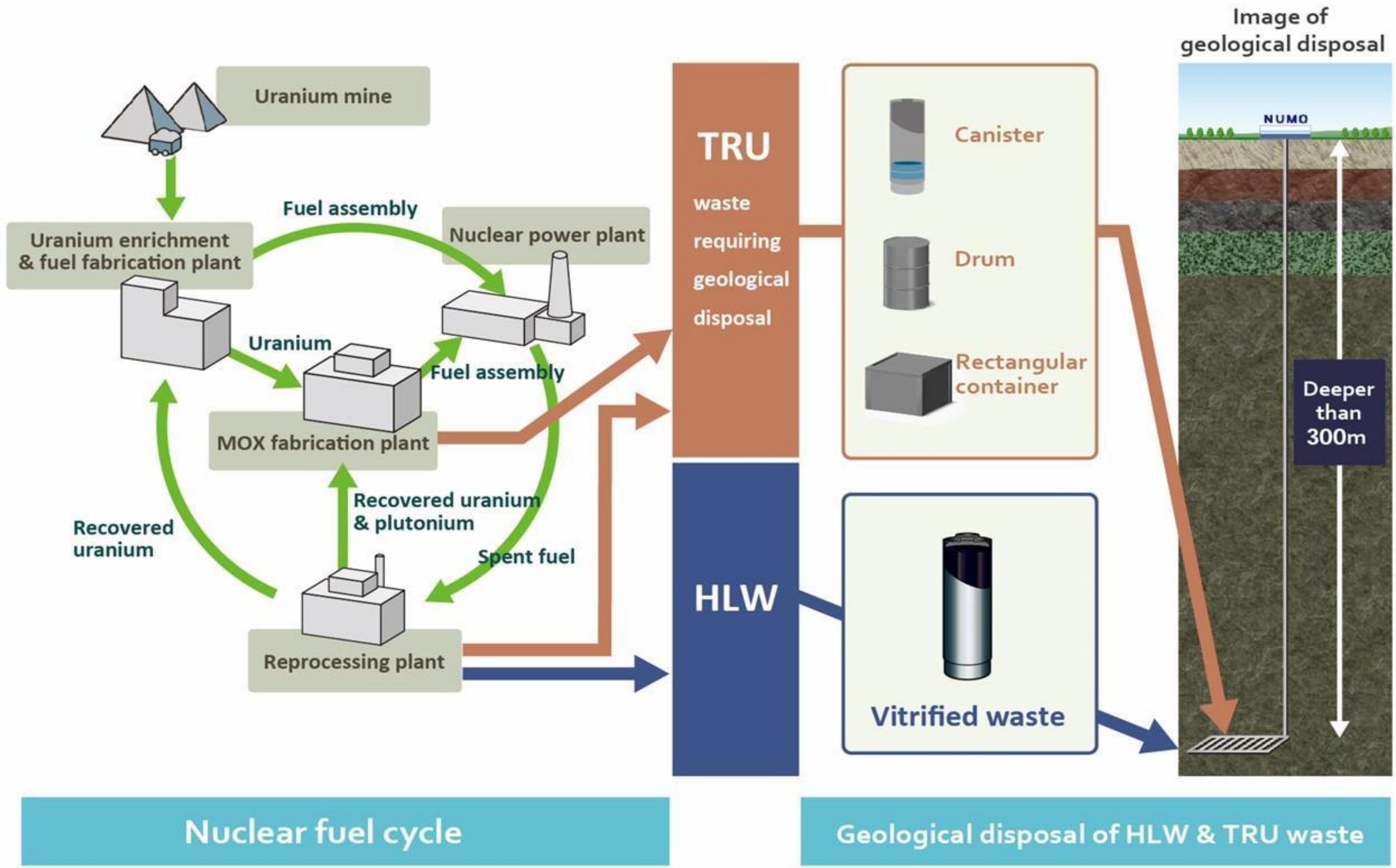

Overview of Horonobe URL project

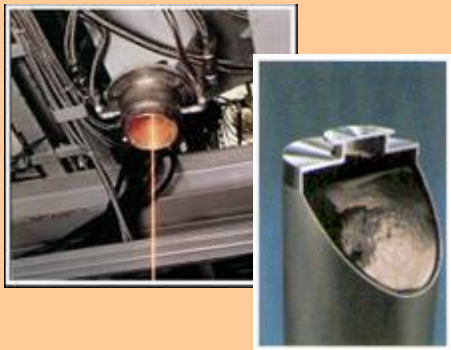
Nuclear Fuel Cycle & Disposal of nuclear waste in Japan



TRU: TRans-Uranic waste
HLW: High-Level radioactive Waste

What is vitrified Waste?

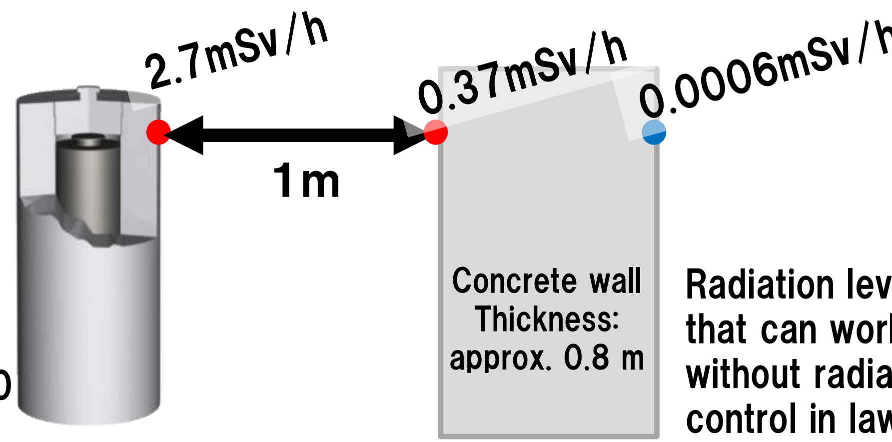
Vitrification



- Material: borosilicate glass
- Melting temperature: 1,100~1,200℃
- Height: 134cm
- Diameter: 43cm
- Weight: 500kg
- Radioactivity: about 1.5×10^{16} Bq/can.
- Initial surface dose: 1,500Sv/h

Vitrified Waste in canister

Storage for cooling (30-50 years)



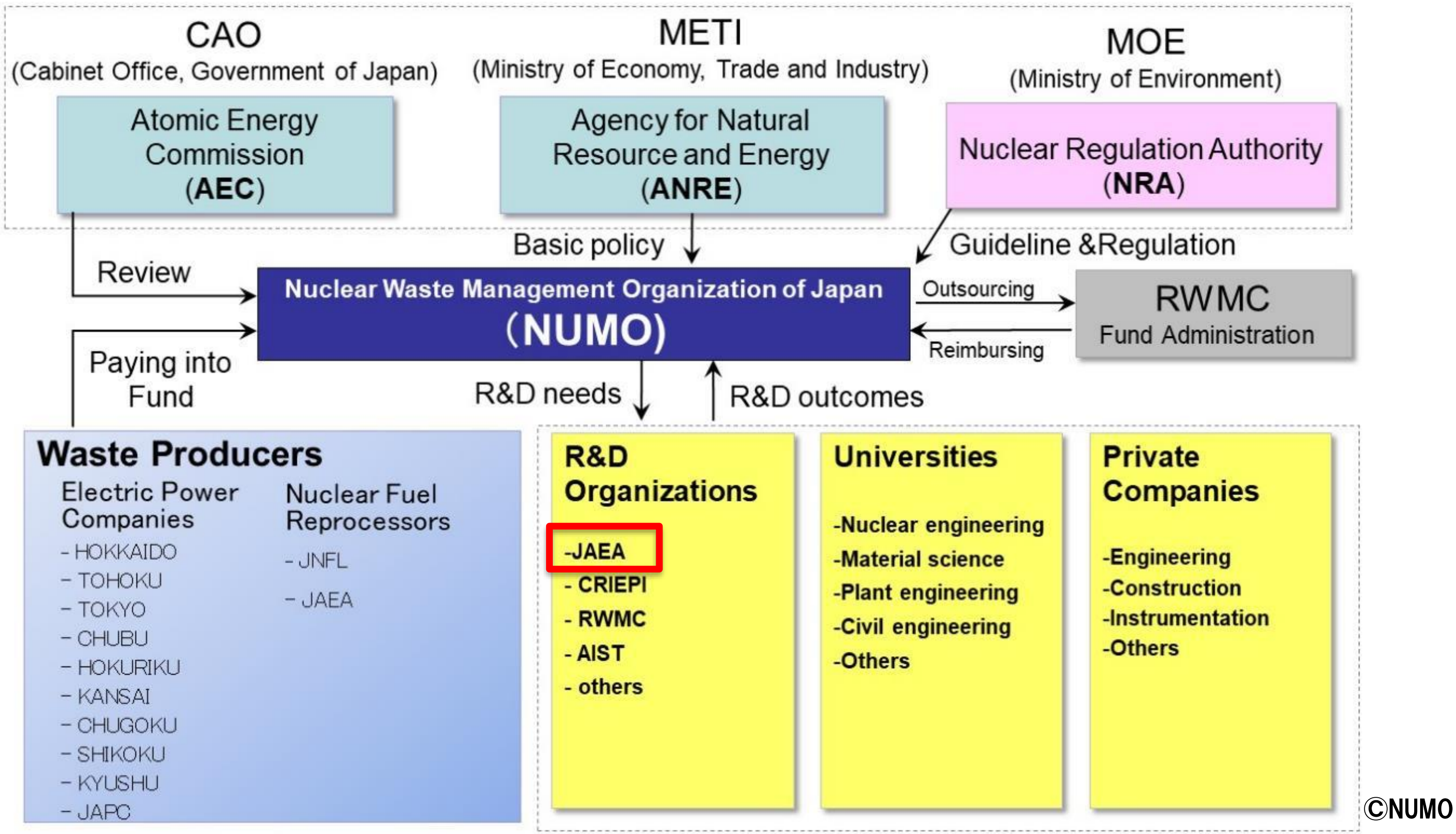
Vitrified waste in a 19 cm thick metal container (after 50 yrs of cooling)

Radiation levels that can work without radiation control in law.

Spent fuels of about 30t are discharged by operation of a 1GWe power plant for a year, and about 30 canisters are produced by reprocessing those spent fuels.

Currently, HLW equivalent to 26,000 vitrified wastes have accumulated in Japan.

Framework for HLW Disposal in Japan & Role of JAEA



JAEA has responsibility for R&D for both implementation and regulation to ensure the reliability of geological disposal technology and safety assessment methodology.

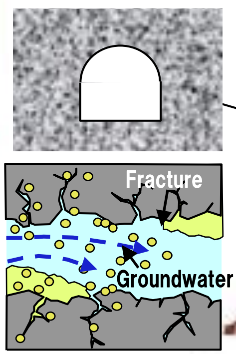
In 1994, Atomic Energy Commission recommended. "URLs should be constructed at several places."

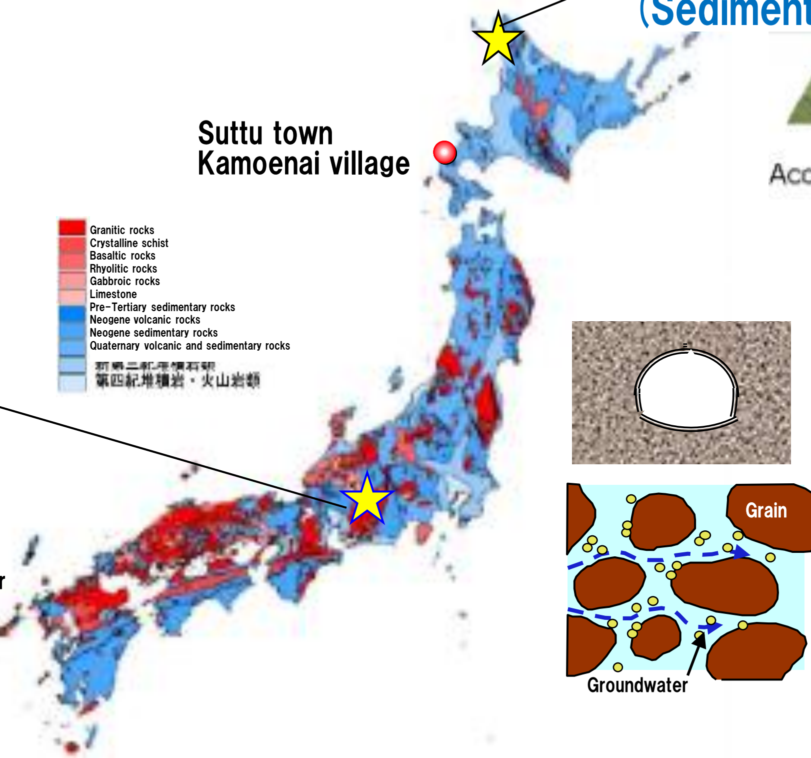
JAEA started two "generic" URL projects at Mizunami URL in 1996 and Horonobe URL in 2001.

Two generic URLs in Japan

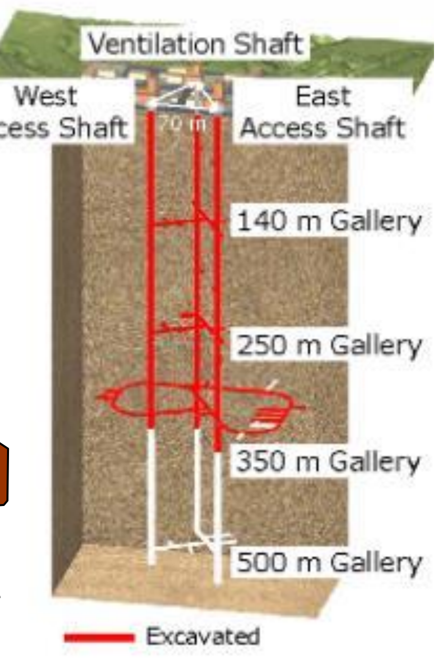
The two URLs are subjected to representative rock and groundwater environments in Japan.
URLs are used for only geoscientific research and/or R & D of geological disposal technology, and are not a candidate site for geological disposal. It is forbidden to bring in or use any radioactive materials.

Mizunami URL Project
(Crystalline rocks, fresh water)





Horonobe URL Project
(Sedimentary rocks, saline water)



Layout of Horonobe URL

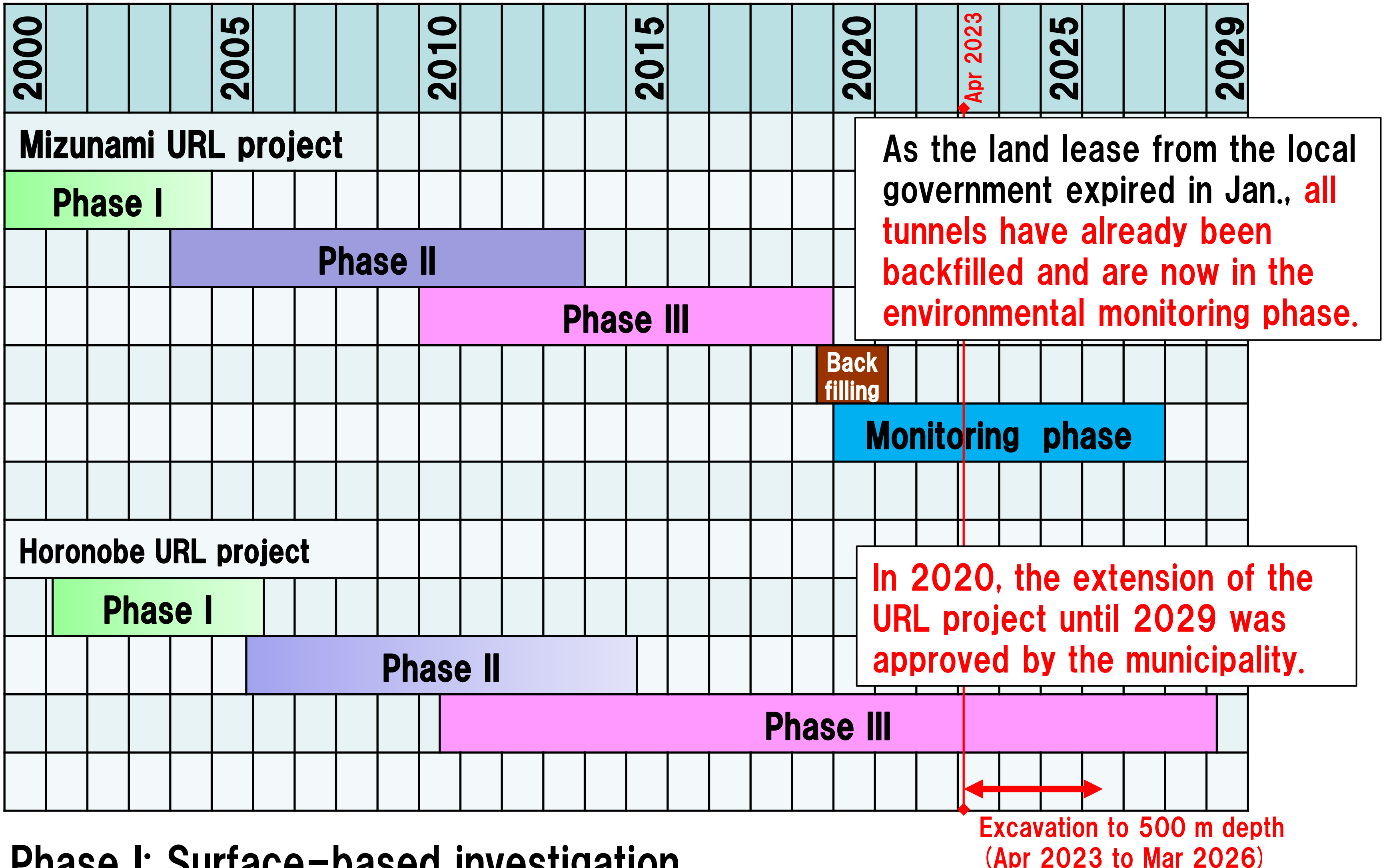
R&D related to geoscience

- Site investigation methods for granite
- Facility construction and operation (eg. countermeasure for groundwater inflow)
- Modeling technologies for solute transport etc.

R&D related to geoscience and disposal technology

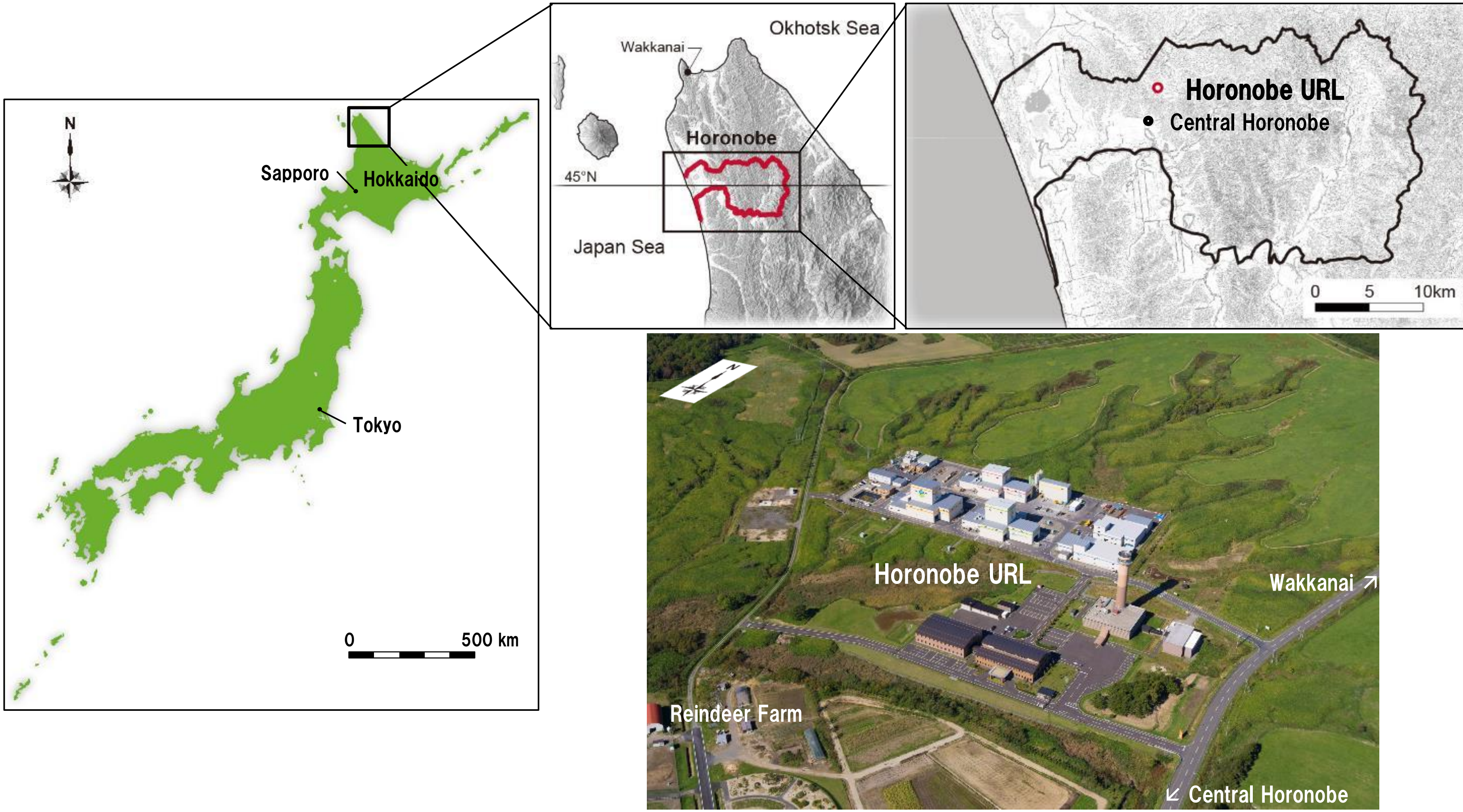
- Engineering technologies
- Safety assessment methods
- Promote public's understanding etc.

History of URLs



Phase I: Surface-based investigation
Phase II: Construction (investigation during tunnel excavation)
Phase III: Operation (investigation in subsurface facilities)

Outline of the Horonobe site



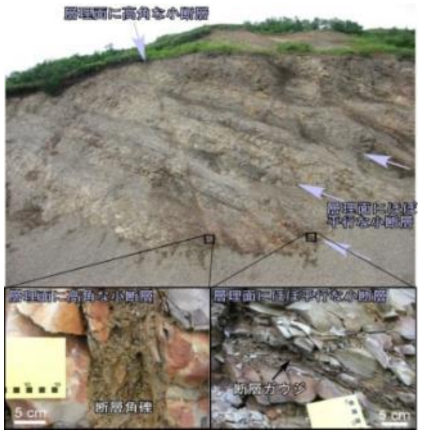
The URL is constructed in Neogene sedimentary rocks of the coastal area.
The area is characterized by relatively soft sedimentary rocks, porous media, and saline groundwater.

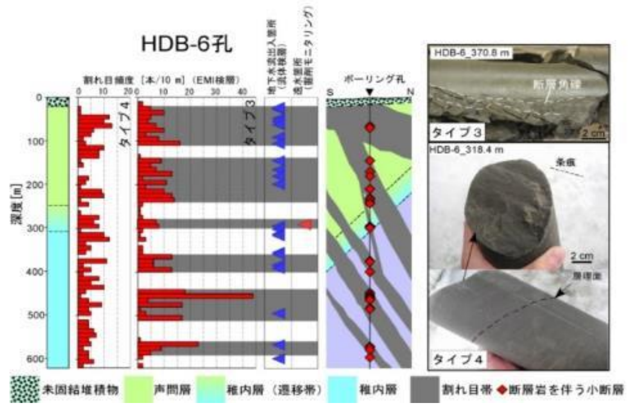
Policy for social concerns on the Horonobe URL Project

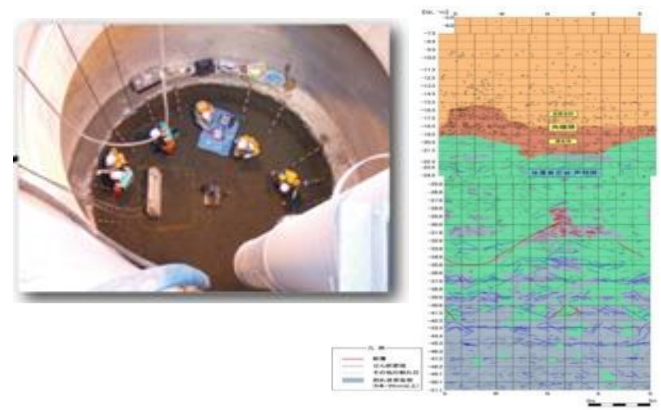
JAEA promised with Hokkaido Prefecture and Horonobe Town(2000) that;

- ✓ JAEA never brings nor uses any radioactive wastes in the area for the project during and after the project.
- ✓ JAEA never lends nor transfers the URL facilities to the implementing organization (Nuclear Waste Management Organization of Japan: NUMO) for the final disposal of HLW.
- ✓ JAEA closes the facilities on the ground and refill the underground facility after completion of the project.
- ✓ JAEA never introduces a permanent disposal site nor an interim storage for radioactive waste in Horonobe.
- ✓ JAEA openly discloses information related to the project.
- ✓ The Horonobe site will be open to academic research and education.

Phased R&D at Horonobe URL



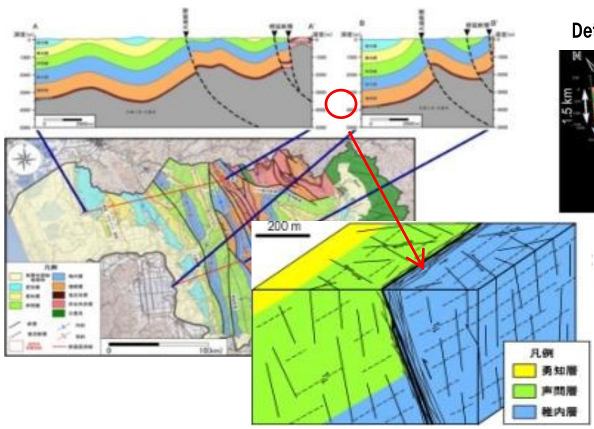


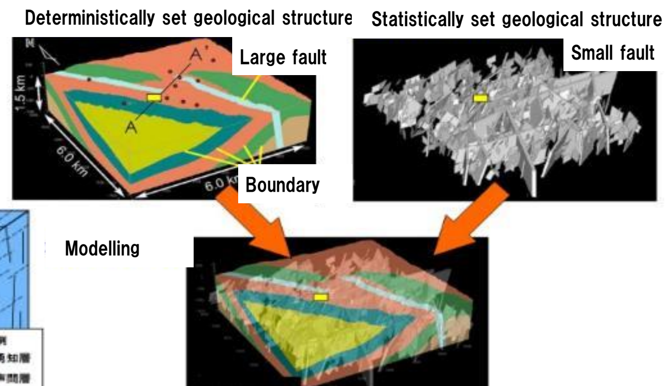


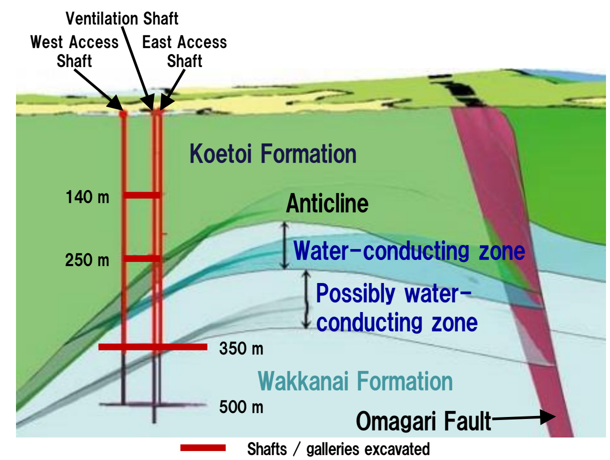
Survey geology and geological structure

Estimate mechanical strength, groundwater flow, water chemistry

Layout design of the facility, estimate the amount of water inflow and quality







- Neogene argillaceous marine sedimentary rocks (Koetoi and Wakkanai Formations)
- Soft rock and saline groundwater with dissolved methane gas
- Several hundreds meter far from Omagari Fault at ground surface

Specificity and generality of the Horonobe site

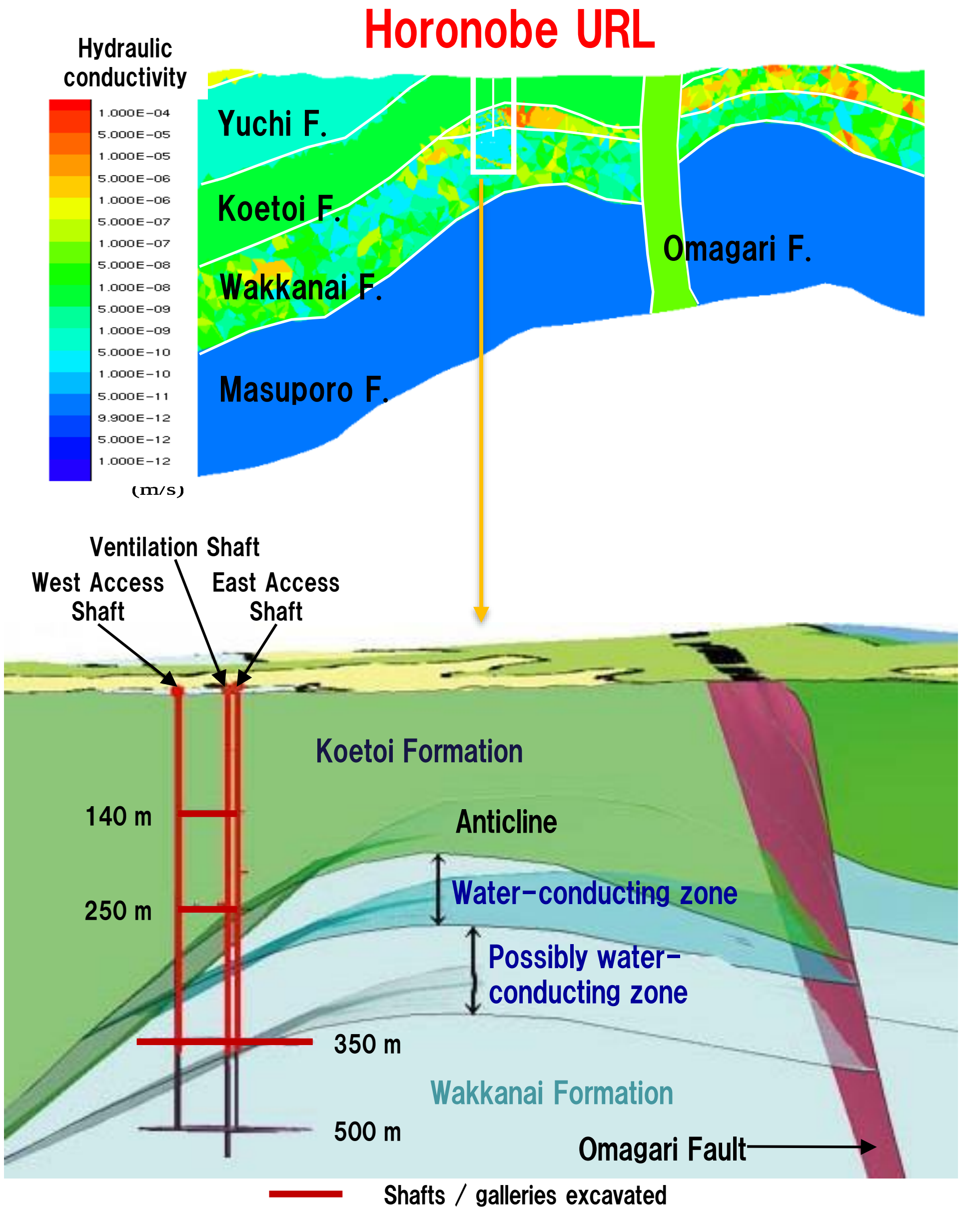
Name of formation		Koetoi Formation	Wakkanai Formation	Boom Clay	Opalinus Clay	Callovo-Oxfordian Clay
Country		Japan	Japan	Belgium	Switzerland	France
Location		Horonobe	Horonobe	Mol	Benken	Bure
Age	[Ma]	4~2	7~3	33~29	180	158~152
Thickness	[m]	400~700	600~1000	102	113	130~145
Clay content	[wt %]	17~25	19~33	60	54	45
Porosity	[vol %]	57~65	35~37	38.0	10.8	6~10
Hydraulic conductivity	[m/s]	1.0×10^{-11} ~5.0×10^{-10} a)	7.0×10^{-13} ~5.0×10^{-12} b)	H: 2.8×10^{-12} V: 7.0×10^{-12}	H: 1.0×10^{-13} V: 2.0×10^{-14}	5.0×10^{-14} ~5.0×10^{-13}
Porewater chemistry		Na-Cl	Na-Cl	$Na\text{-}HCO_3$	Na-Cl	$Na\text{-}Ca\text{-}SO_4\text{-}Cl$
Porewater TDS	[mg/L]	~22,000	~20,000	1,650	12,900	—
Uniaxial strength	[MPa]	3~5	5~30	2.0	H: 28.0 V: 30.3	V: 25
Heat conductivity	[W/mK]	0.9~1.2	1.2~1.6	V: 1.7	H: 2.0~3.2 V: 1.3~1.7	1.7

H: parallel to bedding plane, V: perpendicular to bedding plane
Measured values by in-situ test are a) 3.0×10^{-8}~9.0×10^{-10} & b) 1.0×10^{-5}~1.0×10^{-12}, respectively.

(modified based on Boisson, 2005; Andra, 2005; Ota et al., 2007, Ota, 2010, Hiraga & Ishii, 2008)

The age of the bedrock is younger than that of overseas, but the chemical composition of groundwater and the strength of the bedrock are similar.

Investigation and facility design



3D geological model in the vicinity of Horonobe URL

<u>Phase I: Surface-based investigation</u>

Develop a geological model and plan the facility design and research

- Three shafts up to a depth of over 350m and a gallery with 140, 250, and 350m depths avoiding water conduction zones.
- The ventilation shaft and two main shafts were designed for safety control.

<u>Phase II: Investigation during the facility construction</u>

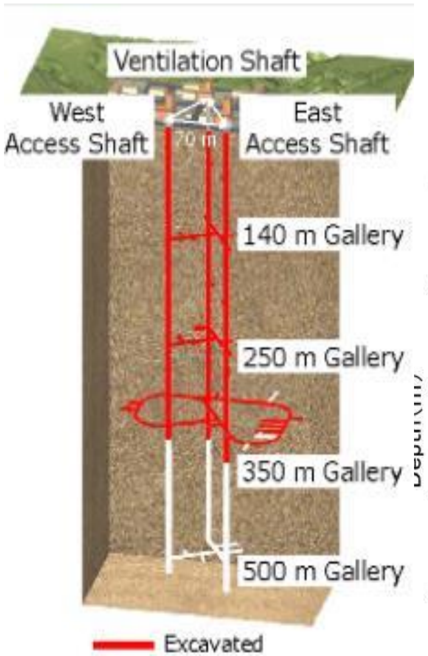
Verify the model constructed in Phase I and understanding the Excavation Damage Zone / Excavation disturbed Zone

<u>Phase III: Investigation in the underground facility</u>

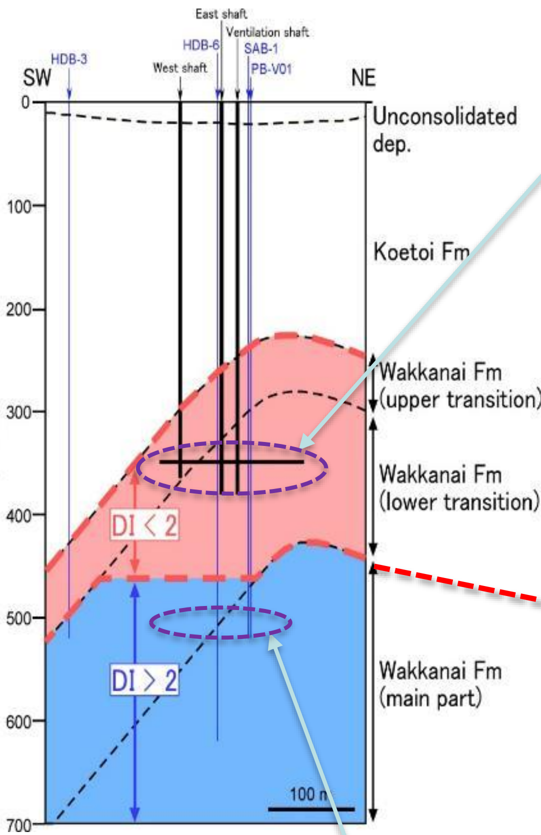
Currently, various tests are being conducted mainly in the 350m gallery.

The shaft and gallery will be extended to 500m by FY 2025.

Geological features at 350 and 500m depths



Layout of Horonobe URL



Geological section

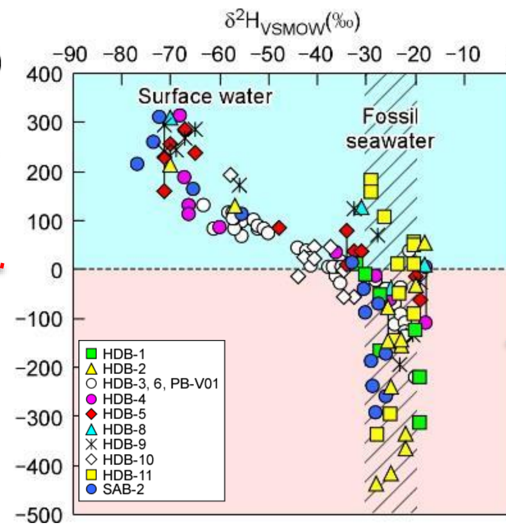
The Wakkanai Formation is mechanically divided into two domain; the shallow domain preferable to tensile failure (DI<2) and the deep domain suitable to shear failure (DI>2).

Ductility Index (DI) = Effective mean stress / Tensile strength

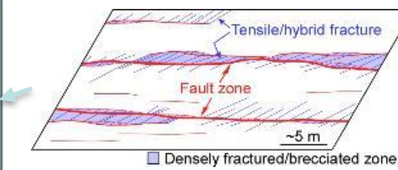
350m gallery

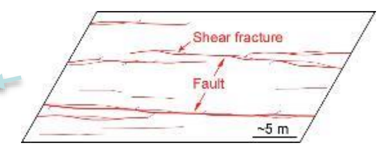
- Mixing of young shallow water and fossil seawater
- Advection-dominant via fault network

Faults are hydraulically connected by numerous dilational fractures along the faults.



Isotopic signature of groundwater





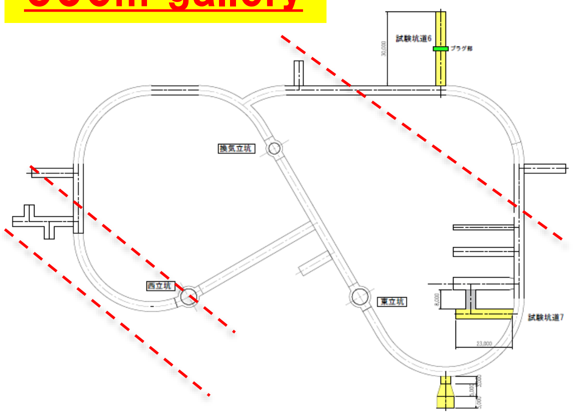
Faults are hydraulically less connected by a few dilational fractures along the faults.

500m gallery to be built in the future

- Fossil seawater older than 1 Ma
- Hydraulically closed due to the limited fault connectivity

R & D activities in the galleries

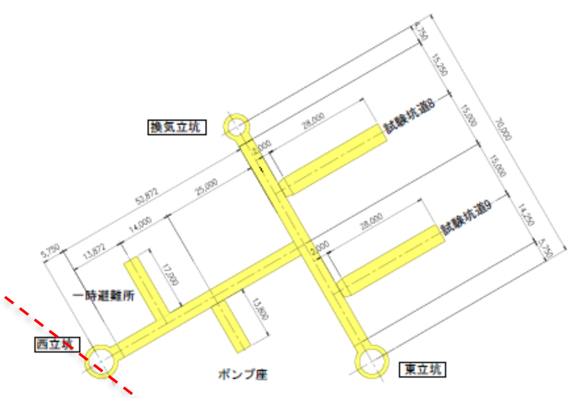
350m gallery



Occurrence of faults at 350 m level

- **Solute transport** in the area where fractures are connected over hundreds meters (severe geological feature case).
- **Engineered barrier system (EBS) emplacement/retrieval**
- Excavation Damage Zone (EDZ) sealing experiment
- Dismantling the full-scale EBS
- Water-tight plug and backfilling test
- Evaluation of an initial environments if repository maintained for retrievability

500m gallery to be built in the future



Occurrence of fault at 500 m level

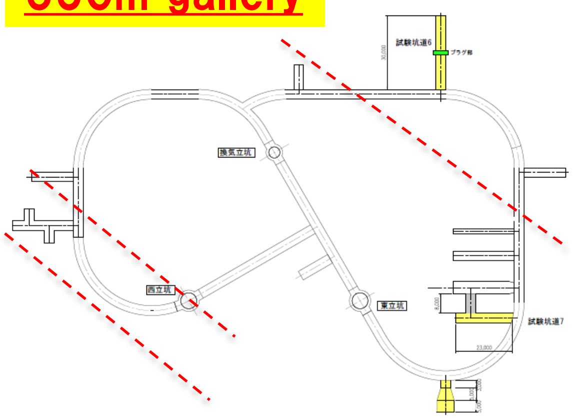
Galleries currently under design

- **Solute transport** in regions where small-scale faults exist, but with limited hydraulic connectivity and relatively closed migration paths (preferable geological feature case).
- Demonstrate the construction technology of a repository tunnel for sedimentary rocks under higher rock stress
- Differences in geological characteristics and engineering know-how can be compared between two depths.

Optimisation of a systematic combination of technologies towards EBS emplacement

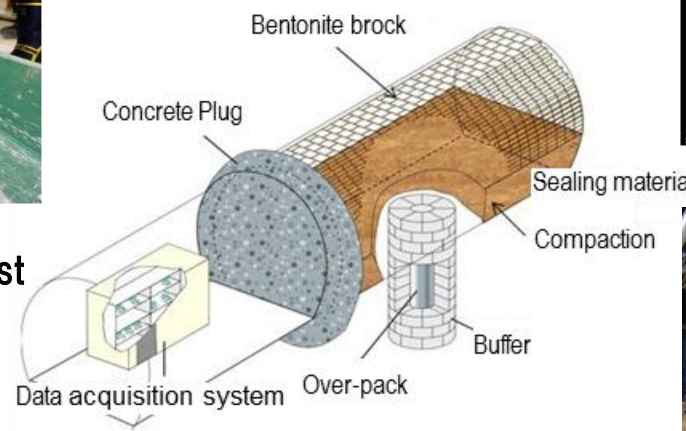
Research on engineered barrier system

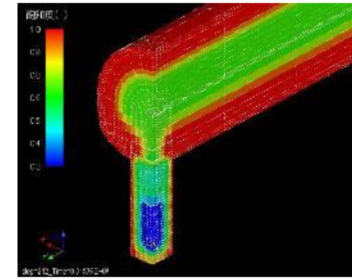
350m gallery



Occurrence of faults at 350 m level

Overpack corrosion test

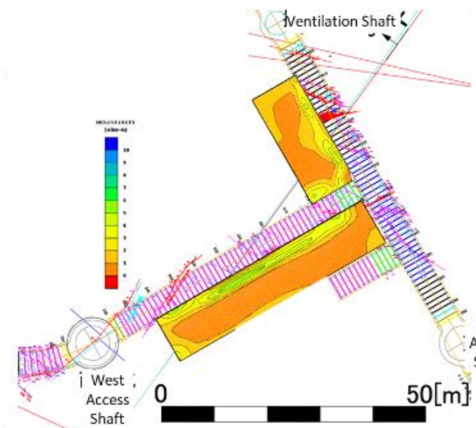




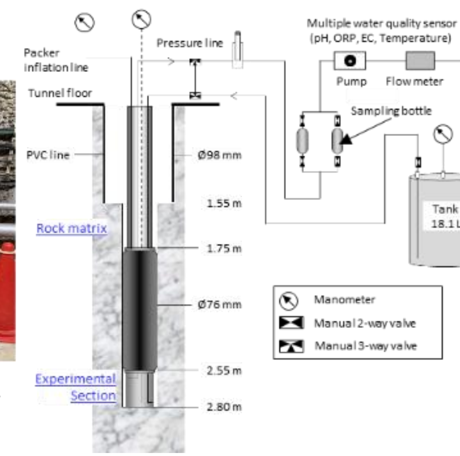
T-H-M simulation

Dismantling

Full-scale Engineered Barrier System (EBS) test

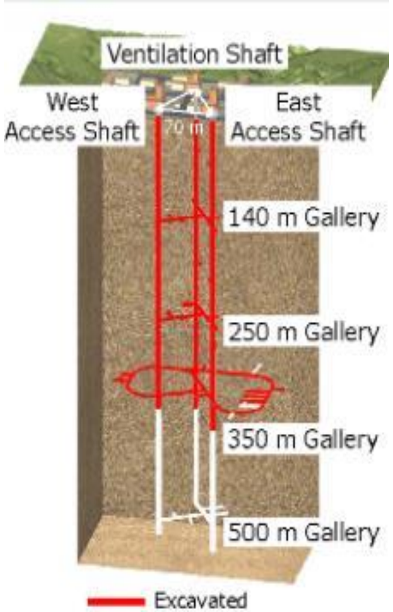


Excavation Damage Zone (EDZ) identification and sealing test



Solute transport tests involving colloids/organics and microbe

Status of the facility construction



Layout of Horonobe URL

Shaft Excavation Status

East Access Shaft : 380.0 m
Ventilation Shaft : 380.0 m
West Access Shaft: 365.0 m

Gallery Excavation Status

GL −140 m Gallery : 186.1 m
GL −250 m Gallery : 190.6 m
GL −350 m Gallery : 757.1 m

GL −500 m Gallery will be constructed by FY 2025

Niche No.4
(East Loop Gallery of the depth of 350 m)
Full-scale Engineered Barrier System Experiment
(2015.1.13)

West Access Shaft
(2014.3.26)

East Access Shaft
(2014.3.26)

Gallery of the depth of 350 m
(2023.6.15)

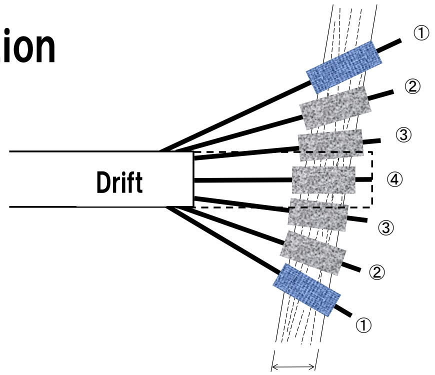
Video of the excavation: https://www.youtube.com/watch?v=cS8C_UMaXMY

Safety measure for groundwater inflow and methane

Safety measure for a large amount of spring water

① Based on the agreement with the fishermen's cooperative association
- Remove boron and the ammonia
- Maximum drainage is limited to 750 m^3 per day

② Groundwater inflow restraint by the grouting
- Pre-grouting：Grouting before excavation
- Post-grouting：Grouting after excavation



Safety measure for the rise of the methane gas content

① Ventilation of the URF: Sending ground fresh air to underground forcibly

② Stratified management by the methane content
- Watching the methane gas content by a large number of sensors for 24 hours
- Use of non-explosive machines

Safety measure standard

methane gas content（Vol%）	Correspondence measures
≧0.25	Prohibition of the firearms use work
≧ 0.5	Patrol light lighting
≧ 1.0	Worker evacuation
≧ 1.5*	Power supply interception

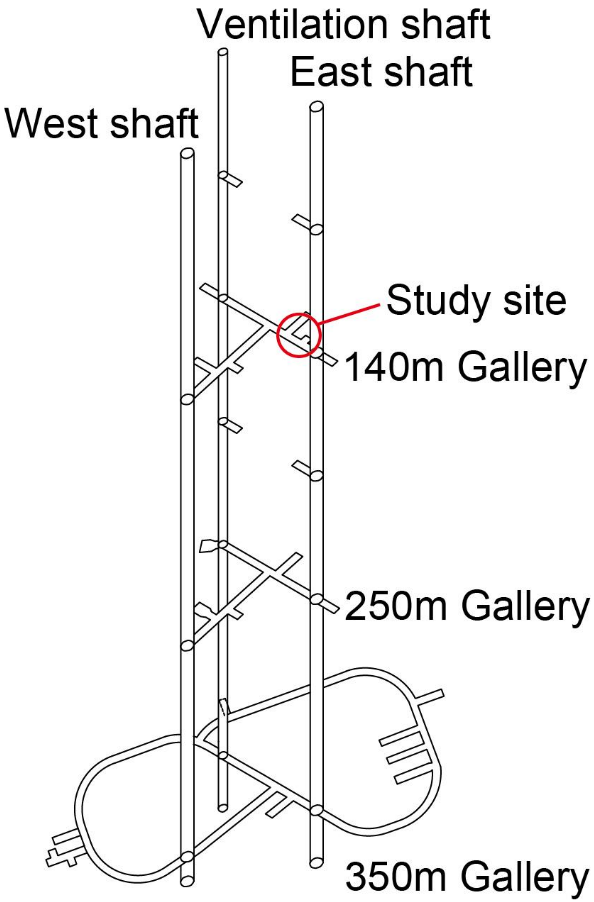
＊ Measures based on the labor security hygiene rule

Promoting better understanding of geological disposal

1. Public experience of the site

   Horonobe URL, about 13,200 people experienced the real underground and 124,000 visited the exhibition hall until 2022.
2. Hosting young researchers under the Internship Scheme for Students and the International Fellowship Scheme for Sabbatical Leave Researchers to transfer the experiential knowledge.
3. Use the digital tools: Access log analysis and sequential updating of web pages, more YouTube videos, Twitters
4. Publication of a series of articles in local PR magazines
5. Science Cafe for local residents
6. Delivery lessons at primary schools to universities

Experience of geophysical survey

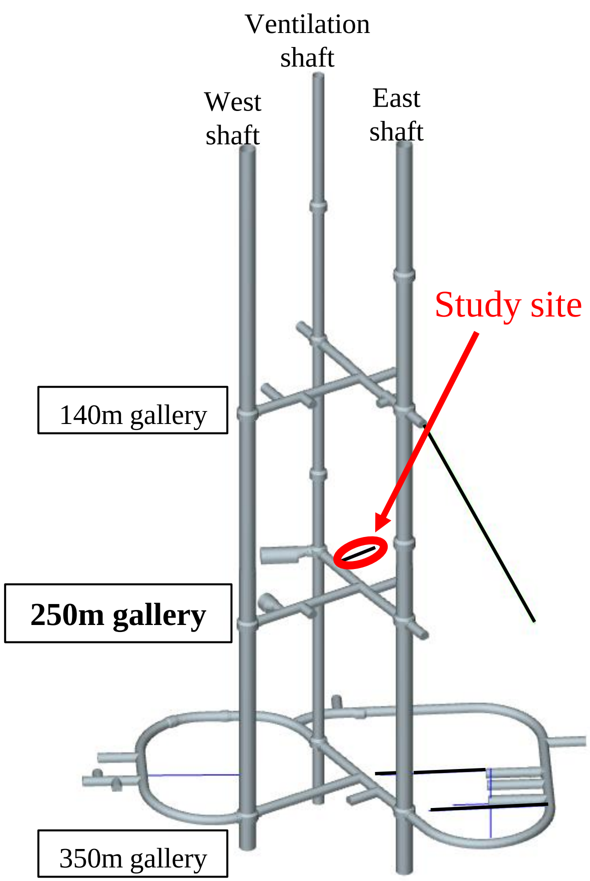


- Experience of the geophysical survey (Seismic tomography).
- Technology to investigate inside rock without destruction.
- Generate very small artificial seismic (vibration) and measure the propagation time of it in the rock.

What you do is:
Hit the tunnel wall by hammer and special machine and observe the generated signals.

Seismic wave measurement using boreholes.

Experience of groundwater investigation

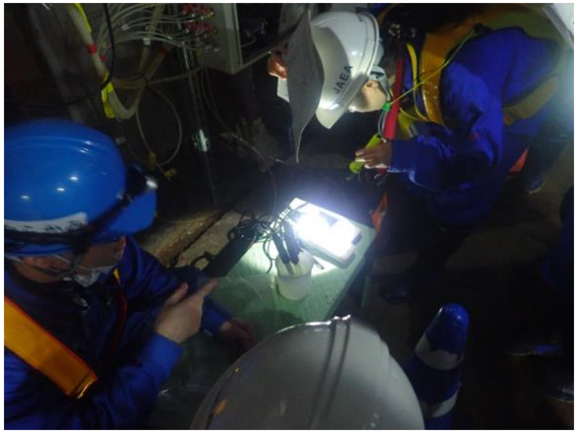


Layout of Horonobe URL

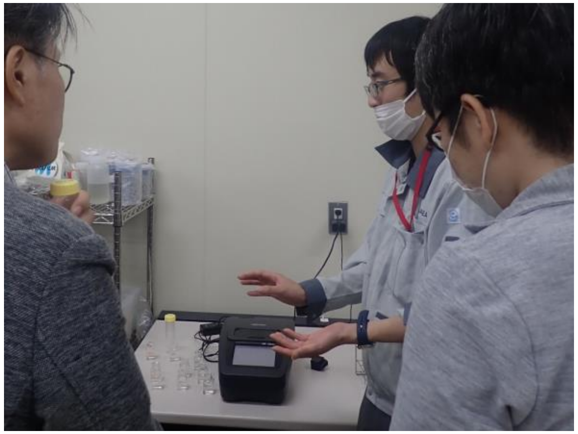
- Experience of the groundwater sampling.
  - ➢ How to collect and measure to get the reliable chemical data of deep-groundwater?

What you do is:

- Measure the physico-chemical parameters of groundwater
- Analyze concentration of Iron species
  - ➢ What happens over time?



Groundwater sampling and measurement at the gallery



Analyzing at Laboratory