Nuclear Waste Technical Review Board
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Spring Board Meeting

The role of monitoring in the Swiss disposal program

Piet Zuidema - Zuidema Consult GmbH

(formerly Director Science & Technology, Nagra, Switzerland)

The questions asked

i. How is monitoring related to Nagra's safety case?

ii. What motivated Nagra to adopt a repository design that features a separate area for monitoring?

iii. What features, events, or processes will be monitored during the preclosure period? Postclosure period? Has the instrumentation been developed to carry out the monitoring?

iv. What are the requirements in Switzerland for retrievability?

v. What benchmarks, if any, have already been identified that would trigger a decision to retrieve the waste?

vi. How would that decision be made? What are the institutional and technical challenges of implementing such a decision?

Monitoring in Swiss disposal program: The issues

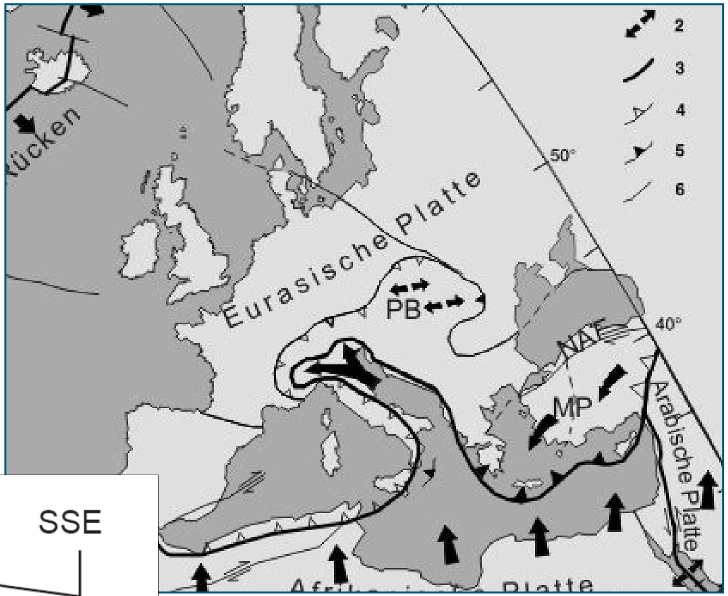
- Relation of monitoring to safety and repository implementation
  - monitoring is an essential source of information for the safety case
  - the safety case is a key element for the stepwise decision-making in Swiss disposal program
  - thus, monitoring plays an important role in all phases of disposal program
- Monitoring in the different phases of repository implementation …
  - … to acquire regional geological information to assess geological stability for site selection
  - … as part of RD&D: long-term experiments in URL & lab, including experiments to evaluate host rock suitability
  - … as part of site characterisation (incl. site URL)
  - … as part of surveillance of performance of repository system (site, disposal rooms, specific long-term experiments at site & elsewhere)
- Results of monitoring need interpretation, results of interpretation may require action (flexibility & options to act, including retrieval of waste)

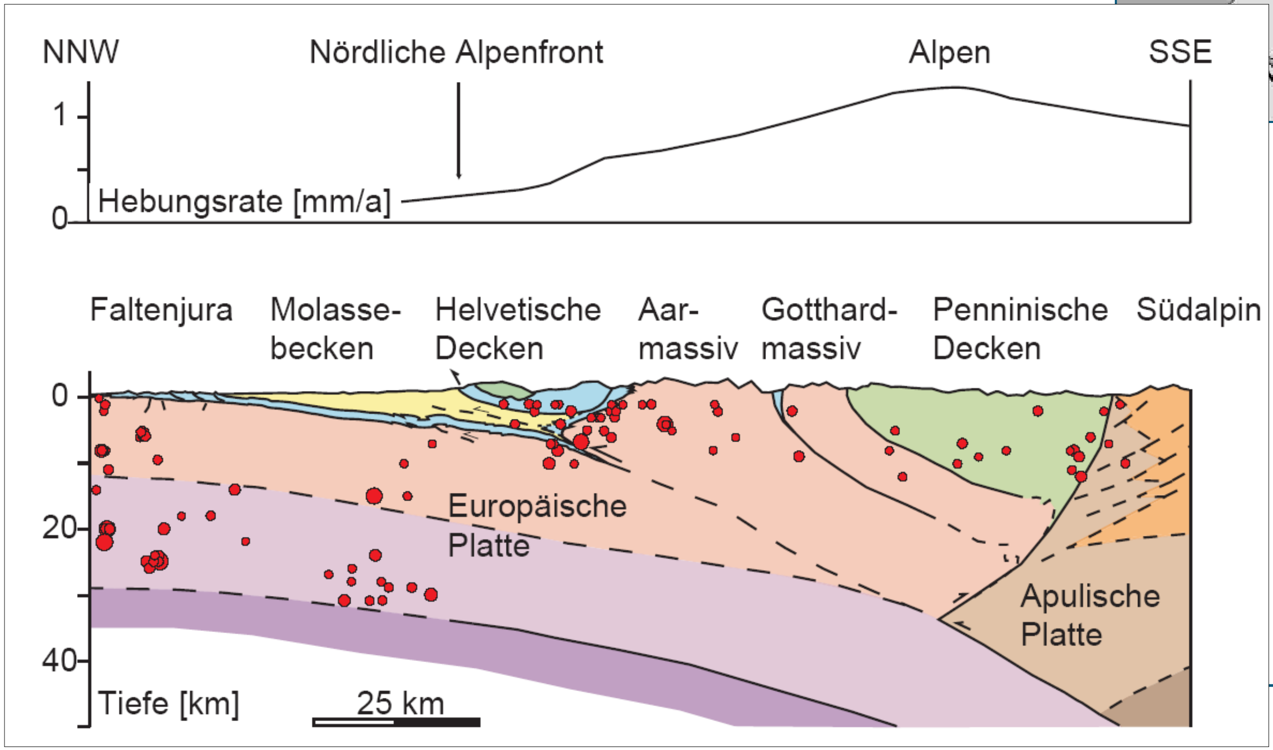
Monitoring – geological long-term stability for site selection

Switzerland: Geological and tectonic environment

Complex geology

- Alps (→ erosion; glaciation)
- Uplift continues → erosion
- Differences in neotectonic activity (more quiet in Northern Switzerland)



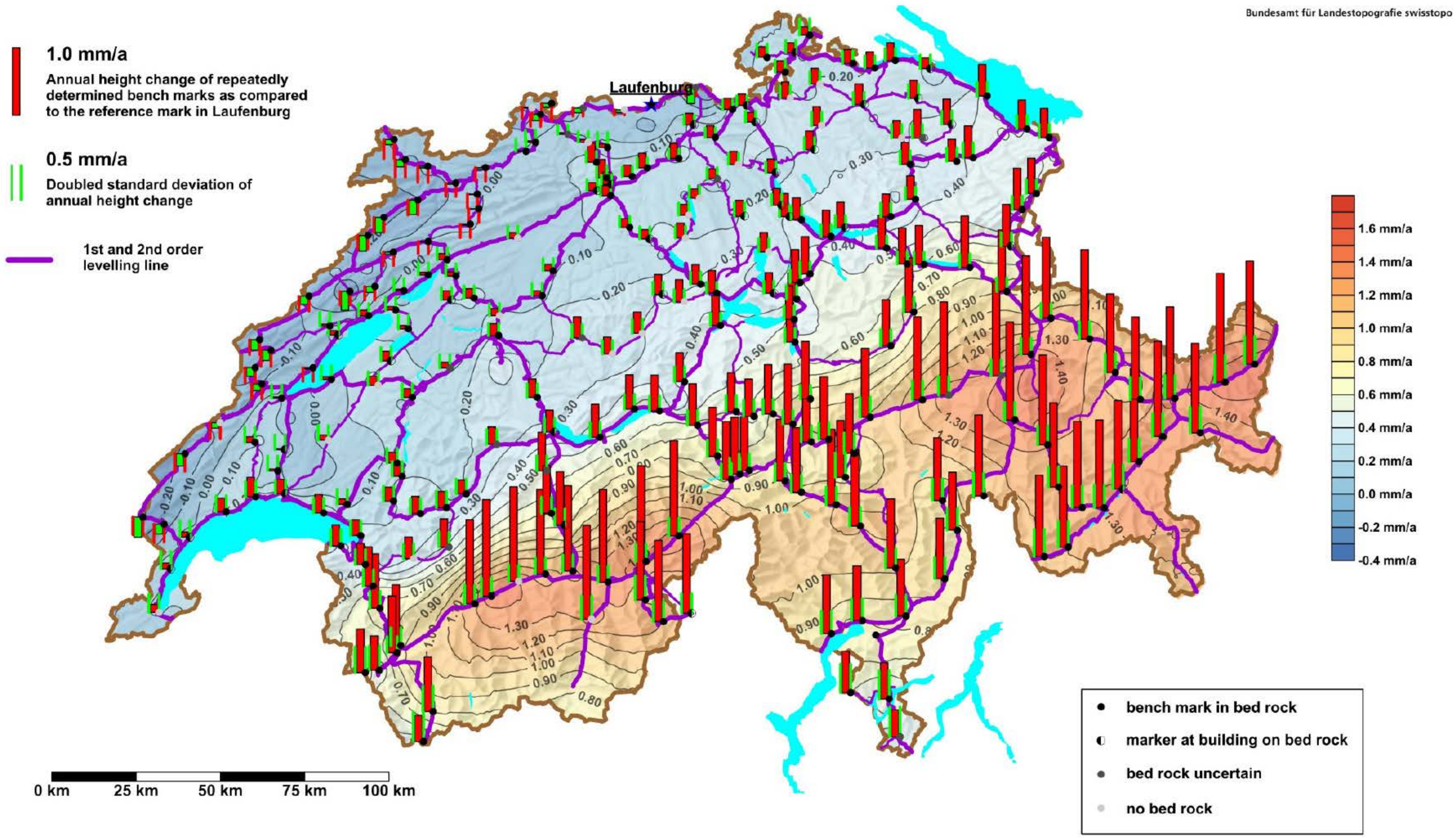


Geological stability: Regional high precision levelling

Measuring series for more than 100 years

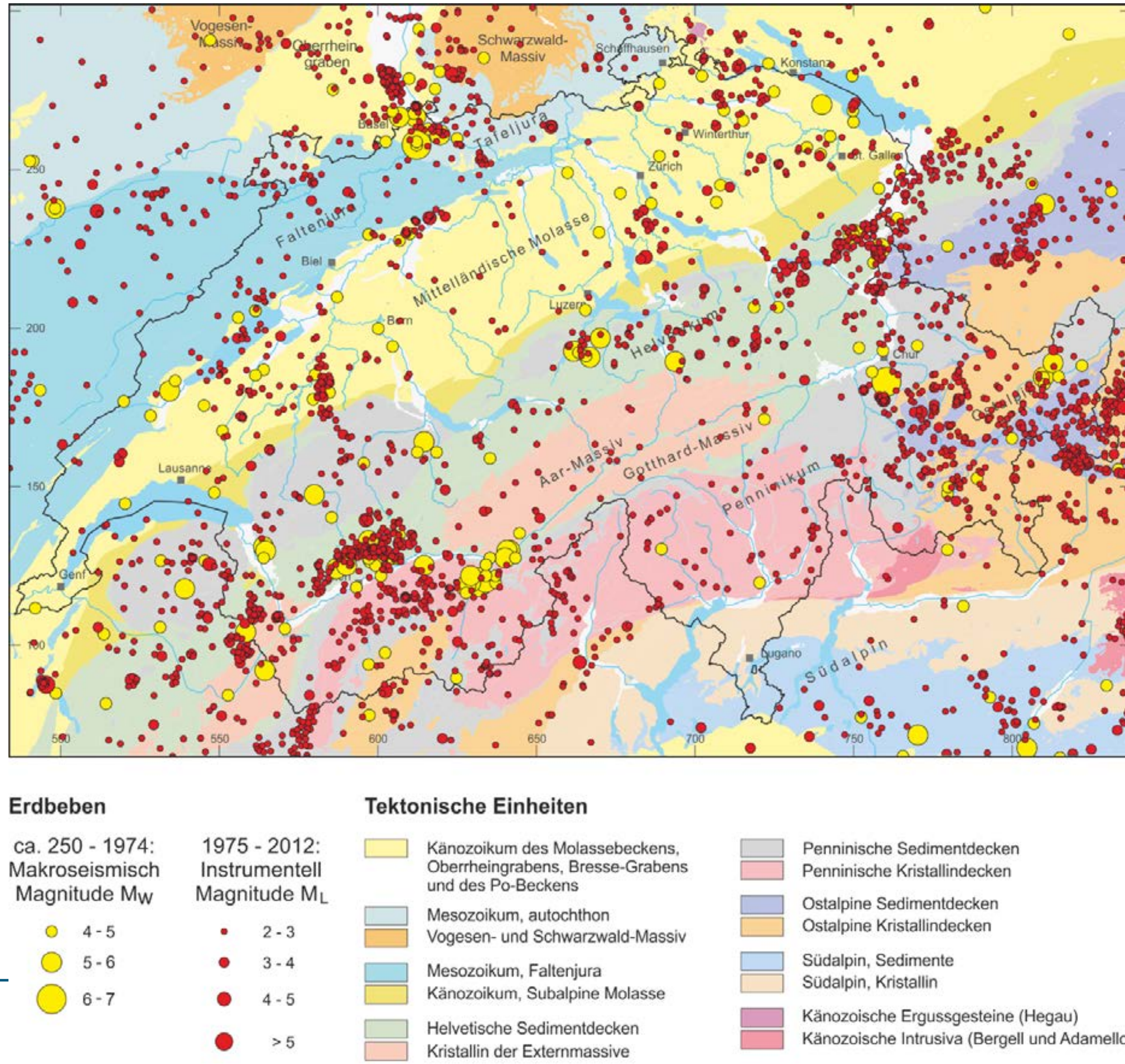
… to support other geological information

P.S.: also network of GNSS-stations implemented



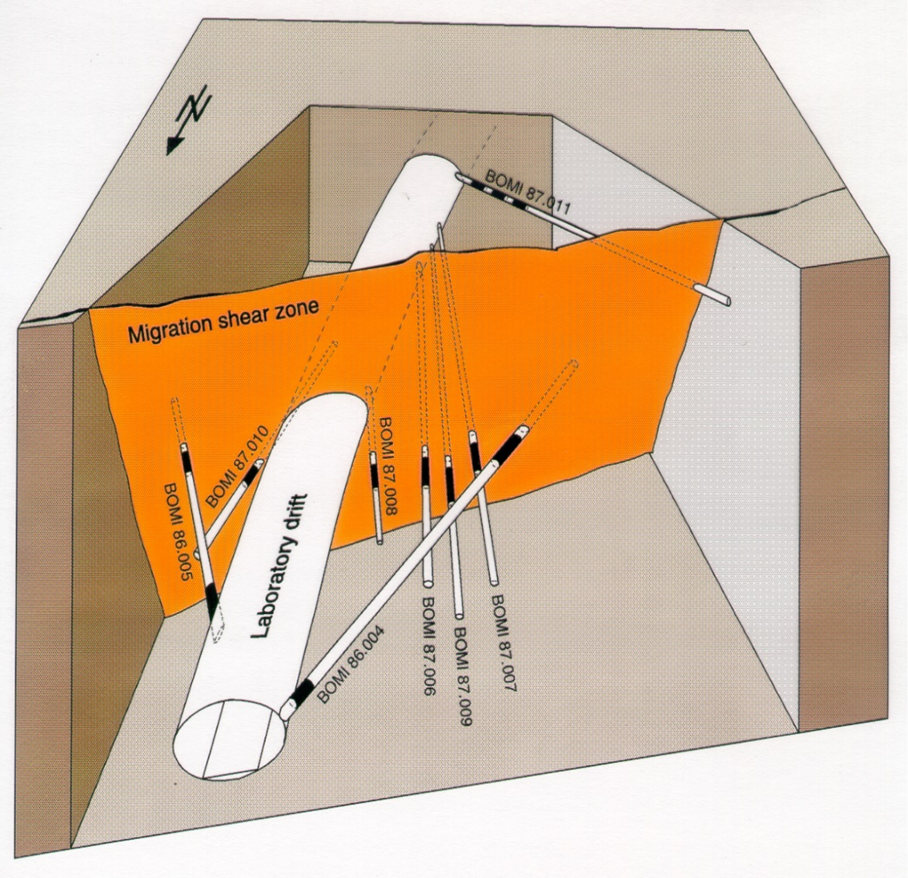
Geological stability: Regional monitoring of seismicity

… to support other geological information



Monitoring – part of RD&D

Host rock performance: Migration experiment (GTS)

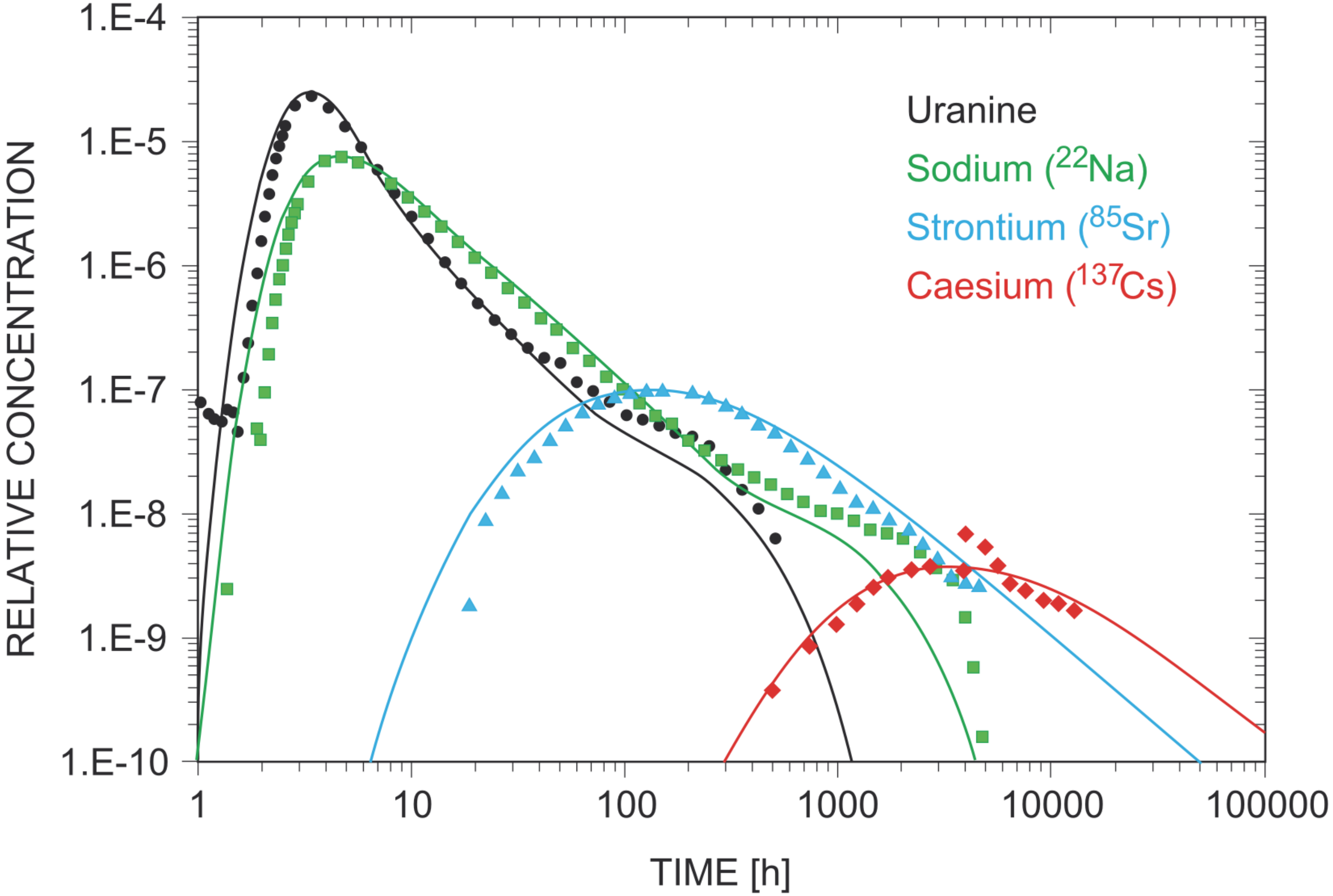


For a well characterized system

- to see: qualitative confirmation of basic conceptual understanding
- to provide a data set for rigorous model testing
- to test transferability of lab data to in-situ conditions

Migration experiment (GTS): Results

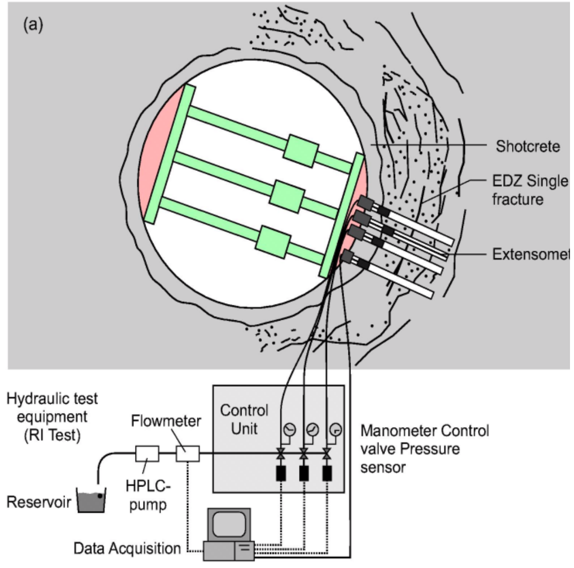
Consistency between lab/model-predictions and field observations found

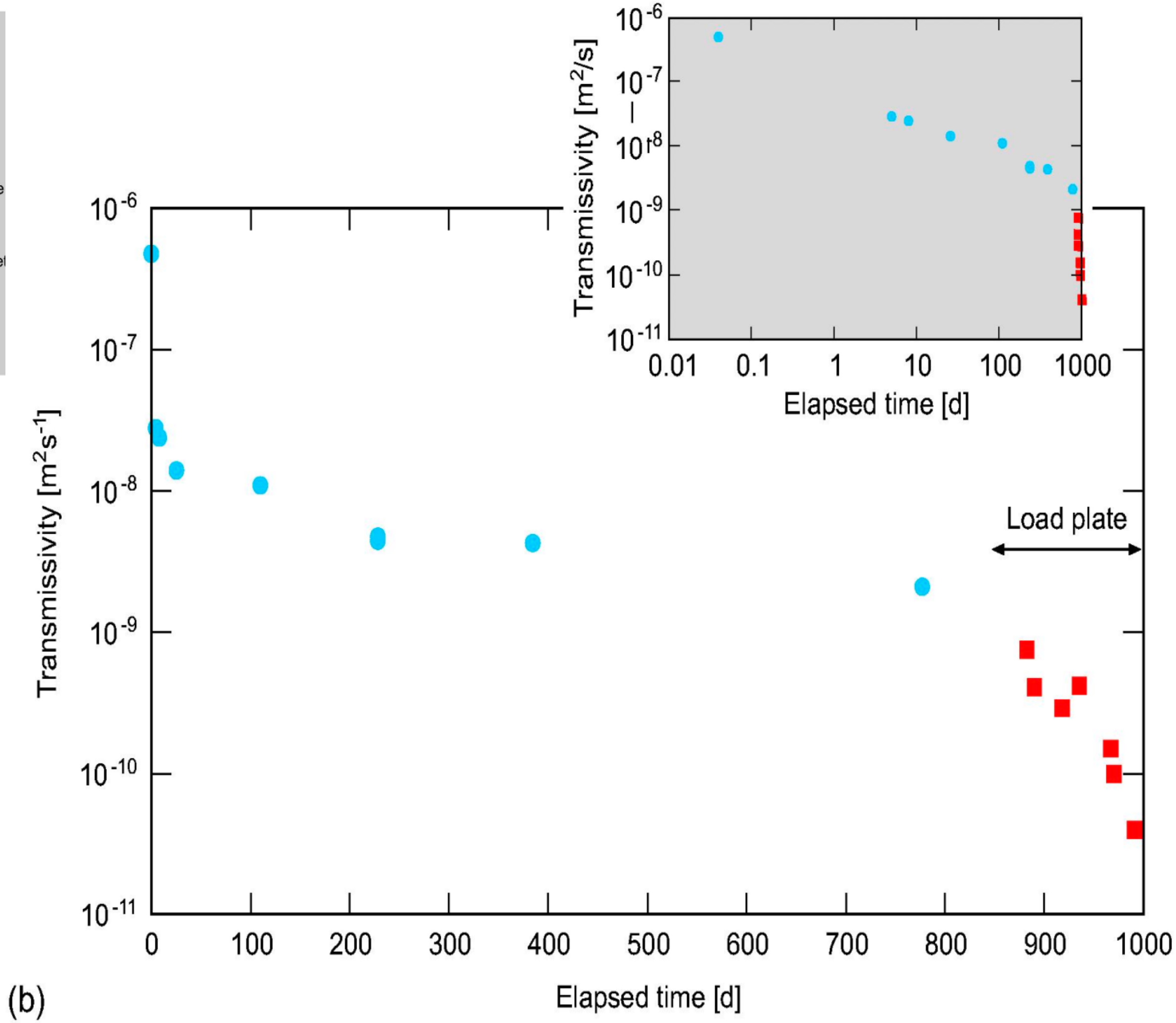


e.g.: Heer, NTB 04-03 (Fig. 14)

Host rock performance: Transmissivity of the EDZ (FMT)

Performance acceptable?

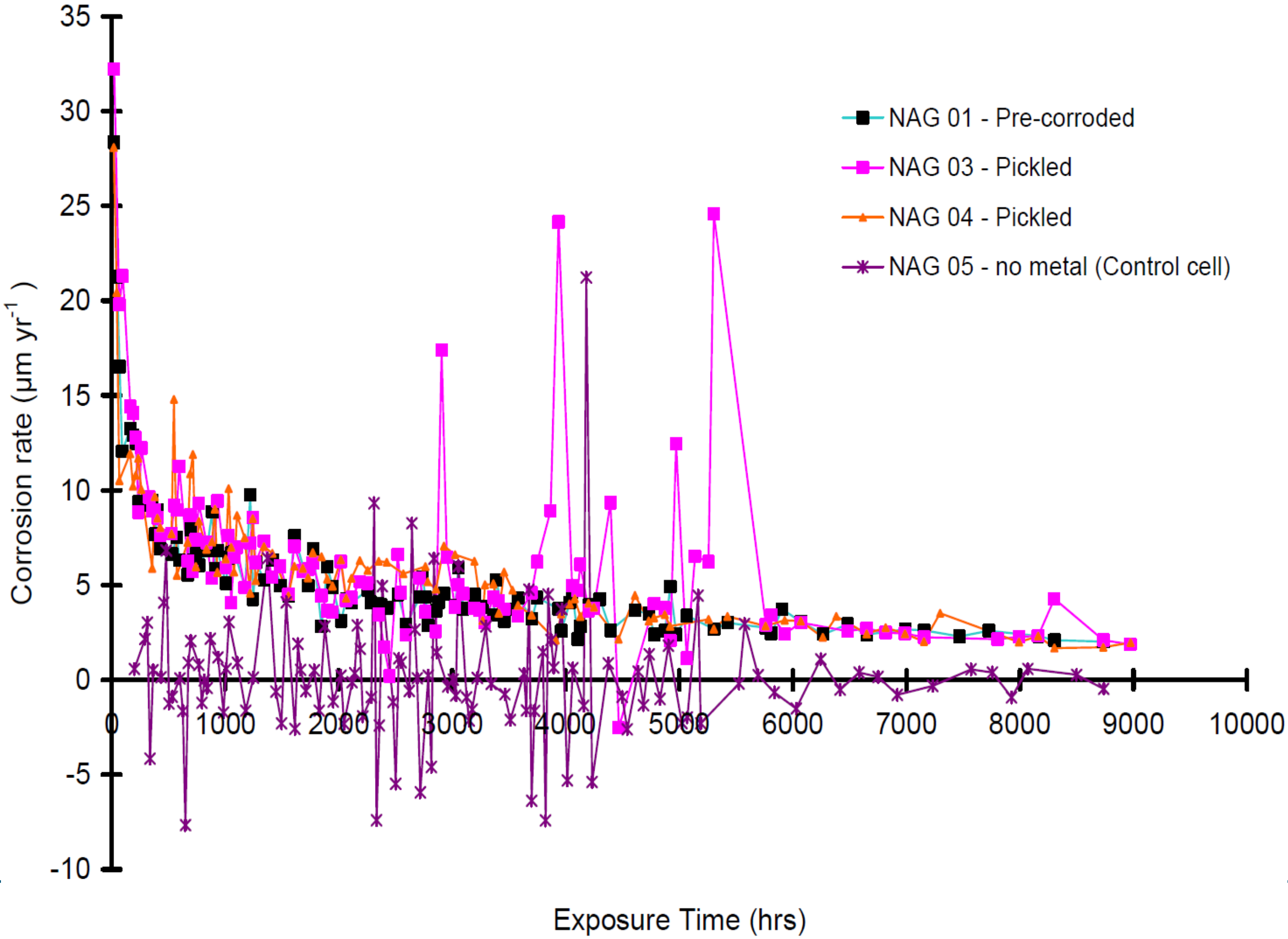




- Open tunnel (EH): Reduction of T from 5E-7 m²/s to 5E-9m²/s over a period of 800d
- Load plate (SELFRAC) (< 5 MPa): Reduction of T from 5E-9 m²/s to 2E-11m²/s (early stop of experiment)

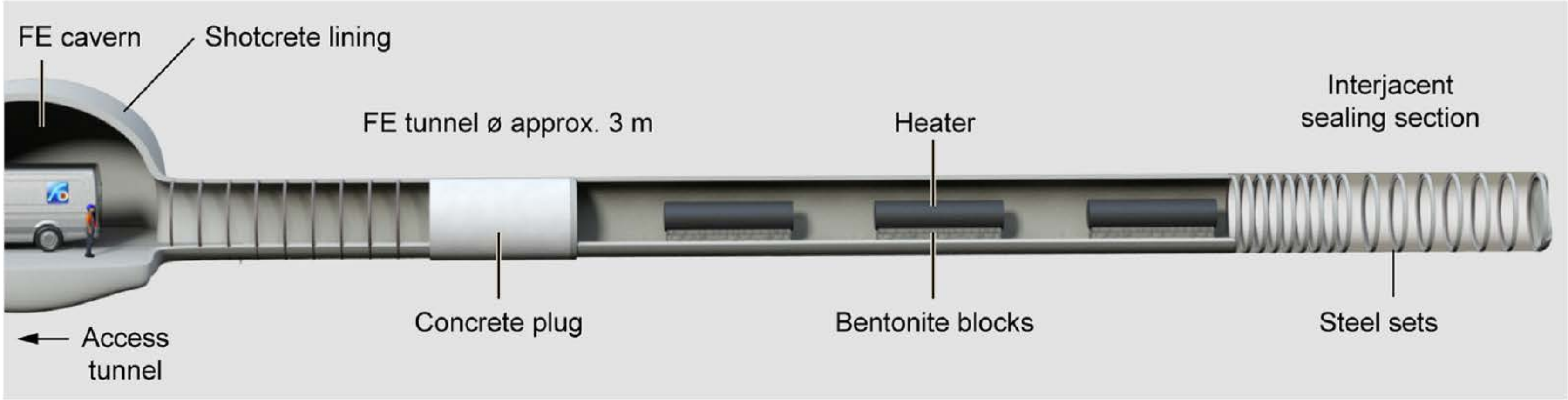
Performance of canister: Steel corrosion rates

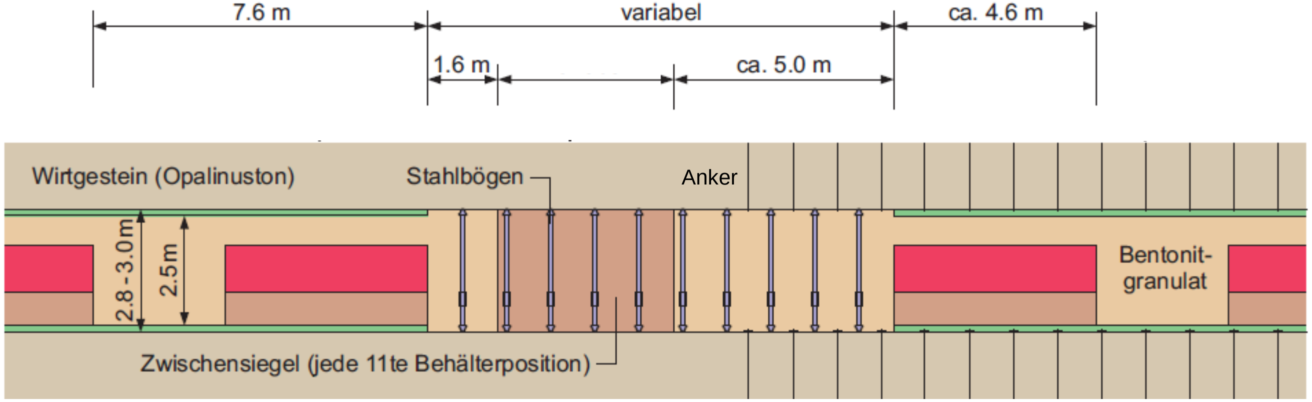
Performance acceptable?



FE Experiment at URL Mont Terri

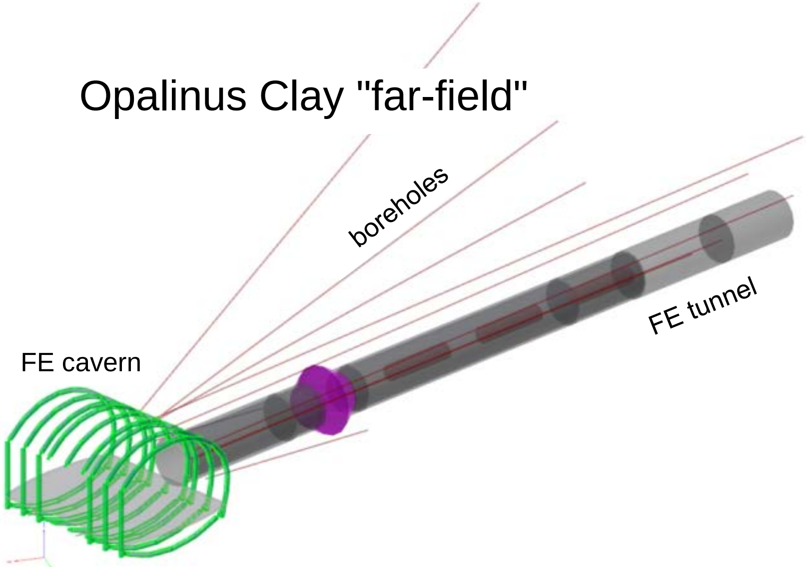
… is a 1:1 representation of the disposal tunnels for SF/HLW



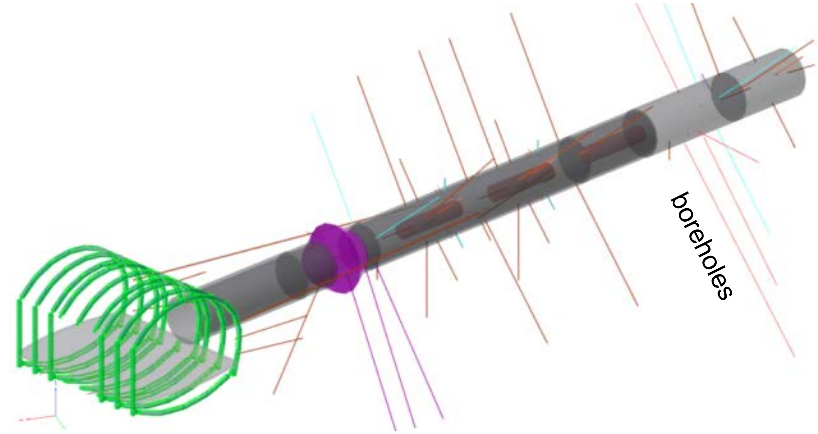


… strongly instrumented: monitor system performance

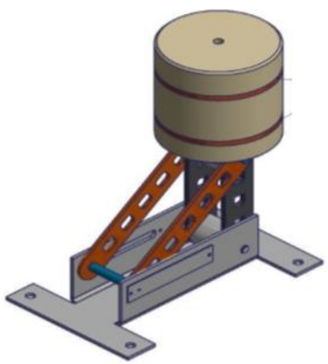
Opalinus Clay "far-field"



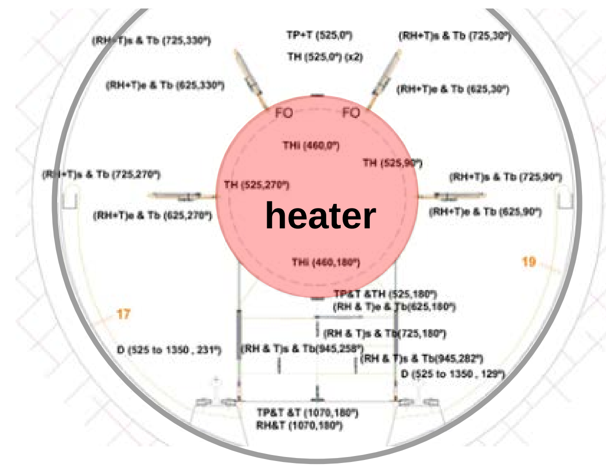
Opalinus Clay "near-field" / EDZ



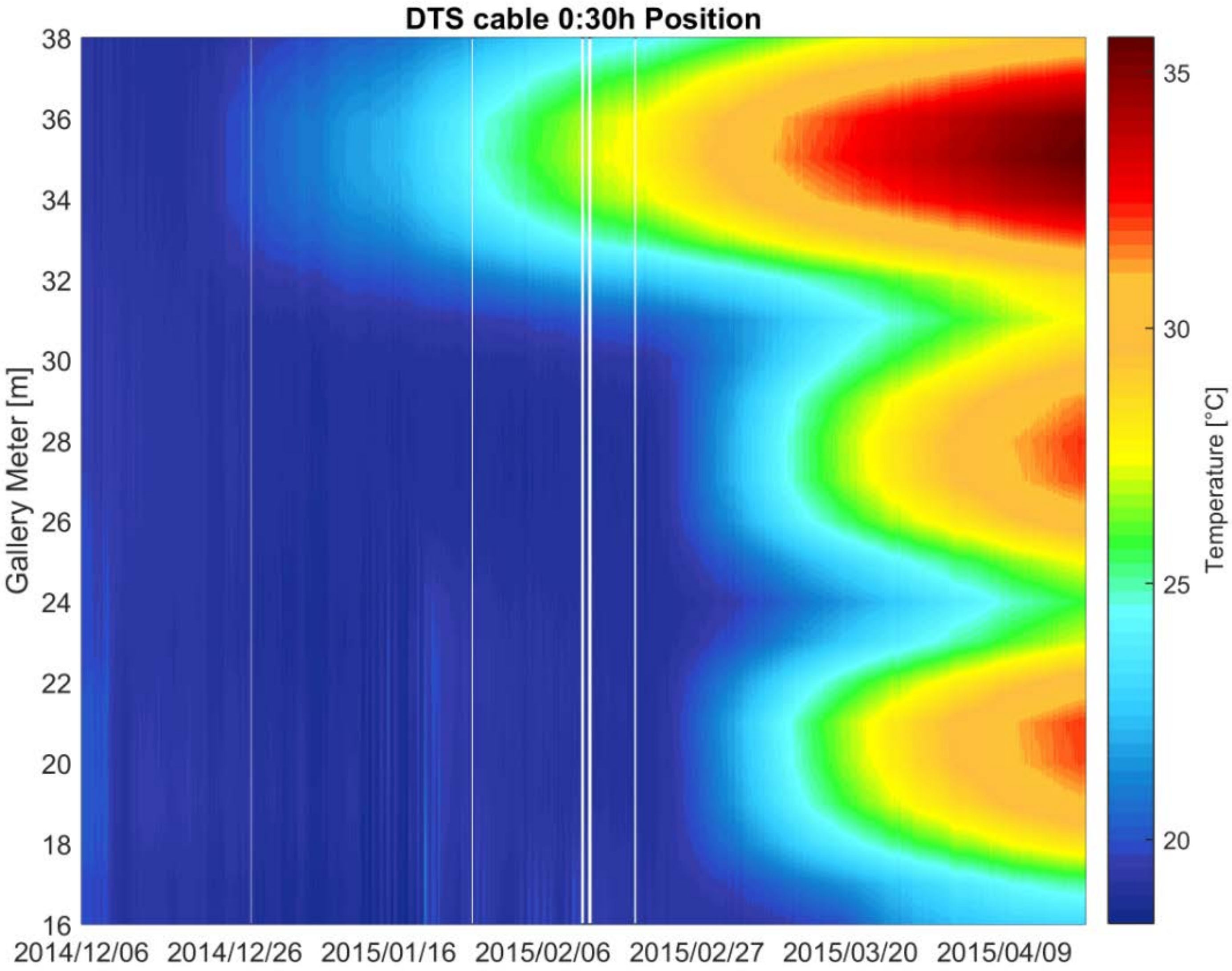
On tunnel wall / in bentonite



On heaters / in bentonite

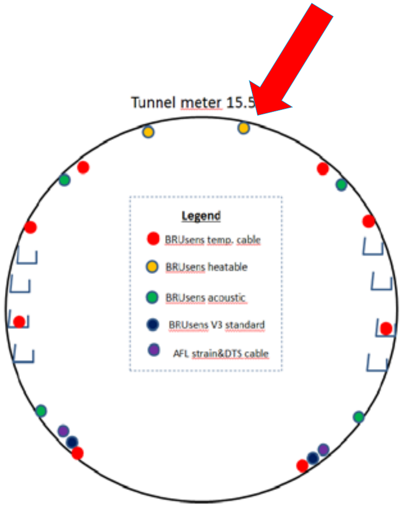


FE-experiment: Evolution of temperature at tunnel wall



Heating started:

- Dec 14 (heater 1)
- Feb 15 (heater 2)
- Feb 15 (heater 3)

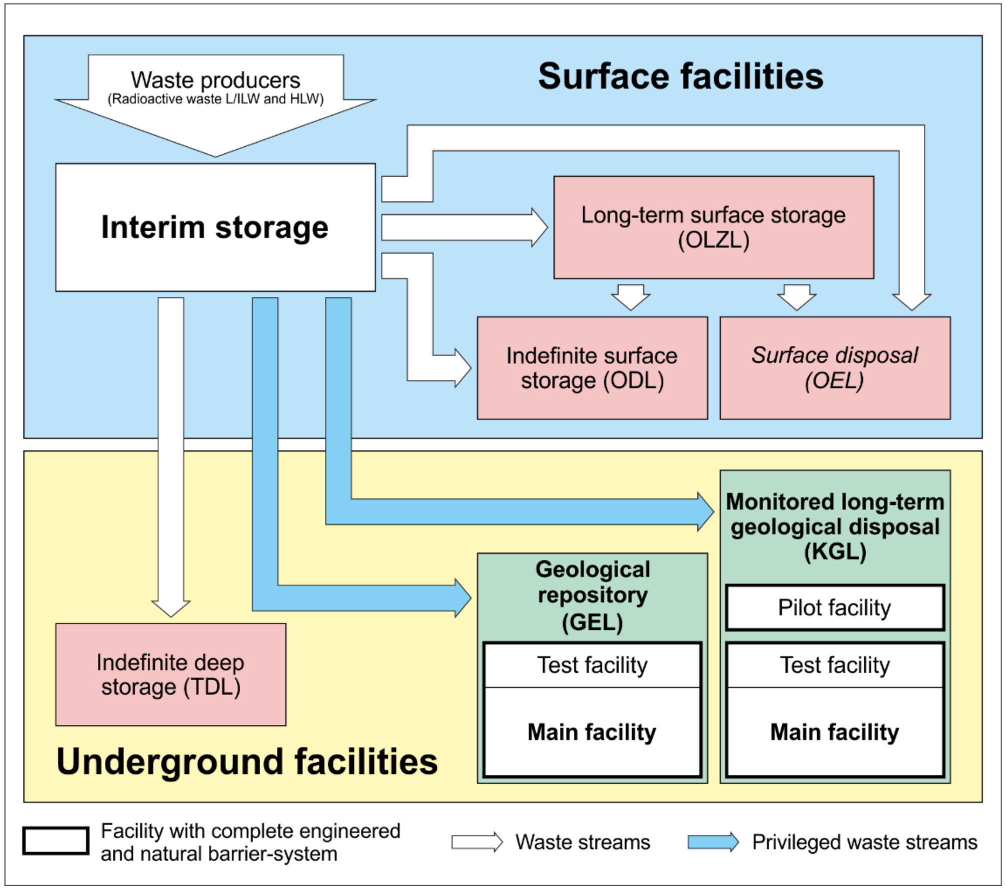


Monitoring as part of repository 'surveillance'

Monitoring of repository: Background

- Proposals for alternative concepts to geological disposal were discussed already very early (already in 70'ies)
- Concepts with main emphasis on monitoring & retrievability led to concepts with more reliance on social control ('nuclear guardianship')
- In Switzerland these concepts found some support by some NGOs
- In preparation of new nuclear energy act (2003), an 'energy dialogue working group' with pro / anti nuclear representatives had to address fundamental aspects of nuclear waste management (Ruh 1998)
- Group did not reach any conclusion → EKRA (Expert Group on Disposal Concepts for Radioactive Waste) established by Government
- EKRA: comparison of concepts (→ proposal) with respect to
  - active and passive safety
  - monitoring and control
  - retrievability of waste
- EKRA's basic ideas were implemented in law (nuclear energy ordinance)

Broad evaluation of disposal concepts



EKRA, 2000

Investigations by EKRA

Assess options with respect to

- active / passive safety
- monitoring & control
- retrievability

Result: combine …

- passive safety

… with

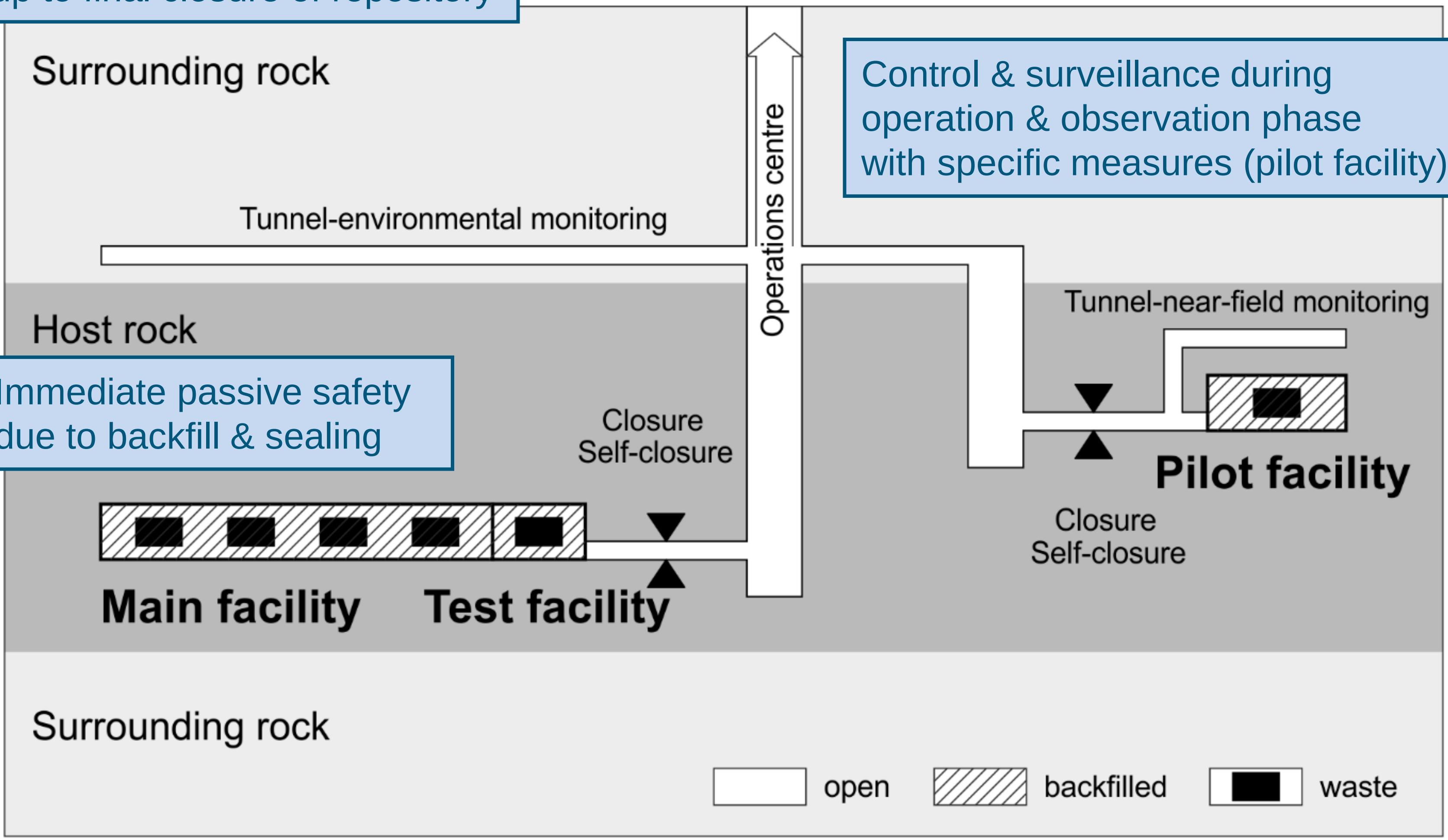
- reversibility (retrievability)

Concept proposed by EKRA: Key elements

Retrieval without undue effort up to final closure of repository

Control & surveillance during operation & observation phase with specific measures (pilot facility)

Immediate passive safety due to backfill & sealing



EKRA, 2000

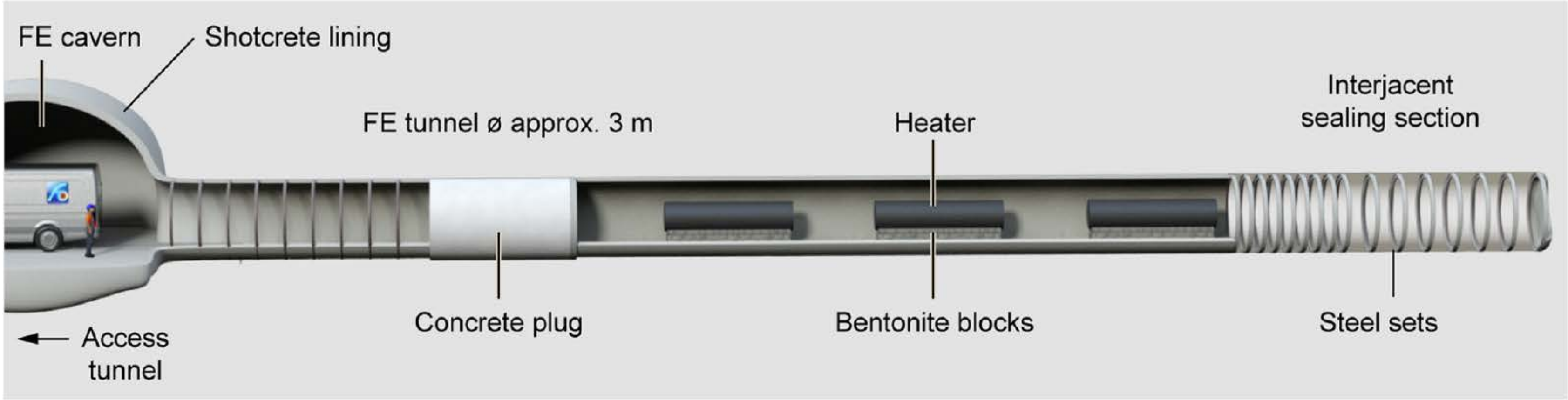
Monitoring and retrievability (legal requirements)

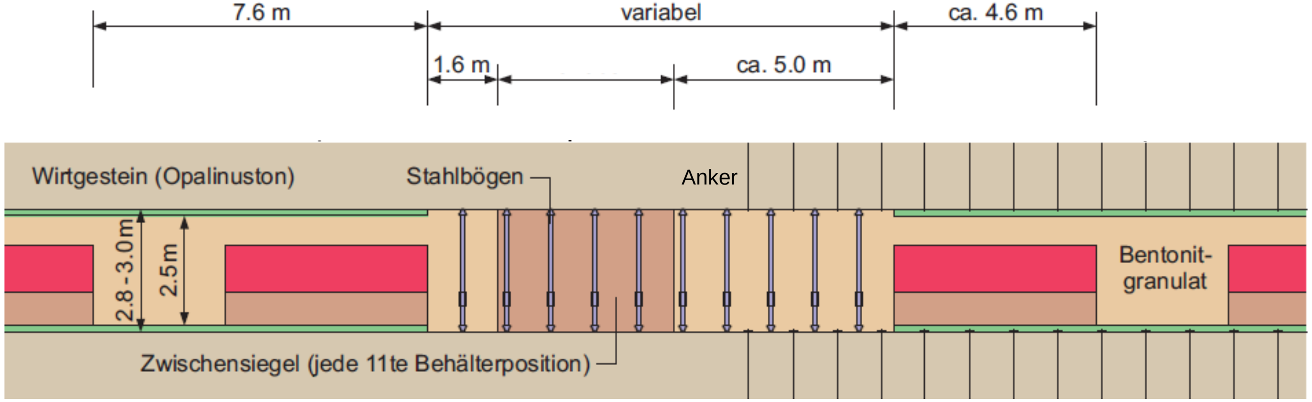
- Monitoring of repository during operation and observation phase
- Retrieval possible without undue effort until end of observation phase
- … both without compromising passive long-term safety
- Elements of repository
  - Main facility with high level of passive safety
    - disposal rooms to be continuously backfilled/sealed (no specific monitoring)
  - Test facility / in-situ URL[1)]
    - to further investigate safety relevant properties of host rock and technology before start of operation
    - during operation of repository: investigate closure
  - Pilot facility
    - monitor behaviour/performance of waste, backfill & host rock during operation & observation phase → data to support safety case for closure of repository
    - transferability of information of pilot facility to main facility to be ensured
    - layout of pilot facility: comparable with main facility, with representative wastes
  - Additional monitoring in other places, including regional monitoring

1) Option to use test facility also for dedicated long-term experiments (complementary to pilot facility)

FE Experiment: Example for pilot facility

… is a 1:1 representation of the disposal tunnels for SF/HLW





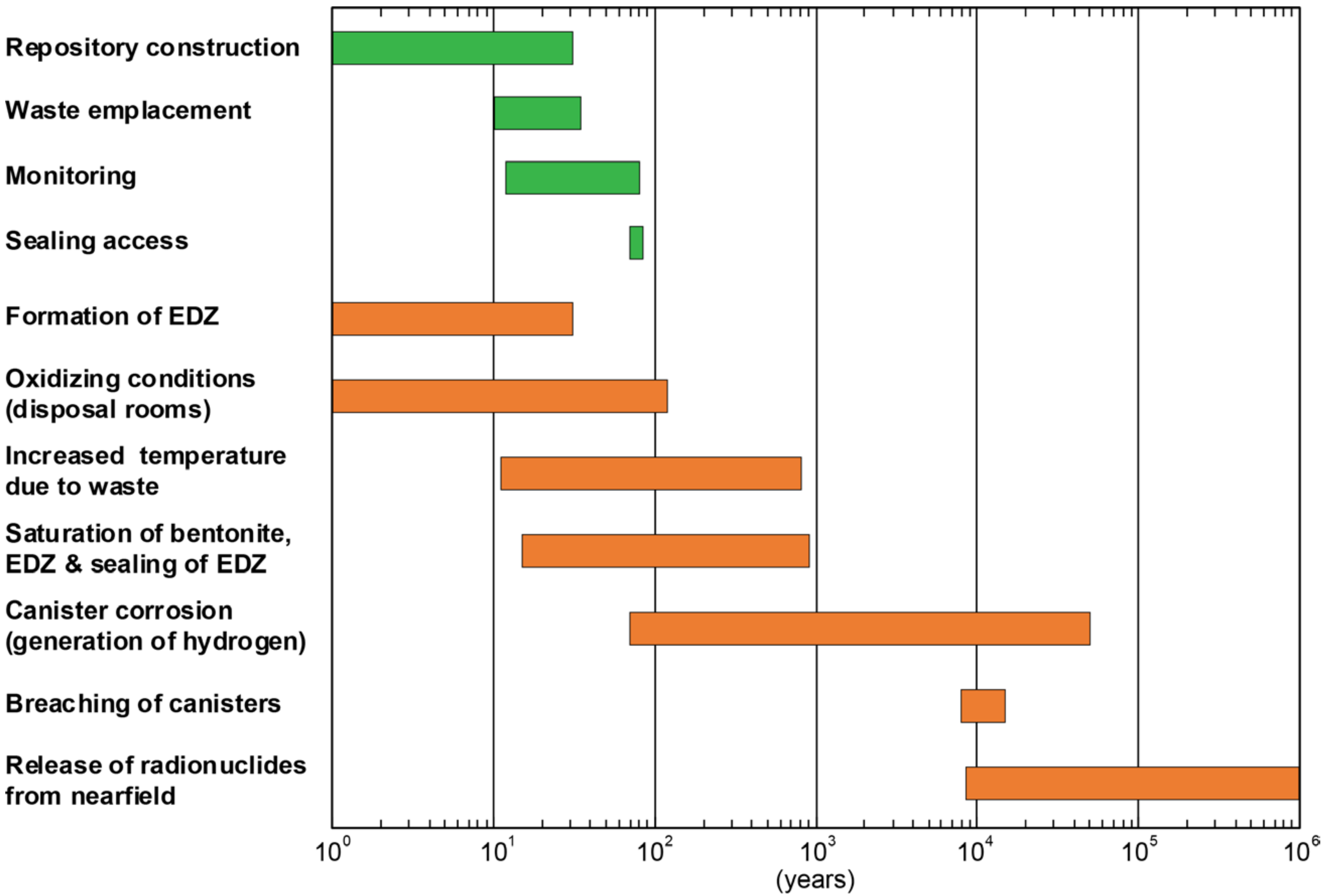
Monitoring: Discussion points (Swiss concept)

- 'Control' consists of technical & societal components
  - what can be measured?
  - who is involved in measurements, interpretation & decisions on actions?
- Parameters measured in pilot facility before final closure of repository must be meaningful as indicators for system performance
  - parameters measurable and directly/indirectly relevant for safety
  - parameters relevant but not measurable in pilot facility → experiments in test facility or elsewhere
- Measurable (in pilot facility):
  - when is 'relevant' phenomenon occurring? (physics, chemistry, …)
  - performance of sensors (resolution, averaging/area covered, ...)
  - transients vs. 'relevant endpoint' (often steady-state or close to it)
  - *….*
- 'Relevance': derived from safety (phenomenological descriptions, sensitivity analyses, ….)

List of phenomena (HLW repository nearfield)

- Excavation: evolution of EDZ, convergence of drifts (after backfilling: self sealing)
- Thermal loading: temperature increase, impact of temperature (bentonite, host rock, porewater pressures, deformations, …)
- De-/re-saturation, impact of water content (transport, temperature, gas release, chemistry, …)
- Swelling of bentonite (impact on EDZ → self-sealing)
- Corrosion of canister (oxic/anoxic), gas formation, breaching of canister, corrosion products, volume increase, …
- Gas release
- Evolution of geochemical conditions
- Corrosion / dissolution of waste matrix
- Radionuclide transport, precipitation, sorption, release into host rock, …
- ….

HLW emplacement tunnels: Temporal evolution



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- ….

With respect to overall system performance not that much can be monitored …

Monitoring of overall repository performance …

… in direct manner not possible, only few relevant phenomena captured

- The time needed for ….
  - resaturation of emplacement room
  - canister corrosion & breaching
  - eventual start of waste matrix dissolution
  - … and release of radionuclides (the issue of highest relevance to society)

  … is by far too long to be monitored

- Also steady-state conditions (relevant for safety) are not reached within time-scales that allow monitoring in pilot facility

  … but strong transients can be captured (indicator for evolution)

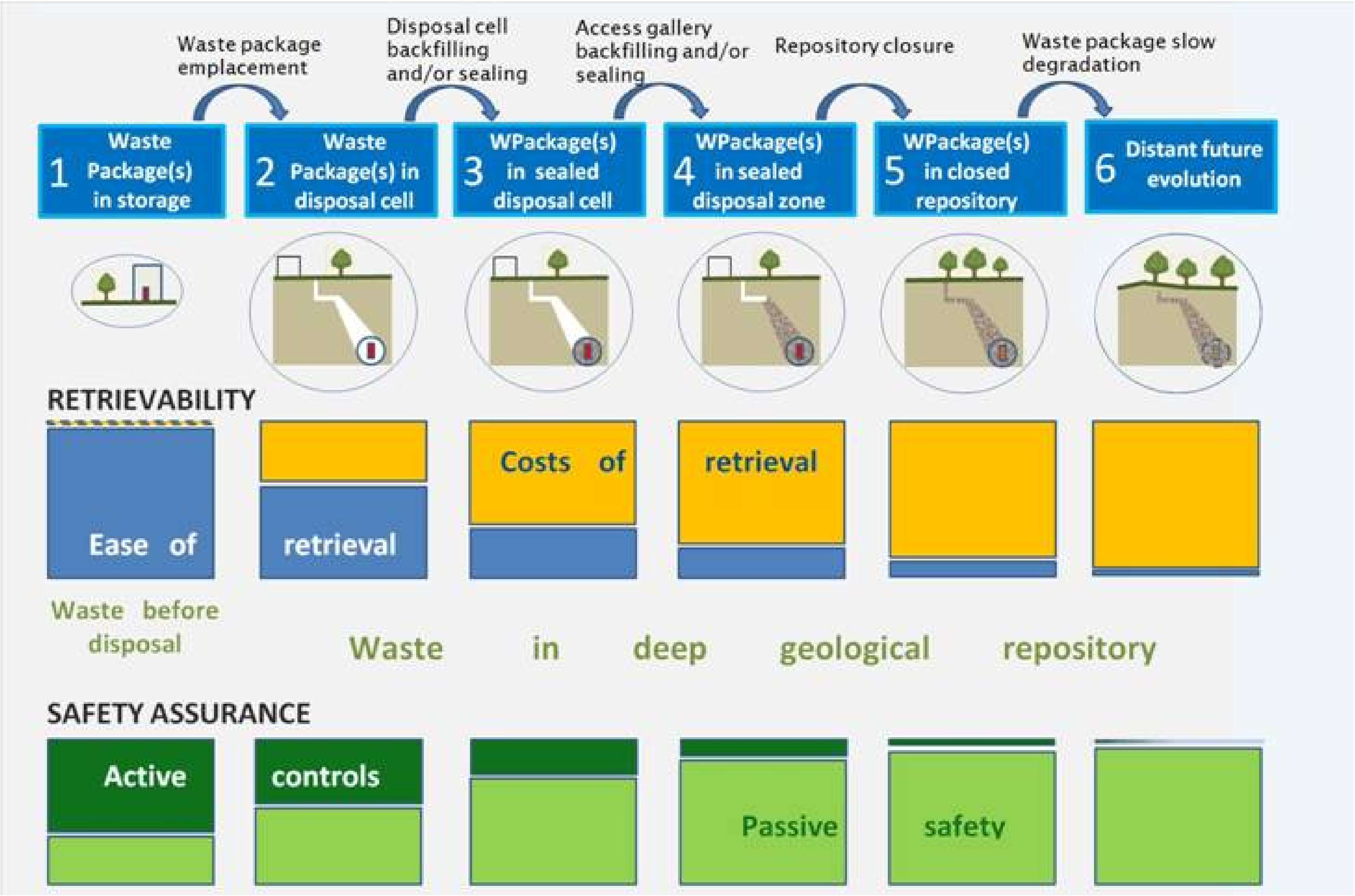
- To monitor phenomena relevant to containment, retention & slow release of radionuclides: need for additional specific experiments
  - RD+D-experiments in 1st generation URLs (e.g. URL Mont Terri)
  - dedicated experiments at site

Retrieval …

- … easily possible during operation ('good engineering practice'); e.g.:
  - deviation in emplacement process
  - deviation in 'production'
  - whatever makes it necessary
- … in observation phase possible without undue effort; e.g.:
  - monitoring results pilot facility, experiments, etc.: whatever could trigger the decision
  - external environment (science/technology, society, …)
- … after closure: still possible (with increased effort → access, …)

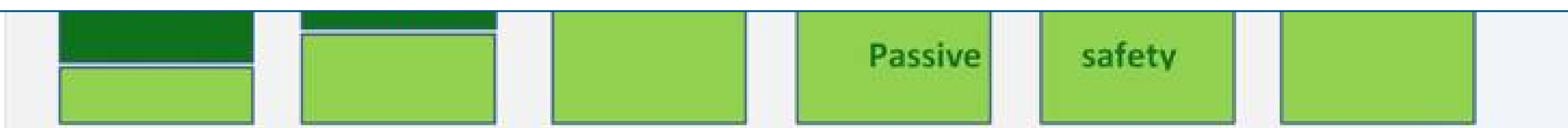
- Summary: it is possible to retrieve the waste if this is decided to be necessary
- The reason/justification to retrieve is up to those that take the decision ('no need to find the reasons for retrieval today')

Retrievability: Discussion within NEA (2007 – 2011)



Retrievability: Discussion with NEA working group

- Effort for retrieval depends upon level of closure of facility (emplacement room open, access to emplacement room open, access to panel open, …)
- Level of passive safety also depends upon level of closure of facility
- Leaving facility open, puts a burden on future generations
- There is a need to find a balance between …
  - efforts needed to fully close the facility (burden on future generations)
  - available level of passive safety
  - effort needed for retrieval
- Planning for retrieval makes actual retrieval more easy (simple things can help; e.g. adequate packaging (strength, shielding, handling, …))



View of society on monitoring & retrievability

Societal needs: a brief summary

- Monitoring
  - The question: *'Will the repository be safe for the required time span?'* can only be answered by arguments (incl. modelling), not by monitoring
  - Nevertheless, the question *'Did you measure what the models predicted?'* will be asked
  - Thus, identify performance indicators that can be reliably monitored and are relevant for safety (→ dedicated experiments)
  - Society must be made aware of *'what can be done and what not'*; be honest about the strengths and inherent limitations of monitoring
- Retrievability
  - Possibility to retrieve and to know that disposal is not irreversible gives *'a good feeling'*, it is also consequence of monitoring (*'able to act'*)
  - Be clear that system is robust - small deviations do not require retrieval
- Conclusion
  - Start dialogue on monitoring & retrievability with society already early on
  - P.S.: Decision-making related to retrieval can in principle be handled within current legal framework (but: not explicitly defined)

What monitoring can do …

- Provide specific technical information for implementation of geological disposal (operational aspects, covering all phases)
  - site selection (host rock, geological setting)
  - selection of repository concept & concept of engineered barriers
  - repository construction, operation and closure according to specifications & requirements (confirmation / corrective actions)
  - monitoring performance for a restricted number of phenomena
- Provide important contributions to scientific & technological basis (RD+D: develop & confirm understanding of key phenomena)
  - geological long-term stability
  - host rock performance
  - performance of engineered barriers
  - operational procedures
- Provide platform to help interaction between technical experts & society to enhance mutual understanding (*'see and understand each others view'*)

But: monitoring …

- cannot be a part of system to ensure long-term safety (repository system with passive barriers must be safe without monitoring)

  P.S.: surface monitoring after final closure possible, no decision yet on any details about monitoring
- cannot provide direct proof of performance of overall repository system
- cannot provide meaningful measurements … [1)]
  - … for all conceivable parameters with the required accuracy / resolution
  - … and for whatever location wanted in the repository
  - … and for as long as anybody wants

1) limitations on …

- measurability (sensors)
- data transfer
- energy supply
- calibration
- longevity of sensors
- accessibility as far as needed (impact on barrier system)

Summary and conclusions

- Monitoring is important for repository implementation (site selection, RD+D, site characterisation, operation & surveillance of repository)
- Monitoring addresses both technical and non-technical expectations
- But:
  - Inherent limitations on what can be achieved by monitoring regarding demonstration of performance of overall repository system
  - And: some technological challenges still exist (sensors, energy supply, data transfer, …)
- The evolution over the last ~ 40 years
  - Monitoring is 'good engineering practice' (since the start of engineering)
  - Therefore: monitoring has always been essential in repository development (but: with moderate expectations with respect to 'overall demonstration')
  - Last ~ 25 years: more emphasis on societal needs (in-situ demonstration)
- Collection of the data is only half of the story, interpretation and well-balanced input to evaluations & decisions are equally important

thank you
for your attention