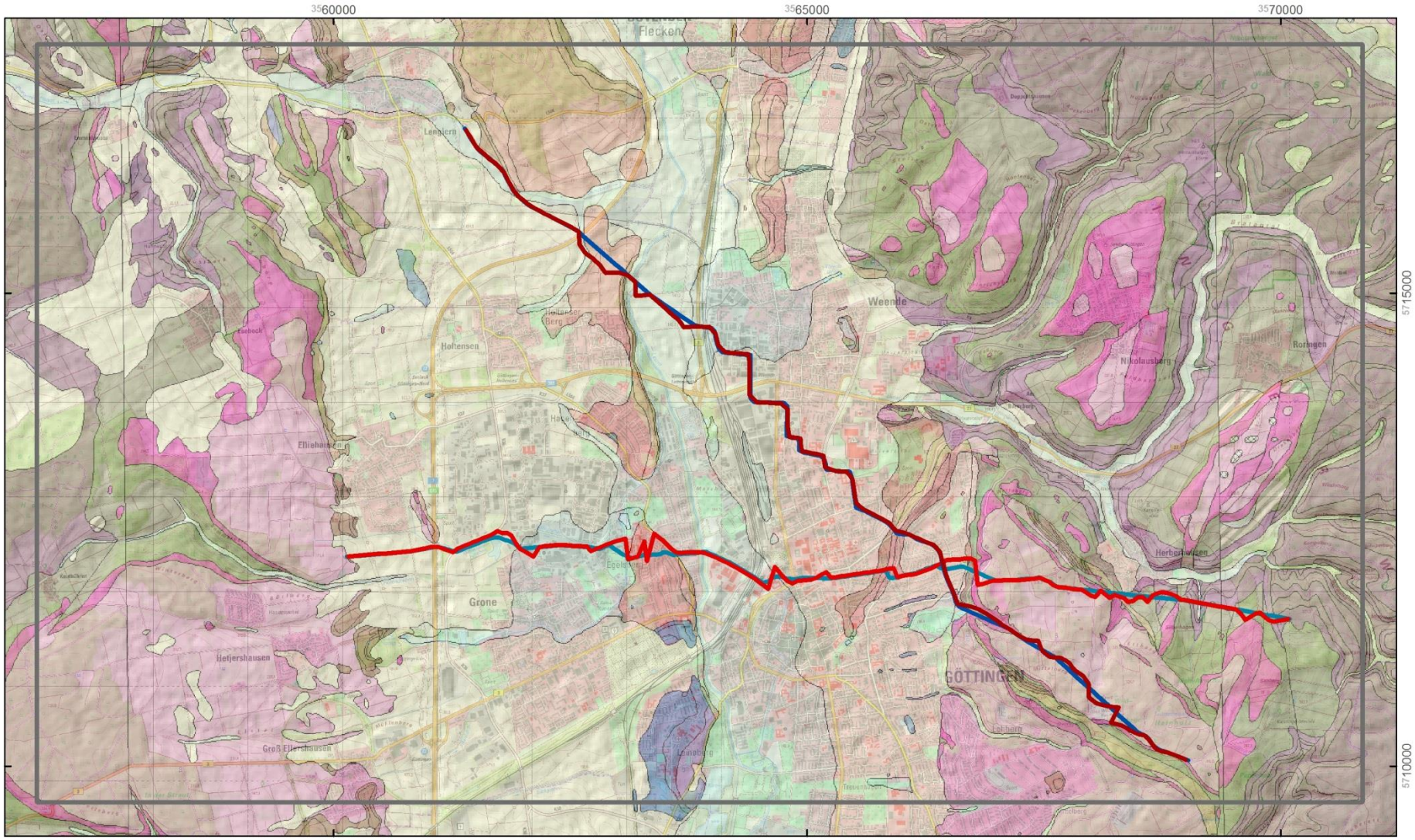
Geological Setting: Seismic Campaign 2015



Exploration depths 5000 m
10-120 Hz, 12 to 16 seconds, >200kN peak force (normal 75%)
Line 1: 10 km, vibs/records 50/50 m
Line 2: 11,5 km, vibs/records 25/25 m

Geological Setting: Seismic Campaign 2015



Geologische Kartenblätter 4426 Dransfeld, 4425 Göttingen und 4424 Ebergötzen

Legende

- Anregungspunkte Profil "Base 1"
- Geophon-Messpunkte Profil "Base 1"
- Anregungspunkte Profil "Graben 1"
- Geophon-Messpunkte Profil "Graben 1"
- Erlaubnisgebiet

0 0,5 1 2 km

Length of Lines 10 and 11.5 km:

Basement section: record distance 50 m, vib points 50m
Graben section: record distance 25 m, vib points 25/50m

Geological Setting: Seismic Campaign 2015

Deep Seismic Profile GOE_2015_02

Seismic lines not yet published

no specific target definable
(horizon/structure/tectonic unit)
Engineered Geothermal System needed

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Engineered Geothermal System needed!

How to approach the development of such an unconventional reservoir?

MEET
Multi-sites EGS Demonstration

HORIZON 2020, EU-Call: LCE-18-2017:
Enhanced Geothermal Systems in different geological conditions

Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potentials

(May 2018 to October 2021/January 2022)

This project has received funding from the European Union's Horizon 2020 research and innovation programme und grant agreement No 792037

1. Introduction
2. Energy infrastructure setting of the University Campus
3. Geological setting of the Göttingen region
4. **Exploration strategies**
    - **MEET-project: analogue studies, reservoir modelling, recommendations for EGS-stimulations**
    - Research well: strategy and public funding
5. Summary and Outlook
6. Time for questions and discussion: 10 to 15 min

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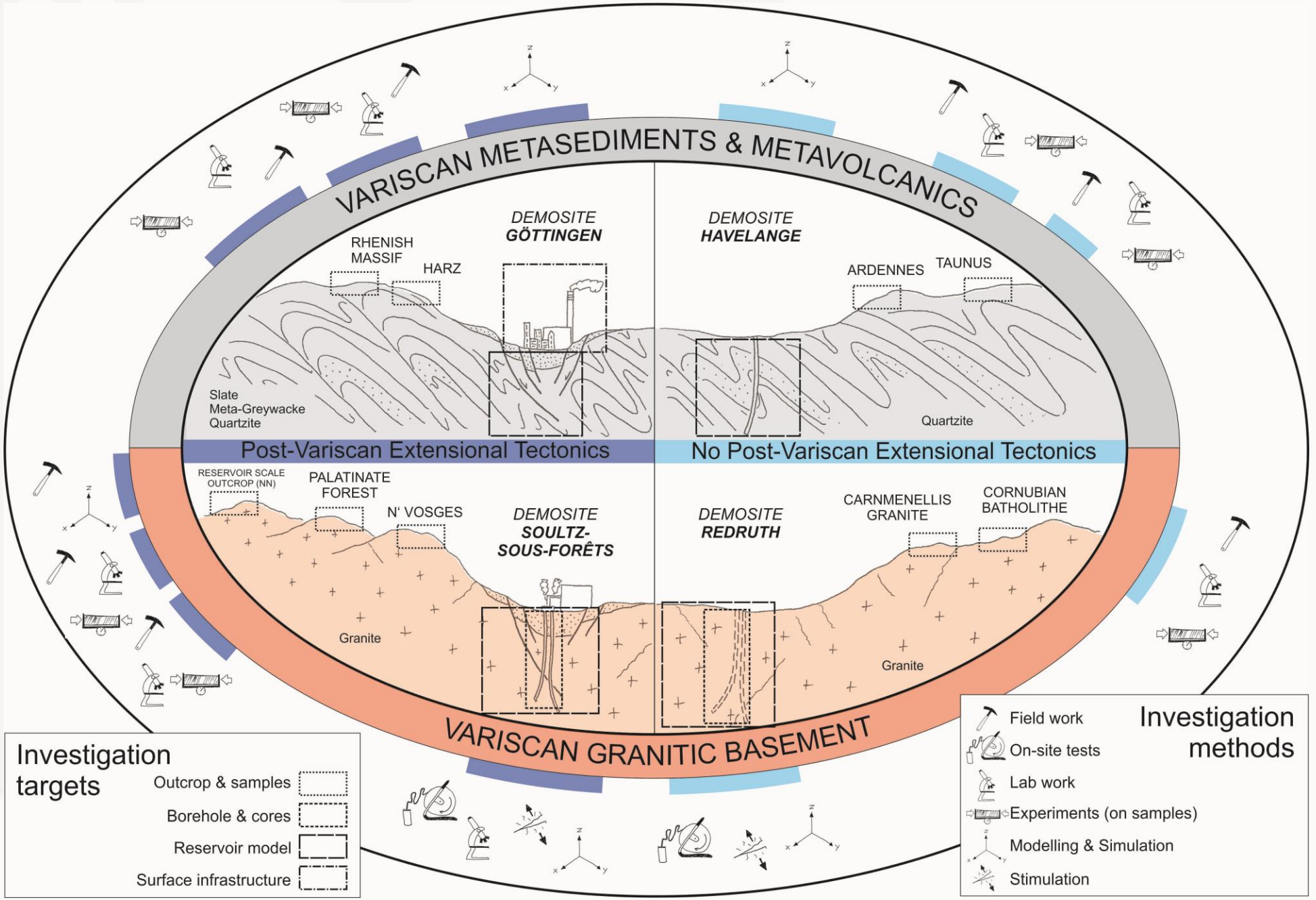
Campus of the University of Göttingen is a demo site of

MEET

Multi-sites EGS Demonstration

Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potentials

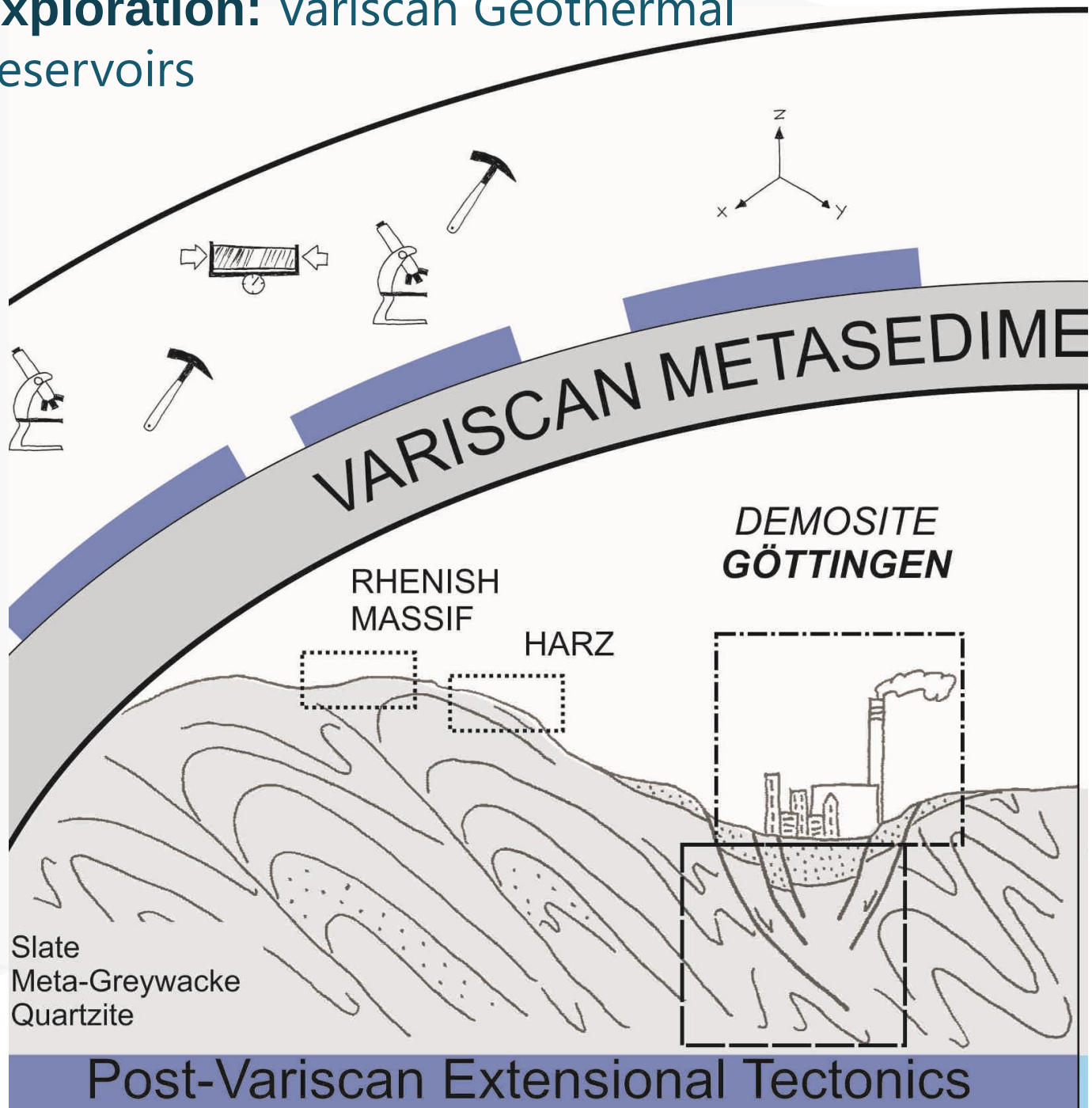
Exploration: Variscan Geothermal Reservoirs



Variscan Geothermal Reservoirs in Granitic and Metasedimentary (**unconventional**) Rocks

Trullenque et al. 2018;
Leiss & Wagner 2019

Exploration: Variscan Geothermal Reservoirs



MEET Multi-sites EGS Demonstration

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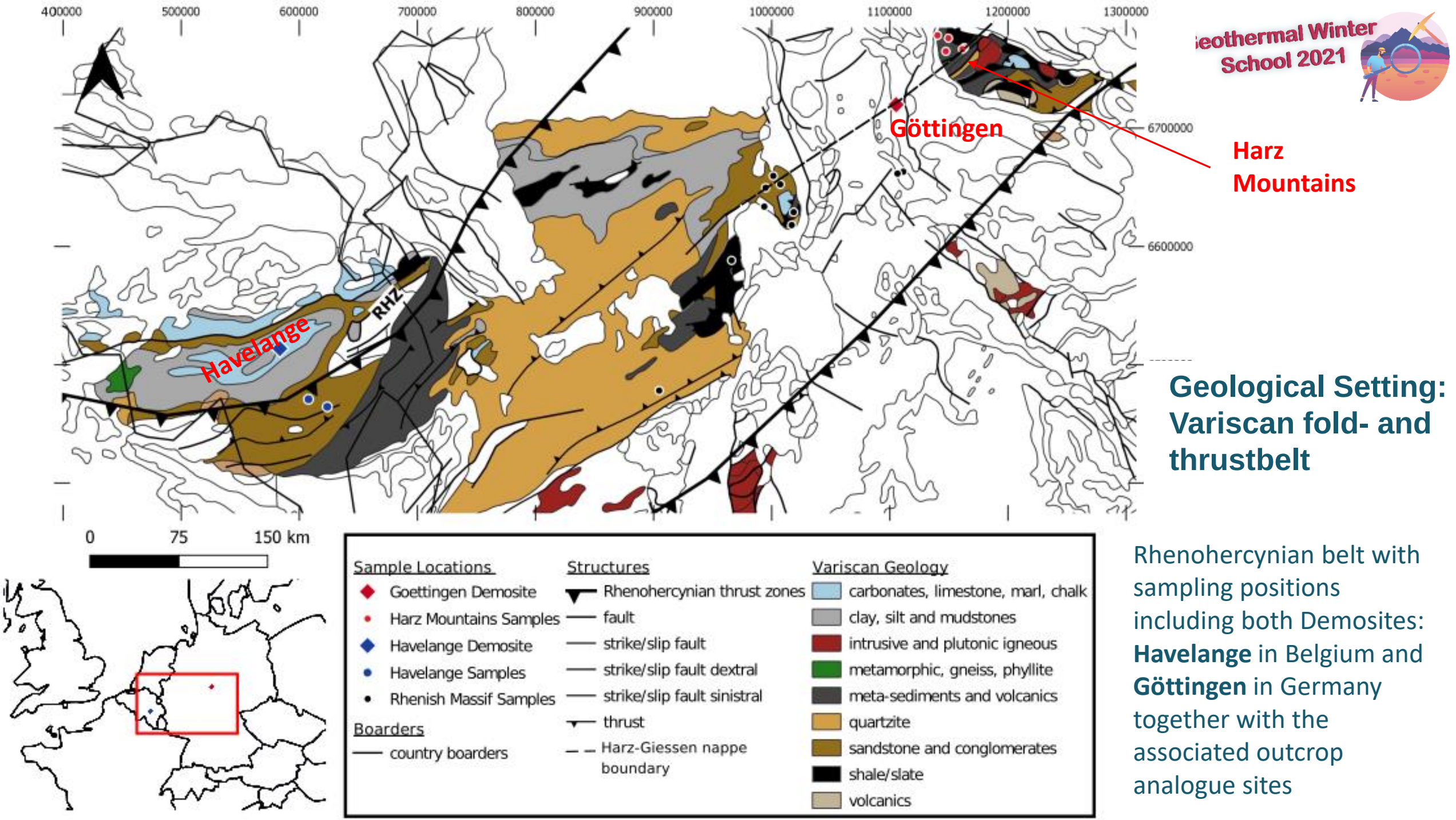
Demosite: Heat Supply of the Göttingen University Campus

Analogue studies:

- far-field: Rhenish Massif
- near-field: Western Harz Mts.

Rock sampling for lab experiments: physical properties and long-term fluid-rock interactions

Trullenque et al. 2018;
Leiss & Wagner 2019



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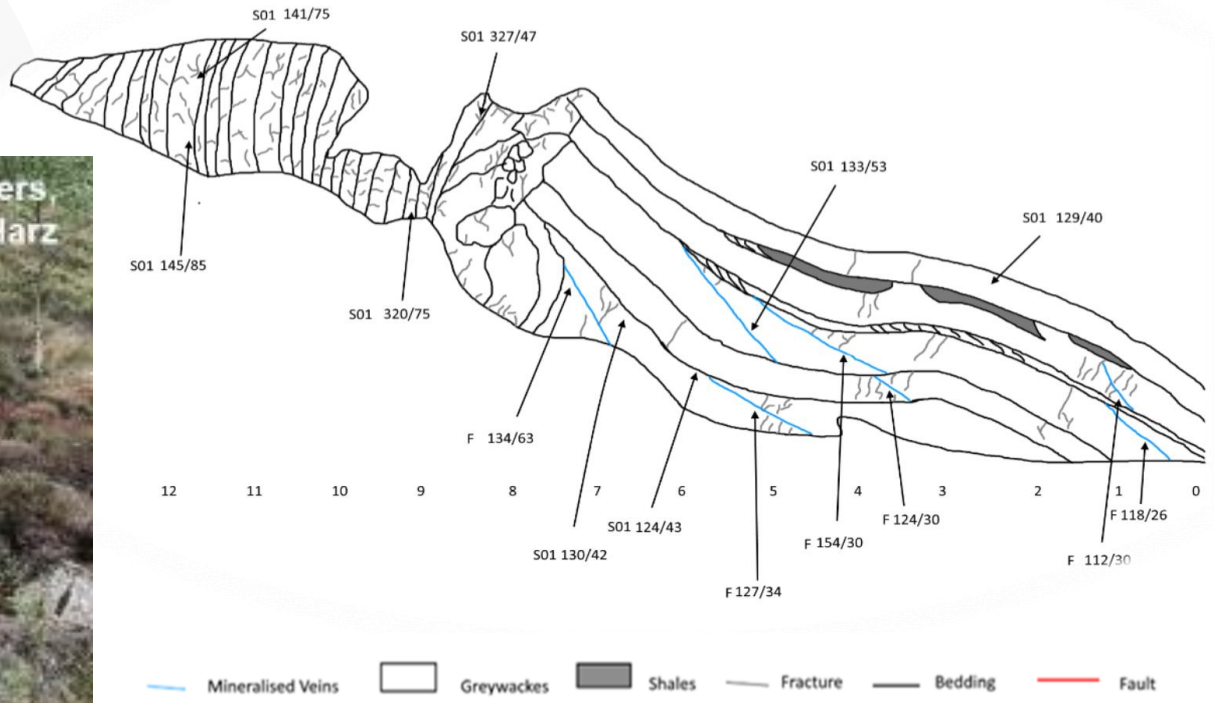
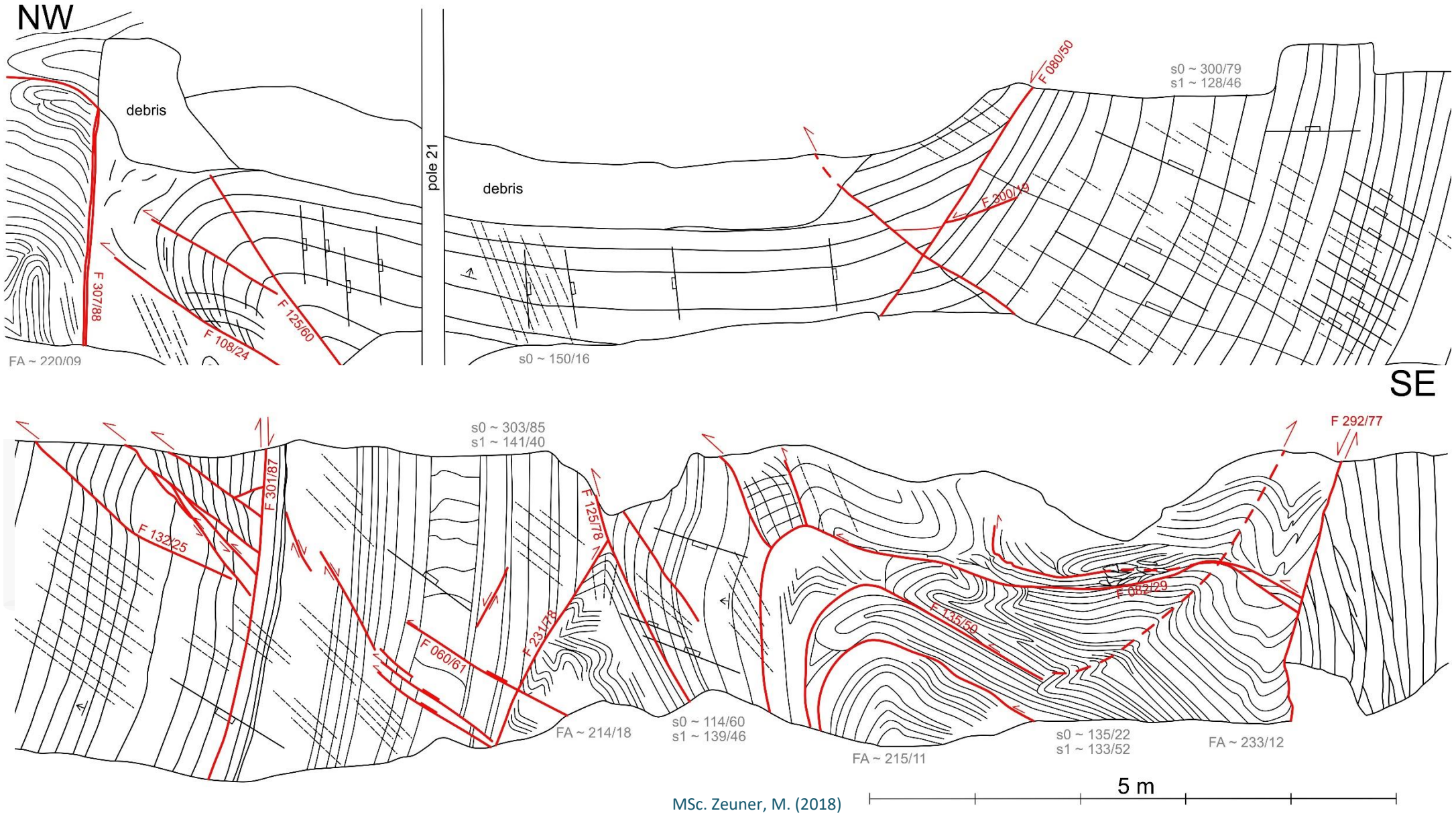
Geological Setting: Variscan fold- and thrustbelt

Rhenohercynian belt with sampling positions including both Demosites: **Havelange** in Belgium and **Göttingen** in Germany together with the associated outcrop analogue sites

Exploration: Reservoir characterisation



Exploration: Reservoir characterisation



MSc. Zeuner, M. (2018)

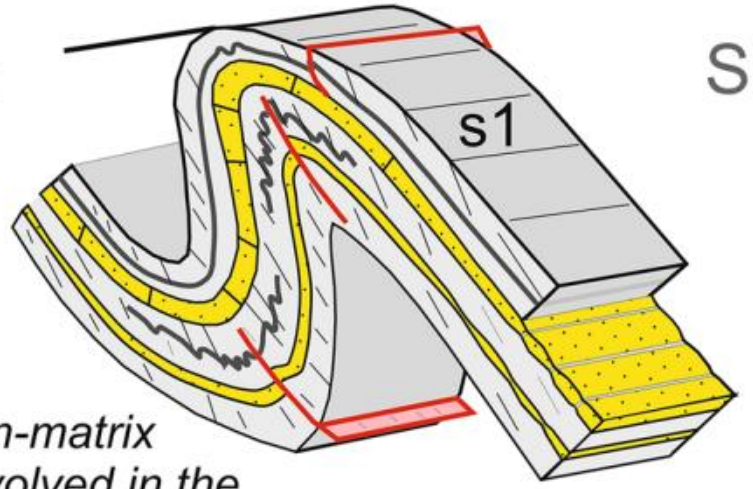
Exploration: Reservoir characterisation

(a) D1: NW-vergent folds (F1) associated with synmetamorphic penetrative axial plane cleavage (s1)

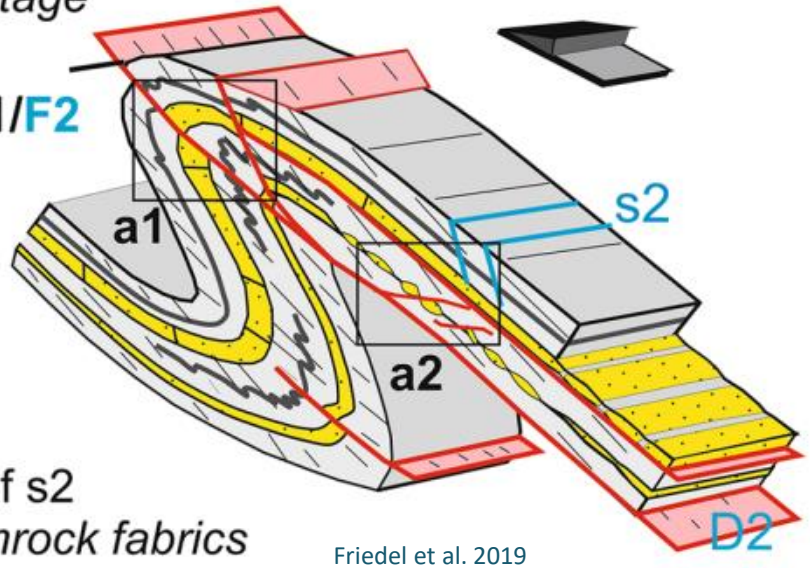
NW

F1

SE

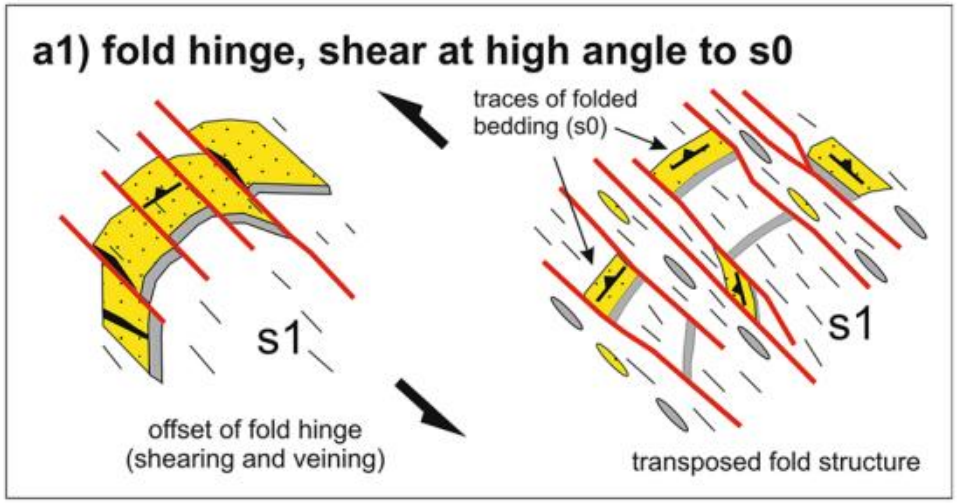


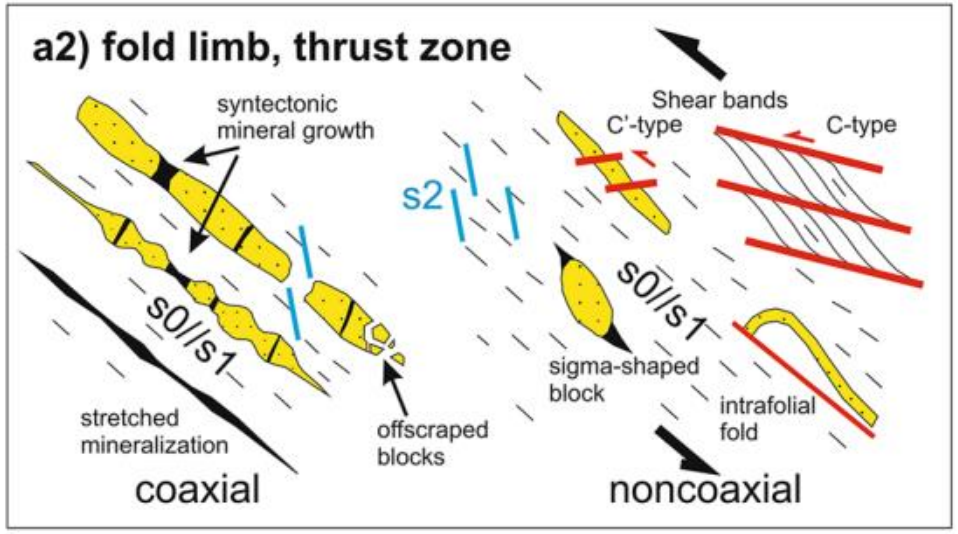
progressive simple shear
tectonic block-in-matrix fabric mainly evolved in the advanced D1 stage



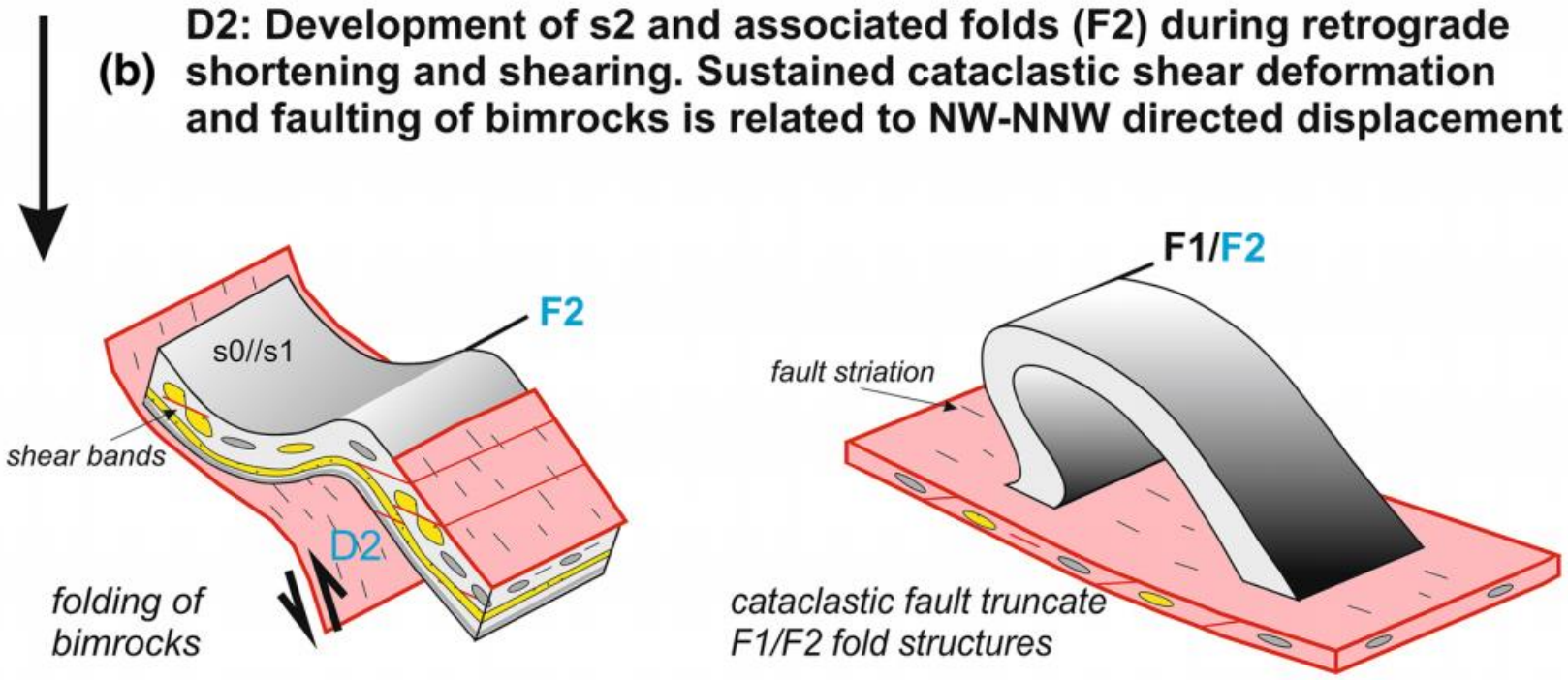
development of s2
s2 transect bimrock fabrics

Friedel et al. 2019



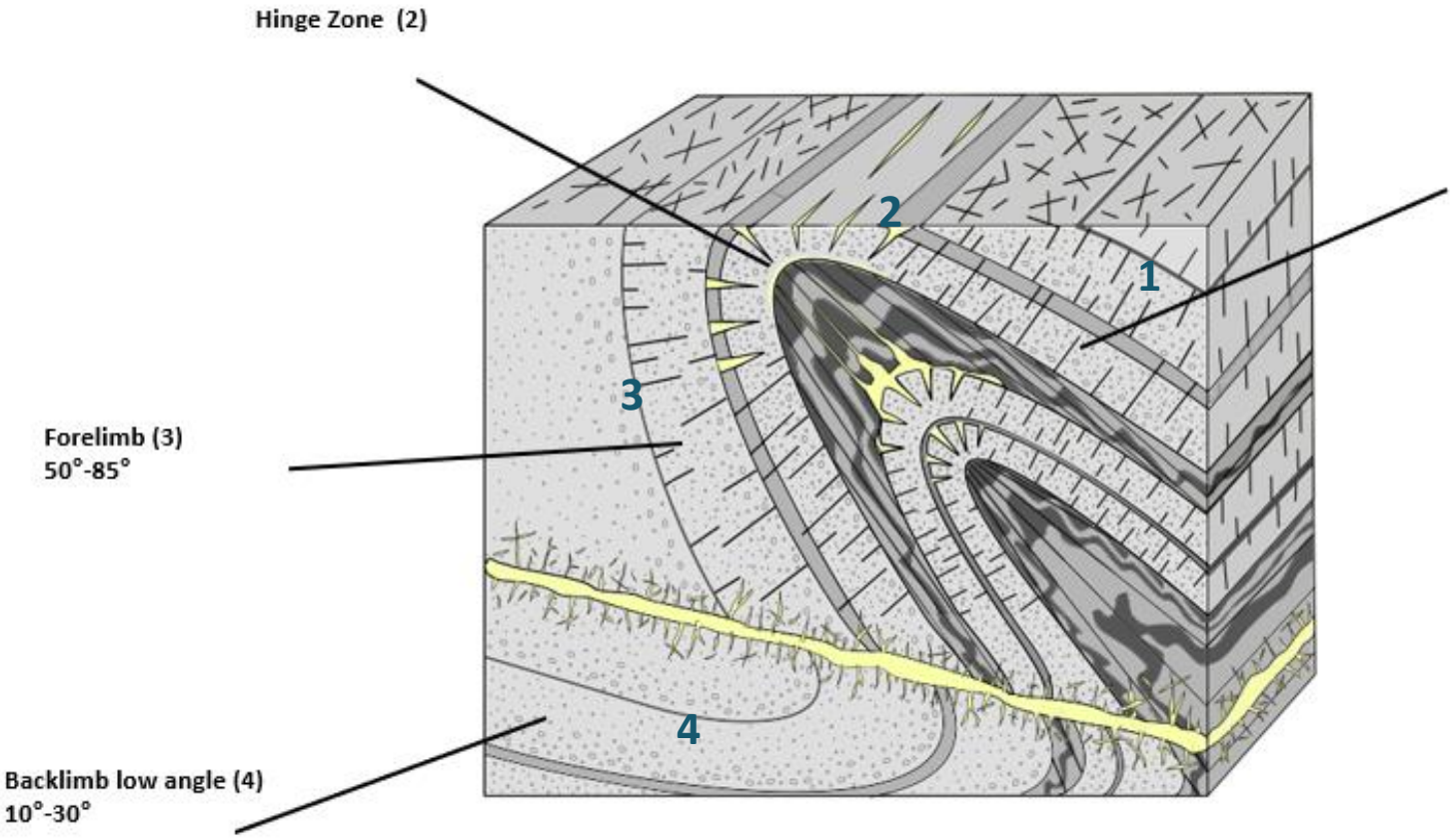


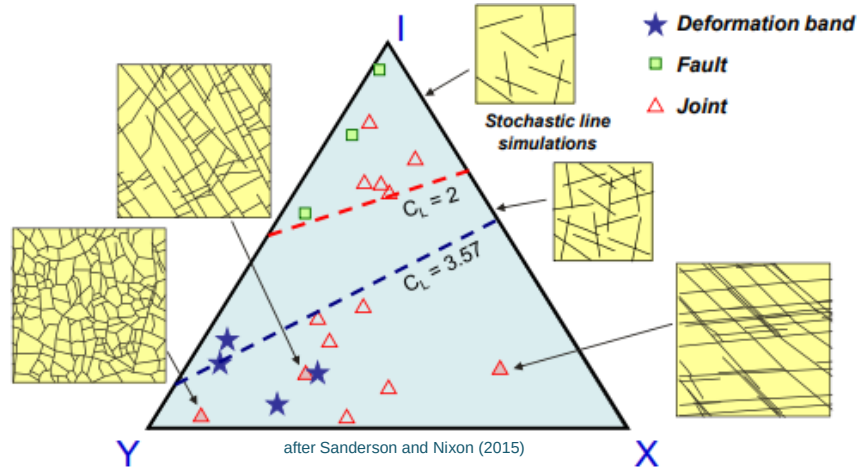
Exploration: Reservoir characterisation



Friedel et al. 2019

Exploration: Reservoir characterisation

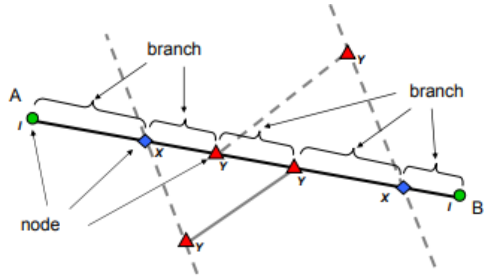




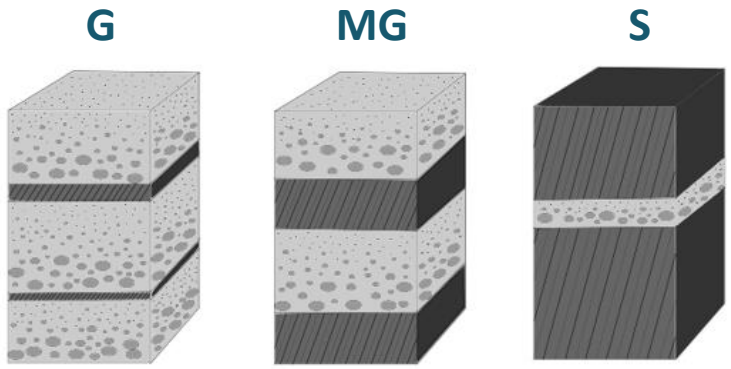
Node - connection or end point of fractures

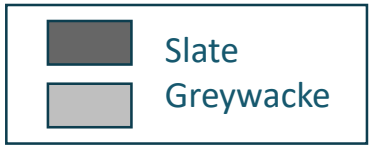
Line – the trace of a fracture

Branch – the trace between two nodes



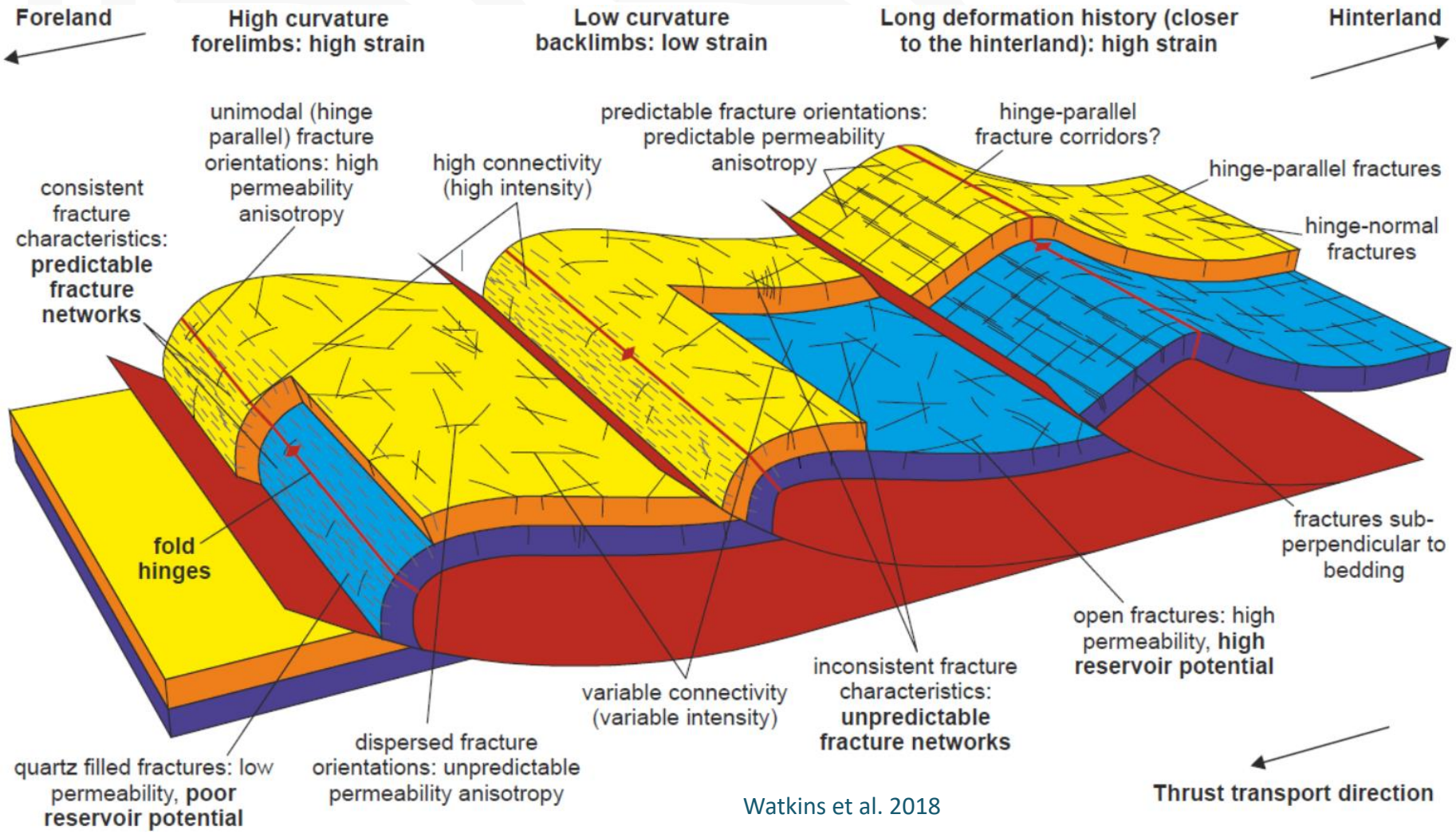
G – Thick greywacke beds with slate intercalations
MG – Greywacke with thick slate beds
S – Thick slate beds with greywacke intercalations





Ford et al. (2021)

Exploration: Reservoir characterisation



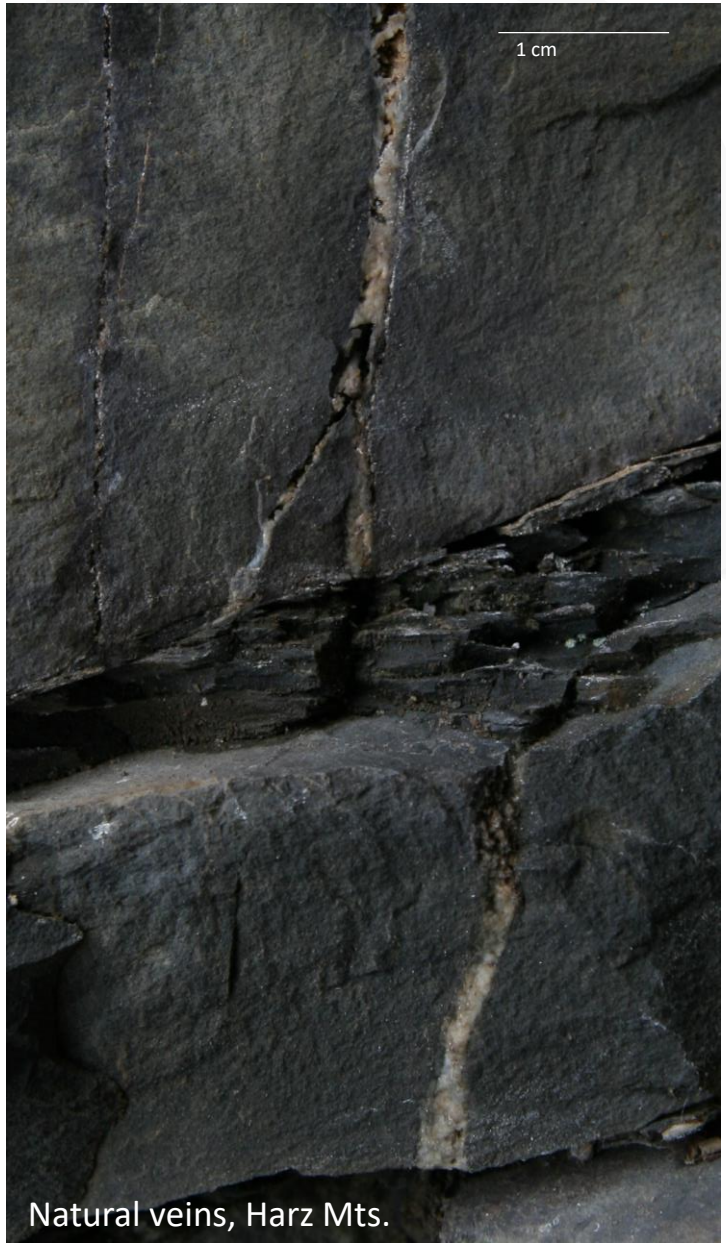
Watkins et al. 2018

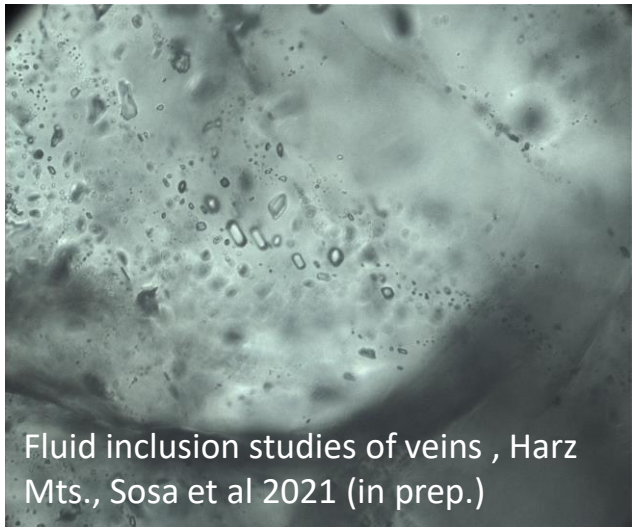
Which combination of lithological and structural/tectonic setting can be developed as a heat exchanger?

3D-Field Survey → Structural Model → Conceptional Structural Model → Parametri-zation → Reservoir Model

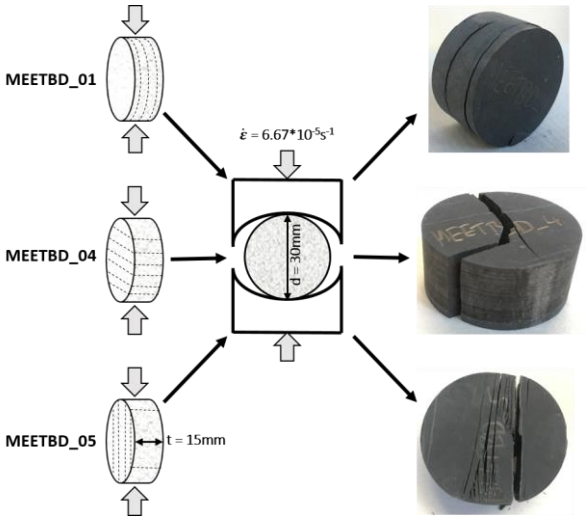
Lab-work: TUDa, GFZ

Exploration: Reservoir characterization/modelling



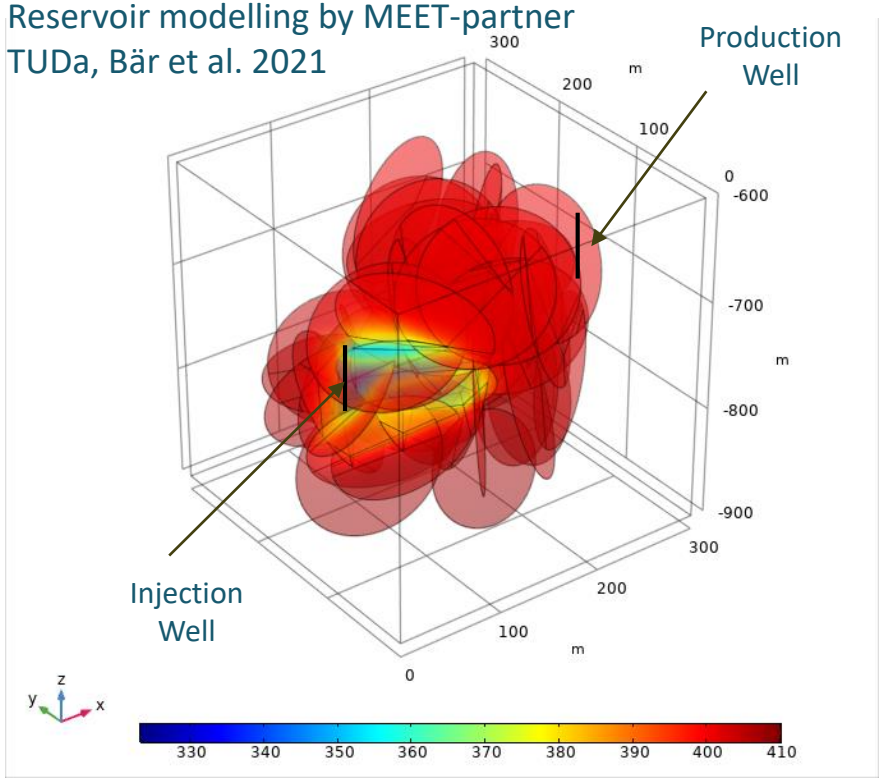


Paleo-fracture development in slate/greywacke (Quarzite) alternations



Physical properties at TUDa Darmstadt (Bär et al. 2021), Long-term Experiments on fluid-rock interactions at GFZ in Potsdam (Cheng et al. 2021)

Reservoir modelling by MEET-partner TUDa, Bär et al. 2021



1. Introduction
2. Energy infrastructure setting of the University Campus
3. Geological setting of the Göttingen region
4. **Exploration strategies**
   - MEET-project: analogue studies, reservoir modelling, recommendations for EGS-stimulations
   - **Research well: strategy and public funding**
5. Summary and Outlook

Exploration: Research well strategy

Deep Seismic Profile GOE_2015_02
(seismic line not available yet)

Research well

no specific target definable (horizon/structure/ tectonic unit)

Well filling = dead end

Unorthodox approach:
Target definiton after drilling follwing the idea to find the most effective combination of lithological and structural/ tectonic setting to develop a heat exchanger

- **by considering lateral extension in a highly anisotropic reservoir**
- **societal acceptance of stimulation measures**

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Bottleneck?

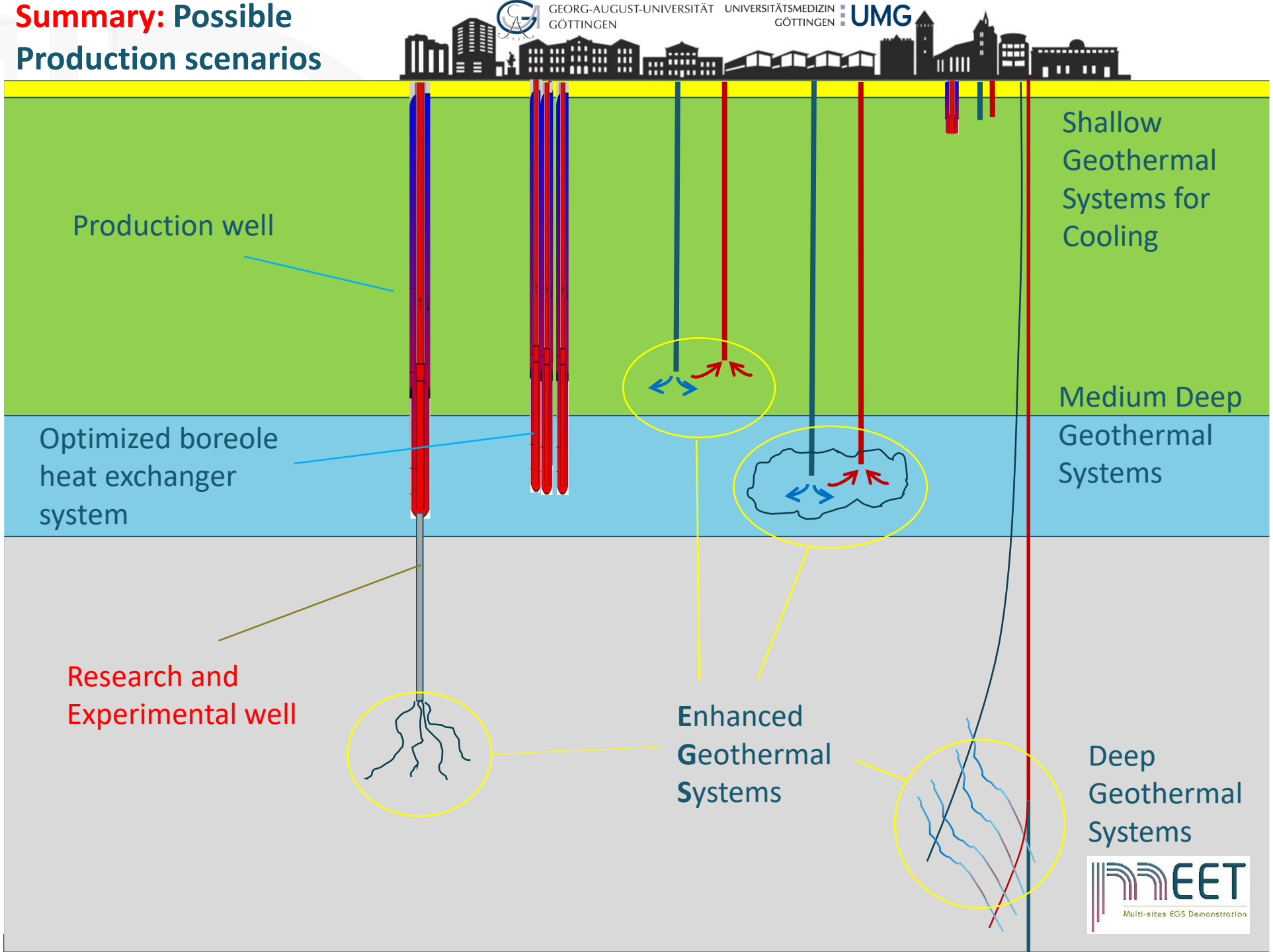
Getting money for such a **risky** research well

Risk mitigation measures?

- completion and optimization of the pre-studies (currently done in MEET)
- considering the conditions of public funding:

„Geothermal energy (research/exploration) well can only be an integrated element in a complete energy transition concept“

Summary: Possible Production scenarios



Exploration: Research well strategy

Exploration: Energy transition concept for the campus

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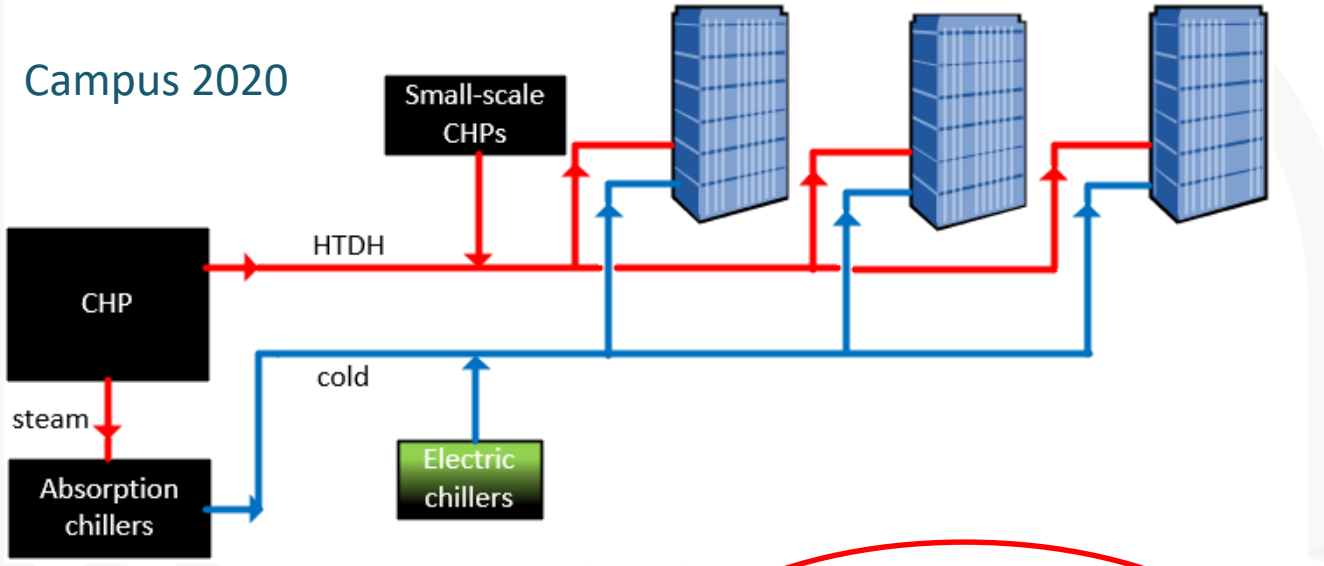

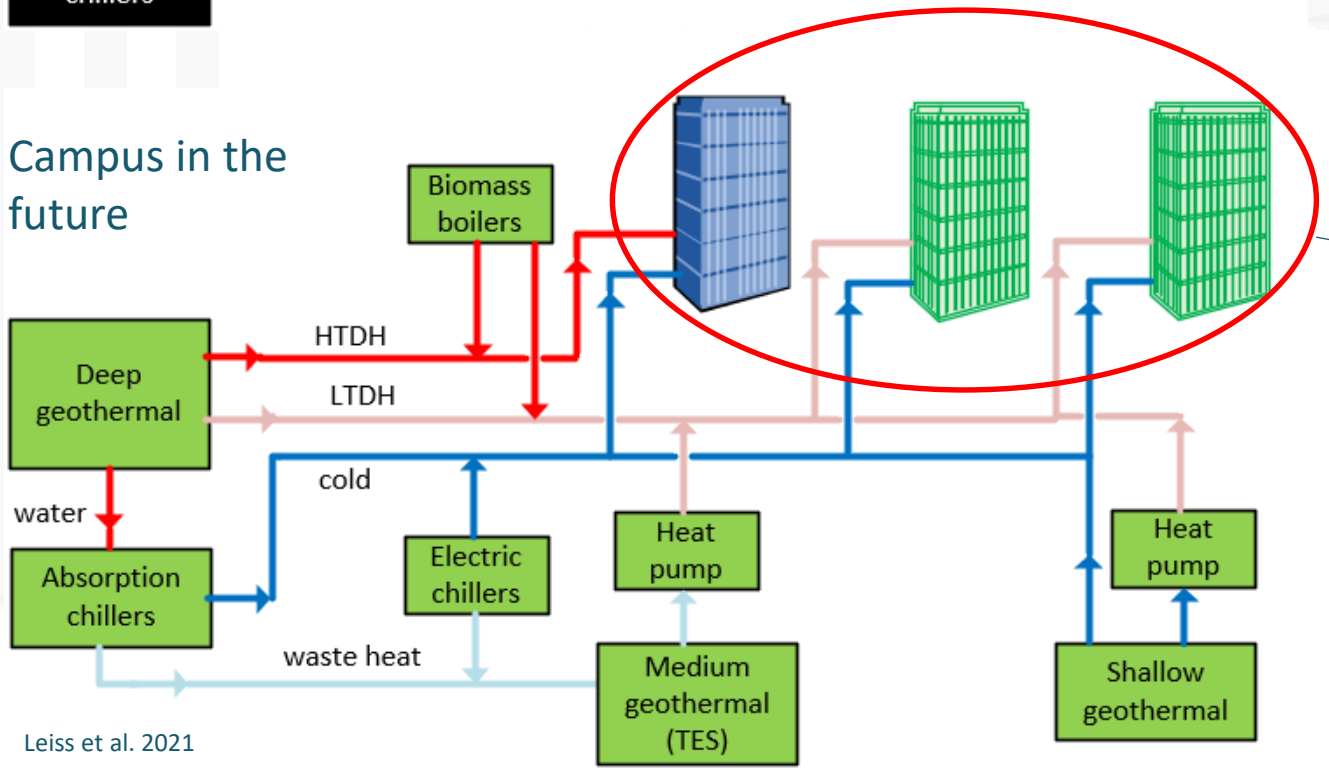

Leiss et al. 2021

MEET Multi-sites EGS Demonstration

Analysis of potential scenarios of Enhanced Geothermal System development for the Göttingen University campus, Romanov et al. (to be submitted)

New bottleneck:
The energy supplying planning of the new buildings and the remodelling of old buildings need to be opitimized for geothermal integration to give the geothermal energy development an economically competetive standing

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Summary and outlook

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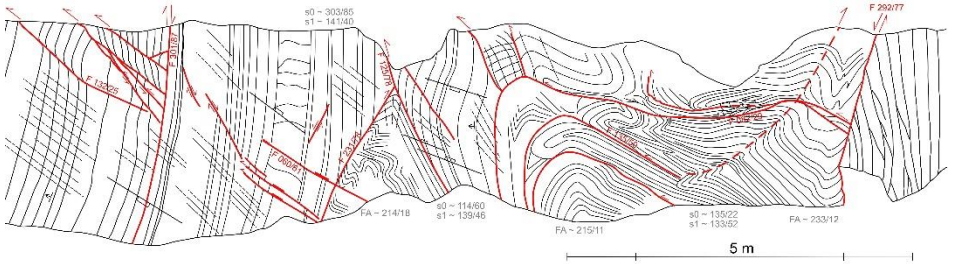
Complex System

Surface infrastructure

MEET

Multi-sites EGS Demonstration



Complex System

Subsurface infrastructure

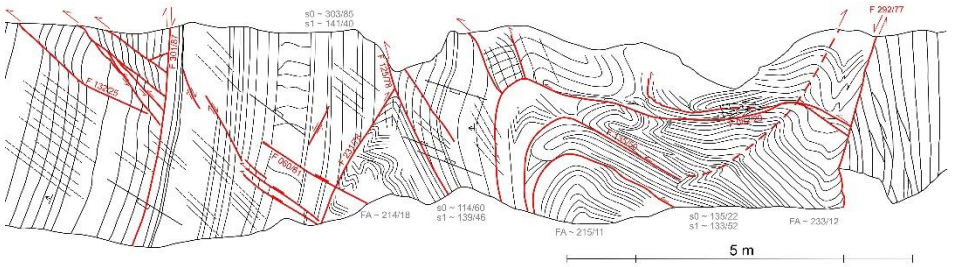
Summary and outlook

Integrated and sustainable energy supply including building infrastructure

Bottleneck: Iterative and coupled process needed

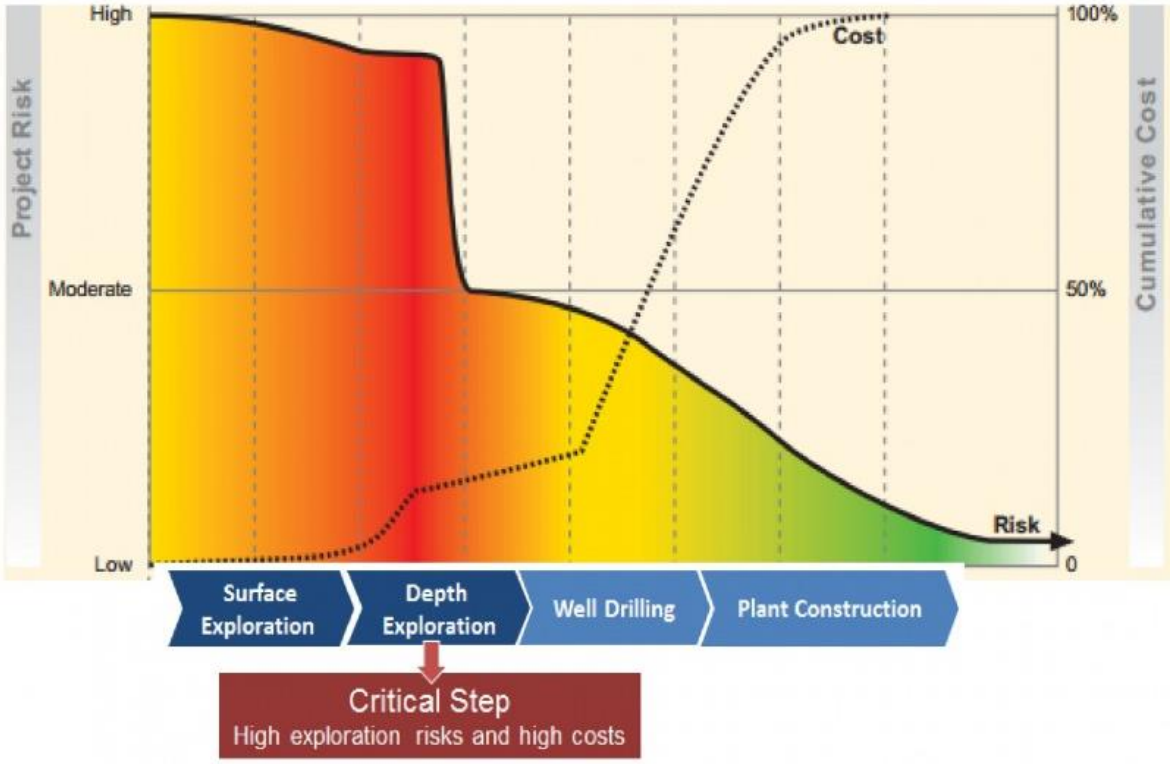
Integrated geothermal systems: shallow, medium and deep systems

Surface infrastructure



Subsurface infrastructure

Summary and outlook



From: https://www.thinkgeoenergy.com/regulation-risk-mitigation-and-adequate-funding-main-ingredients-for-geothermal-development/

Bottleneck

To bring the project to the next investment level:

- Project management
- Responsibilities (geoscientists to building management, working level to management level to politics)
- Financial investment

Speciality in our case:

Complex System

Summary and outlook

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A **complex system** can be seen as a problem, but in our case, it is a **great chance** and can be changed into a **challenge.**

Developing an **integrated energy supplying** system (holistic approach) is the **most effective way** to contribute to a **carbon dioxid balanced atmosphere**!

Summary and outlook

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Challenge for the scientist: how to deal with the pressure of the only interest of the (financial) stakeholders:

„When and how much geothermal energy for what costs?“

compare with recent situation of virologists:

„When is a vaccine available and when is the pandemic gone and when can we go back to „normal“ life?“

Summary and outlook

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Outlook:

Ivan Rasjsl: Site-specific environmental and economic assessment of EGS using Decision-Making Tool (DMT)

Bianca Wagner: Concepts and data sources for mapping deep geothermal ressoures throughout Europe

Thank you very much for your attention

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GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

UNIVERSITÄTSENERGIE GÖTTINGEN GMBH

UNIVERSITÄTSMEDIZIN GÖTTINGEN UMG

GZG Geowissenschaftliches Zentrum Göttingen

MEET Multi-sites EGS Demonstration

This work was performed in the framework of the H2020 MEET EU project which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037