
Progress of Geological investigation in Japanese Candidate sites

Preliminary Report on Study Results

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KEK Linear Collider Project Office

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Introduction

Background

- This report is based mainly on the research contract between KEK and **Tohoku University, Kyushu University**.
- Because the survey analysis has not yet been completed in both site, this report is an intermediate breaking.

Considerations about comparison between the two candidate sites

- Now, evaluation work is just going to be done about the two candidate sites in Japan.
- Therefore, we report only the **technical results** of the geological investigation in this stage.

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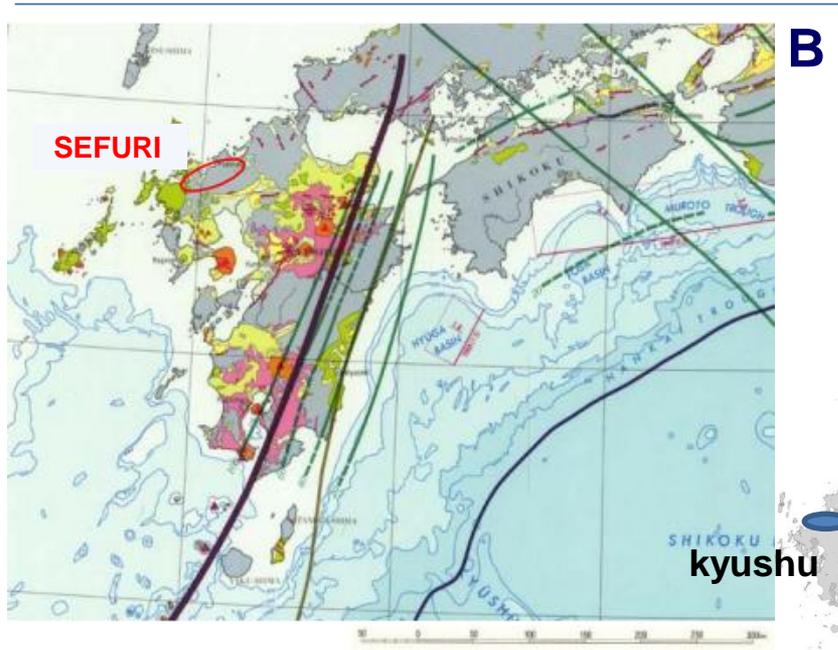
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I . Outline of the Geological Investigation

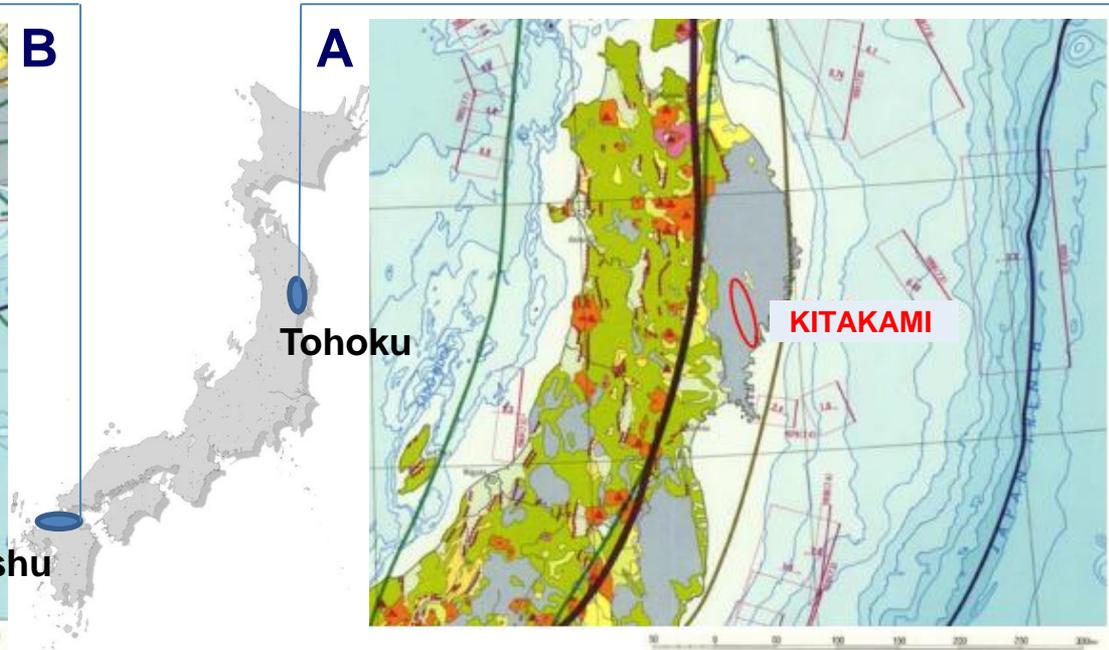
□ Two Candidate Sites in Japan

SEFURI-Site



- Belong to FUKUOKA & SAGA Prefecture in KYUSHU District
- **Kyushu University**
- Saga University

KITAKAMI-Site



- Belong to IWATE & MIYAGI Prefecture in TOHOKU District
- **Tohoku University**
- Iwate University

□ Outline of Investigations

Basic Policy in this Investigation Plan

1. Confirmation of the Geological Feature Constitution

- Distribution of the **Stable bedrock zone** for 50 km Length
- Natural Ground Condition, Bedrock constitution, Weathering Layer, Intrusive Rocks, etc.

2. Confirmation of the Bedrock Property

- Grasp of **Bedrock Property and Strength** in preparation for ILC underground facilities design in near future

3. Confirmation of the Dislocation Zone

- Extraction of **dislocation zone** becoming the serious trouble in the construction of ILC underground structures

□ Common Investigation contents in both sites

Item	Investigation outline
<p>Lineament Survey</p> <ul style="list-style-type: none"> - Aerial photography interpretation - Field survey 	<p>Judging the topography & geological feature using the information in the aerial photograph</p> <ul style="list-style-type: none"> - The extraction of the lineament - Confirmation of the dislocation (fault)
<p>Geophysical Exploration</p>	<p>Grasp of the bedrock constitution and properties by measuring the physical phenomenon such as elastic wave generated artificially</p> <ul style="list-style-type: none"> - Elastic wave exploration (Seismic) - Electromagnetic wave exploration - Electric exploration
<p>Boring Investigation</p>	<p>Grasp of various geological information directly by drilling the bore hole in the place to check</p> <ul style="list-style-type: none"> - Density and hardness of the bedrock - Initial rock pressure in natural ground state - Frequency of a crack, water permeability, etc.

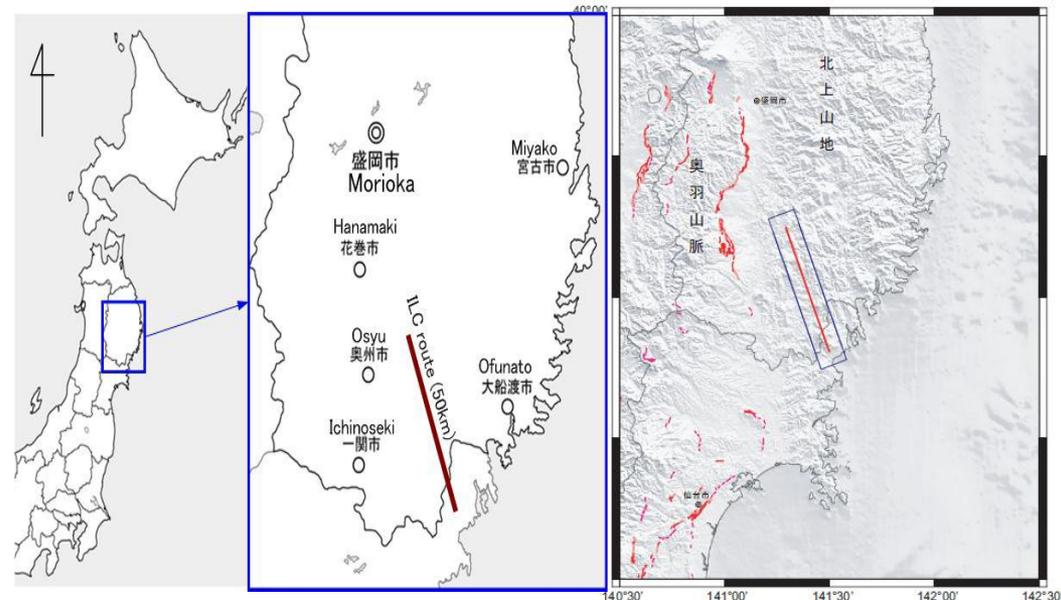
II. Overview of the Investigation results in KITAKAMI site

□ Main Contents of Field Investigation

Item	Quantity	Remarks
Lineament survey	104km ²	Detailed mapping by Aviation Laser survey Field investigation
Geophysical Exploration	14 km	Seismic exploration, Electric survey Electromagnetic exploration
Bedrock Boring	2 point	Drilling depth 300m, Various examinations

Main content of field survey

- Aviation Laser Survey:
Making the detailed topographical map for Lineament survey.
- Field survey to confirm the surface topography and geology
- Seismic exploration in the central central region.
- Boring Survey in the vicinity of the experiment hall area.



□ Topographical mapping by aviation laser survey

Overall measurement Figure

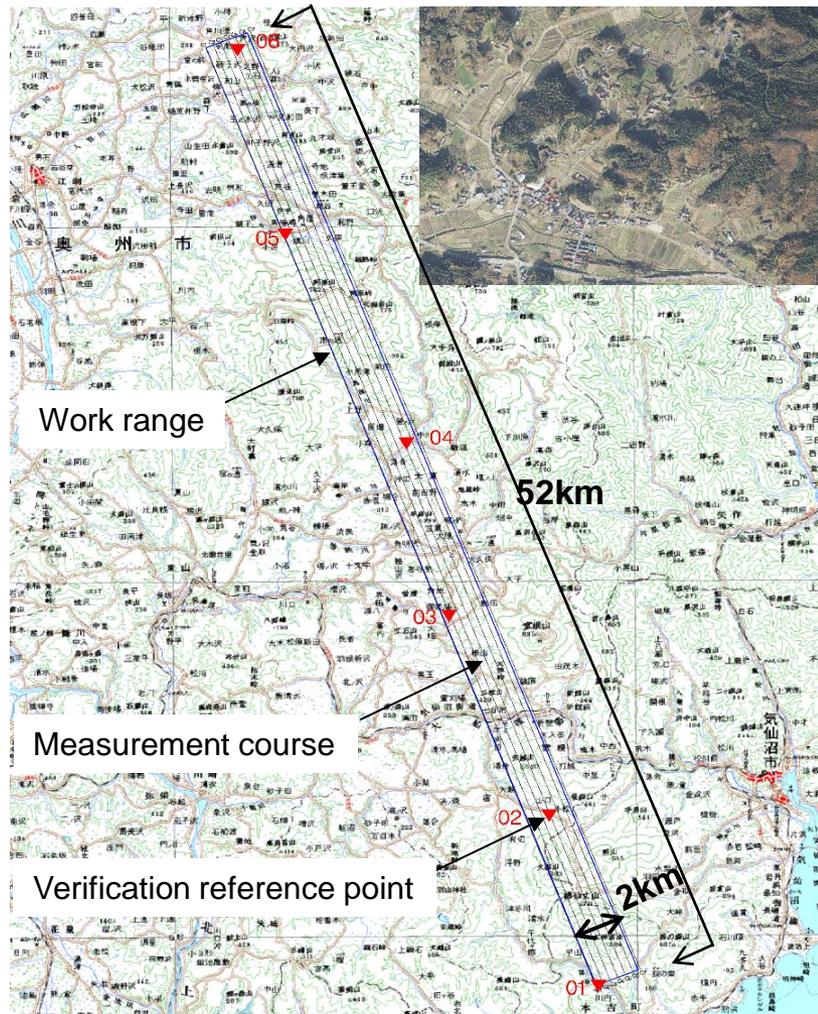
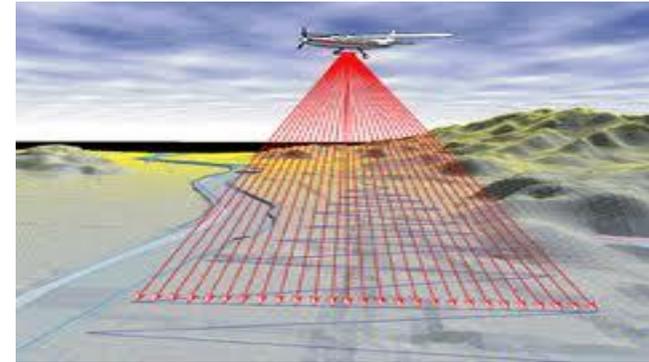
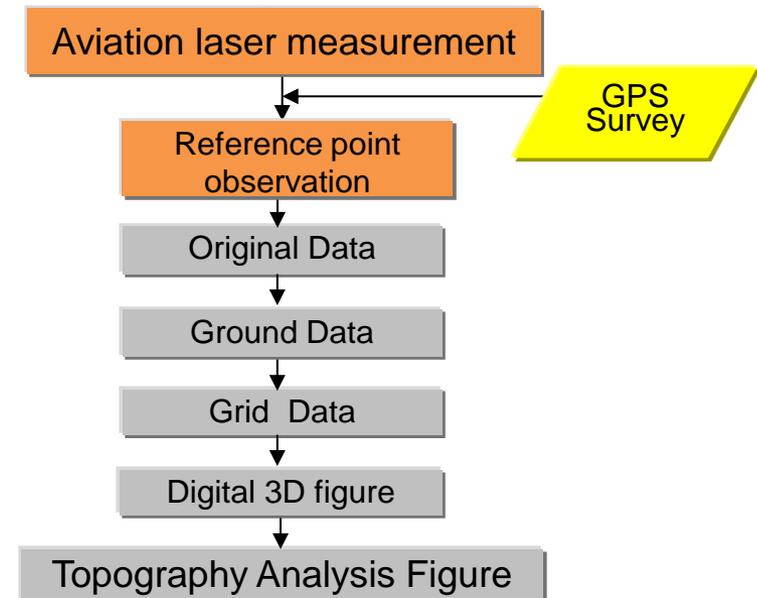


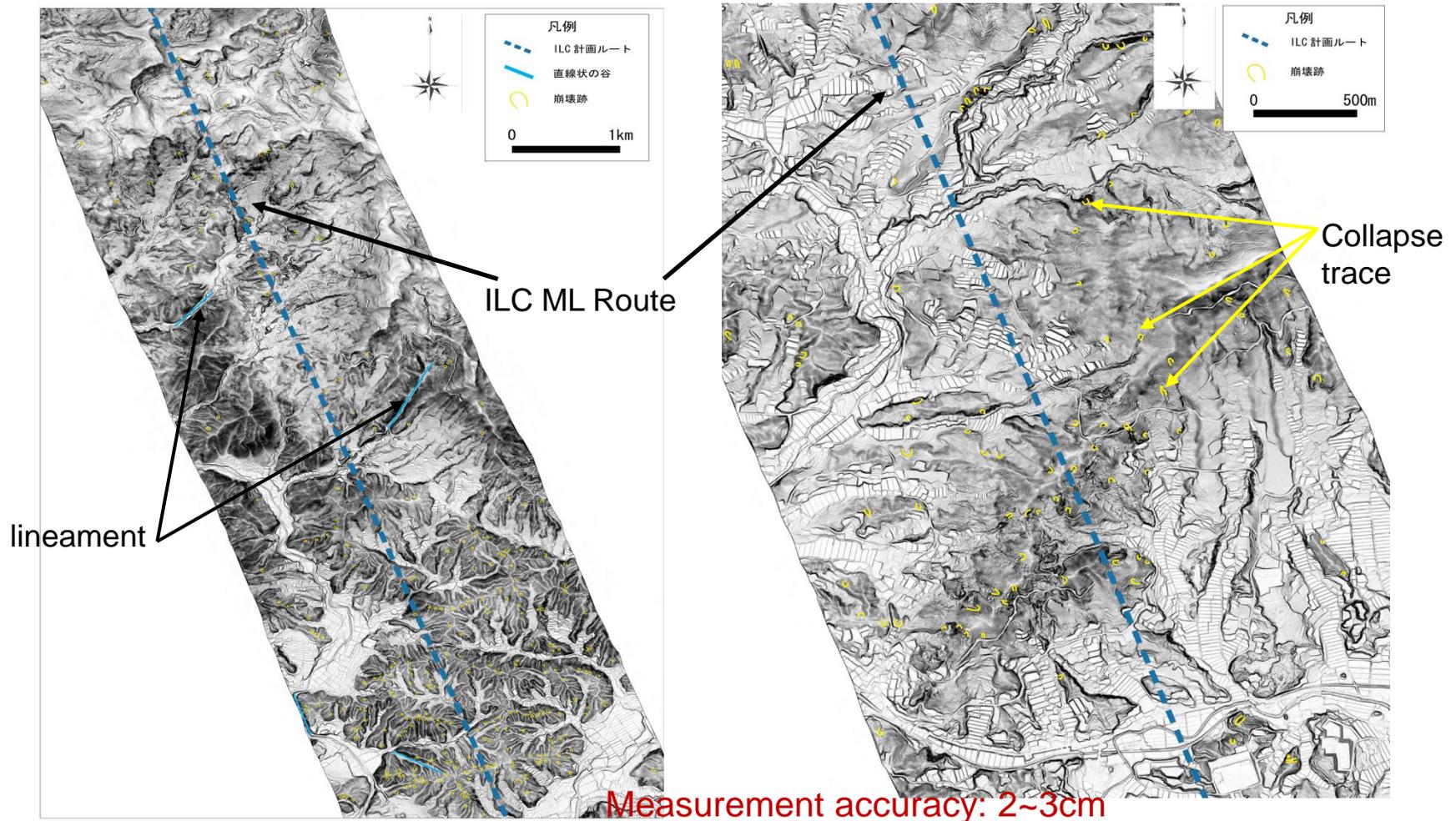
Image of laser surveying



Survey Flow



□ Topography reading using the digital map of three-dimensional grade by aviation laser survey (1)

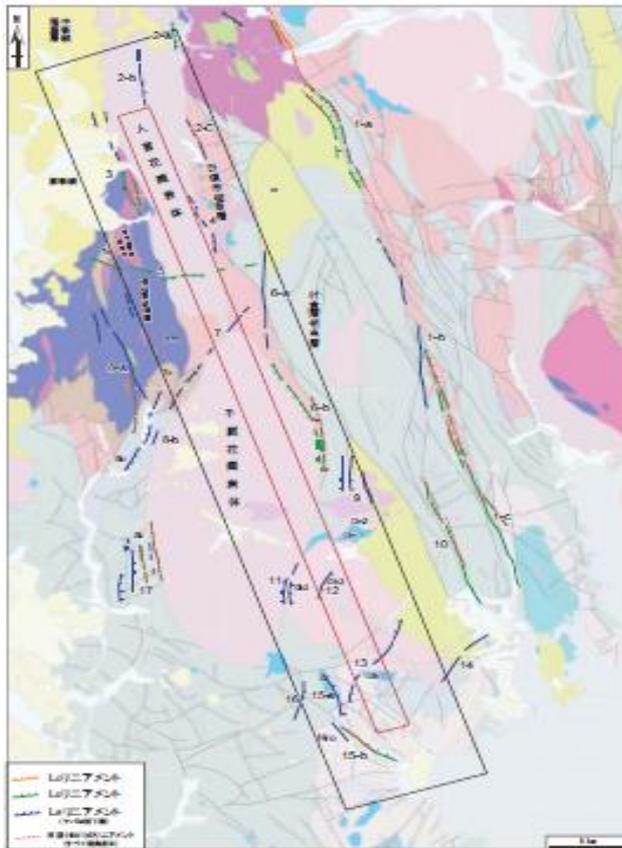


HITOKABE Granite rock mass

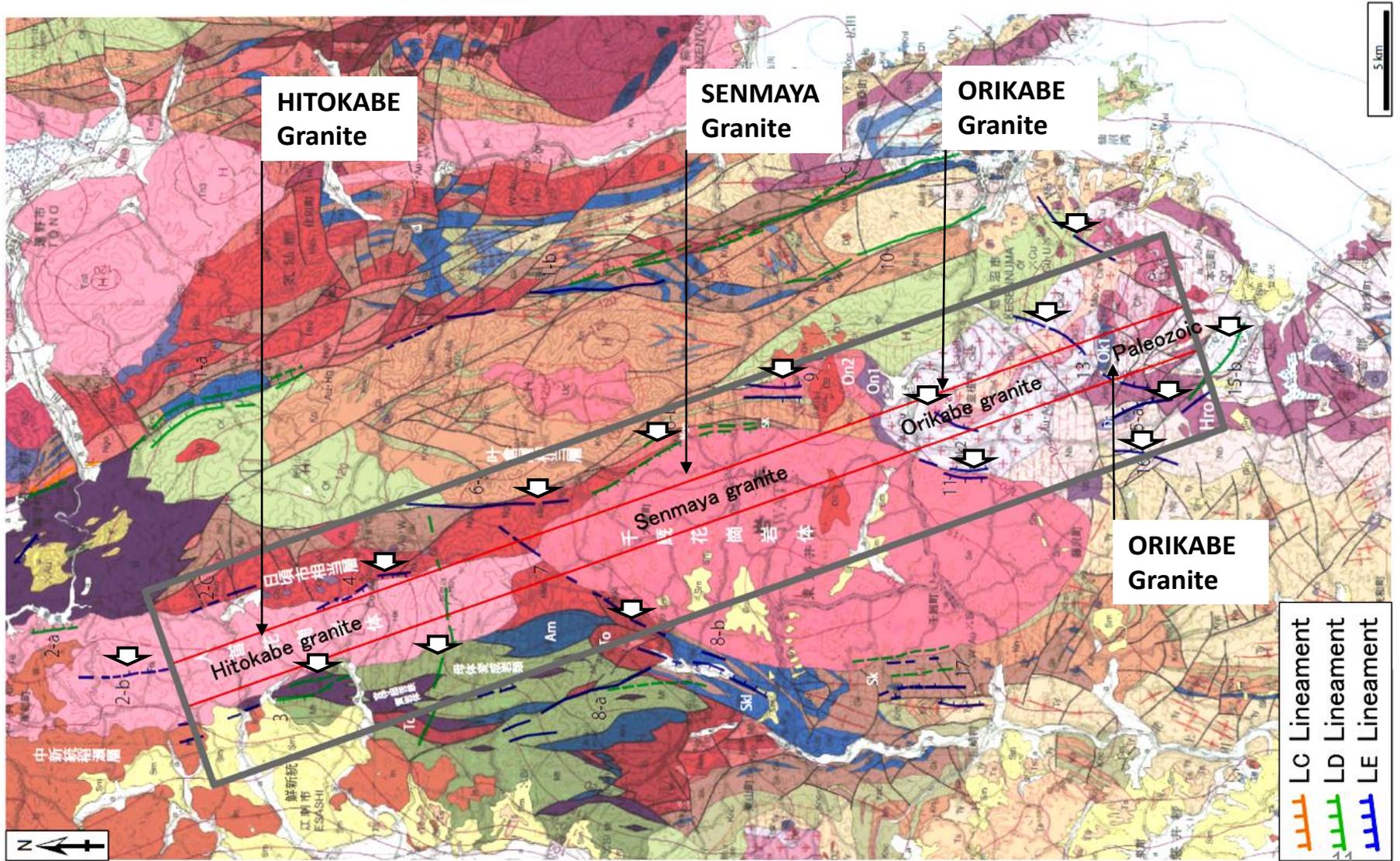
ORIKABE Granite rock mass

□ Topography reading using the digital map of three-dimensional grade by aviation laser survey (2)

- 15 lineaments was extracted in the assumption route area
- As a result of the field survey, it was confirmed not to be a lineament related to an active fault



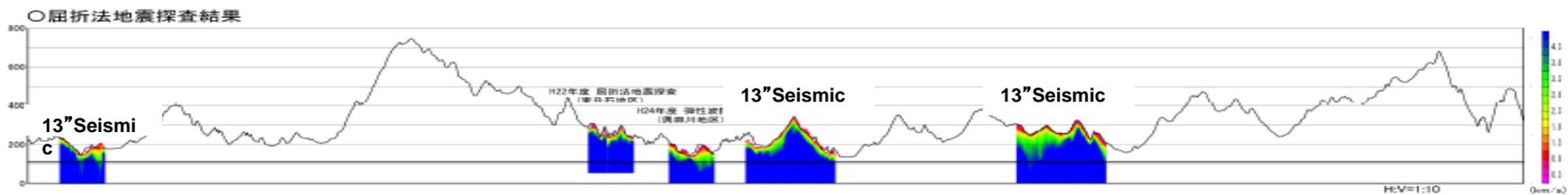
□ Lineaments with Geological Map



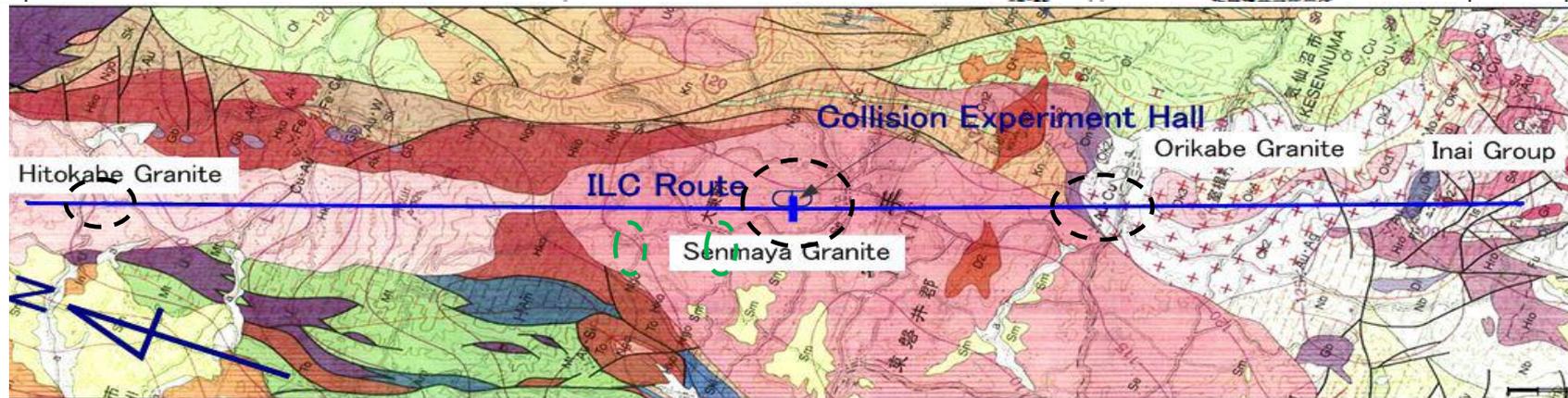
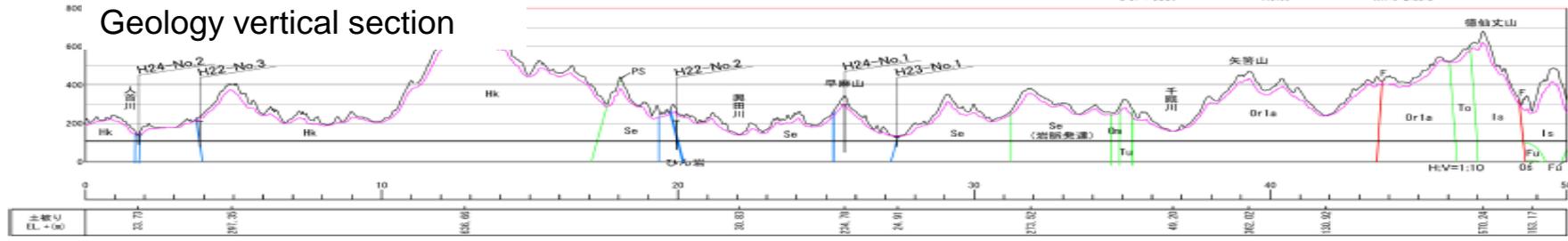
□ Seismic Exploration Survey and Boring Survey

Geological Map and Vertical Section along the ILC route of KITAKAMI

Refraction method earthquake exploration

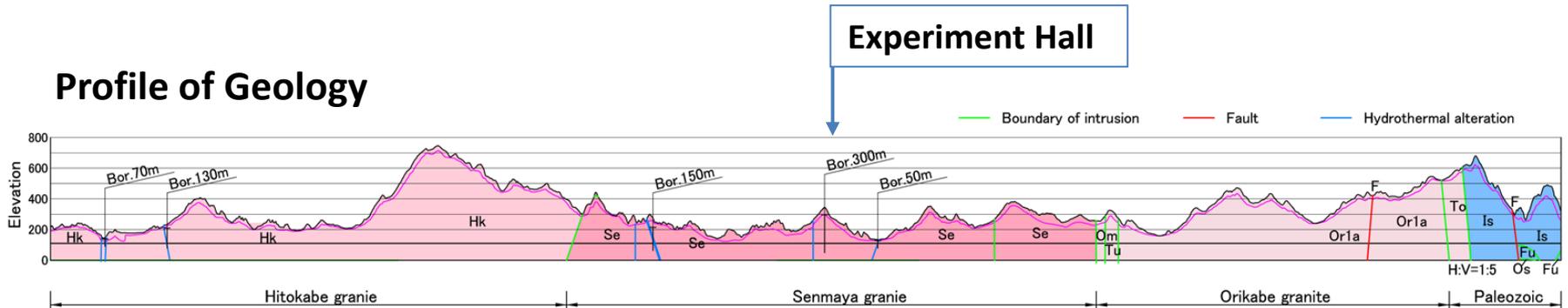


Geology vertical section

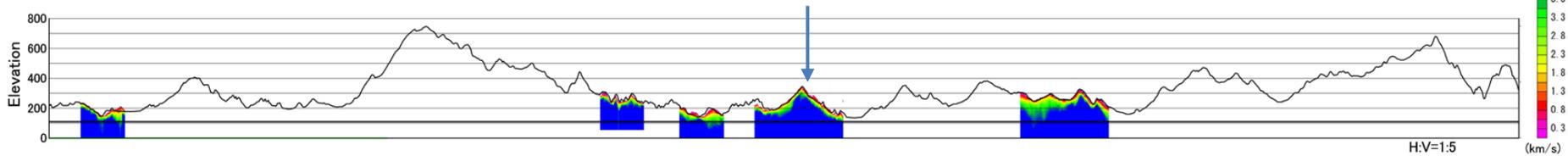


□ Profiles of Site Surveys along ILC Route

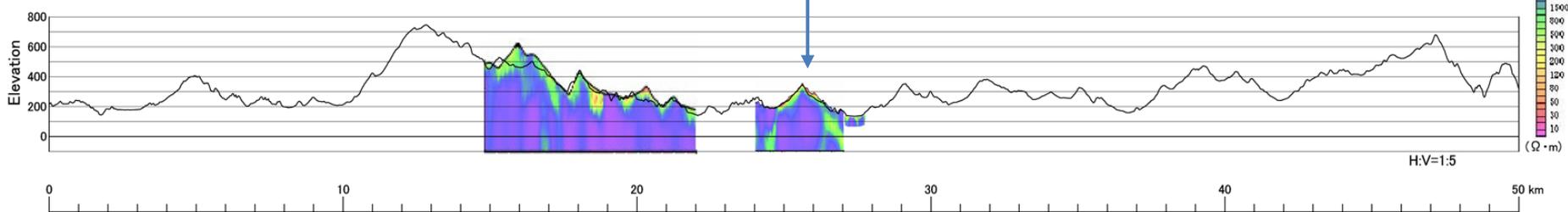
Profile of Geology



Profile of Seismic Exploration Survey

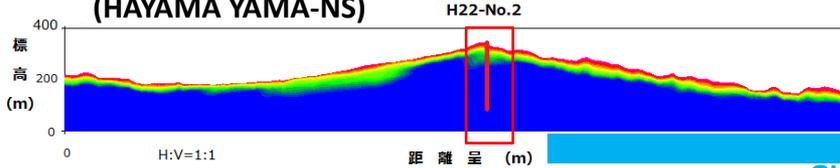


Profile of Electromagnetic Survey

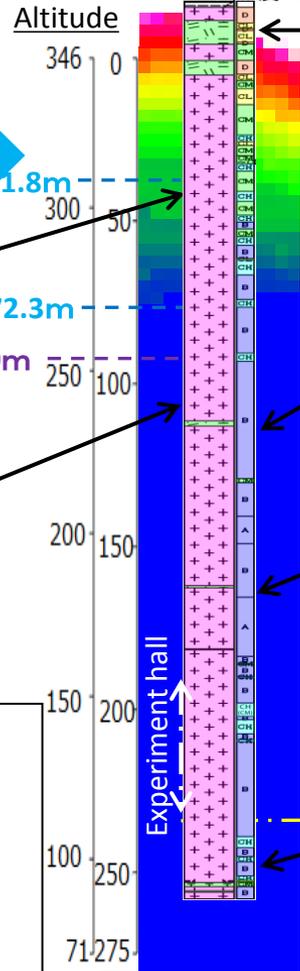


□ Correspondence of Elastic Wave Exploration and the Boring Investigation result

Seismic wave exploration analysis section (HAYAMA YAMA-NS)



Columnar section



GL-5.0~10.0m (D~CL)



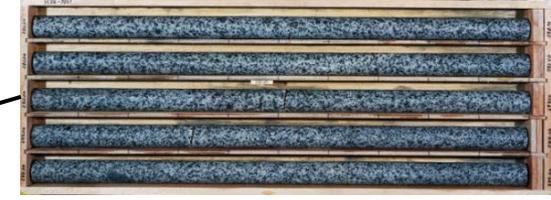
GL-115.0~120.0m (B)



GL-160.0~165.0m (A)



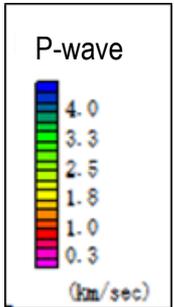
GL-240.0~245.0m (B)



GL-32.0~37.0m(class CM)



GL-100.0~105.0m(class B)



- Surface ~ -31.8m : $V_p < 2.3 \text{ km/s}$ class D ~ CL
- GL-31.8 ~ 72.3m : $2.3 < V_p < 3.0 \text{ km/s}$ class CM
- GL-72.3m ~ : $3.0 \text{ km/s} < V_p$ class B, class CH
- GL-90.0m ~ : more than 4.5 km/s

※As a result of boring investigation, Class B base rock serves as a subject below EL 72.3m, and a seismic wave exploration result also corresponds.

Legend: Columnar section

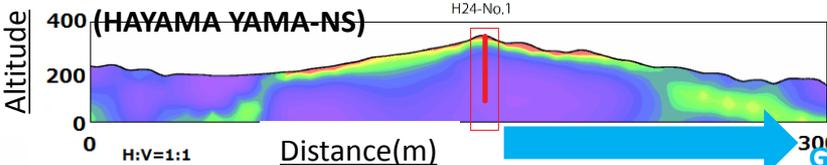
- Surface soil
- Intrusive rock
- Granite

□ Correspondence of Electromagnetic Wave Exploration and the Bowling Investigation result

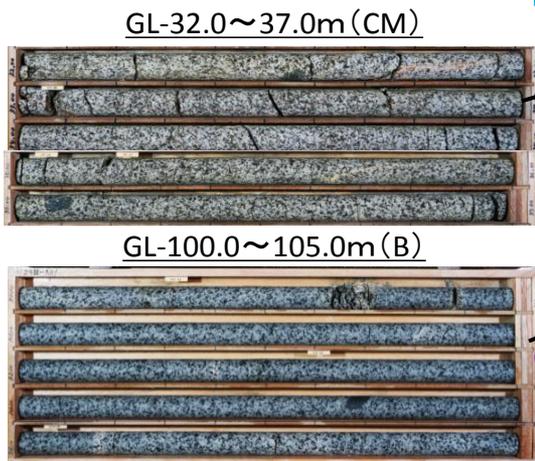
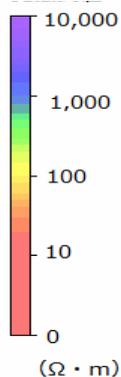
Earthquake exploration analysis section

(HAYAMA YAMA-NS)

H24-No.1

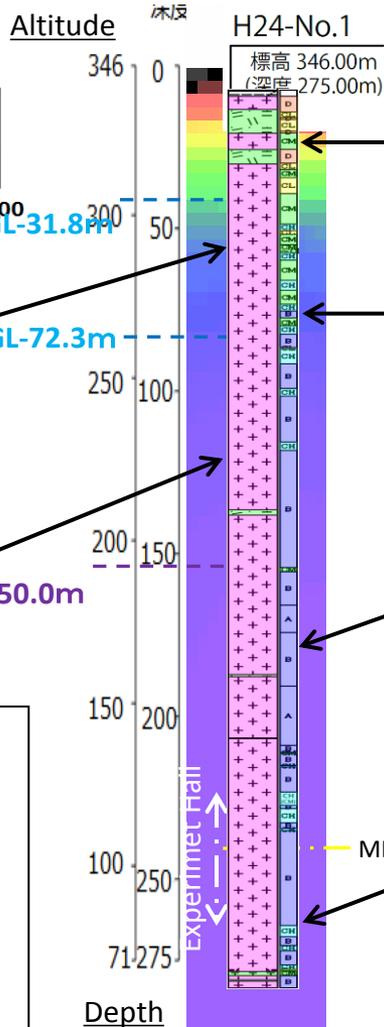


Resistivity



- Surface ~ GL-31.8m : 200~1,000Ω·m, class D~CL
- GL-31.8~72.3m : CM class Rock
U: 700~1,000Ω·m
D: 1,000~2,000Ω·m
- GL-72.3m ~ : class B (partly class CH)
2,000~5,000Ω·m
- GL-150.0m ~ : more than 5,000Ω·m

※As a result of bowling investigation, Class B base rock serves as a subject below EL 72.3m, and a seismic refraction survey result also corresponds.



GL-5.0~10.0m(class D~CL)



GL-60.0~65.0m(class CM~CH)



GL-160.0~165.0m(class A)



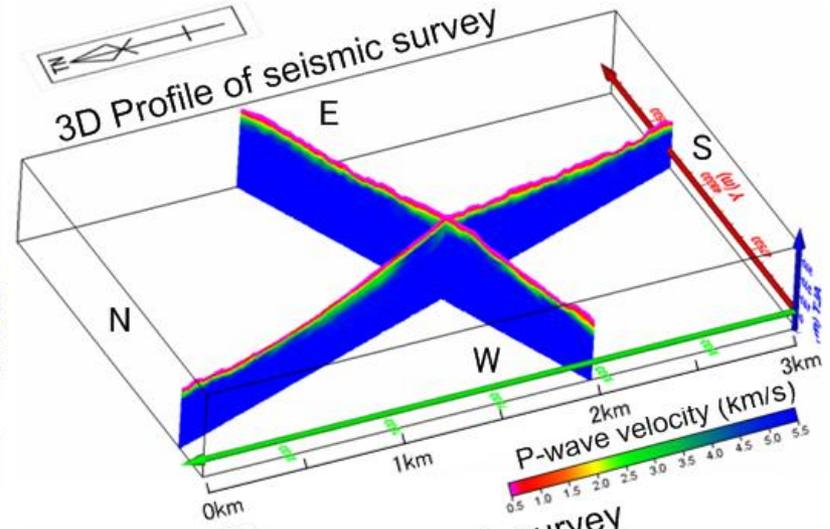
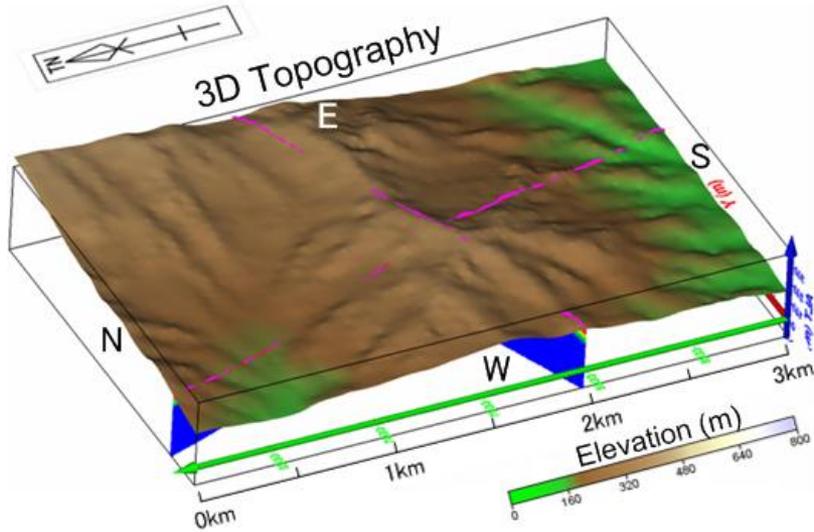
GL-240.0~245.0m(class B)



Legend: Columnar section

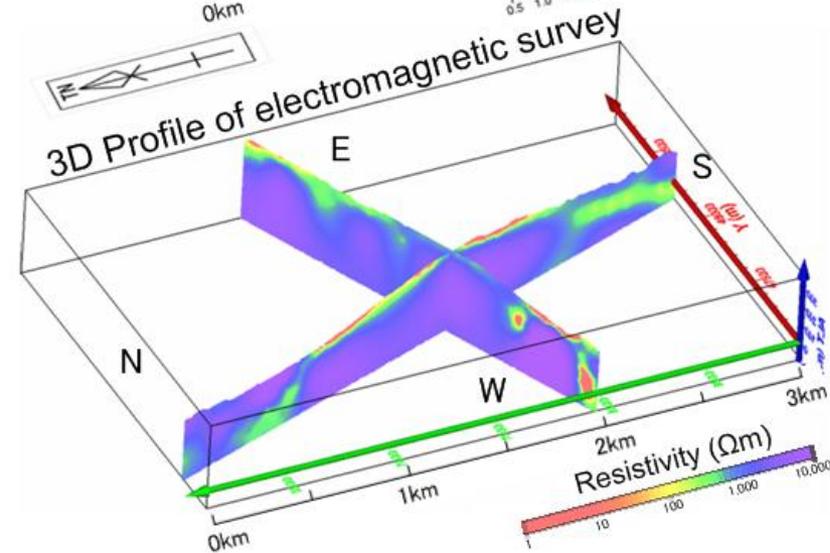
- Surface soil
- Intrusive rock
- Granite

□ 3D Profiles of Site Surveys at Central Region



Bedrock Classification

Classification	Elastic wave speed (km/s)	Deformation Modulus (MN/m ²)
A ~ B	> 3.7	> 5000
CH	3.0 ~ 3.7	2,000 ~ 5000
CM	1.5 ~ 3.0	500 ~ 2,000
CL	< 1.5	< 500
D		

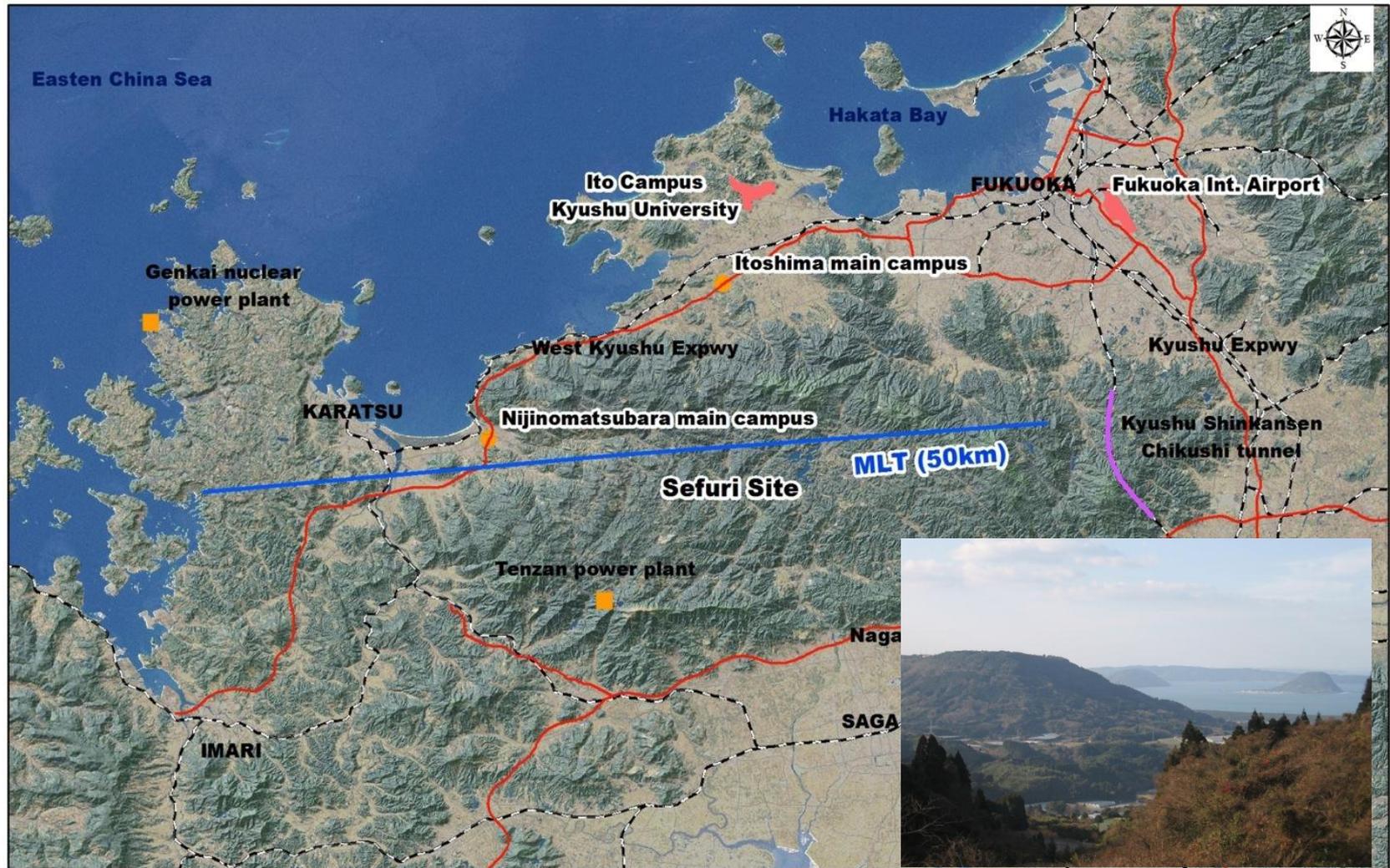


Summary of KITAKAMI Site Investigation

1. The Natural Ground of KITAKAMI site is composed of Granite belts with three rock belts and partly some Sedimentary rocks.
2. As a result of lineament survey and field survey, it was confirmed not to be a lineament related to the active fault
3. It was confirmed good granite was distributed in the central region except the neighborhood of surface part.
4. From results of the physical exploration, It is estimated that the base rock with elastic wave speed of 4.5 km or more is distributed continuously at the depth level of the ILC tunnel.
5. Sedimentary rock in the south part is also in a good condition.

III. Overview of Investigation result in the SEFURI-Site

General map of SEFURI site and surrounding major facilities



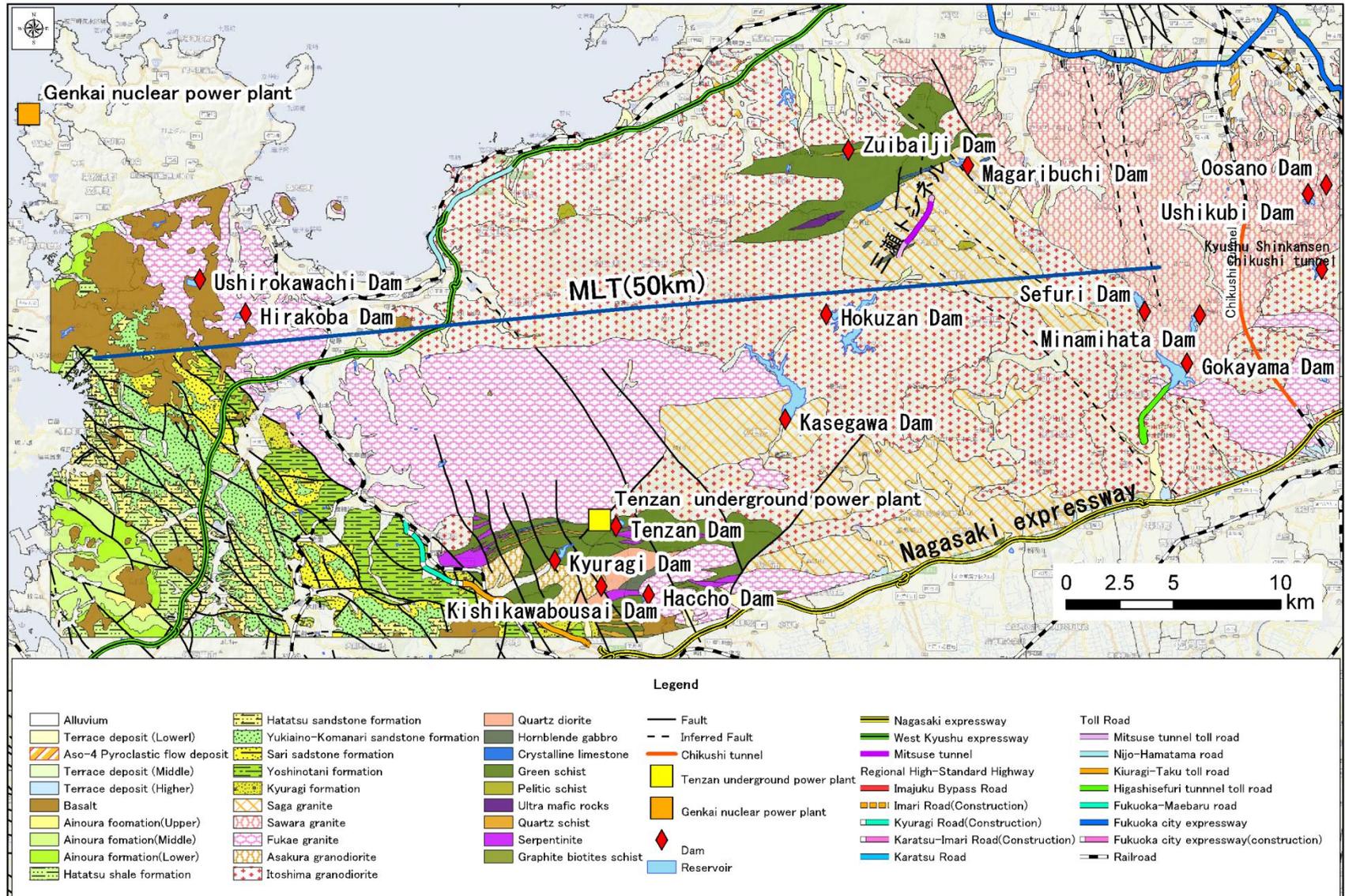
II. Overview of Investigation result in the SEFURI-Site

Item	Quantity	Remarks
Lineament survey	300km ²	Arial photography interpretation Field survey
Geophysical Exploration	14 km	Electromagnetic exploration, Electric survey 5 survey lines, total of 60 points
Bedrock Boring	1 point	Drilling depth 300m, Various examinations

Main Contents of geological survey at Sefuri-site

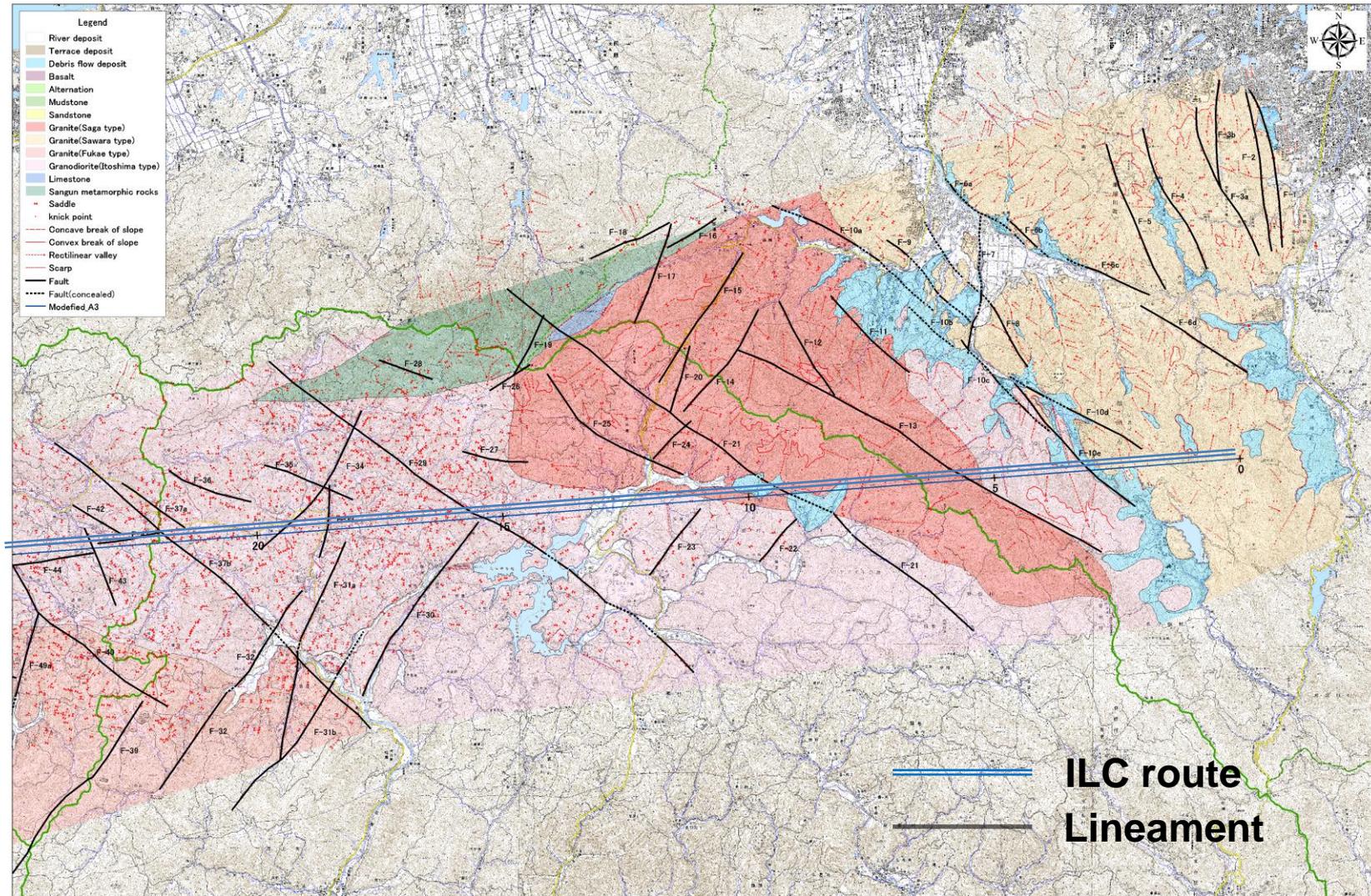
1. Arial photography interpretation, field investigation and hydraulic measurement along the MLT route (300km² area) , by 25 skilled geologists of Japan Society of Engineering Geology.
2. Referring the geological records of the past construction projects ;
4 tunnels, 11 dams, 2 power plants, etc
3. Geological, geotechnical and hydraulic investigation for quantitative evaluation of faults and underground water
4. 300-m drilling and physical exploration in center area of ILC.

□ Surface Geology and the Location of major facilities in SEFURI Candidate site



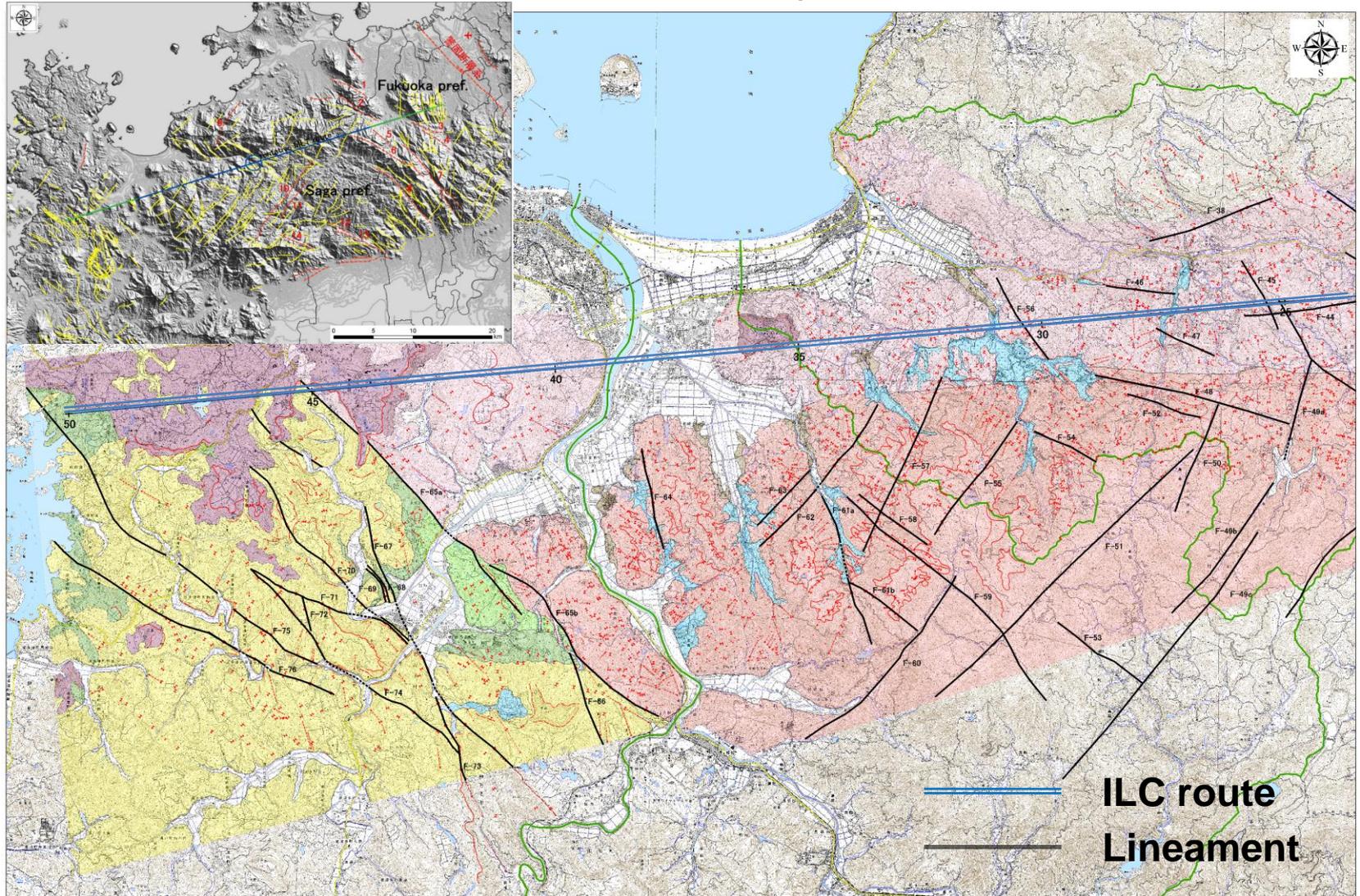
☐ Extracted Lineaments and Geology in SEFURI-site

East half area of the assumption route

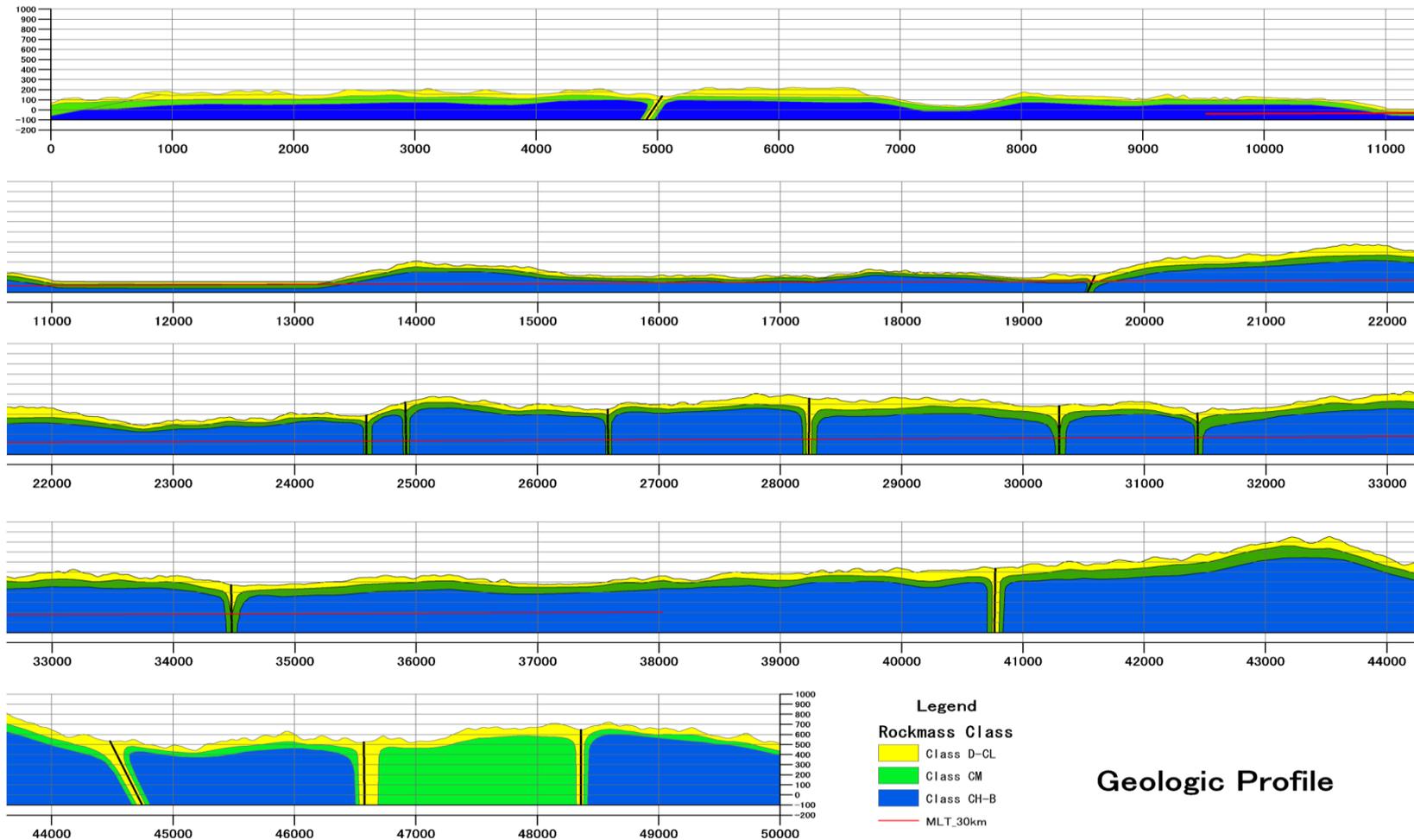


□ Extracted Lineaments and Geology in western SEFURI-site

West half area of the assumption route

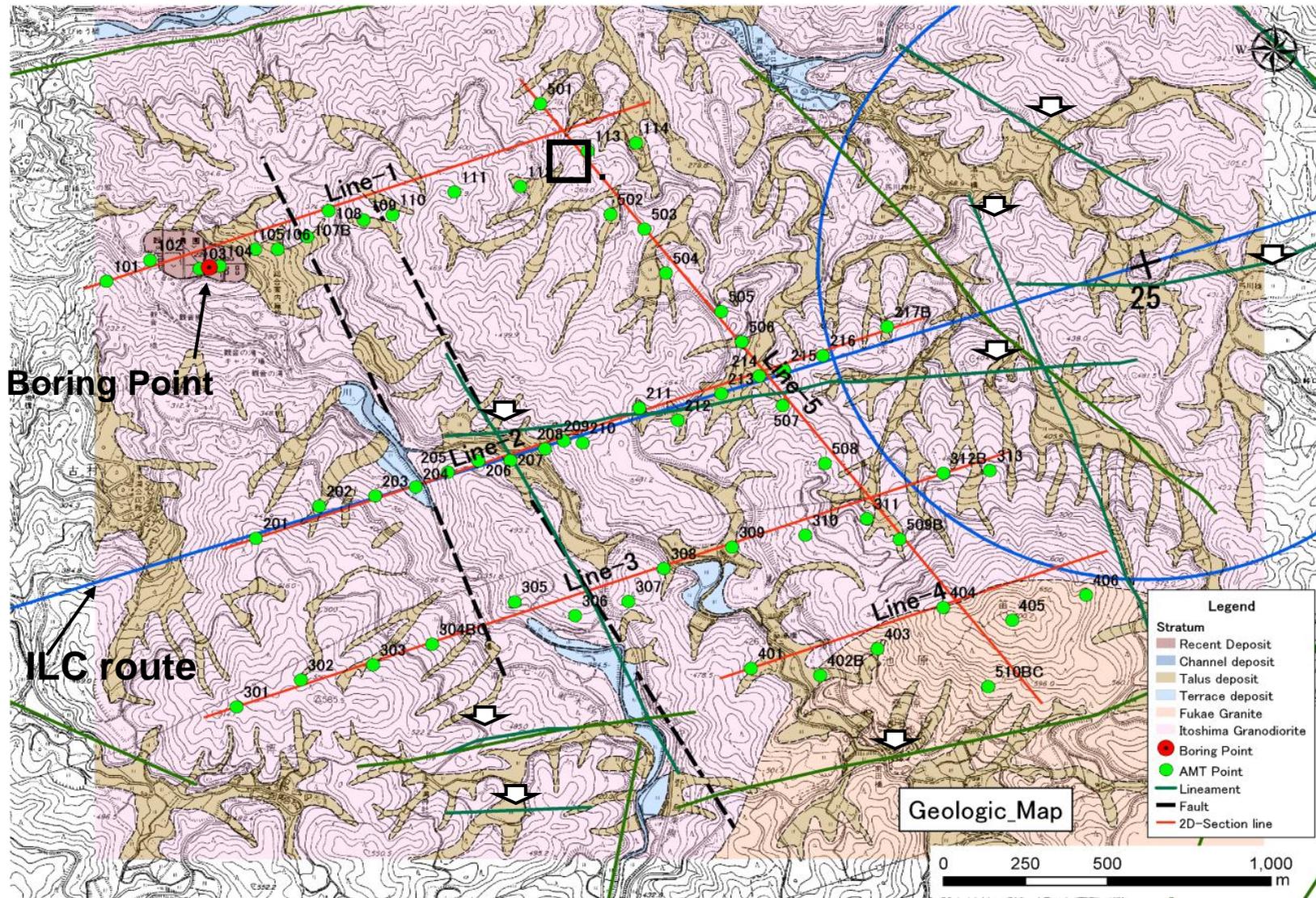


□ Geologic Profile along the MLT in SEFURI-site



- Most of rock mass are very good condition (fresh and few joints) except some faults.

□ A drilling point and 5 lines of Electromagnetic survey in the central region



□ Boring Investigation in the central area

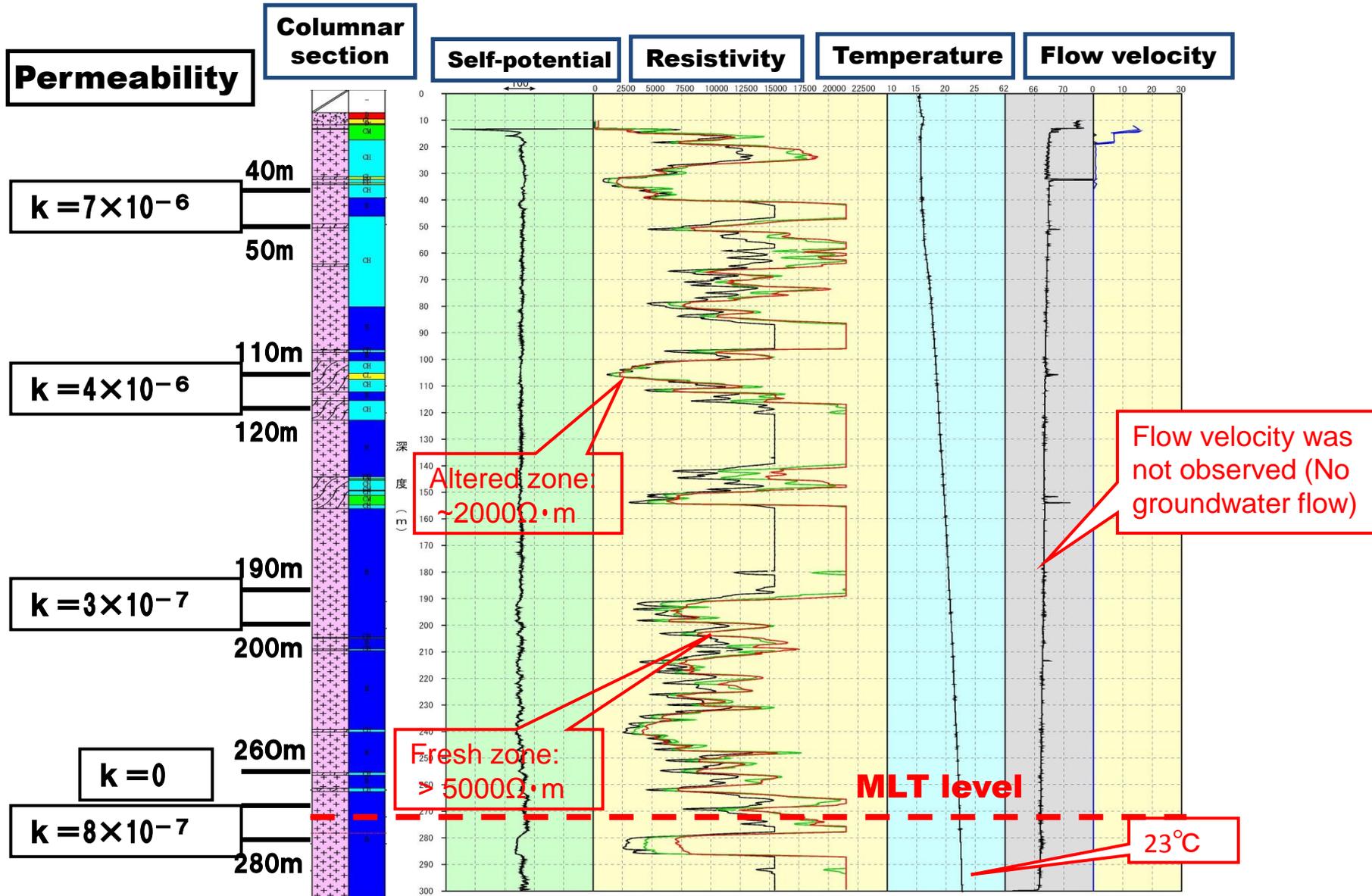
Outline of investigation result

- Drilling depth to 300M (MLT level= 225m)
- 0-8m; buried material, 8m-13m; weathered granite
- 13-300m; fresh hard granite, slightly including weak alteration, totally including a few joints

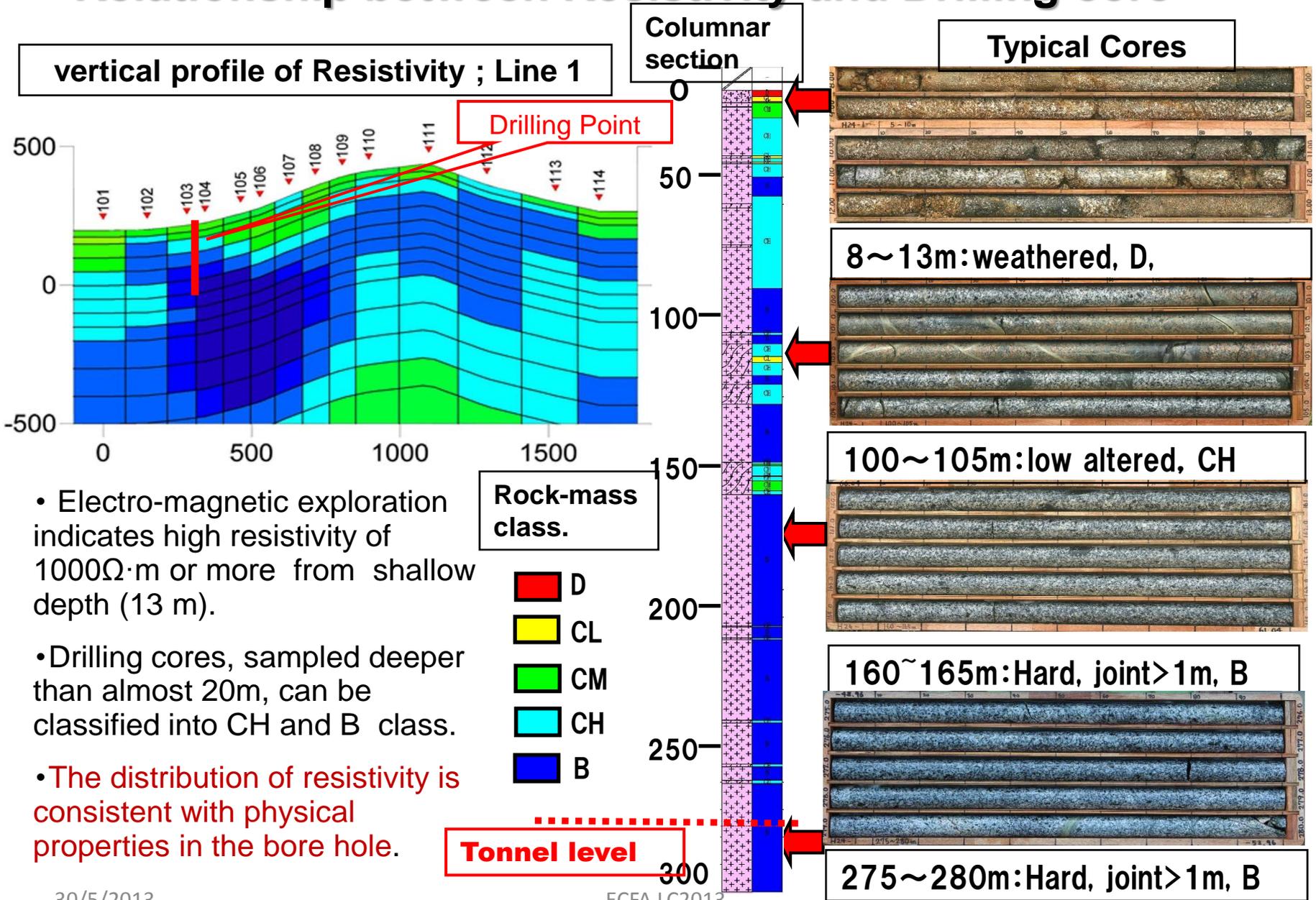
uniaxial compressive strength=147MPa,
permeability $k=10^{-6} \sim -7$ cm/sec



□ Physical properties of the 300m bore hole



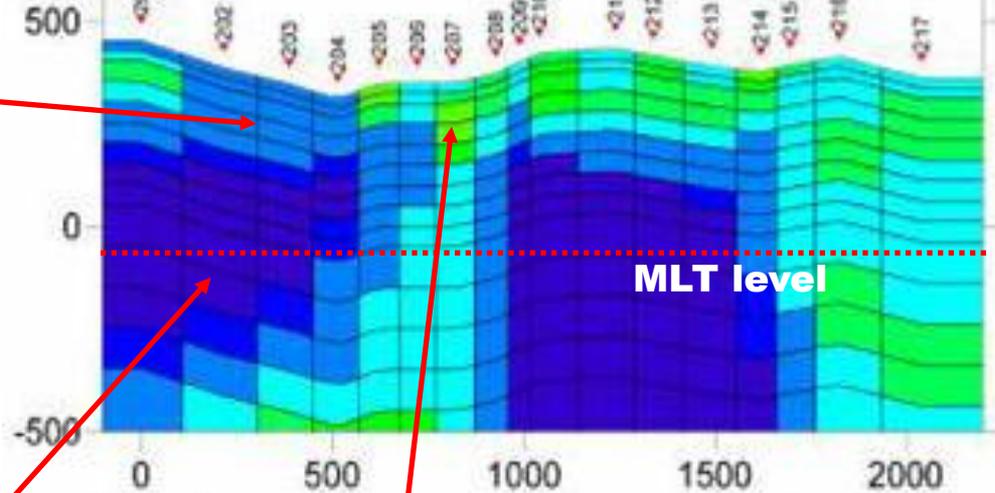
□ Relationship between Resistivity and Drilling core



- Electro-magnetic exploration indicates high resistivity of 1000Ω·m or more from shallow depth (13 m).
- Drilling cores, sampled deeper than almost 20m, can be classified into CH and B class.
- The distribution of resistivity is consistent with physical properties in the bore hole.

Comparison of resistivities and field observations

Line2:vertical profile of resistivity along MLT



Resistivity: 1000 to 5000 $\Omega \cdot m$
CH-Class, joint < 1m

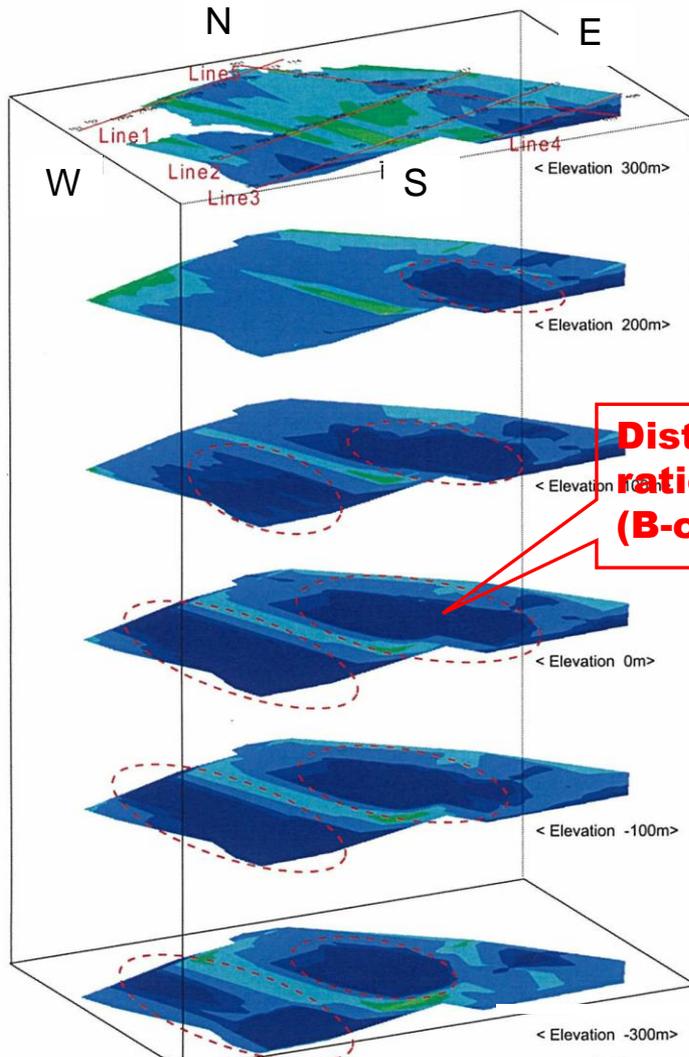


Resistivity: > 5000 $\Omega \cdot m$
B-Class, joint > 1m

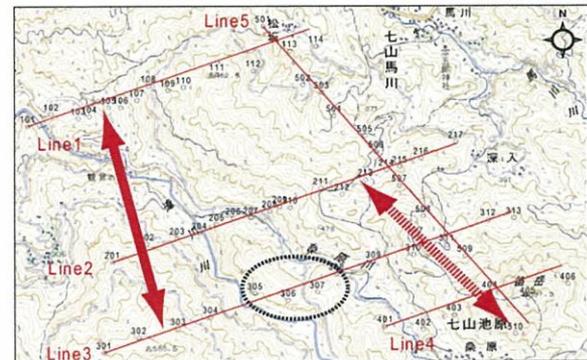


Resistivity: < 200 $\Omega \cdot m$, CM-Class,
including Fracture zone (L-3)

□ Result of electromagnetic exploration



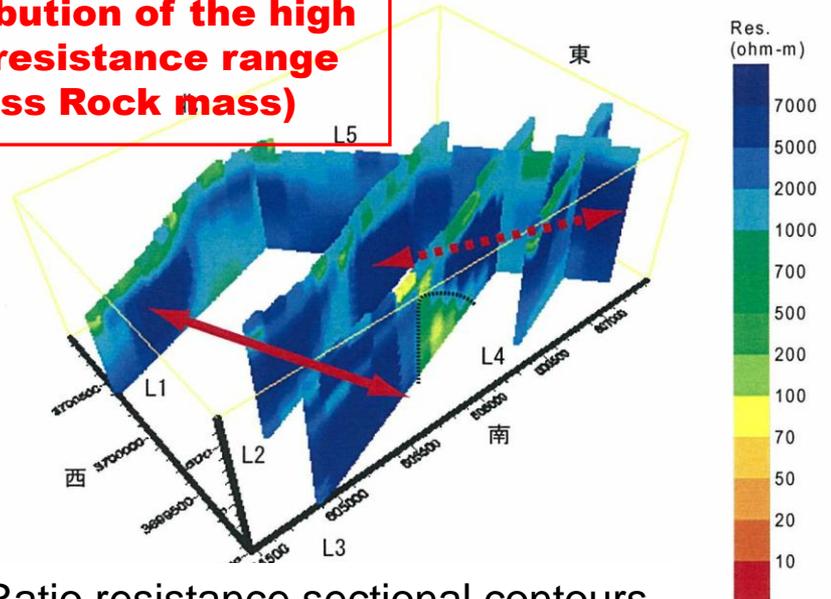
Distribution of the high ratio resistance range (B-class Rock mass)



○ 1,000Ω・m 以下
の中比抵抗域

○ **>7000Ωm**

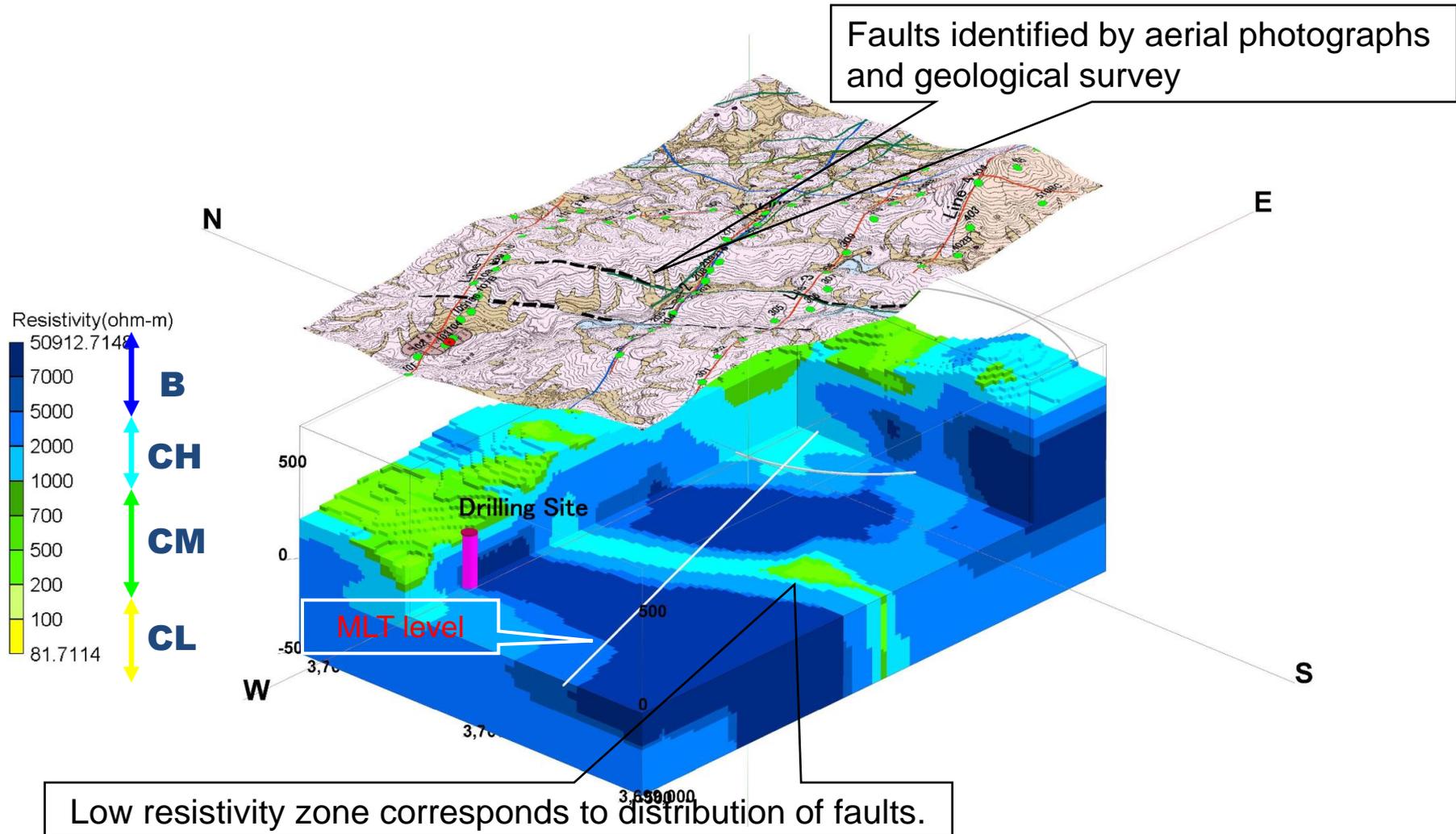
Trend of similar values



Ratio resistance sectional contours

Bird's-eye view of the resistance ratio

□ An image of bedrock of MLT level



Bedrock of the MLT level can be mostly classified into CH class (RMR=77-87) or B class (RMR=87-100).

Summary of SEFURI Site Investigation

1. The Natural Ground of SEFURI site is composed of almost **Granite and some Sedimentary rocks**.
2. 83 Lineaments by areal photography interpretation along the MLT have been investigated through field exploration. The active fault was confirmed no existence on the route.
3. Some Dislocation was confirmed around the route, but it is supposed that the construction of the underground structure does not have the big trouble.
4. Good bedrock is distributed generally in the granite zone. Especially, a quite excellent rock-mass has been identified by deep boring and physical exploration In the Experiment hall area. (B~CH class)
5. Sedimentary rocks in the west part are also in a good condition and are classified from CH to CM classes.

IV. Summary

- **We pushed forward the preliminary geological investigation by the first national budget.**
- **It is reported that both sites have sufficient good foundation for construction of ILC facilities if limited to geology.**
- **Larger-scale geological investigation which focuses on one site is needed in next stage.**
- **We need to develop more detailed investigation plan by cooperation of ILC researches (accelerator & detector) and CFS team toward the next design stage.**