Mizunami Underground Research Laboratory Project

- Program Update -

27 May , 2010

JAEA Tono
Katsuhiro Hama

Hydrangea

-sorption using what species, colloids
-pH? T?
-operation?
-fracture filling

Contents

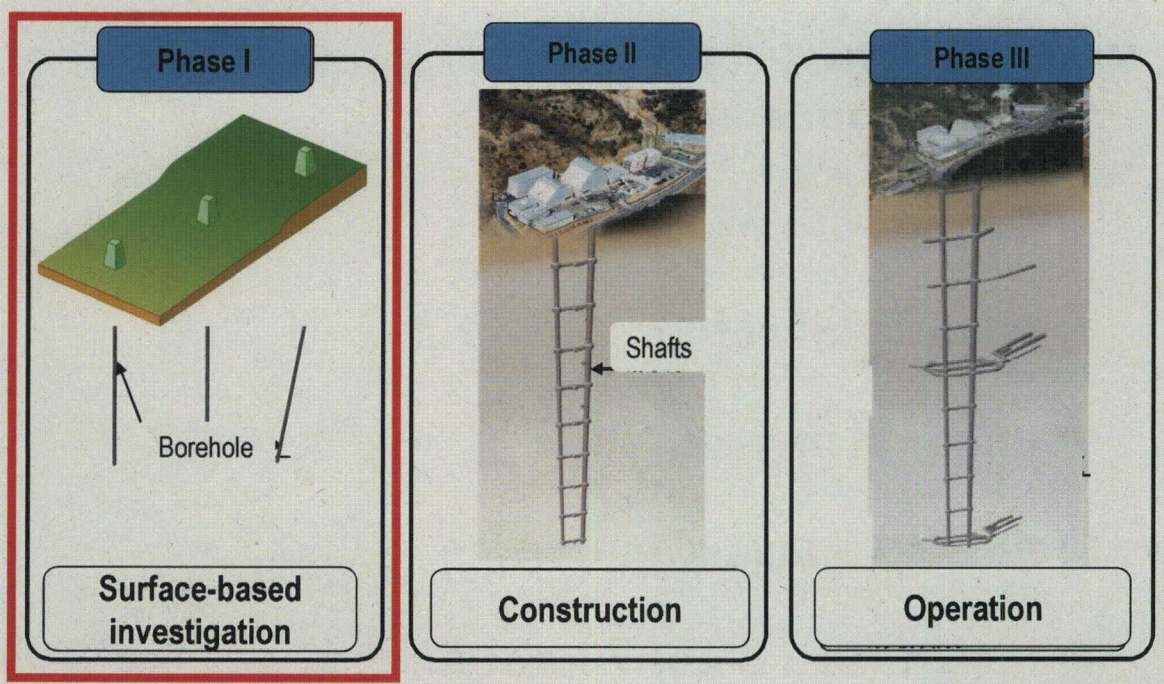
Expected outcome

By applying several investigation methods to the "real " geological environment, followings can be achieved

- Feedback evaluation
  - ✓ by confirmation and revision of geological environmental model
  - ✓ by confirmation adequacy of investigation method adopted in previous phase
- Evaluation of relationship between the characterization methods and degree of understanding of the geological environment

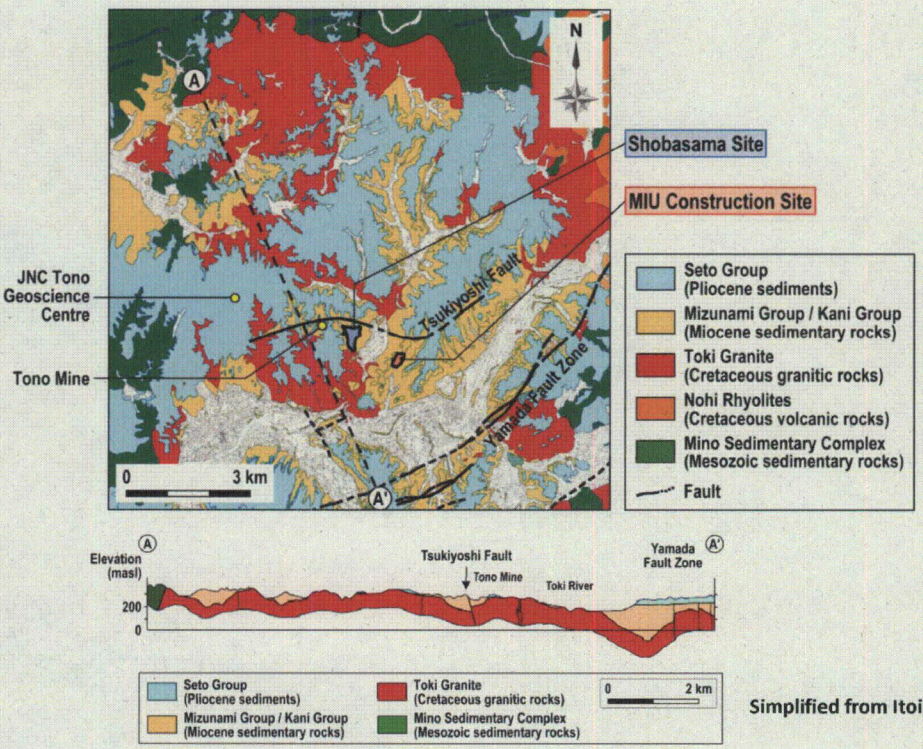
- Synthesized investigation, analysis and assessment techniques for each site investigation phase on NUMO's siting process
- **Technical know-how (success / failure experiences) on related the techniques for investigation, analysis and assessment**

Step-wise Investigation



*Plan is subject to change

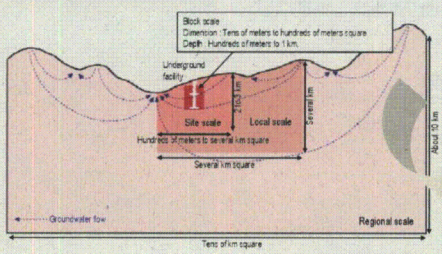
Geology of the Tono Area



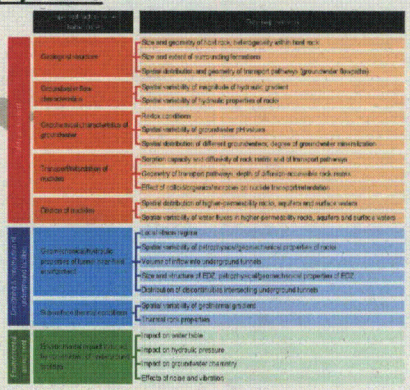
Simplified from Itoigawa (1980)

Strategy of R&D in MIU project

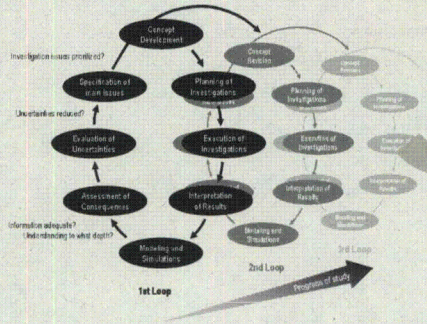
(1) Spatial scale



(2) Aims



(4) Iterative approach

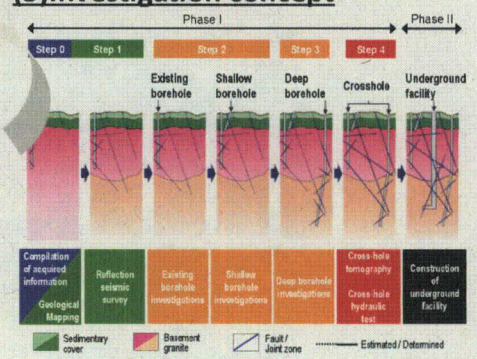


JAEA

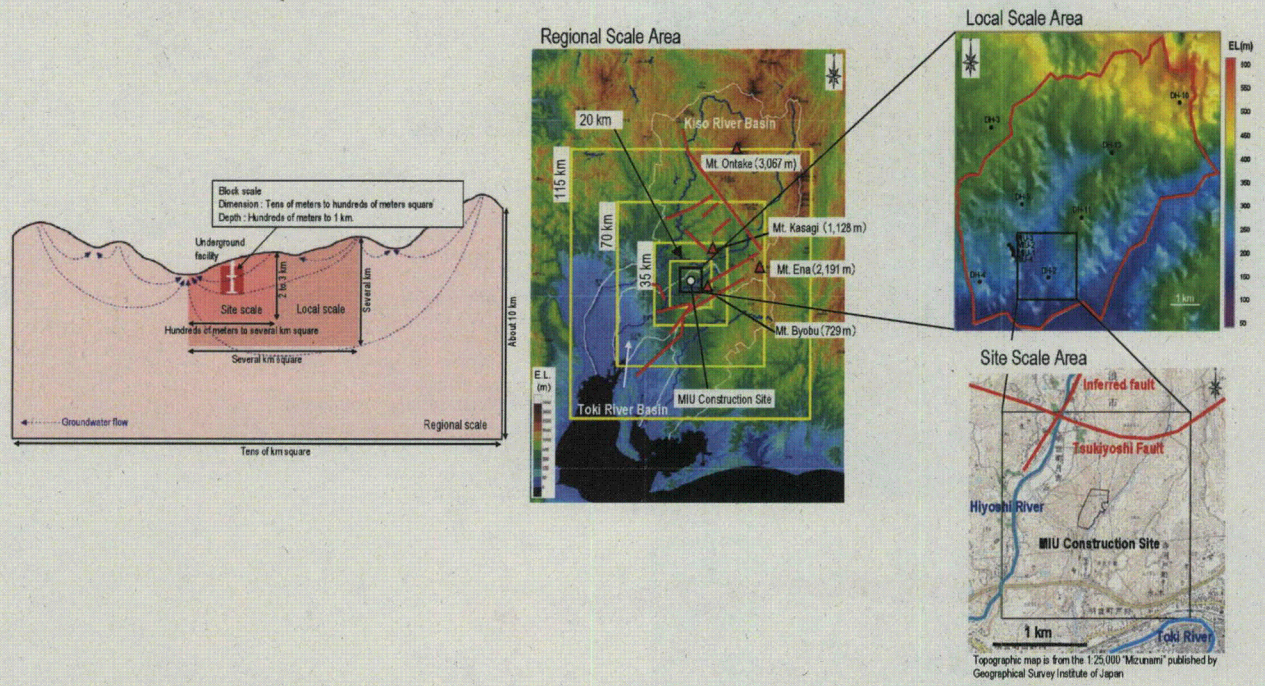
Master Plan

Plan for investigation, analysis and assessment

(3)Investigation concept



Spatial scale

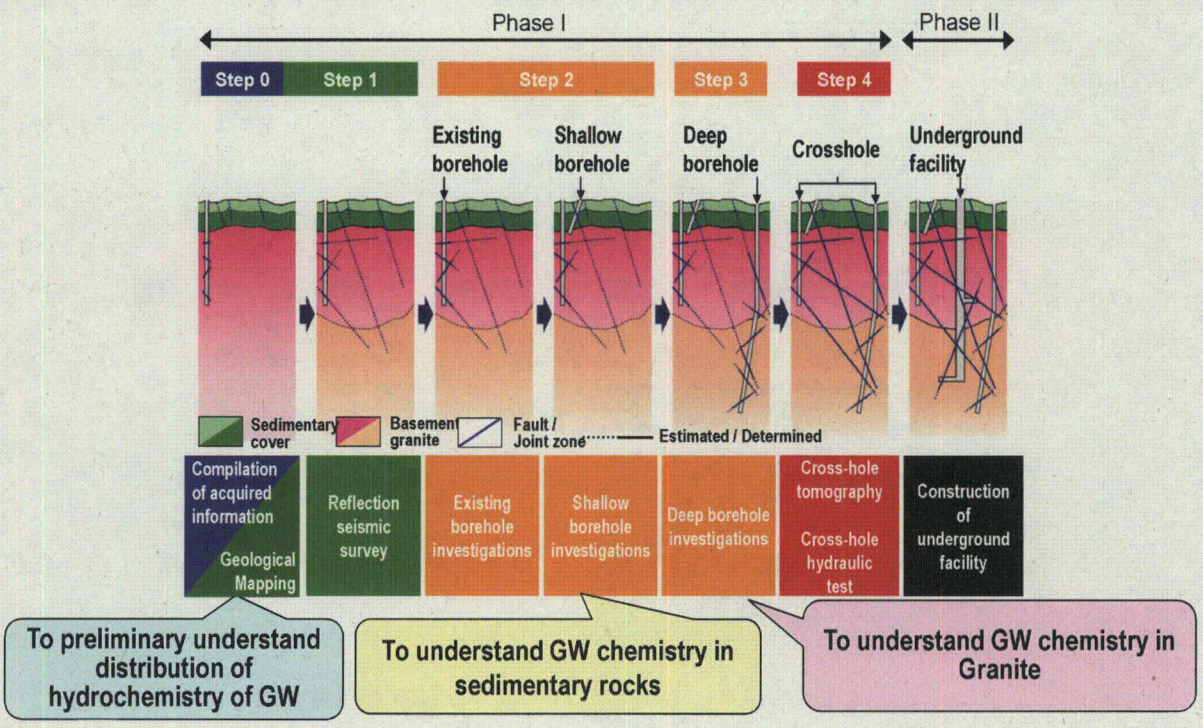


Topographic map is from the 1:25,000 "Mizunami" published by Geographical Survey Institute of Japan

Important factors to be characterized and data requirements

	Important factors to be characterized	Data requirements
Safety assessment	Geological structure	Size and geometry of host rock; heterogeneity within host rock
		Size and extent of surrounding formations
		Spatial distribution and geometry of transport pathways (groundwater flowpaths)
	Groundwater flow characteristics	Spatial variability of magnitude of hydraulic gradient
		Spatial variability of hydraulic properties of rocks
	Geochemical characteristics of groundwater	Redox conditions
		Spatial variability of groundwater pH values
		Spatial distribution of different groundwaters; degree of groundwater mineralization
	Transport/retardation of nuclides	Sorption capacity and diffusivity of rock matrix and of transport pathways
		Geometry of transport pathways; depth of diffusion-accessible rock matrix
		Effect of colloid/organics/microbes on nuclide transport/retardation
	Dilution of nuclides	Spatial distribution of higher-permeability rocks, aquifers and surface waters
		Spatial variability of water fluxes in higher-permeability rocks, aquifers and surface waters
Designing & construction of underground facilities	Geomechanical/hydraulic properties of tunnel near-field environment	Local stress regime
		Spatial variability of petrophysical/geomechanical properties of rocks
		Volume of inflow into underground tunnels
		Size and structure of EDZ; petrophysical/geomechanical properties of EDZ
		Distribution of discontinuities intersecting underground tunnels
	Subsurface thermal conditions	Spatial variability of geothermal gradient
		Thermal rock properties
Environmental assessment	Environmental impact induced by construction of underground facilities	Impact on water table
		Impact on hydraulic pressure
		Impact on groundwater chemistry
		Effects of noise and vibration

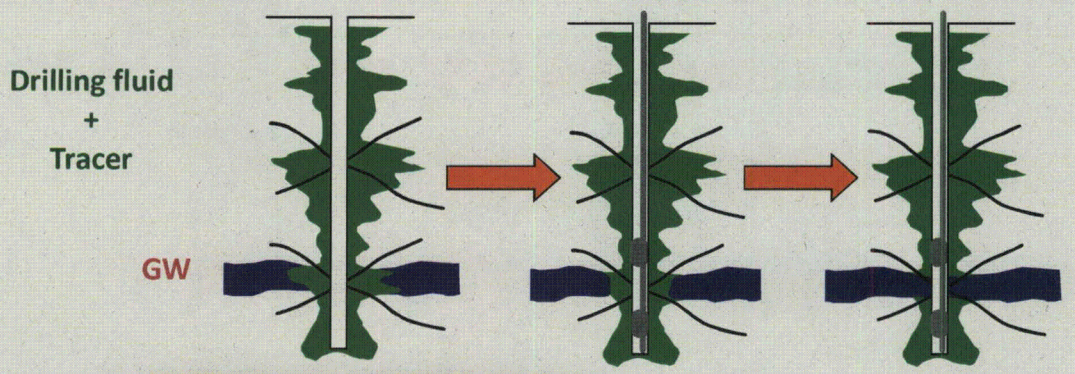
Investigation concept

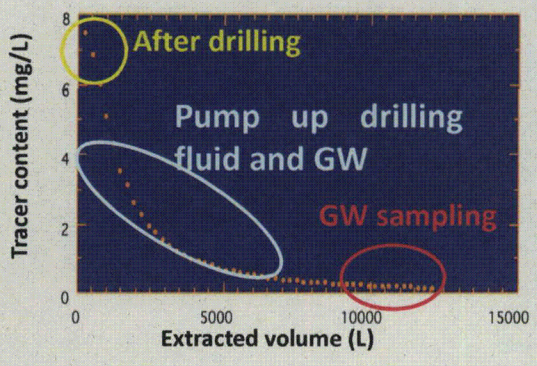


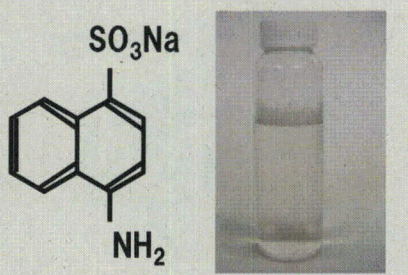
Investigations in Phase I

1. Geological investigation
2. Hydrogeological investigations
3. **Hydrochemical investigations**
   - Survey of existing information
   - Surface water/precipitation sampling/analysis
   - **Groundwater sampling/analysis**
   - Bulk rock/mineral analysis
   - Geochemical modeling
   - Geostatistical analysis
4. Rock mechanical investigations

GW sampling procedure



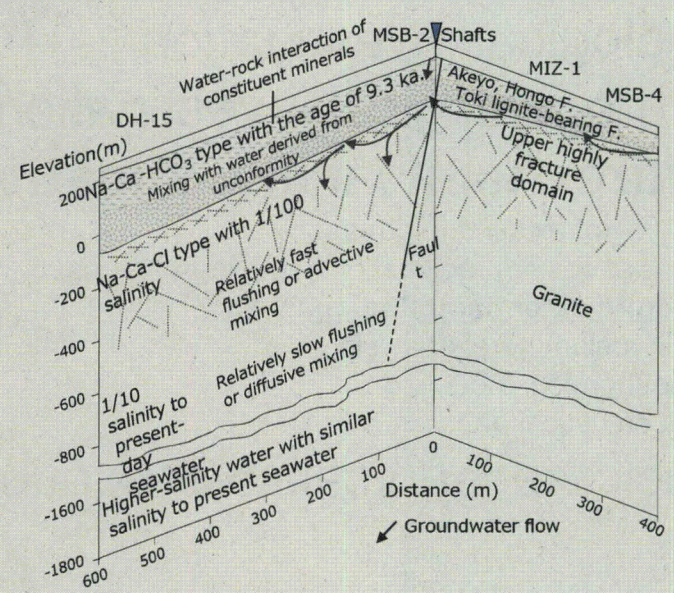




Tracer (Na-naphthionate)

Hydrochemical conceptual model around MIU

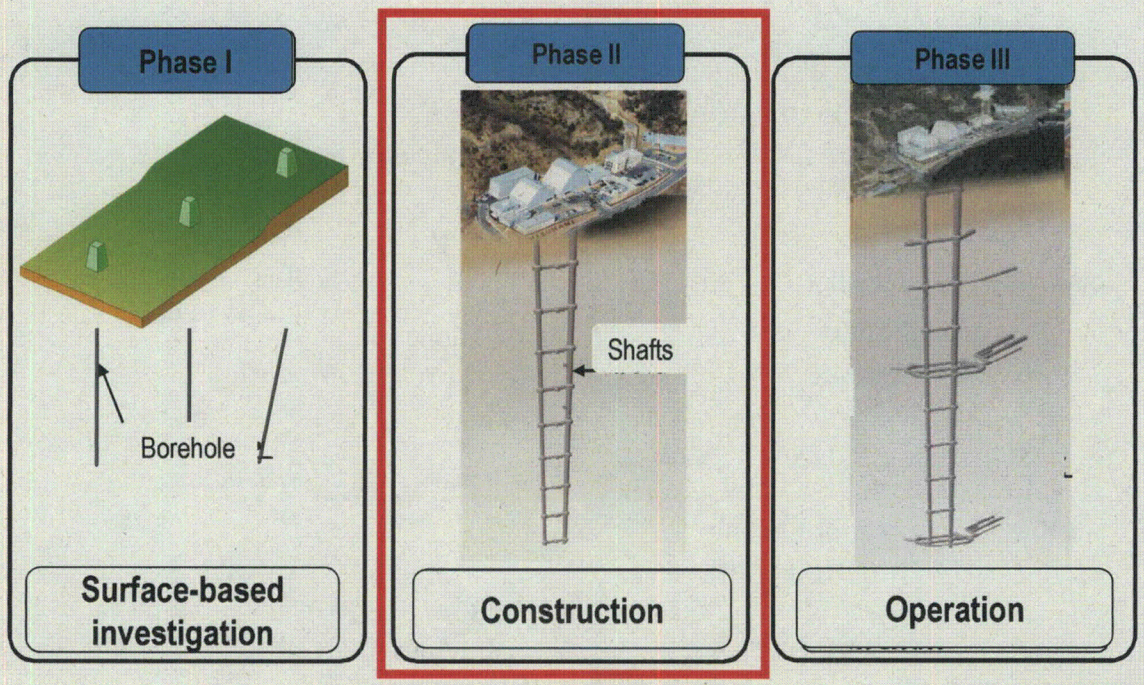
after step3 (deep borehole investigation) investigation



Issues for Phase II investigation

- Validation of the hydrochemical model constructed through the investigations in Phase I.
- Identification of the general processes and mechanisms involved in the changes in the hydrochemical environments in and around the MIU.

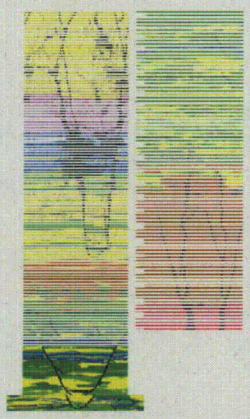
Step-wise Investigation



*Plan is subject to change

Phase II Field Investigations

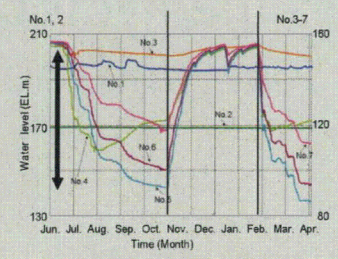
- Geological mapping
- Geophysical investigations (*eg* reverse VSP)
- Hydraulic investigations
- Monitoring (inflow rate, pressure)
- GW sampling/analysis
- Physical/mechanical tests
- Stress measurement



Shaft Wall Sketch

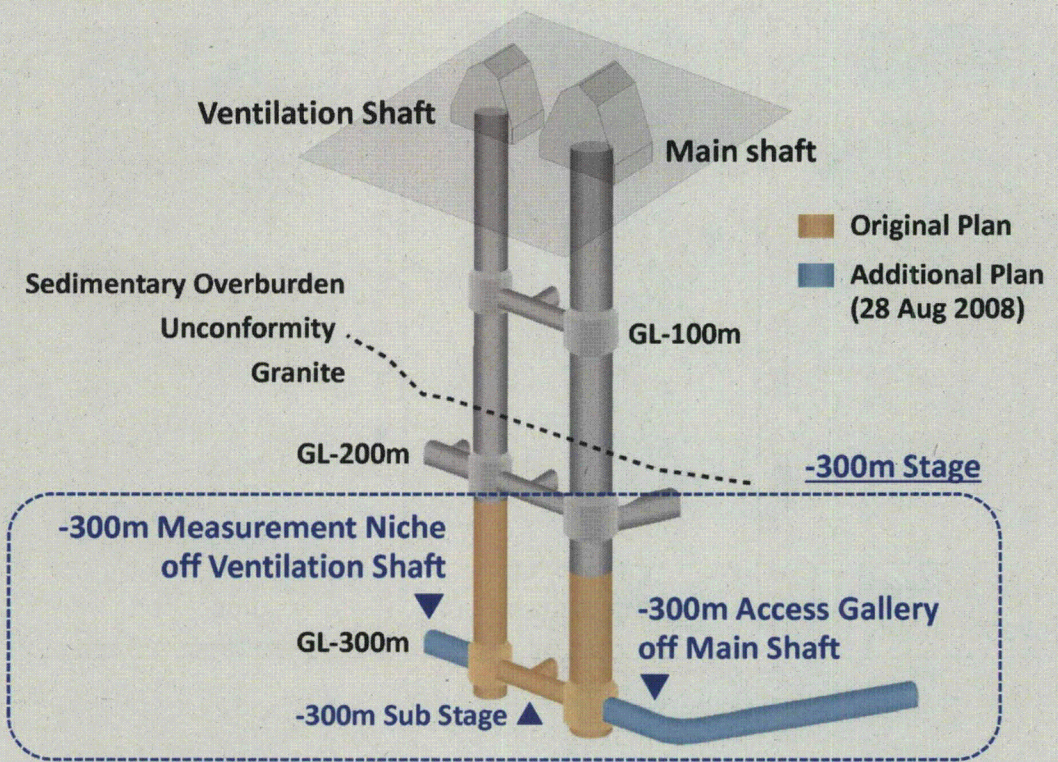
Geological Mapping/Sampling

Hydraulic/Hydrochemical Monitoring



Water Level Change

Revision of Financial 2008 Plan



Why -300m Gallery?

- Producing certain outcome without delay to the disposal project and for safety regulations

  ...as assigned in Revised Basic Policy & Plan, Generic Programme *etc*

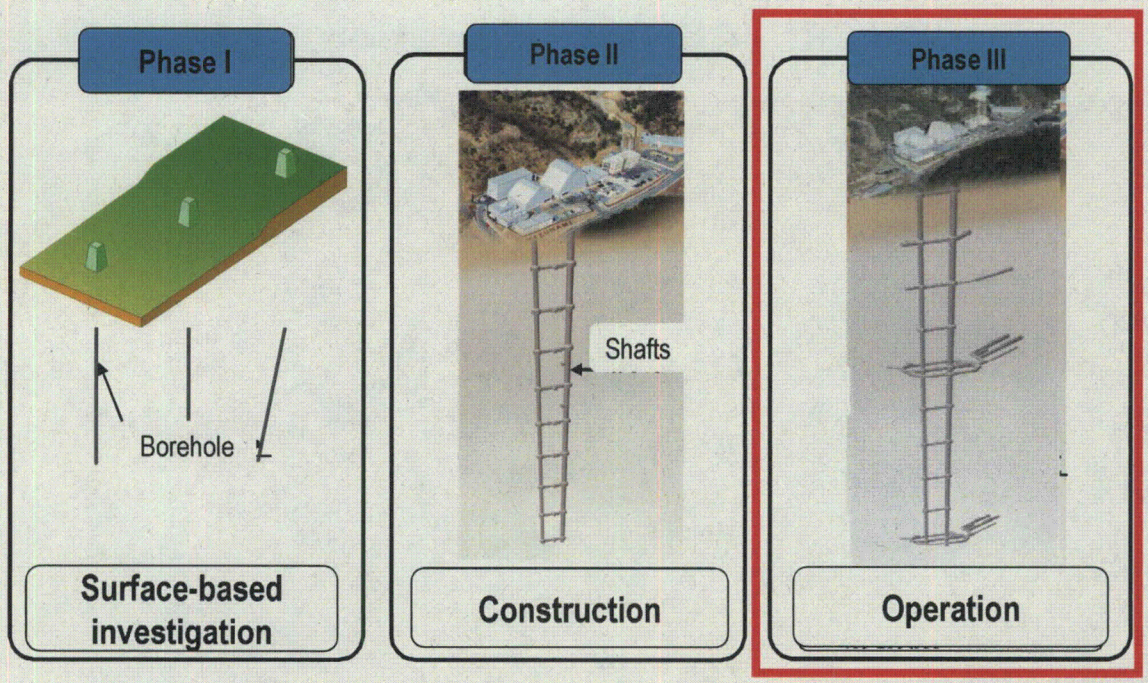
- UHFD with larger inflow being suitable for studying countermeasures against inflow, solute transport *etc*

  ...based on the investigation results obtained to date

- Promoting mutual understanding of the final disposal by establishing an open facility

  ...as assigned in revised Basic Policy & Plan, General Framework *etc*

Step-wise Investigation



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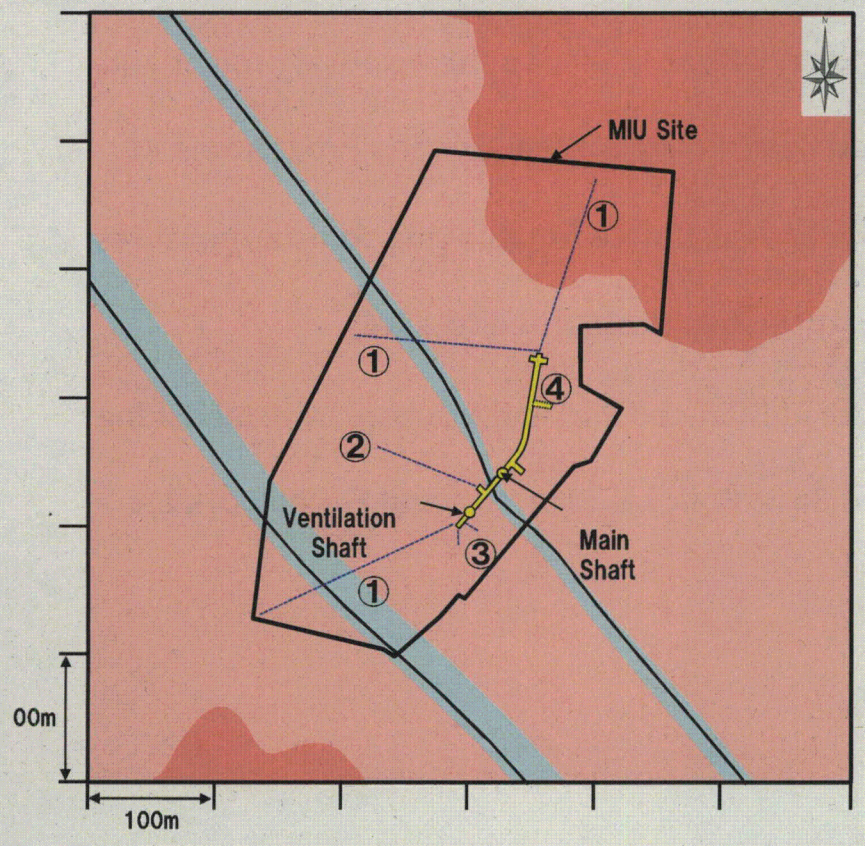
Planned Investigations



①Geological investigation
(Fault/Fracture)
②Hydrochemical investigation
③Rock mechanical investigation
④Mine-by experiment
⑤Mass transport investigation

※Specific location of investigation ⑤ should be optimized by the geological invetigations.

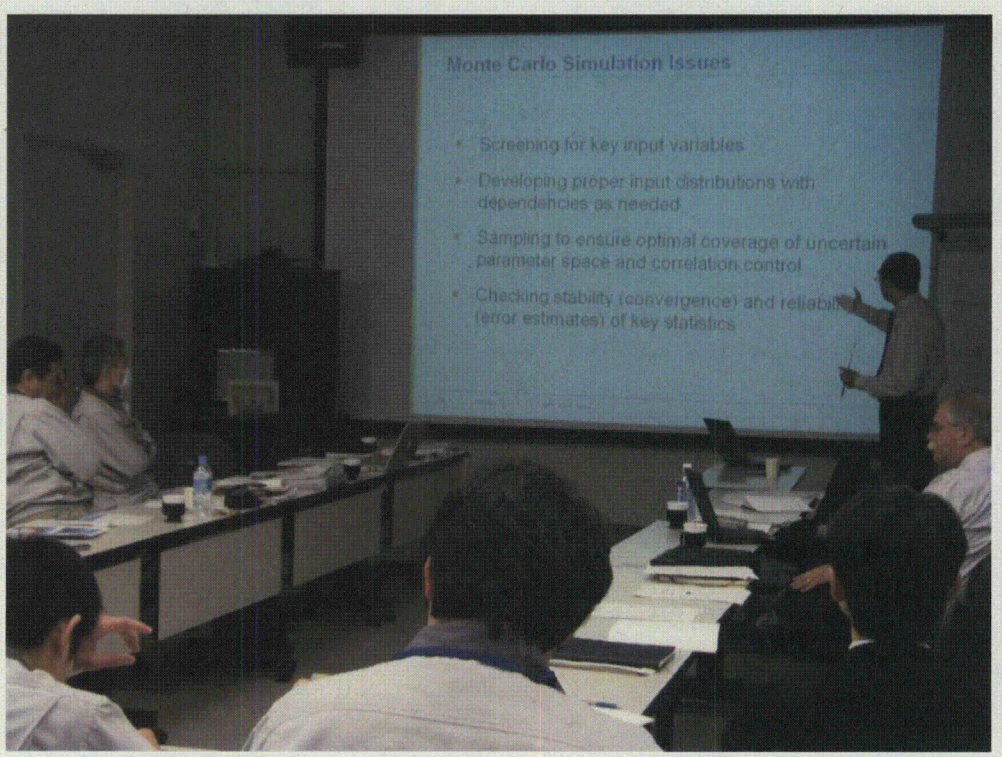
Lower sparsely fractured domain
Upper highly fractured domain
Fault predicted

International collaboration

KAERI/JAEA collaboration

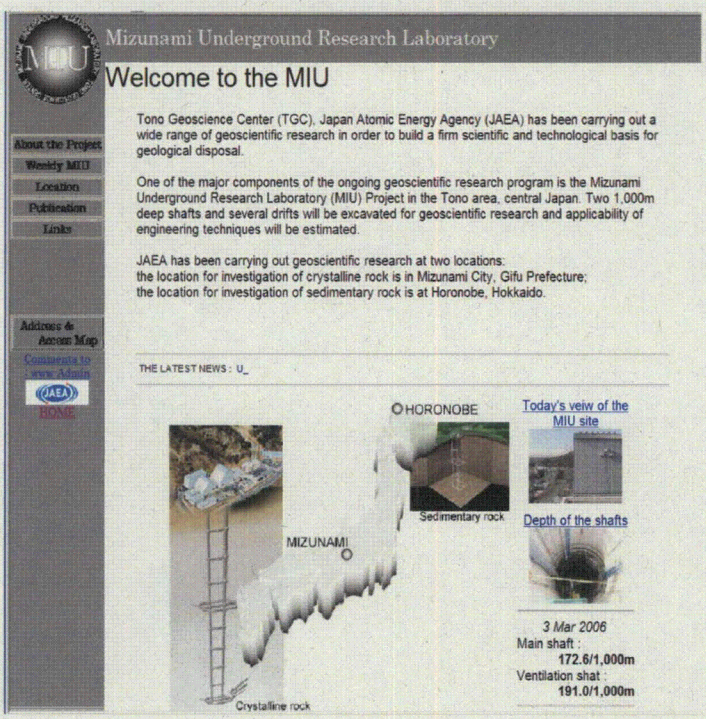
International collaboration

Nagra/JAEA collaboration



More information of the MIU project is available on

http://www.jaea.go.jp/04/tono/miu_e



Addressing tectonic issues for siting a HLW repository in Japan

Junichi Goto
Site Characterization Group
Science and Technology Department
Nuclear Waste Management Organization of Japan (NUMO)

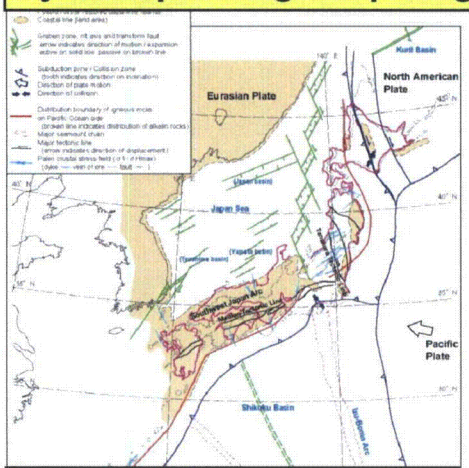
NRC Meeting
28 May 2010

NUMO Nuclear Waste Management Organization of Japan

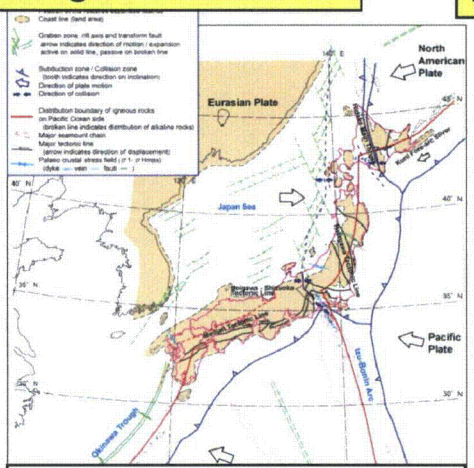
Long-term predictability of tectonics in Japan

- Fundamental structure of the present plate system was established at around 15 Ma
- It takes more than one million years for a plate system to change
  - Present tectonic condition will not change for the next one hundred thousand years

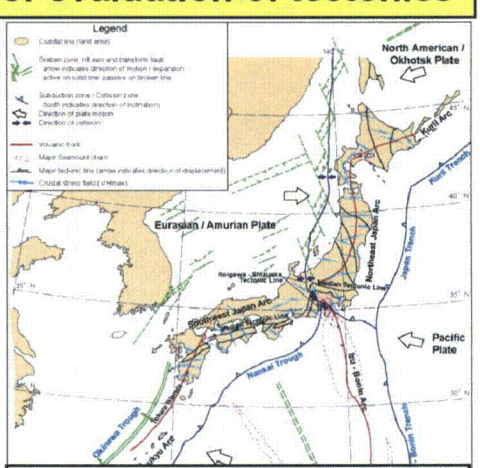
Geological environment in Japan can be predicted over several tens of thousand years by extrapolating the past geological evidences → **Deterministic approach can basically be applied for evaluation of tectonics**



15Ma:
Termination of opening of the Japan Sea (rotation of the NE and SW Japan Arcs)



1.8Ma:
Development of ISTL, start of activity of MTL, opening of Okinawa trough and Izu-Ogasawara back-arc basin



Present:
Collision of the Izu-Peninsula and convergence of plates along the eastern margin of the Japan Sea

Development of Siting Factors for selecting PIAs

Legal requirements

- ◆No record of significant movement in geological formations
- ◆Small possibility of significant movement in geological formations in the future
- ◆No record of unconsolidated Quaternary deposits in the host formation
- ◆No record of mineral resources that are economically valuable in the host formation

NUMO's requirements

- ◆Legal requirements of DIA selection, repository site selection
- ◆Practicality of repository construction, operation

Siting Factors

Evaluation Factors for Qualification (EFQ)

Nationwide Evaluation Factors (NEF)

To assess suitability based on uniform nationwide criteria

Site–specific Evaluation Factors (SSEF)

To assess suitability based on site-specific literature information

- Earthquake/Fault activity
- Igneous activity
- Uplift/Erosion
- Unconsolidated Quaternary deposits
- Mineral resources

Favorable Factors (FF)

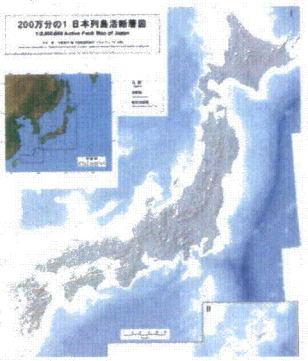
To assess and compare the areas comprehensively where compliance with the legal requirements is met

- Properties and conditions of geological formations
- Hydrogeological properties
- Investigation and assessment of geological environment
- Natural disasters during construction and operation
- Procurement of land
- Transportation

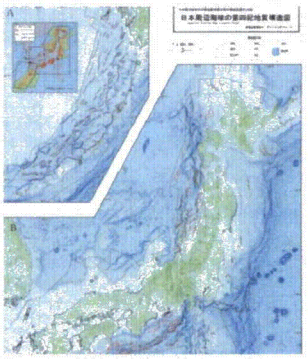
Siting Factors for earthquake and fault activity

Nationwide Evaluation Factors (NEF)

PIAs should not include active faults identified in the nationwide-scale maps, based on aerial photographs for inland areas and sonic prospecting for offshore.



"1:2,000,000 Active Fault Map of Japan" (2002)



"Quaternary Structure Map of Japanese Waters"(2001)

Site-specific Evaluation Factors (SSEF)

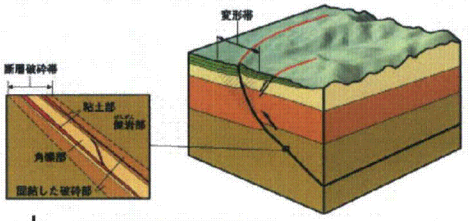
PIAs should not include the following locations and zones identified by site-specific literature surveys;

a. Locations where active faults are identified in other literature information

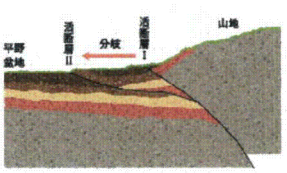
b. Crushed zones and surrounding deformation zones of active faults

c. Potential Zones of branching, extension, new generation, reactivation of active faults

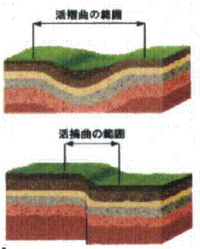
d. Zones of active folds or flexures .



b. 活断層の幅・変形帯の概念図

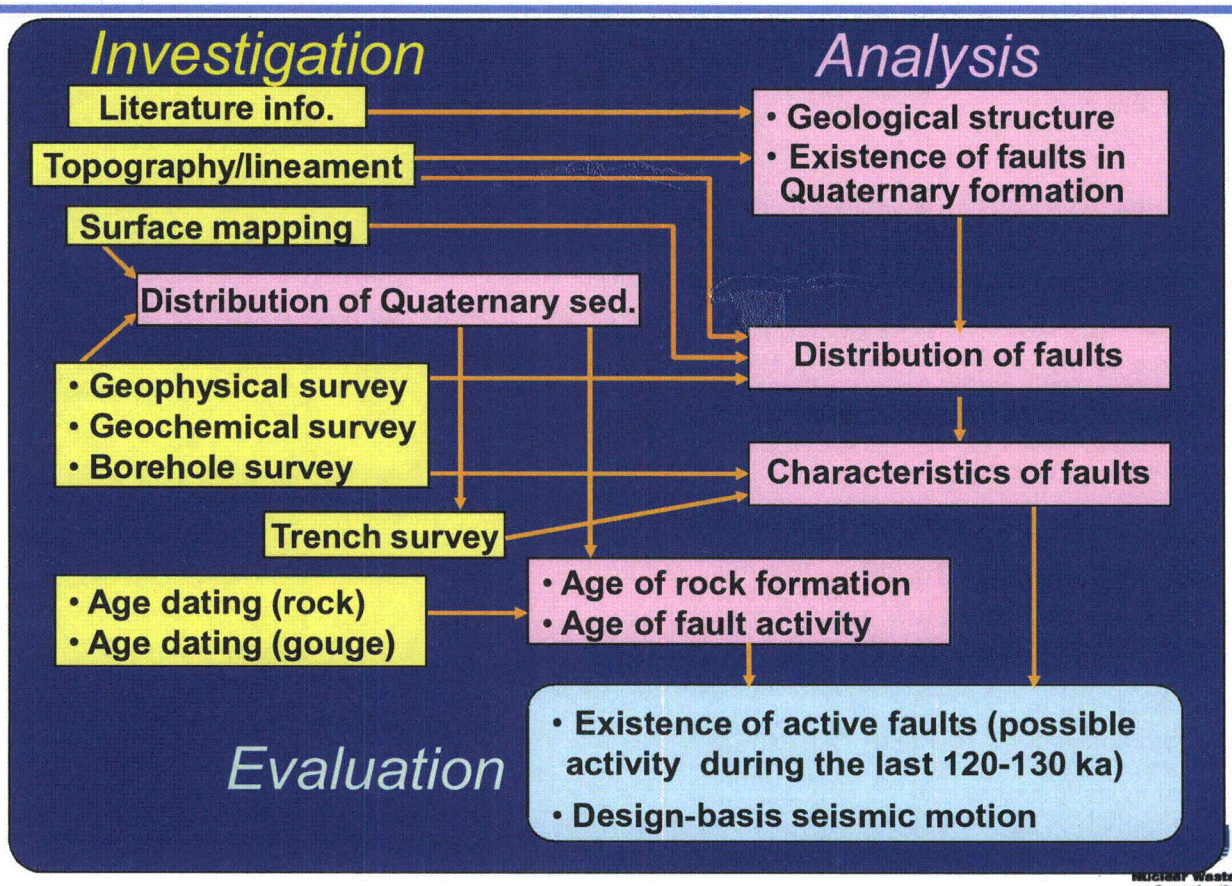


c. 活断層の分岐の概念図

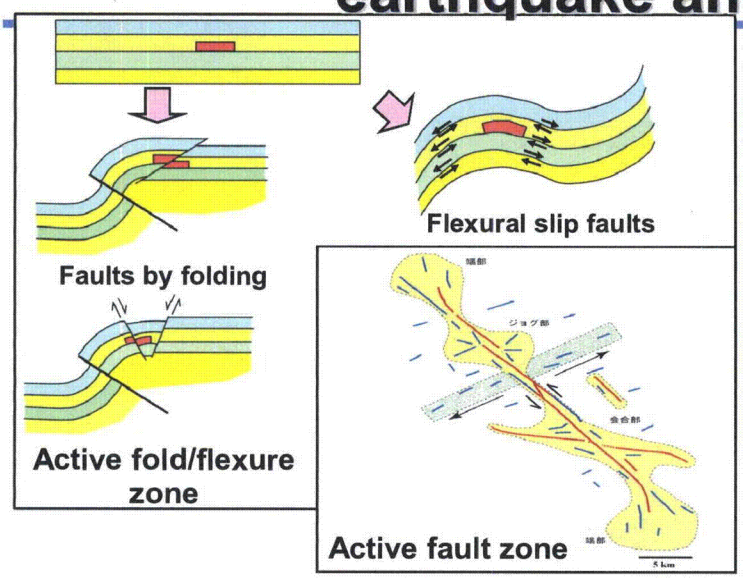


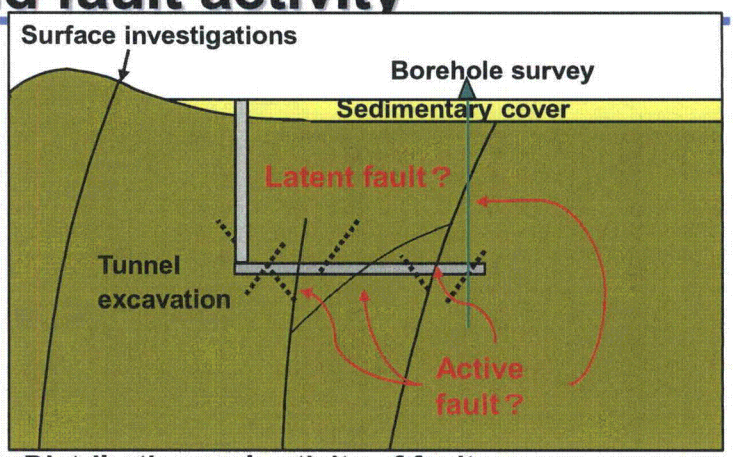
d. 活褶曲、活撓曲の範囲の概念図

Deterministic assessment for siting NPP

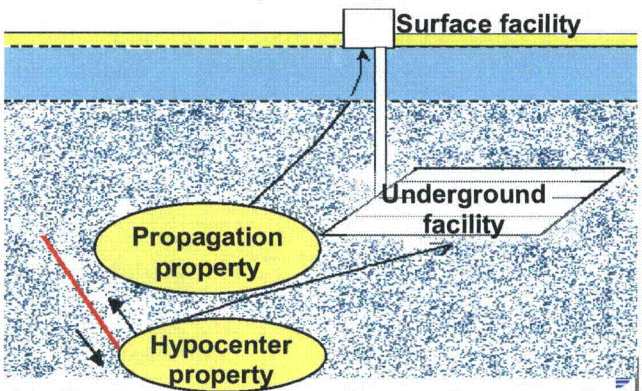


R&D on the remained issues: earthquake and fault activity





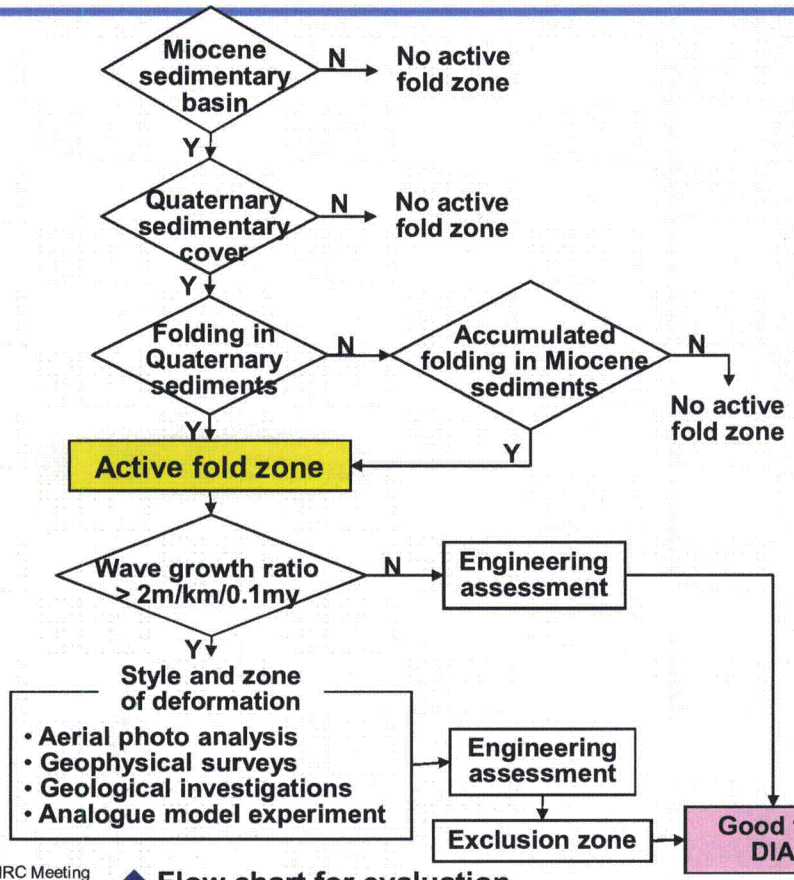
Distribution and activity of faults



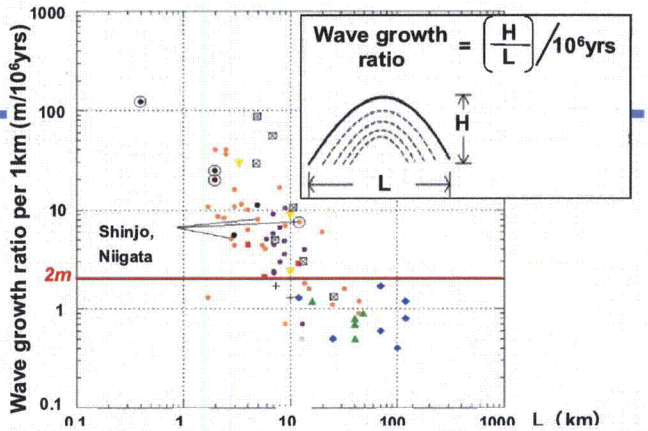
Earthquake ground motion underground

- Evaluation of active fold/flexure zones
- Evaluation of active fault zones
- Distribution of latent active faults
- Activity of faults intersected underground
- Earthquake ground motion underground
- Probabilistic assessment of fault activity

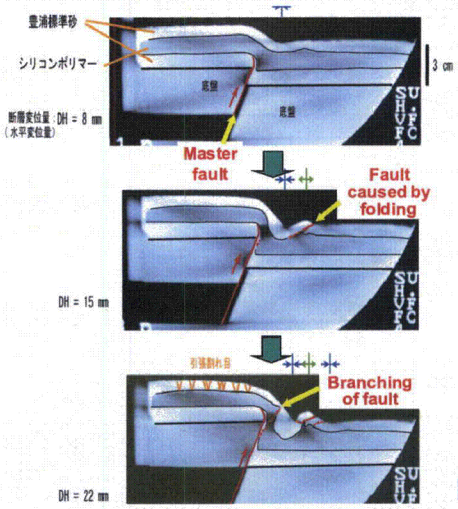
Active fold/flexure zones



◆ Flow chart for evaluation



◆ Identification of relevant active fold zones



◆ Model experiment using CT- scanner

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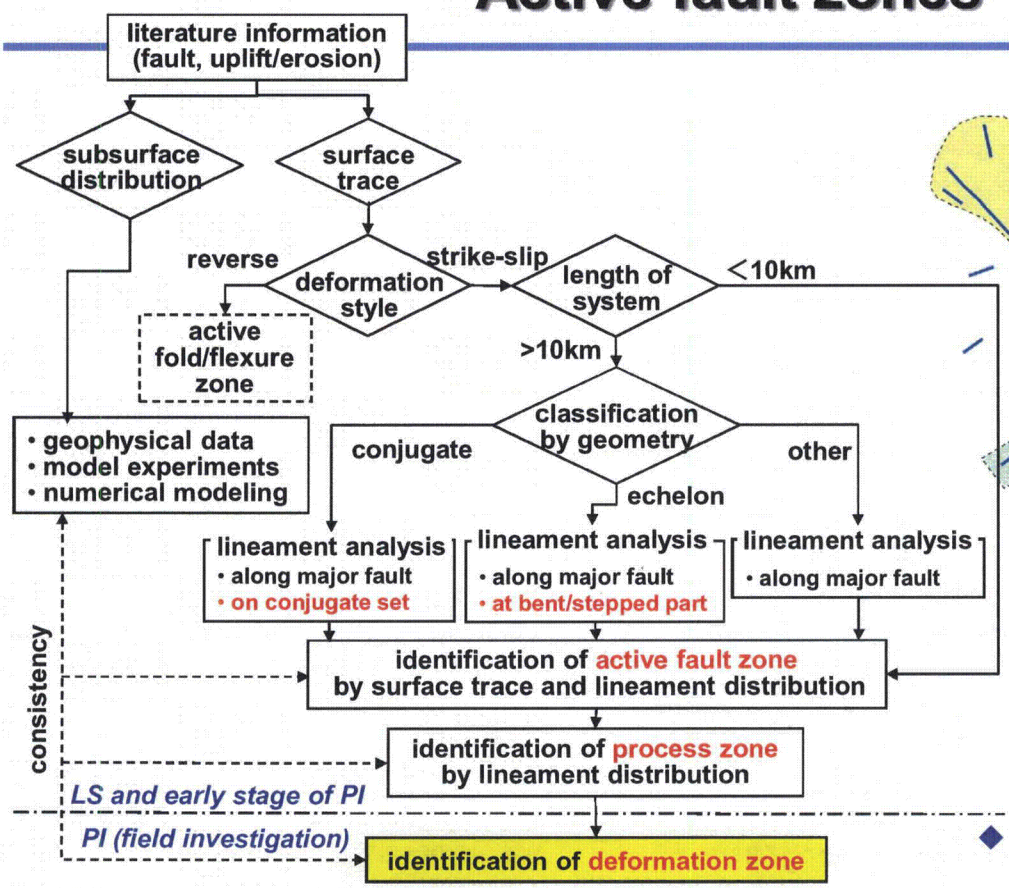
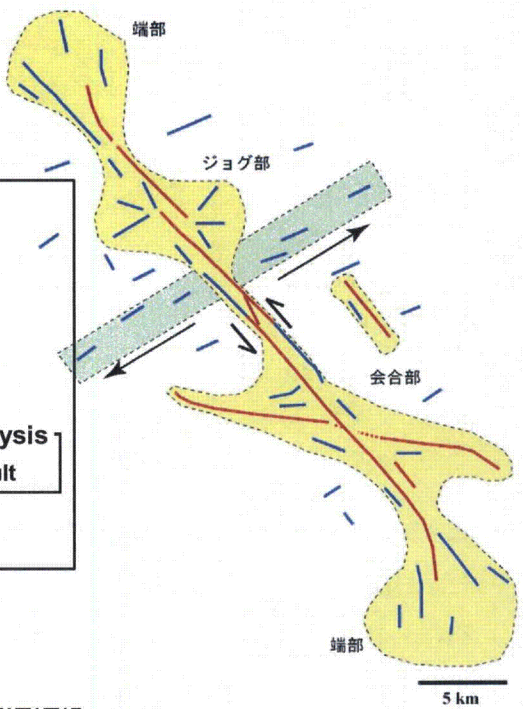
Active fault zones



◆ Flow chart for evaluation



◆ Concept of lineament analysis

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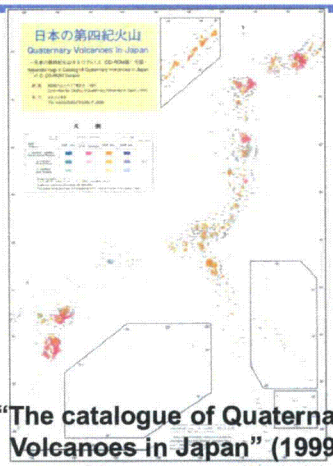
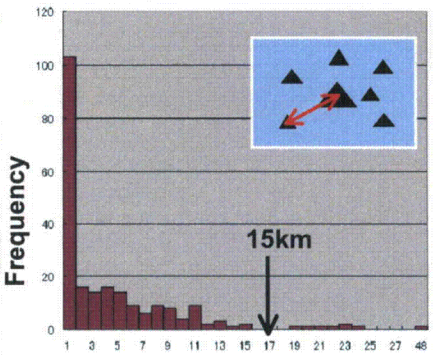
Siting Factors for igneous activity

Nationwide Evaluation Factors (NEF)

PIAs should not include the areas within a 15km radius from the center of the Quaternary volcanoes.



"The catalogue of Quaternary Volcanoes in Japan" (1999)



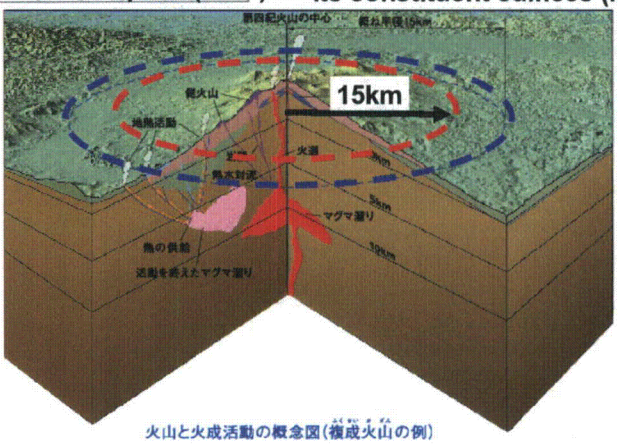
"Maximum distance" between the center of a volcano and its constituent edifices (km)

Site-specific Evaluation Factors (SSEF)

PIAs should not include the areas that:

- are definitely expected to have magmatic intrusion or eruption, or
- have significant thermal and hydrothermal effects,

outside the 15km circle.



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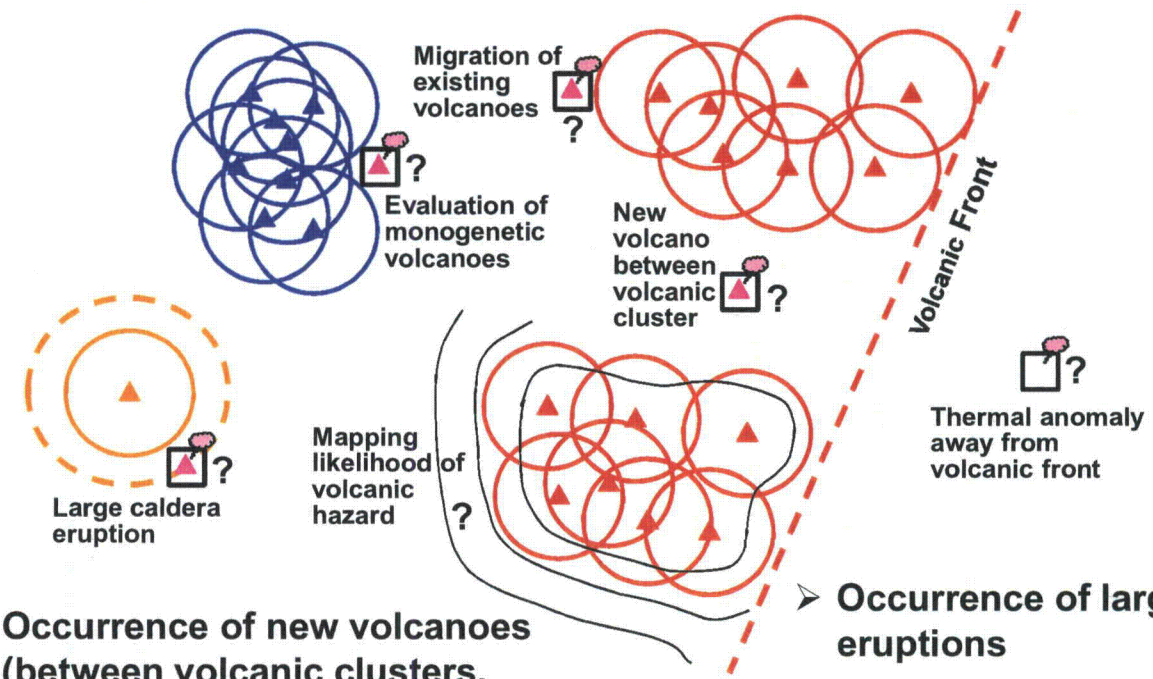
R&D on the remained issues: igneous activity



- Occurrence of new volcanoes (between volcanic clusters, monogenetic volcanoes)
- Migration of magma from existing volcanoes
- Occurrence of large caldera eruptions
- Evaluation of thermal and hydrothermal effects
- Probabilistic assessment of igneous activity

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Occurrence of new volcanoes

Flow chart showing basic procedure for evaluating regions of future volcanism around the target area

Evaluation on a scale of island arc

- Distribution, lithofacies, stratigraphy and ages of igneous rocks
- Tectonic evolution, etc

→
- Position of the volcanic front and its migration
  - ➢ Trench side or back-arc side?
- Continuity of subduction conditions (temporal changes in tectonics)
  - ➢ Determination of the time range of evaluation

Evaluation on scale of volcanic cluster

- Distribution, lithofacies, stratigraphy of igneous rocks
- Radiometric age data
- Chemical analysis data, etc

→
- Spatio-temporal patterns in volcanism among volcanoes
  - ➢ Regularity or uneven distribution of volcanism

- Topographical data
- Distribution and temporal changes of fault movements
- Distribution and temporal changes of uplift and subsidence
- Gravity anomaly data, etc

→
- Crustal structure and movement related to volcanism
  - ➢ Indicating concentration of volcanism
  - ➢ Controlling volcanism

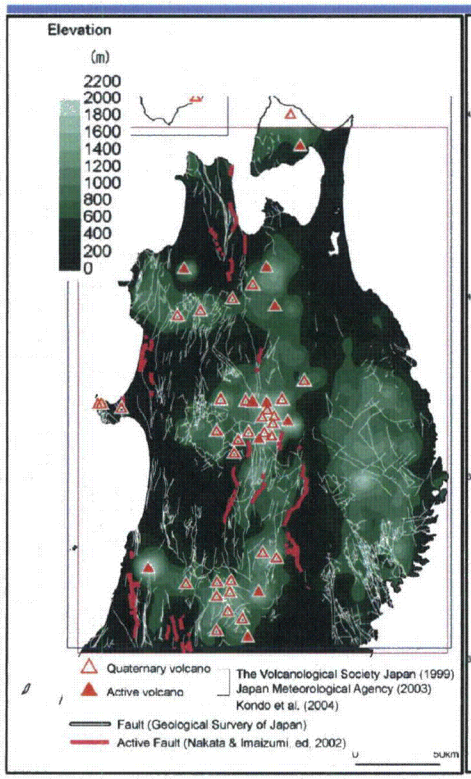
- Seismic velocity structure
- Thermal structure of the crust, etc

→
- Evolution of hot regions within the mantle wedge
  - ➢ Present state of the position and extent of low velocity anomalies
  - ➢ Continuity of hot regions based on correlation with spatio-temporal patterns in volcanism

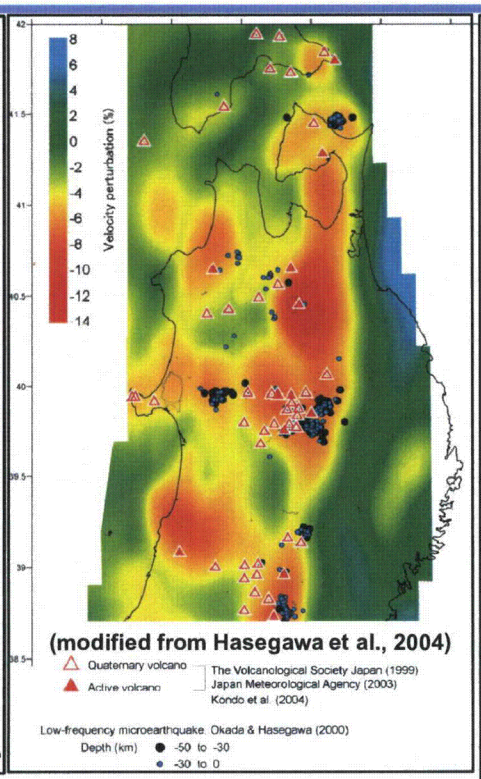
↔ Geological model

◆ Determination of regions of future volcanism

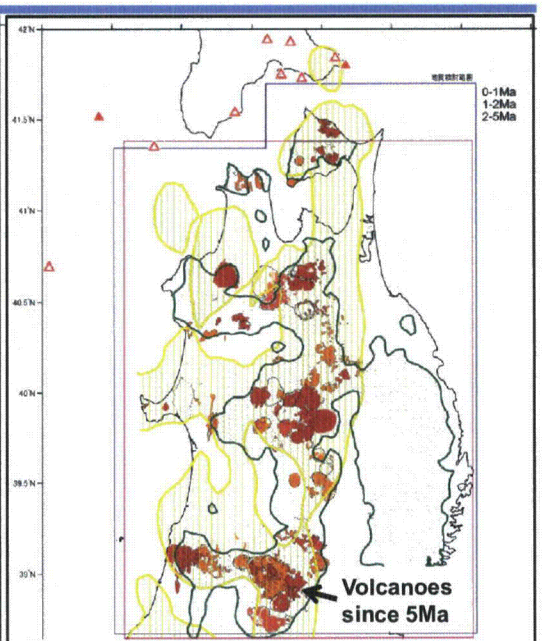
Occurrence of new volcanoes - case study -



◆ E-W trending basement topography



◆ Low-velocity anomalies within the mantle wedge

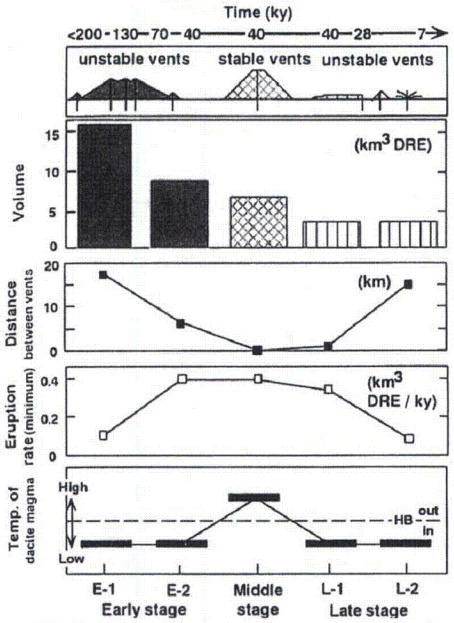


○ : elevation > 500m
volcanism since 5 Ma
+ uplift due to magmatism
high likelihood of volcanism

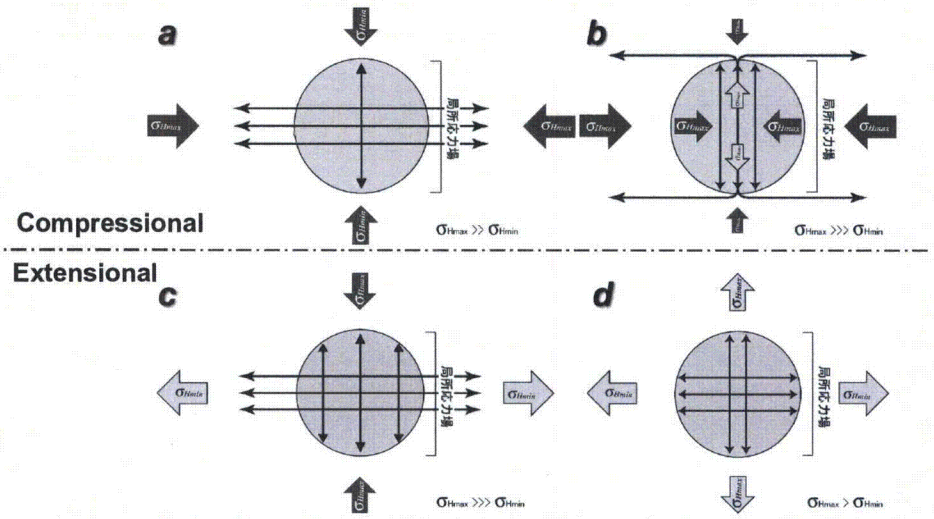
○ : velocity perturbation < -4%
potential magmatism in the mantle
need careful investigation

Key Phenomena related to volcano distribution → **Evaluation (example)**

Migration of magma from existing volcanoes



◆ Relationship between vent migration and volcanic features (Ishizuka, 1999)



◆ Relationship between preferred orientation of vein growth and stress distribution (Miura, et.al., 2006)

Indicator for tendency of migration

- **No central vent** (monogenetic volcanoes)
- **Decreasing eruption rate** (or constant low rate)
- **Mafic magma activity** (or change to mafic composition)

If more than one apply, magma tends to migrate

Indicator for preferred orientation

- **Orientation of vent alignment**
- **Orientation of regional stress**
  - **in compressional regime: σ*Hmax***
  - **in extensional regime: σ*Hmin***
- **Orientation of strike-slip fault**

If more than one apply, the area is in a preferred orientation of magma migration

Siting Factors for uplift and erosion

Site-specific Evaluation Factors (SSEF)

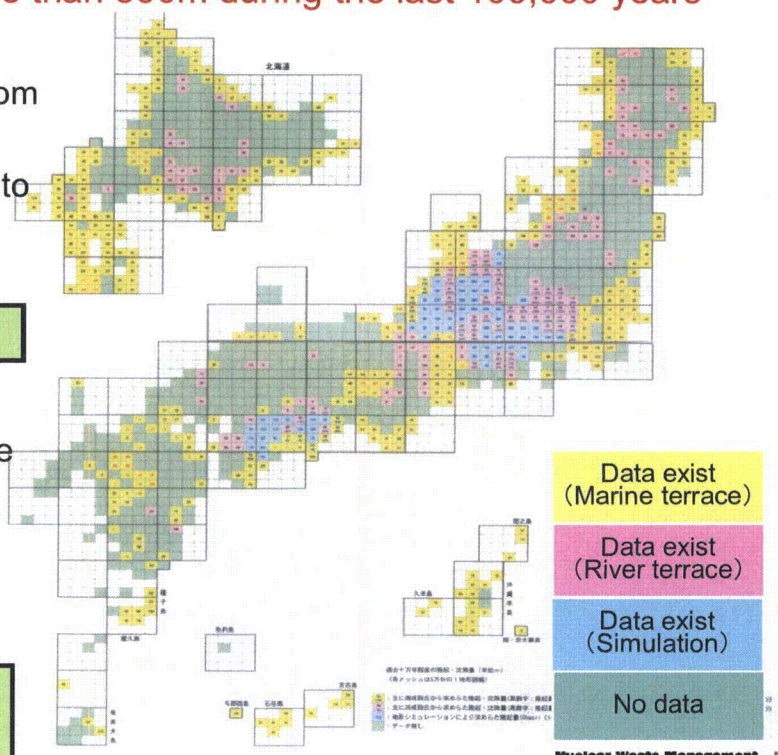
Areas with clear evidences of uplift more than 300m during the last 100,000 years will be excluded from PIAs

- ◆Trend of future uplift can be estimated from analyses of existing terraces
- ◆Long-term behavior of erosion is difficult to estimate

Conservative evaluation : Uplift = Erosion

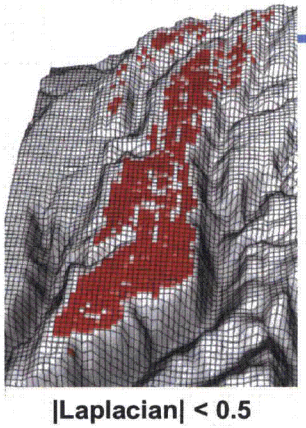
- ◆Adequate disposal depth will make the effect of approaching waste to the surface due to uplift and erosion less significant
- ◆Final Disposal Act defines the disposal depth as 300m or greater

Exclusion criteria: Uplift more than 300m during the last 100,000 years



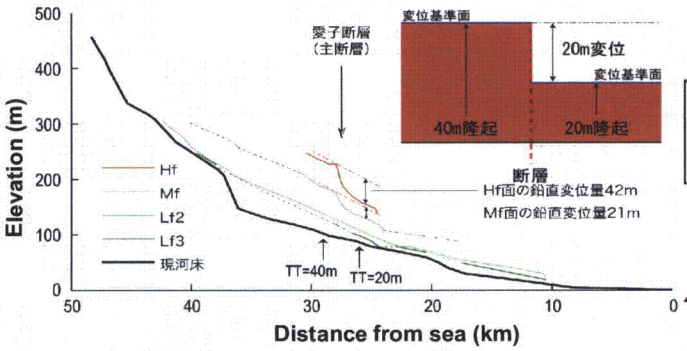
Improved assessment of uplift/erosion

River terrace



|Laplacian| < 0.5

◆ Correlation of river terraces using DEM data



◆ Detailed correlation of river terraces: difference in elevation ⇒ consistent with fault displacement

Investigation planning for:
- Distribution of terraces
- Stratigraphy and age of terraces
- Relative elevation (indicator of uplift)
- Distribution of uplift/subsidence
- Initial model of uplift/erosion

Uplift/subsidence
- Surface mapping
- Dating of geological formations
- Dating of terraces
- Borehole surveys
- Trench surveys

Maximum erosion
- Geophysics
- Borehole surveys
- Dating of geological formations

Target of investigations
- Amount and distribution of uplift/subsidence in the past

Target of investigations
- Maximum amount of erosion in the past

Items of evaluation
- Amount and distribution of uplift/subsidence in the future

Items of evaluation
- Maximum amount of erosion in the future

Uplift/subsidence model

Conformity with favorable factors

◆ Flow chart for evaluation

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Probabilistic tectonic hazard assessment

Step 1 Data gathering
- Area: $10^4 \sim 10^5$ km²
- Literature and database information (topography, geology, geophysics, volcanism, active fault, uplift, GPS, seismicity)

Step 2 Dataset preparation
- Check contents and quality of data
- Correction/addition for improvement

Step 3a Data analyses on volcanism
- Classification/grouping of volcanoes
- Geophysical data analysis
- Conceptual models, alternative models
- Event definition of volcanism

Cladistic Analysis

Step 3b Data analyses on rock deformation
- Data processing: GPS, seismicity, surface deformation
- Conceptual models, alternative models
- Setting parameters and weights

Expert Elicitation

Logic Tree

Volcano-tectonic interaction

Step 4a Probability mapping of volcanism
- Kernel method, Cox Process method
- Setting smoothing parameter
- Probability maps for each group

Step 4b Strain rate mapping
- Conversion to strain rate: GPS, seismicity, surface deformation
- Mapping by Monte Carlo simulation
- Differencing three maps

Step 5 Probabilistic site evaluation
- Area: 5 km x 5 km
- Occurrence of volcanic event
- Occurrence/exceedance of strain rate
- Uncertainty evaluation

Step 6 Interfacing with PA
- Event description (place, timing, duration, extent, magnitude)
- Description of impacting processes
- Assessment in different timeframes

Repository Concepts

Performance Assessment

Step 7 Siting confidence evaluation
- **High:** Low susceptibility of hazards. No need for detailed PA and investigations
- **Medium:** Need detailed PA and further investigations for reducing uncertainties
- **Low:** Need investigations for significant improvement of uncertainties

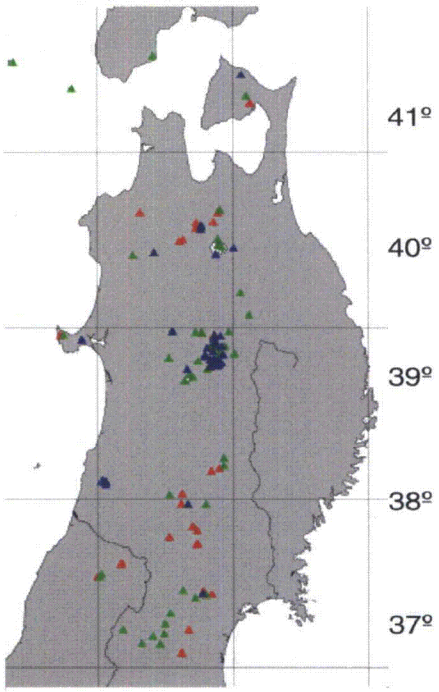
Decision-making on siting

Step 8 Requirement on data
- Data for reducing uncertainties and improving siting confidence levels

Planning investigation programme

Step 3a: Data analysis on volcanism

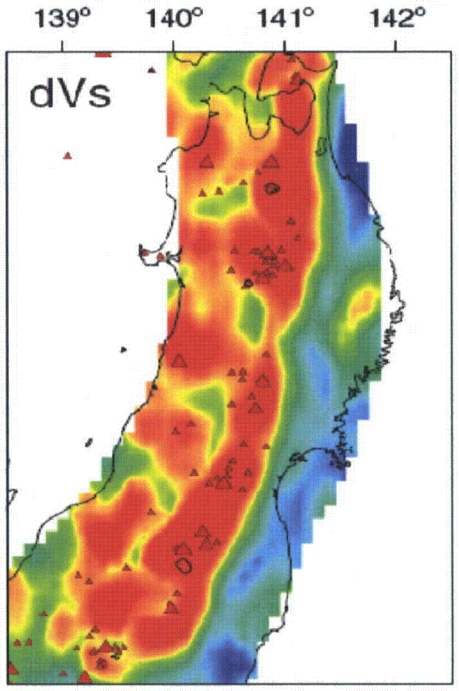
Grouping of volcanoes



▲ Group 3A
▲ Group 3B
▲ Group 3C

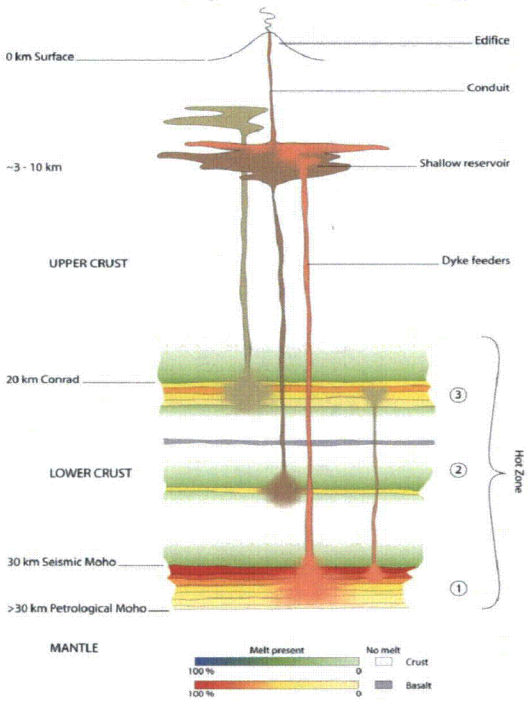
Cladistic analysis

Geophysical data analysis



Hasegawa & Nakajima, 2004
dVs perturbations along the inclined low-velocity zone in the mantle wedge

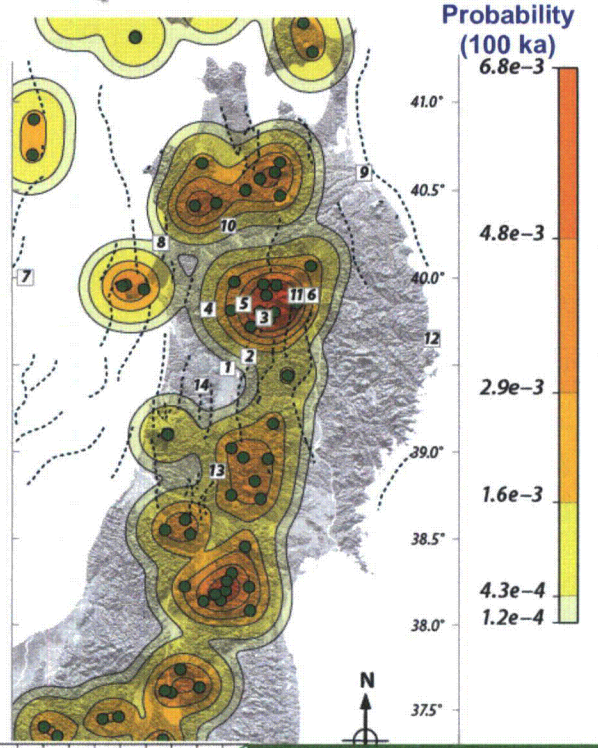
Conceptual modeling

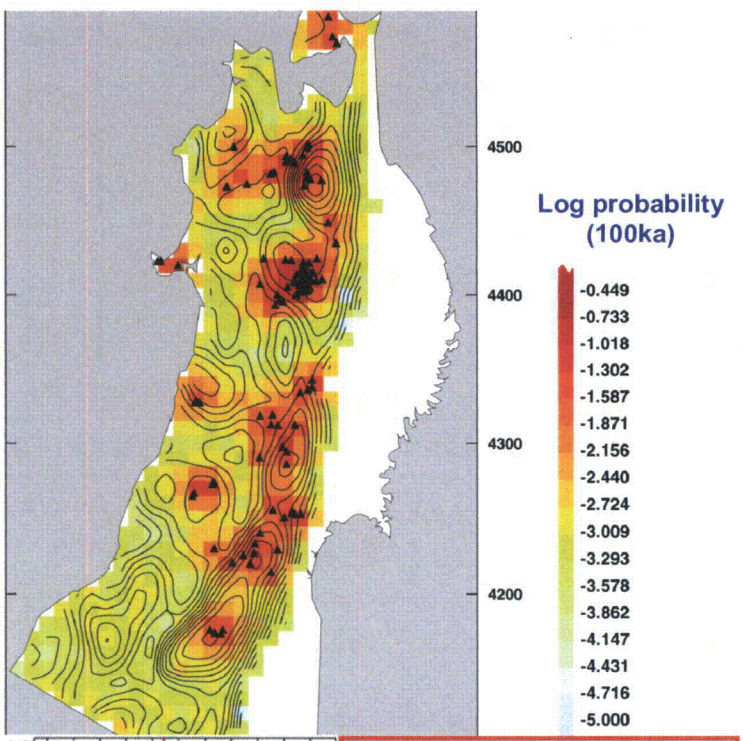


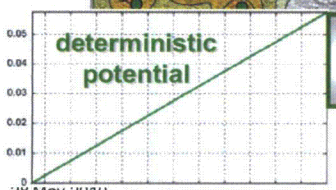
Hot zone model

Volcano hazard increases in areas with geophysical features associated with magma fluxes

Step 4a: Probability maps of future volcanism

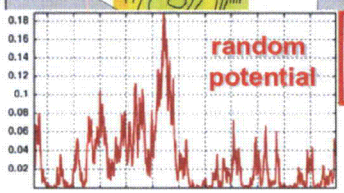






$$P\{N(v)=n\} = e^{-z(v)}\frac{(z(v))^n}{n!}$$

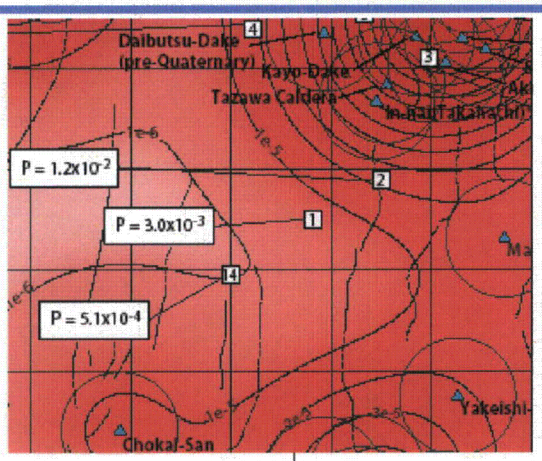
Kernel Method

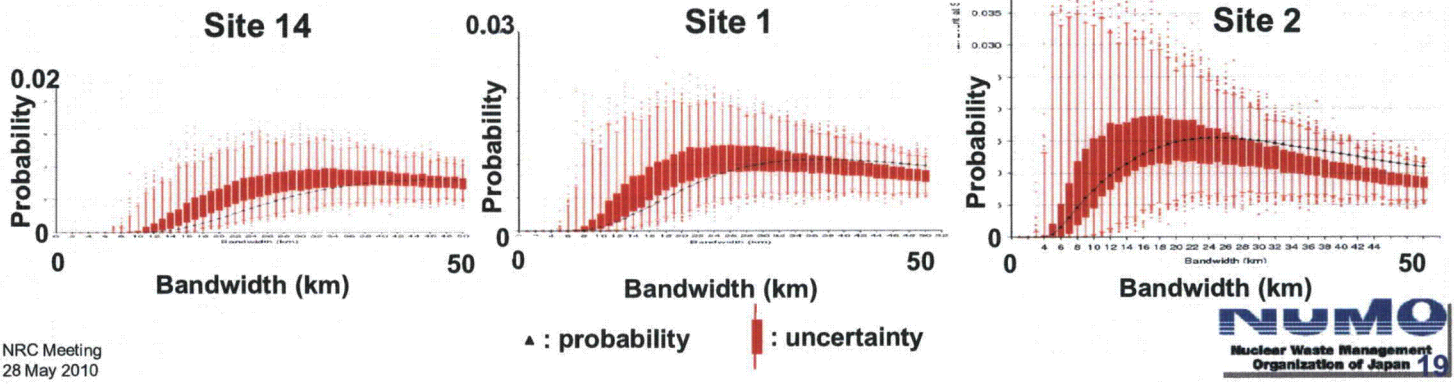


$$P\{N(v)=n\} = E\left\{e^{-Z(v)}\frac{(Z(v))^n}{n!}\right\}$$

Cox Process Method

Step 5: Probabilistic site assessment - volcanism -





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28 May 2010

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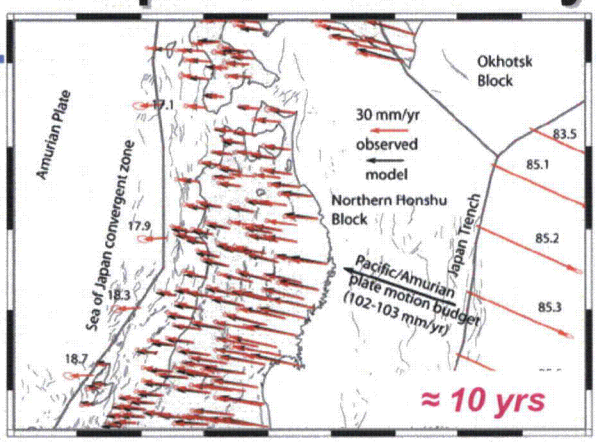
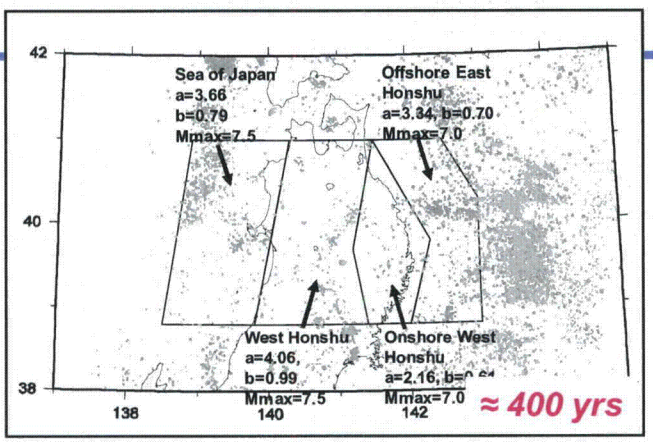
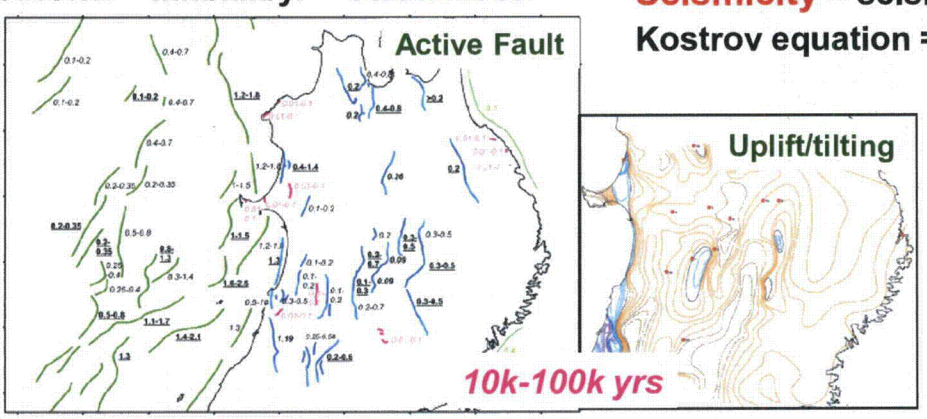
Step 3b: Data analysis on rock deformation





GPS velocity gradient = mm/km/yr = strain rate

Seismicity = seismic moment + Kostrov equation = strain rate



Surface deformation (slip or tilting rate) = mm/km/yr = strain rate

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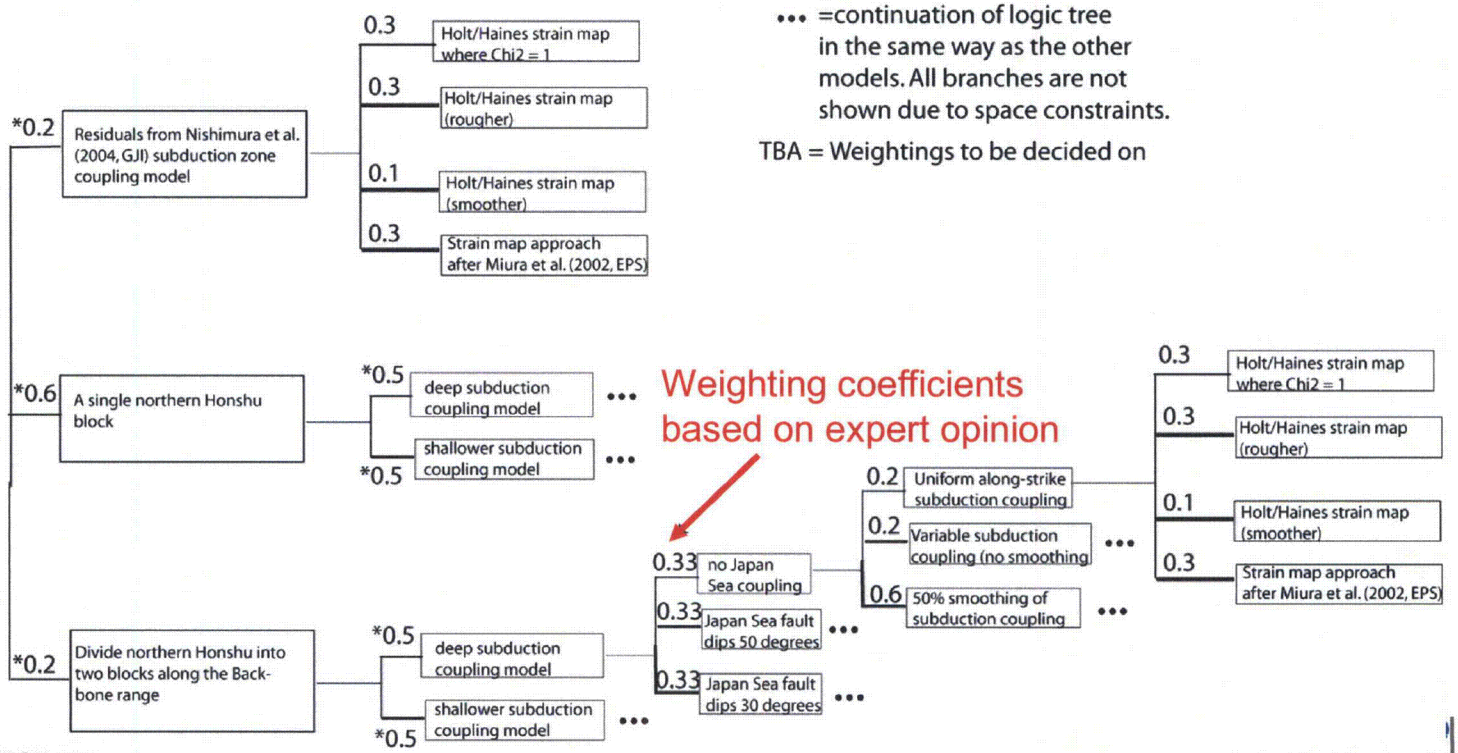
Step 3b: Logic tree development

GPS logic tree for probabilistic strain map

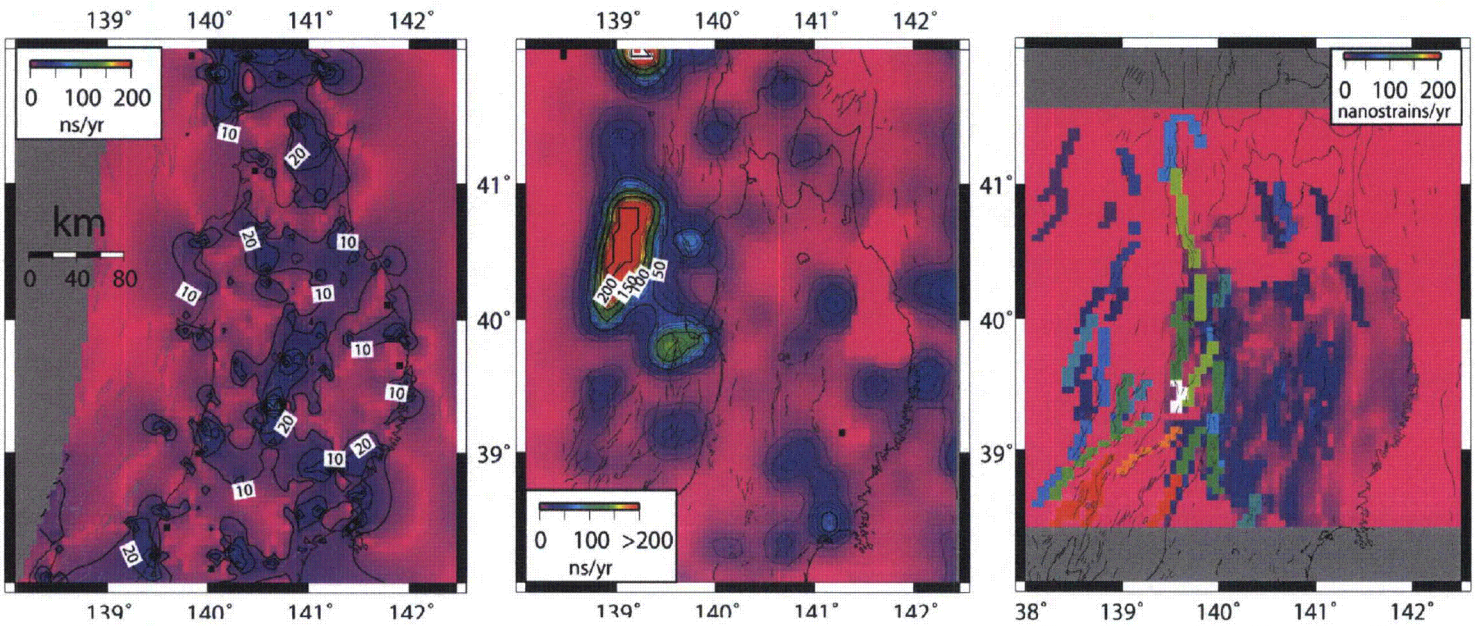


••• =continuation of logic tree in the same way as the other models. All branches are not shown due to space constraints.

TBA = Weightings to be decided on

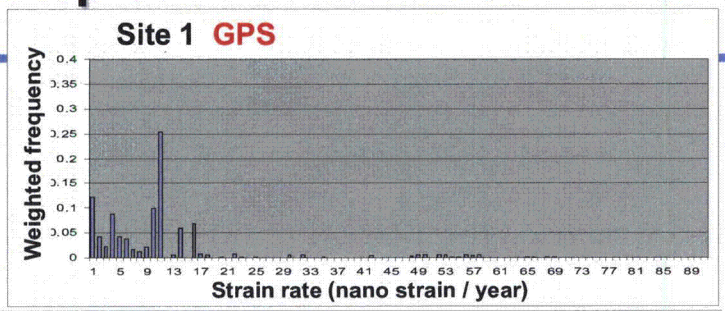
Step 4b: Probabilistic strain mapping

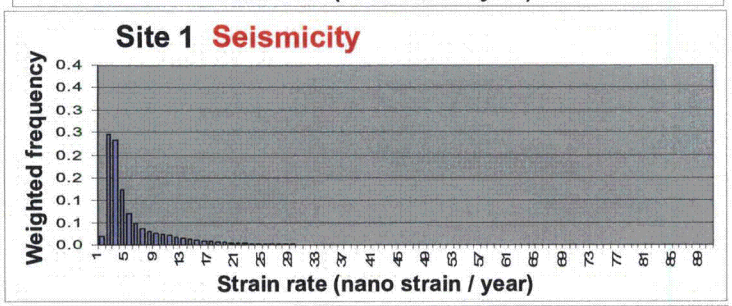
"Best-estimate" strain models

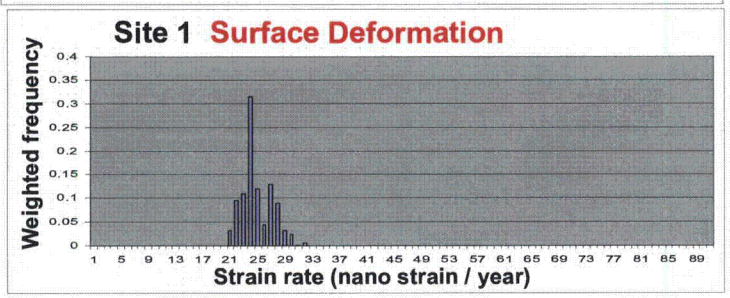


GPS | Seismicity | Surface Deformation (active fault + tilting)

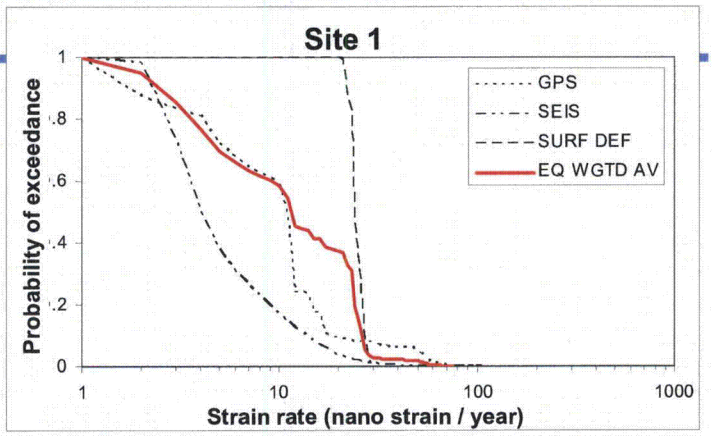
Step 5: Probabilistic site assessment - rock deformation -



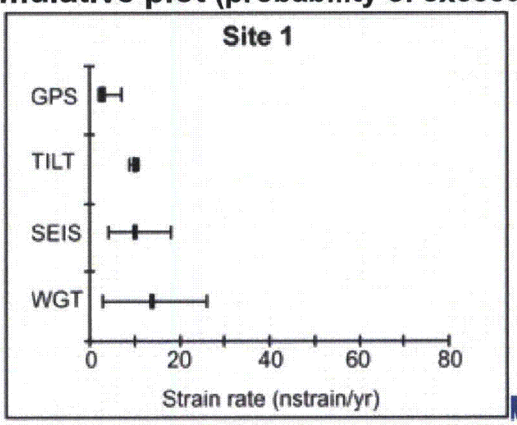




◆Frequency (probability) histogram



◆Cumulative plot (probability of exceedance)



◆Uncertainties (1σ) of strain rate

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Conclusions

- It is considered that the PIAs and DIAs can be selected with a certain degree of confidence by applying the improved deterministic approach.
- The probabilistic approach, which provides a quantitative measure for assessing tectonic hazards and inherent uncertainties, will complement the deterministic approach.
- These approaches will be more reliable by incorporating the results of independent studies performed by other domestic research institutes.

Overview of Research on Geosphere Stability for Long-Term Isolation of Radioactive Waste

Neotectonics Research Group (NRG)
Japan Atomic Energy Agency (JAEA)

Specific geotectonic conditions of the Japanese islands

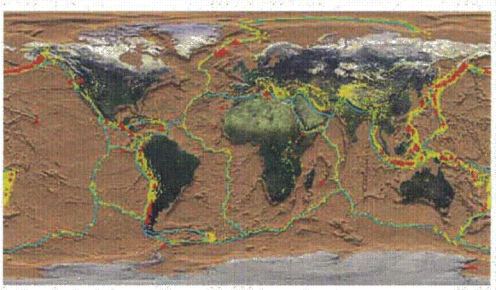
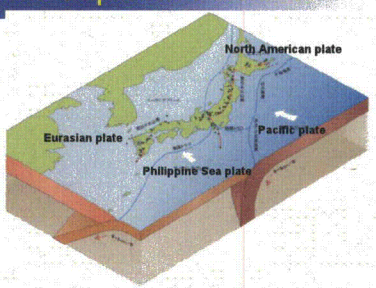
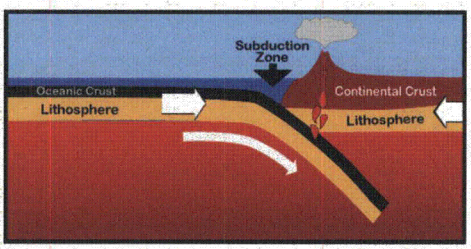


Plate boundaries (blue lines), the distribution of recent earthquakes (yellow dots) and active volcanoes (red triangles).



Location of 4 plates around Japan

Ten percent of the World's active volcanoes are found and more than 1,500 earthquakes are recorded per year in Japan.



Conceptual model of volcanism in subduction zone

Safety concept of geological disposal in Japan

Geological characteristics of the Japanese islands, especially with regards to geosphere stability

The Japanese Islands are located in the tectonically active circum-Pacific belt (the Ring of Fire), so earthquakes and volcanic eruption frequently occur...

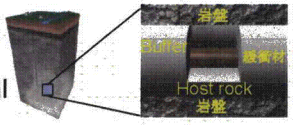
Disturbing the isolation function of geosphere
(Isolation Failure scenarios)

Two potential impacts of geotectonic events on geological disposal system

Disturbing the expected safety function of geosphere
(Perturbation Scenarios)

Site selection

Selection of tectonically stable regions for geological disposal



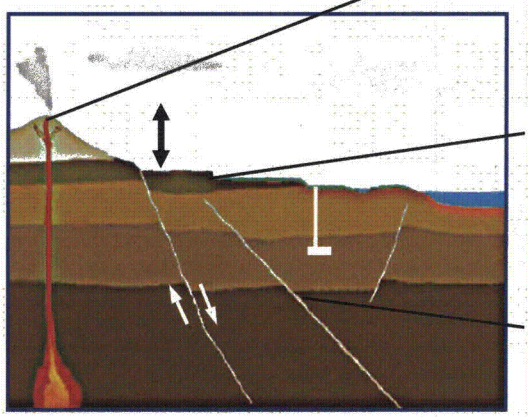
Engineering measures

Design and installation of the engineered barrier system suitable for the future changes in hydraulic condition etc.

Safety assessment

Confirmation of the safety of the constructed geological disposal system

Possible geotectonic events affecting the geosphere stability



(Japan Atomic Energy Commission, 1997)

【Volcanism】
- Destruction of the repository due to magmatic intrusion and transport of waste to the surface by eruption
-Changes in geothermal and hydraulic gradients due to hydrothermal activity

【Uplift / Sea-Level change】
- Exposure of the repository due to large-scale denudation and transport of waste to the surface
- Changes in hydraulic gradient due to topographic and sea-level changes

【Faulting】
-Destruction of the repository due to intersection of new faults and fractures
-Changes in groundwater flow system and hydrochemistry due to formation of permeable flow paths

JAEA's Research and Development program

Objectives

To provide scientific base focusing on assessment of the geosphere stability for geological disposal

R&D activities

1. To develop research technologies for reconstructing geotectonic events in the past and detecting potential events perturbing geosphere stability in the future
2. To develop prediction methods for evaluating the future changes in thermal, hydraulic, mechanical and geochemical conditions due to geotectonic events

Research technology for potential volcanism

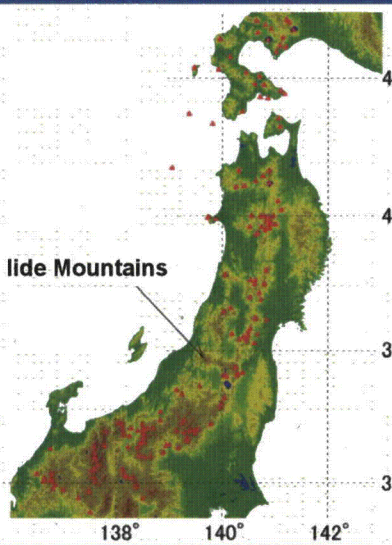
Background

- According to NUMO's siting factors, areas within a radius of 15 km from Quaternary volcanoes are due to be excluded from candidate disposal sites to reduce volcanic hazard in the future.
- To enhance confidence in site selection, it is important to examine the potential for new volcanism at any site regardless of non-volcanic regions.

To provide an integrated approach combining geophysical and geochemical methods to detect the presence of crustal magma storage in non-volcanic regions.

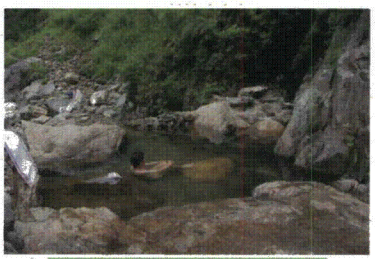
The developed methods will be available for examining the likelihood of new volcanism at any given site.

Research technology for potential volcanism



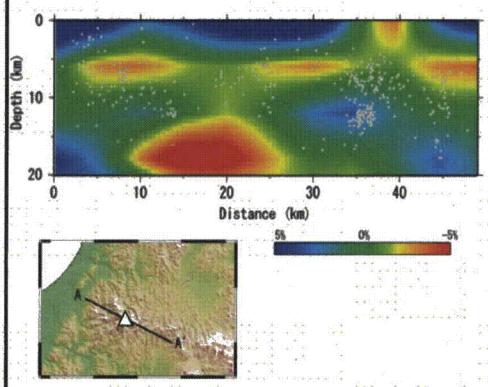
Geographical distribution of Quaternary volcanoes in Northeast Japan

A distant view of the Iide Mountains

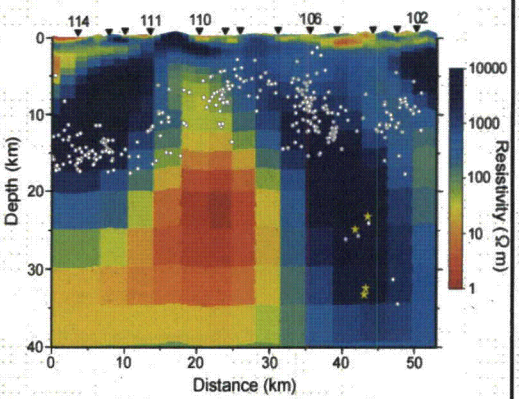


Yunohira hot spring (60℃)

Research technology for potential volcanism



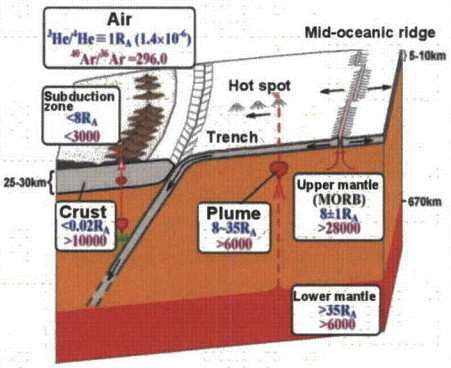
Vertical cross-section of 3D S-wave seismic velocity structure along the line A-A'



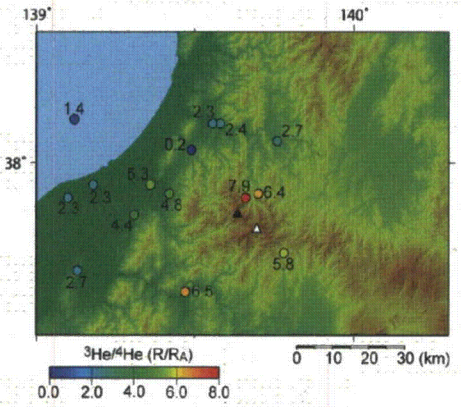
2D resistivity structure along the line A-A'

Geophysical data indicate the existence of materials with temperatures of more than 400 degrees centigrade.

Research technology for potential volcanism



$^3He/^4He$ and $^{40}Ar/^{36}Ar$ end-members in the Earth



Geographical distribution of $^3He/^4He$ ratios of gases from hot springs around the Iide Mountains

Geochemical data indicate the high-temperature materials are estimated to be newly ascending magma rather than solidified old magma.

JAEA's Research and Development program

Objectives

To provide scientific base focusing on evaluating the geosphere stability of long-term isolation of radioactive waste

R&D activities

1. To develop research technologies for reconstructing geotectonic events and determining the geophysical structure in the crust needed for site selection

2. To develop prediction methods for evaluating the future changes in thermal, hydraulic, mechanical and geochemical conditions due to geotectonic events.

Prediction method for future topographic changes

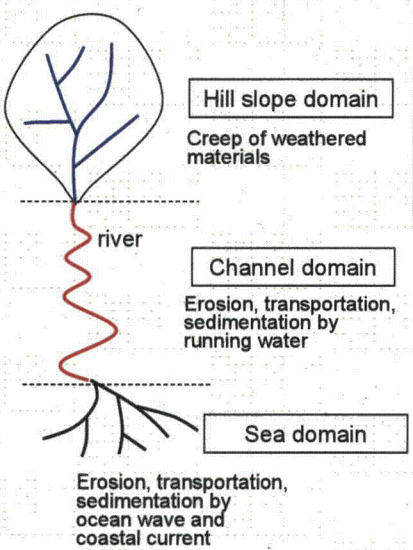
Background

- According to NUMO's siting factors, areas with uplift of more than 300m during the last 100,000 years will be excluded from candidate disposal sites.
- To enhance confidence in long-term safety, it is important to predict the future changes in hydraulic condition due to topographic evolution, and assess whether or not the engineered barrier system suitable for the expected changes in hydraulic condition.

To provide numerical simulation of the future topographic changes that can be useful for evaluation of the changes in hydraulic condition in the future.

The developed methods will be available for engineering measures and safety assessment taken into account perturbation scenario.

Prediction method for future topographic changes

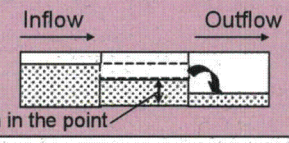


The flux of materials from hill slope domain can be calculated by a diffusion phenomenon dependent on gradient using the following equation:

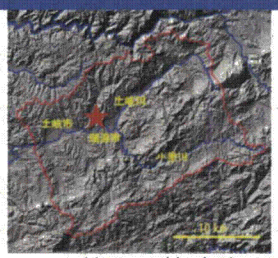
$$\partial u / \partial t = k (\partial^2 u / \partial x^2)$$

where **u** is height at time **t** and position **x**, **k** is the diffusion coefficient.

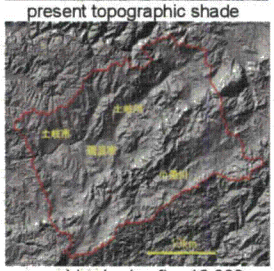
The elevation of each point can be calculated from the balance between inflow and outflow of materials.



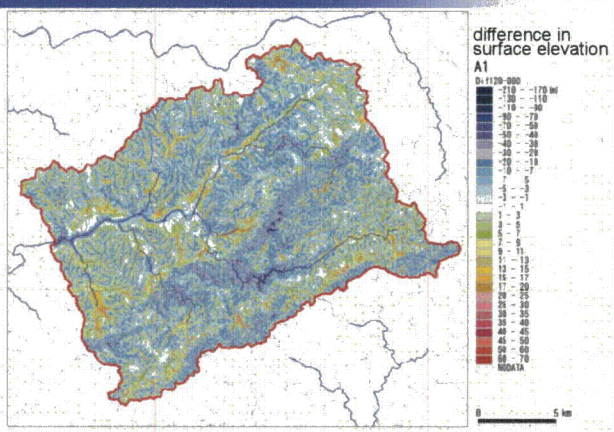
Prediction method for future topographic changes



present topographic shade



topographic shade after 12,000 years



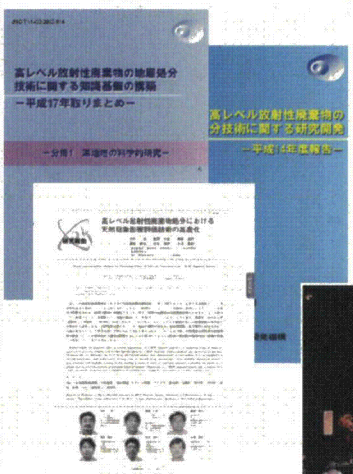
Distribution map showing the difference in surface elevation between present and after 120,000 years (uplift rate of 0.6 mm/y.)

average erosion, 9.09m; average deposition, 5.50m

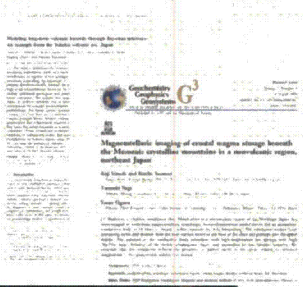
Topography after 12,000 years is not recognized to be remarkable changes, in comparison with that present.

Communication with society

Project reports and annual reports



Report through academic journals and meetings



Press releases