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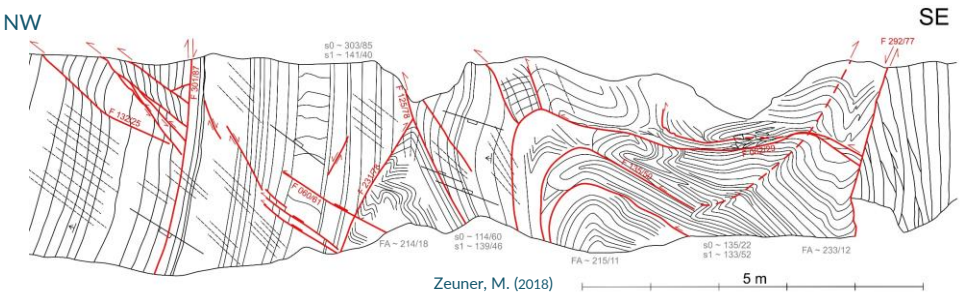
MEET
Multi-sites EGS Demonstration



Zeuner, M. (2018)

Final Demonstration Workshop:

28th January 2022, Online

Lessons learnt:
Exposed analogues for understanding Variscan geothermal reservoirs (WP5)

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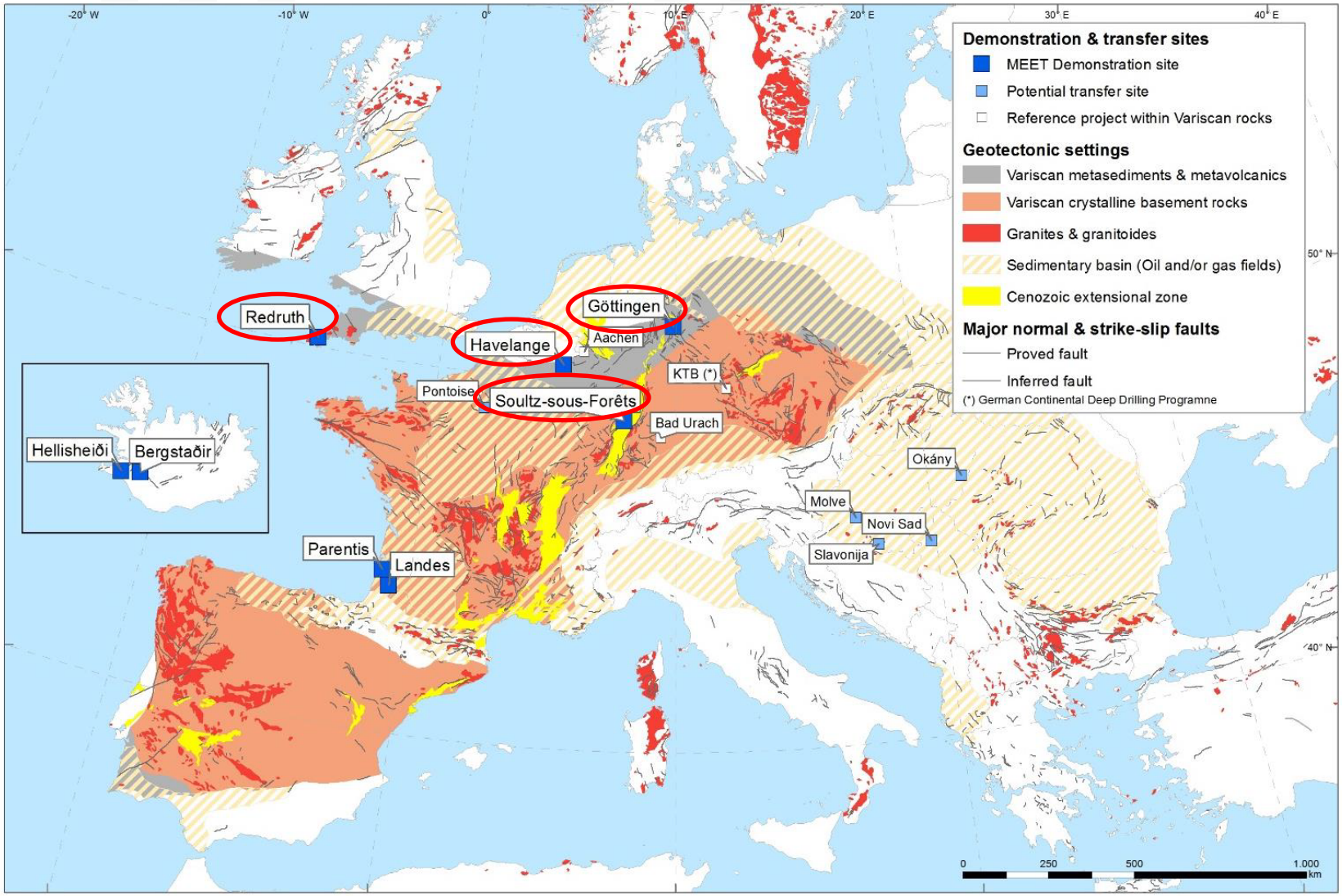
University of Göttingen (UGOE) and Universitätsenergie Göttingen GmbH (UEG)

General objective of WP 5

Evaluation and demonstration of European Variscan basement rocks as ***Enhanced Geothermal Systems*** **(EGS)**, which are previously under-explored



Sources of geological datasets:
Asch, K. (2005): IGME 5000: 1 : 5 Million International Geological Map of Europe and Adjacent Areas. BGR (Hannover).
U.S. Geological Survey World Petroleum Assessment 2000: U.S. Geological Survey Digital Data Series DDS60: http://greenwood.cr. usgs.gov/energy/WorldEnergy/DDS-60

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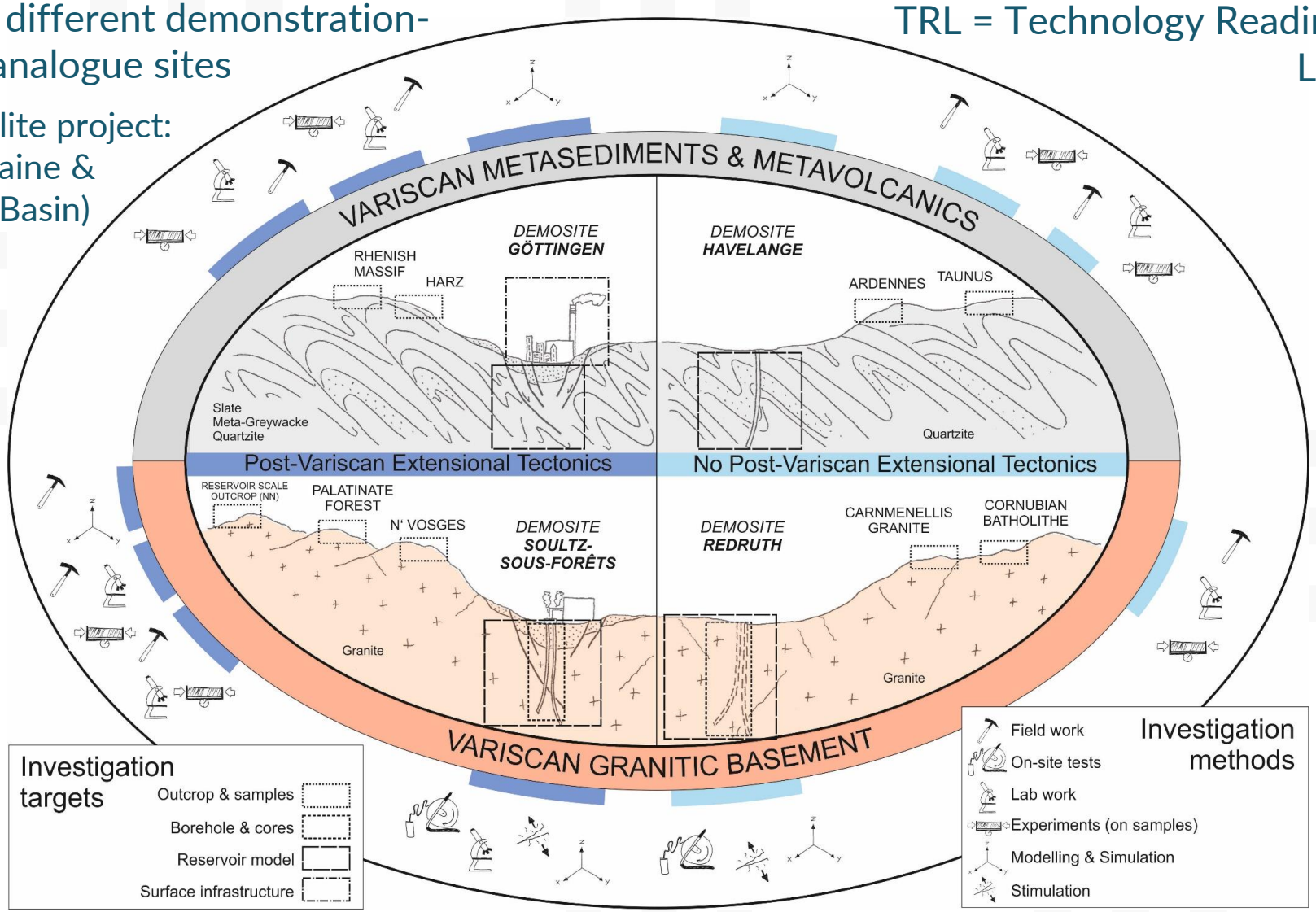
Contents

Introduction to the demonstration/analogue sites

Four different demonstration- and analogue sites

(Satellite project: Aquitaine & Paris Basin)

TRL = Technology Readiness Level



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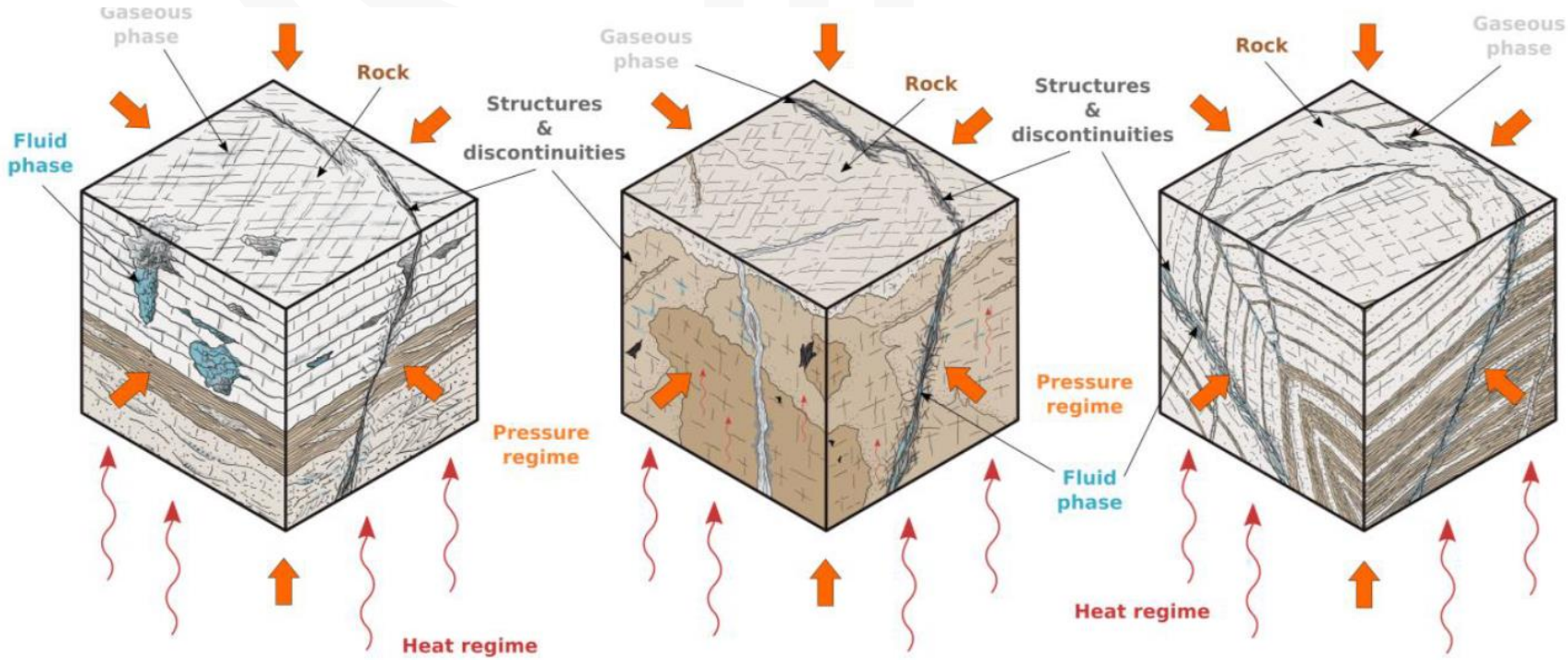
Introduction to the demonstration/analogue sites

Schematic figures of the main geothermal reservoir (play) types investigated, showing (1) lithological and structural elements and (2) geothermal-related parameters

Sedimentary rocks (not studied here)

Granites & crystalline rocks

Meta-sedimentary & meta-volcanic rocks



Wagner et al (2021)

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Contents

Aims of the exposed analogues studies

Make predictions about the sub-surface geology of actual or potential geothermal reservoirs, including:

- Measure the mechanical and thermal properties of reservoir rocks (Deliverable 5.5*)
- Numerical modelling of reservoir behaviour (Deliverable 5.6*)
- Develop stimulation strategies (Deliverable 5.7*)
- Characterise the exposed analogues, including creation of new methods and strategies using analogues (Deliverable 5.9*, focus of this presentation)

Use of fieldwork and exposed analogues played key roles in each of these tasks

*MEET-Deliverables are (will be) publicly available, e.g. on Zenodo

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Aims of the exposed analogues studies

EGS ⇒ use of any technique / physical process to enhance either the reservoir permeability or the hydraulic link between well and reservoir in order to increase flow rate (production and/or injection)

proposed application order

Technique	Description	Benefits	Disadvantage	Risks
well cleaning		part of the well testing procedure	none	none
shock pumping	cleaning of fractures in the vicinity of the borehole by pulsed pumping	can be part of the well testing procedure	none	none
thermal stimulation	opening preexisting fractures by thermal contraction of the formation through cold water injection; needs proppant	easy to perform	- only on the injection side - needs permanent cold water injection if not propped - scaling issues	- induced seismicity
chemical stimulation	dissolution of fracture mineralisation	no induced seismicity	- needs proper handling of chemicals - spatially limited extend of effect - contaminated flowback	- no public acceptance - chemical reactions not as predicted - spill of stimulation acid
hydraulic stimulation	open preexisting fractures in the borehole vicinity by pressurising the well; needs proppant	relatively easy to perform	- induced seismicity - not applicable in unfractured reservoirs	- low public acceptance - undesired fluid pathways and contamination
hydraulic fracturing	creating new fractures to engineer the reservoir by pressurising packered sections	applicable in tight reservoirs	- induced seismicity - not applicable in naturally fractured reservoirs - contaminated flowback	- no public acceptance - undesired fluid pathways and contamination
drilling a sidetrack	increasing open hole section within the reservoir	predictable added value	costly	- drilling risks - limited added value due to proximity to the first borehole (hydraulics)
drilling additional wells	increasing open hole section within the reservoir at considerable distance to other wells	flexibility in managing well use (change injection-production, workover/maintenance)	very costly	- drilling risks - POS

from Deliverable 5.7

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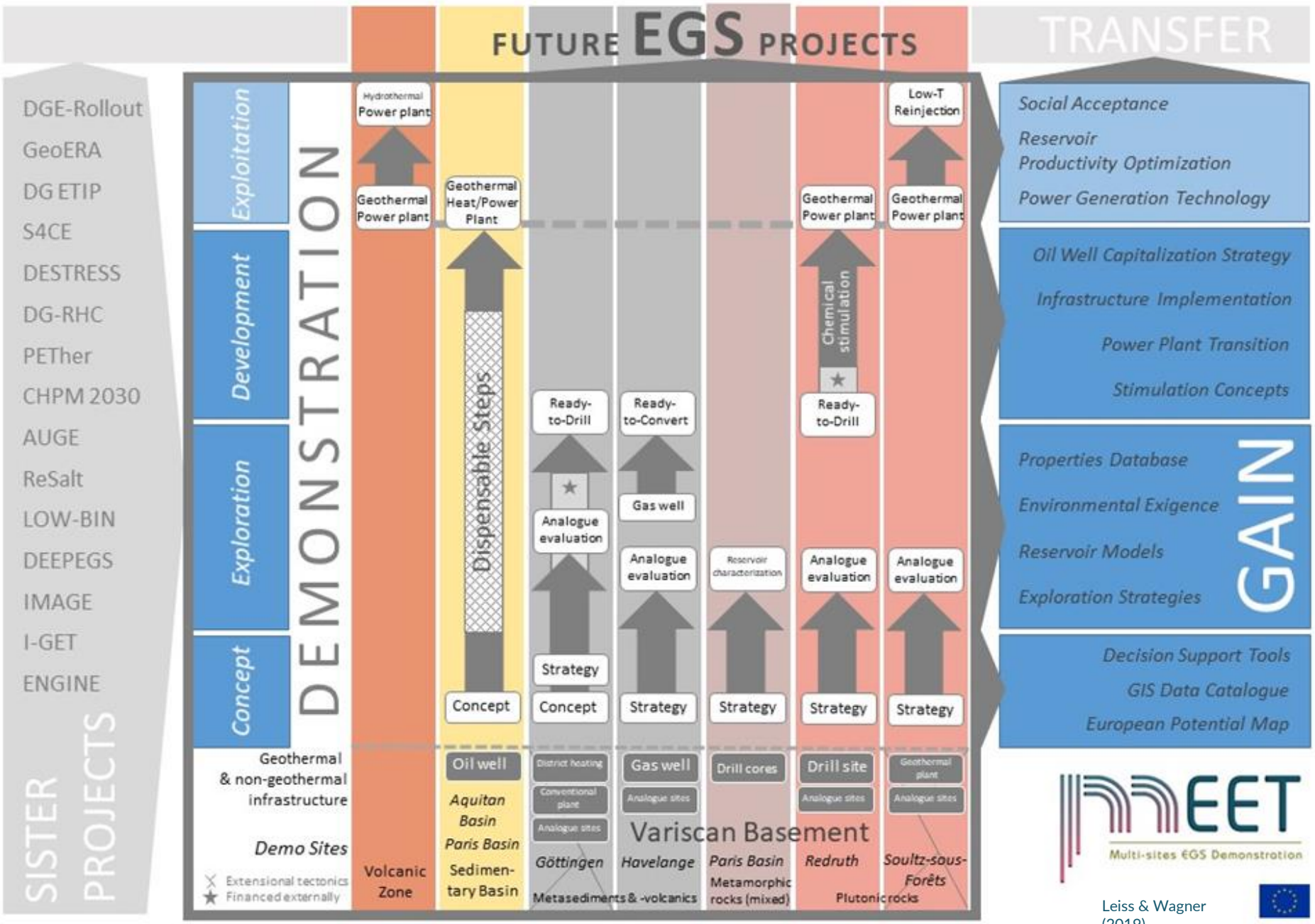
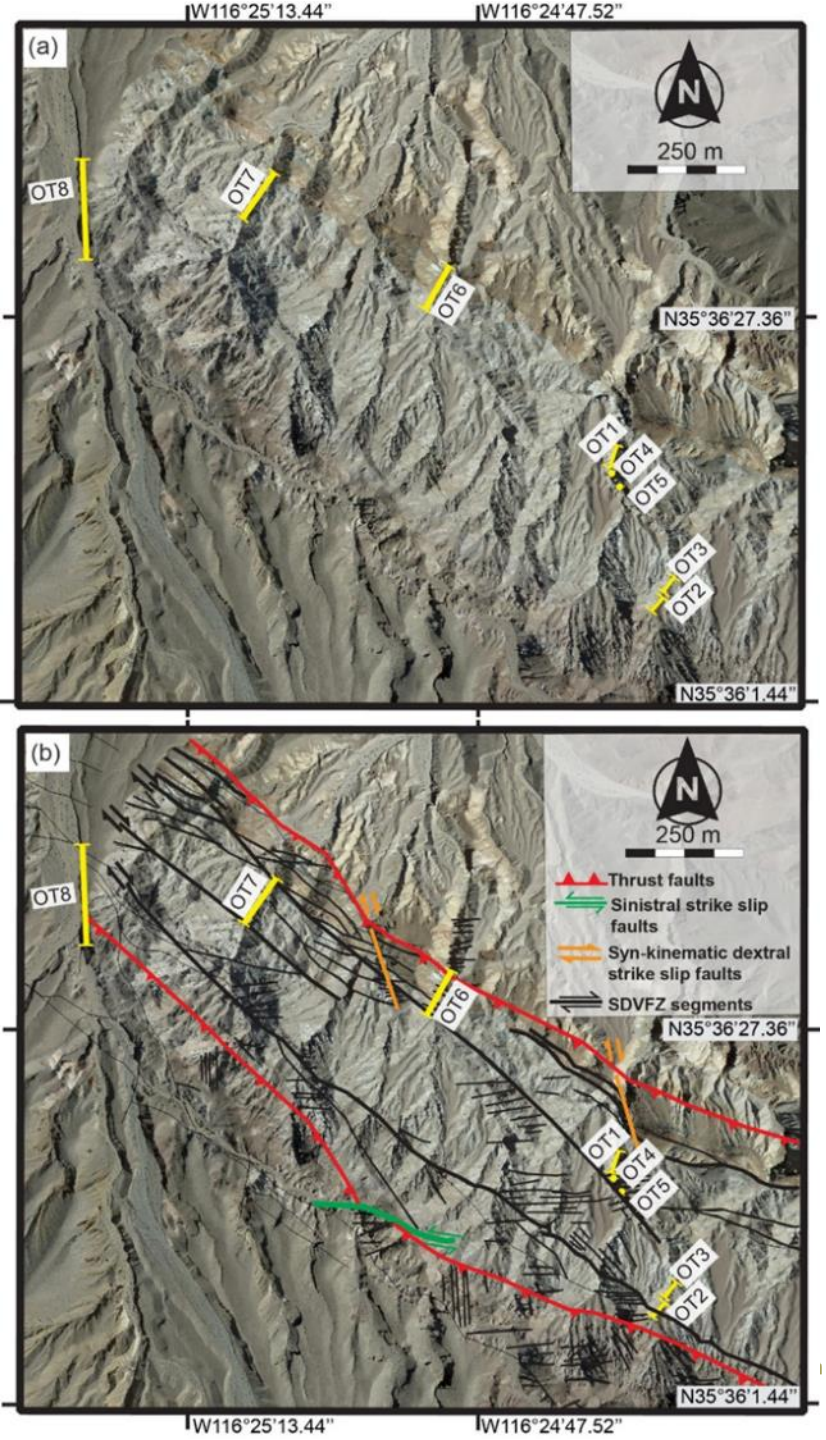
Key findings from the study areas



Leiss & Wagner (2019)



Key findings from the study areas

1. Death Valley (for Soultz-sous-Fôrets), granites, tectonically overprinted

- Three stages of metamorphism and alteration are distinguishing: (1) a pervasive propylitic alteration; (2) a more local alteration, producing clays, calcite and oxides; (3) weathering

- Several generations of fluids have migrated through the rock

- Fracture networks have been quantitatively characterised and described in terms of a palaeo-hydrothermal system

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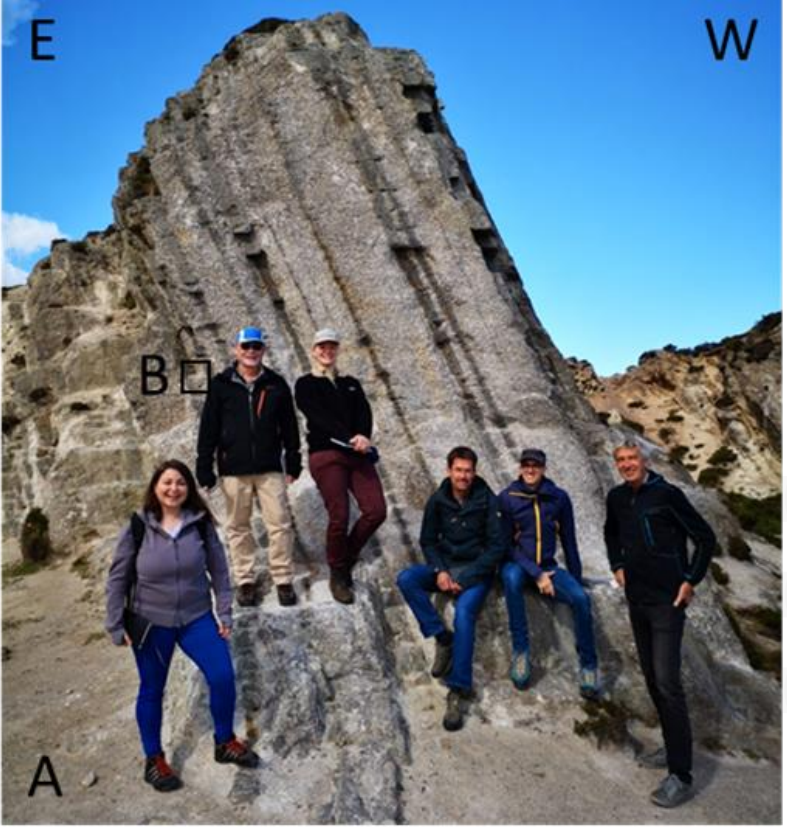

Key findings from the study areas

2. Cornwall (for United Downs Deep Geothermal Power Project), granites not tectonically overprinted

- Rock samples from exposures enable prediction of the behaviour of rocks in the sub-surface (for chemical stimulation)

- Such rock samples enable clay minerals to be studied, which is not possible for drill cuttings

- Exposed analogues enable correlations to be made between petrophysical properties and mineralogical changes relative to hydrothermal alteration

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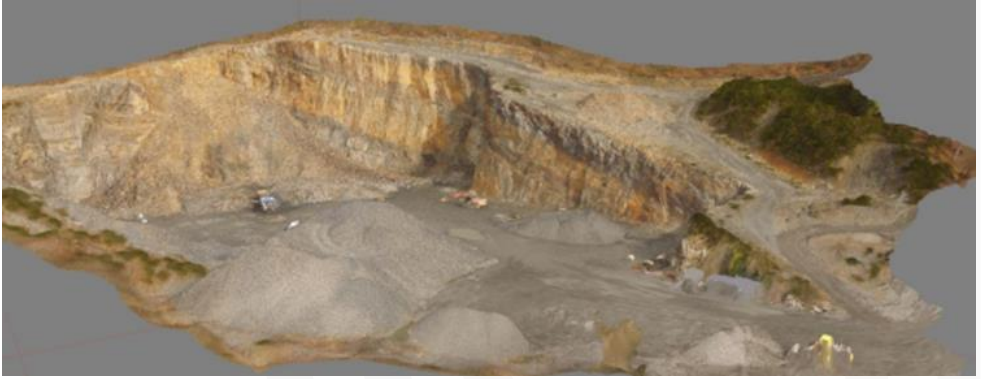

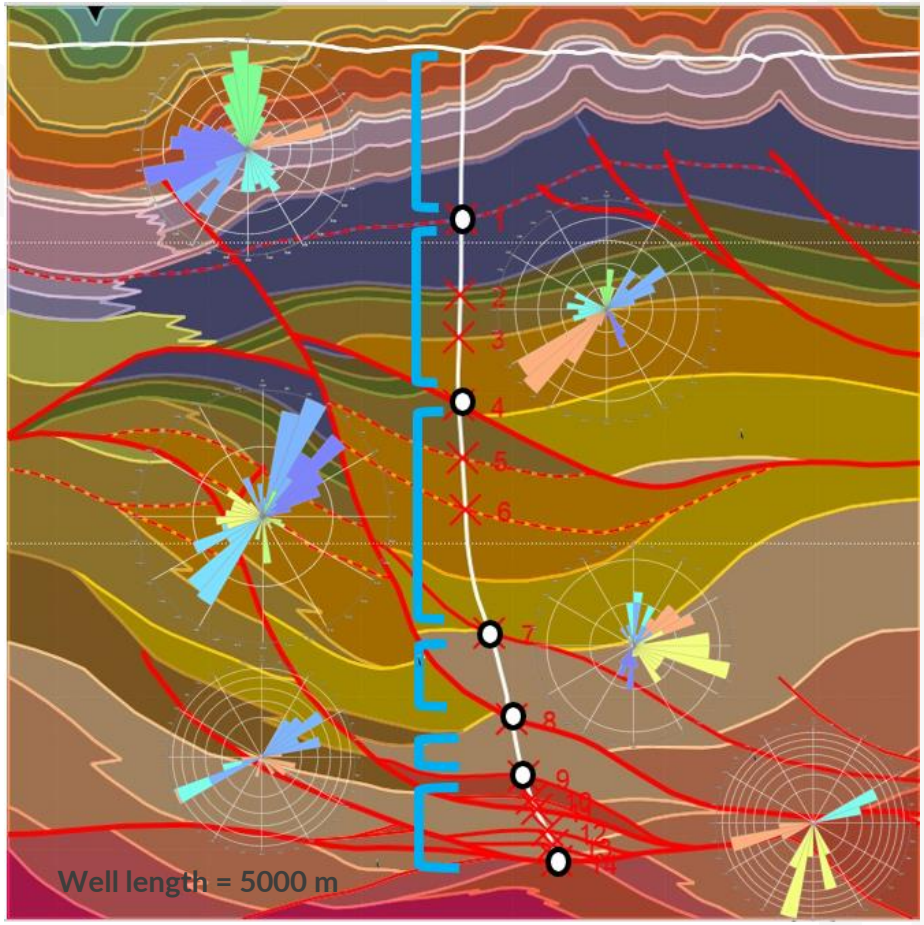

Key findings from the study areas

3. Ardennes (for Havelange), metasedimentary rocks not tectonically overprinted

- Pragian quartzites (Devonian) are considered to have the best potential as a geothermal reservoir rocks

- Reinterpretation of well logs have enabled new litho-structural interpretation

- XRD, Raman, SEM/EDS and calcimetry analyses have helped understand the mineralogy and the degree of metamorphism

- Spring water samples show numerous physico-chemical that indicate active hydrothermal systems

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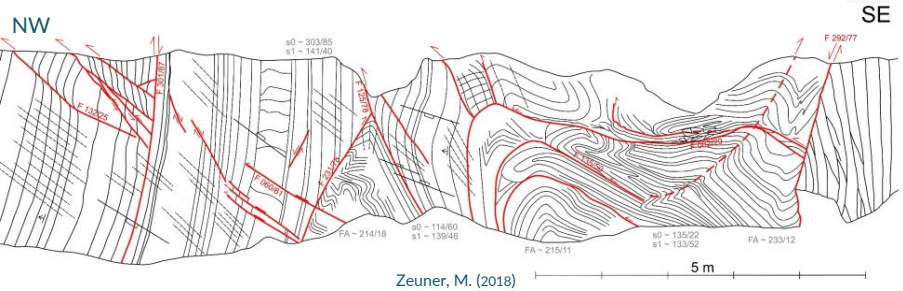
Key findings from the study areas



Zeuner, M. (2018)

4. Harz Mountains (for Göttingen), Metasedimentary rocks tectonically overprinted

- Folds, faults, veins, cleavage and joints have been characterised

- Veins and joints in slates suggest that slates can be reservoir rocks

- Information about lithologies, their mechanical properties and the structures present that have enabled us to make predictions about the rocks beneath Göttingen

- Limitations in the use of the Harz Mountains as an analogue include differences in cover sequences, post-Variscan structures, tectonic settings, stresses and fluid pressures

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Contents

Lessons learnt about the use of analogues

Lessons learnt about the use of analogues

1. Clarity about problems to be solved

Typical questions that may be asked about a potential exposed analogue:

- Is the field area being used to illustrate a palaeo hydrothermal system, or is it being used to make predictions about present-day fluid flow in the sub-surface?

- What lithologies and lithological relationships occur?

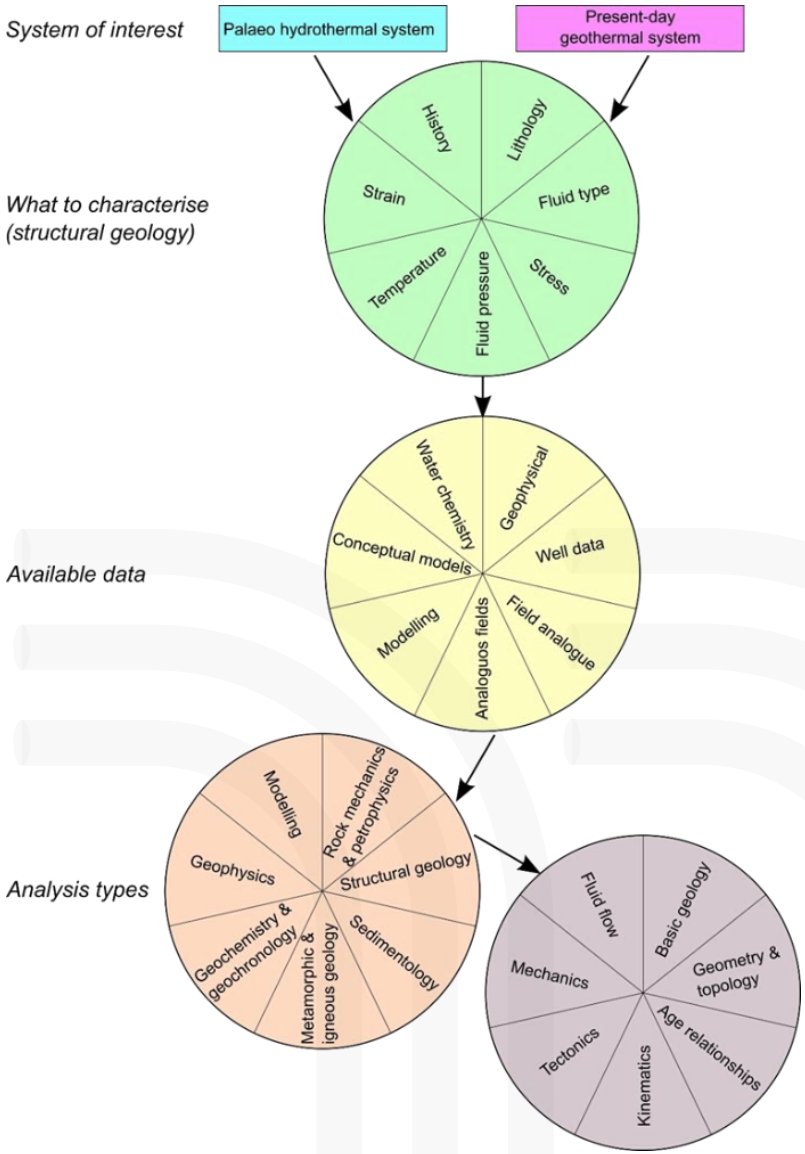
- Can rock samples be collected that are suitable for triaxial testing and geochemical analyses?

- What structures occur in the exposed analogues?

- What are the spatial and temporal relationships between those structures?

- What frequencies and patterns of open fractures occur in different lithologies?

- Is there evidence of hydrothermal fluids in spring water?



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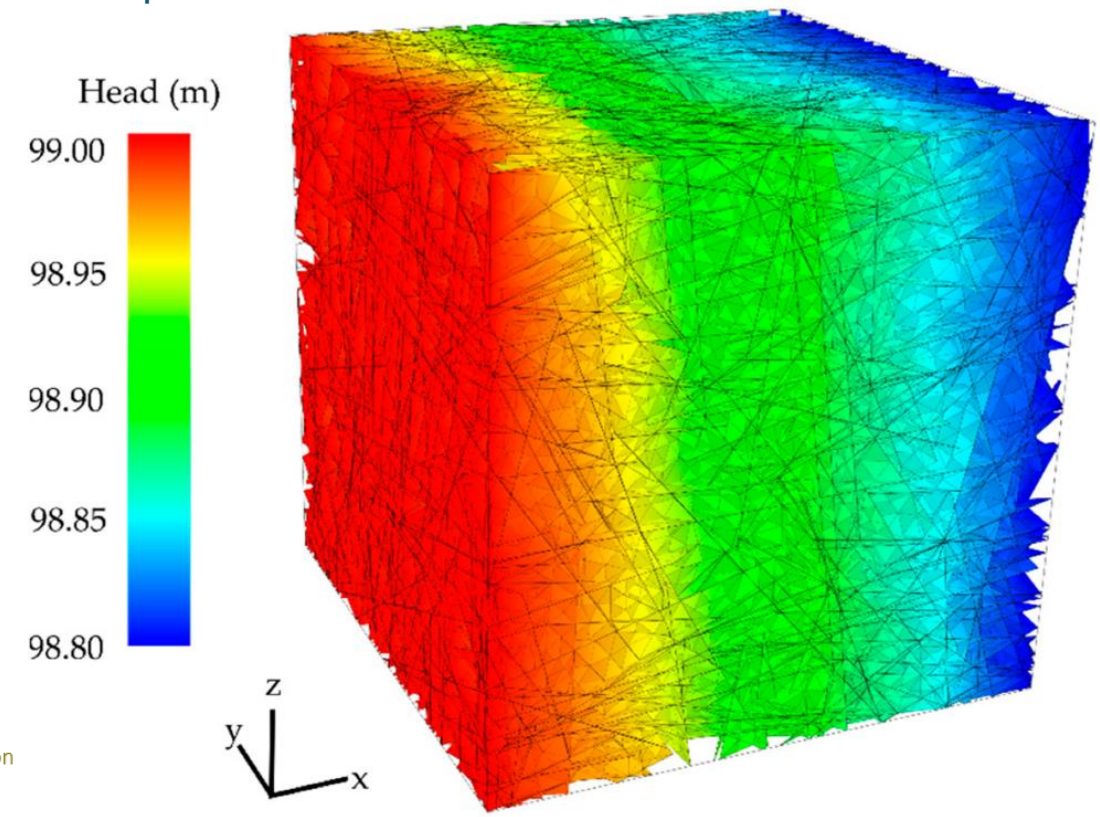
Lessons learnt about the use of analogues

2. Understanding needs of other disciplines

Field analogues can provide input data for people who are not field geologists.

It is therefore important to:

- Understand the data they need
- Let them know what data you can and cannot provide
- Express the uncertainties in the field data, including the ranges of likely values
- Define the geological terms used clearly for non-geologists
- Make sure there is common under-standing of the terms used



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Lessons learnt about the use of analogues

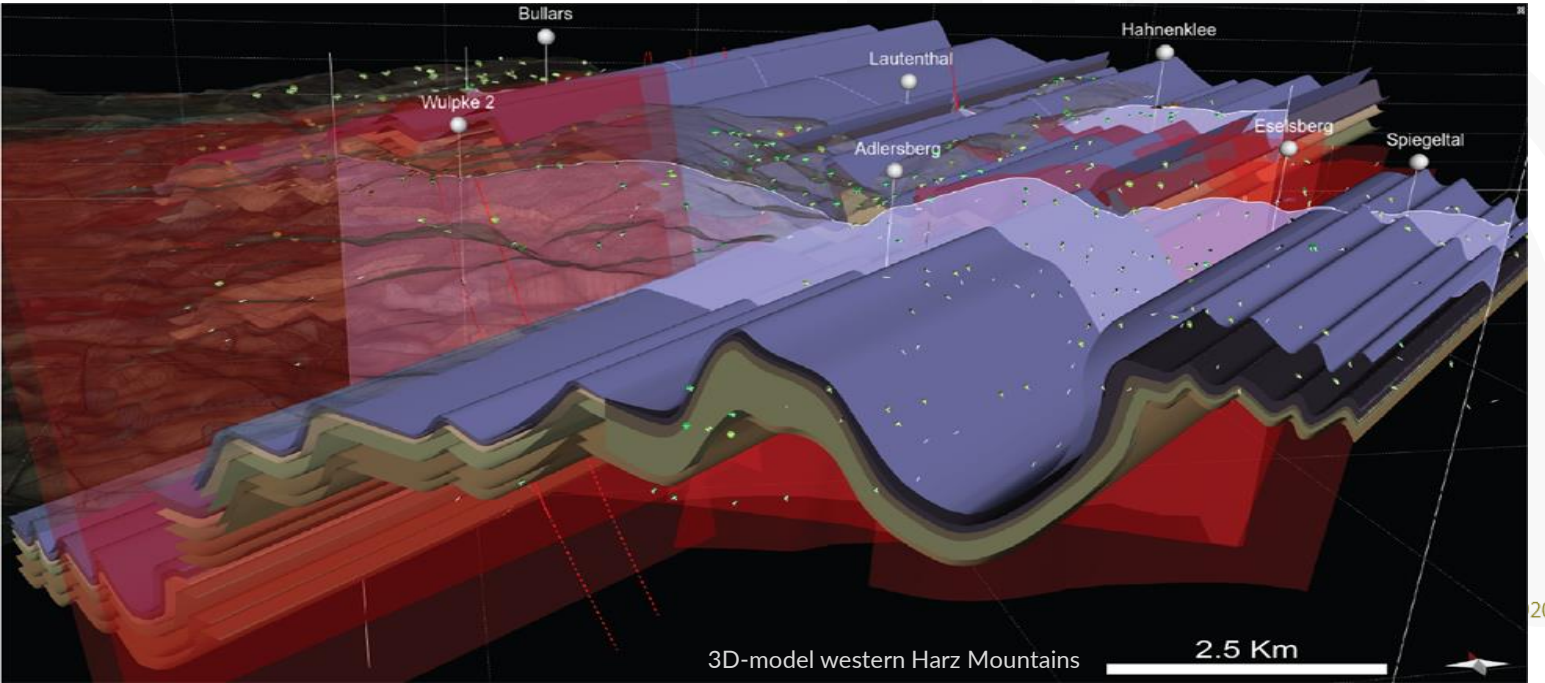
3. What field analogues can and cannot tell you

What they *can* tell you about:

- Lithologies
- Folds, faults, veins, etc.
- Deformation and fluid flow history
- Aspects of mechanical behaviour (e.g. mechanical stratigraphy)

What they *cannot* tell you about the present-day sub-surface:

- With any certainty, the open fractures and fracture porosity
- Stresses, temperatures and fluid flow
- Field analogues do not provide enough detailed information to create a meaningful model for fluid flow in the sub-surface



3D-model western Harz Mountains

Lessons learnt about the use of analogues

4. Choice of field analogues

No field analogue is a perfect match to the sub-surface, but the field area must show enough commonality to the reservoir to make it meaningful, including similar:

- Lithologies, including lithological relationships, bed thicknesses, weathering, etc.
- Folds, faults, veins and joints geometries
- Age relationships
- Kinematics
- Mechanical properties
- Tectonic settings and
- Fluid flow histories, including likely porosities, permeabilities, phases of fracturing and mineralisation.

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Lessons learnt about the use of analogues

5. Use of the term "fracture"

It has become common for "fracture" to be used as a field description, but this means that key information is lost

Different fractures have different origins, distributions and properties.
For example:

- Veins are commonly clustered around faults and in fold hinges

- Joints are typically more distributed through a rock mass

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Lessons learnt about the use of analogues

6. Palaeo fluid flow vs. present-day fluid flow

Different fractures also have different implications for fluid flow. For example:

- Veins contains minerals that give information about ancient fluid flow
- Joints are not mineralised, so are more likely to give information about present-day fluid flow

It is therefore important to be clear whether you are studying the field area and particular structures to obtain information about palaeo hydrothermal systems or about present-day fluid flow in the sub-surface

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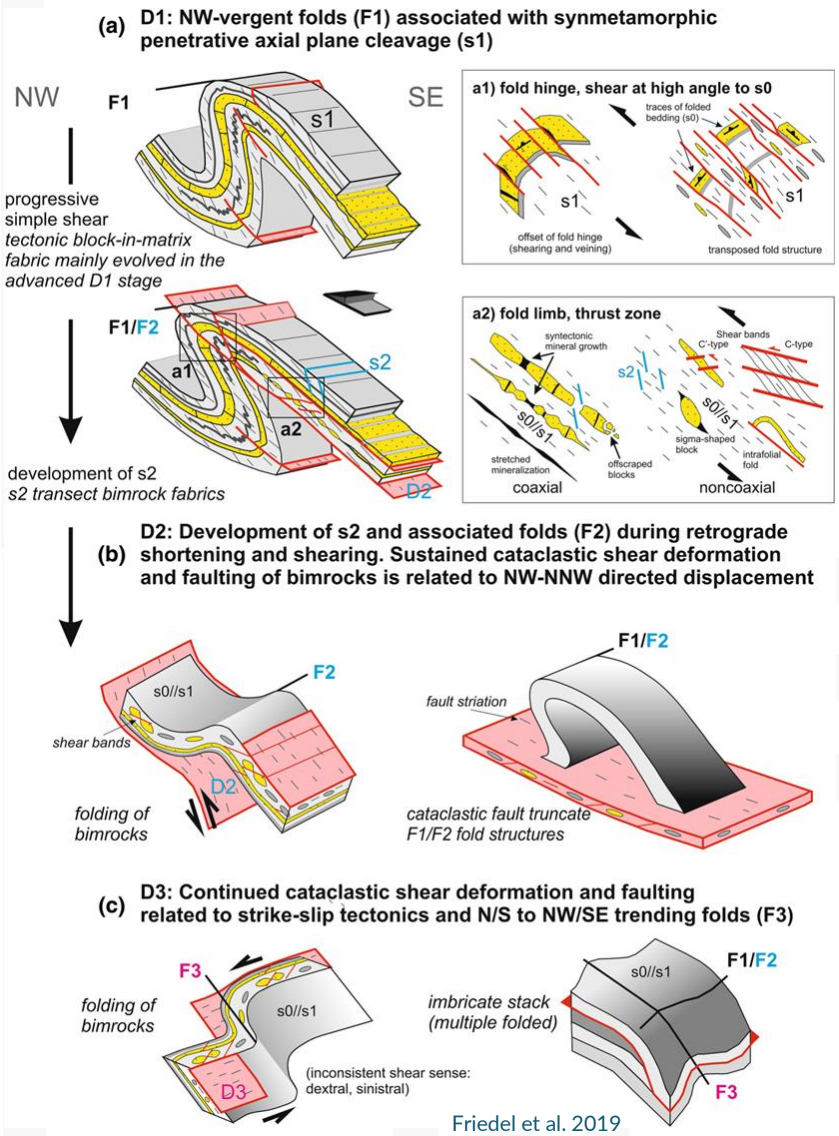
Lessons learnt about the use of analogues

7. Avoid distracting topics

- Analogues are studied to give information about reservoir rocks

- The MEET demonstration sites have Variscan reservoir rocks, so understanding Variscan tectonics is import

- There is, however, a tendency for the field study to become *about* Variscan tectonics rather than about use of the area as an analogue



Friedel et al. 2019

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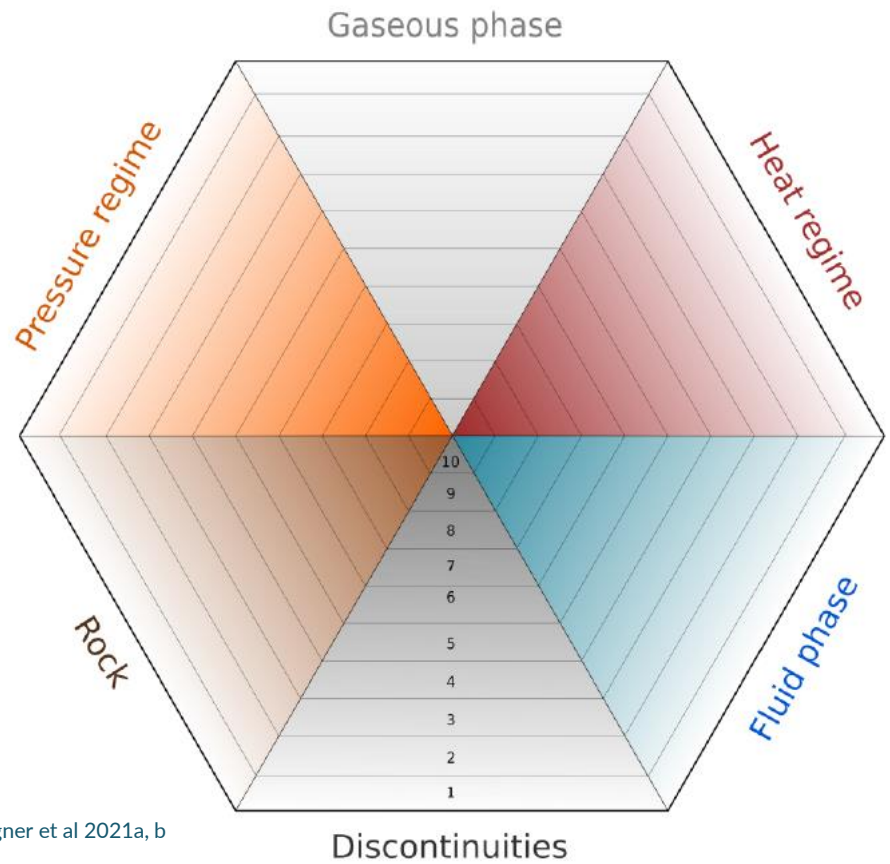
Conclusions: Better integration in the analysis of geothermal reservoirs

The "hexagon concept" for analysing geothermal plays

Compartments of geothermal reservoir



Wagner et al 2021a, b

Parameter level	Methods
Level 10 Reservoir model output (T/H/C/M models)	Numerical modeling & simulation
Level 9 Calculated from other parameters	Calculation
Level 8 Stochastic approaches & data synthesizing	
Level 7 Interpolated & extrapolated (based on limited data sources)	Interpolated between data points, extrapolated to depth
Level 6 Common standard values	Expert knowledge, widely accepted values, bench-mark measurements
Level 5 Measured in labs (rock samples, thin sections, ...)	Petrophysical, thermophysical, hydrochemical & fluid-rock inter-action experiments, mineralogi-cal, microscopic & texture analysis
Level 4 Measured within near or distant mines, caves or drill holes	Borehole geophysical logging, structural, petrological, hydro-logical & geophysical quanti-tative subsurface data acquistion
Level 3 Measured at drill hole top (near or distant drill holes)	Pumping tests, mud logging, fluid measurements
Level 2 Measuread at surface (outcrops, springs, topsoil, ...)	Structural, petrological, hydro-logical & geophysical quanti-tative surface data acquistion
Level 1 Described at surface (outcrops, springs, ...)	Structural,petrological, hydro-logical & hydrogeological surface field work

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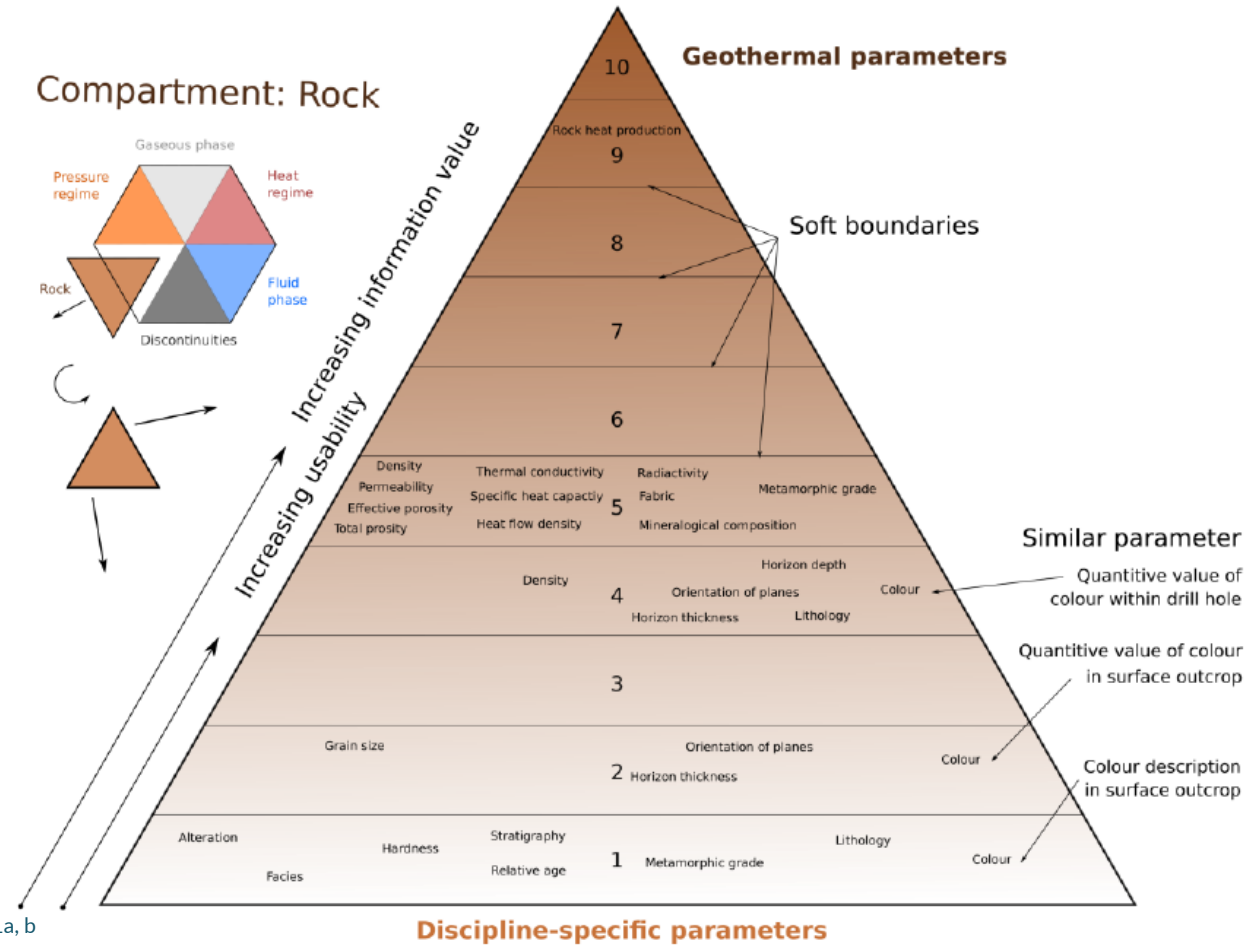
Conclusions: better integration in the analysis of geothermal reservoirs

The "hexagon concept" for analysing geothermal plays



Wagner et al 2021a, b

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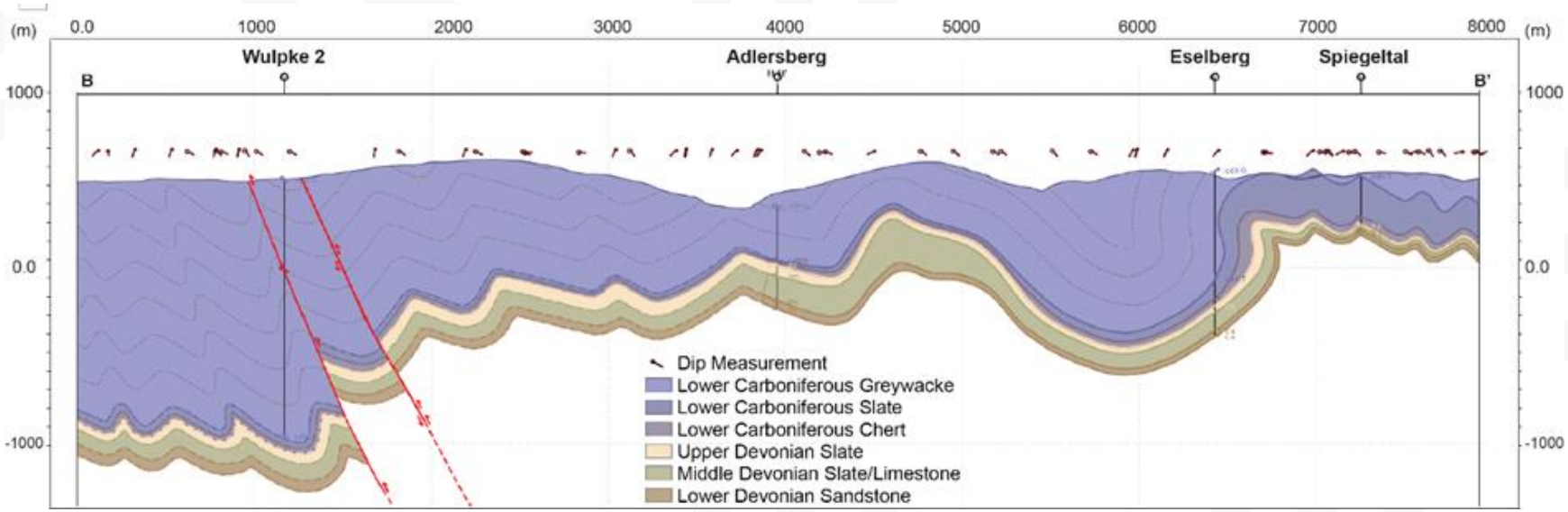
Conclusions: Approaches for better integration in the analysis of geothermal reservoirs

1. Use exposed analogues to determine the ranges and variabilities of such factors as rock mechanical properties and geometries of structures also in regard to scale invariance



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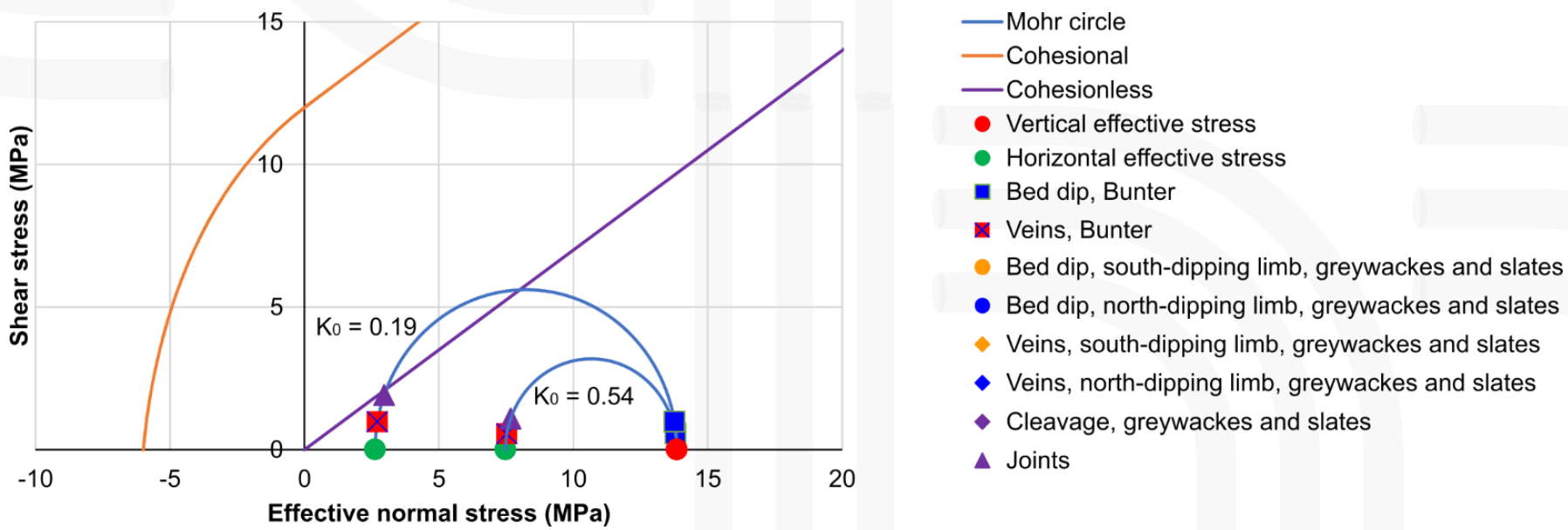
Conclusions: Approaches for better integration in the analysis of geothermal reservoirs

2. Modelling techniques need to be used that are properly suited to answering the right questions at early stages of geothermal assessment, and that are feasible based on the data available at the pre-drilling stage



Deliverable 5.7; Peacock et al., 2021

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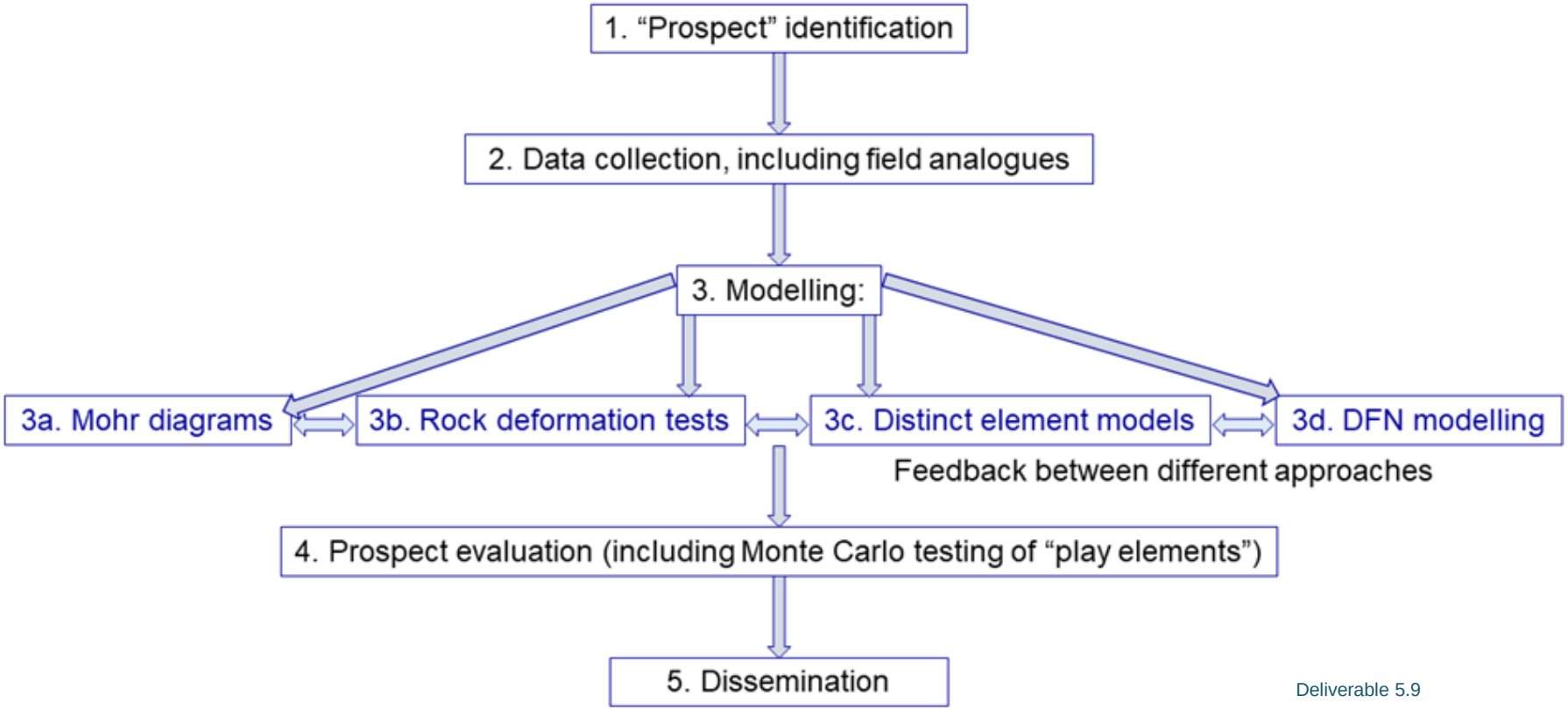
Conclusions: Approaches for better integration in the analysis of geothermal reservoirs

3. Improved workflows are needed for assessing geothermal reservoirs



Deliverable 5.9

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Conclusions: Approaches for better integration in the analysis of geothermal reservoirs

4. Improvements are needed in communication and knowledge transfer between different disciplines, especially between geologists, modellers and engineers

Thank you for your attention!

Team of the analogue studies in MEET

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