Okinoshima site study

GLA2011, June 9, Jyväskylä, Finland

Kiyokazu … i[a)], Tokiyoshi Kaneta[a)], … ori Oshimo[a)] ,
André Ru…

[A)] Penta-c…

[B)] High En…

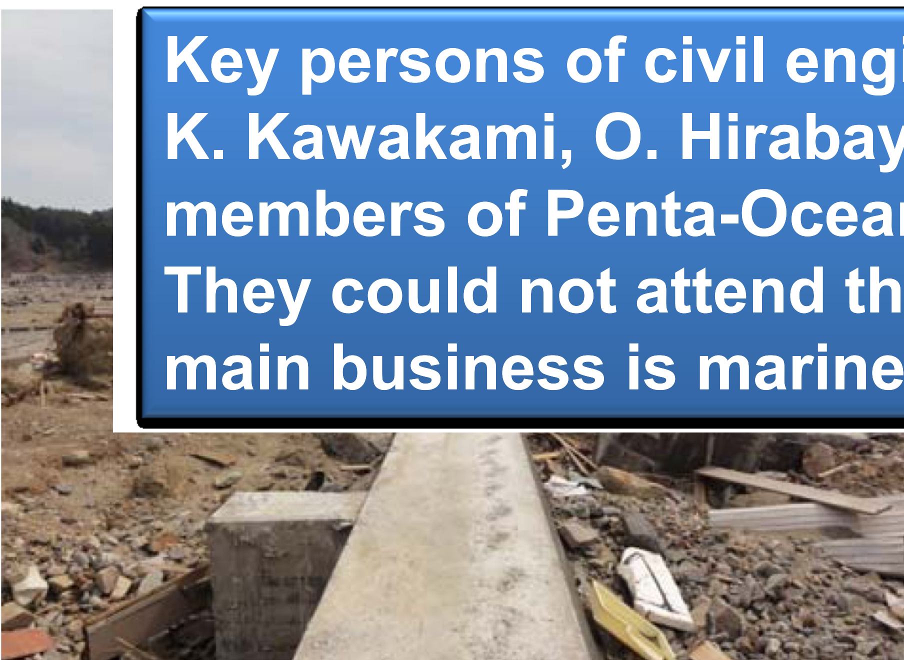
[C)] ETH Zu…

1. H… ere born
2. …
3. …
4. …
5. … on liq. Ar
6. S…

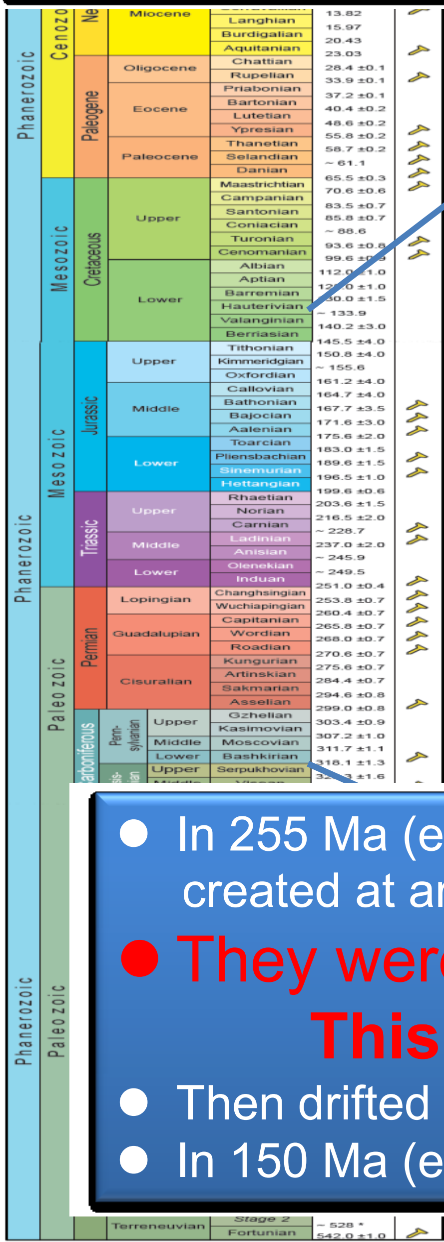
Damaged harbor by mega-quake and tsunami.

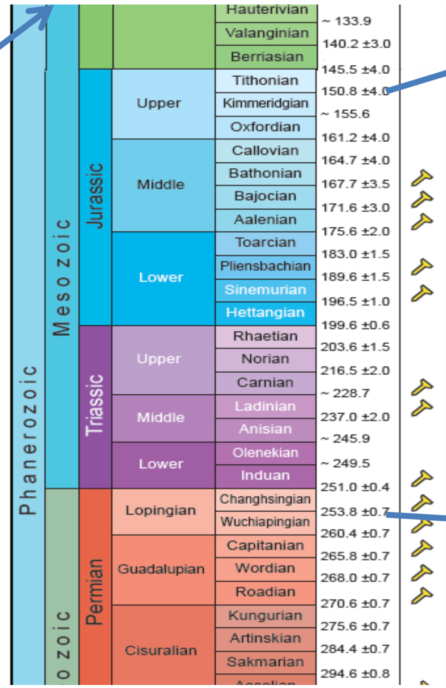
Disaster-relief work by marine construction companies

Key persons of civil engineering
K. Kawakami, O. Hirabayashi and T. Kaneta, members of Penta-Ocean construction co., Ltd
They could not attend this workshop, since their main business is marine construction.



1. How Japanese islands and Okinoshima were born? == 1st STEP ==



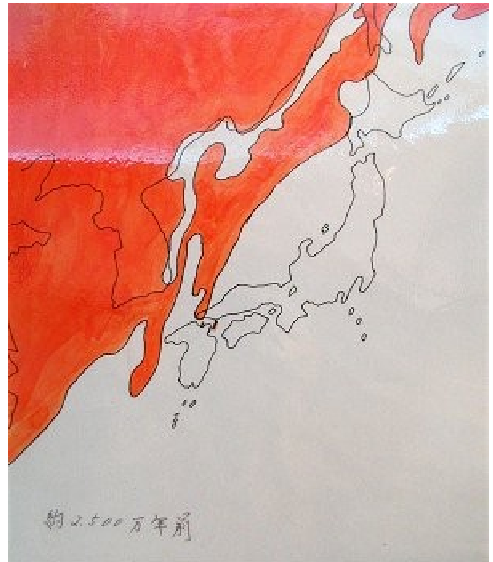


- In 255 Ma (end of the Permian), the basis of Japanese islands were created at around the equator at the edge of the supercontinent Gondwana,
- They were born from the deep sea as accretionary prism.

  This is the original basis of Okinoshima islands.
- Then drifted to the northward,
- In 150 Ma (end of the Jurassic), they were located at the present latitude.

http://www.avis.ne.jp/~ammonite/nihon.htm

70 Ma (Cretaceous~Paleocene)



25 Ma (Oligocene)

14 Ma (Pleistocene)

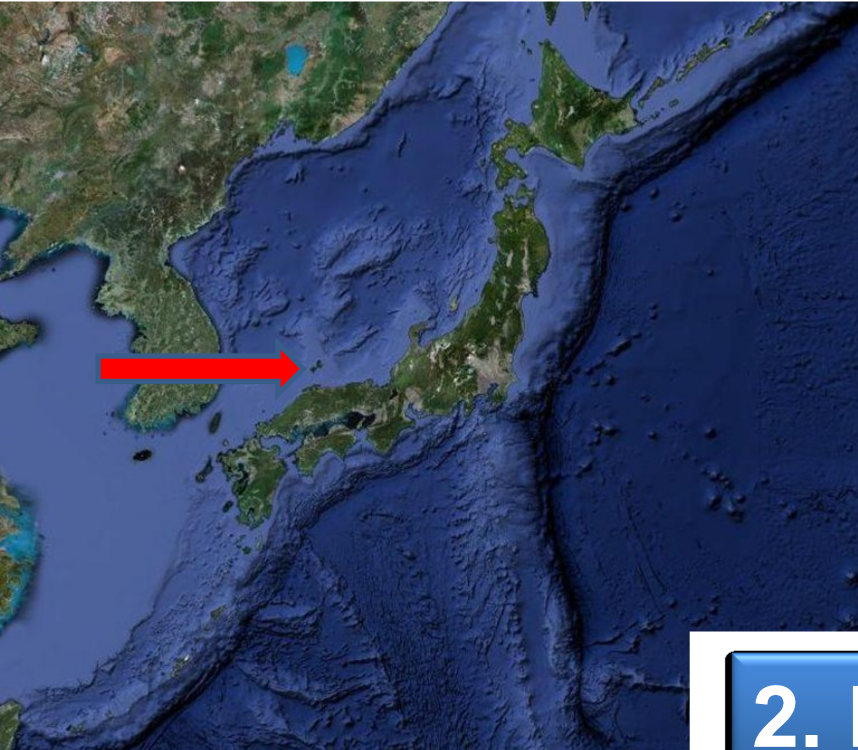
5 Ma

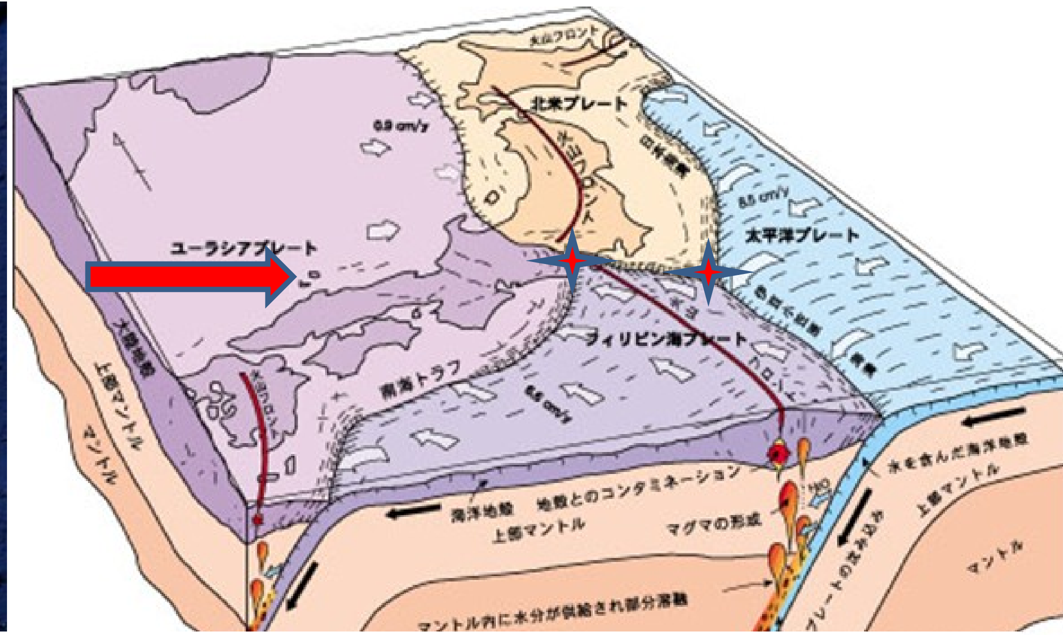
10000 years ago

Still most active place in the world from plate tectonics point of view

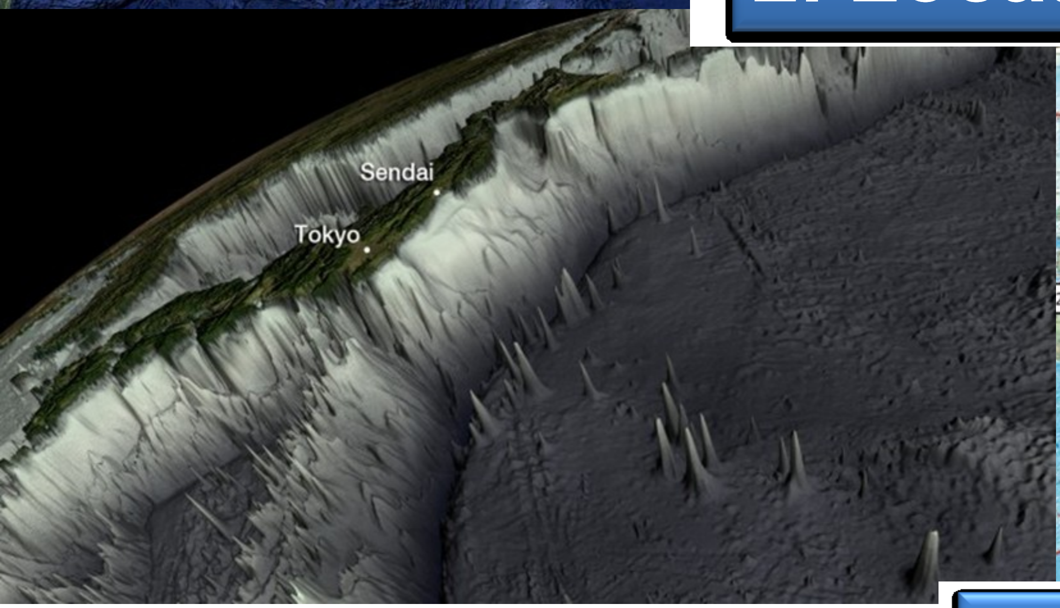
== 2nd STEP ==

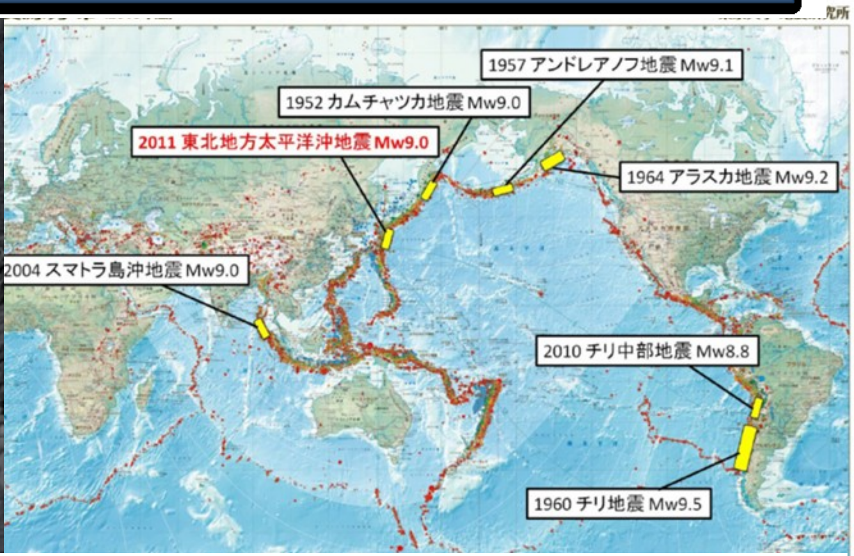
- Japanese islands were splitting off from the Asian continent since 25 million years ago.
- 50,000 years ago, Homo Sapience were getting at Japan and created culture.
- 18,000 years ago, present shape were almost created.



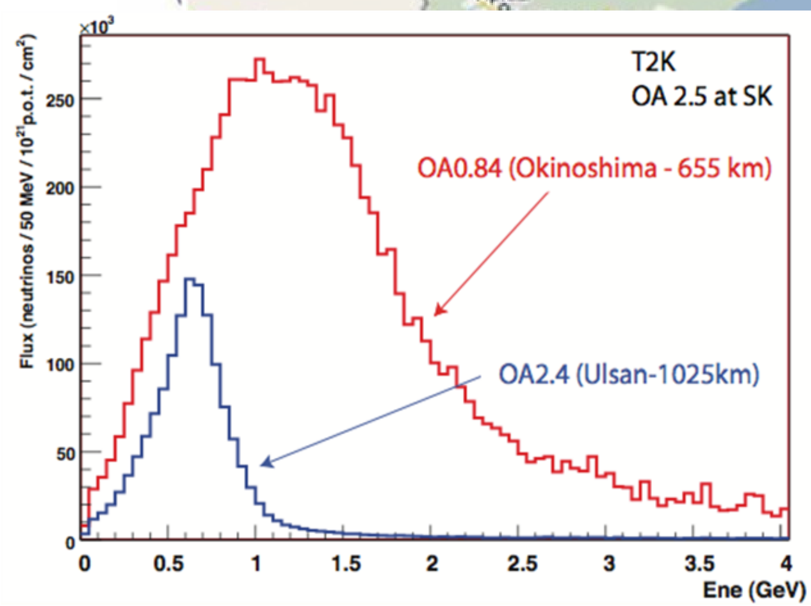


2. Location of Okinoshima





Distribution of mega-earthquake of M-9 class

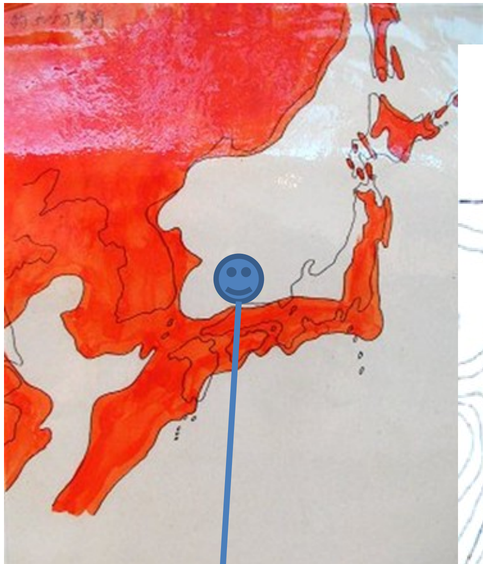


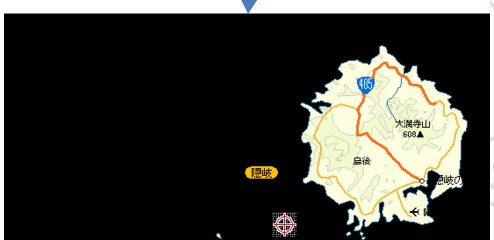
Angle of elevation: 0.76 degree

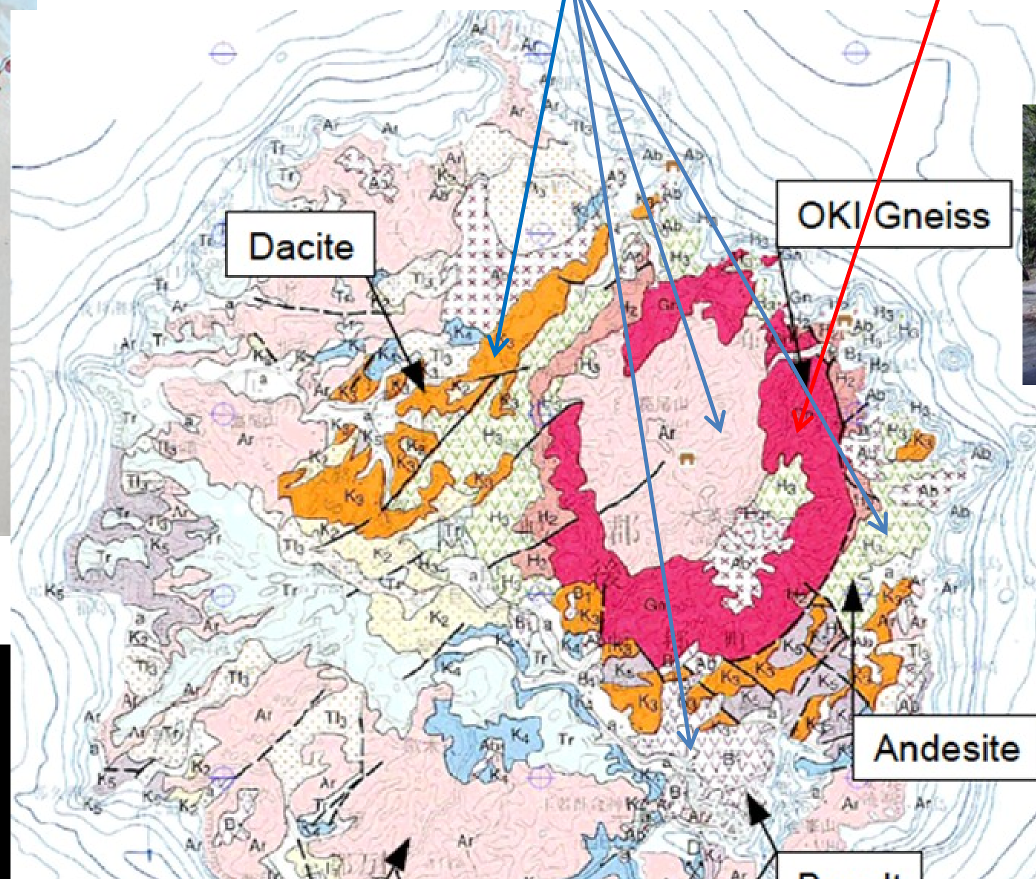
- Good coverage of 1st and 2nd oscillation peaks
- Ideal for Liq. Ar TPC

3. Geology and geography

In 5 Ma, Okinoshima-islans were born by volcanic activities and consisting of igneous and very old metamorphic rocks.

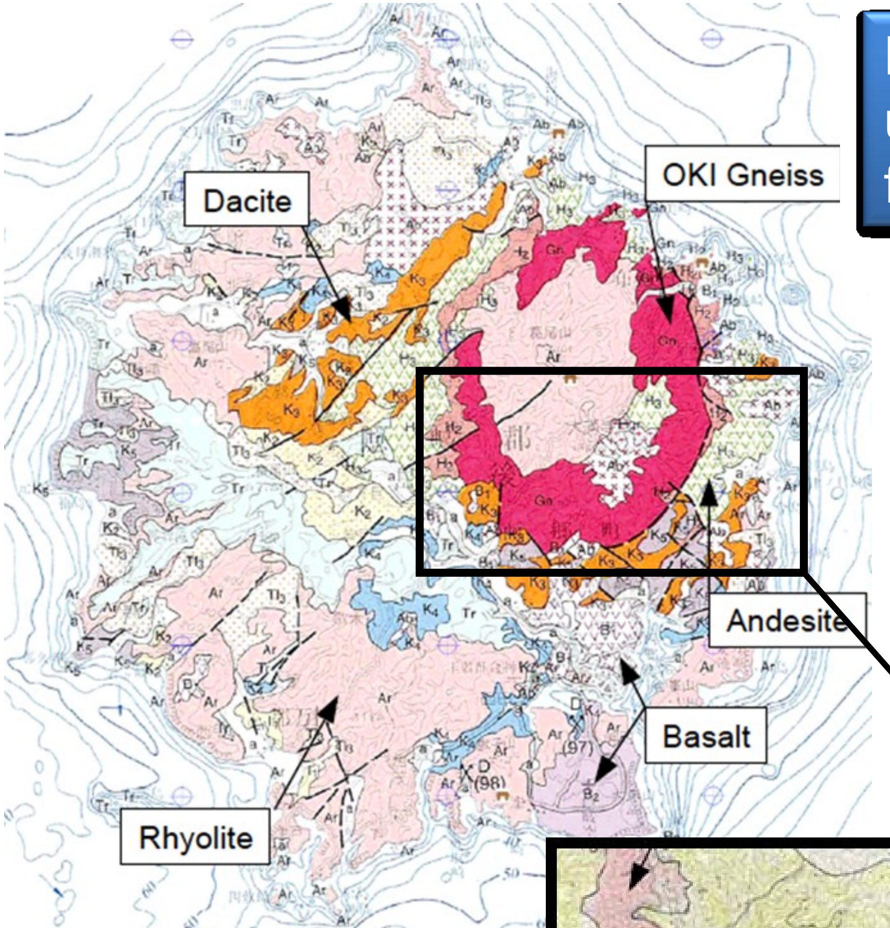




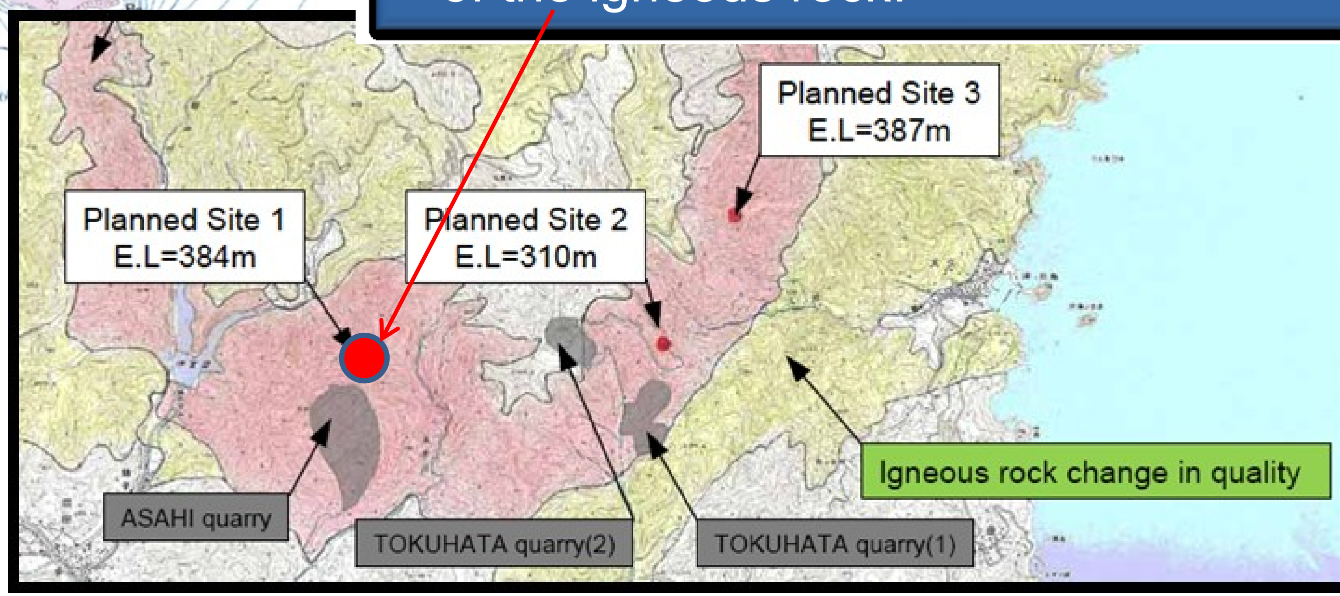


- Metamorphic event of Oki-gneiss was in 250 Ma at the equator position.
- Oki-gneiss contains a small amount of very old zircon (3000 Ma !!), which is one of the evidences that islands have been a part of Asian continent.

Necessary conditions for the large-scale underground cavern construction and for keeping long-term operation safety.



- The site should be in the bedrock of healthy OKI-gneiss.
- Keep enough distance from the dislocation and active faults.
- Keep enough distance from the stratum boundary with the igneous rock, in order to avoid to be changed in quality of the gneiss by the crackle of the igneous rock.



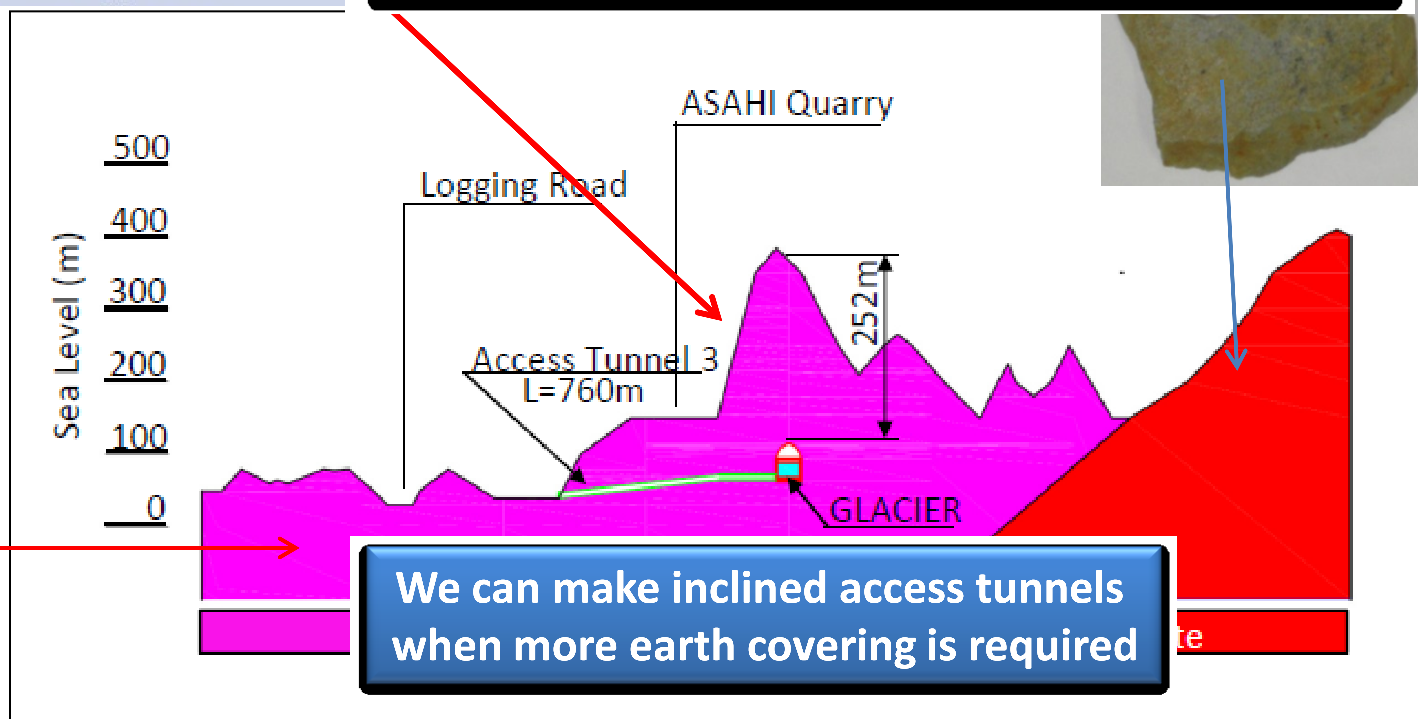
ASAHI quarry

A single layer of the gneiss

Specific Gravity	26.9kN/m^3
Axial Strength	79.2Mpa
The bedrock situation	Form of lump

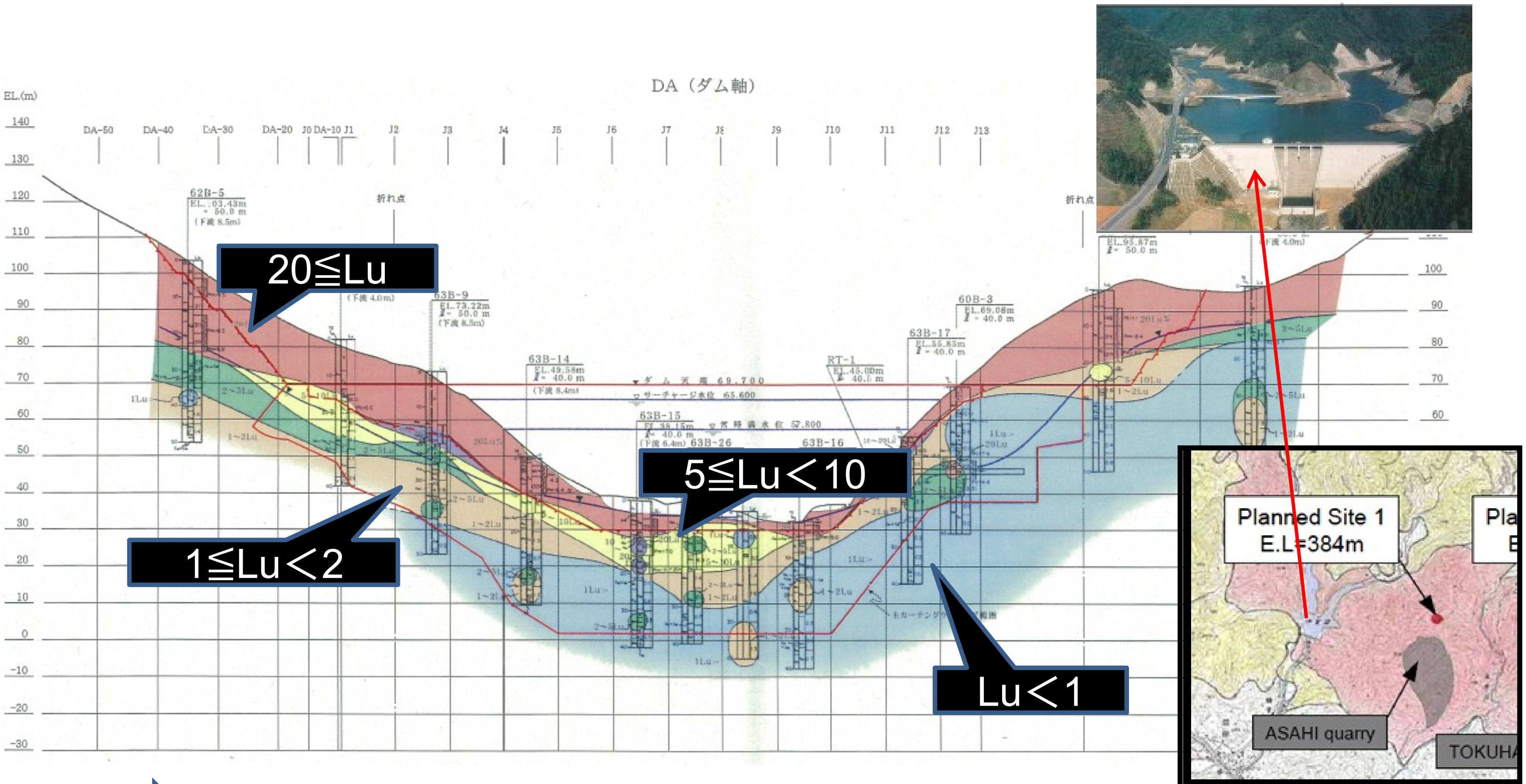
Very good conditions for excavation with New Austrian Tunneling Method using blasting.

Cracks are very few



We can make inclined access tunnels when more earth covering is required

Permeability at OKI-gneiss can be estimated from Chyoshi Dam (agriculture, drinking water) located near the site.



- Lugeon coefficient (Lu) is less then 1 ($\times 10^{-7}$ m/sec)

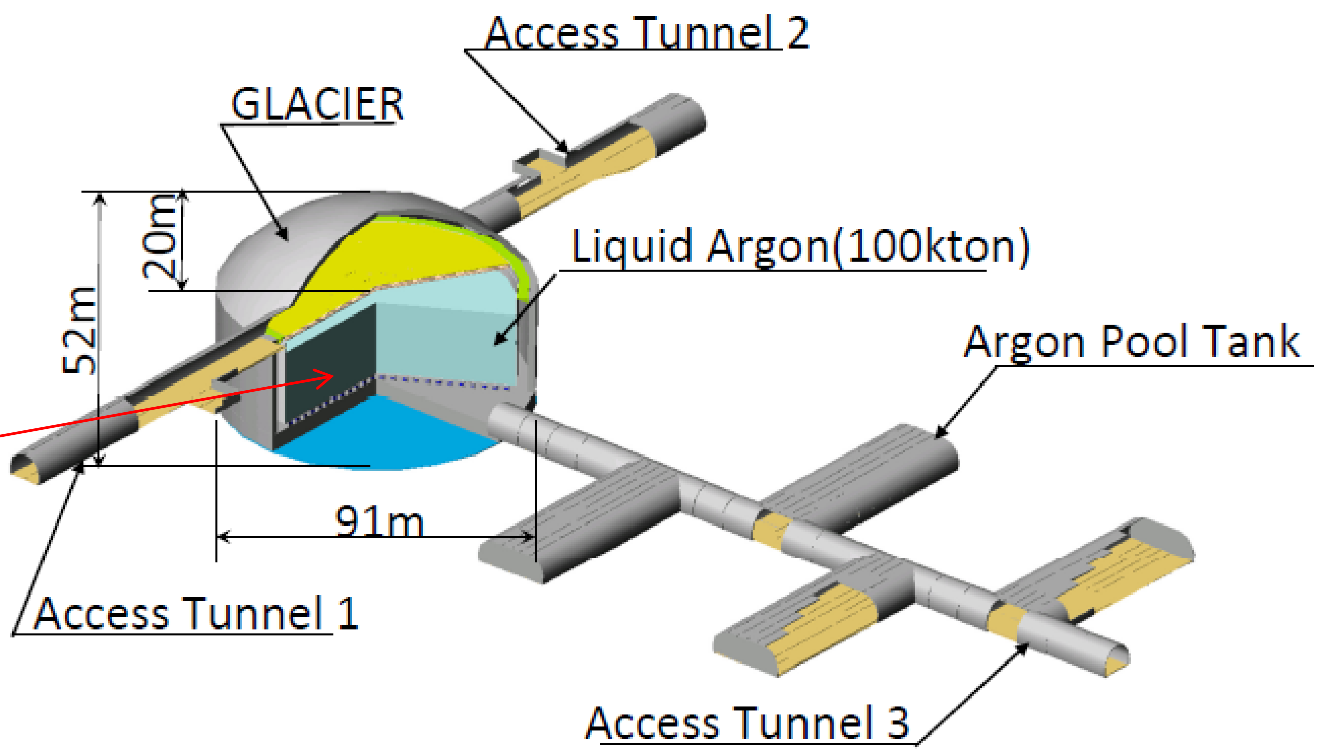
Lu is small enough to avoid the water-inflow from the dam to the cavern.

Necessary Geological Investigation in future

Method		Items identified for investigation
Geophysical prospecting	Seismic prospecting	● Elastic wave velocity of ground. ● Position, scale and velocity of slow velocity zone
	Electrical prospecting	● Specific resistance of ground and cross-sectional distribution of specific resistance
Boring Investigation (vertical and lateral)		● Stratification and distribution of sand and rock. ● Position, scale, properties, continuity of fault, fractured zone, and soft layer. ● Type of rock, weathering and alteration, properties of fracture and joint. ● Possibility of groundwater, pressure and amount of water-inflow
Borehole test, logging	Standard penetration	● Examination of stability around portal, and places where overburden is small. ● To grasp depth of rock and bearing layer.
	Borehole load test	● Deformation coefficient , elastic coefficient , etc
Laboratory test		● Physical and mechanical characteristics of constituting rock : unit weight , elastic wave velocity , compressive strength , etc. ● Mineral characteristics of constituting rock : clay mineral content , slaking characteristic , etc. ● Physical and mechanical characteristics of constituting soil : Particle size distribution , water content , compressive strength , consistency , etc.

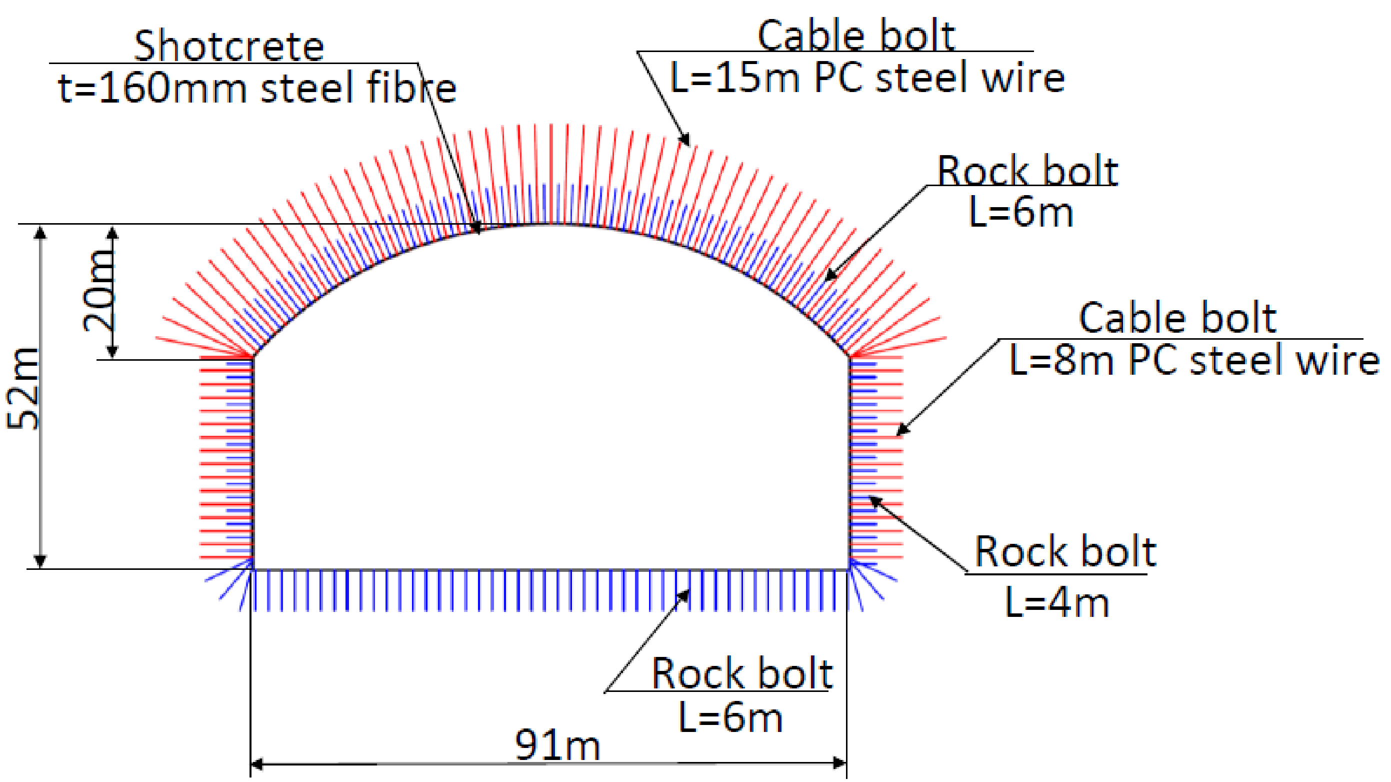
4. Conceptual design of the facility

1. GLACIER: Main Liquid Argon Cavern
2. Three access tunnels
3. Four Argon pool tanks

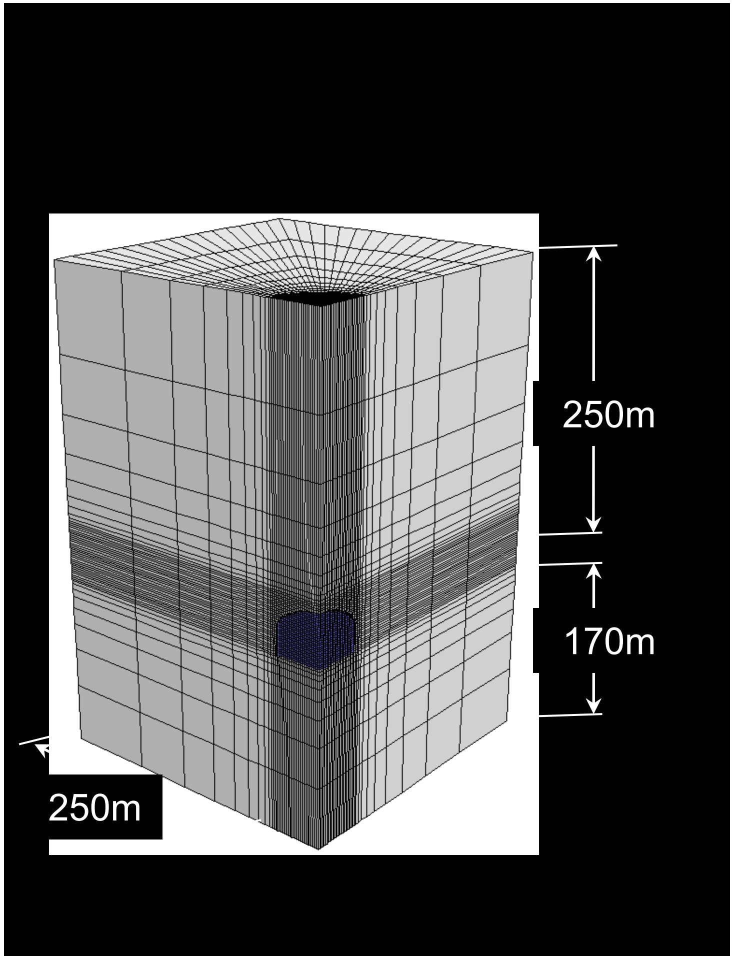


Liq. Ar tank will be isolated from the cavern wall

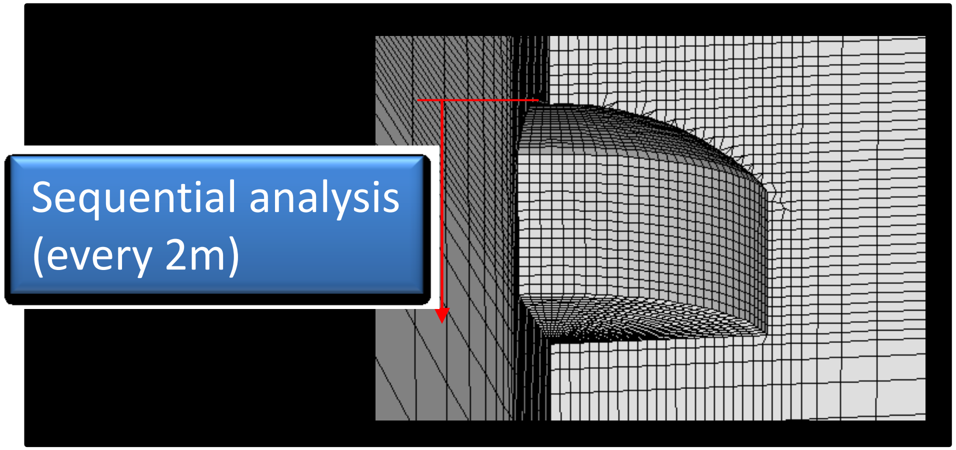
- Rock bolt
  - Floor L=6m
  - Wall L=4m
  - Dome L=6m
- Cable bolt
  - Wall L=8m
  - Dome L=15m
- Shot-crete (t=160mm=80+80mm) with steel fiber



Deformation analysis result using FLAC3D code



Analysis model for FLAC3D



A sequential analysis
(2m digging and install support)

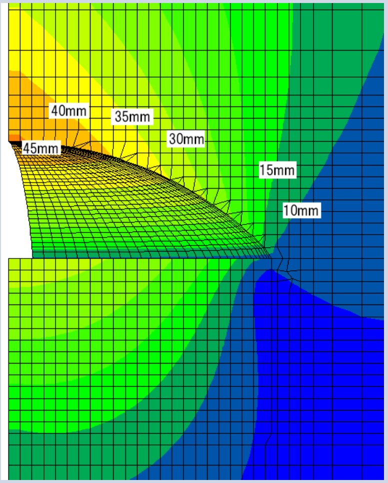
Input properties of ground

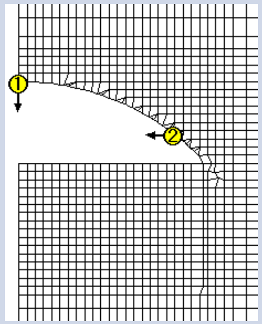
Unit weight (γ) kN/m³	Elastic coefficient (E)MPa	Poisson ratio	Cohesive strength (c)MPa	Friction angle (φ)°
24.3	7,900	0.3	20	36

Result (1)

Distribution of the displacement
① settlement, ② horizontal displacement

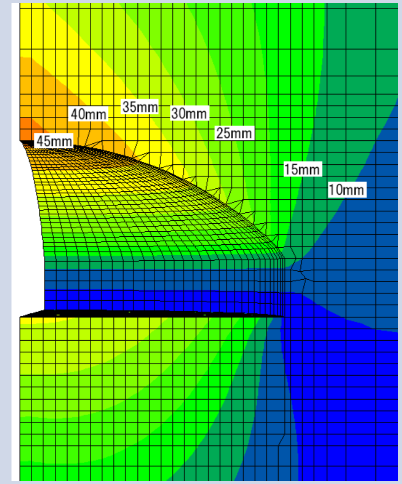
Time of the digging to 20m

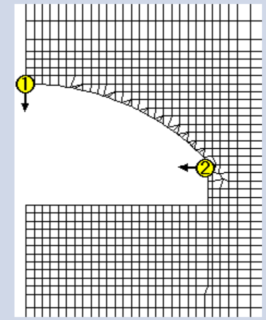




① 45.4mm
② 3.5 mm

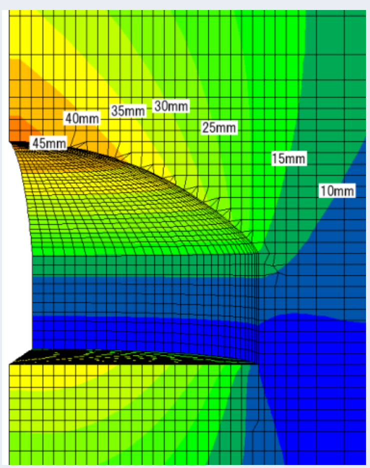
Time of the digging to 30m

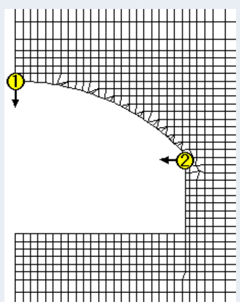




① 46.6mm
② 0.7 mm

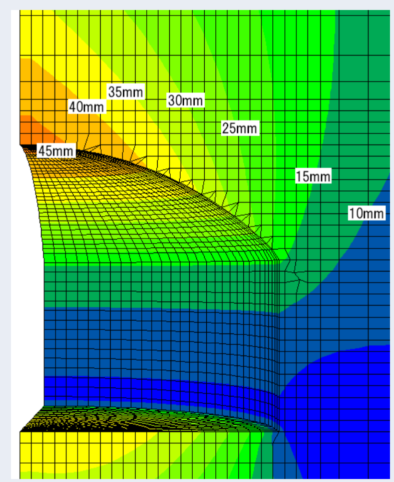
Time of the digging to 40m

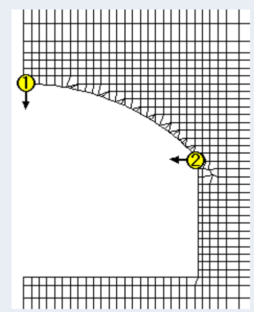




① 47.0mm
② 1.4 mm

Time of the digging to final stage



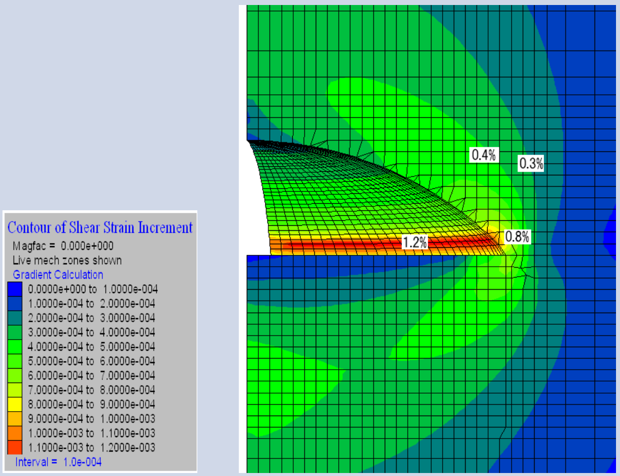


① 47.2mm
② 2.7 mm

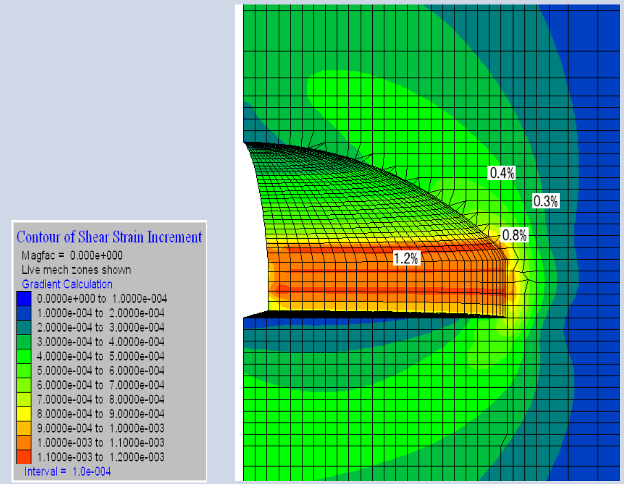
Result (2)

Shear strain distribution

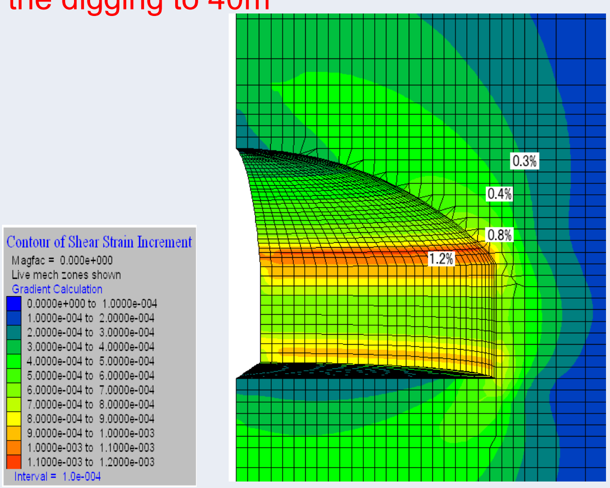
Time of the digging to 20m



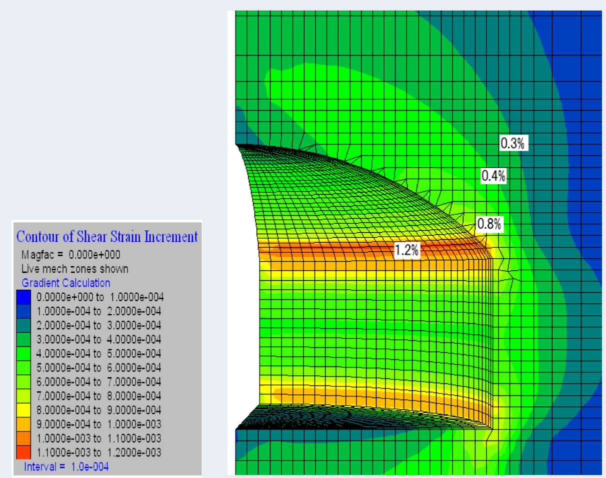
Time of the digging to 30m



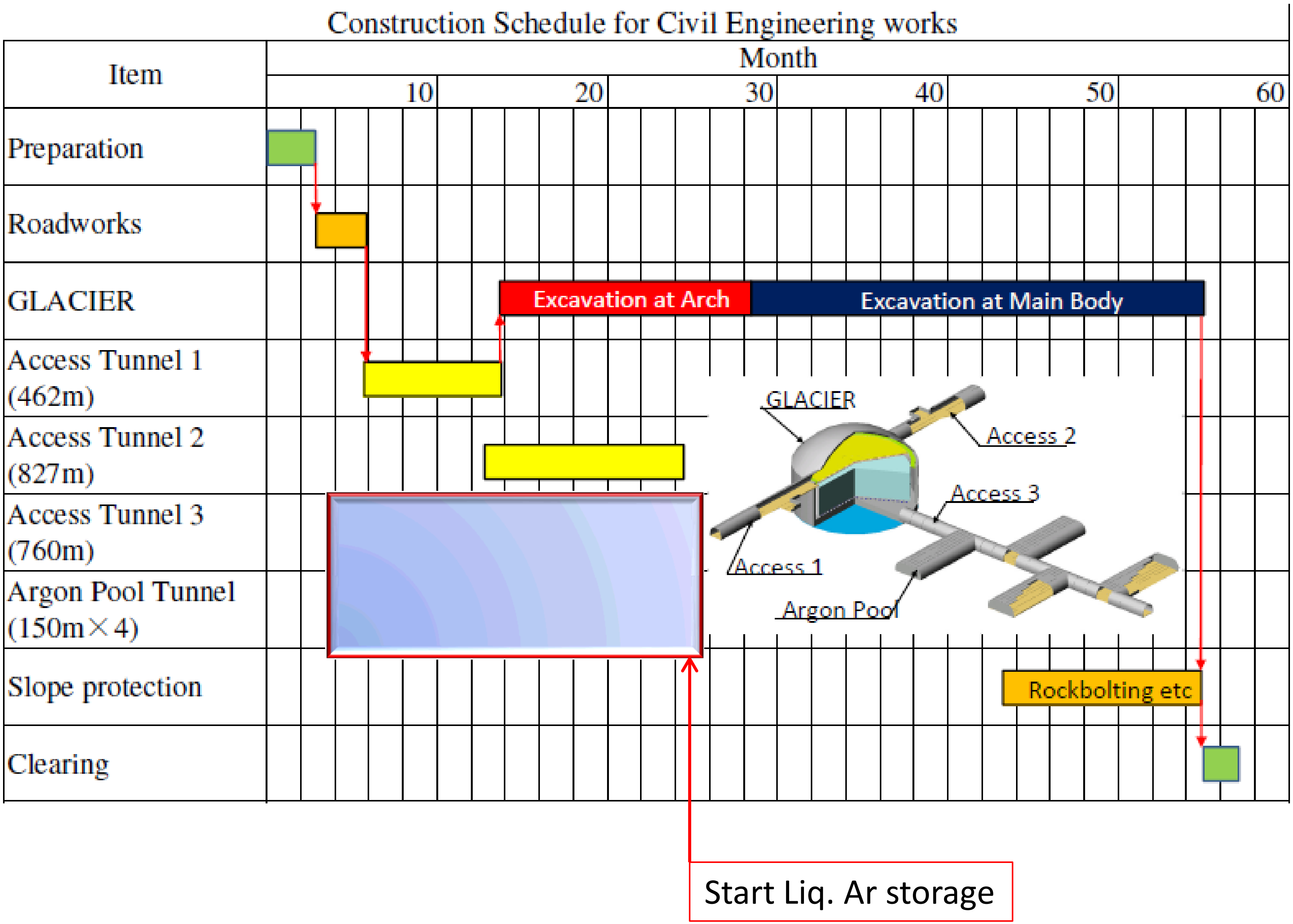
Time of the digging to 40m



Time of the digging to final stage

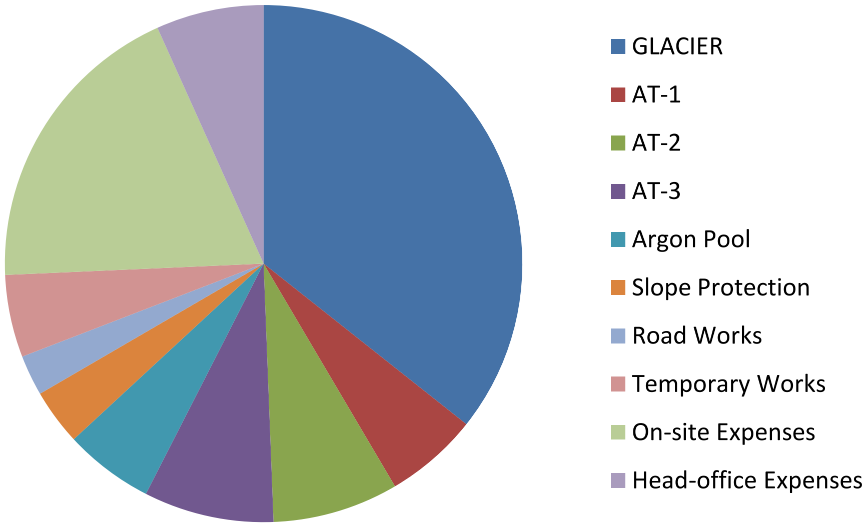


Construction Schedule



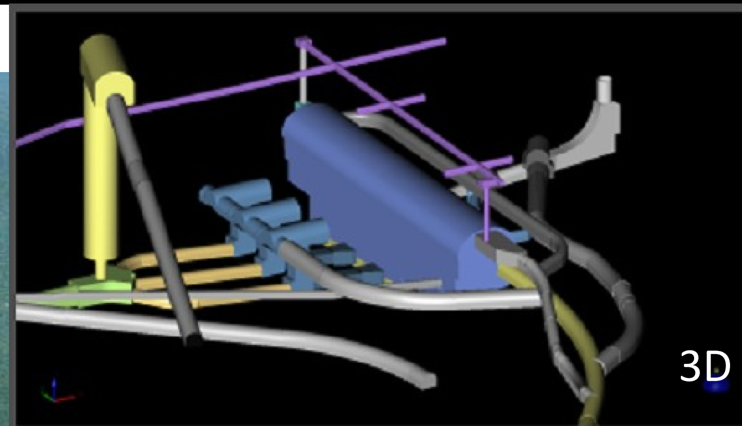
Preliminary cost study

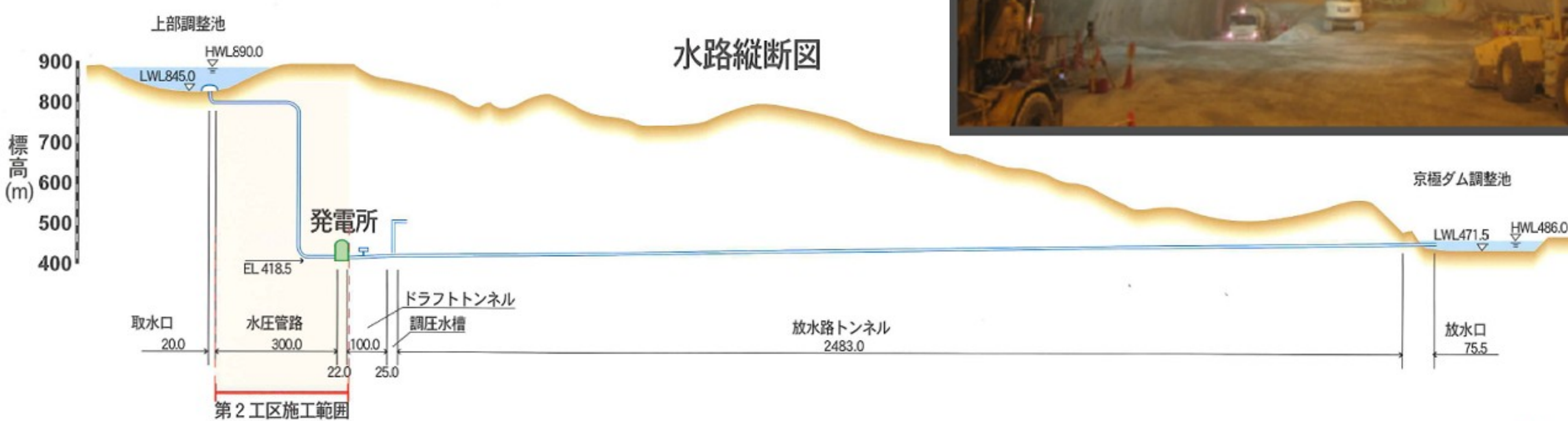
Item	Cost (M €)	Comments
GLACIER	40.8	H=52m, Φ=91m, Dome type cavern
Access Tunnel 1	6.7	462m long
Access Tunnel 2	9.0	827m long
Access Tunnel 3	9.3	760m long
Argon Pool Tunnels	6.4	50m long × 4
Slope Protection	4.0	
Road Works	2.9	Improvement
Temporary Works	5.9	
On-site Expenses	21.7	
Head-office Expenses	7.7	
Total	114.4	



1 € = 116 Yen

An example of of large-scale cavern construction in Japan for pumped-up hydroelectric power plant station (in Hokkaido) (Courtesy of K. Ryoke and M. Nago, Taisei Corporation)





Cavern excavation procedure

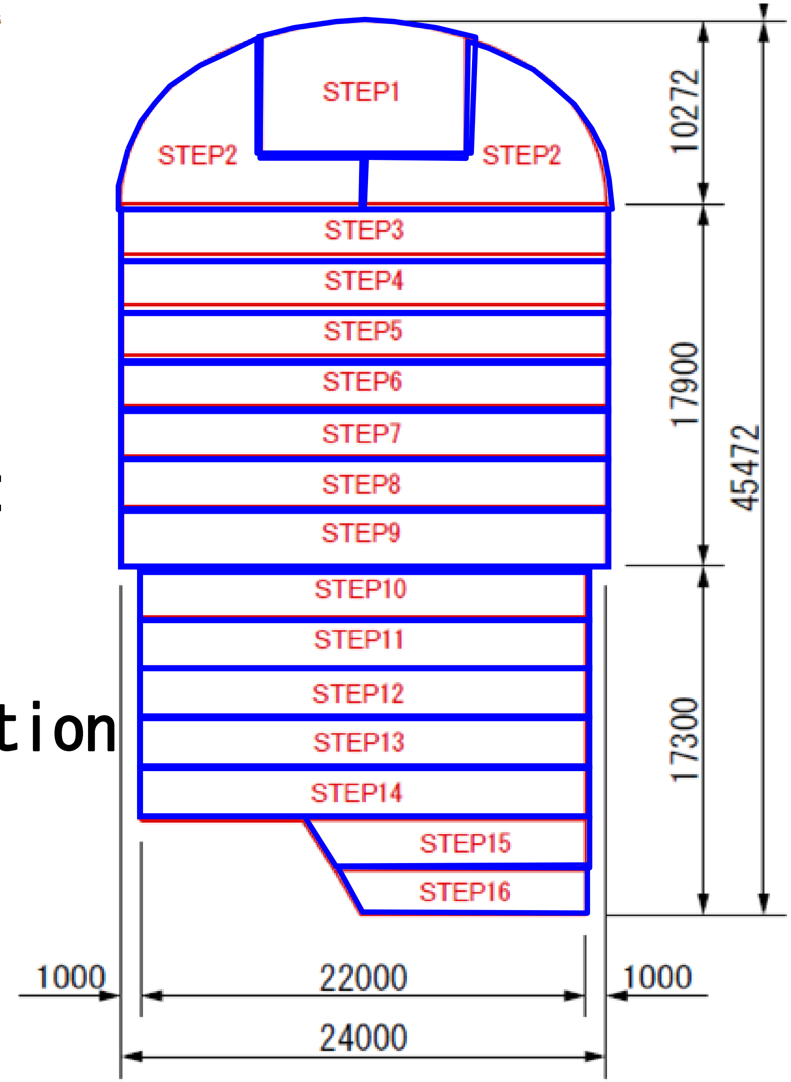
STEP1 Top excavation

↓

STEP2 Arch-part excavati

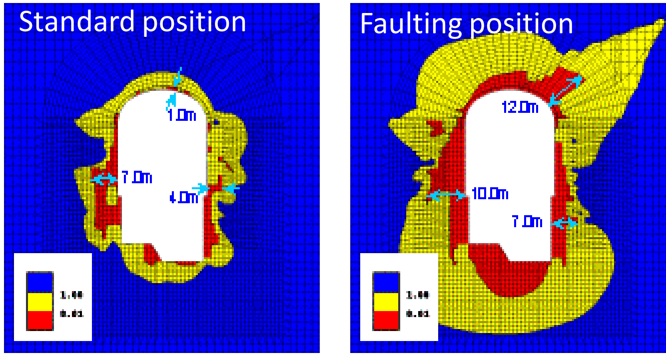
↓

STEP3～ bench-part excavation



K. Ryoke and M. Nago, Taisei Corporation

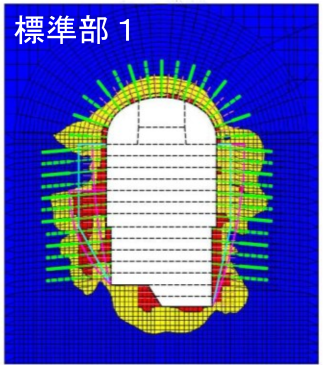
Design and forecast analysis based on not only preliminary survey but also new (real time) information through real excavation works

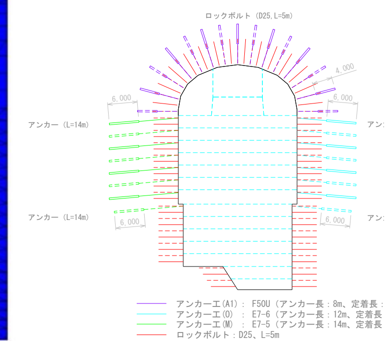


Distribution of loose area

Identify falling rock

Estimate necessary anchor

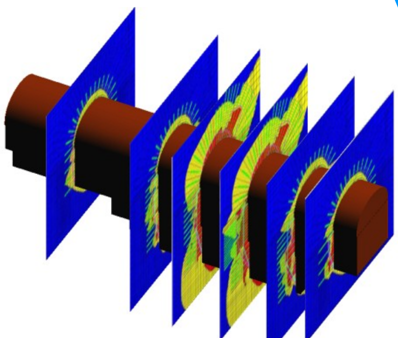




Estimate axial force increment due to displacement

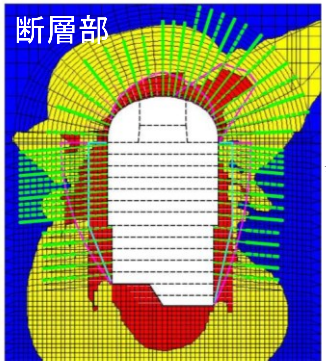
Design of necessary anchor

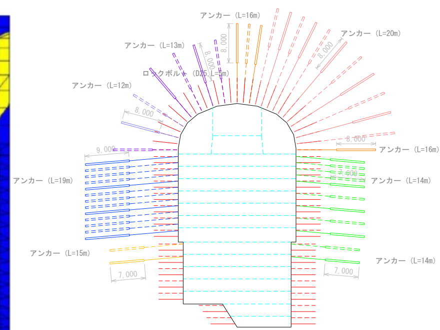
Estimate displacement after anchor setting



Decision of anchor spec.

Type of anchor bolt, length, Pattern, etc.





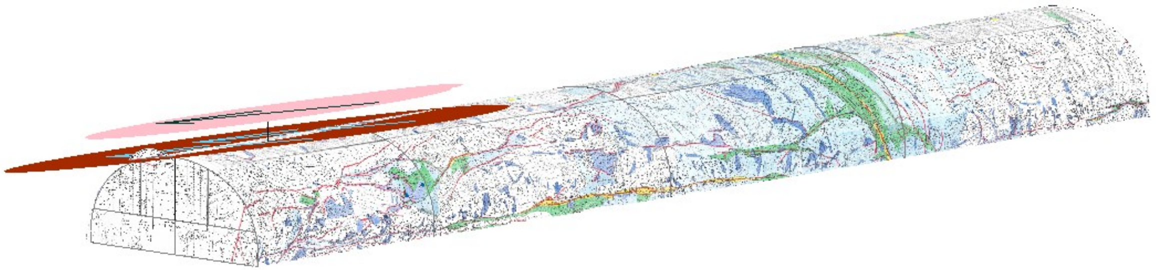
Analyze cavern stability

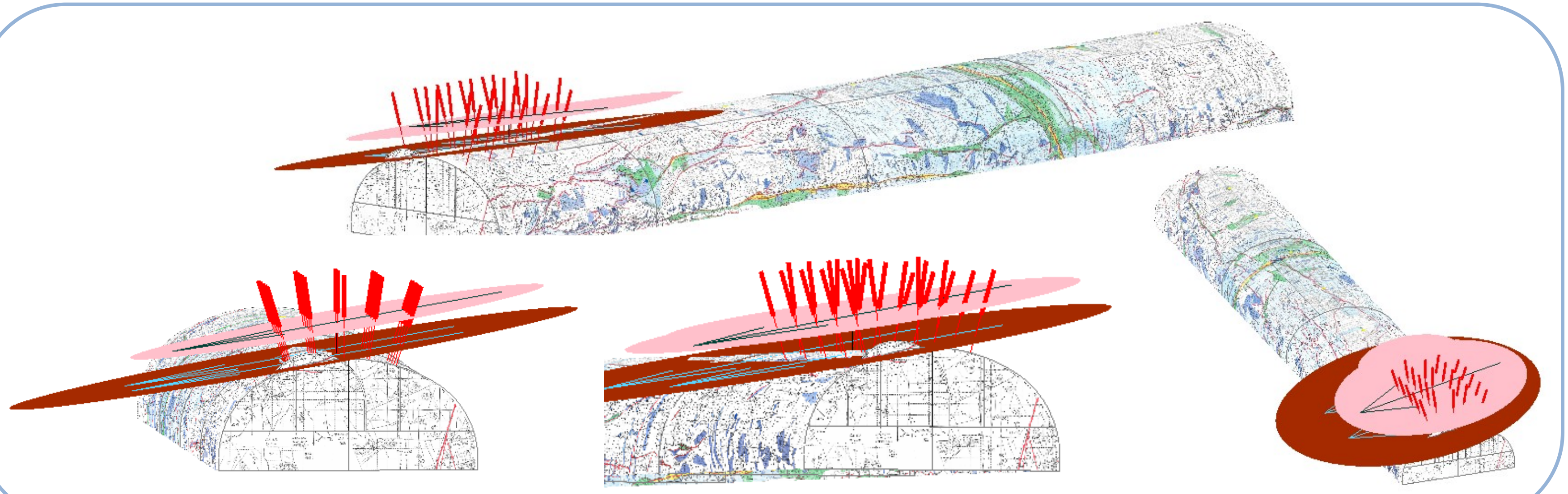
Decide the spec. of rock bolt

K. Ryoke and M. Nago, Taisei Corporation

Decision of the optimum action when the problem: real time analysis and discussions are carried out

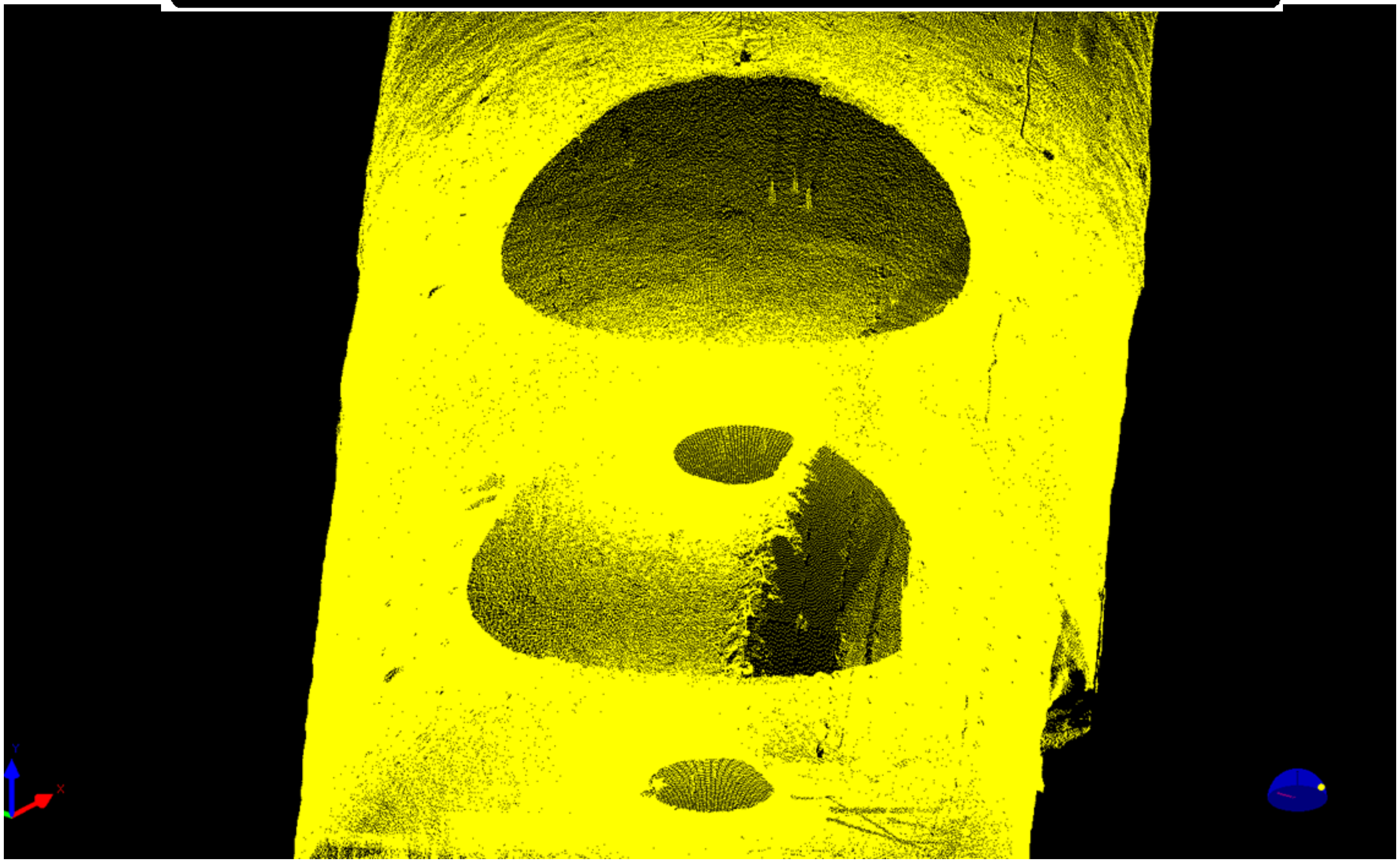
Planning Verification Instructions





K. Ryoke and M. Nago, Taisei Corporation

- 3D laser scan method can be used for the real time monitoring of cavern deformation during excavation.
- Cavern wall itself is the reflector of laser light.
- No special optical reflector is required.
- Personal computer-based analysis
- Very simple and effective



K. Ryoke and M. Nago, Taisei Corporation

5. Procurement of 100k-ton Liq. Ar (in 5 years)

We have studied following 3 cases, and gotten a final solution

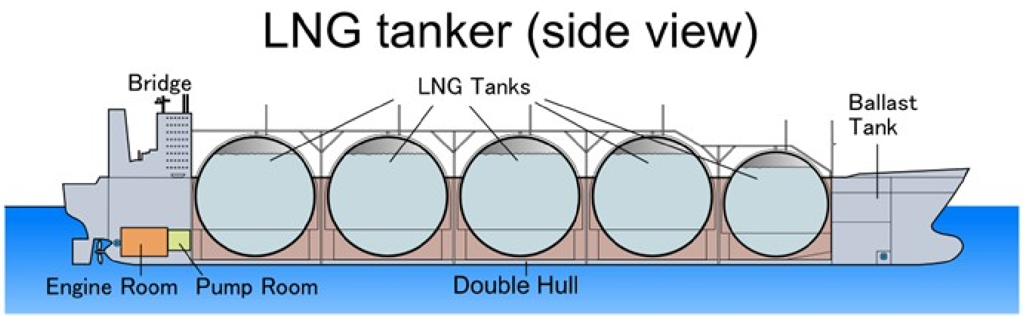
1. Construct an on-site production plant
2. Use an LNG carrier
3. Use regular commercial ferry transport

1. On-site plant
   - The cost for the initial construction would be very expensive.
   - Enough electricity for its operation would not be available in Okinoshima.

Courtesy of Osaka Gas Co. Ltd. (S. Yoshioka, H. Terai)

2. Use an LNG carrier

- We would have to solve the technical and legal problems in converting an LNG carrier to Liq. Ar.
- The cost of hiring such a ship for 5 years would be expensive.



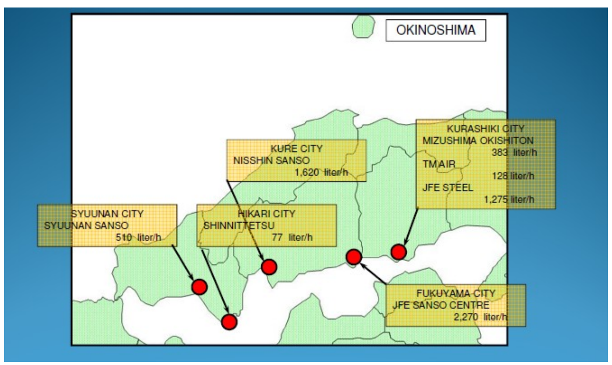
3. Use regular commercial ferry transport

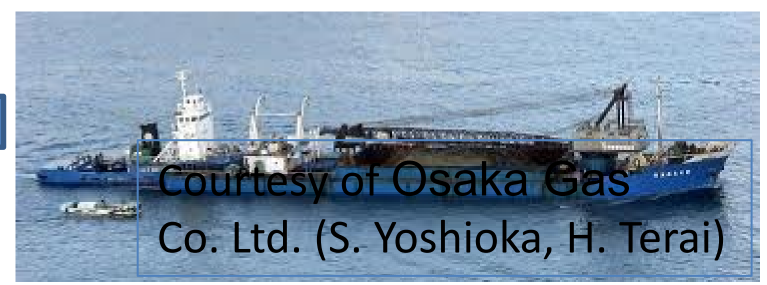
- Currently they are not legally allowed to carry tanker trucks.

Courtesy of Osaka Gas Co. Ltd. (S. Yoshioka, H. Terai)

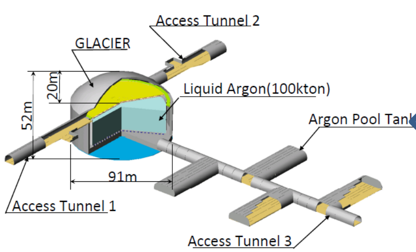
Final solution

- Buy Liq. Ar from several large-scale manufacturing plants having large production capacities. Many such plants are located in Japan and we would contract to buy 10~15 % of their annual production capacity.
- Hire 4 tanker trucks dedicated for the Liq. Ar ground transportation, both in Honshu and Okinoshima for 5 years.
- Hire 1 barge dedicated for the marine transportation between Honshu and Okinoshima for 5 years.





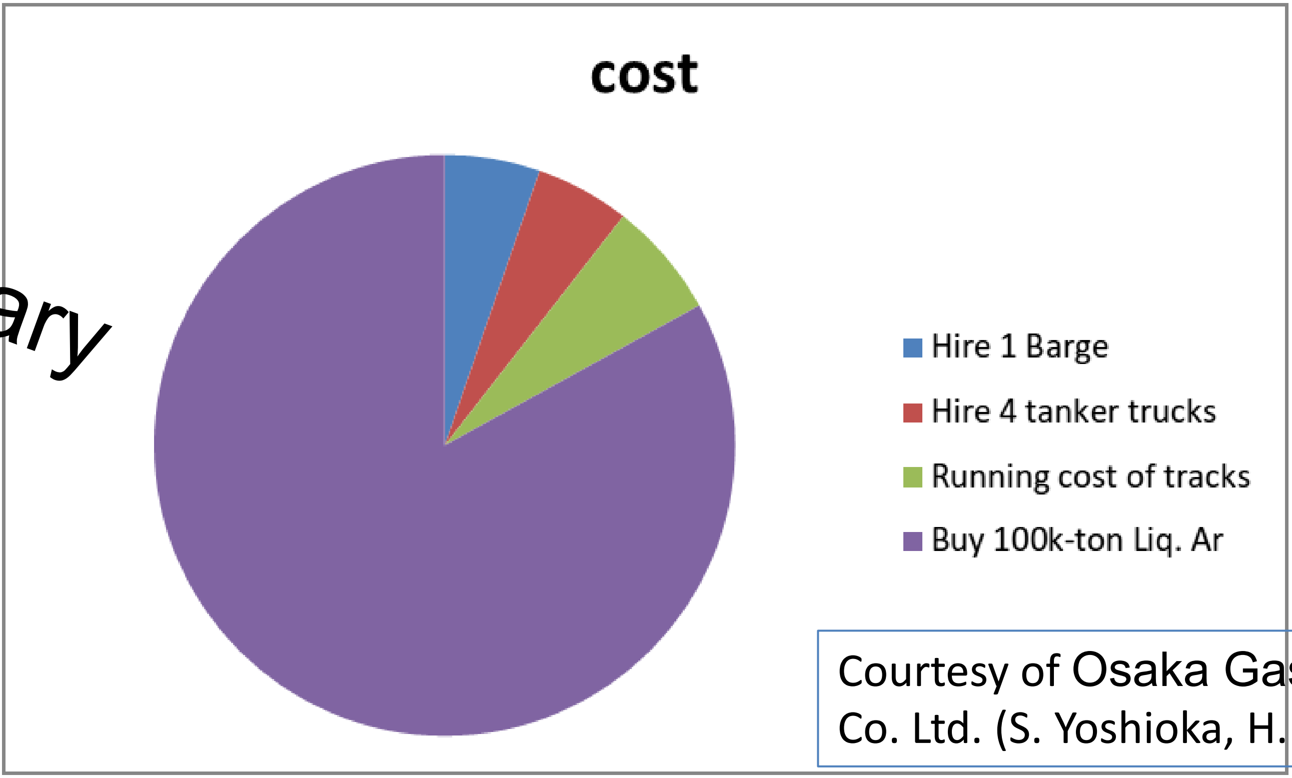
Courtesy of Osaka Gas Co. Ltd. (S. Yoshioka, H. Terai)



Item	Cost (M €)
Hire 1 Barge	4.18
Hire 4 tanker tracks	4.14
Running cost of tracks	5.09
Buy 100k-ton Liq. Ar	65.48
Total cost	78.90

1 € = 116 Yen

preliminary



Courtesy of Osaka Gas Co. Ltd. (S. Yoshioka, H. Terai)

Summary

- Location
  - Good coverage of 1st and 2nd oscillation peaks
  - Ideal for Liq. Ar TPC
- Geology
  - Nice Oki-gneiss for large-scale cavern excavation
- Geography and Infrastructures
  - Enough earth covering
  - Good approach (public road, harbor, air-port, etc.)
- Civil engineering
  - 5 years
  - 114.4 M €
  - No essential technical problem
- Procurement of 100 k ton Liquid Argon
  - 5 years
  - 78.9 M €
  - No essential technical problem

Future tasks (Engineering)

- Liq. Ar vessel and its system
- More detailed cavern design
- Geological survey