Assessing the suitability of host rock

Experience from Nagra‘s geological disposal program in sedimentary rocks

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Objectives of presentation

- Introduce the **methodology** we used in Switzerland to assess host rocks and siting regions, as part of the site selection process
- Introduce the **citeria and indicators** we used for the sedimenatry rocks
- Address **similarities and differences** between criteria used for the assessing the suitanility of **sedimentary** rocks and those used for assessing the suitability of **crystalline** rocks

Sectoral Plan – Stepwise Approach

Selection of potential siting regions for LLW & for HLW

1. Stage

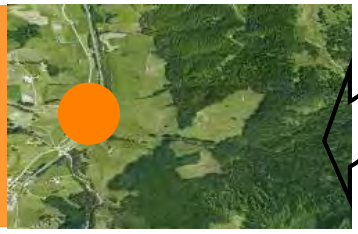
Criteria
- Safety & engineering feasibility
- Preliminary evaluation from land-use perspective

Selection of at least two sites for LLW and for HLW

2. Stage

Site selection & general licence procedure for a LLW and a HLW repository

3. Stage



Source: Bundesamt für Energie (BFE)

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Stage 1: Methodology

Steps for 'Narrowing-Down' to the proposed siting regions

1. Allocation of waste to LLW or HLW repository
2. Safety concept and requirements
3. Suitable geological-tectonic regions
4. Suitable host rocks (incl. adjacent formations)
5. Evaluation with respect to repository configuration/lay-out

Assess Suitability

Quantitative evaluation for each criteria group

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Analogies?

1. Allocation of waste to LLW or HLW repository
2. Safety concept and requirements
3. Suitable geological-tectonic regions
4. Suitable host rocks (incl. adjacent formations)
5. Evaluation with respect to repository configuration/lay-out

L1 or TRU rep.?

H12 or TRU-2

NUMO's published criteria/factors for LS

Criteria for potential host rocks/ emplacement horizons within a PIA

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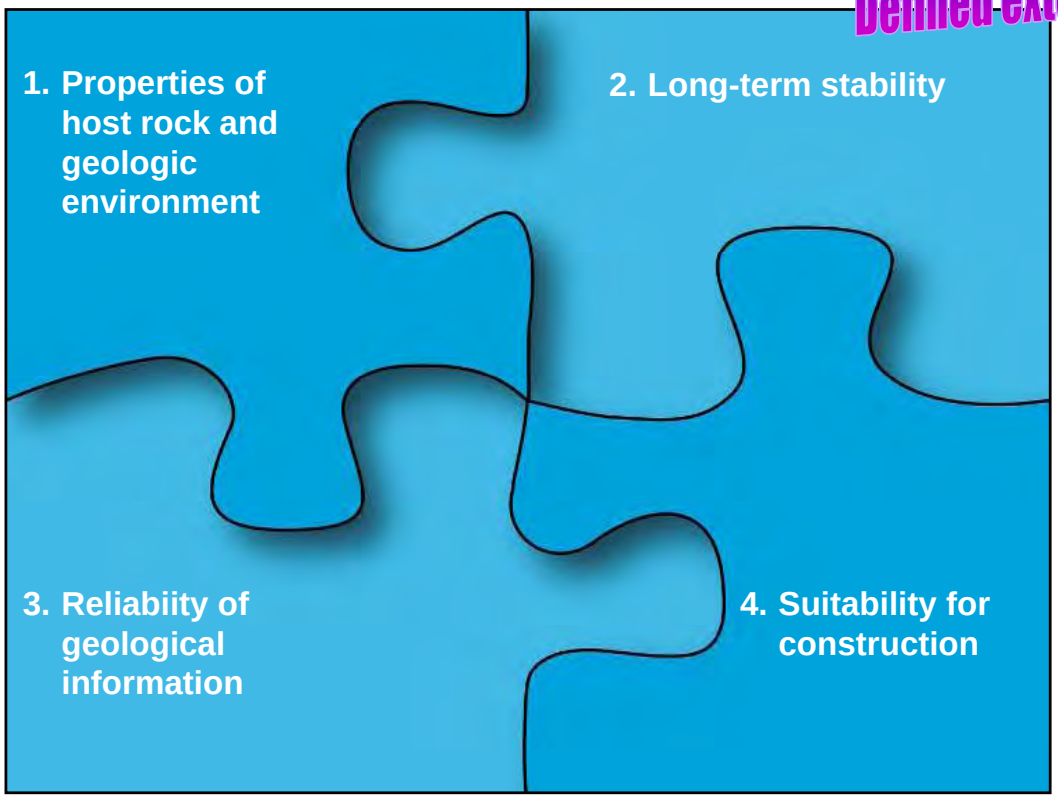
Sectoral Plan requirements: 13 Criteria in 4 groups

Defined externally



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Safety & Engineering Criteria for Site Selection

Defined externally

Group of criteria	Criteria
1. Properties of host rock	1.1 Spatial extent 1.2 Hydraulic barrier efficiency 1.3 Geochemical conditions 1.4 Migration paths
2. Long-term stability	2.1 Stability of properties 2.2 Erosion 2.3 Repository induced effects 2.4 Resource conflicts
3. Reliability of geological information	3.1 Characterisation of host rock 3.2 Spatial explorability 3.3 Temporal predictability
4. Suitability for construction	4.1 Rock mechanical properties 4.2 Underground access

Source: Bundesamt für Energie (BFE)

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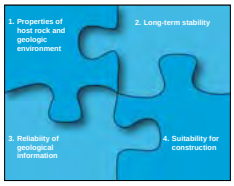
Development of evaluation indicators



1 Reference Disposal Concept

Indicators & requirements for each one

2
- Safety principles related to the site
- Safety principles related to the design

3

Indicators	Requirem.
1. …….	< …
2. …….	>… & < …
3. …	
48. …	
49. …	> …

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Swiss reference disposal concept for HLW/SF

1

Safety functions/principles used

2

For deriving the indicators for assessing the suitability of a siting region the following safety functions/principles were used:

- Isolation of the wastes from the human environment and long-term stability of the barrier system
- Confinement of radionuclides
- Delayed release of radionuclides
- Radionuclide retention in the near-field and in the geosphere
- Small release rates
- Reliability of implementation of the repository
- Reliability of geological conceptualisation

Safety & Engineering Criteria for Site Selection (1/2) 3

Group of criteria	Criteria	Indicators (example)
1. Properties of host rock	1.1 Spatial extent 1.2 Hydraulic barrier efficiency 1.3 Geochemical conditions 1.4 Migration paths	Thickness Lateral extent Depth - construction Depth - erosion
2. Long-term stability	2.1 Stability of properties 2.2 Erosion 2.3 Repository induced effects 2.4 Resource conflicts	
3. Reliability of geological information	3.1 Characterisation of host rock 3.2 Spatial explorability 3.3 Temporal predictability	Regional fault model Continuity of formations Heterogeneity
4. Suitability for construction	4.1 Rock mechanical properties 4.2 Underground access	

Source: Nagra

Safety & Engineering Criteria for Site Selection (2/2) 3

Group of criteria	Criteria	Indicators (example)	Requirements
1. Properties of host rock	1.1 Spatial extent 1.2 Hydraulic barrier efficiency 1.3 Geochemical conditions 1.4 Migration paths	Thickness Lateral extent Depth - construction Depth - erosion	> 100 m > 4 km2 < 900 m.b.s. > 400 m.b.s
2. Long-term stability	2.1 Stability of properties 2.2 Erosion 2.3 Repository induced effects 2.4 Resource conflicts		
3. Reliability of geological information	3.1 Characteris. of host rock 3.2 Spatial explorability 3.3 Temporal predictability	Regional fault model Continuity of formations Heterogeneity	
4. Suitability for construction	4.1 Rock mechanical properties 4.2 Underground access		

Source: Nagra

Assessing host rocks and potential siting regions: The 49 indicators developed

3

- Repository depth - for engineering feasibility
- Repository depth – decompaction effects
- Repository depth – erosion effects
- Repository depth – glacial-induced deep valley erosion
- Thickness
- Distance to regional faults
- Lateral extent
- Space availability
- Hydraulic conductivity
- Groundwater aquifers
- Mineralogy
- pH
- Redox conditions
- Salinity
- Microbial processes
- Colloids
- Type of transport pathways and pore-structure architecture
- Homogeneity of host rock
- Length of transport pathways
- Transmissivity of preferential pathways
- Clay content
- Self-sealing potential
- Geodynamic & neotectonics
- Seismicity
- Geochemical processes
- Rare geologic events (volcanoes)
- Potential for karstification
- Erosion
- EDZ around the repository structures
- Chemical interactions
- Gas migration properties of host rock
- Thermal properties of host rock
- *Natural resources within the host rock*
- *Natural resources below the host rock*
- *Natural resources above the host rock*
- Thermal and/or mineral springs
- Geothermal regime
- Diffuse ‚distrurbed' zones
- Variability of host rock properties and effects to its explorability
- Existing experience
- Regional fault network and conditions for disposal
- Lateral continuity of host rock of interest
- Explorability
- Surface exploration possibilities
- Tectonic situation
- Independent evidence for long-term isolation
- Rock strength and deformation properties
- Geotechnical and hydrogeological conditions in overlaying formations
- Natural gas (in the host rock)

And then what?

- The indicators shown above were applied to the various host rocks and siting regions
- The application is:
  - straightforward
  - specific for each site
  - based on exisiting information (from surface investigations primarily)
- In our case we used these criteria to evaluate individual siting regions and host rocks (multiple-attribute analysis) and provide the basis for a comparative analysis of different siting regions and host rocks
- A total of 6 siting regions were proposed for geologic repositories for LLW/ILW and HLW/SF/LL-ILW

Evaluation of HLW siting areas (Nagra / ENSI)

Siting criteria for a HLW repository	Zürcher Weinland		Nördlich Lägeren		Bözberg	
	Nagra	ENSI	Nagra	ENSI	Nagra	ENSI
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						

Very favourable
Favourable
Less favourable
Unfavourable

- Nagra: 2008 (submission)
- ENSI: 2010 (review)

Note that each site is assessed for its suitability independent from the others

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Applicability of the indicators

Questions

1. From the 49 indicators/criteria used, which are applicable to:
   - assessing the suitability of sedimentary rocks only?
   - assessing the suitability of crystalline rocks only?

2. Which ones are applicable to assessing the suitability of any host rock and thus non host-rock specific?

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Host-rock specific indicators

Sedimentary rocks	Crystalline rocks
Self-sealing potential	x
Clay mineral content	x
Swelling potential	x
Creep	x
Repository-generated gas release	*Relevant if rock sparsely fractured*
Minimum thickness: - *OPA&RG: 100 m* - *Other sediments: 100 to 200m*	*Minimum thickness:* - *200 m below top crystalline (KRI-1)*
Path length in geosphere: - *OPA: min 40 m* - *Other sediments: 50-100 m*	*Path length in geosphere:* - *100 m (KRI-1)*
Explorability with non-destructive techniques	*Applicable with no sedimentary cover and for flat-lying structures*
Colloids (in fractured sediments)	*Colloids*

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Non host-rock specific indicators (selected)

- Repository depth - for engineering feasibility
- ….
- Thickness
- Distance to regional faults
- Lateral extent
- ….
- Hydraulic conductivity
- Groundwater aquifers
- pH
- Redox conditions
- Salinity
- ….
- Tectonic situation
- Independent evidence for long-term isolation
- Rock strength and deformation properties
- ….

Note:
The indicators are similar but the requirements (values) for a positive assessment could be different

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Sedimentary rocks considered in Switzerland:

A few pictures illustrating features to ‚watch‘

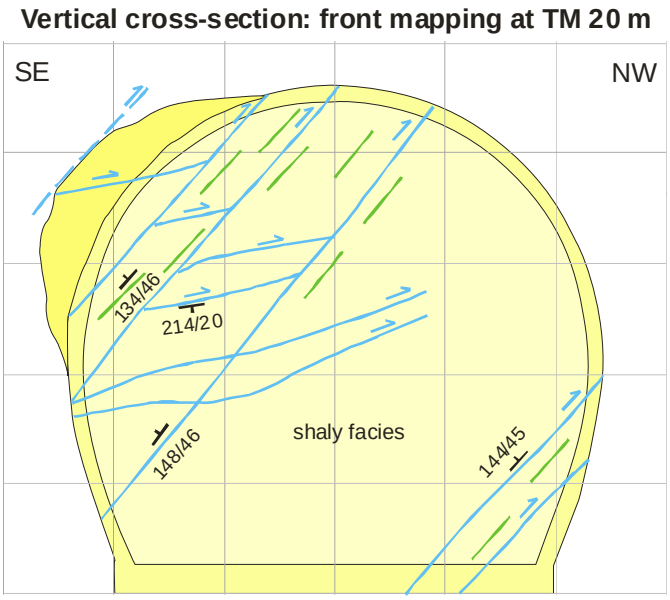
Sedimentary rocks considered for geological repositories (selected)

Effinger Schichten:
Outcrop (Villigen)

Opalinus Clay Mont Terri

← Benken

Influence of Faults on Tunnel Stability (Mt. Terri)



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Influence of faults on tunnel stability (Mt. Terri)

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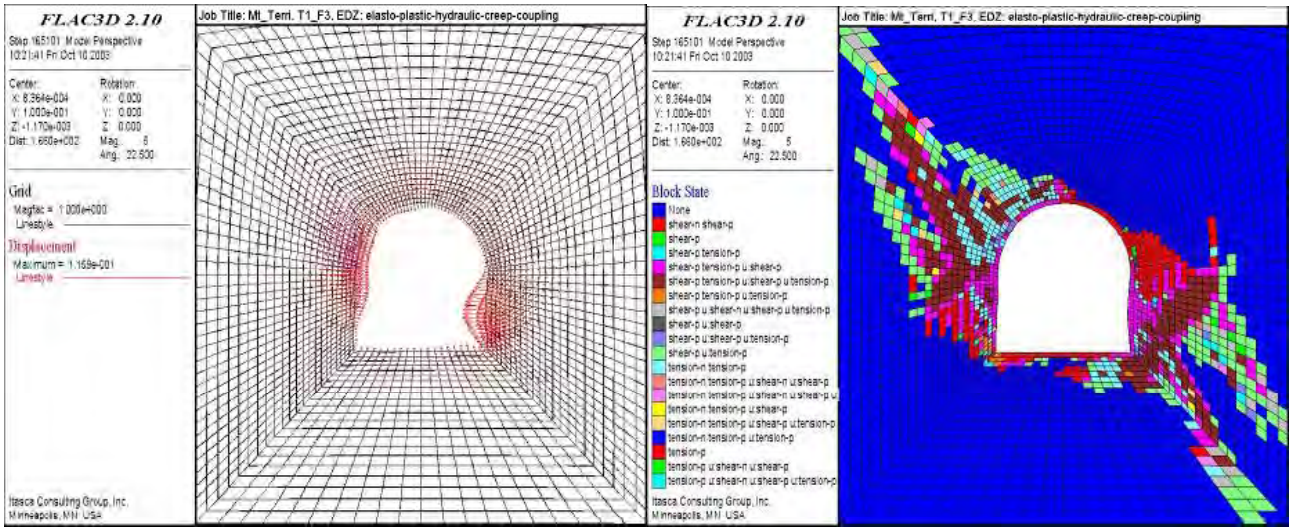
Modelling of breakouts



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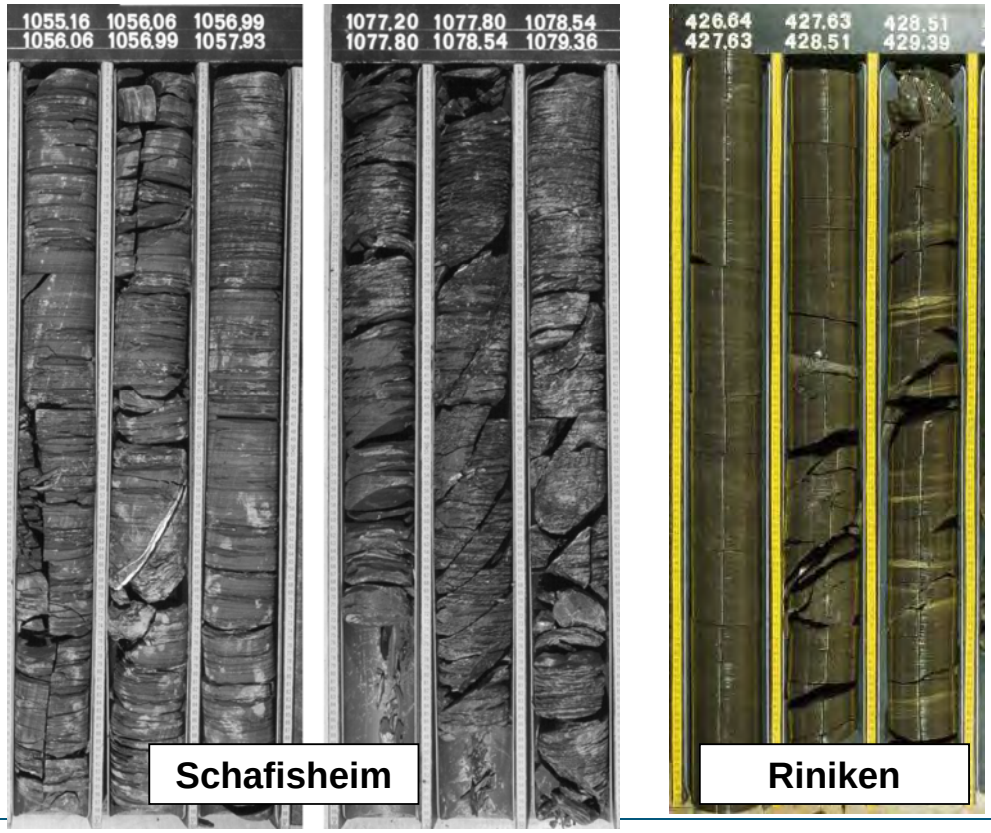
Self-sealing of Faults in Opalinus Clay



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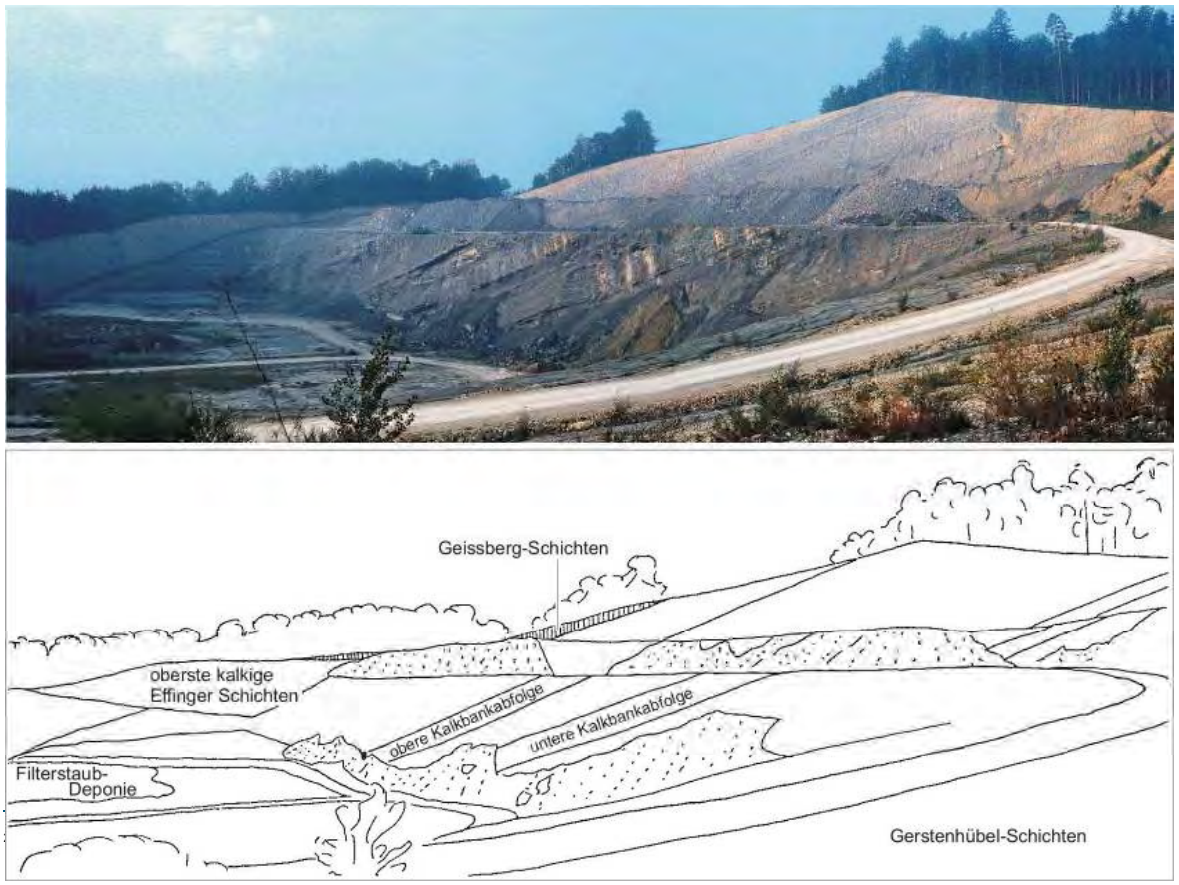
Effingen Beds (Marls and Limestone Sequences)



Effingen Beds (Oftringen)

Concluding remarks

- Assessment of potential host rocks for their suitability for geological repository can be done on the basis of criteria/indicators defined in advance
- The majority of these criteria/indicators are independent from the specific rock type
- An assessment methodology has been developed and used as part of the site selection in Switzerland
- To develop specific criteria and requirements for the geology a reference disposal concept is needed.
- The assessment methodology used by Nagra has been reviewed and accepted by the authorities and their commissions

Thank you
for your interest

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