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Supplement of

Site selection for the best clay-hosted repository in Switzerland

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Interdisciplinary research symposium
on the safety of nuclear disposal practices

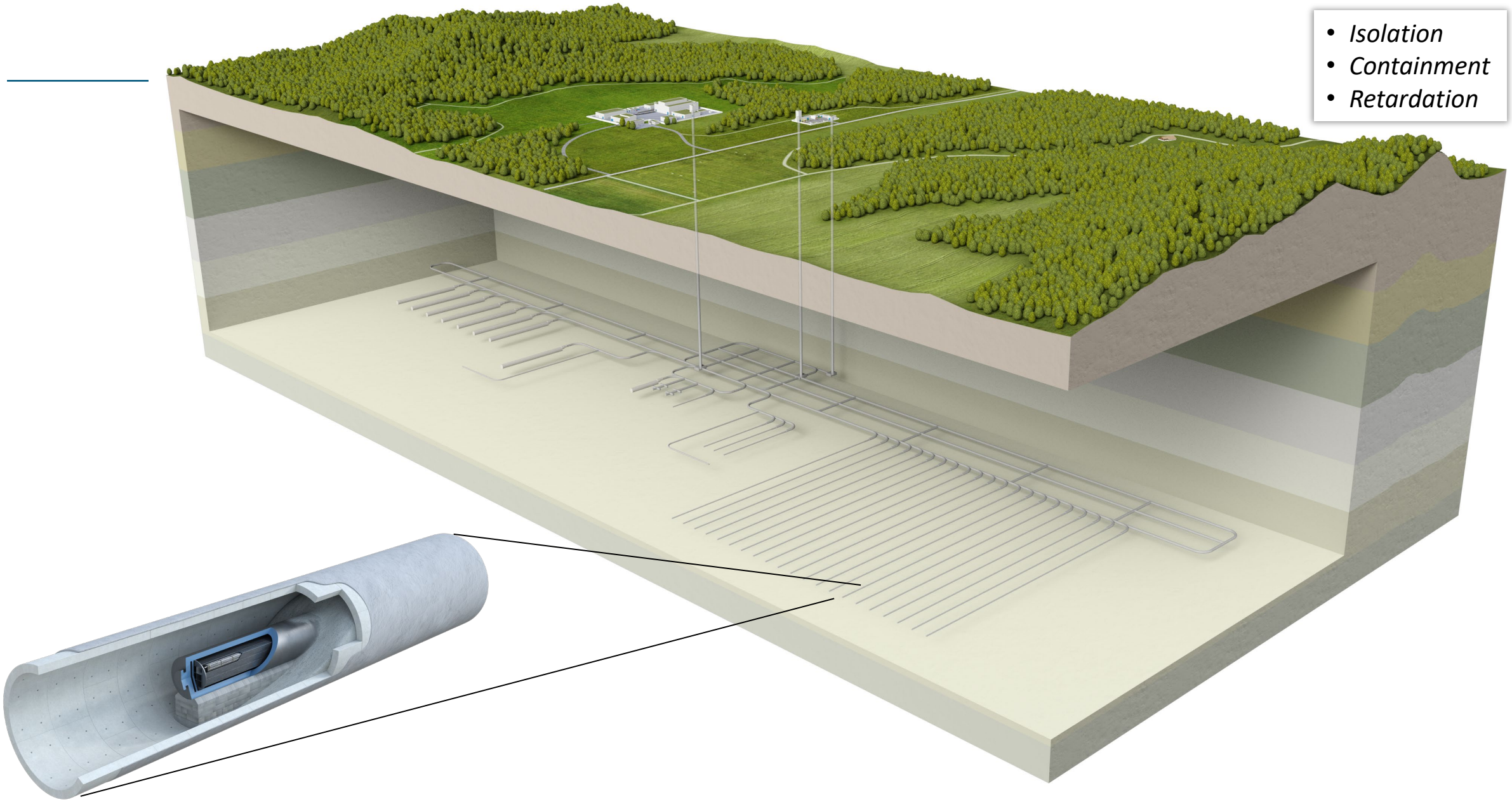
Site selection for the best clay-hosted repository in Switzerland

Tim Vietor and Michael Schnellmann

National Cooperative for the Management of Radioactive Waste

Swiss storage for 12.400 fuel elements and 600 pcs of vitrified waste

- *Isolation*
- *Containment*
- *Retardation*



White map to site: 2008 re-start of process

Criteria for site evaluation: safety and technical feasibility

- 13 criteria in 4 groups
- For all steps of the site-selection process
- No cut-off values
- Application per step to be proposed by implementer

Criteria group	Criteria
1. Properties of the host rock and the effective containment zone	1.1 Spatial extent 1.2 Hydraulic barrier effect 1.3 Geochemical conditions 1.4 Release pathways
2. Long-term stability	2.1 Stability of the site and rock properties 2.2 Erosion 2.3 Repository-induced influences 2.4 Conflicts of use
3. Reliability of geological findings	3.1 Ease of characterisation of the rock 3.2 Explorability of spatial conditions 3.3 Predictability of long-term changes
4. Engineering suitability	4.1 Rock mechanical properties and conditions 4.2 Underground access and drainage

BFE 2008

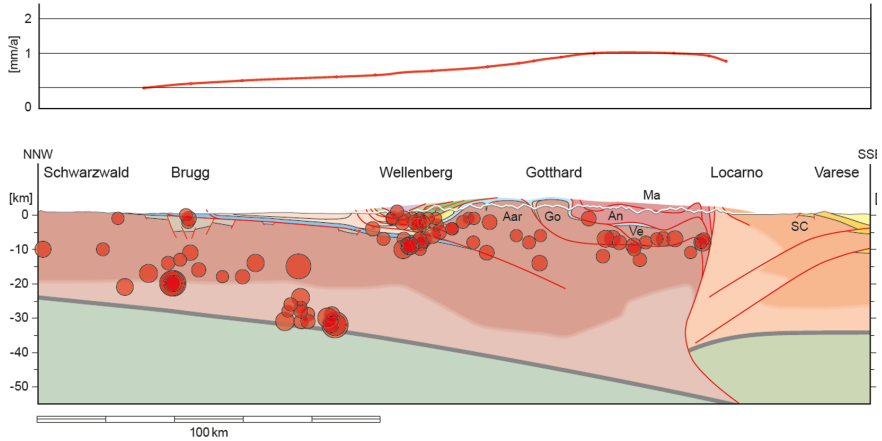
See next slides

Nationwide Stepwise Screening HLW Example: steps 1 and 2

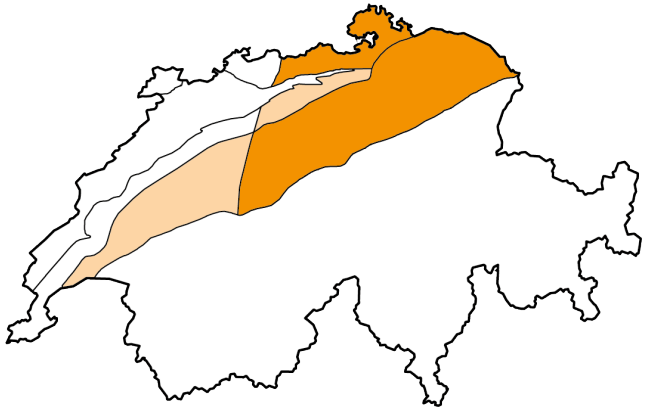
2008 «White Map of Switzerland»

GEODYNAMICS

NW Vertical Uplift Rates [mm/a] SE



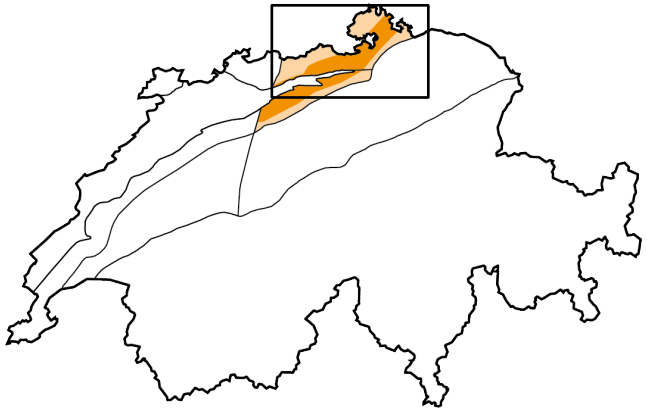
Suitable Geotectonic Units



HOST ROCK DISTRIBUTION

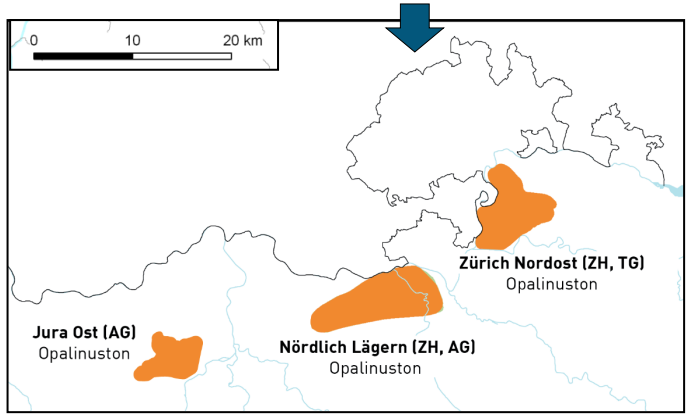
(Depth, Thickness)

Hostrock Configurations



STRUCTURAL FRAMEWORK

(Regional Fault Zones…)



Announcement of site(s): fall 2022

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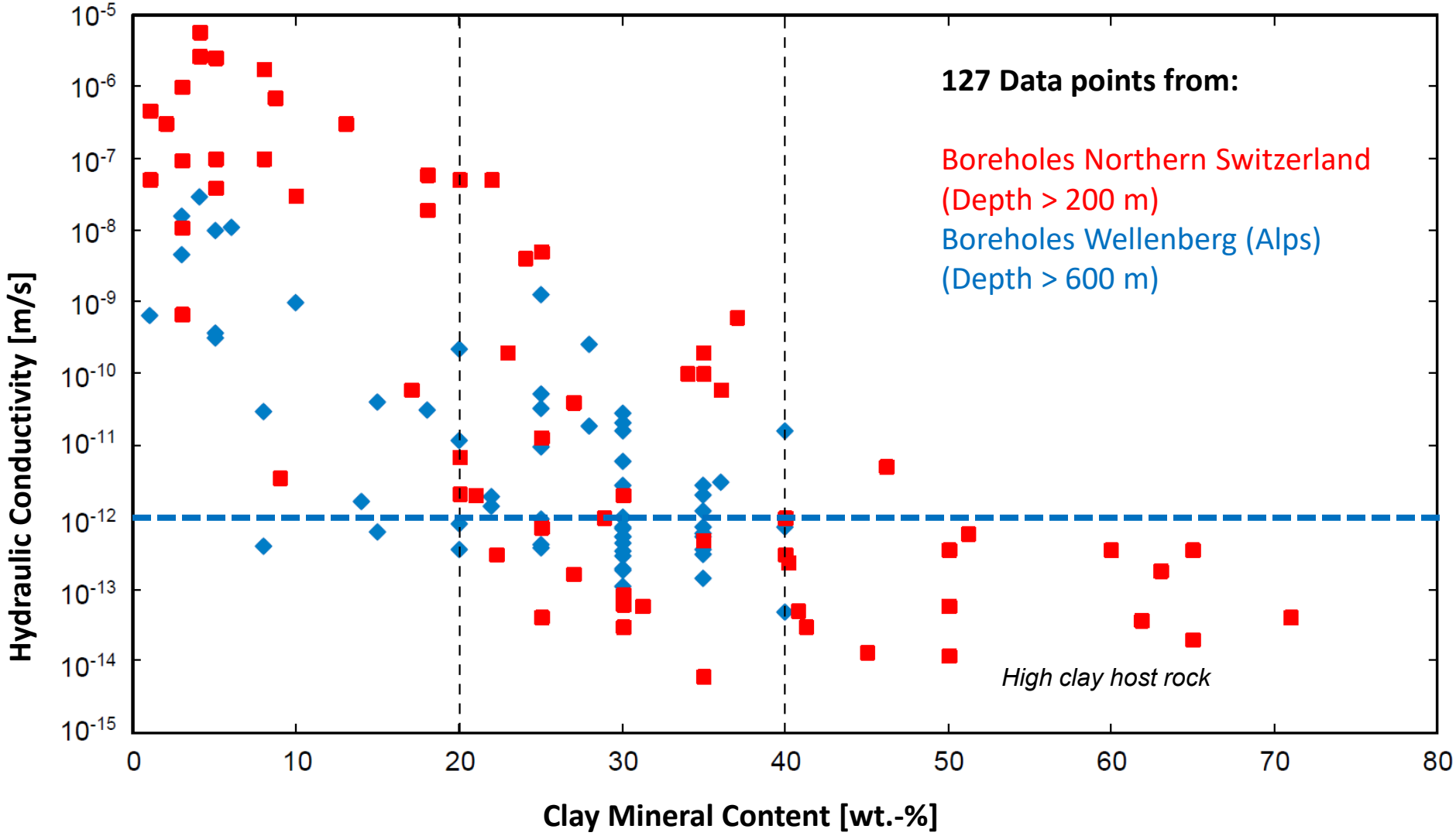
Clay rocks: Low permeability at high clay content



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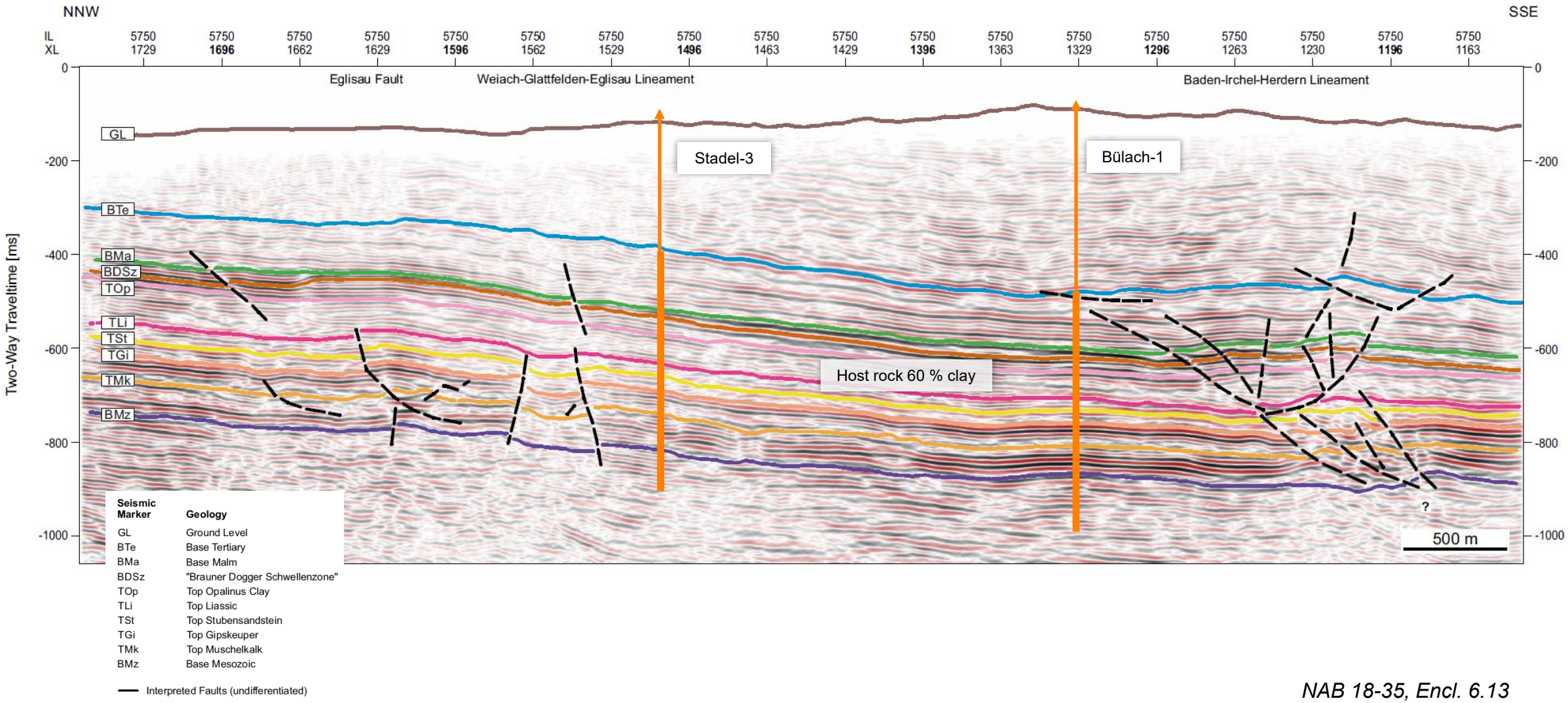
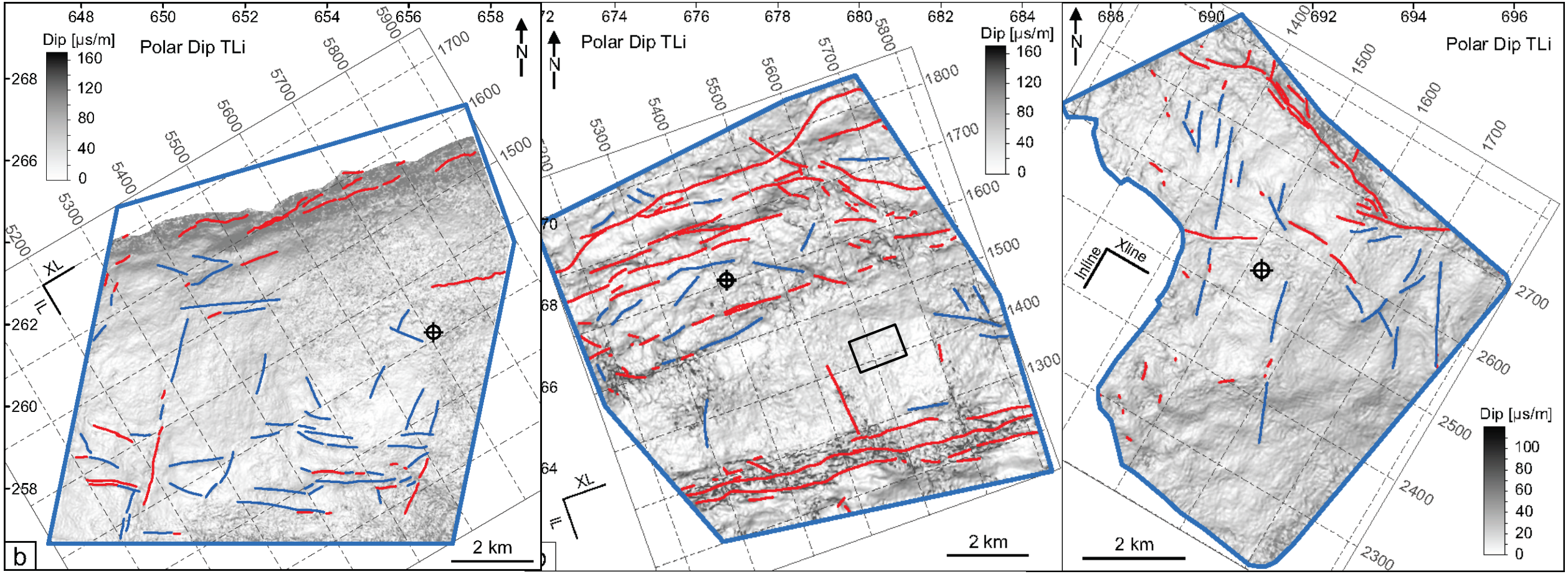
Clays in marine succession: explorable by seismic methods



NAB 18-35, Encl. 6.13

3D Seismics: spatial extent of tectonically quiet zones (crit. 2.1)

Red lines: Faults based on amplitude picking
Blue Lines: indications for minor faults on attribute maps



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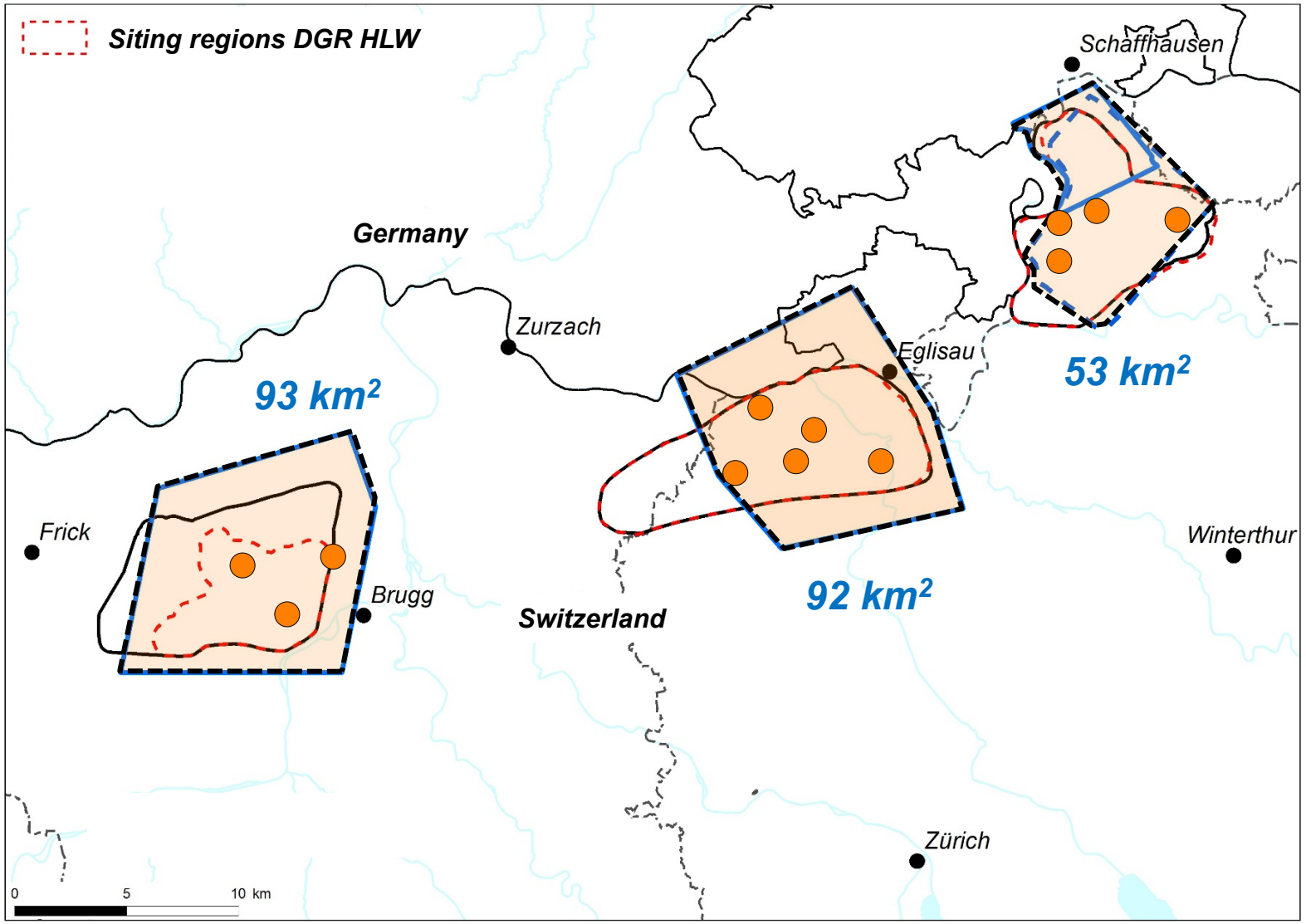
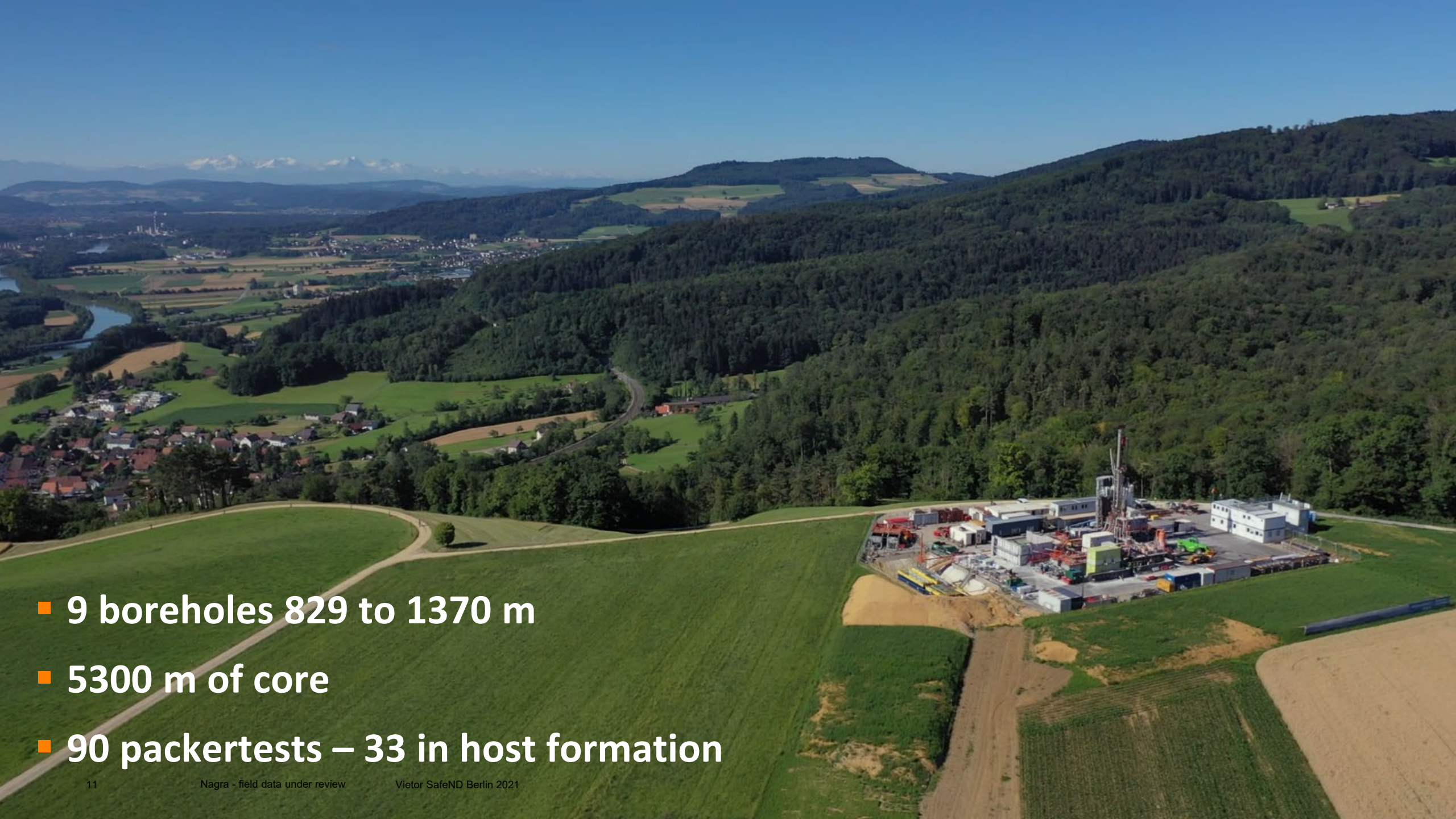
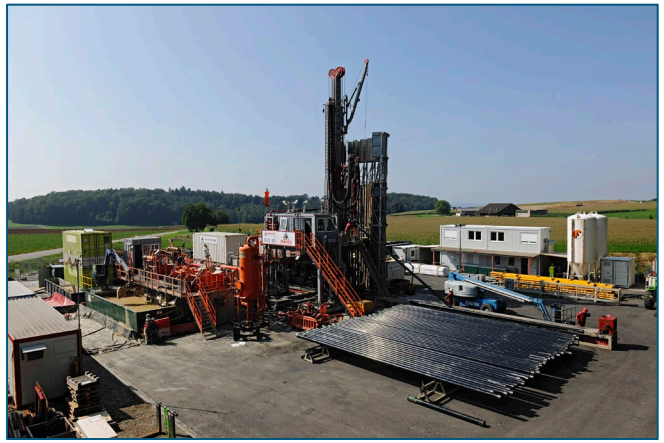
Surface based investigation: Integration of 3D-seismics and boreholes

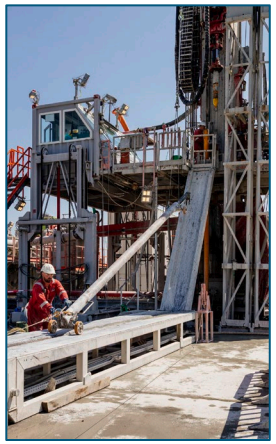


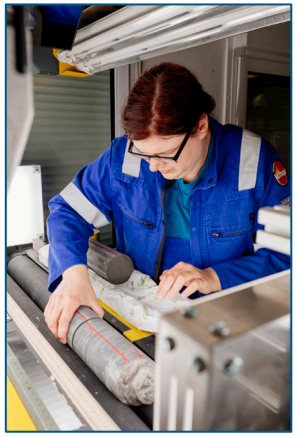


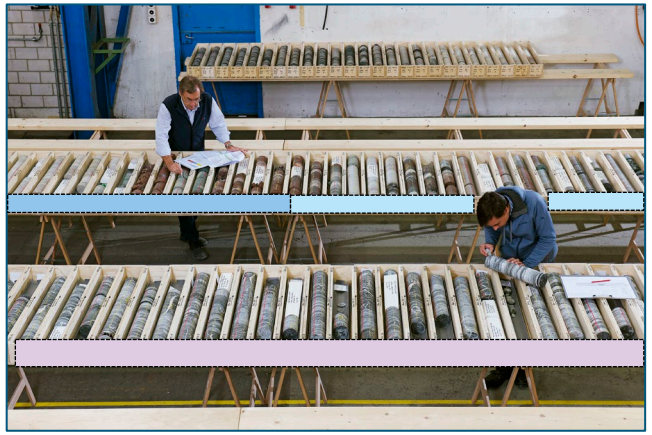
- 9 boreholes 829 to 1370 m
- 5300 m of core
- 90 packertests – 33 in host formation

Drill site to decision base: ensure reliable, reproducible data

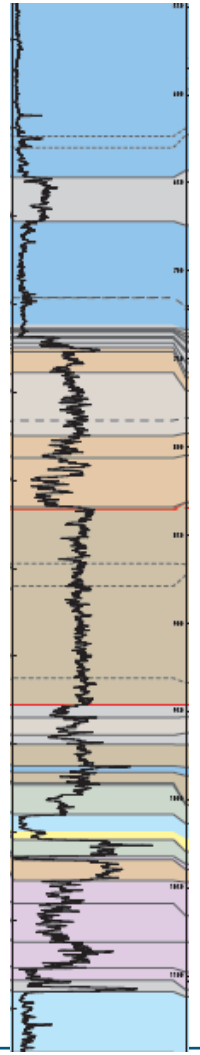








Trüllikon

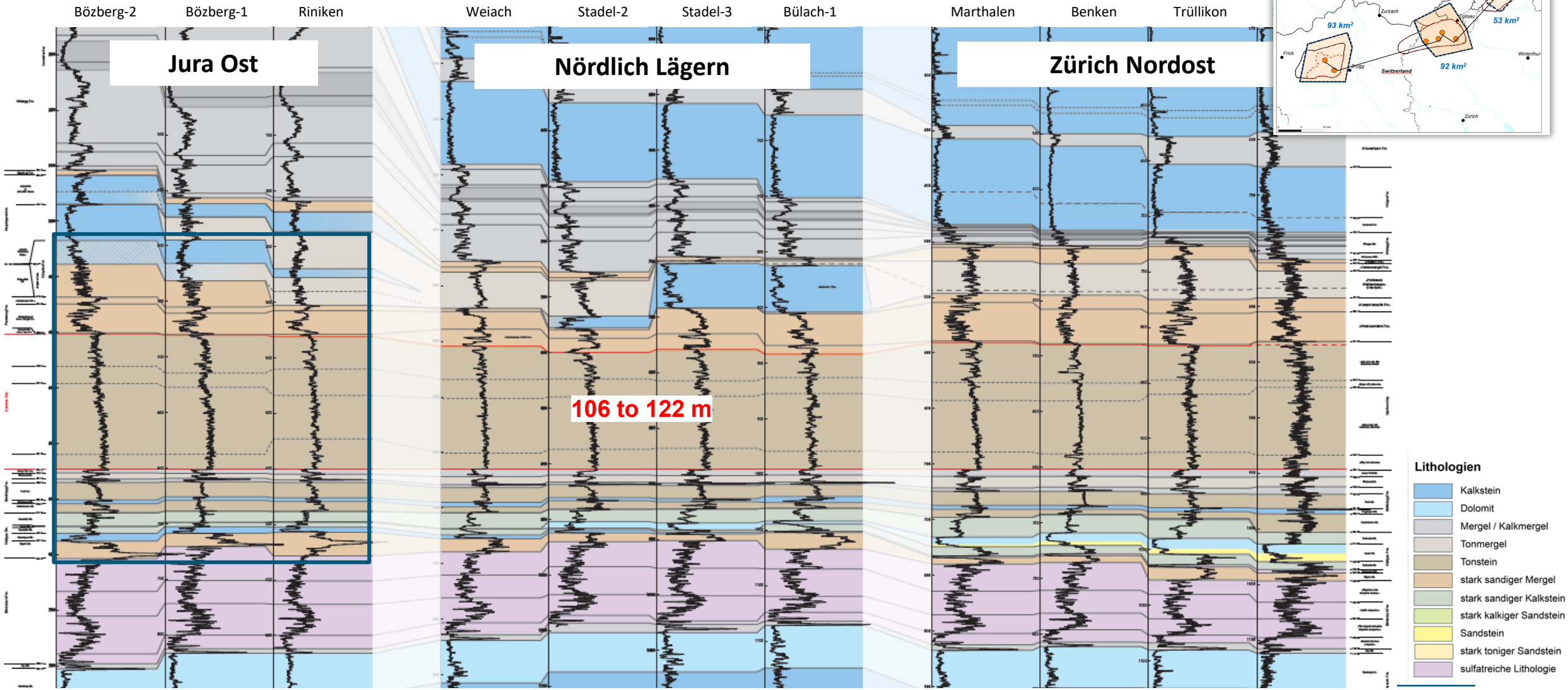


Curves: gamma – count
increasing clay content to right

nagra.

Cored boreholes for comparison of natural barrier layers

Host rock thickness with low variation; differences in surrounding aquitard sequence



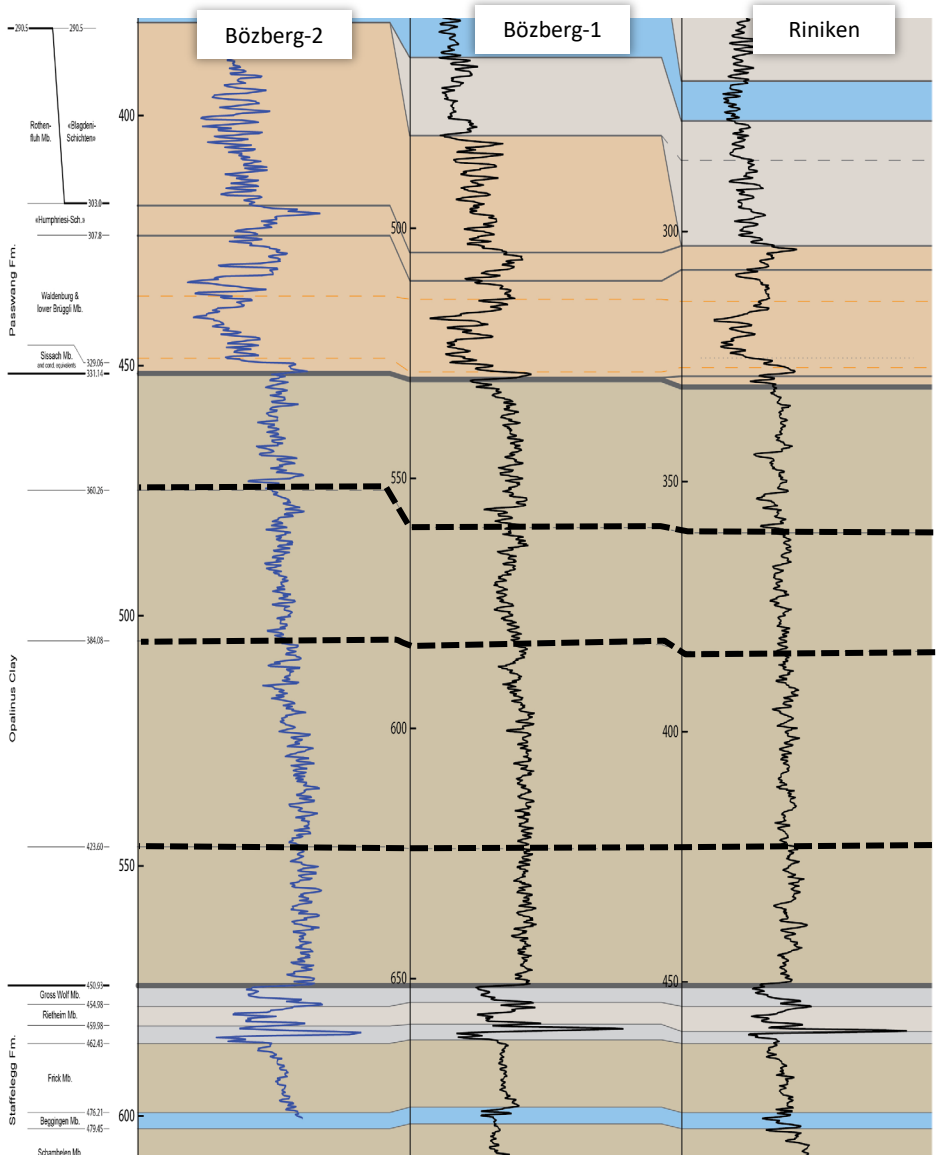
Drilling results

Opalinus Clay

- Stable climate conditions → uniform sediments
- High sedimentation rate
  (10'000 years / 1 m, confining units up to 1 Mio years / 1 m)
- Highly correlatable → 10s of kms very similar
- Little tectonics → uniform thickness

For the DGR

- Average clay content 60%
- Very low hydraulic conductivity (1e-12 m/s or less)
- Reliably self-sealing
- Very low uncertainties
- → **backbone of safety case**



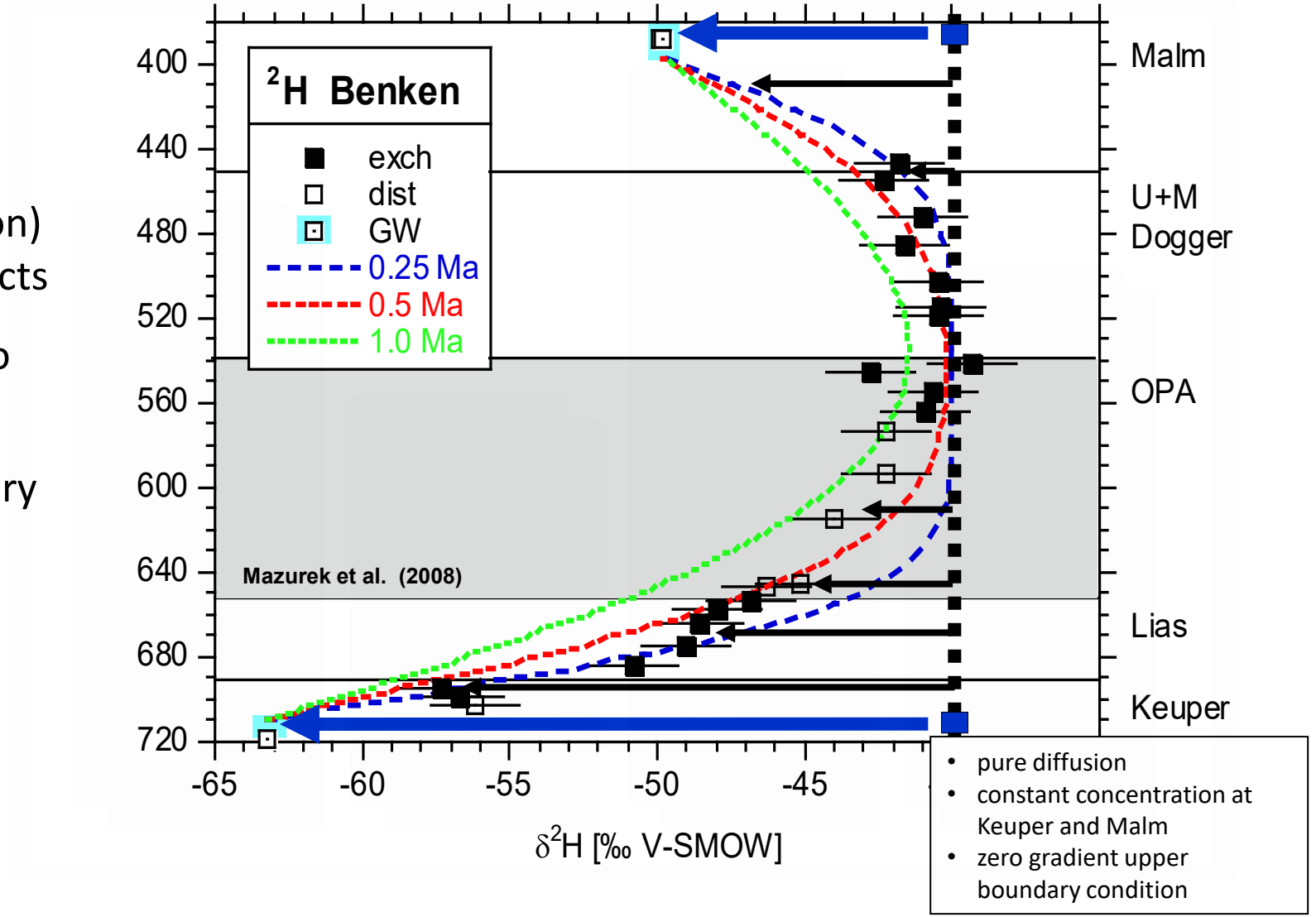
Black curves: increasing clay content to the right

Opalinus Clay

nagra.

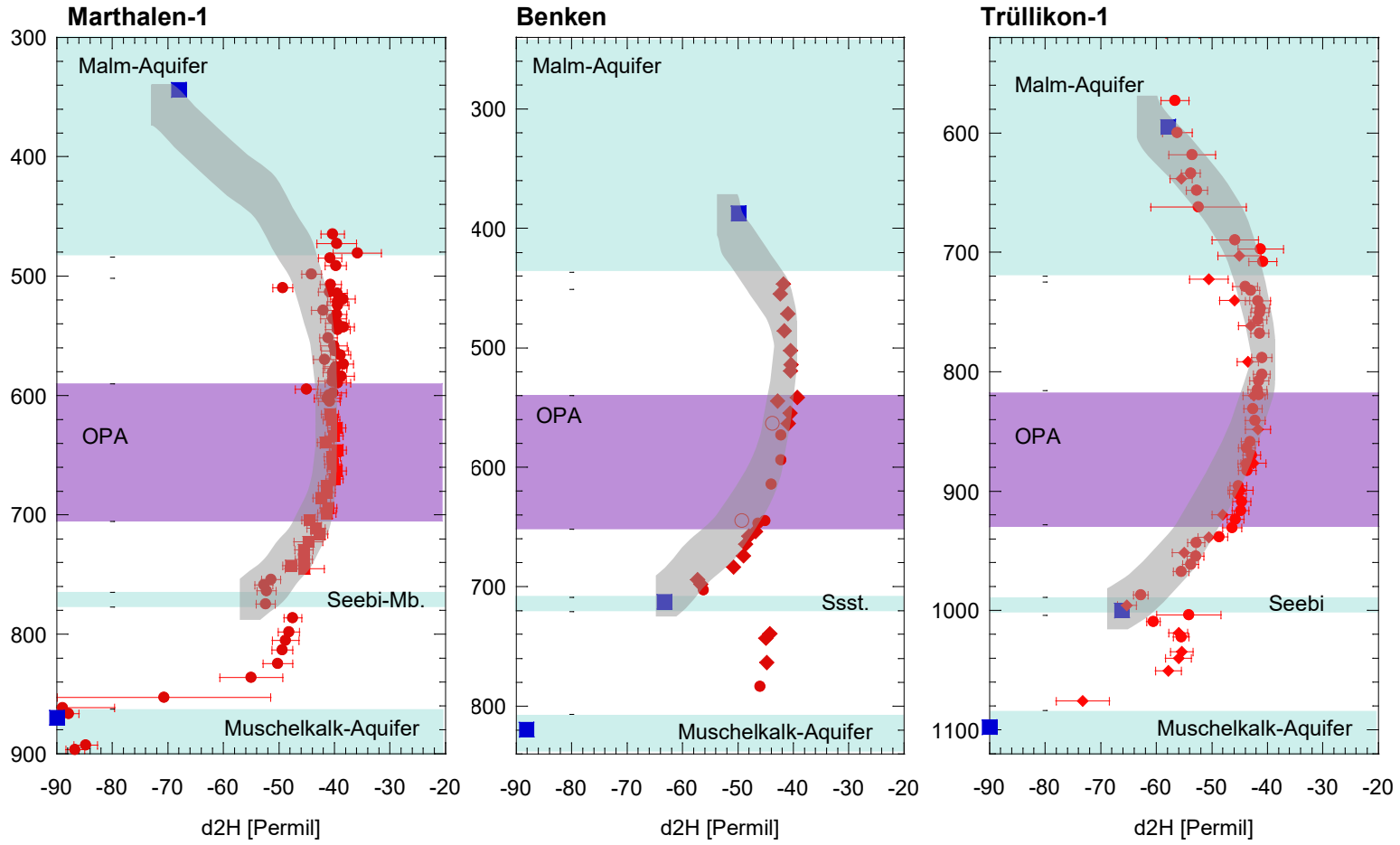
Natural tracer distribution fits hydrogeological history (crit. grp. 1)

- Diffusion properties (plus sorption) govern transport of waste products
- Lab work on rock samples lead to diffusion coefficients
- Diffusion data fit geological history
- Excellent system understanding

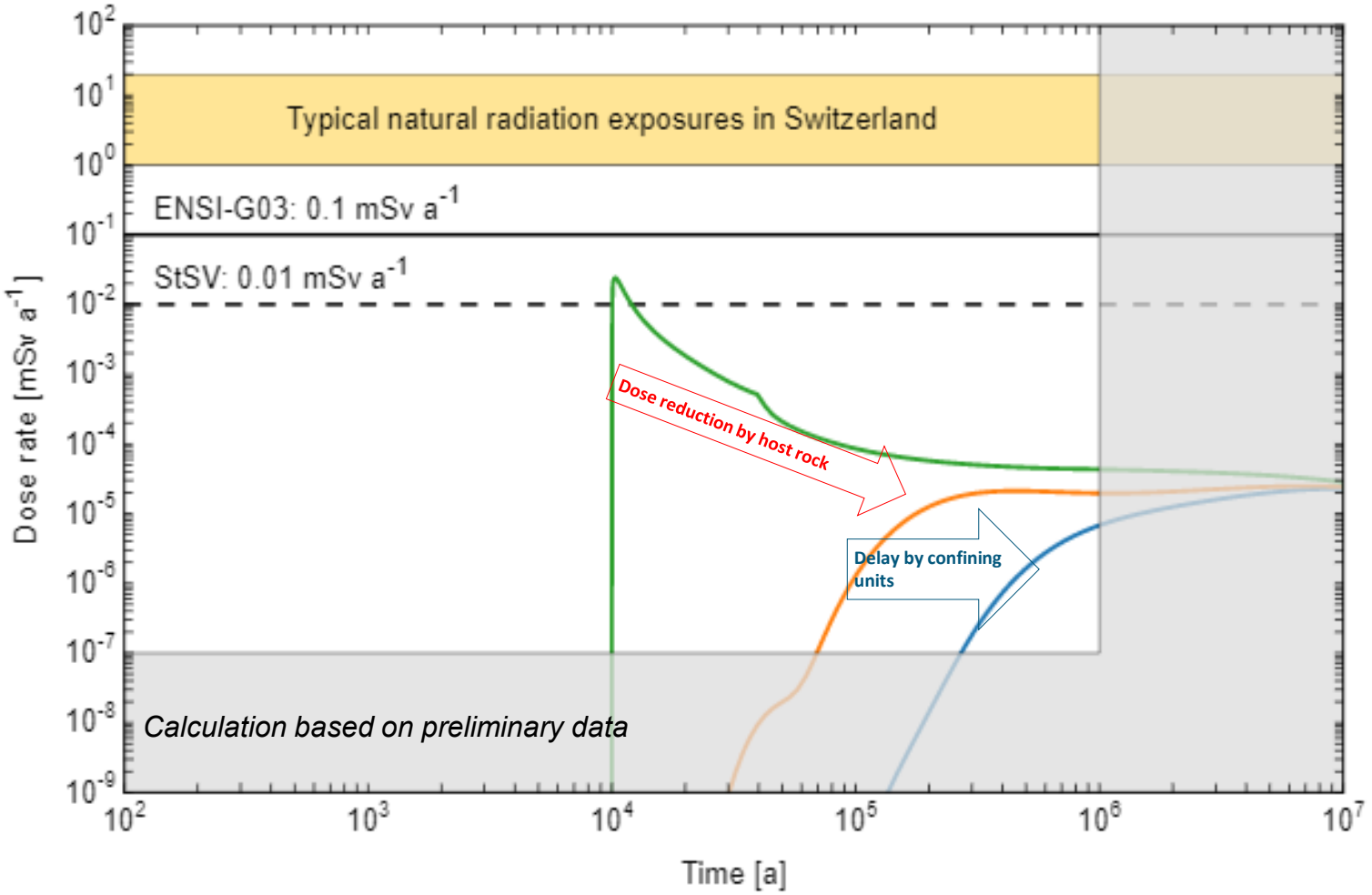


Profiles δ^2H

Porenwasser
Grundwasser



Host rock and confining units lessons from dose calculations



Near field

Geosphere: host rock

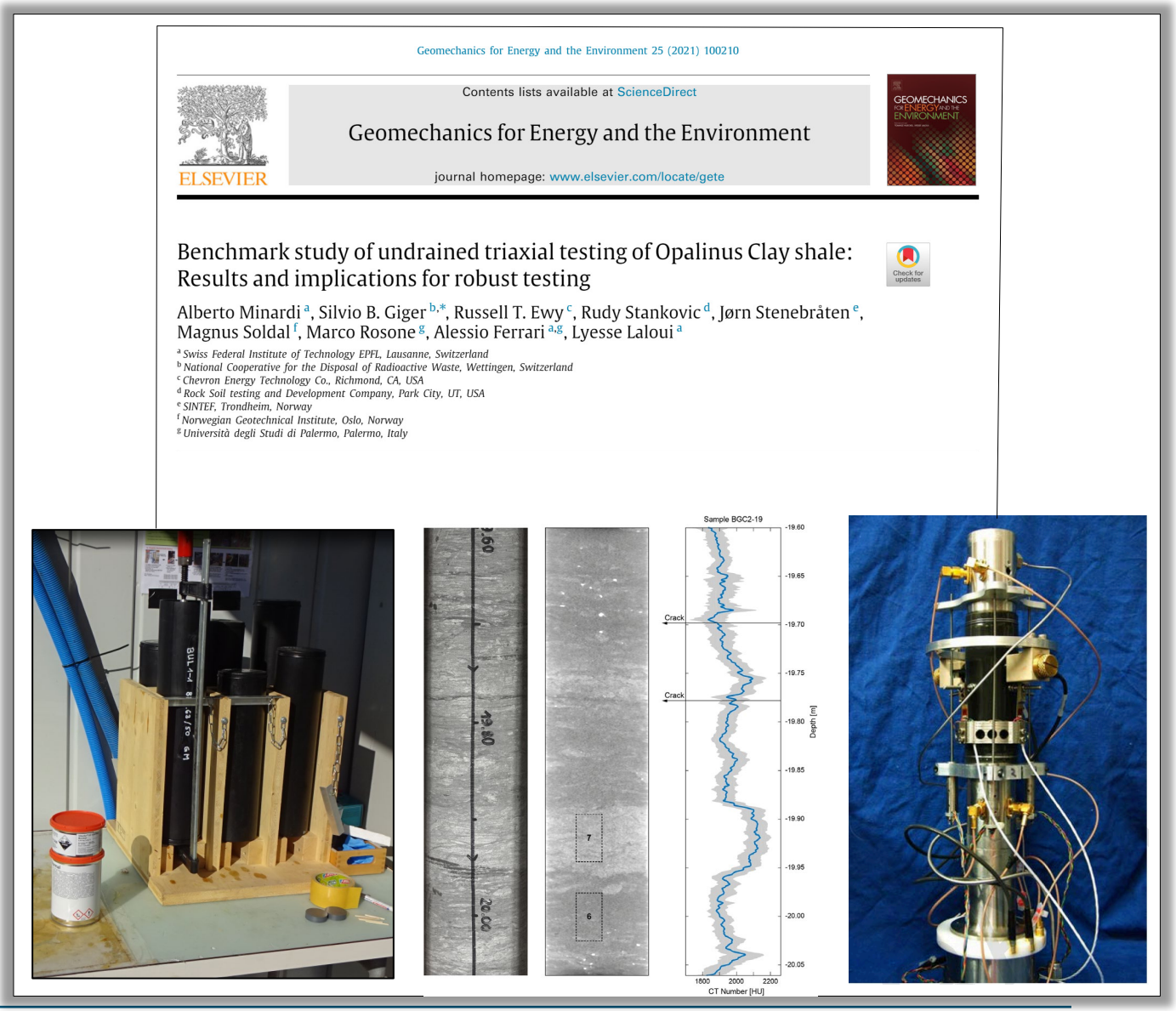
Geosphere: host rock & confining units

Scaling with biosphere dose conversion factors simulates a direct «piping» to the biosphere

nagra.

Construction: revised rock testing methodology

- Sample **Conditioning**
- **CT scan** allows variability assessment
- In-machine saturation / equilibration
- All triax-tests **pore-pressure controlled**
- **multiple labs** for cross checking



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Benchmark study of undrained triaxial testing of Opalinus Clay shale: Results and implications for robust testing

Alberto Minardi [a], Silvio B. Giger [b,*], Russell T. Ewy [c], Rudy Stankovic [d], Jørn Stenebråten [e], Magnus Soldal [f], Marco Rosone [g], Alessio Ferrari [a,g], Lyesse Laloui [a]

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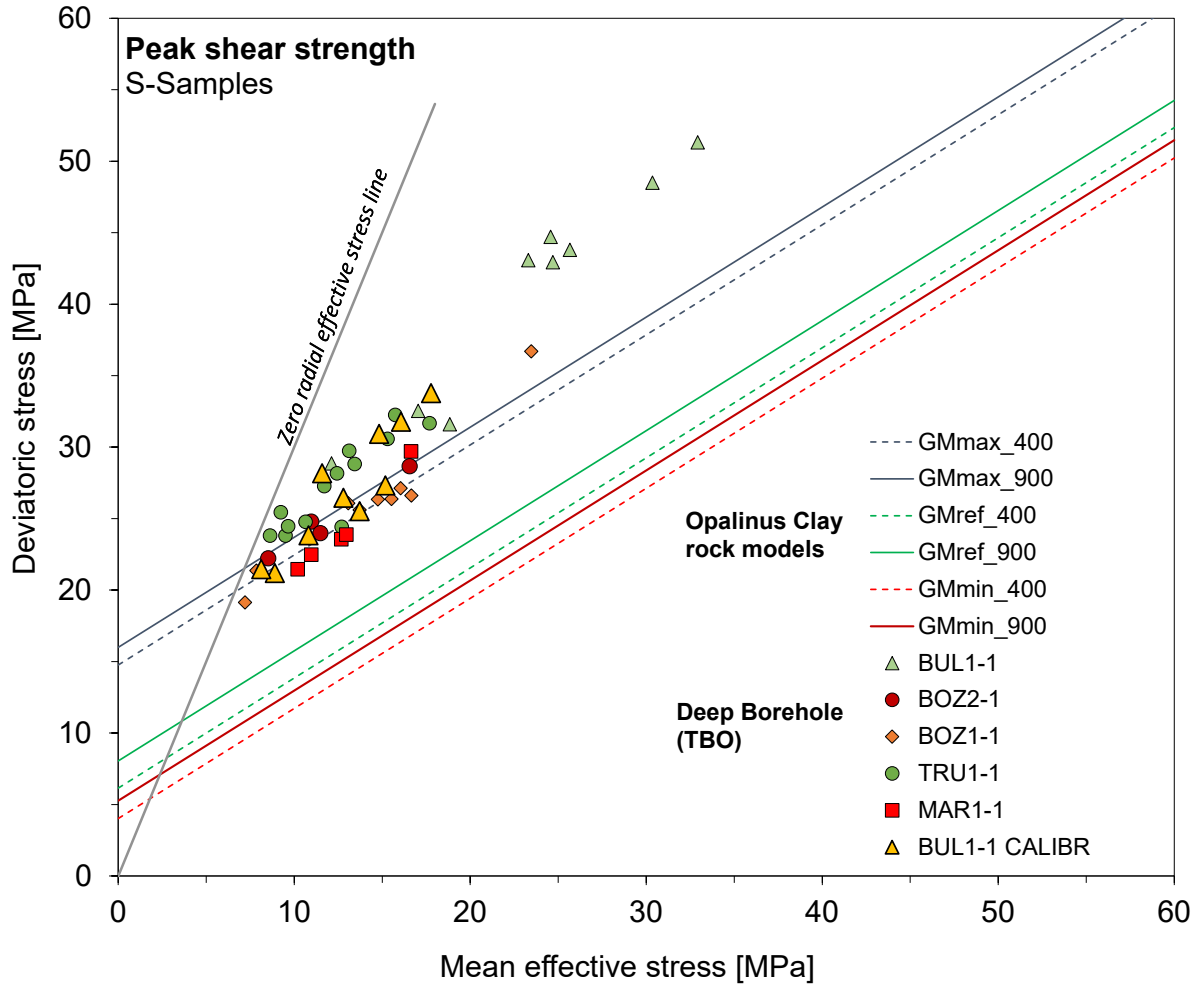
[f] Norwegian Geotechnical Institute, Oslo, Norway
[g] Università degli Studi di Palermo, Palermo, Italy

Construction: core data to emplacement chamber design (crit. 4.1)

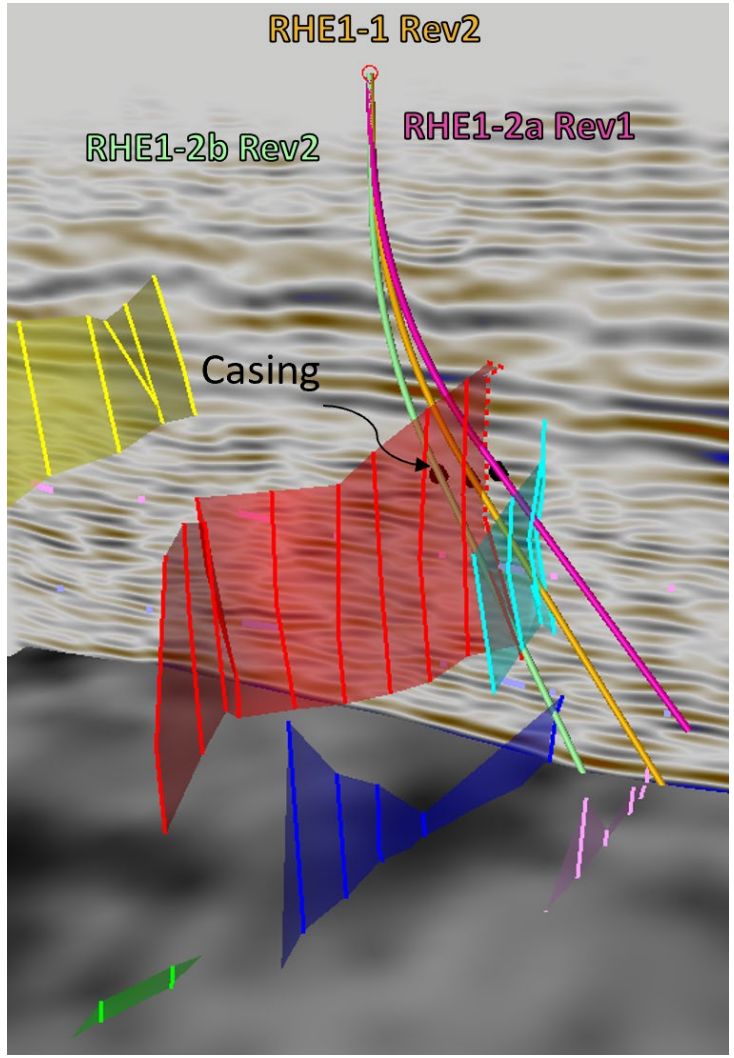
- Rock testing results
  - **low variability**
- Design calculations
  - according to **standard engineering** methods
  - key parameter: **residual strength**
- Effort for construction
  - similar at all sites
  - Repository **at 900 m feasible**

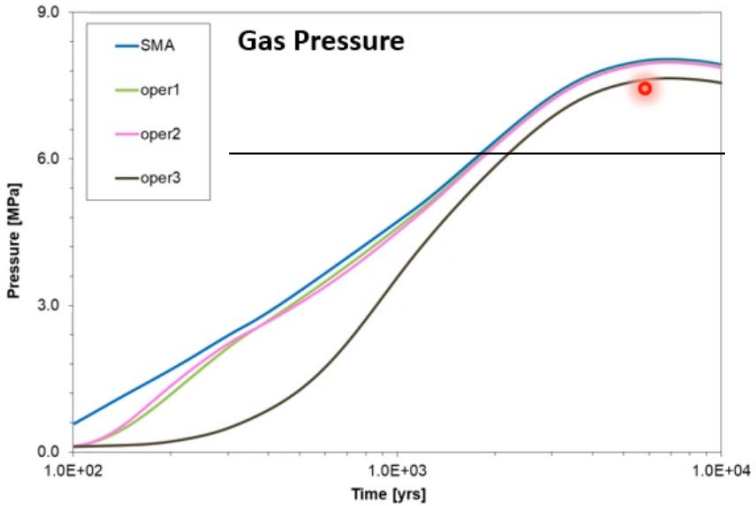
Rock testing results

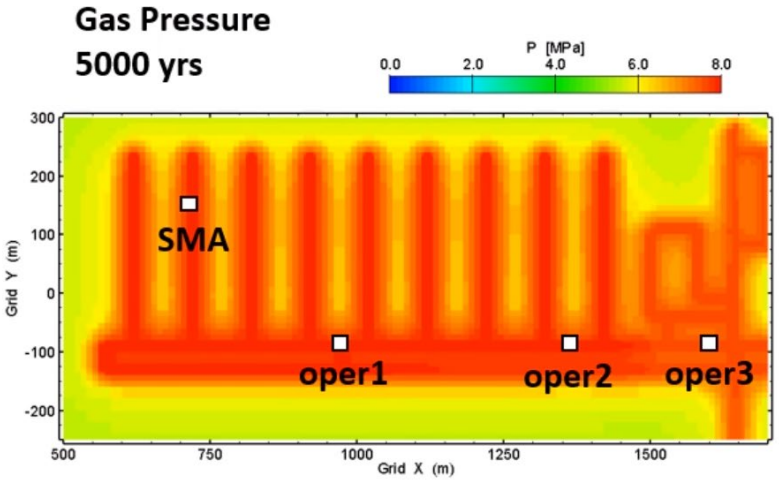


Repository effects: gas transport (L/ILW case)

- gas production in L/ILW
- mainly H_2 from corrosion
- **site conditions and properties** from borehole samples and in-situ tests
- **gas testing of faults**
- model-based assessment
- adjust seal permeabilities to control gas pressure







L/ILW caverns

NTB 16-03

Site selection for the best clay-hosted repository in Switzerland

- **Switzerland with similar site-selection strategy as Germany**
  - White Map
  - Stepwise narrowing-in using technical / scientific criteria
  - Safety driven only («best site»)
  - Transparancy and participitation integrated from the start

Criteria
1.1 Spatial extent 1.2 Hydraulic barrier effect 1.3 Geochemical conditions 1.4 Release pathways
2.1 Stability of the site and rock properties 2.2 Erosion 2.3 Repository-induced influences 2.4 Conflicts of use
3.1 Ease of characterisation of the rock 3.2 Explorability of spatial conditions 3.3 Predictability of long-term changes
4.1 Rock mechanical properties and conditions 4.2 Underground access and drainage

- **2 of 3 steps in Switzerland completed**
  - 3 sites remaining. Similar and simple geology: Flat-lying sediments with 100 m thick clay layer
  - Additional dose by repository far below regulatory limit in all regions
- **3rd step / «Etappe» ongoing**
  - Surface based exploration to feed site selection and safety case
  - Aquisition of reliable high-quality data (undisputable decision basis)
  - Seismic surveys: available space
  - Cored boreholes: depth calibration of seismic data, properties
- **Oct ’22 announcement of site(s)**
- **’24 general license application**