U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD MEETING, JUNE 9, 2026

THE SWISS DEEP GEOLOGICAL REPOSITORY PROJECT 'TERRADURA': FROM SITE SELECTION TO FURTHER PROJECT DEVELOPMENT

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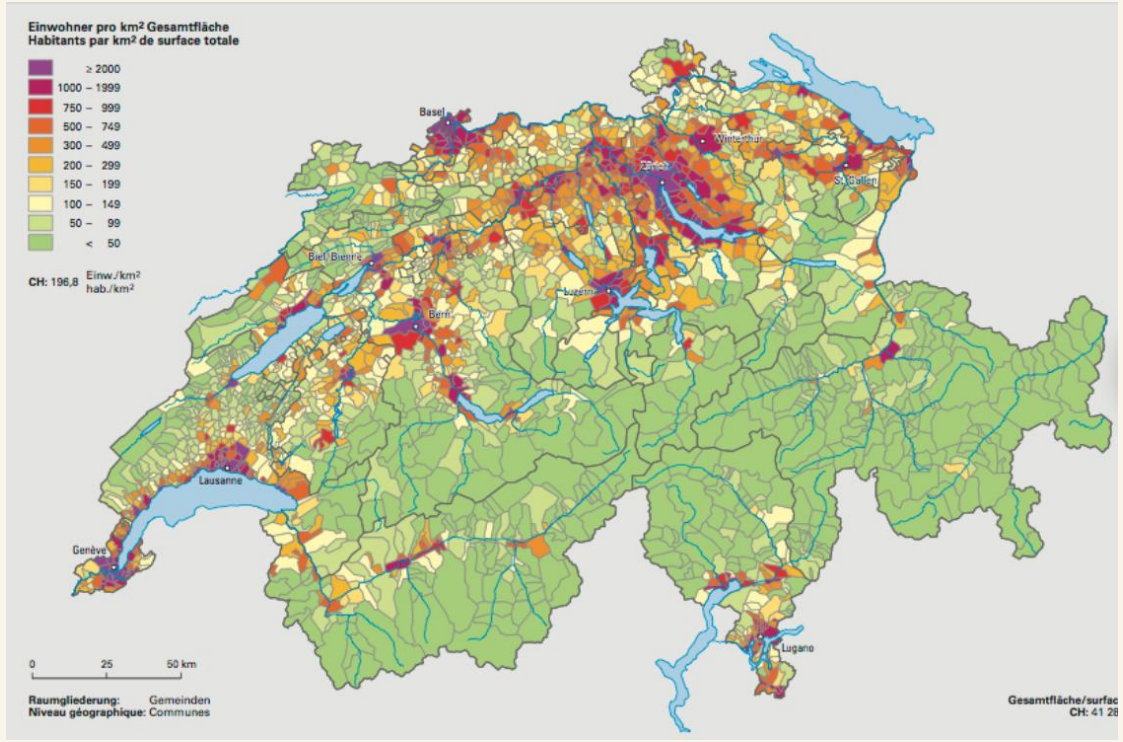
National Cooperative for the Disposal of Radioactive Waste – Nagra

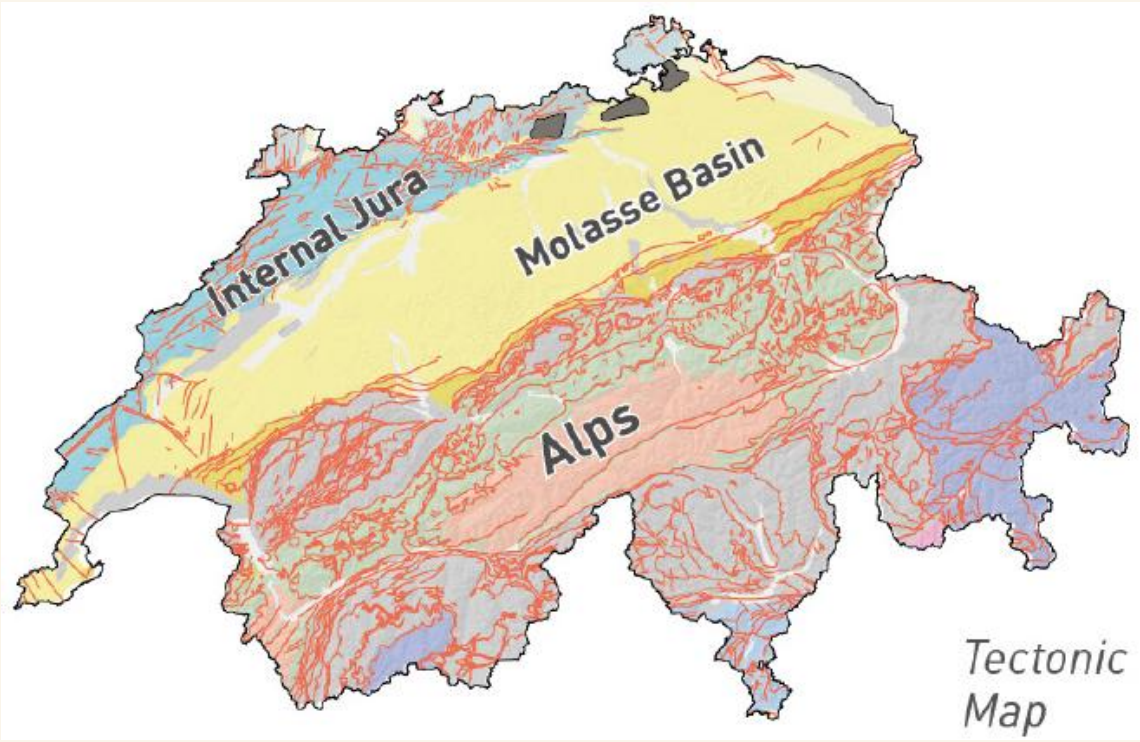
nagra.

NATIONAL CONTEXT (1)

Population density



Tectonic map



- **Densely populated**, except geologically complex mountain regions

NATIONAL CONTEXT (2)

- Procedures and decisions at **three levels**: federal, cantonal and local
- Cantons and communities have a large degree of autonomy
  - They can raise taxes and make their own decisions on important matters such as education and health, but **NOT** on radioactive waste disposal!

- Extensive **democratic rights** (e.g. referendum)

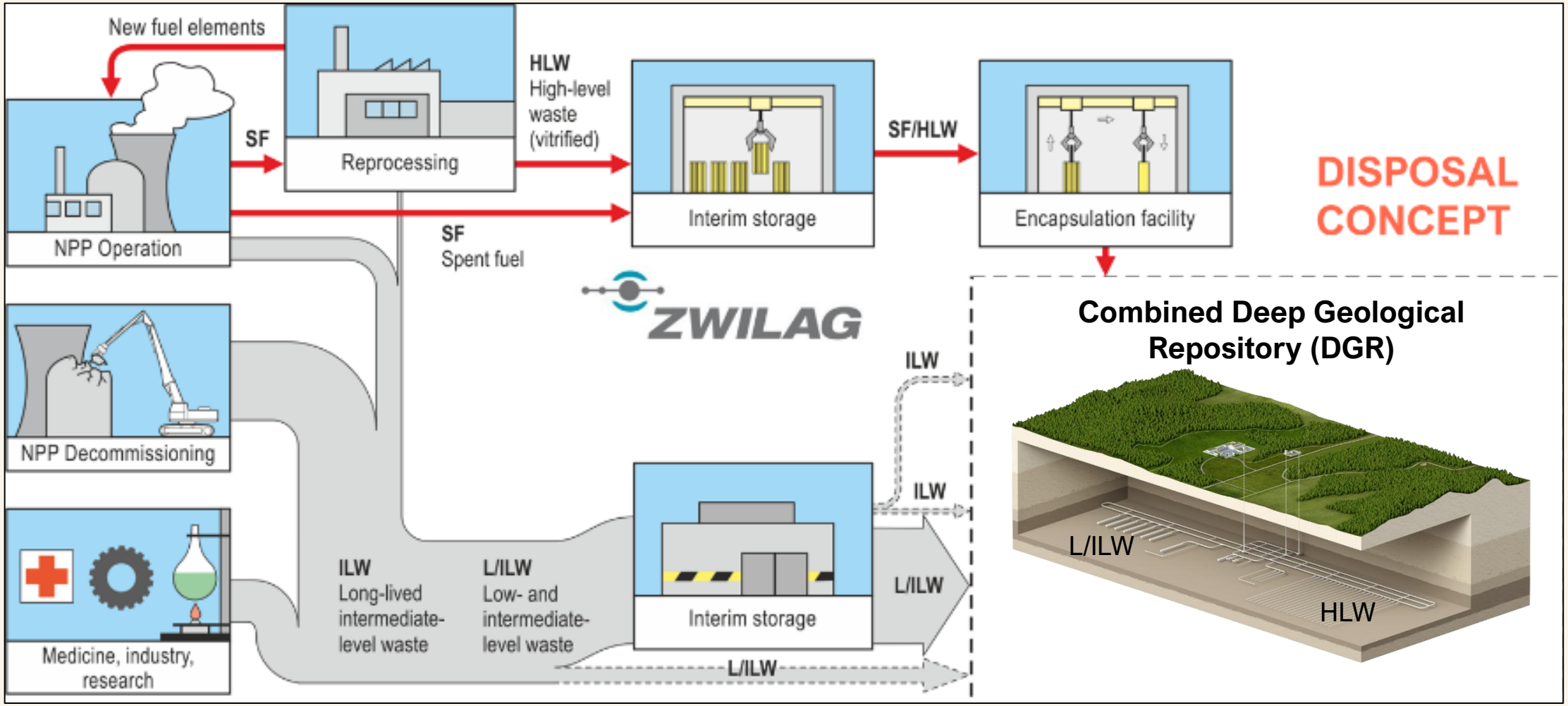
ELECTRICITY PRODUCTION IN SWITZERLAND

Ca. 60 % Hydropower

Ca. 30% nuclear / in total **5 reactors, 1 in dismantling**

~84’000 m^3 packed LLW and ILW and 9’300 m^3 HLW, all in a Deep Geological Repository

STREAMS OF RADIOACTIVE WASTE

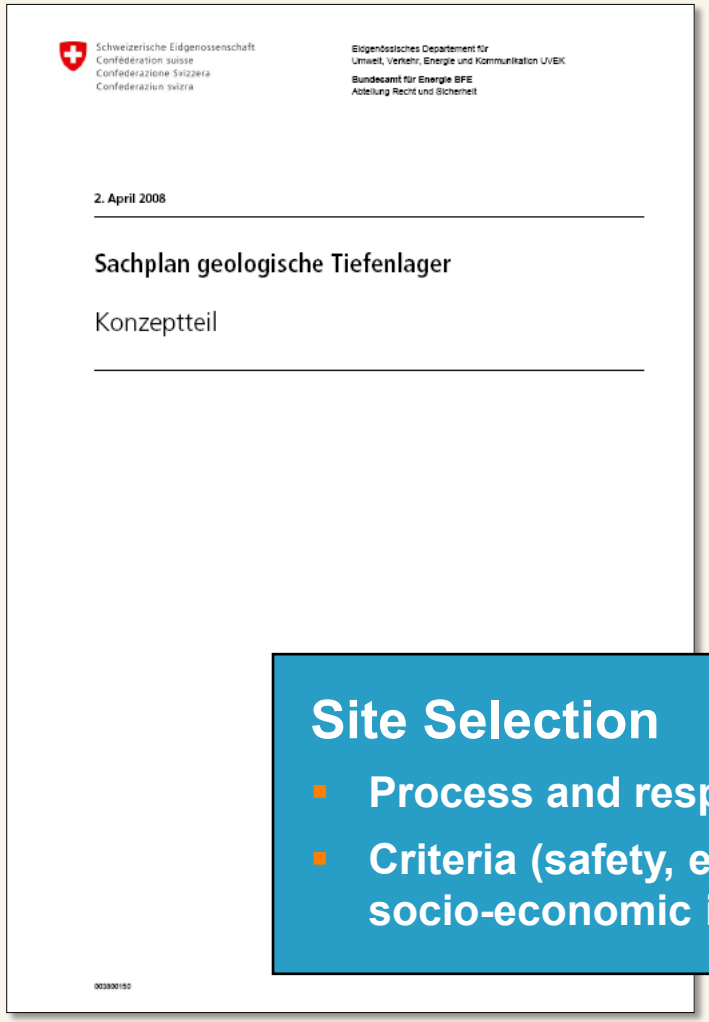


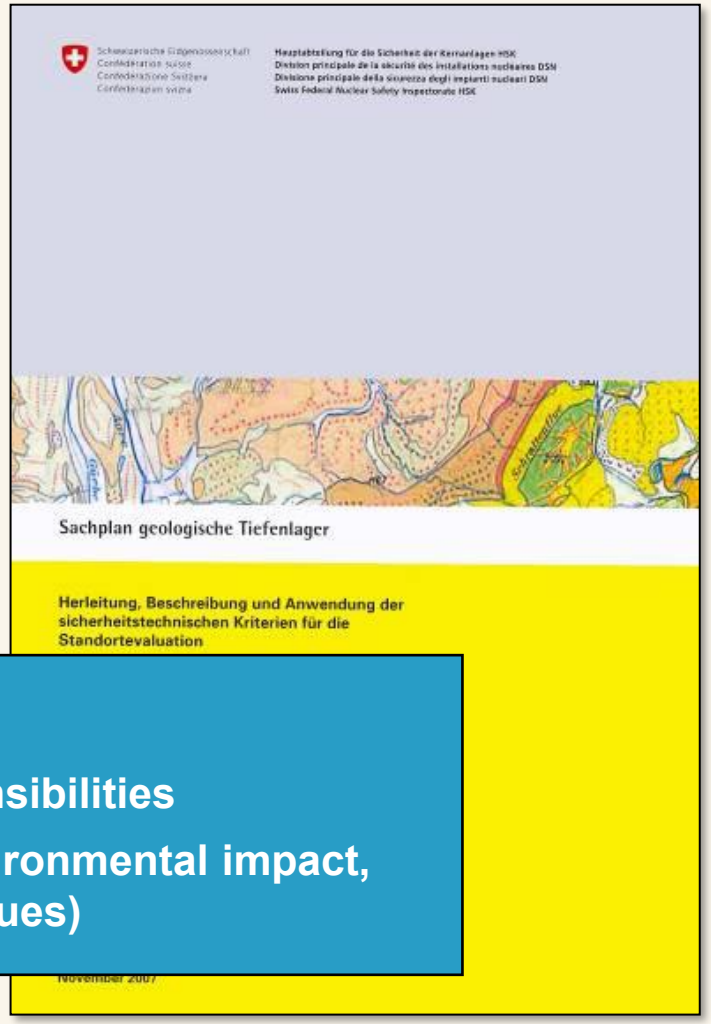
POLICY AND REGULATORY FRAMEWORK FOR THE SITING PROCESS

SITE SELECTION PROCESS – OPTIONS

Nomination	Voluntary Approach	**Swiss Stepwise Site Selection and Decision-making Approach**
Implementor investigates and evaluates various sites	Implementor announces criteria and call for volunteers	Plan, criteria, roles, responsibilities are defined and agreed upon
	One or more communities volunteer	Implementor proposes **siting regions** *Authorities evaluate & approve*
	Implementor investigates and evaluates sites	Implementor proposes (at least) **two sites** *Authorities evaluate & approve*
		Implementor investigates and evaluates sites
Implementor proposes site		
Authorities evaluate		
Approval (in Switzerland subject to facultative national referendum)		

SECTORAL PLAN 'DEEP GEOLOGICAL REPOSITORIES'

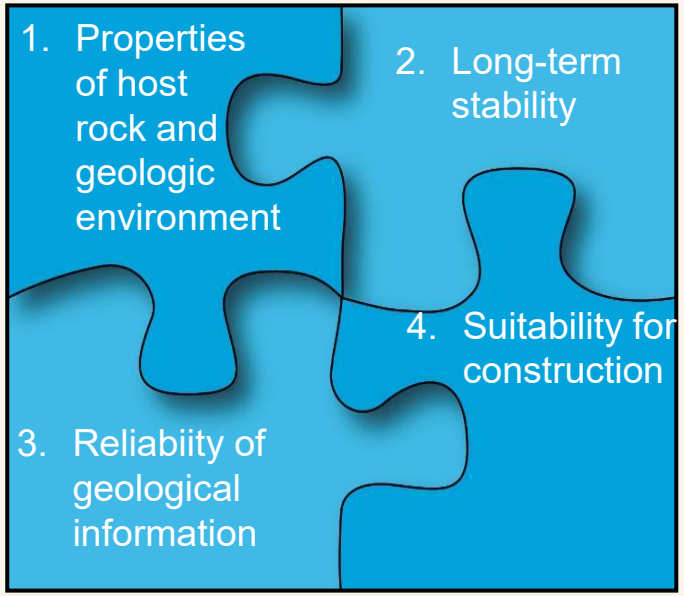




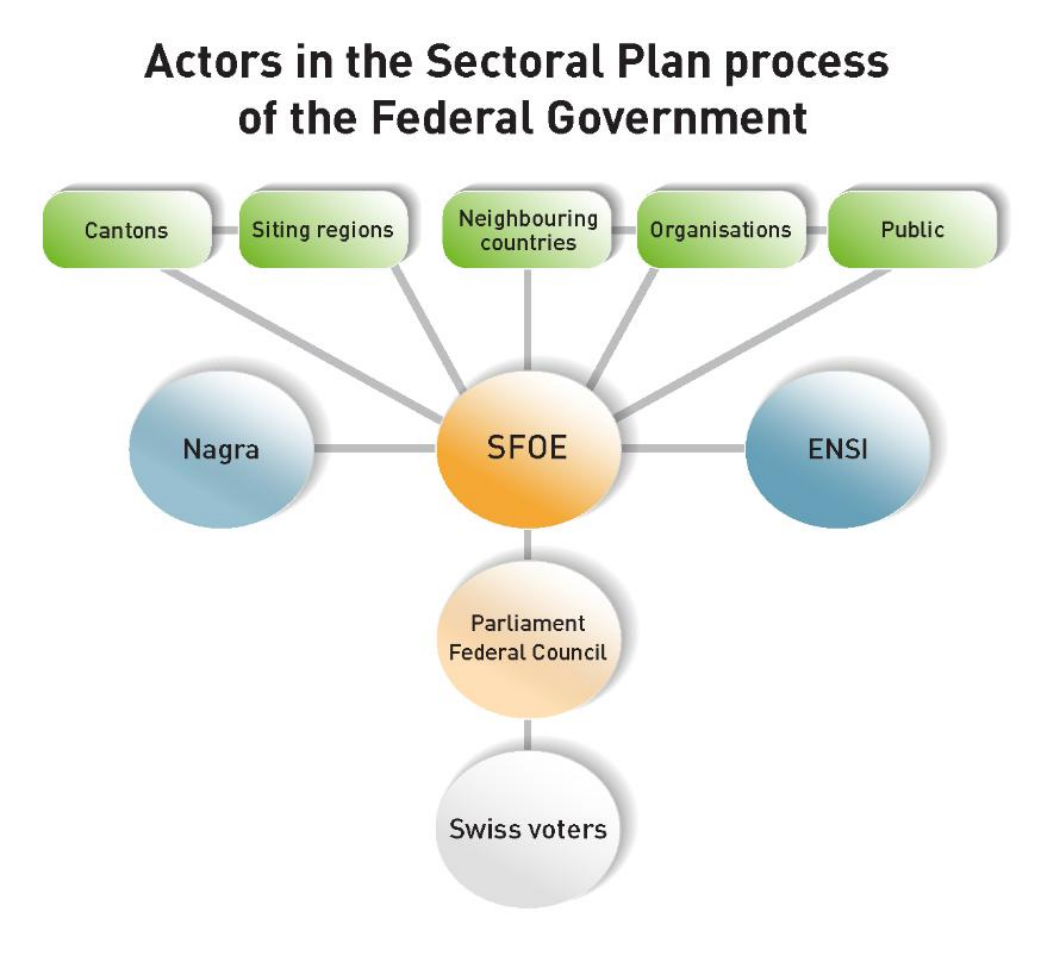
Site Selection

- **Process and responsibilities**
- **Criteria (safety, environmental impact, socio-economic issues)**

Safety and Engineering Feasibility highest priority



MAIN ACTORS IN THE SITE SELECTION PROCESS



Roles and responsibilities clearly defined:

- SFOE (Federal Office of Energy / Government)
  - Defines rules
  - Decides (following open consultation)
- Nagra (implementor)
  - proposes
- ENSI (regulator)
  - evaluates

Site selection: Safety criteria and stepwise narrowing down approach

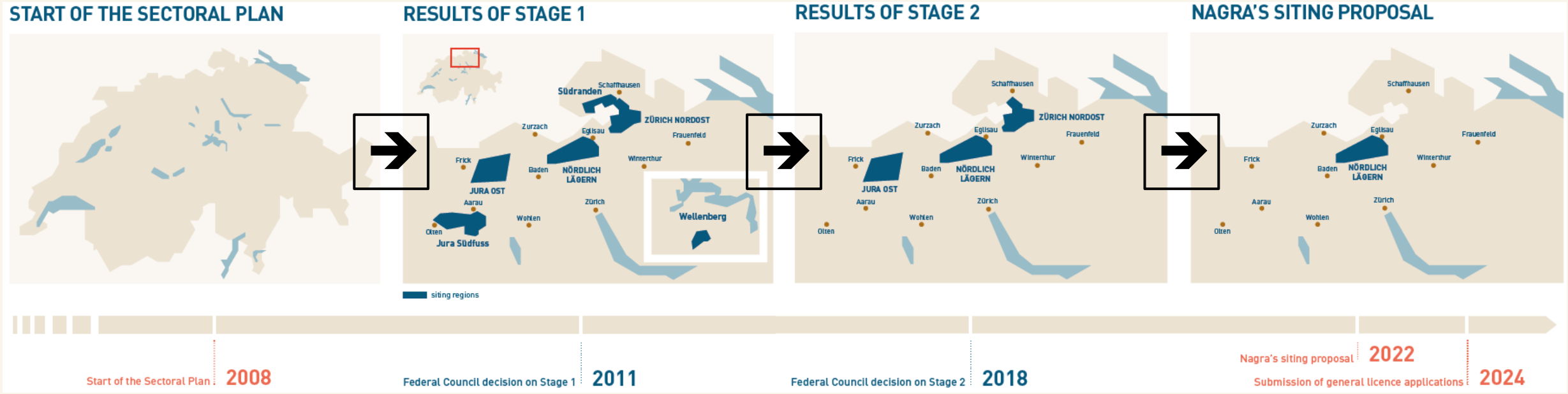
SITE SELECTION: SAFETY CRITERIA

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

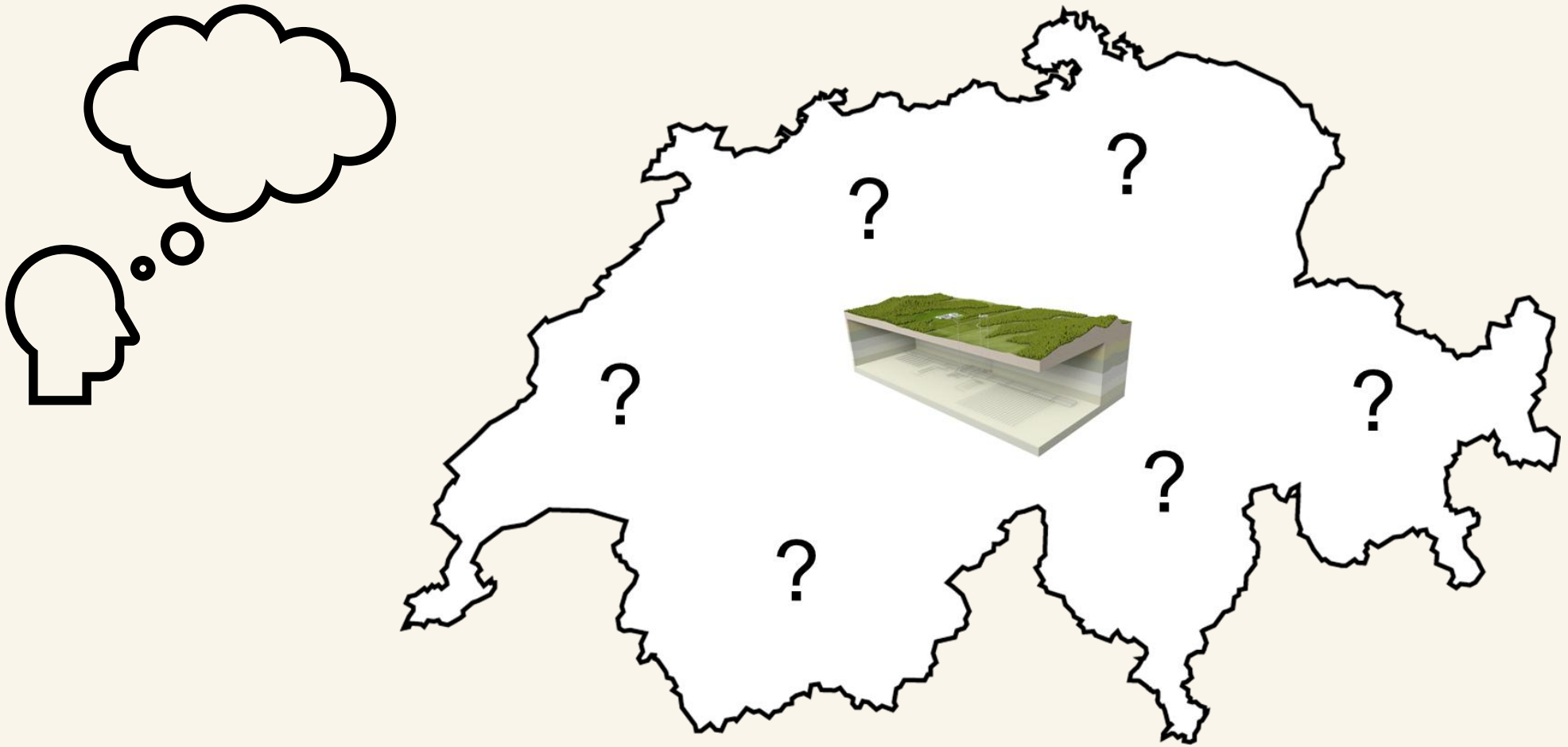
SITE SELECTION PROCESS OVERVIEW

→ Repeated confirmation by the Federal Council

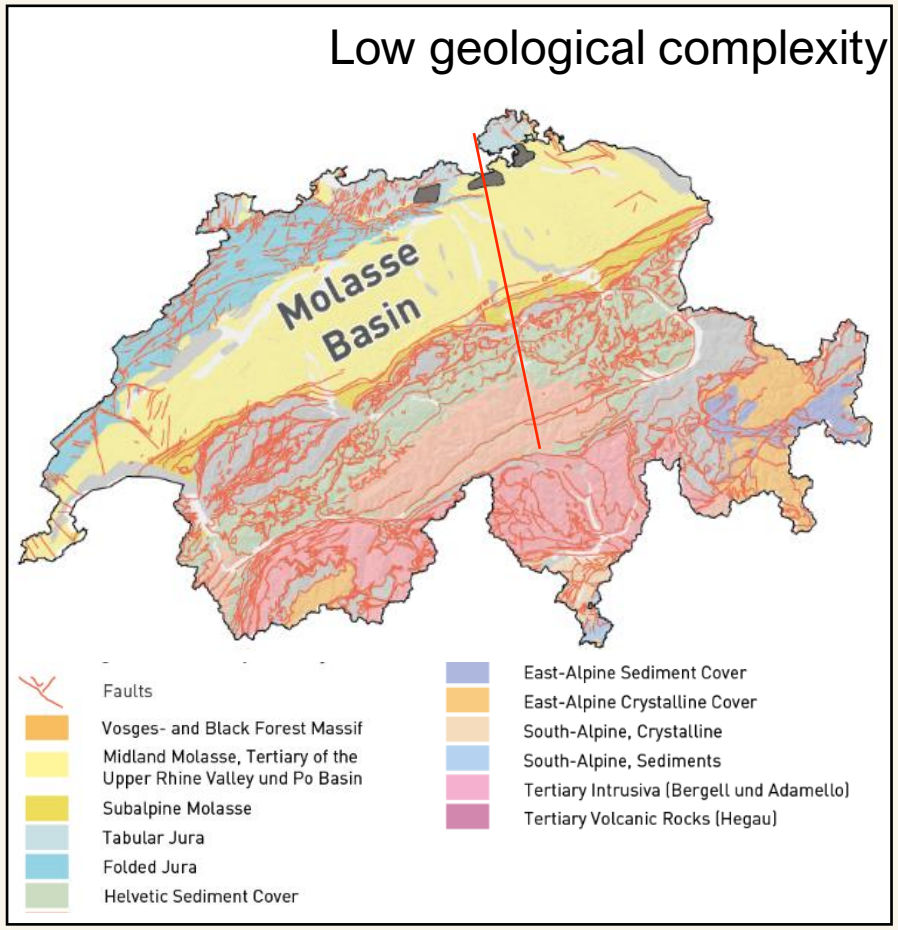


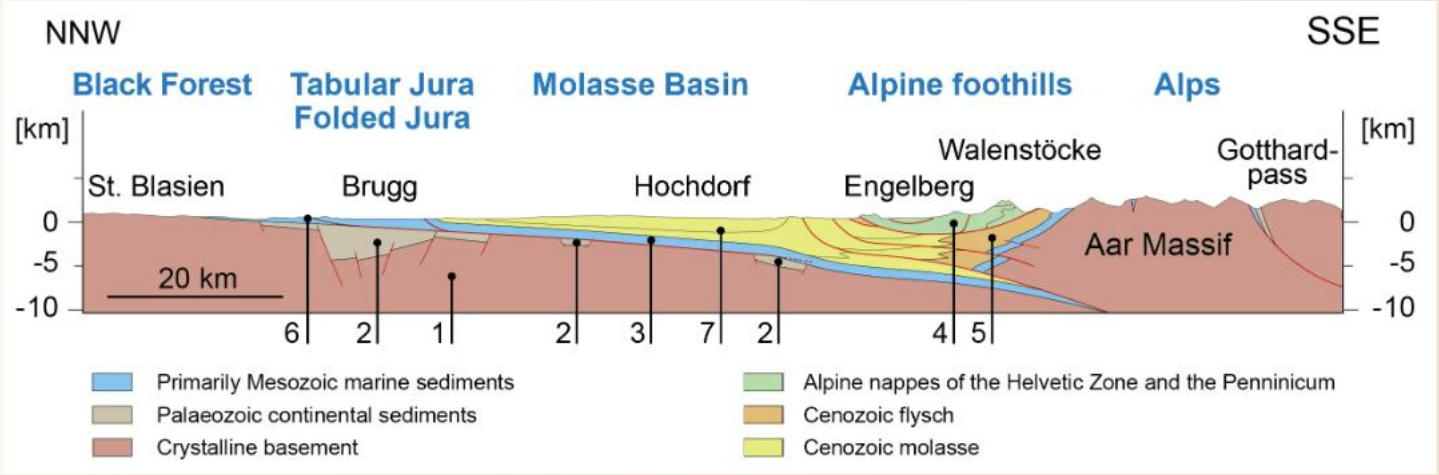
PROCESS AND METHODOLOGIES APPLIED

SITE SELECTION PROCESS FOR DEEP GEOLOGICAL REPOSITORY

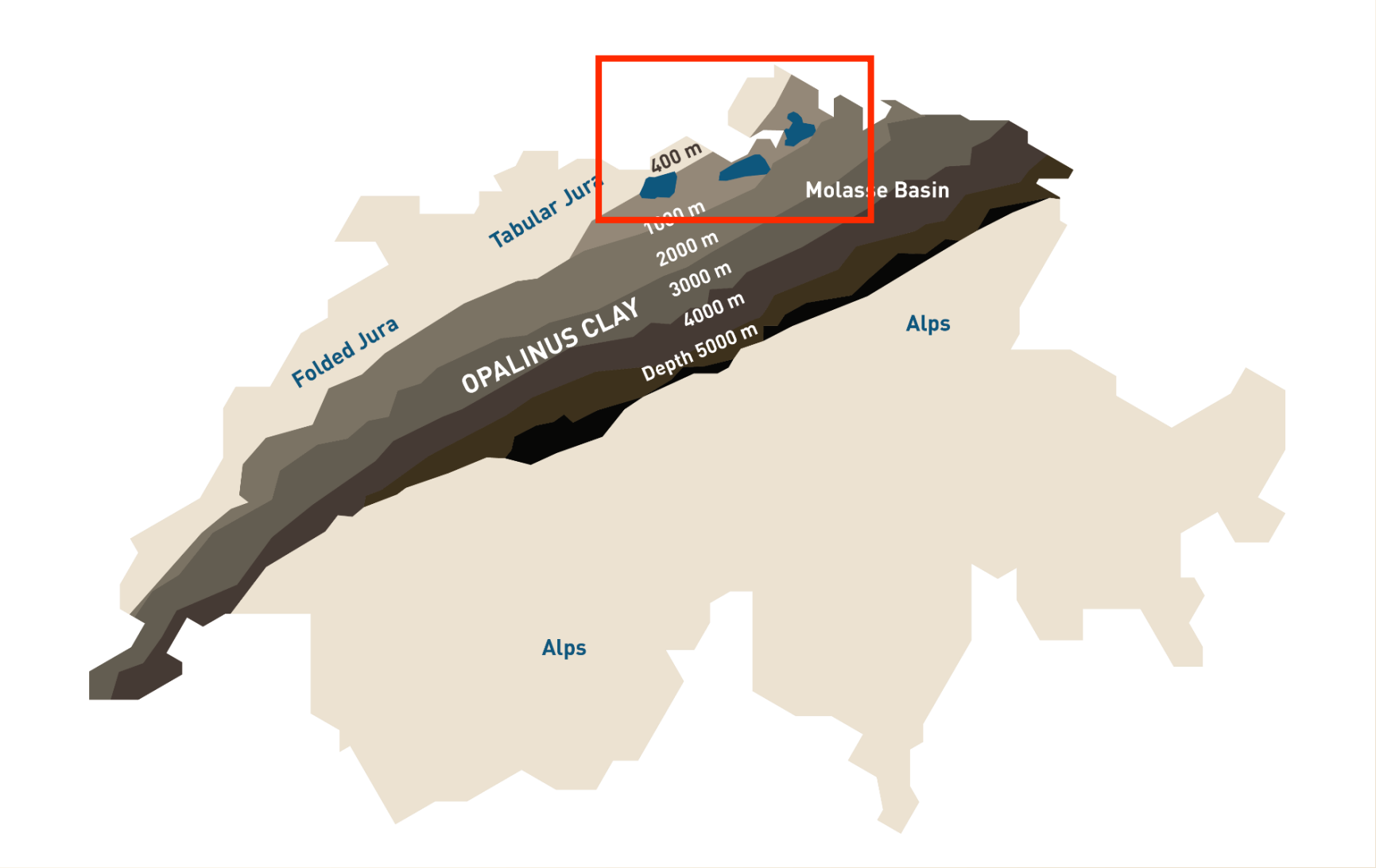


WHY NORTHERN SWITZERLAND: TECTONIC SITUATION

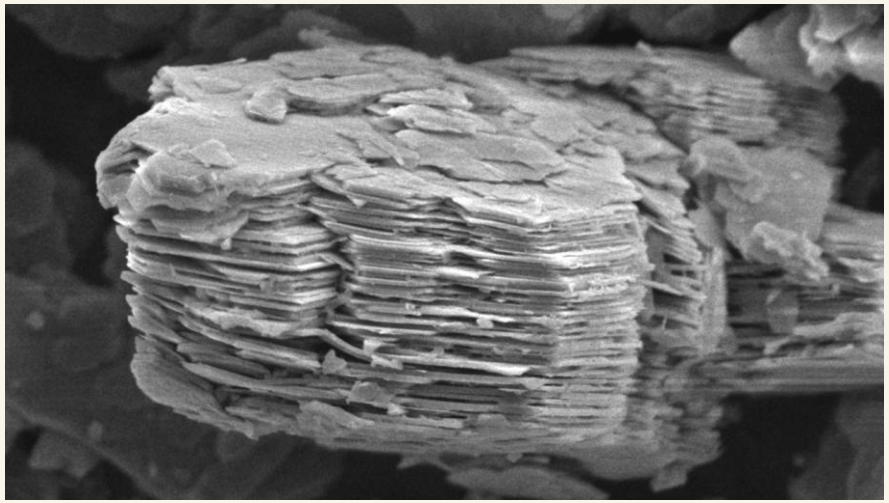




WHY NORTHERN SWITZERLAND: HOST ROCK AT SUITABLE DEPTH



HOST ROCK = **OPALINUS CLAY** (OVER-CONSOLIDATED SHALE)

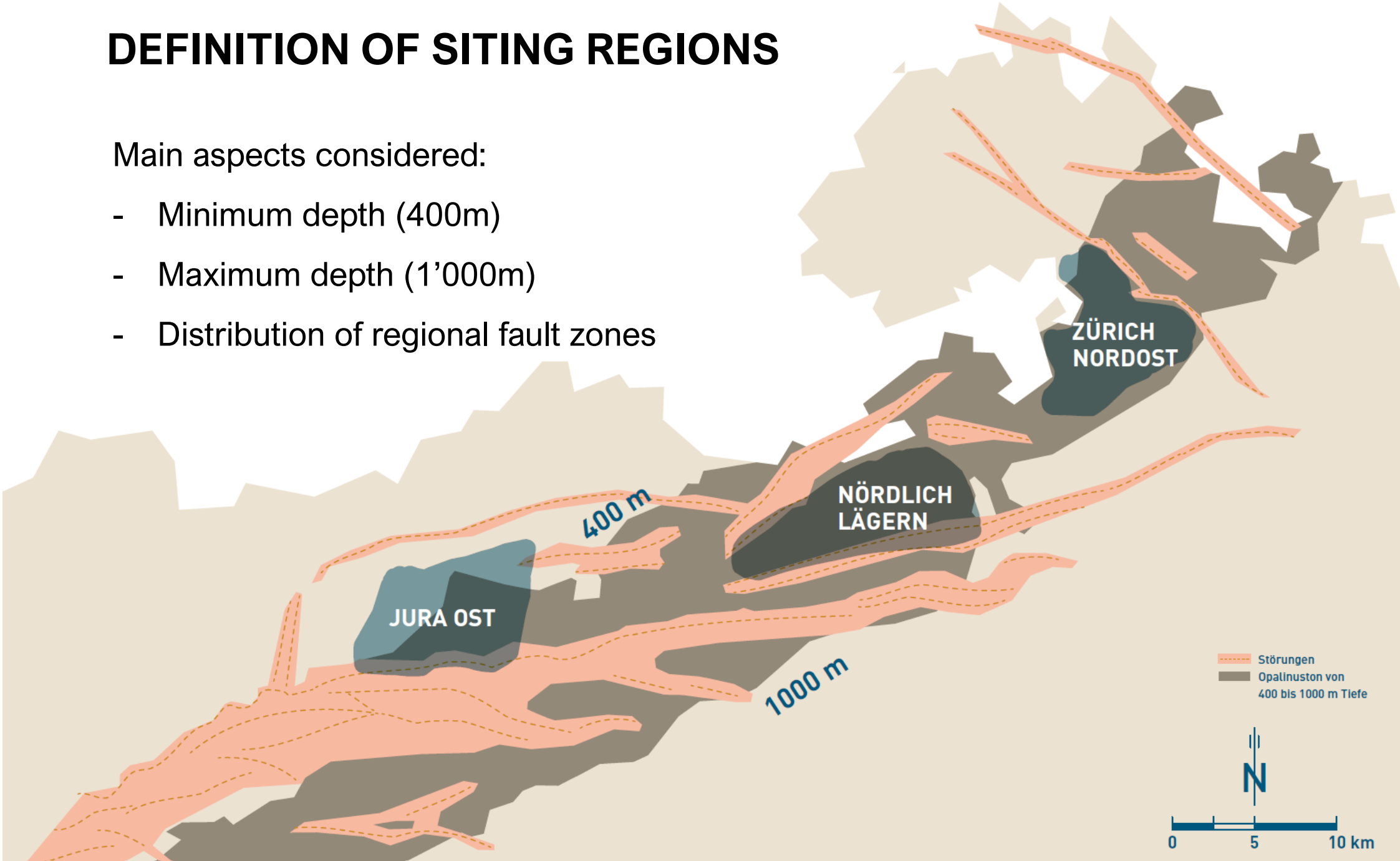


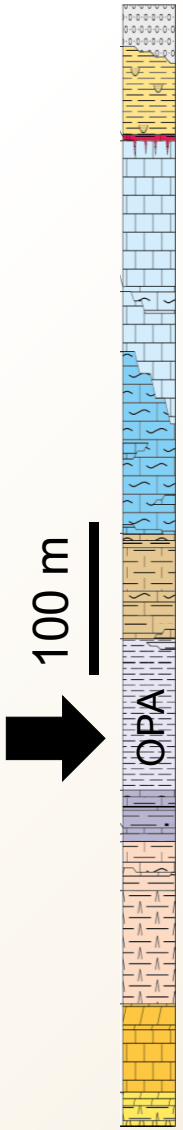
- Large thickness (>100m)
- Low variability
- High clay-mineral content
  - Very low hydraulic conductivity
  - Efficient self-sealing behaviour
  - High sorption capacity
  - Well-known diffusion properties

DEFINITION OF SITING REGIONS

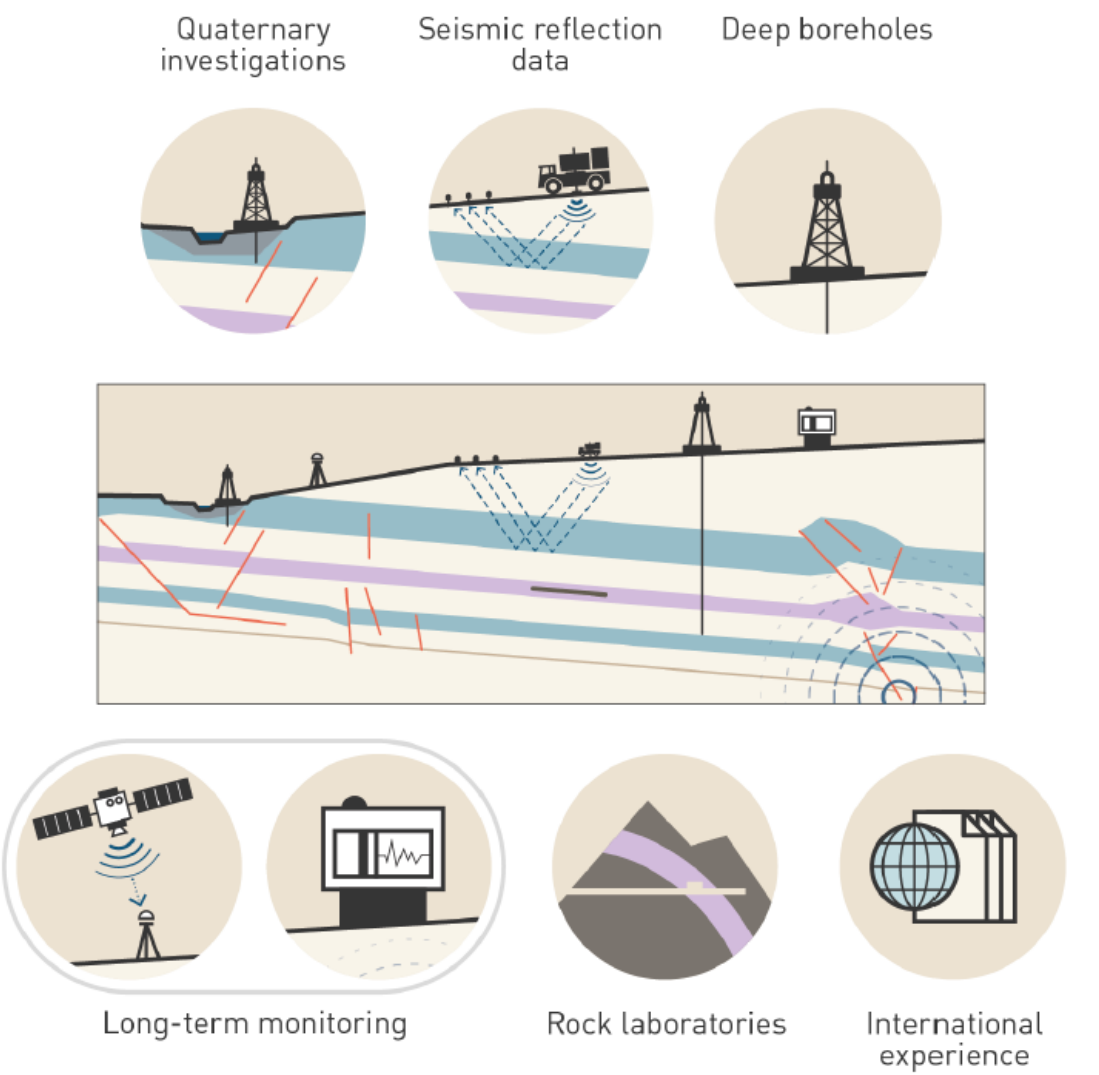
Main aspects considered:

- Minimum depth (400m)
- Maximum depth (1’000m)
- Distribution of regional fault zones





FIELD INVESTIGATIONS STAGE 3: EXTENSIVE DATA BASIS



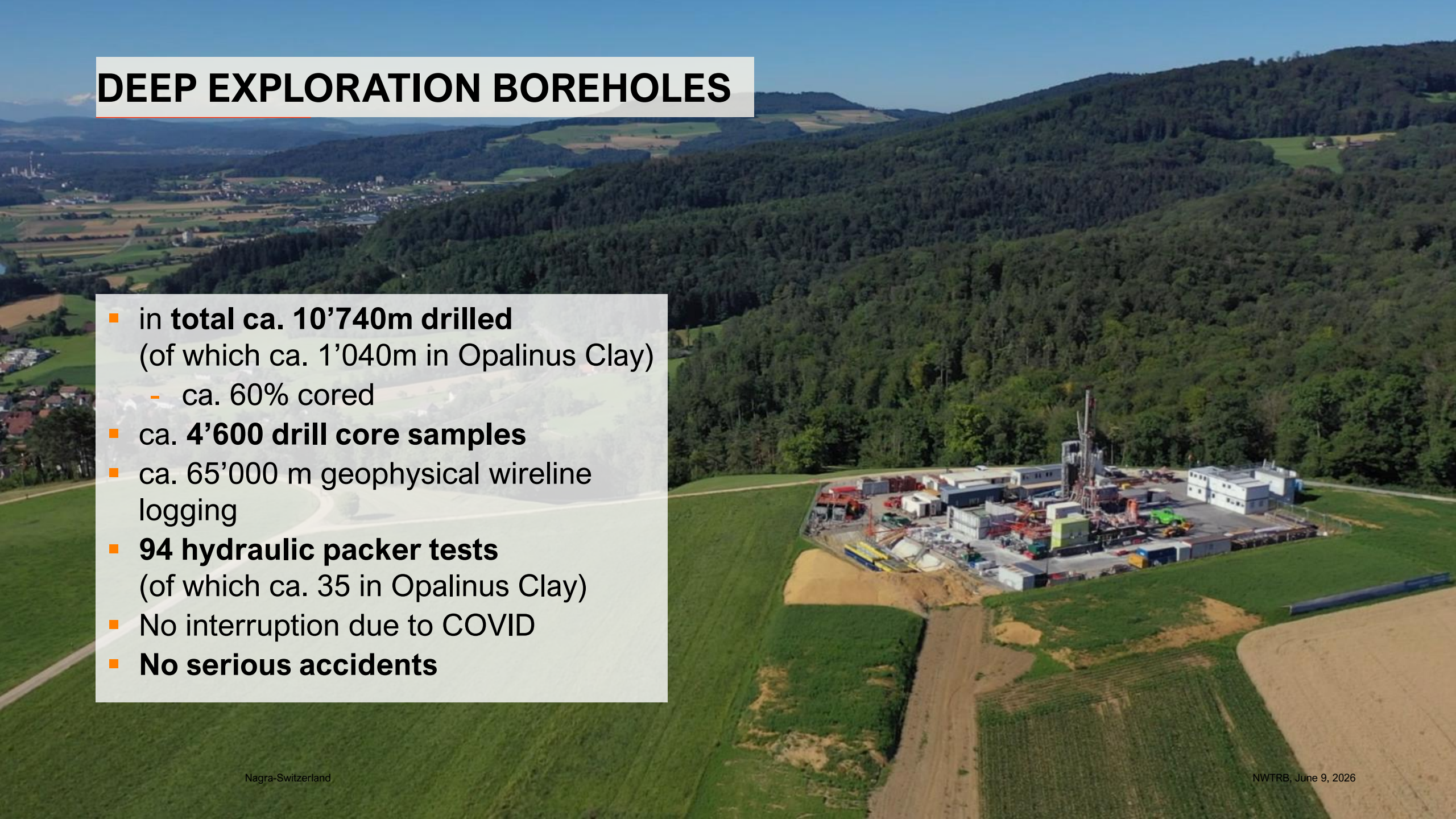
3D seismic surveys covering 230 km²

2D regional lines bridging the 3D

9 exploration boreholes (depth: ca. 1 km)

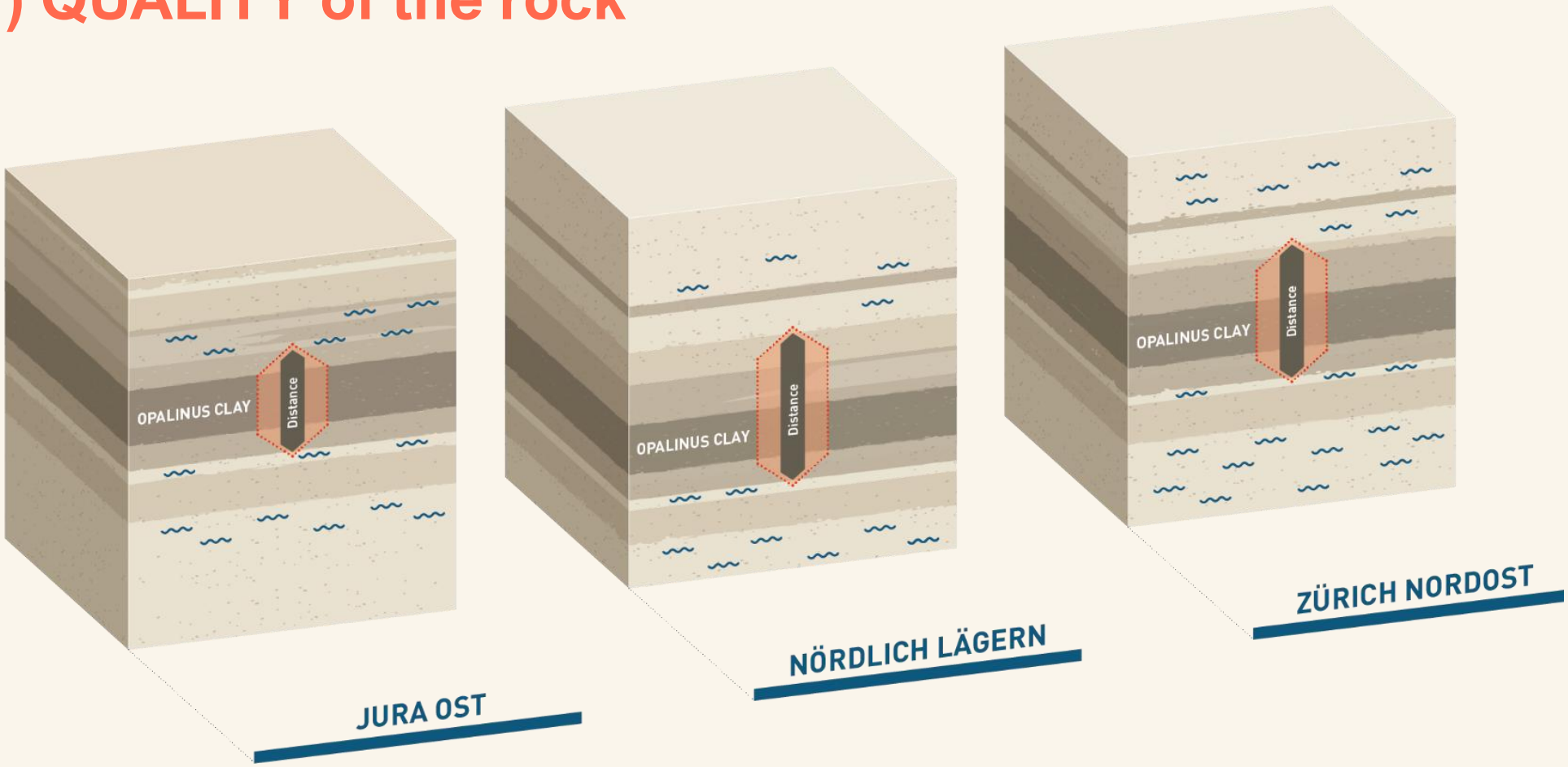
DEEP EXPLORATION BOREHOLES

- in **total ca. 10’740m drilled**
  (of which ca. 1’040m in Opalinus Clay)
  - ca. 60% cored
- ca. **4’600 drill core samples**
- ca. 65’000 m geophysical wireline logging
- **94 hydraulic packer tests**
  (of which ca. 35 in Opalinus Clay)
- No interruption due to COVID
- **No serious accidents**



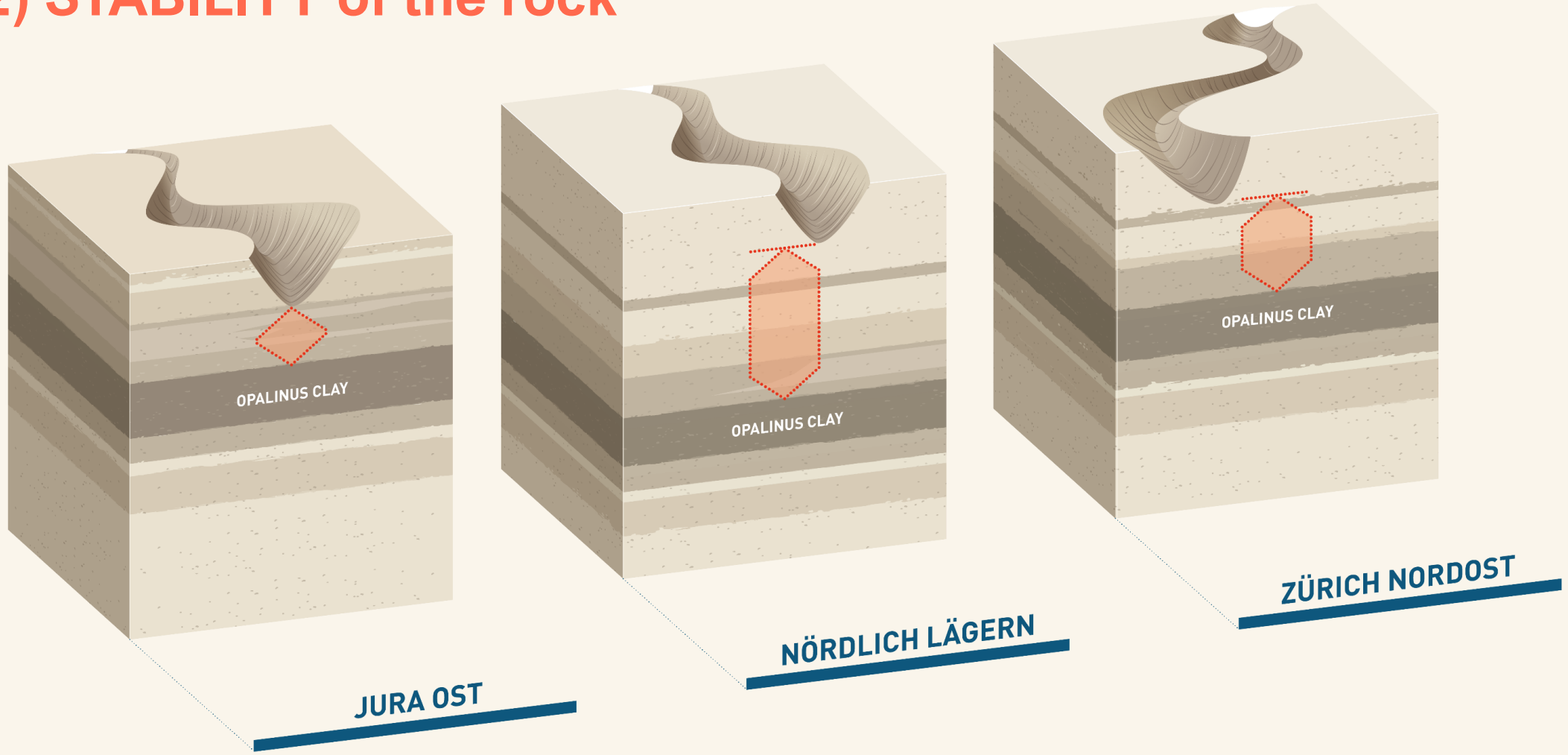
MAIN ARGUMENTS FOR SITE SELECITON

(1) QUALITY of the rock



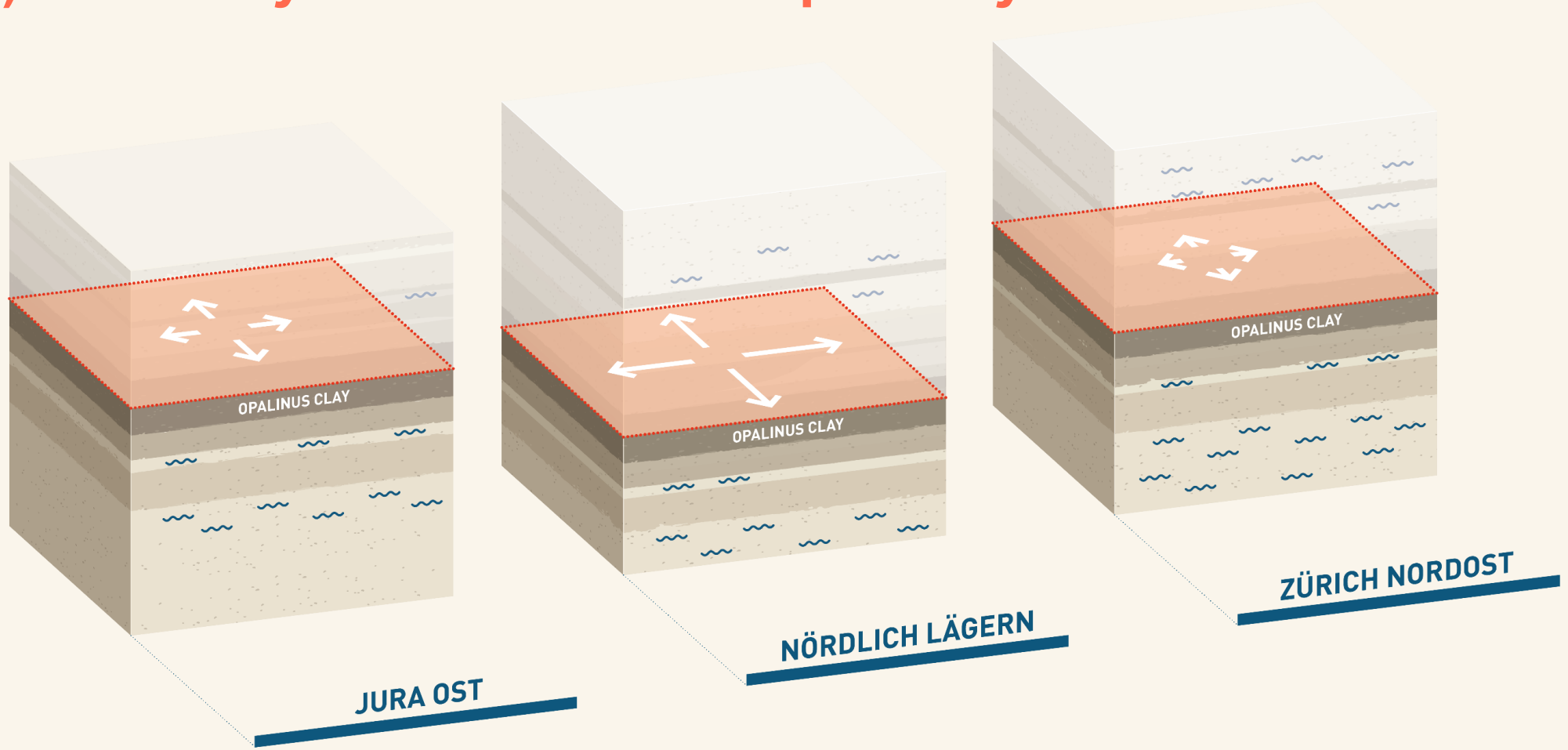
MAIN ARGUMENTS FOR SITE SELECITON

(2) STABILITY of the rock

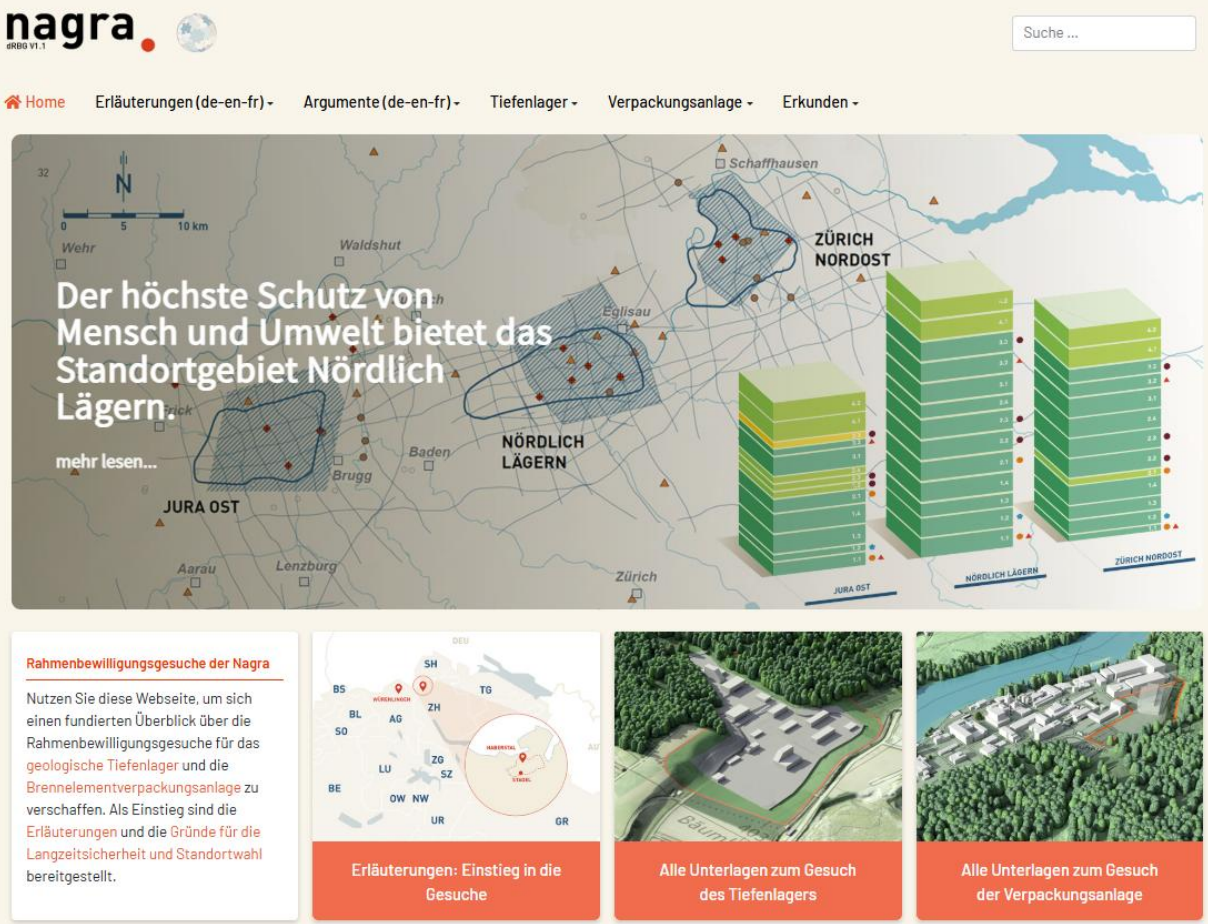


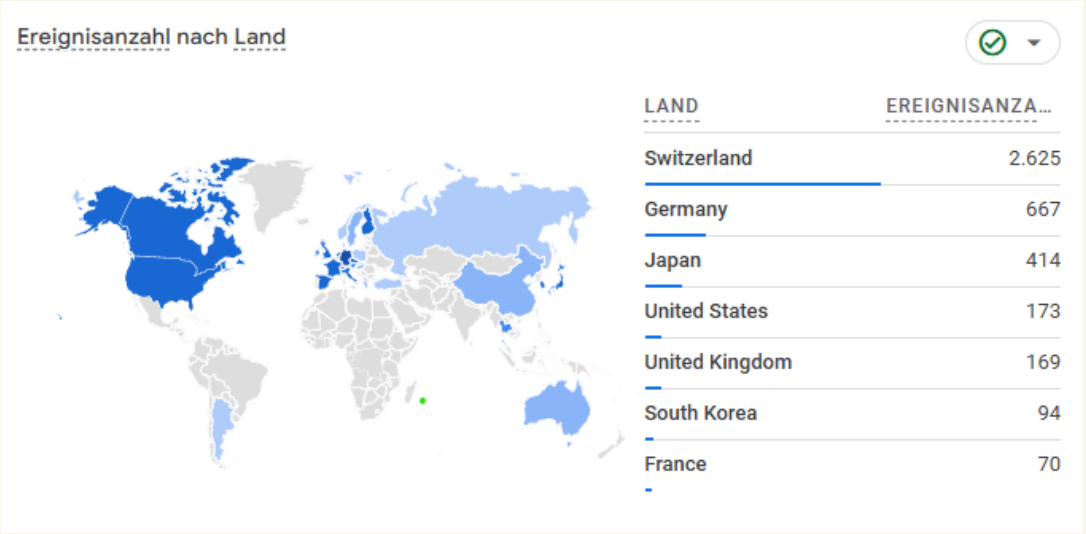
MAIN ARGUMENTS FOR SITE SELECITON

(3) Flexibility to accomodate repository



DIGITAL GLA: WORLDWIDE INTEREST www.drbg.ch

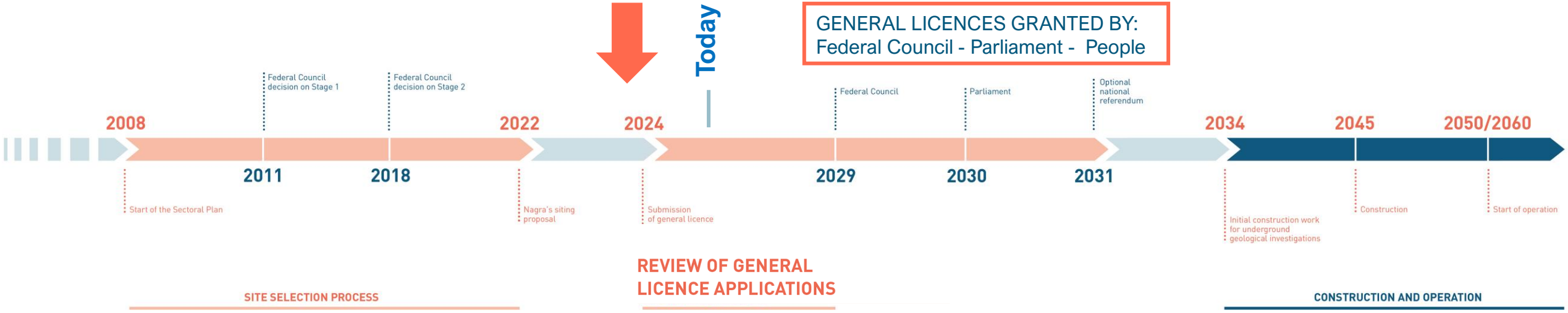




WHAT NEXT?

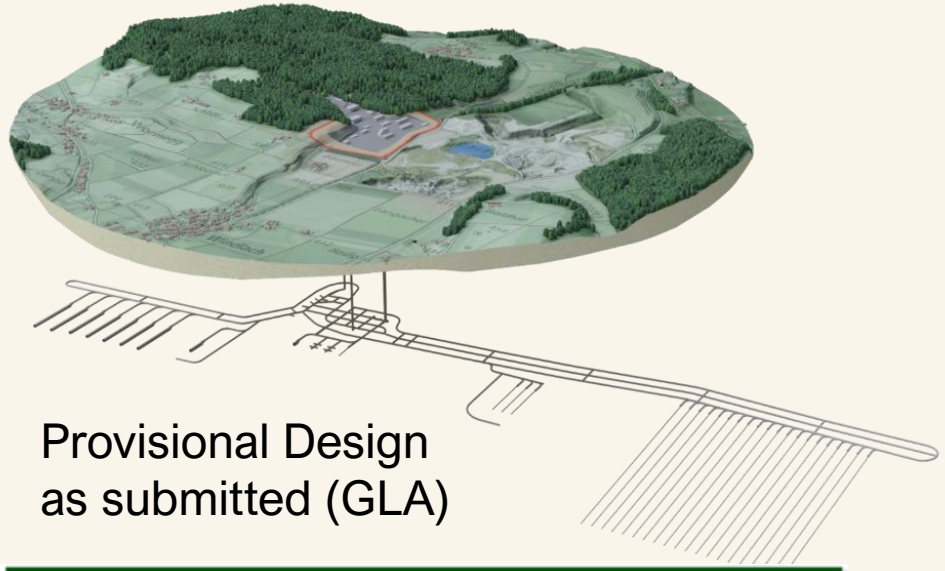
OUTLOOK – SITE PROPOSAL IS THE BEGINNING…

SUBMISSION OF GENERAL LICENCE APPLICATIONS



TERRADURA project development

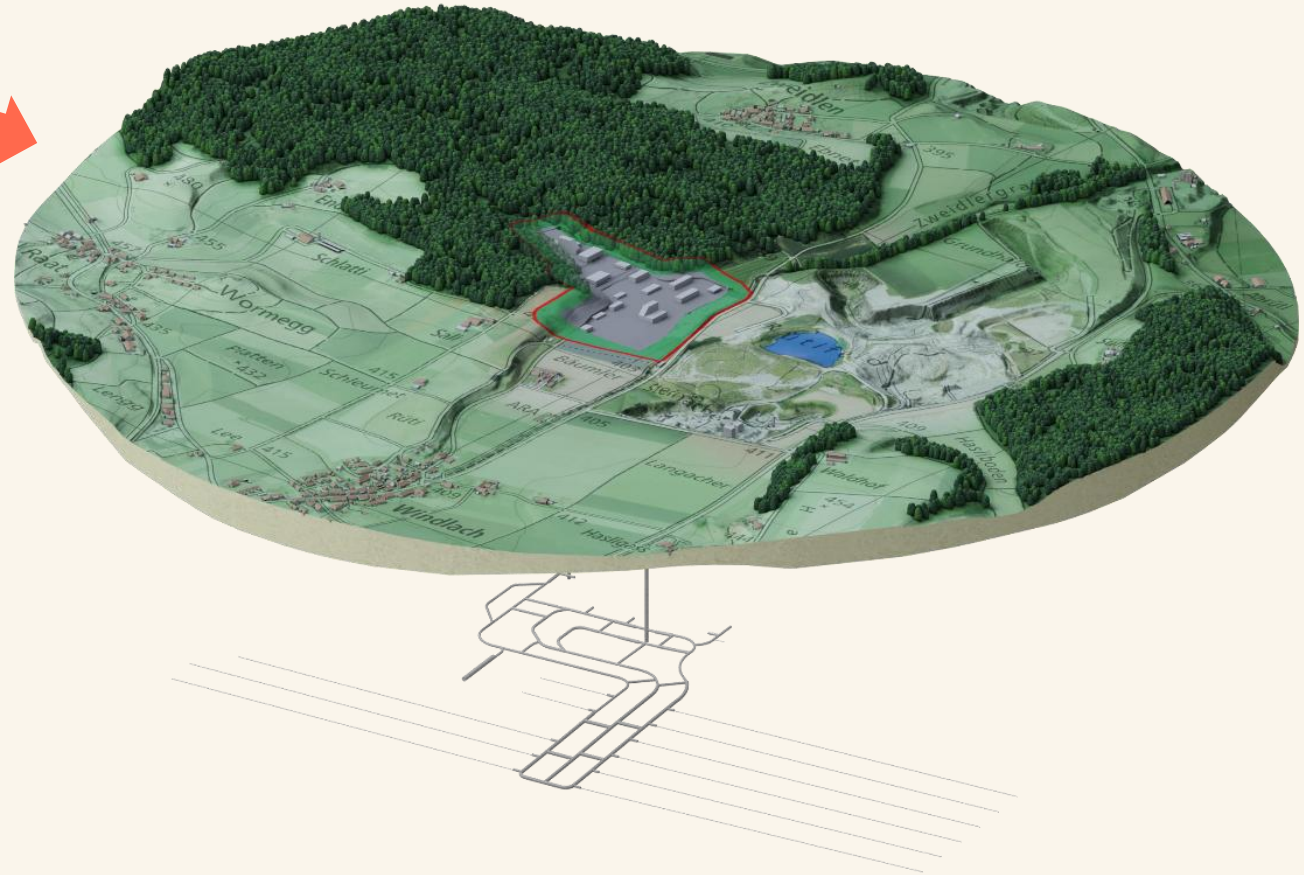
OPPORTUNITIES OF TERRADURA PROJECT DEVELOPMENT



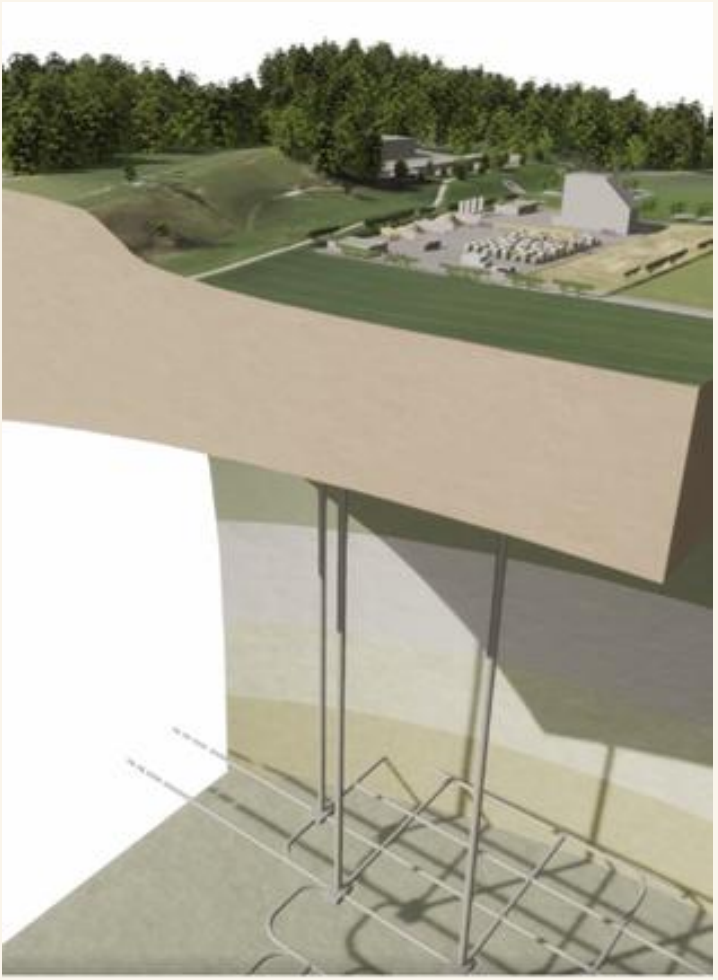
Provisional Design
as submitted (GLA)

- Fulfilling safety requirements
- In-line with spatial planning
- Influence on environment
- Accepted by local stakeholders
- Developed site-specific
- Realisation and careful use of resources

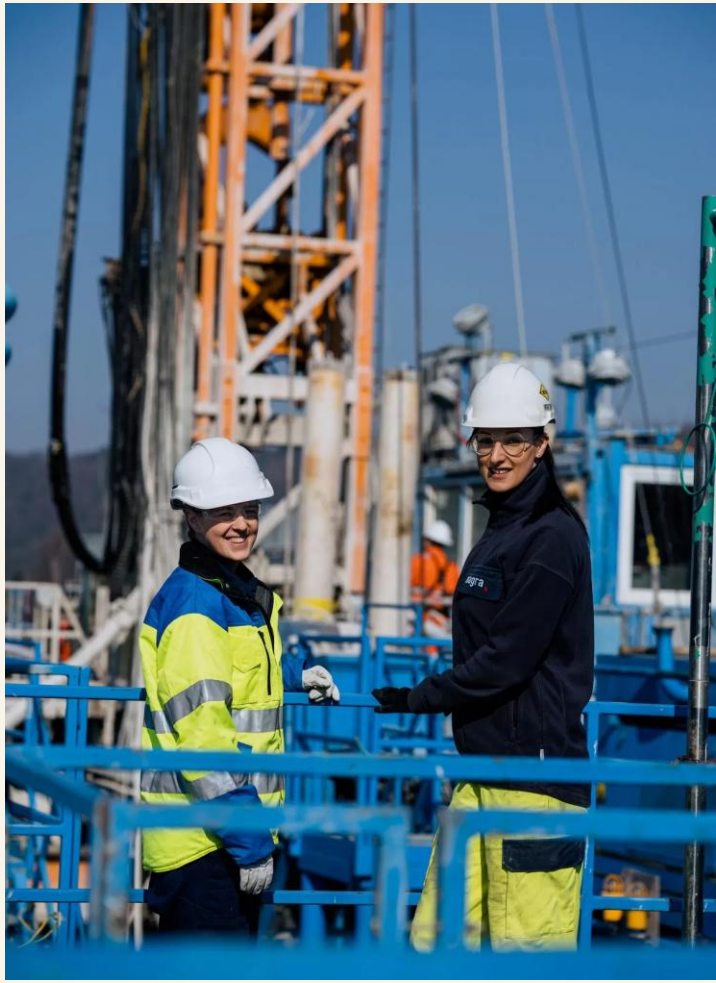
Concept variant of
repository design



IN ADDITION
UPCOMING PREPARATORY WORK AT THE SELECTED SITE



- Shaft design and construction (c. 2034+)
  - ➢ Shaft exploration boreholes (planning and execution, 2028+)
- Establish on-site monitoring system (baseline, construction activities, continues and expands to site)
- Environmental impact assessment
- Data acquisition for update/confirmation reference models and safety case

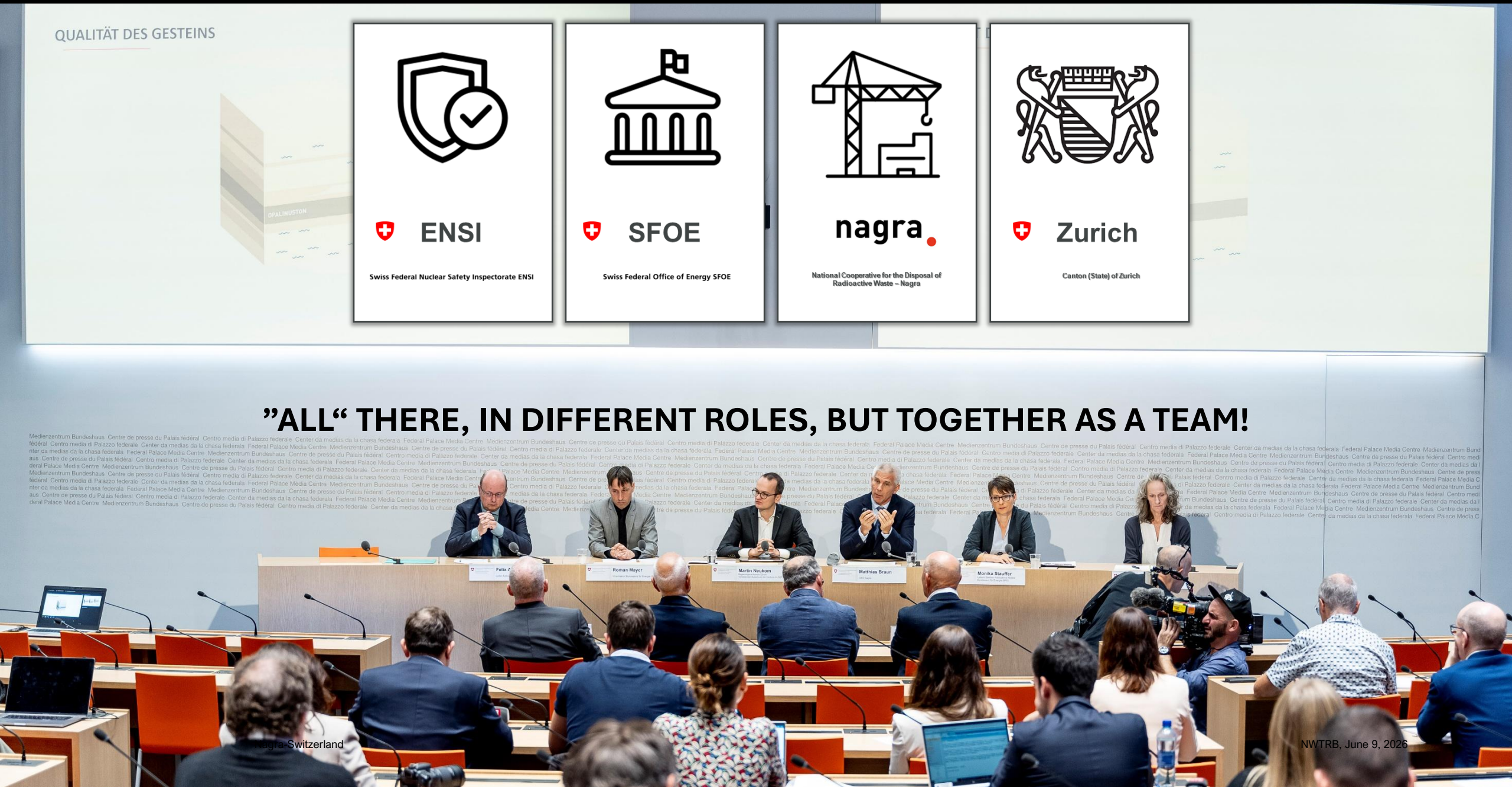


WHAT PATHED THE WAY AND A FEW TAKEAWAY POINTS

AGREED AND ACCEPTED PROCESS

- Clearly defined roles and responsibilities
- Safety criteria-driven, high-quality data approach
- Effective stakeholder engagement (e.g. incl. Regional Conferences)

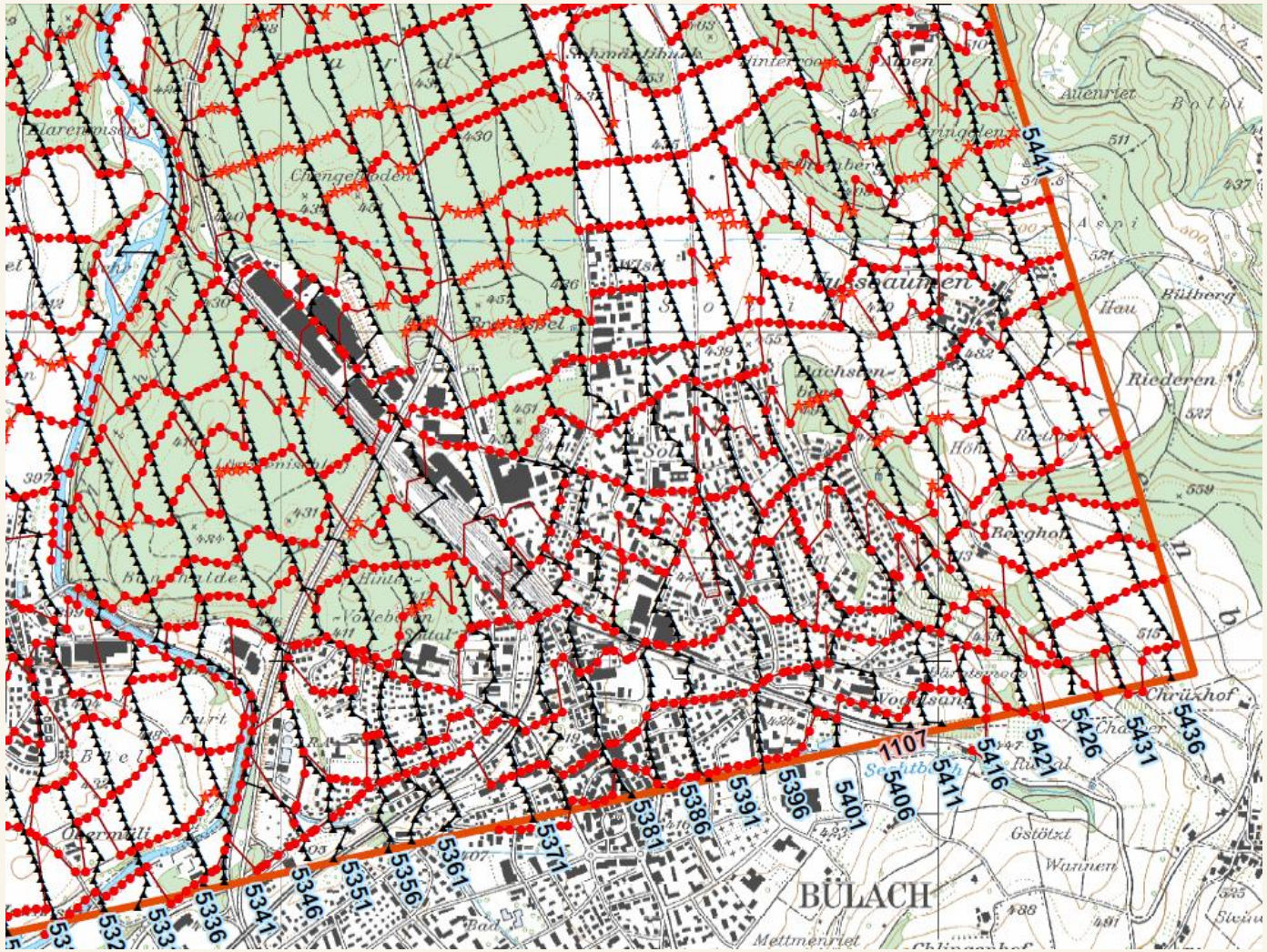
➢ Trust in the process and its participants


QUALITÄT DES GESTEINS
ENSI
Swiss Federal Nuclear Safety Inspectorate ENSI
SFOE
Swiss Federal Office of Energy SFOE
nagra.
National Cooperative for the Disposal of Radioactive Waste – Nagra
Zurich
Canton (State) of Zurich
”ALL“ THERE, IN DIFFERENT ROLES, BUT TOGETHER AS A TEAM!
Roman Mayer
Martin Neukom
Matthias Braun
Monika Stauffer

SITE INVESTIGATIONS AS A TRUST BUILDING PROCESS

- Inform partners and stakeholders about your plans with adequated time to think and react
- Talk to the people in person!

SITE INVESTIGATIONS AS A TRUST BUILDING PROCESS



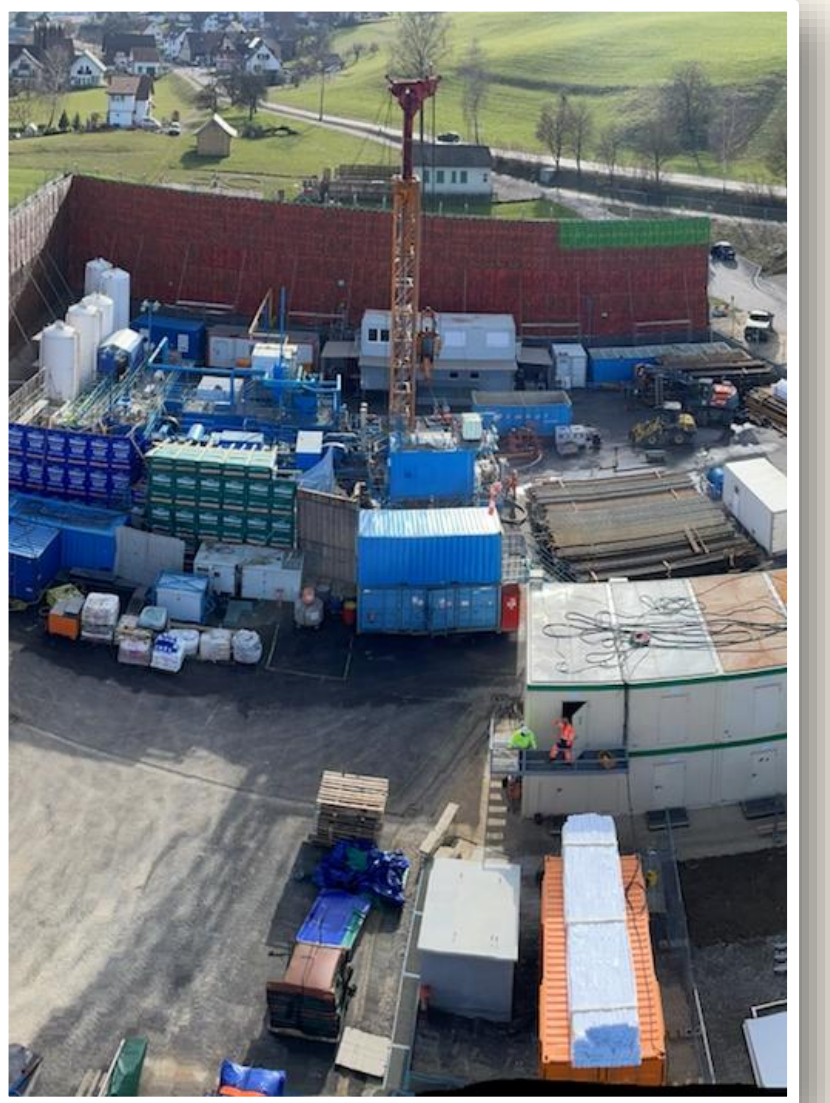
Number of surveys	3
Informed landowners	3999
Vibro-/Shotpoints	34031 / 6208
Permits	**97 - 99 %**

KEEP LISTENING AND ACT

- Solve any issues as quick as possible.

  → Noise. Traffic. Anything.

- Provide a variety of formats for information, consultation and complaint.



SHARING IS CARING

Discuss your Data and arguments

Continuously with

- Regulator
- Stakeholder’s experts
- Local public

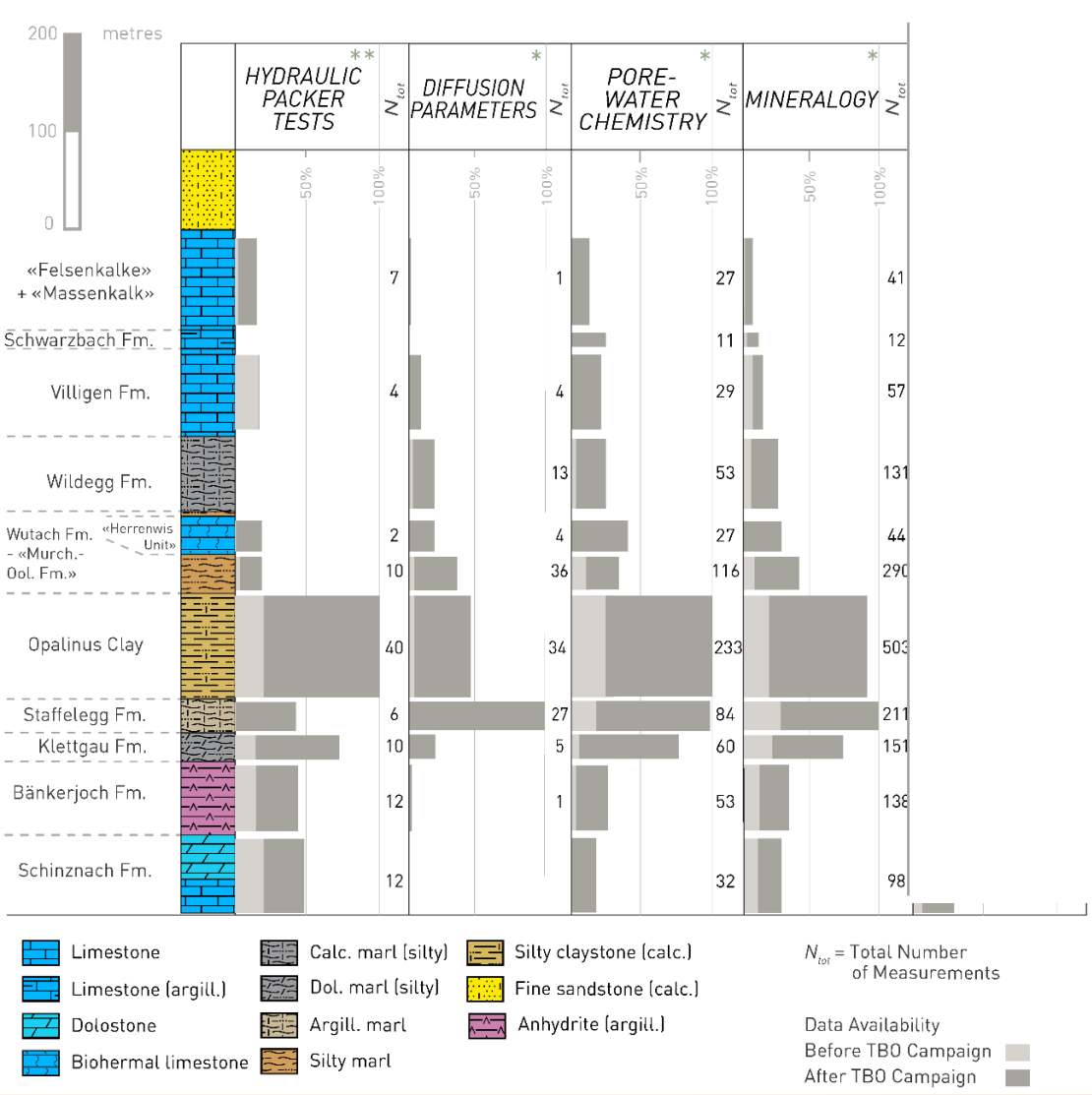
Allow people to digest and react to the data.

Avoid surprises.

LESSONS LEARNED: PLANNING OF EXPLORATION CAMPAIGN

- Ensure flexibility for implementation (number of drilling locations, drilling sequence, work programs)
- Know your aims and focus the data aquisition accordingly
- Plan drilling activities, based on agreed priorities among teams (e.g. geology, safety) and feasibility (from deep drilling project team)
- Multi-purpose boreholes can be tricky to handle, but the results are easier to integrate
- Use/create opportunities for training (e.g. in underground rock labs, pilot boreholes)
- Define workflows and measurement protocols early and make sure they are supported by the regulator and their experts (e.g. conditioning of samples, protocols for lab measurements).
- Make sure terminologies are clear and applied consistently

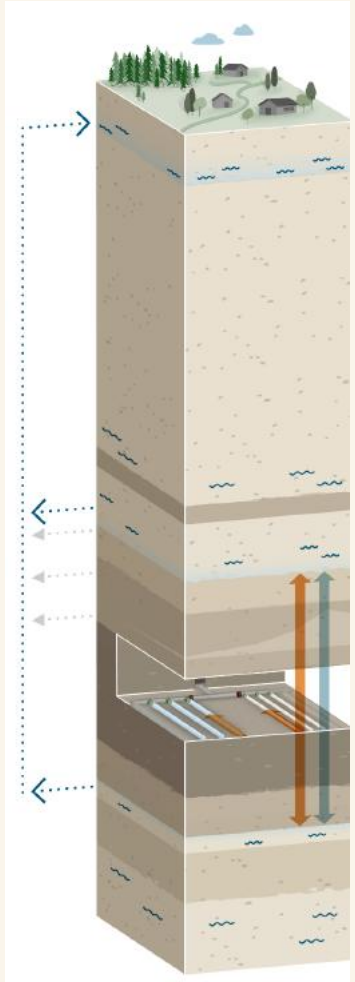
DEEP DRILLING CAMPAIGN: KEY DATASETS

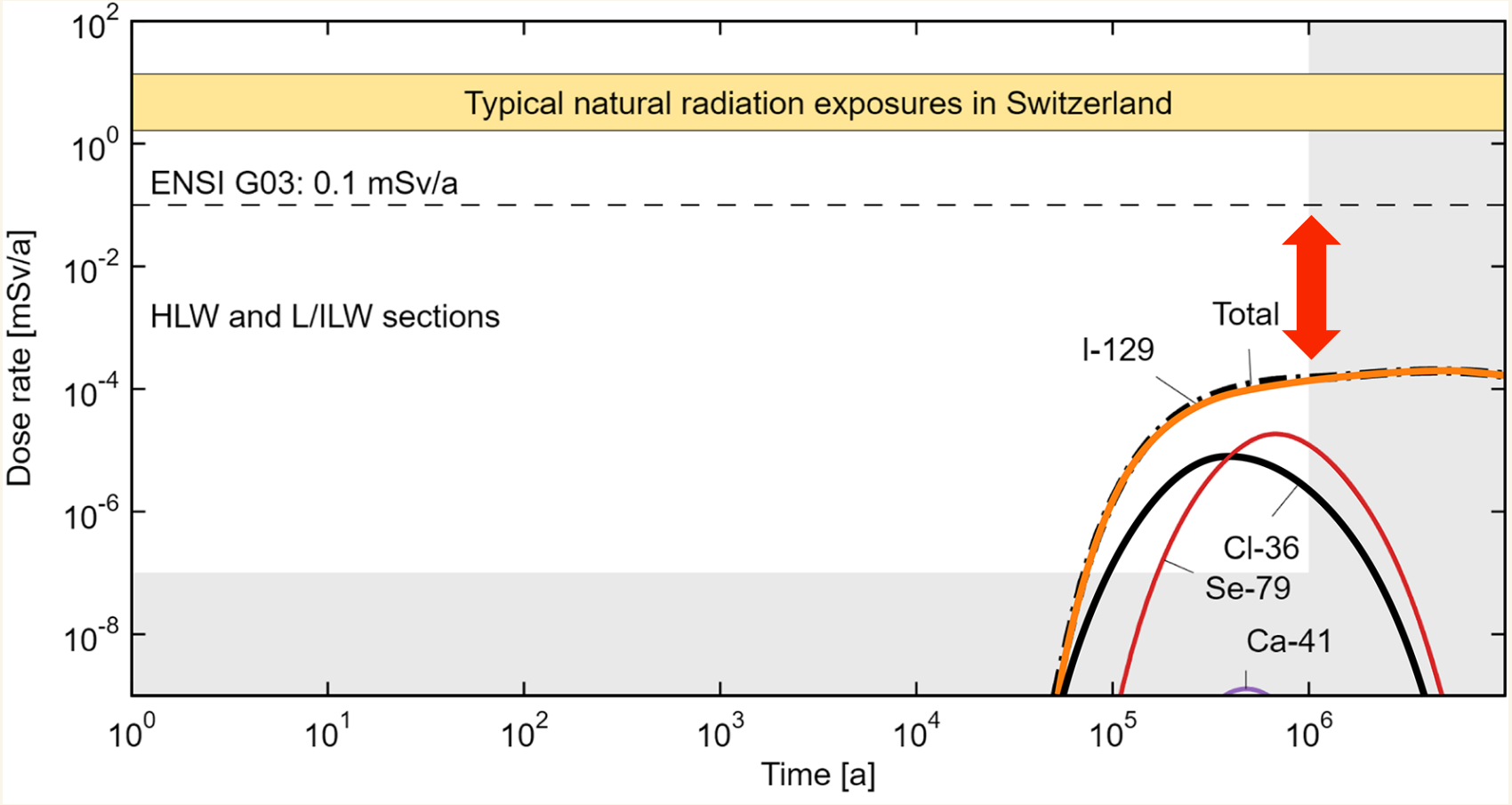


Focus/priority:

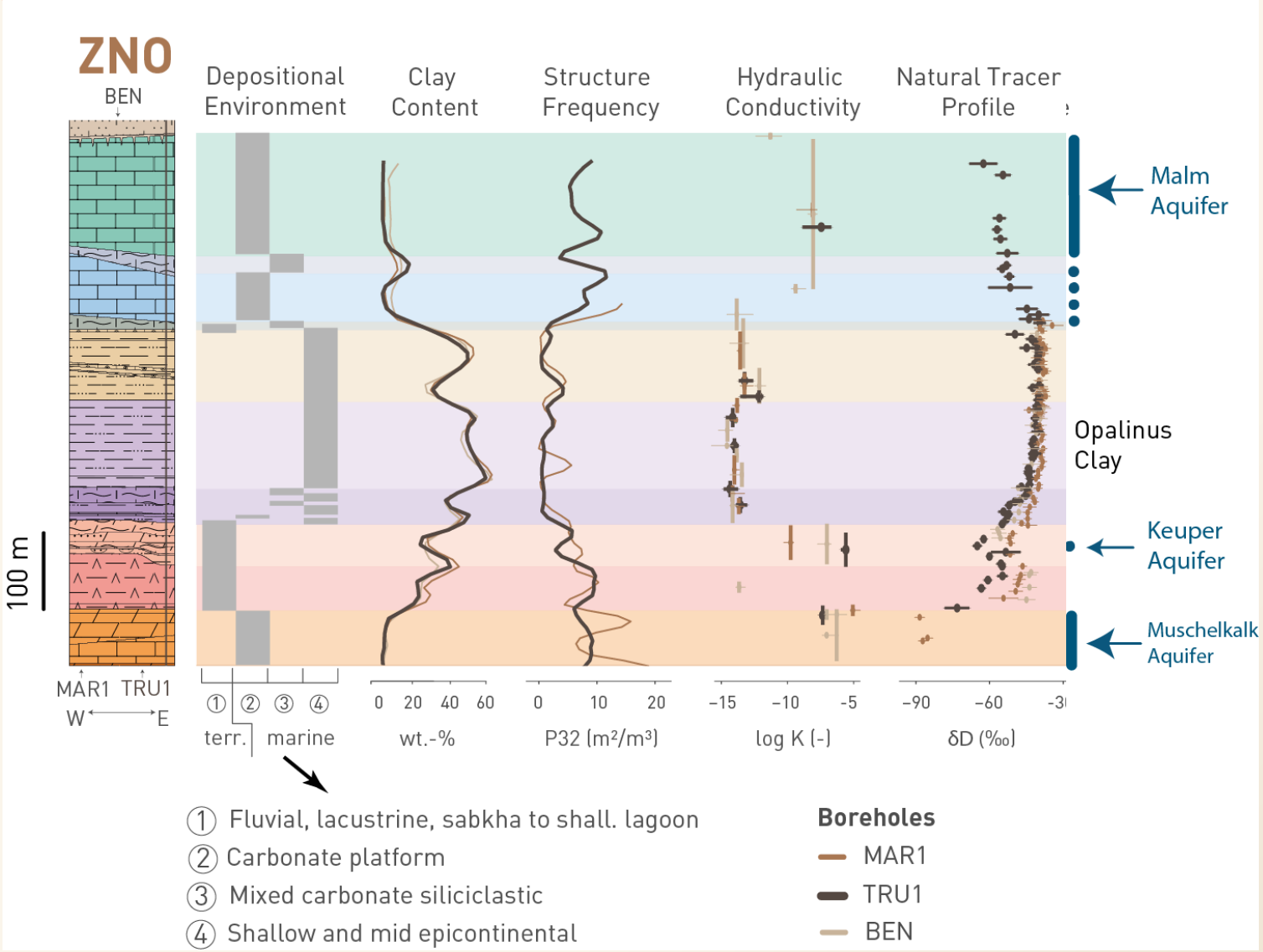
- Parameters with relevance for radionuclide transport
- Focus on Opalinus Clay, low-permeability confining units rocks and confining aquifers
- ➢ Robust data basis for site comparison and demonstration of safety

GEOMETRIES AND PROPERTIES KNOWN → DOSE CALCULATIONS





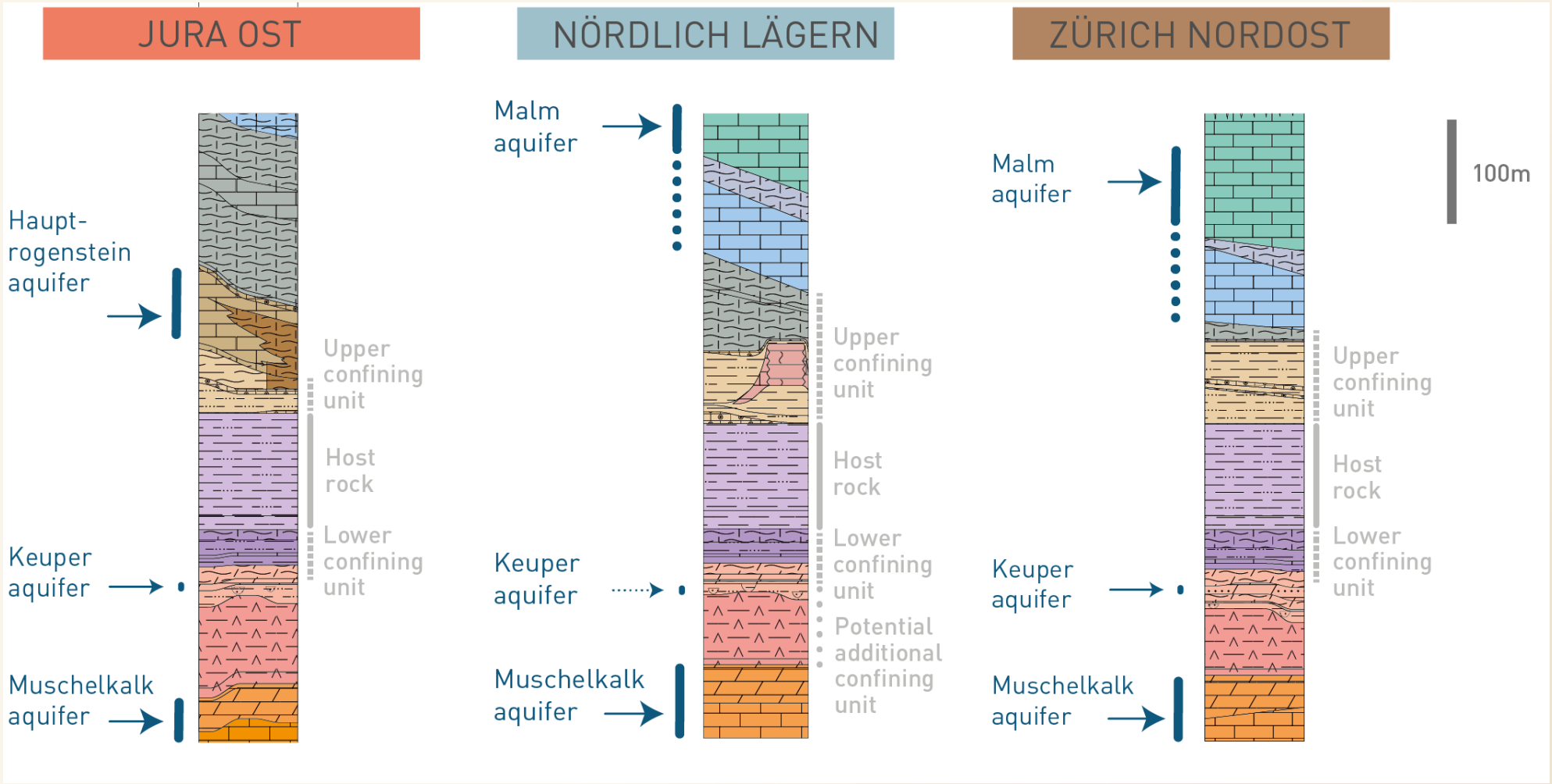
DEEP DRILLING CAMPAIGN: VISUALISATION OF KEY RESULTS



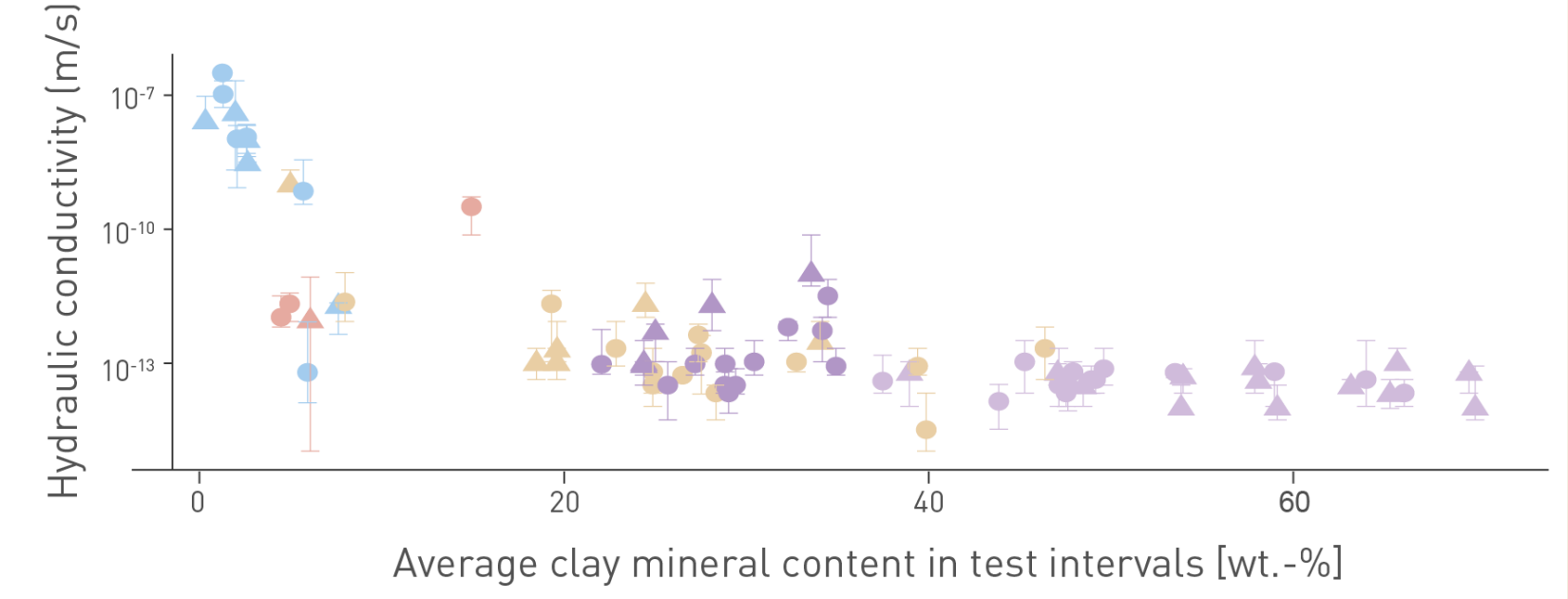
Data-based delimitation and characterisation:

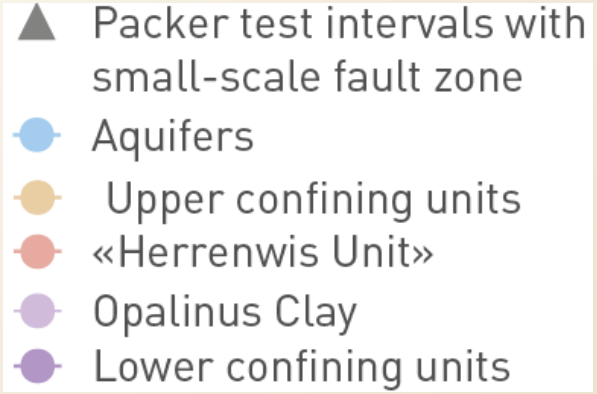
- Host rock
- Low-permeability confining units
- Confining aquifers

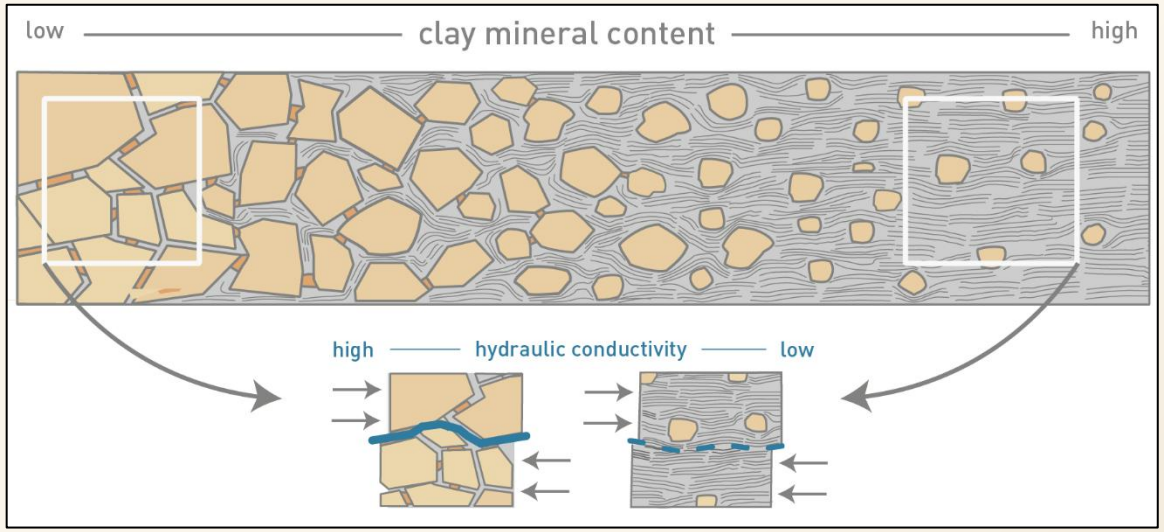
DEEP DRILLING CAMPAIGN: VISUALISATION OF KEY RESULTS



DEEP DRILLING CAMPAIGN: VISUALISATION OF KEY RESULTS







Clay mineral content determines key processes:

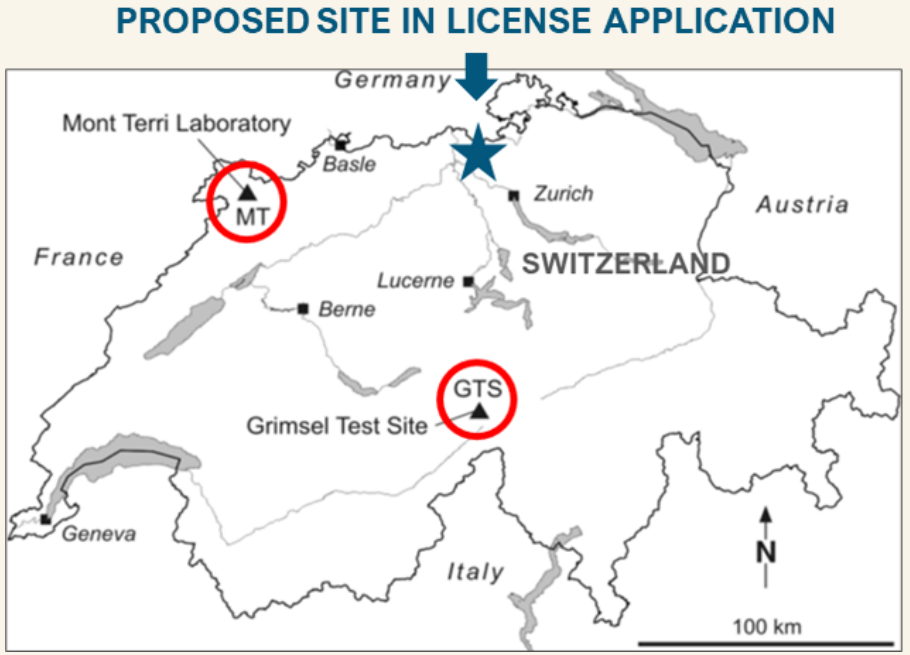
- hydraulic conductivity

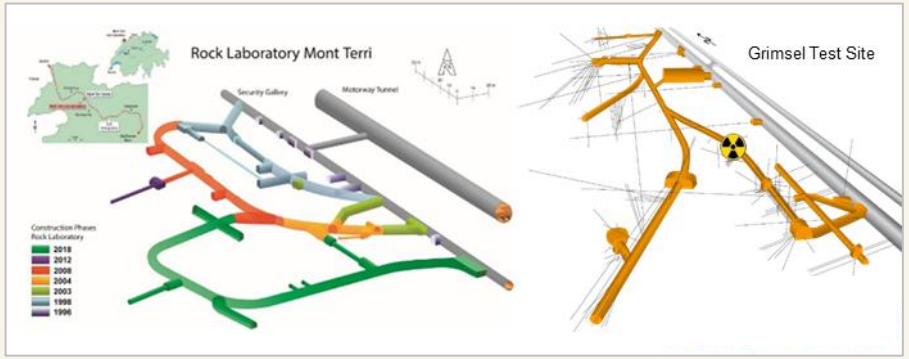
THE ROLE OF GENERIC UNDERGROUND ROCK LABS

- **Grimsel Test Site (GTS)**, crystalline rock, since 1984
- **Mont Terri (MT)**, Opalinus Clay, since 1996

Extremely valuable for:

- Develop & Test workflows
- Support argumentation for safety case
- Test & demonstrate technologies
- Build up international networks
- Communicate with stakeholders

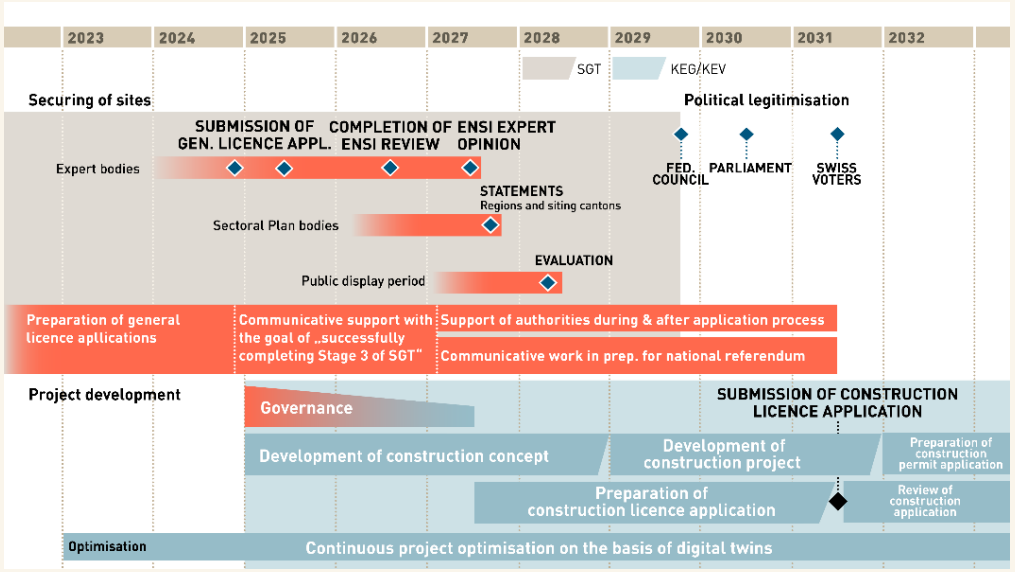




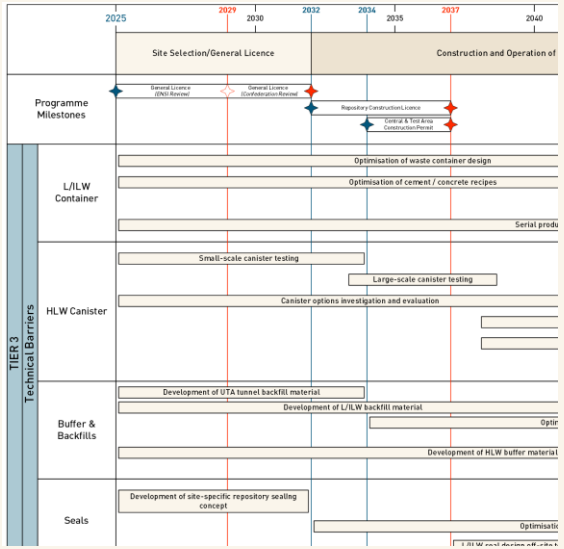
LOOK AHEAD: MID-TERM PLANNING

STAGED APPROACH → WHAT DO WE NEED TO KNOWN WHEN AND AT WHICH LEVEL OF DETAIL?

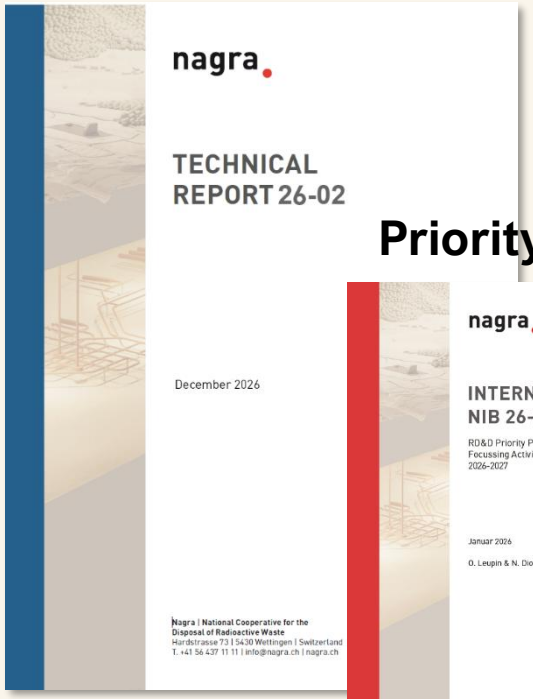
Mid-term planning



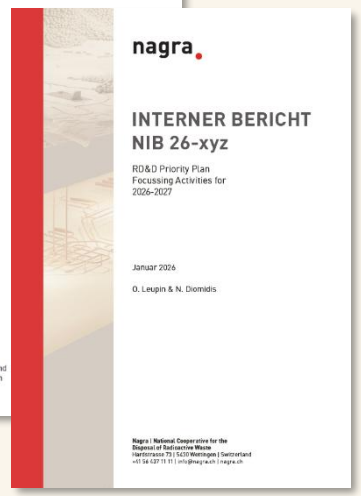
Roadmaps



RD&D plan



Priority plan



SUMMARY: WHAT WORKED IN SWITZERLAND (SO FAR)

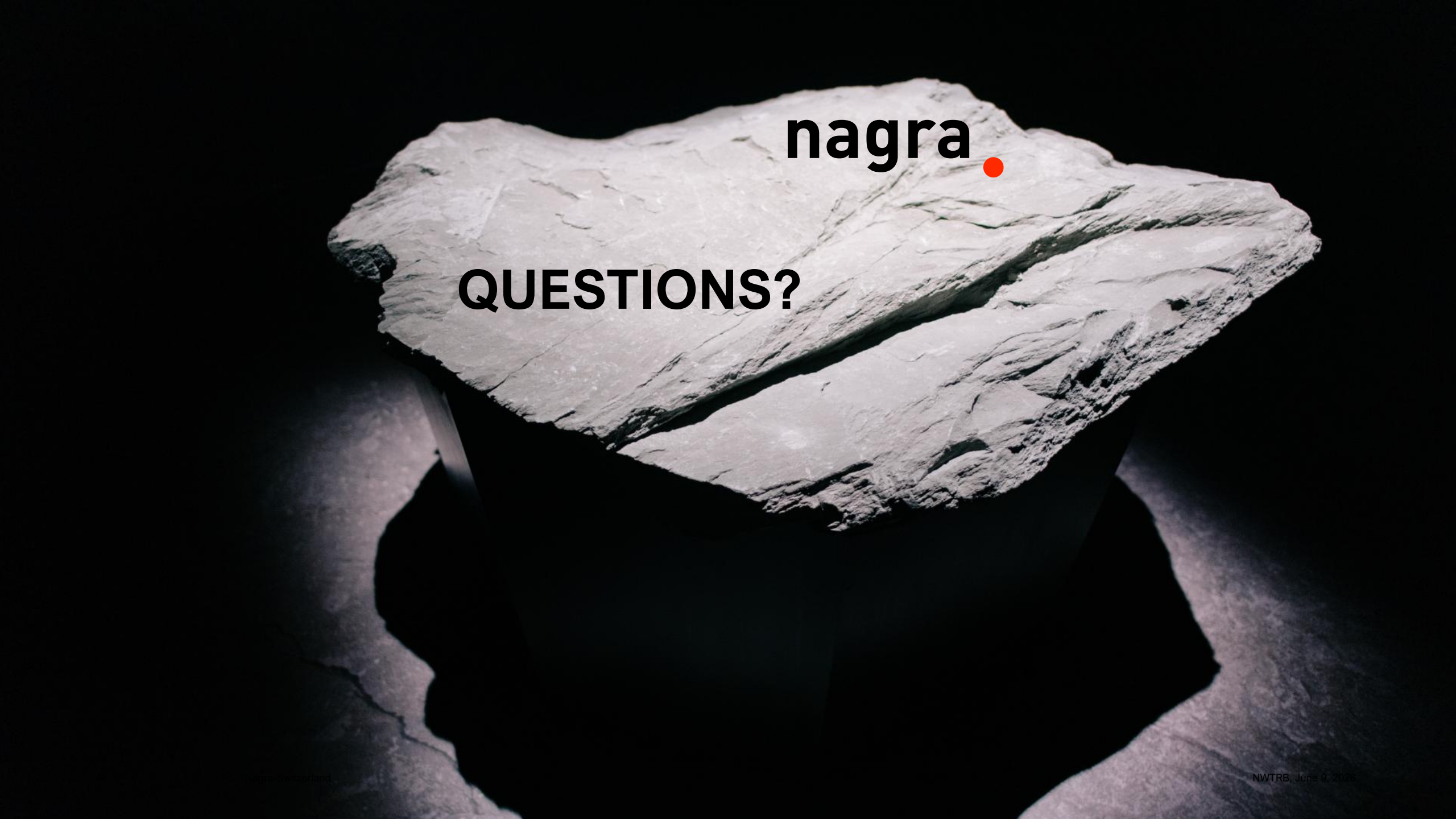
- **Science based** approach
- Staged data collection, confirmation and **legitimation** of decisions
- **Team Switzerland** drives the siting process (Partners in defined roles)
- **Flexibility** in location and implementation is key (Plan B and C and D)
- **Listen**. And do as you say.
- **Discuss your data** to prepare for site announcement.

Result: **no more delays since 2016**.

SUMMARY: LOOKING AHEAD – PROJECT TERRADURA

As site **selection process completed successfully:**

- **Nagra is adapting** to the new phases ahead → **project development** to the selected site (incl. preparation of Construction License)
- **Multi-objective Optimisation** is key for deep geological disposal – higher or similar level of safety!
- **International exchange** and **collaboration** was, is, will be of great value to Nagra
- **URLs as platforms for international exchange** and collaboration were, are and will be an integral part of our program


nagra.
QUESTIONS?