

“Natural Analogue Working Group NAWG-18 workshop”
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Approach to compilation of a natural analogue database for geological disposal programme

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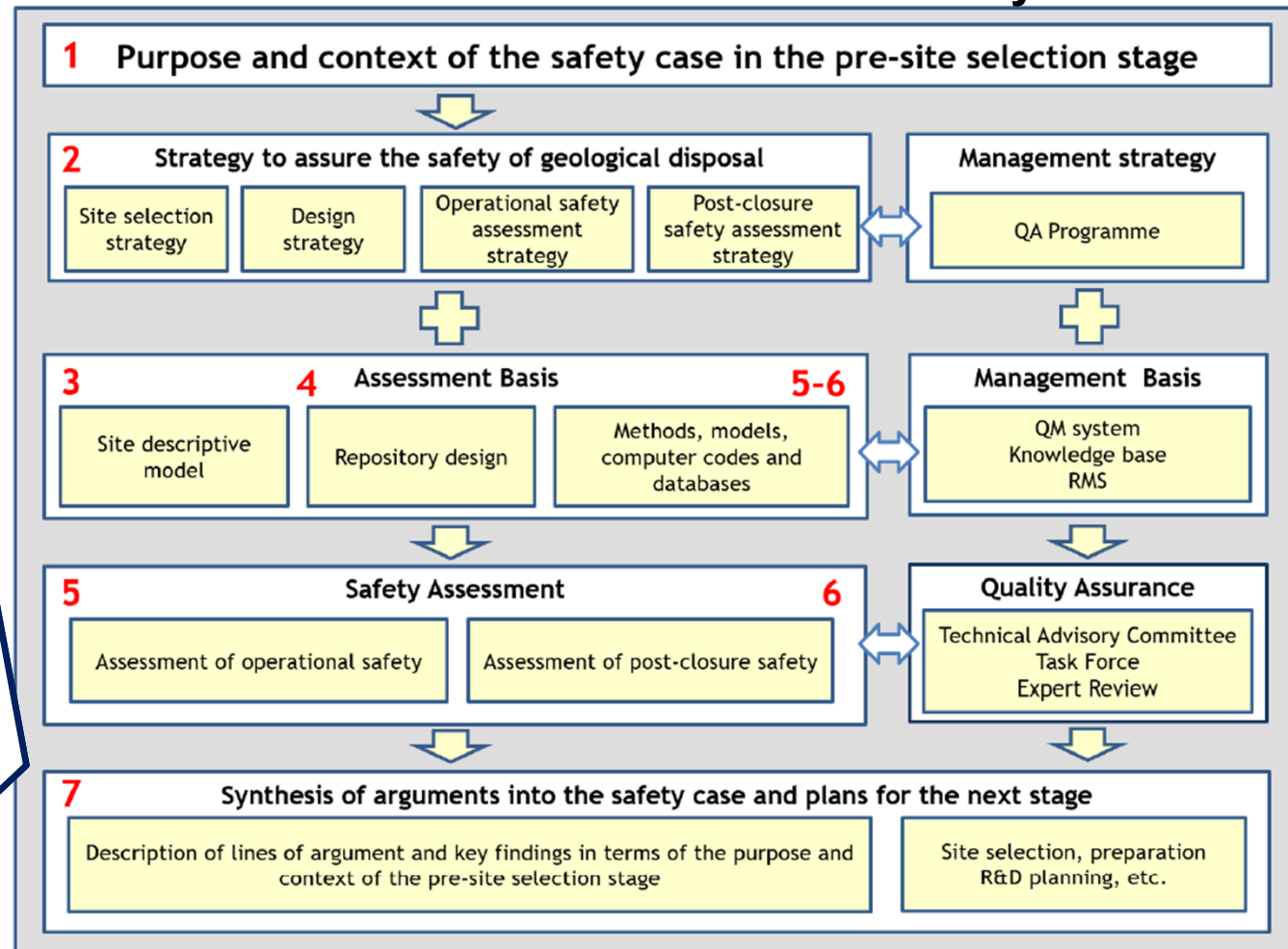
Analogue in the NUMO safety case

- NUMO published “The NUMO Pre-siting SDM-based Safety Case” (hereafter referred to as the NUMO-SC) in 2021

Chapter 7

- NUMO has developed multiple lines of evidence, which includes natural analogues, to build the safety case.
- The long-term safety of geological disposal will be demonstrated in a logical manner by way of a “safety assessment”, together with “supporting evidence”, such as that provided by natural analogues, that will reinforce/support the assessment results.

Structure and contents of NUMO safety case

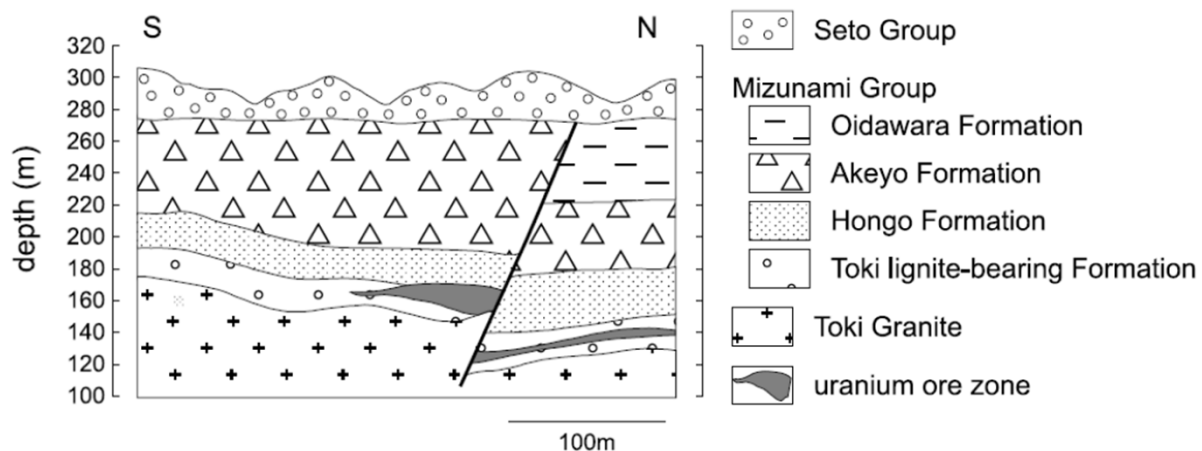


Supporting arguments from natural analogues

- Analogues supporting the long-term safety of geological disposal
(Chapter 7 in NUMO-SC and its supporting report “SR 7-5”)

◆ Example of NA arguments supporting long-term geological stability

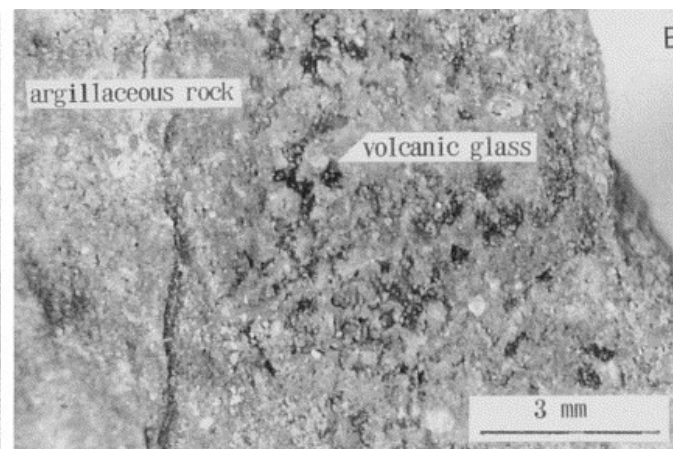
- In Tono uranium mine, uranium ore has been preserved in Neogene sediments for about 10 My despite the uplift, erosion, sea-level changes and fault activity.
- This is explained by a stable hydrogeological setting in which pH and reducing conditions are buffered by interactions between water, minerals and microbes.



Cross-section of the Tono uranium mine [Sasao et al., 2006]

◆ Example of NA arguments supporting EBS barrier roles

- Volcanic glass within Japanese argillaceous rock similar to compacted bentonite was observed.
- No dissolution or precipitation of andesitic glass has been observed.
- Furthermore, EPMA has not detected any leaching of elements from the andesitic glass (Na, K, Mg, Ca, Al, Si, Fe, and Ti).



A hand specimen of the argillaceous rock including volcanic glass shards in the Ohtadai Formation.

[Kamei et al., 2000]



Lessons learnt from existing natural analogue in NUMO-SC

- Overall, natural analogues support the main conclusions regarding the high isolation potential of a robust system of engineered barriers located in a suitable deep geological setting in Japan.
- However, these analogues also highlight **limitations in their applicability to the safety assessment of the repository system**—particularly due to overly simplistic representations of hydrogeology and the assumption of thermodynamic equilibrium.
- These limitations will constrain their application in comparing different sites and associated repository concepts, as will be required as the NUMO programme advances.

→ Therefore, the following items are important:

- ✓ Expanding analogue studies **to cover components of the repository system**
- ✓ Expanding analogue studies to include those representing **specific geological environments in Japan**

Natural Analogue Workshops 2023 & 2024

- To further leverage insights from analogue studies, NUMO hosted NA workshops twice, in 2023 and 2024.

Objectives

- ① Integration of state-of-the-art knowledge from analogue studies performed by universities, research institutes and private companies.
- ② Expert discussion on how analogues can be applied to future updates of the NUMO safety case and how they can be used for communication with a wide range of stakeholders to further improve confidence in the geological disposal system.
- ③ Strengthen links between experts within the research network involved in analogue studies in Japan.

Discussion themes

- ① Construction of an analogue study database
- ② Application to verification and validation (V&V) of models
- ③ Improvement of public communication skills
- ④ Strengthening complementary considerations for safety case reliability



Photo of group discussion in NA workshop in 2024



Key messages of workshops for NA database

- Through discussions in NA workshops, NUMO has identified challenges to address going forward.

- ◆ Analogues from researcher's perspective

- ✓ Integration of case studies with FEPs (Features, Events, and Processes) and design requirements to facilitate usability and ensure consistency checks
- ✓ Development of a sustainable update mechanism, possibly supported by AI tools, to effectively capture information from technical papers

- ◆ Analogues as tools for dialogue activities

- ✓ Providing syntheses that avoid complex terminology and incorporate visual materials to help communicate relevance to deep underground environments and vast timescales (up to millennia or beyond), serving as a basis for narrative-based communication of scientific understanding to non-specialist audiences

- ◆ Analogues as tools for human resource development

- ✓ Development of a communication platform aimed at encouraging participation from young researchers
- ✓ Expansion into new research areas (e.g., climate change impacts on coastal sites, amber as an analogue for industrial resins, etc.)

Outline for a NA database

◆ Aim

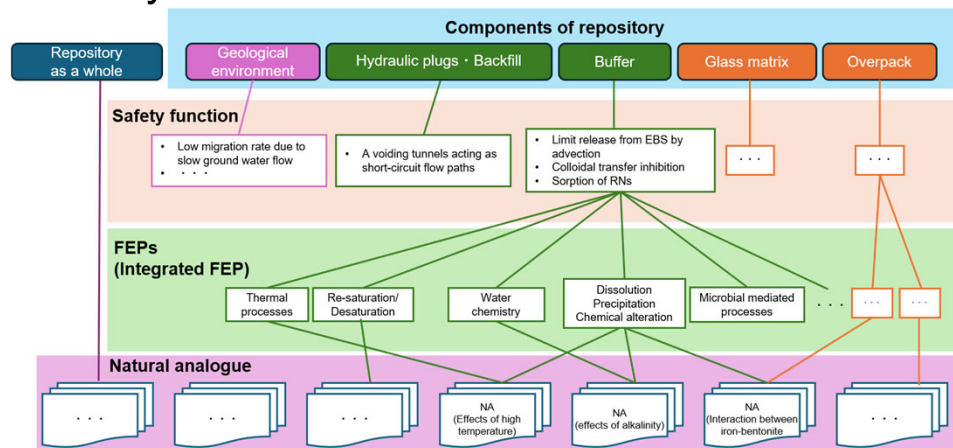
- Expand analogues to specific physical and chemical processes that occur in geological disposal system
- Expand analogues as tools for communication with a wide range of stakeholders

◆ Design concept of NA databases

- Because the required information differs, we are developing separate databases: one to improve **technical reliability** and another to **support dialogue with stakeholders**

【Data base for improving technical reliability】

(Target) Experts who search for analog case suitable for demonstrating the rationale behind safety assessments



【Data base for improving dialogue activities】

(Target) Experts who search for analog case to support communication with stakeholders

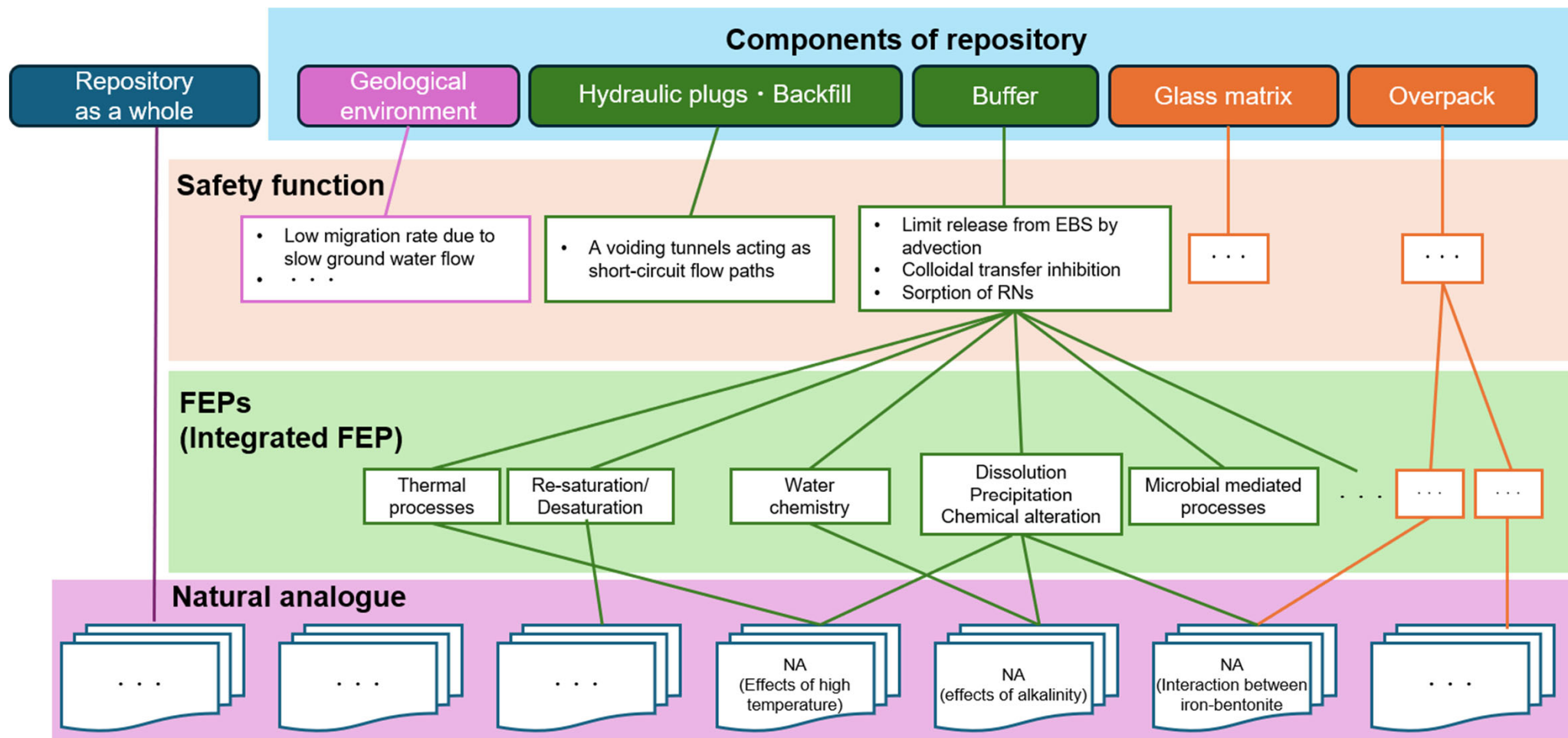
- ✓ Analog case studies covering the entire disposal system (e.g., the natural nuclear reactors at Oklo)
- ✓ Intuitively easy-to-understand analog case studies (e.g., stag beetles preserved in geological formations for about 2,500~2,800 years)



[Archaeological Institute of Kashihara, 2011]

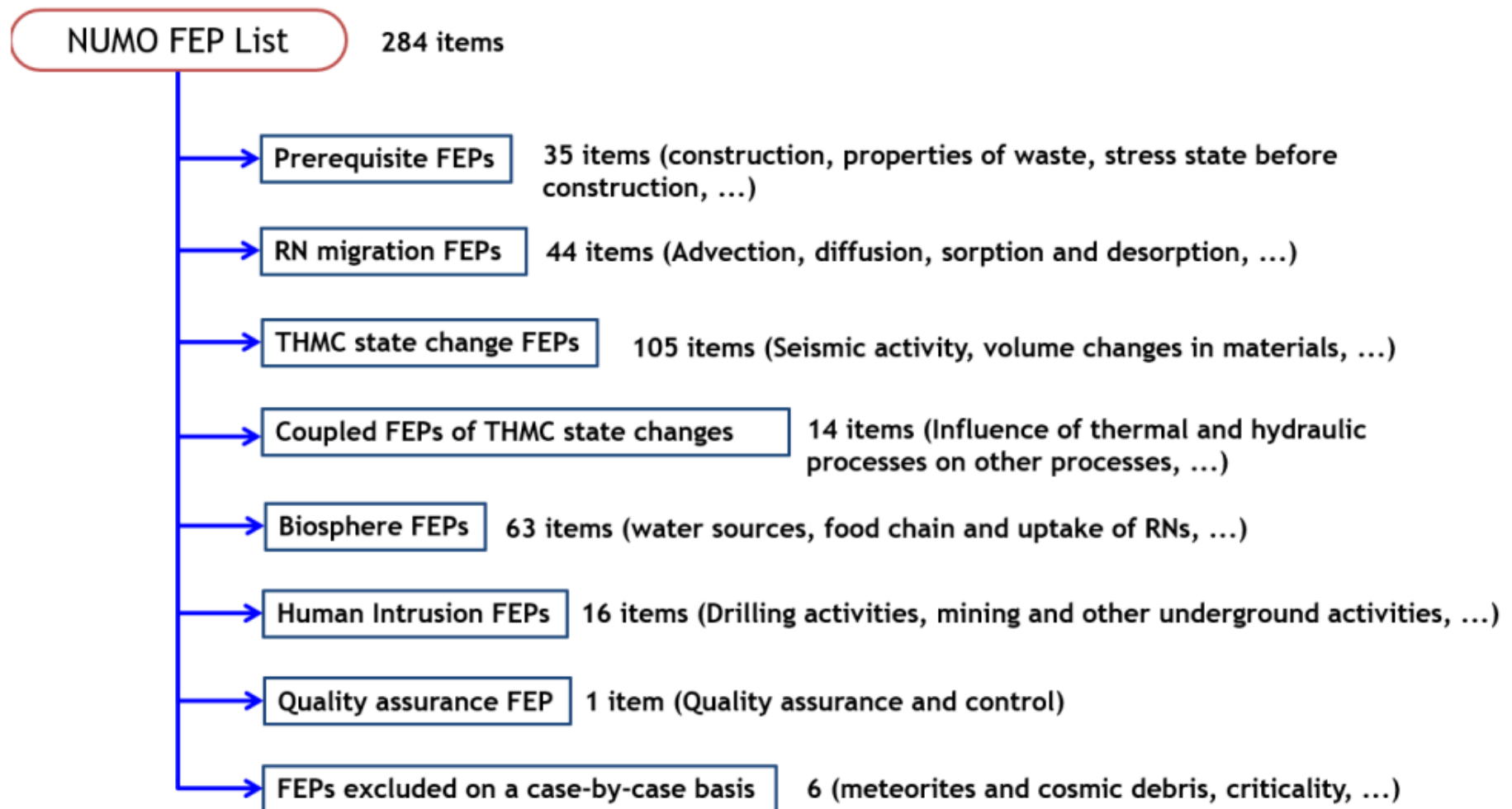
Outline for a technical NA database

- The database framework is the linkage of analogue cases to features, events, and processes (FEPs), which describe the characteristics of each component of the repository that may be relevant to its safety function (Feature), the events that affect these characteristics (Event), and the process of the repository's evolution over time (Process).



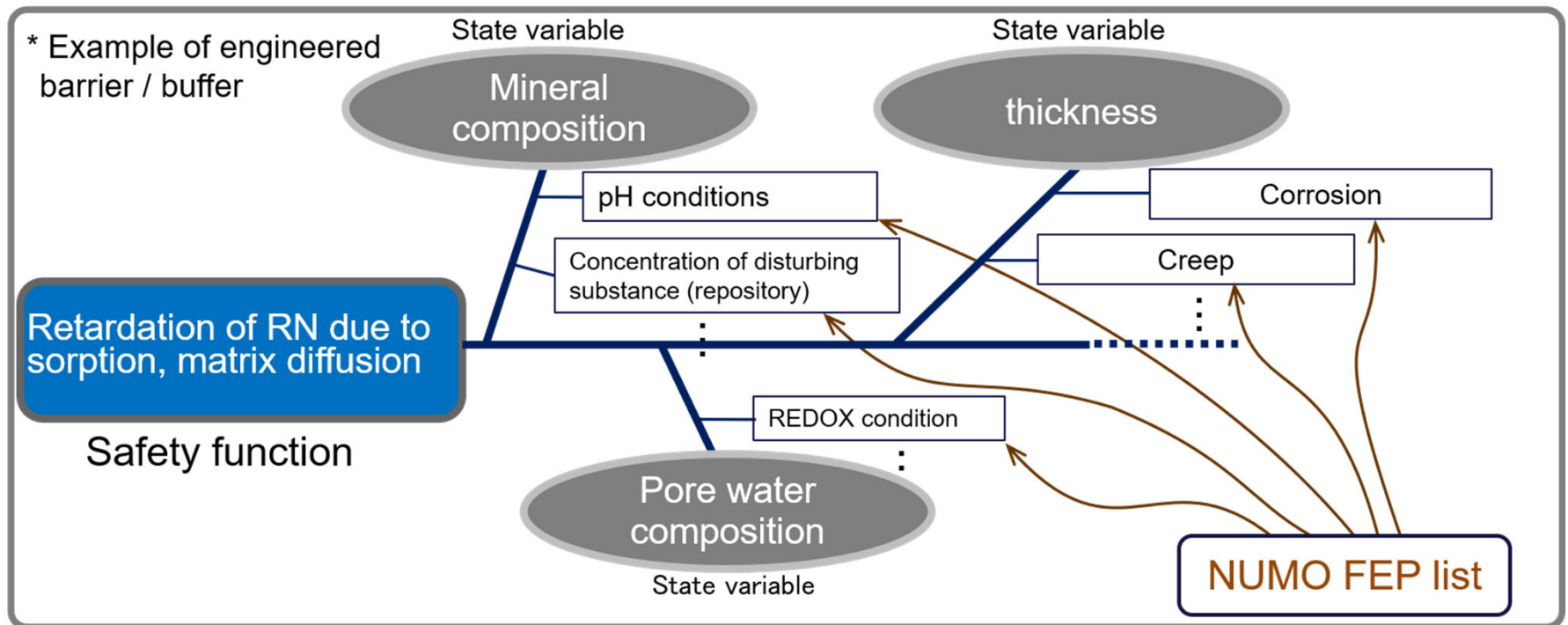
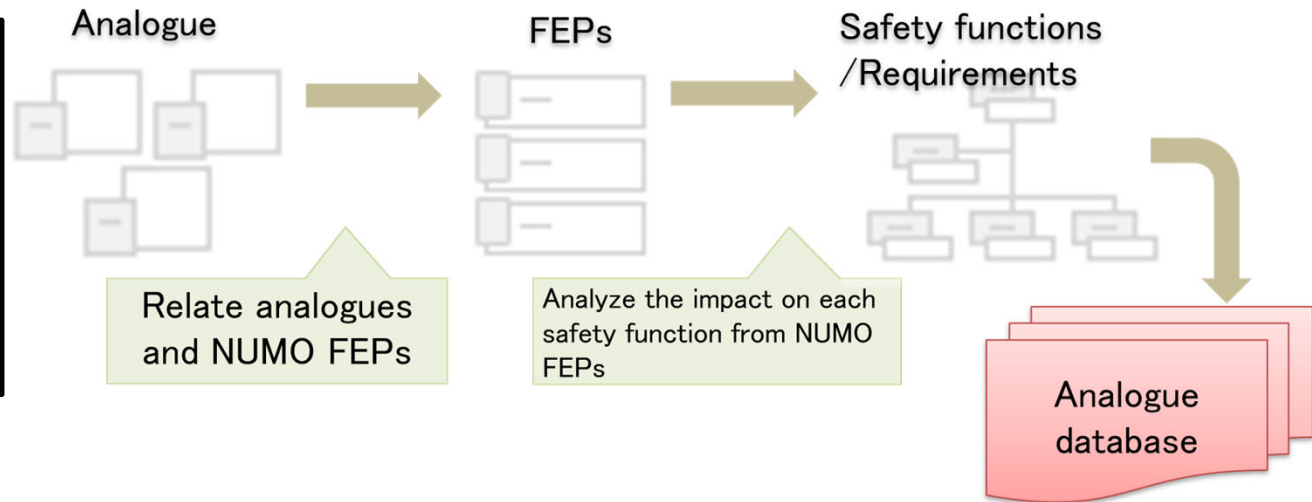
The NUMO FEP list

- In order to assess changes in the THMC state for each component FEPs (Features, Events and Processes), a specific FEP list (termed the “NUMO FEP list”) was created to reflect repository designs in the specific geological environments considered based on the latest scientific and technical knowledge.



Mapping analogues to GDF system with FEPs

This framework will consolidate scattered information from NA studies by linking cases to FEPs and design requirements, thereby facilitating their use and enabling consistency checks.



Database No.

Title

Subtitle

Analogue database format (draft ver.)

Relationship between the research site and the geological disposal system

Application of the knowledge
(Repository as a whole or name of components of repository)

Related design requirements

Related FEPs

Questions addressed in this report

Area of research (key words)

Research contents

Information of investigation spot

Location

Primary minerals

Influence on primary minerals

Spatial scale

Time scale

Analysis items

Main results

References cited

Relationship between the research site and the safety functions of geological disposal system

Whether the information is presented as a NA? (Yes or No)

Key viewpoints related to safety of DGR

Differences from the environment of disposal system

Reference information

References for related experiments

Database No. of related NA

Database No.

Title

Subtitle

Analogue database format (draft ver.)

Database No.

Title:

Subtitle

- The main title refers to categories that compile information on the relevant components and FEPs
- The subtitles are labeled according to each investigation site

Analogue database format (draft ver.)

Relationship between the research site and the geological disposal system

Application of the knowledge
(Repository as a whole or name of components of repository)

Related design requirements

Related FEPs

Questions addressed in this report

Area of research data

Relationship between the research site and the geological disposal system

Application of the knowledge
(Repository as a whole or name of components of repository)

Related design requirements

Related FEPs

Questions addressed in this report

- Enter the information required for structuring the database

Reference information

References for related experiments

Database No. of related NAs

Analogue database format (draft ver.)

Database No.

Title

Subtitle

Relationship between the research site and the geological disposal system

Application of the knowledge
(Repository as a whole or name of components of repository)

Related design requirements

Related FEPs

Questions addressed in this report

Area of research (key words)

Research contents

Information of investigation spot

Location

Access route

Area of research (key words)

- Key words for classification according to the characteristics of analogue cases

Relationship between the research site and the safety functions of geological disposal system

References cited

Whether the information is presented as a NA? (Yes or No)

Key viewpoints related to safety of DGR

Differences from the environment of disposal system

Reference information

References for related experiments

Database No. of related NA

Analogue database format (draft ver.)

Research contents	Information of investigation spot	Location
		Primary minerals
		Influence on primary minerals
		Spatial scale
		Time scale
	Analysis items	
	Main results	
	References cited	

- Summary of the content described in the cited references
 ※Note: Except for the yellow group, the information does not necessarily correspond directly to the content described in the cited references

Analogue database format (draft ver.)

Relationship between the research site and the safety functions of geological disposal system	Whether the information is presented as a NA? (Yes or No)
	Key viewpoints related to safety of DGR
	Differences from the environment of disposal system
Indicate the relationship with the safety functions of the geological disposal system	

Relationship between the research site and the safety functions of geological disposal system	Whether the information is presented as a NA? (Yes or No)
	Key viewpoints related to safety of DGR
	Differences from the environment of disposal system
Reference information	References for related experiments
	Database No. of related NA

Analogue database format (draft ver.)

Database No.					
Title					
Subtitle					
Relationship between the research site and the geological disposal system	Application of the knowledge (Repository as a whole or name of components of repository)				
	Related design requirements				
	Related FEPs				
	Questions addressed in this report				
Area of research (key words)					
Research contents	Information of investigation spot	Location			
		Primary minerals			
		Influence on primary minerals			
		Spatial scale			
<table border="1"> <tr> <td rowspan="2">Reference information</td> <td>References for related experiments</td> </tr> <tr> <td>Database No. of related NA</td> </tr> </table> Information on other related investigation sites			Reference information	References for related experiments	Database No. of related NA
Reference information	References for related experiments				
	Database No. of related NA				
Key concepts related to safety of ODR					
Differences from the environment of disposal system					
Reference information	References for related experiments				
	Database No. of related NA				

Sample of NA database sheet

データベースNo.		1
タイトル (大項目)		緩衝材の熱影響に関するアナログ事例
タイトル (小項目)		村上鉱床におけるイライト化への温度・時間条件
調査地と地層処分システムとの関連	調査地の適用先(特定の構成要素)	緩衝材
	関連する設計要件	放射性物質の移流による移行の抑制 コロイド移行の抑制 放射性物質の収着
	関連するFEP	熱プロセス 化学的変質
	調査地が回答している疑問	イライト化現象の起こる時間・温度スケール
研究分野 (キーワード)		
研究内容	調査地のセッティング	場所 日本、村上鉱床
		一次鉱物の種類 流紋岩質凝灰岩
		一次鉱物に影響を与える因子 噴出岩 (黒雲母流紋岩) による熱影響
		空間スケール 数百m
		時間スケール 海水域での凝灰岩の堆積 (6.7M年)
	分析項目	・珪藻化石群 ・顕微鏡観察 ・Rb-Sr年代 ・K-Ar年代 ・ジルコンのFT年代 ・二次元での熱履歴解析 ・XRD(イライト化率) ・海水を用いたサンプルCの溶出試験 ・サンプルA, Cの乾燥密度や化学組成、海水濃度
		・XRD ・Rb-Sr年代 ・K-Ar年代 ・ジルコンのFT年代 ・熱履歴解析 ・水素同位体比(D/H)
	主要な見解	・温度が340°Cから100°Cまで低下するのに350万年 イライト化率は40%、160°Cから100°Cまで低下するの ・反応溶液はK:560-6400, Mg:800-1700, Ca:360 ・温度が240°Cから105°Cまで低下するのに340万年
	引用文献	Kamei, G., Yusa, Y. and Sasaki, N. (1992) Natural condition and water chemistry on illitization at https://jopss.jaea.go.jp/pdfdata/PNC-TN8410-Kamei, G., Arai, T., Yusa, Y., Sasaki, N., & Saku history of Murakami deposit, Japan. MRS Online
調査地と地層処分システムとの関連	NAと称しているか	○
	安全性に関わる主要な見解	緩衝材中のモンモリロナイトがイライト化すると じた時間・温度スケールと地層処分で想定される いて想定され得るかどうか、検討できる。
	処分システムとの相違点	・母岩の鉱物組成やバルク組成は締固めベントナ ・比較的低い液固比条件で反応している点も類似 ・熱履歴の期間が地層処分施設で想定されるより
参考情報	関連する実験に関する参考文献	
	関連する他の調査地のデータベースNo.	

Future plan

- ✓ Continuous updating of the database
- ✓ Evaluation of database usability
- ✓ Configuring the system to enable interactive retrieval of analogue database information using AI
- ✓ Setting keywords with a view to publishing on the internet



Conclusions

- A natural analogue (NA) database was designed to promote the utilization of existing analogue cases.
- A foundation was established for accumulating cases in a consistent format, including the classification of analogue cases using FEPs and the organization of descriptive items to clarify their relationships with the disposal system.
- To further enhance the applicability of natural analogues, future efforts will focus on refining the database structure in greater detail, as well as improving the usability of the database format.



Thank you for your attention

