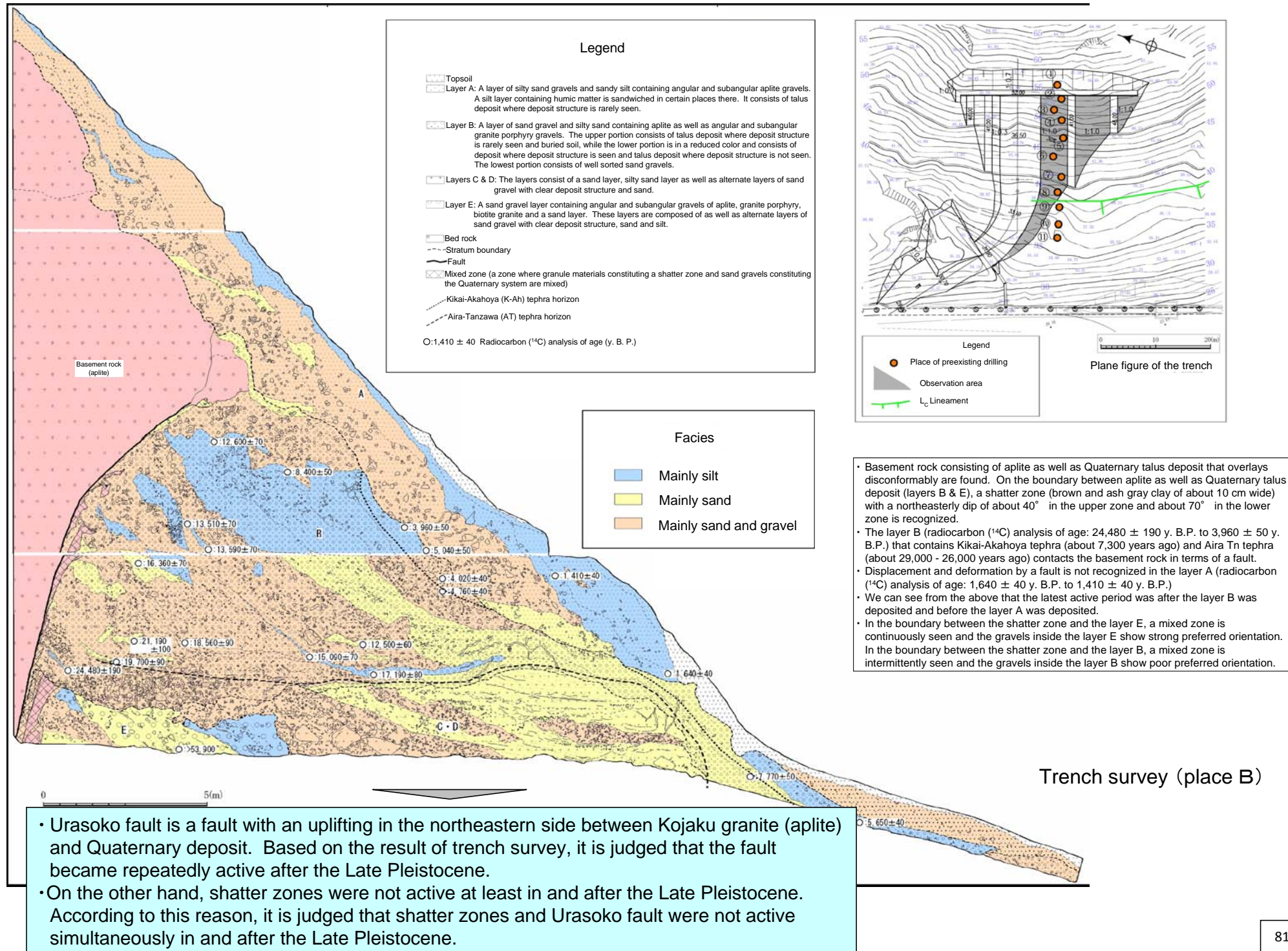


(Draft) EMS's views against JAPC's claim concerning the fault evaluations of Tsuruga PS site, EMS on shatter zones in the site of Tsuruga Power Station		JAPC's opinion	Reference No.
Main texts	Issues		
<p><EMS's views on the claim 4> The evaluation document points out that the D-1 shatter zone could give impacts on the important facilities, by being active working together with the activity of the Urasoko fault near there.</p> <p>This is because the K fault which continues to the D-1 shatter zone is a reverse fault accompanied by left-lateral slip and the possibility it would move, lead by the activity of the Urasoko fault is high as it is extremely close to the Urasoko fault, which is 20 – 30m at the horizontal distance.</p> <p>In addition, the numerical analysis implemented by the operator is the evaluation based on the 'elasticity theory of dislocation'; however, the specialists of seismic back-check in the former Nuclear and Industrial Safety Agency pointed out that it was difficult to confirm the impacts, applying the 'elasticity theory of dislocation' in case it is too close like the case of the Urasoko fault. The EMS inherited the stance.</p>	<ol style="list-style-type: none"> 1. The possibility that the D-1 shatter zone would become active, lead by the activity of the Urasoko fault is high. 2. The EMS inherited the opinion of the specialists of seismic back check in the former Nuclear and Industrial Safety Agency that it is difficult to confirm the impacts, applying the 'elasticity theory of dislocation' in case it is too close like the case of the Urasoko fault. 	<p>(Outline of today's explanation (Original thoughts)) - The operator implemented the evaluation for the simultaneous activities of the D-1 shatter zone and the Urasoko fault <u>based on the activity record and the numerical analysis.</u></p> <p><Evaluation based on the activity record> ☞The latest activity period of the Urasoko fault is after approx. 4000 years ago and the average interval of the activity is 5,000 years ± 2,000 years (AIST, etc 2012); however, the D-1 shatter zone has not been active at least since approx. 120,000 years ago. ☞Therefore, it is considered that the Urasoko fault has become active 10 – 40 times since approx. 120,000 years ago while the D-1 shatter zone has never been active in that period. ☞In addition, it is considered that the Urasoko fault and the D-1 shatter zone should not simultaneously become active in future, too, considering the view that the regional stress field has not changed since the Late Pleistocene.</p> <p><Evaluation based on the numerical analysis> ☞The bearing capacity of the ground which contains the D-1 shatter zone when being impacted by the activity of the Urasoko fault is evaluated by implementing the numerical analysis. ☞In the numerical analysis, 'basic study' and 'study to consider uncertainty' were implemented first in the ground deformation analysis based on the 'elasticity theory of dislocation' which assumes the ground as an elastic half-space to extract the evaluation conditions for obtaining the most strict result for the bearing capacity evaluation of the reactor building foundation. ☞After that, it was analyzed based on the evaluation conditions, applying the FEM model which is made, considering the topography, the ground structure, the ground property and the nonlinearity of the ground, etc for which the 'elasticity theory of dislocation' cannot be applied in detail while the stability of the shatter zone was evaluated based on the local safety factor obtained from the FEM analysis result. ☞Though the result shows shear failures and induction of tensile stresses in the shatter zone near the Urasoko fault, the area is limited while the local safety factor of the shatter zone near the building is sufficiently large. Therefore, it is concluded that the bearing capacity of the ground is sufficiently strong.</p> <ul style="list-style-type: none"> • In addition, the purpose of the numeric analysis implemented by the operator is to evaluate 'if the shatter zone under the reactor building could be broken by the tensile stress in the ground induced due to the activity (displacement) of the Urasoko fault' and it is the evaluation for the ground stability, in other words. • Therefore, it is not the evaluation for calculating the displacement magnitude of the shatter zone. • Such method for the ground stability evaluation is widely applied in the field of geotechnolgy. <p>(Points to be clarified by EMS)</p> <ul style="list-style-type: none"> • The operator has been implementing the evaluations for the simultaneous activities of the D-1 shatter zone and the Urasoko fault based on the following process and is that correct? ☞'The regulatory guide for reviewing seismic safety design of nuclear facilities for power generation (approved by Nuclear Safety Commission as of December 20, 2010) instructed that the fault displacements due to earthquakes should be evaluated by calculating the displacements / deformations of the ground where buildings and structures are established due to the fault displacements. Complying with the guideline, the evaluation was implemented by the numeric analysis to identify whether a gap could be made or not due to the activity of the Urasoko fault in the surrounding shatter zone including the D-1 shatter zone. ☞Being instructed by the former NISA as of November 11, 2011 'to show the evaluation method of the geological displacements around the active layers in Tsuruga NPP and implement impact evaluations for the reactor building, etc, applying the concerned method', we have been implementing the evaluations. ☞The operator presented the additional survey plan of the site in the opinion hearing meeting of the former NISA regarding earthquakes and tsunamis as of May 14, 2012 and explained that 'it is evaluated comprehensively based on the results of various geological surveys and the numerical analysis, etc in case it is difficult to evaluate it by overlying strata analysis method'. • The former NISA discussed that 'it should take time to review the applicability' and 'it is necessary to evaluate more in detail' as for the elasticity theory of dislocation; however, it only pointed out that the theory should be evaluated carefully but did not mean that it was inapplicable. • In addition, though the EMS expressed that 'they would inherited the stance', the EMS and 'The study team on the new safety design standards for earthquakes and tsunamis for light water reactors for electric power generation' have not discussed the application of the elasticity theory of dislocation, at all. We would like to know the process how they reached to the conclusion to inherit the stance. • Though the possibility that the D-1 shatter zone could move, lead by the activity of the Urasoko fault was pointed out, we would like to know what sort of mechanism was assumed when you meant by 'lead by the activity' and how large the impact would be. 	79-135

Consideration based on the history of activity

Activity of Urasoko fault (Overlying strata analysis method)



Evaluation of simultaneous activities based on history of activity

Contents	Urasoko fault	D-1 Shatter zone
Latest activity	<u>After about 4,000 years ago</u>	<u>No activity</u> in and after the Late Pleistocene <i>D-1trench</i>
Average activity interval	<u>5,000 years ±2,000 years</u> ※	—
Activity times for the past about 120,000 years	<p style="text-align: center;"><u>Over 10 ~ 40</u> <i>120,000years ÷ average activation interval</i></p> <div style="border-left: 1px solid black; border-right: 1px solid black; border-radius: 15px; padding: 10px; margin: 10px auto; width: 80%;"> <p style="text-align: center;">In the trench at place B, there are signs which indicate moving more than one time after 60,000 years ago. (DKP ash fall)</p> </div>	<u>No activity</u>

※ Survey on active faults in coastal zones; Yanagase and Sekigahara fault zones; Urasoko-Yanagase fault belt; Report of Results; May 2012; the National Institute of Advanced Industrial Science and Technology & Tokai University; p33

Evaluation based on the numerical analysis

Table of Contents

1. Introduction
 2. Outline of Urasoko-Uchiikemi fault
 3. Flow of evaluations
 4. Investigation for Urasoko fault and area in the vicinity of the facility
 5. Examination based on “the elasticity theory of dislocation”
 6. Vertical two-dimensional FEM analysis
 7. Horizontal two-dimensional FEM analysis
- <Information>

1. Introduction

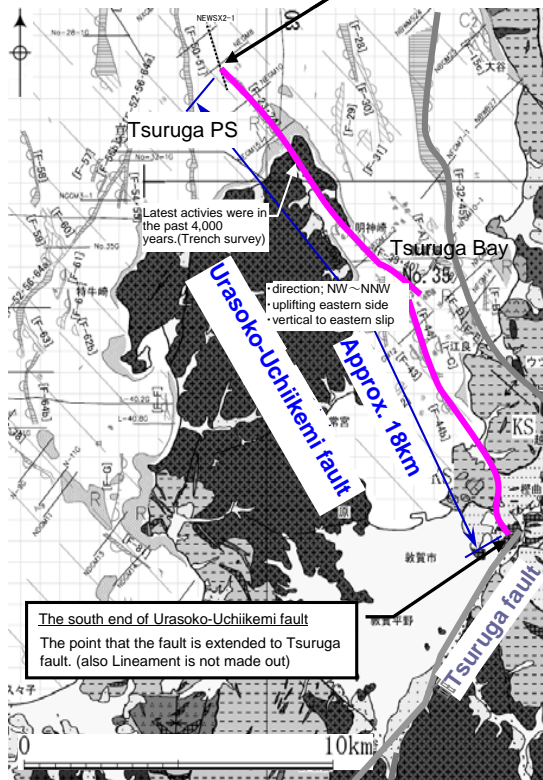
- The Nuclear and Industrial Safety Agency requested “Clarification of the assessment method for heterotaxis in the vicinity of the active fault at Tsuruga PS site and impact assessment of heterotaxis on the reactor buildings or other facilities based on the method” .*
- * ”Regarding Implementation of Safety Assessment Concerning the Impact of Seismic Ground Motion and Tsunami on the Nuclear Facilities Based on the Knowledge of the 2011 Off the Pacific Coast of Tohoku Earthquake “ 11th Nov. 2011, NISA
- In accordance with the direction, the assessment methods for displacement and deformation of the ground caused by activity of Urasoko-Uchiikemi fault was organized, and impact assessment on the reactor buildings was considered.

2. Outline of Urasoko-Uchiikemi fault

- Survey results of geography and geology indicate that Urasoko fault runs in a direction of NW-SE and is vertical to easterly dip.
- Because the fault has signs for activities after the Late Pleistocene, the fault is an active fault that should be taken into account in the seismic design, the length is estimated 18km.
- The sea part of the fault is located western edge of higher level surface of C layer (Middle Pleistocene) in Tsuruga bay, the displacement sense is left-lateral slip sense including constituent of uplifting in northwestern side.
- The offset distance between Urasoko fault and centers of unit 1 & 2 reactor buildings is approximately 250m.

The north end of Urasoko-Uchiikemi fault

The point that displacement and deformation has not been recognized in the layer after the Late Pleistocene.



The south end of Urasoko-Uchiikemi fault

The point that the fault is extended to Tsuruga fault. (also Lineament is not made out)

Table Properties list of Urasoko-Uchiikemi fault

Contents	Properties	Main Survey
Direction	•NW – SE	Geography Surface geology Sea surface sonic
Fault dip angle	•generally vertical to easterly dip	Geography Boring Trench Sea surface sonic
History of activity	•active in the past 4,000 years	Trench
Fault length	•18km	Surface geology Sea surface sonic
Displacement sense	•Left-lateral slip including constituent of uplifting in northwestern side	Geography Boring Trench Sea surface sonic

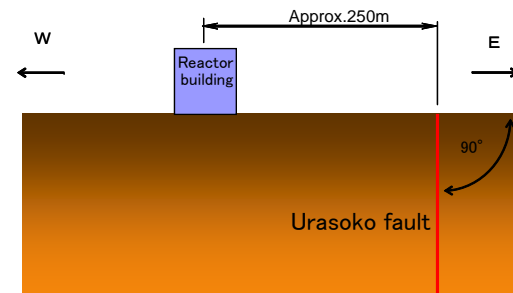


Fig. Urasoko-Uchiikemi fault

Fig. Offset distance between Urasoko fault and the reactor building (Concept map)

3. Flow of evaluations (1)

1. Evaluation contents

- Using numerical analysis in accordance with “Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities” and “Guidelines for Reviewing safety related Seismic Safety of Nuclear Power Reactor Facilities”, JAPC evaluated bearing capacity of the basement ground of reactor building against the displacement caused by activity of Urasoko-Uchiikemi fault.
- ”Influence of displacement of the ground in vertical cross section to the facility” and “Influence of horizontal deformation to the facility in the case which a fault displacement has constituent of lateral slip” were evaluated, referring to ” Guidelines for Reviewing safety related Seismic Safety of Nuclear Power Reactor Facilities“

2. Selection of a numerical analysis method

- Taking into account the situation that the fault is near to the reactor facility and properties of Urasoko-Uchiikemi fault, elasticity theory of dislocation and FEM were selected.

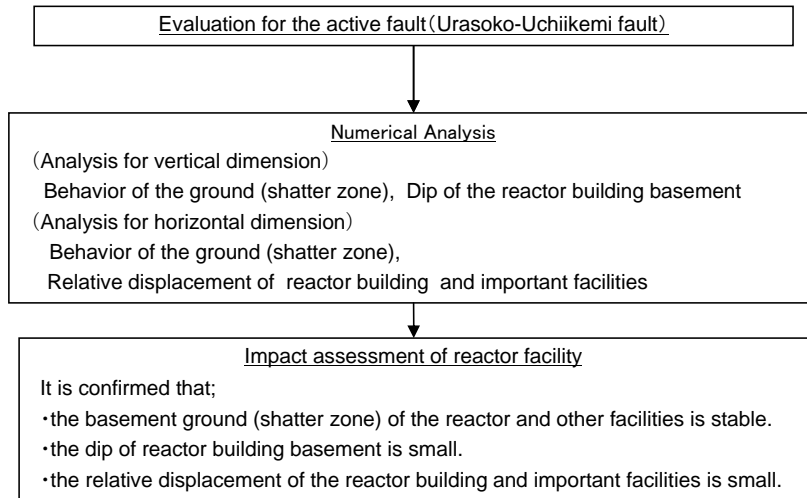


Fig. Evaluation contents

Table Selection of numerical analysis method

Contents	Policies, Supplements	Selection criteria	Main methods
Understanding of the ground behavior affected with displacement caused by Urasoko fault ^① activity, and influence to the reactor building and other facilities.	①Urasoko fault acted repeatedly after at least the Late Pleistocene, and the distribution of fault is understood by geological survey.	Methods inputting slip into advance fault surfaces.	•Elasticity theory of dislocation •FEM (Finite Element Method) •BEM (Boundary Element Method)
Evaluation has to be due to numerical analysis ^② .	②Methods having accomplishments or inspection examples for displacement and deformation of ground are preferable.	Methods used at organizations like Geospatial Information Authority of Japan, or National Research Institute for Earth Science and Disaster Prevention, or U.S. Geological Survey.	•Elasticity theory of dislocation •FEM (Finite Element Method)
<u>Cases took into consideration uncertainties of broken area in a fault, slip, model.</u> ^③	③Because of many cases, comparatively easy methods are preferable.	Methods obtaining analysis solutions during short time.	•Elasticity theory of dislocation
And, careful consideration for the fact that Urasoko-Uchiikemi fault is distributed <u>nearby reactor facilities.</u> ^④	④The actual conditions of ground around the fault should be considered in order to analyze the case that the ground of facilities have large displacement or deformation. facilities	Methods that could represent non-homogeneity and others of the geography and ground.	•FEM (Finite Element Method)

- The Elasticity theory of dislocation is selected to evaluate because of its many accomplishments in principle, and a lot of evaluations take into account uncertainties.
- In addition, FEM(Finite Element Method) analysis is selected, which is able to represents more detailed behavior of the ground of the fault that is near the reactor facilities.

3. Flow of evaluations (2)

3. Procedure of numerical analysis

- In the numerical analysis, “basic study” and “study taking uncertainties into account” have been examined.
- By using the severest conditions, which are drawn up from the evaluation of bearing capacity of the foundation ground, a FEM analysis has been examined based on the elasticity theory of dislocation.

【Analysis conditions】 * Basic parameters and uncertainties have been surveyed

- Geometric shape of the fault (length, width, dip angle, depth)
- Slip of the fault (slip angle, slip quantity)
- Model of the fault (structures, poisson's ratio)

The Elasticity theory of dislocation

- First of all, deformation analysis of the ground at “basic study” and “study taking uncertainties into account” have been examined based on “the elasticity theory of dislocation” with assuming that the ground is semi-infinite elastic medium, and analysis conditions have been drawn up which would produce the severest results in evaluation of bearing capacity of the foundation ground of the reactor building.

Drawing up the severest analysis conditions for the reactor facilities

FEM

- Stability of the shatter zone has been evaluated from local safety factors calculated with detail modeled FEM in which geography/ground structure and physical properties/non-linearity of the geography and others taken into account, and using conditions that would produce the severest results based on the elasticity theory of dislocation.
- Forced displacement has been inputted on the boundary of FEM, which was examined with the elasticity theory of dislocation at the boundary.
- Vertical two-dimensional FEM analysis was used for the examination of vertical slip, and horizontal two-dimensional FEM was used for lateral slip.

Fig. Procedure of the numerical analysis

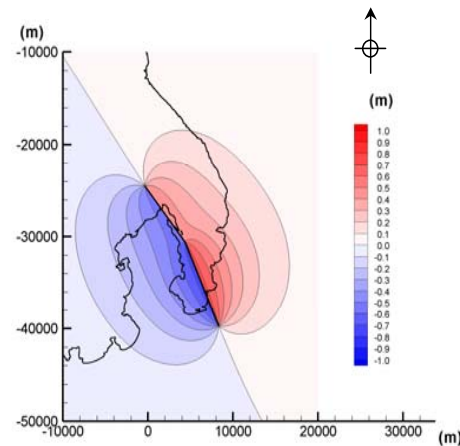


Fig. The elasticity theory of dislocation (distribution of vertical displacement)

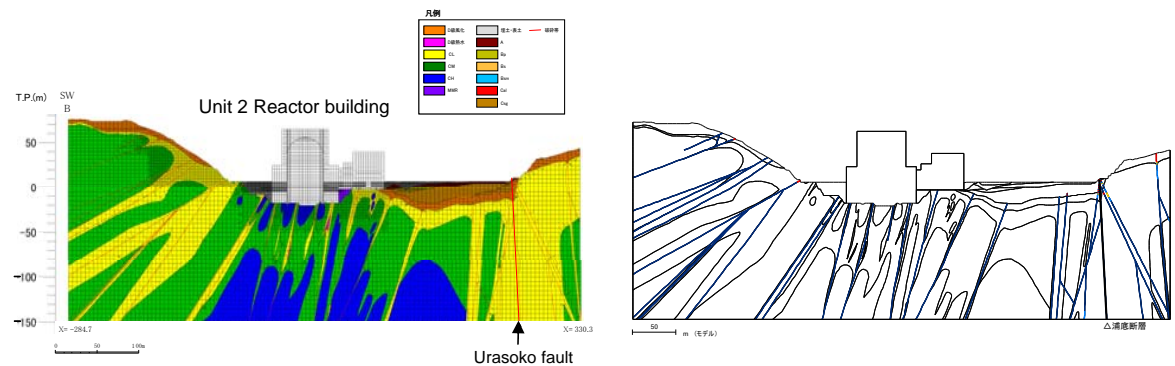
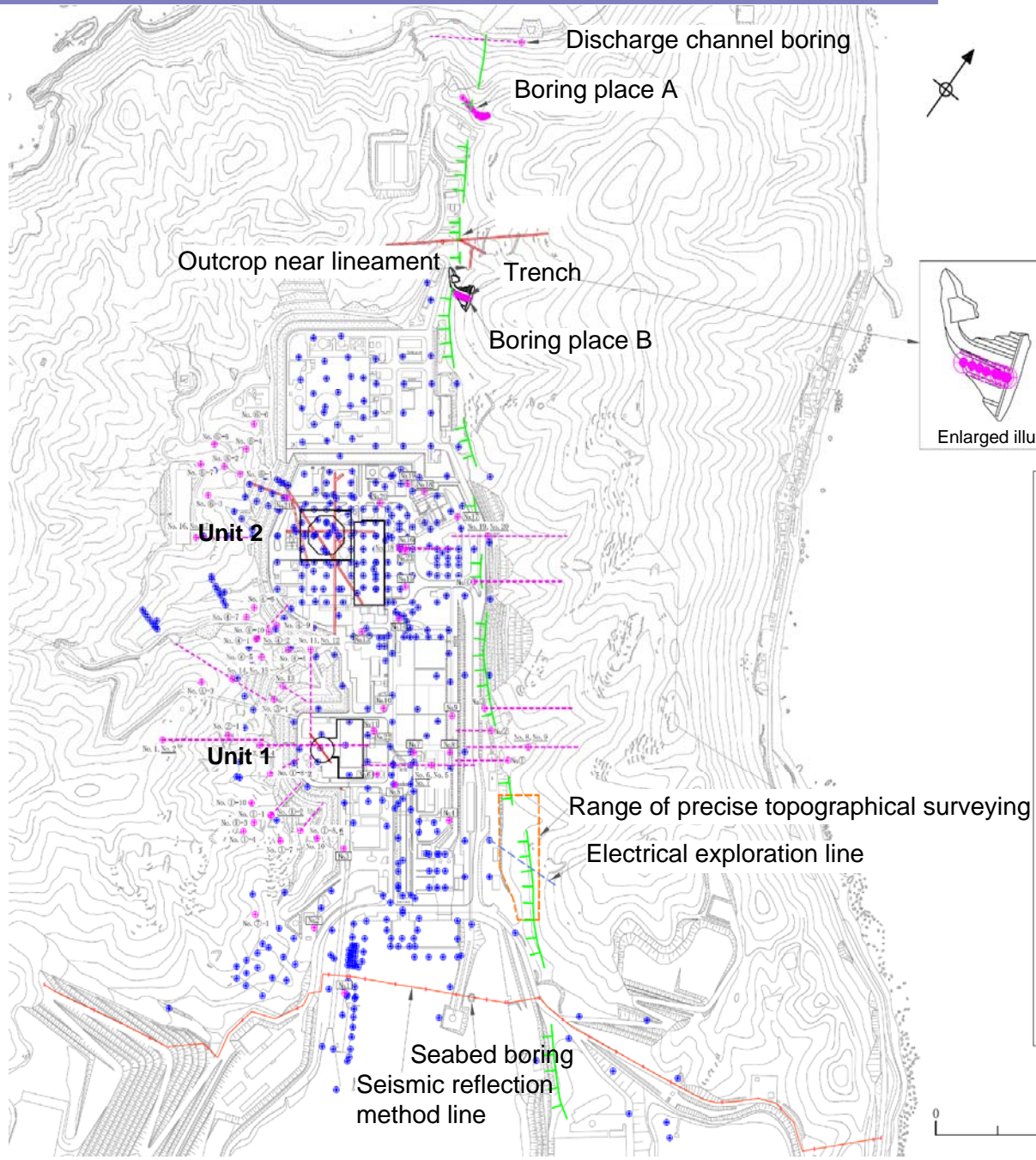
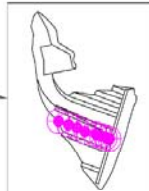


Fig. Vertical two-dimensional FEM analysis (analysis model, distribution of local safety factors)

4. Survey for Urasoko fault and around facilities (1) Survey locations



For Urasoko fault, location and angle and others have been confirmed from surveys in boring or trench or trial pit (when unit 2 was constructed).



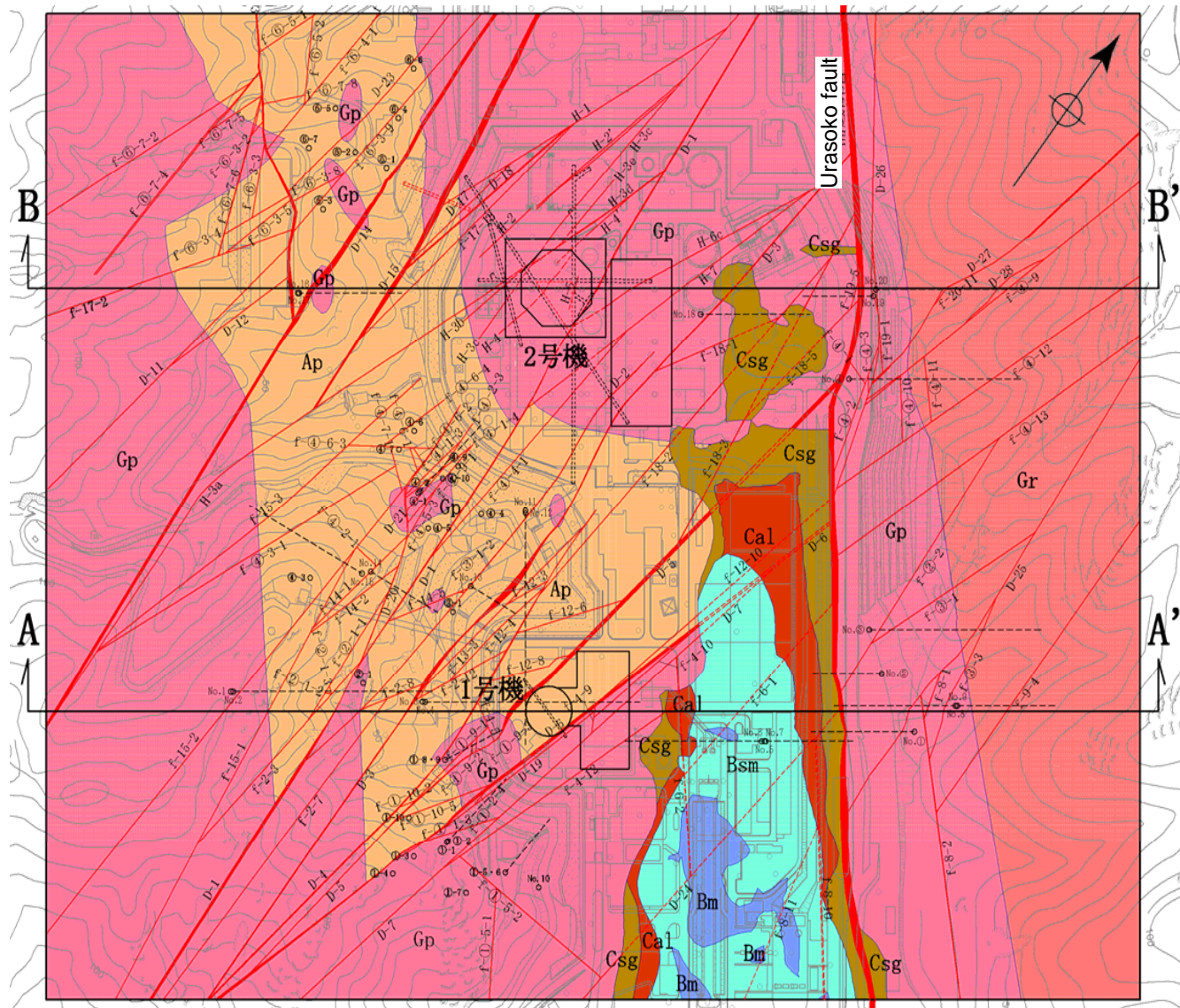
Enlarged illustration of the trench

Legend

- : Lineament
- : Place of preexisting drilling around units 1&2
- / : Place of drilling implemented for seismic back-check of units 1&2 (vertical)(dip)
- : Test pit, trial pit
- : Electrical exploration line
- : Seismic reflection method line
- : Range of precise topographical surveying
- : Trench











4. Survey for Urasoko fault and around facilities (2) Results ① Horizontal geological section (Units 1&2)



- Urasoko fault is distributed NW-SE direction.
- Shatter zones are predominant with directions between N-S and NE-SW.

Geological classification legend

	Bm layer : Enclosed bay deposits (that contains silt, fine sand and shell)	} Quaternary system
	Bsm layer : Enclosed bay deposits (that contains medium sand, coarse sand, granule, silt and shell)	
	Cal layer : Lowland deposits (that contains a large volume of fine sand, medium sand and humus)	
	Csg layer : Fan deposits (that mainly contain gravel, coarse sand, medium sand and humus)	
	Ap Aplite	} Kojaku Granite
	Gp Granite porphyry	
	Gr Biotite granite	
	H-3a Shatter zone and its number	

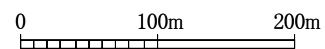
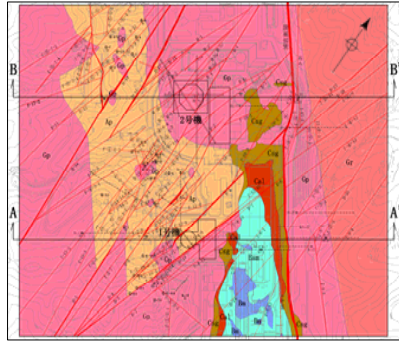


Fig. Horizontal cross section (T.P.-15m)

4. Survey for Urasoko fault and around facilities (2) Results ② Vertical geological section (Unit 1)

- Urasoko fault is a fault with an uplifting in the northeastern, bordered with bedrock and the Quaternary system in the shallows.
- As for dips, middle-angle easterly in the shallows, vertical mainly in the deeps.
- A lot of Shatter zones are high-angle westerly dips, and these have displaced the boundary between rocks types (Gp/Ap boundary).



Location of this section

Geological classification legend

bk	Surface soil and filling soil	Ap	Aplite	Kojaku granite
A	A layer : Alluvial plain deposits and talus deposits (that contain sand, gravel, silt, humus and humic matters)	Gp	Granite porphyry	
Bs	Bs layer : Deltaic deposits (that contains coarse sand, medium sand and shell)	Gr	Biotite granite	
Bsm	Bsm layer: Enclosed bay deposits (that contains medium sand, coarse sand, granule, silt and shell)	H-3a	Shatter zone and its number	Boring
Cal	Cal layer : Lowland deposits (that contains a large volume of fine sand, medium sand and humus)	—	Geological boundary	
Csg	Csg layer: Fan deposits (that may contain gravel, coarse sand, medium sand and humus)			

Quaternary system

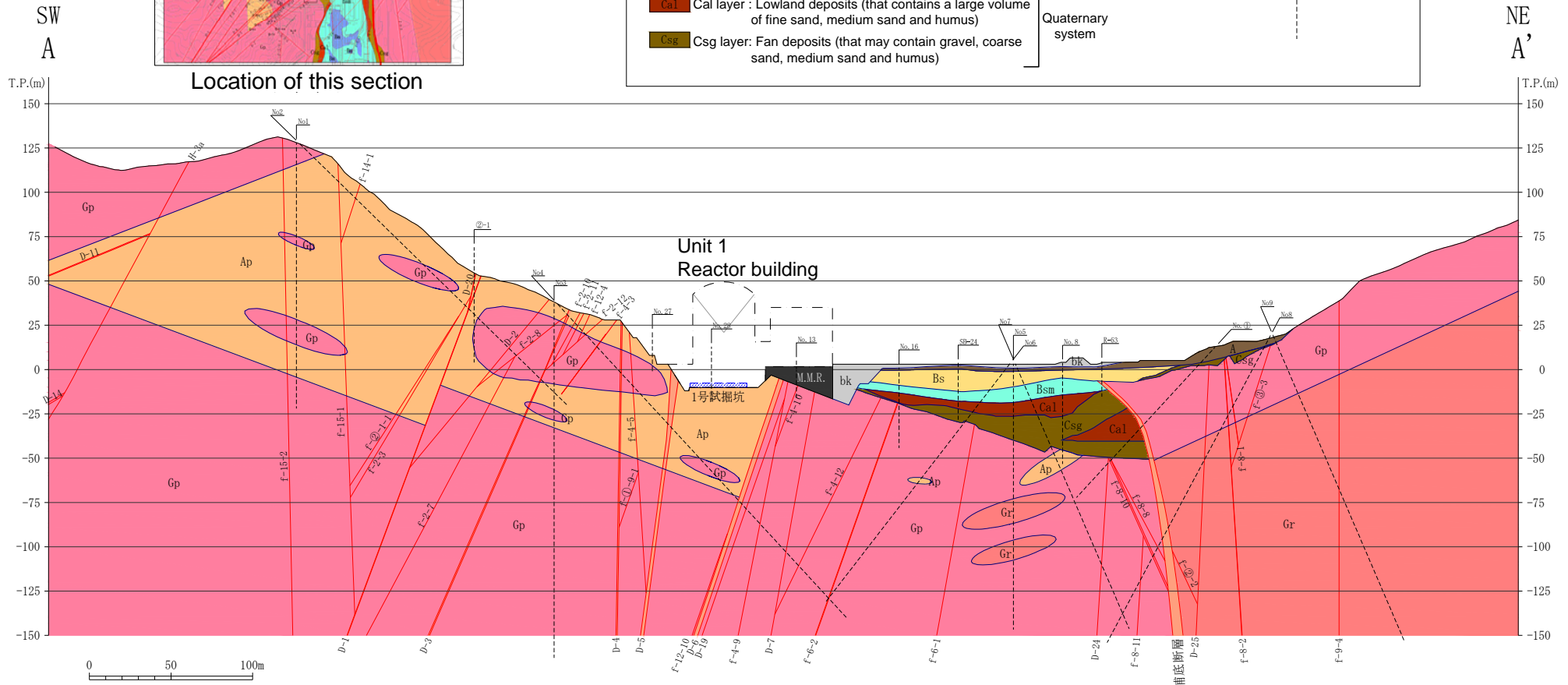
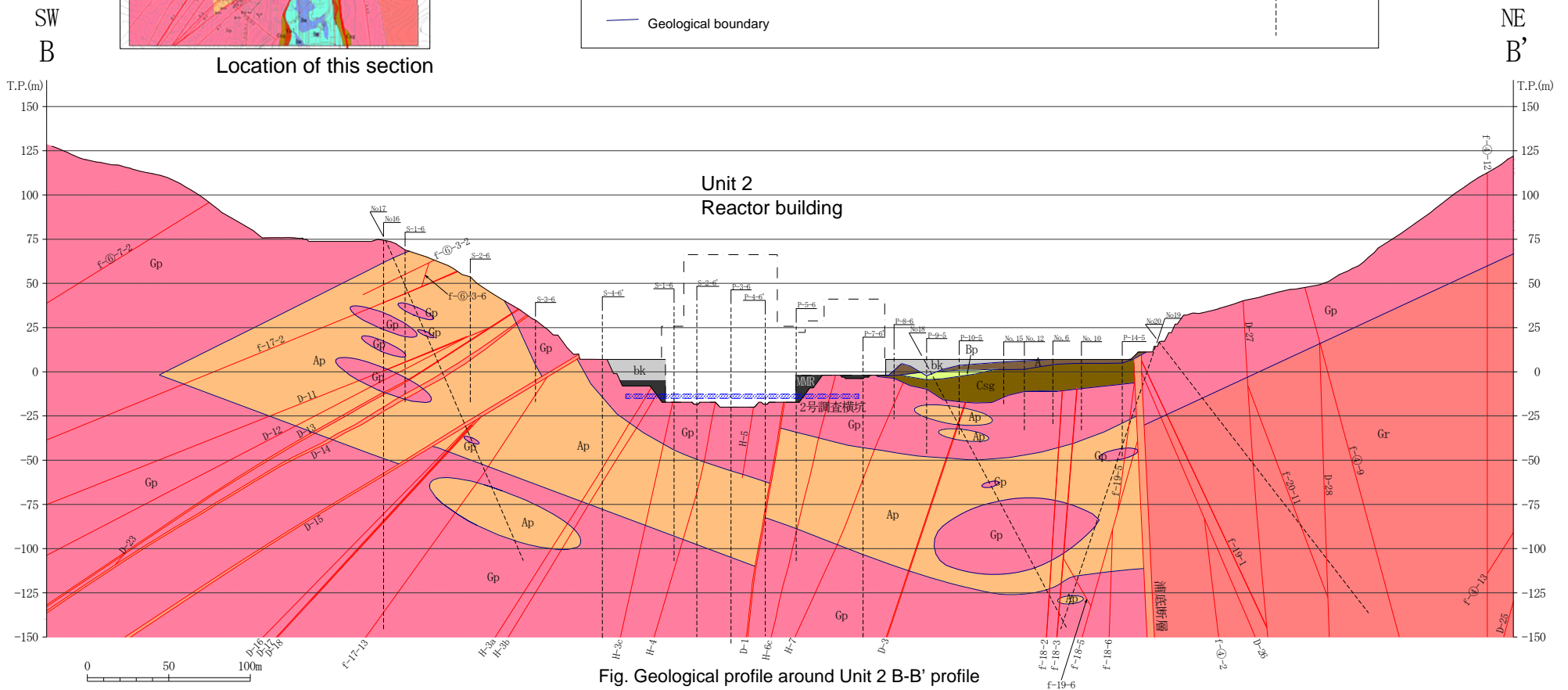
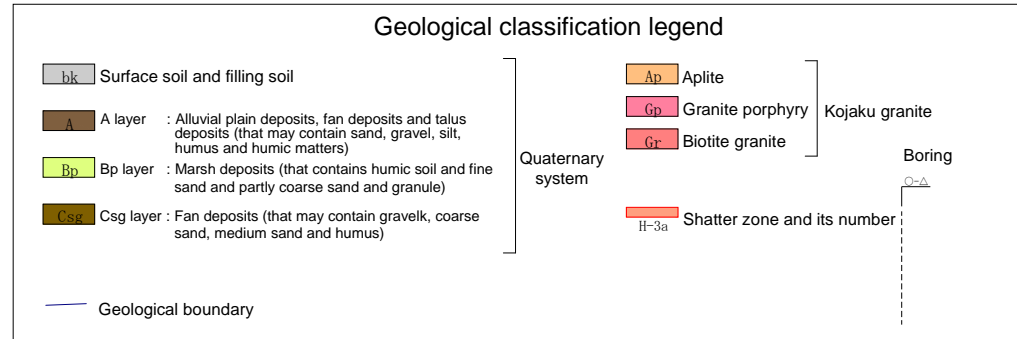
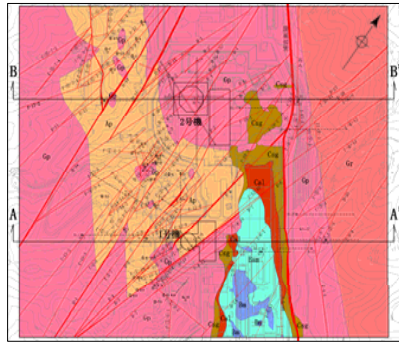


Fig. Geological profile around Unit 1 A-A' profile

4. Survey for Urasoko fault and around facilities (2) Results ③ Vertical geological section (Unit 2)

- Urasoko fault is a fault with an uplifting in the northeastern, bordered with bedrock and the Quaternary system in the shallows. And these have vertical dips mainly.
- A lot of Shatter zones are high-angle westerly dips, and these have displaced the boundary between rocks types (Gp/Ap boundary).



5. Examination based on the elasticity theory of dislocation (1) Policy of analysis

- Based on the elasticity theory of dislocation, we studied vertical displacement (inclination) and horizontal deformation (shearing strain) of the foundation for reactor building to be caused by the activity of Urasoko-Uchiikemi fault.
- We set the conditions of study with using the concept of Tsunami Evaluation Method* as a reference, which is based on geological survey and the elasticity theory of dislocation.
- In conducting study, we also took into consideration the uncertainties of parameters (length of fault, angle of dip, width of fault, etc.) that are used in analysis.

* Tsunami Evaluation Subcommittee, Nuclear Civil Engineering Committee, Japan Society of Civil Engineers (2002)

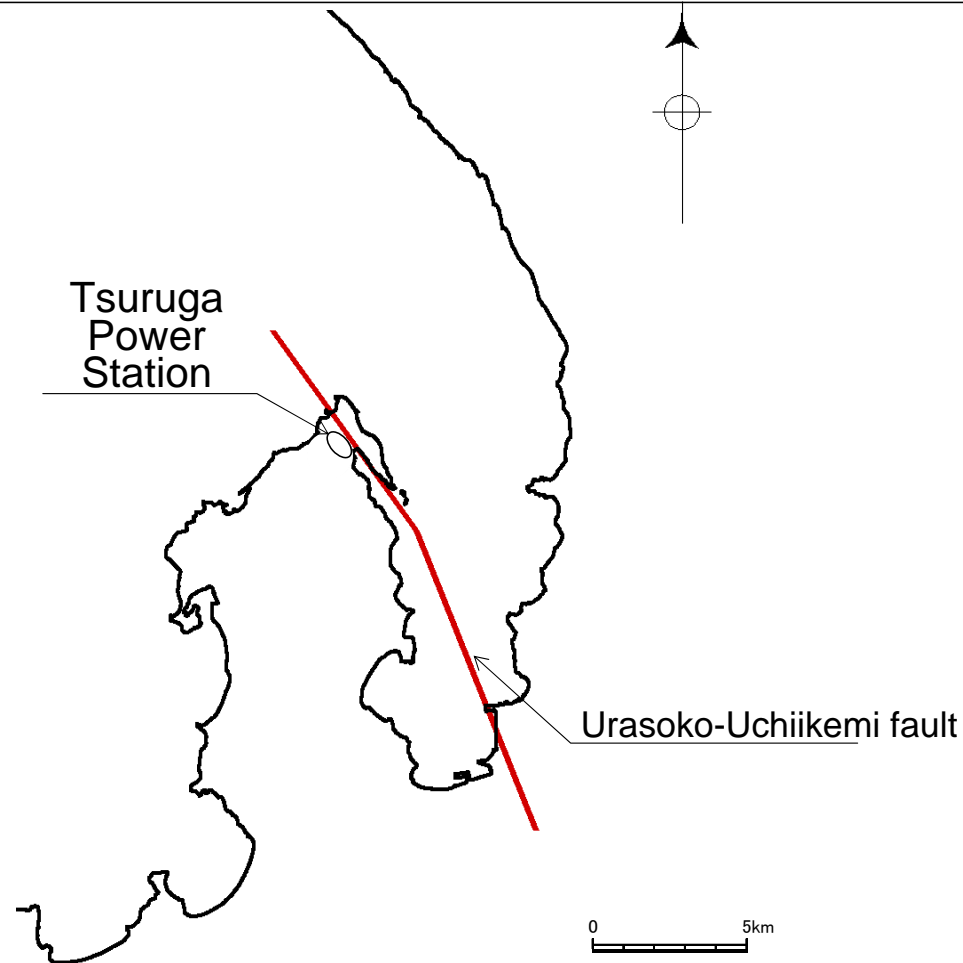


Fig. Modeled fault to be analyzed

5. Examination based on the elasticity theory of dislocation

(2) Analysis conditions

Parameters using in examination based on the elasticity theory of dislocation is organized below.
Basic values of each parameters and uncertainties and its reason are listed.

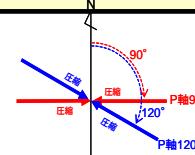
Table Analysis conditions of basic study and study taking uncertainties into account

Urasoko-Uchiikemi fault		Geometric shape of the fault				Slip of the fault		Ground model		
		Length of the fault	Width of the fault	Angle of dip	Depth of the fault	Slip angle (direction of P-axis)	Slip quantity	Structure	Poisson's ratio	
Basic	Basic study (Case ①)	18km (20km equivalently with a width and slip)	13.3km	90°	0km	Calculated from the relation between the fault plate and the direction of compression axis in regional stress field (90° ~ 120°)*1	1.66m	Single-layer model ³ (homogeneous semi-infinite medium)	0.25	
	Reason	•18km: length of the active fault •20km: length set as Ss	“Tsunami Evaluation Technique for Nuclear Power Station” ²	Results of geological survey indicates it almost vertical, it is estimated that the fault has lateral-slip because of its geography and direction and dip, etc.	The fault plate is confirmed to be reached for ground surface from geography.	“Tsunami Evaluation Technique for Nuclear Power Station” ²	“Tsunami Evaluation Technique for Nuclear Power Station” ²	There is a reproduce example using single-layer model.	Ground model in seismic evaluation	
Study taking uncertainties into account	Length of the fault (Case ②)	• 14.6km ~ 13.0km (Fixed south end) • Study for influence of the fault end location. • As Tsuruga PS is located north of Urasoko-Uchiikemi fault, movement of north end could affect to length of the fault (Slip) larger than south end. • Movement range is set to observe peaks of dip angle and horizontal deformation. • Urasoko-ikekawauchi (25km) • As it is one of the uncertainty in seismic evaluation.	13.3km	90°	0km	The slip angle that indicated maximum dip or maximum horizontal deformation in basic study.	Slip quantity due to fault length	Basic study	Basic study	
	Width of the fault (Case ③)	18km	5/6 times 4/6 times 3/6 times • The width is set to be less than a half of the length.	90°	0km	The slip angle that indicated maximum dip or maximum horizontal deformation in basic study.	1.66m	Basic study	Basic study	
	Angle of dip (Case ④)	18km	13.3km	85° E 80° E 75° E 70° E • As the uncertainty in seismic evaluation is set to 70° E.	0km	The slip angle that indicated maximum dip or maximum horizontal deformation in basic study.	1.66m (85°) 1.64m (80°) 1.61m (75°) 1.56m (70°) (slip angle)	Basic study	Basic study	
	Slip quantity (Case ⑤)	18km	13.3km	90°	0km	The slip angle that indicated maximum dip or maximum horizontal deformation in basic study.	Calculated from formulas • Comparing with the Matsuda formula to calculate displacement of ground surface, etc.	Basic study	Basic study	
	Ground model (Case ⑥)	18km	13.3km	90°	0km	The slip angle that indicated maximum dip or maximum horizontal deformation in basic study.	1.66m	Ground model using in seismic evaluation Multi-layer model ³	Value due to each density ρ , Vs, Vp of layers	
	Fault model (Case ⑦)	The fault model using in seismic evaluation (upper: Basic factor of seismic center, downward: Considered depth uncertainty)							Single-layer model	0.25
		20km	16km	90°	4km	0° (Left-lateral slip)	Considering asperity			
20km	17km	90°	3km							

*1 Direction of the compression axis (P-axis) in regional stress field is represented angle from north with clockwise.

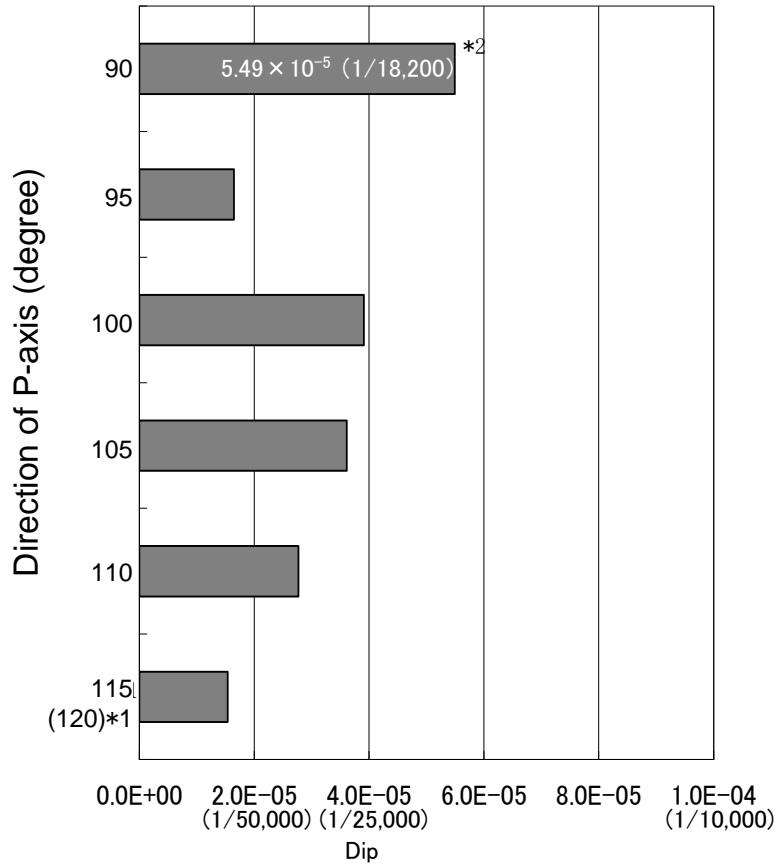
*2 This analysis refers to a concept of “Tsunami Evaluation Technique for Nuclear Power Station” (Tsunami Evaluation Subcommittee, Nuclear Civil Engineering Committee, Japan Society of Civil Engineers (2002)), as tsunami evaluation is need to calculate initial seabed movement.

*3 Single-layer model due to Okada(1992), Multi-layer model due to Wang et al.(2003)

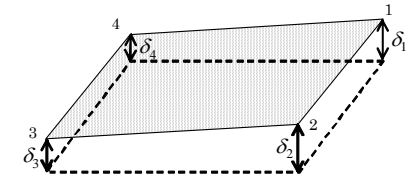
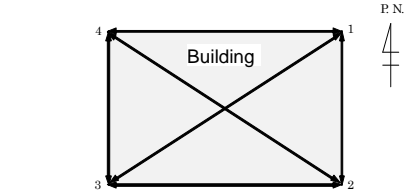
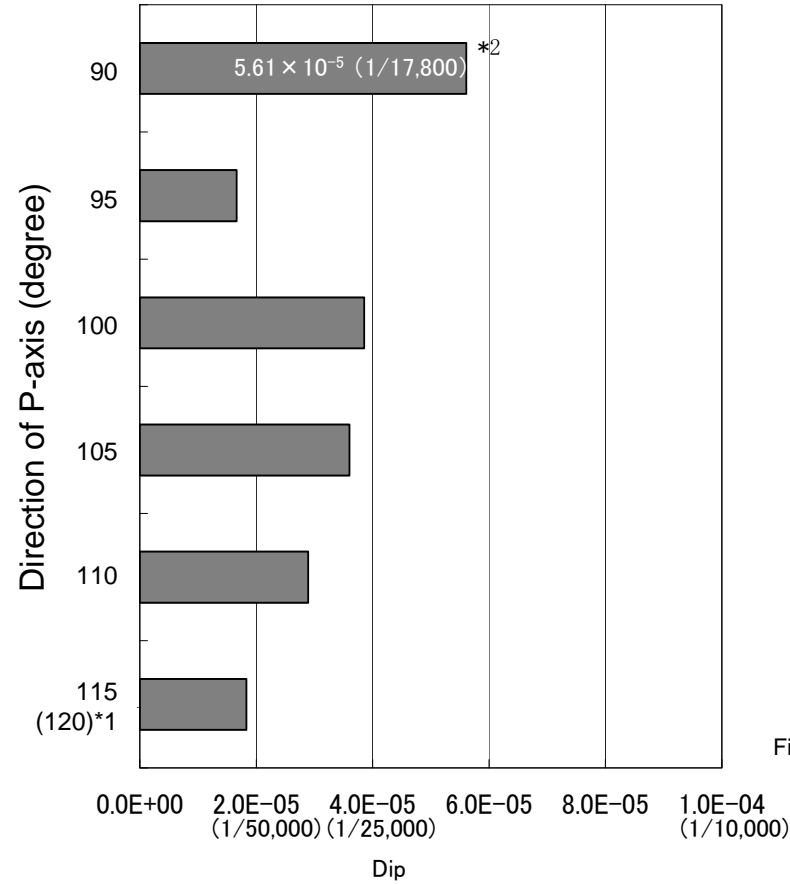


5. Examination based on the elasticity theory of dislocation (3) Dip of Reactor building (basic study) Case① depend on P-axis variable

Dip (Reactor building of Unit 1)



Dip (Reactor building of Unit 2)



Vertical displacement is maximum value of $\delta_1, \delta_2, \delta_3, \delta_4$

Dip is maximum value of six directions calculated from below equation.

$$\text{Dip}_{ij} = \frac{|\delta_i - \delta_j|}{L_{ij}}$$

L: distance between two points

Fig. Calculation of vertical displacement and dip of building

Fig. Dips of reactor buildings

- In this basic study, the P-axis direction which make dip maximum have been defined.
- As for dips of reactor buildings, six dips are calculated from vertical displacement at 4 corners as illustration.
- Maximum dips is indicated when P-axis is 90 degree in both Unit 1 and Unit 2.
- In later study taking uncertainties into account, P-axis direction is set to 90 degree.

*1 In the P-axis 120°, only lateral slip occurred as the P-axis 115° .
 *2 Maximum dips are 1/18,200 at Unit 1, and 1/17,800 at Unit 2.

5. Examination based on the elasticity theory of dislocation (3) Dip of the site (basic study) Case① basic study (P-axis 90°)

	Vertical displacement [m]	Dip
Unit1 Reactor Building	-0.55 (P-axis 90°)	5.49×10^{-5} (1/18,200)
Unit2 Reactor Building	-0.55 (P-axis 90°)	5.61×10^{-5} (1/17,800)

Vertical displacement and dip is showed below in the case using P-axis 90° that indicated maximum dip at Unit 1&2.

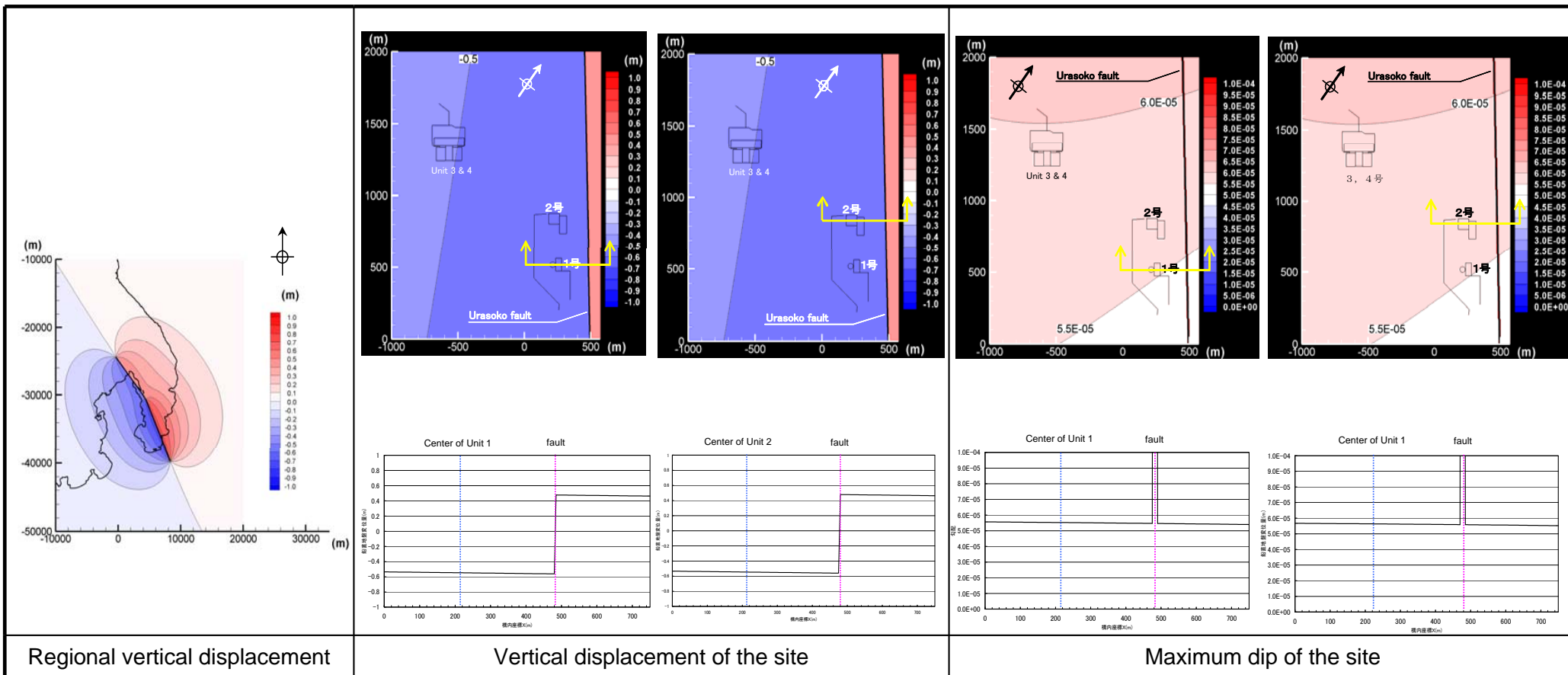
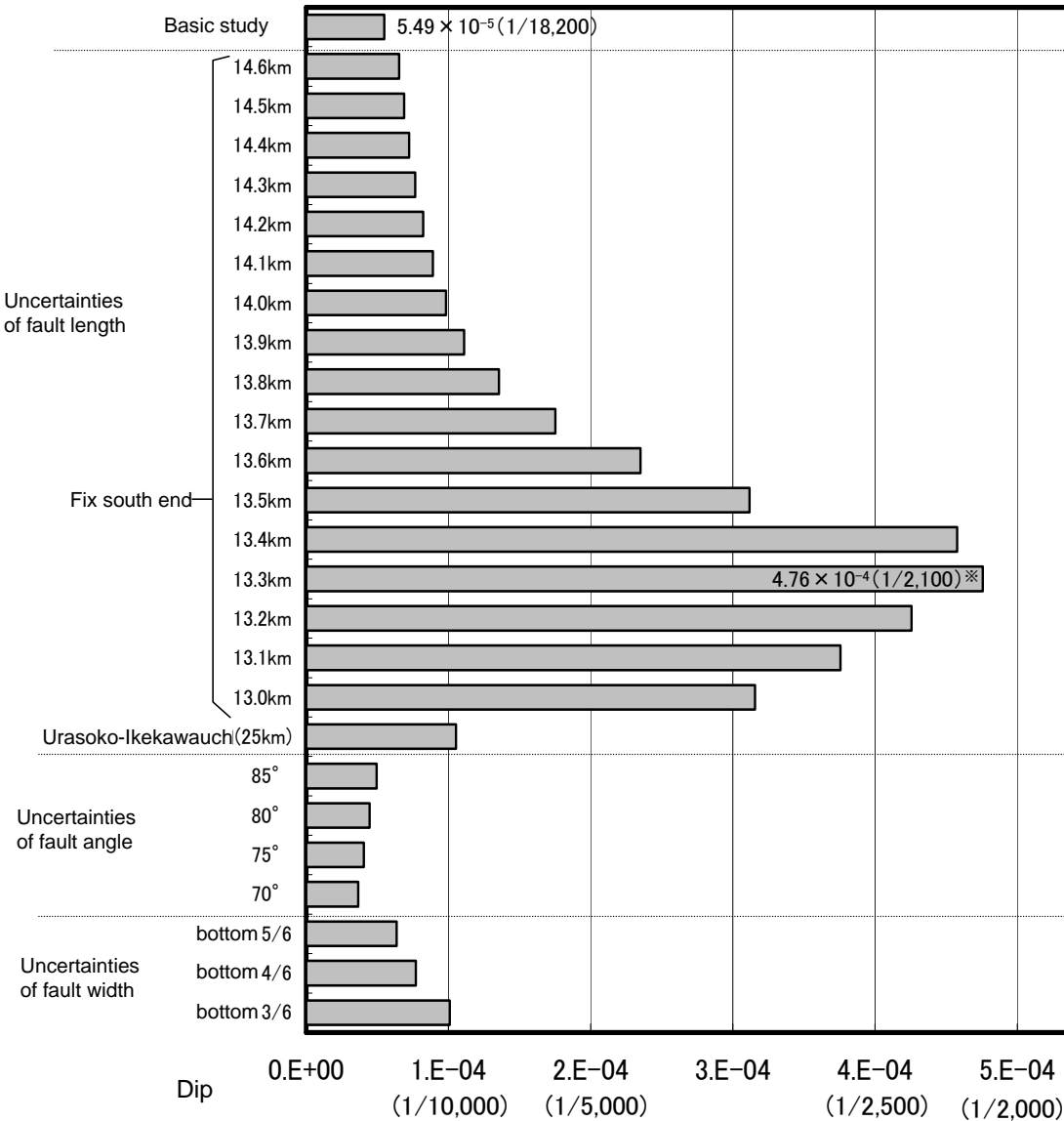


Fig. Vertical displacement and maximum dip of the site

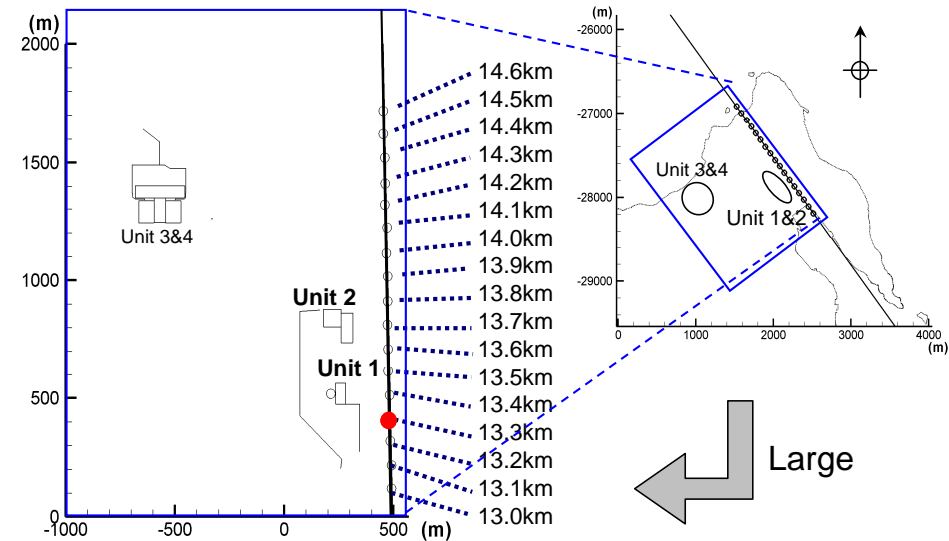
Result with P-axis 90° is illustrated.

5. Examination based on the elasticity theory of dislocation (4) Dip of reactor building (taking account of uncertainty) Case②~④ Length and angle and width of the fault (Unit 1 Reactor Building)

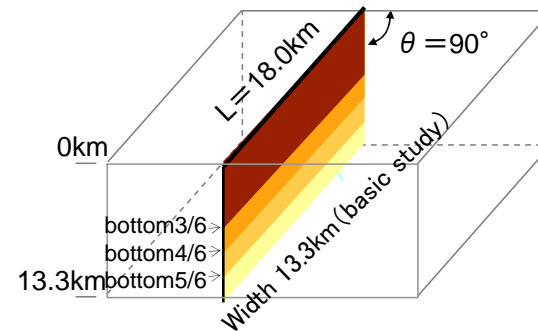
- The case is examined with uncertainties of fault length and angle and width for P-axis 90° that indicated maximum dip in the basic study.
- Result of examinations, the case indicates maximum dip, in which assuming that the fault length (north end of the fault) is around the reactor building. The value of Unit 1 Reactor building is $1/2,100$.



※ Maximum value of dip $4.76 \times 10^{-4} (1/2,100)$



As Tsuruga PS is located north of Urasoko-Uchiikemi fault, movement of north end could affect to length of the fault (Slip) larger than south end, therefore south end of the fault is set to be fixed.

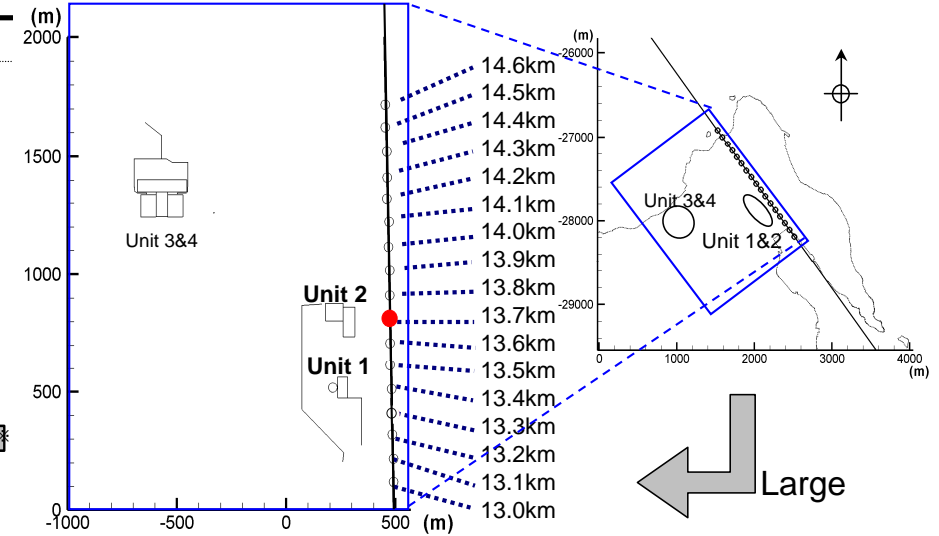
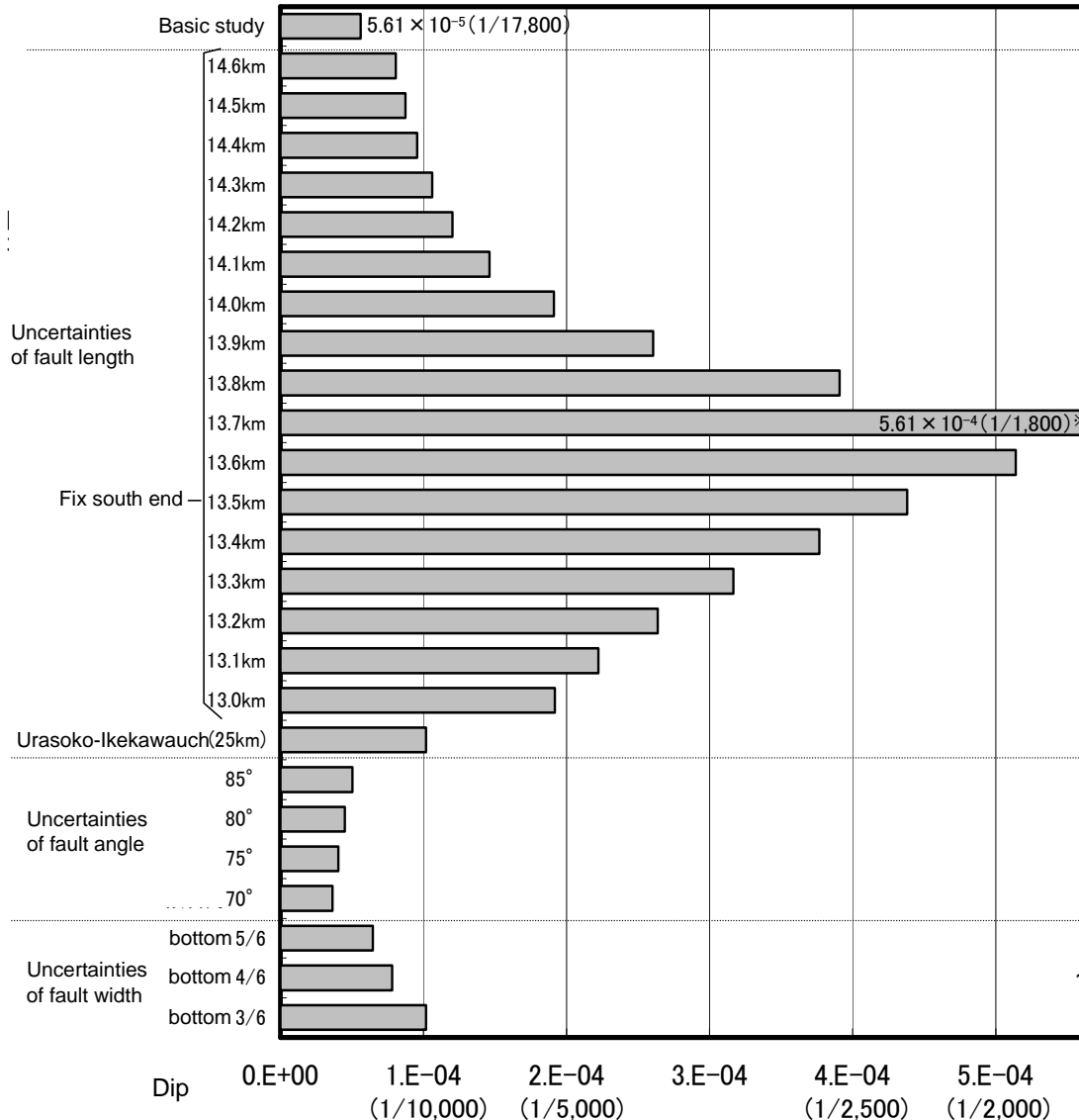


- Fault width W 13.3km (basic study)
- ① 5/6 W = 11.1km
 - ② 4/6 W = 8.9km
 - ③ 3/6 W = 6.7km

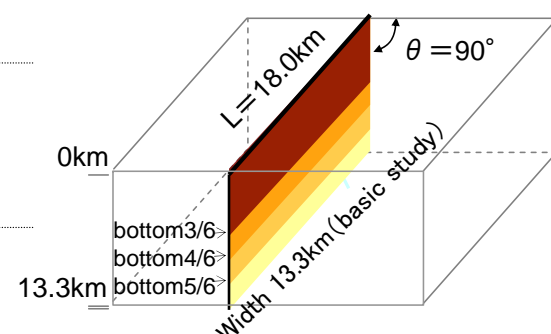
Fig. Dip studied with uncertainties (Unit 1 Reactor Building)

5. Examination based on the elasticity theory of dislocation (4) Dip of reactor building (taking account of uncertainty) Case②~④ Length and angle and width of the fault (Unit 2 Reactor Building)

- The case is examined with uncertainties of fault length and angle and width for P-axis 90° that indicated maximum dip in the basic study.
- Result of examinations, the case indicates maximum dip, in which assuming that the fault length (north end of the fault) is around the reactor building. The value of Unit 2 Reactor building is $1/1,800$.



As Tsuruga PS is located north of Urasoko-Uchiikemi fault, movement of north end could affect to length of the fault (Slip) larger than south end, therefore south end of the fault is set to be fixed.



- Fault width W 13.3km (basic study)
- ① $5/6 W = 11.1\text{km}$
 - ② $4/6 W = 8.9\text{km}$
 - ③ $3/6 W = 6.7\text{km}$

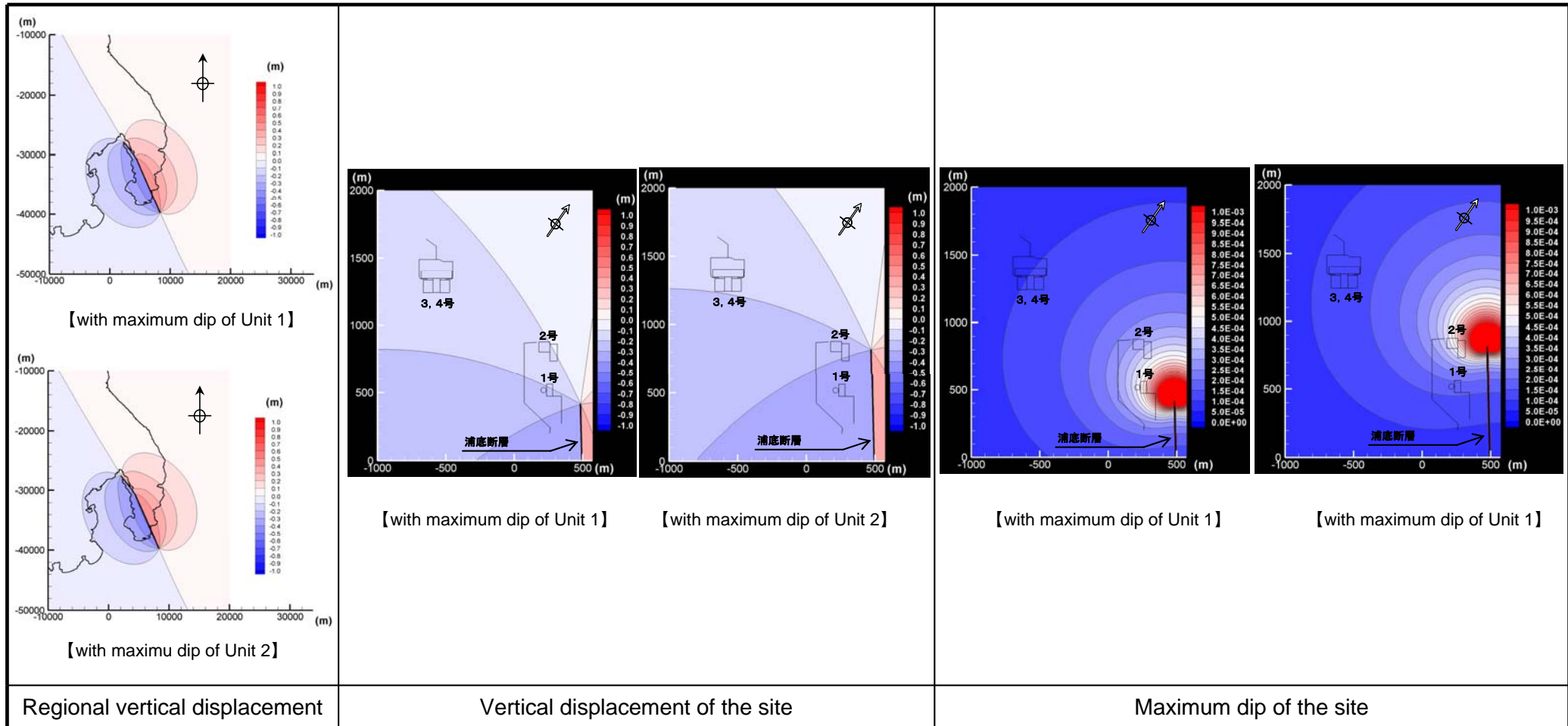
※ Maximum value of dip $5.61 \times 10^{-4} (1/1,800)$

Fig. Dip studied with uncertainties (Unit 2 Reactor Building)

5. Examination based on the elasticity theory of dislocation (4) Dip of the site (taking account of uncertainty) Case②~④ with maximum dip of reactor building

Vertical displacement and dip of the site are shown below, in the case when reactor buildings indicated maximum dips with examination of uncertainties and P-axis90° .

	Vertical displacement [m]	Dip	Uncertainty
Unit 1 Reactor Building	- 0.23	4.76×10^{-4} (1/2,100)	Fault length 13.3km (P-axis90°)
Unit 2 Reactor Building	- 0.28	5.61×10^{-4} (1/1,800)	Fault length 13.7km (P-axis90°)



Result with P-axis 90° is illustrated.


Fig. Vertical displacement and maximum dip of the site

5. Examination based on the elasticity theory of dislocation (4) Dip (taking account of uncertainty) Case⑤ Comparison of slips

- Slip of the fault is set based on the concept of Tsunami Evaluation Technique(2002) in principle.
- In order to make sure that set slip quantity has validity, we have compared with value from other formulas which were related to slip.
- As a result, values based on Tsunami Evaluation Technique(2002) have been larger than others
- The method in which slip is set based on Tsunami Evaluation Technique(2002) has been conservative results, because vertical displacement and dip are becoming larger in proportion to slip In the elasticity theory of dislocation.

Table Comparison of slip in Urasoko-Uchiikemi fault

	Fault length	Fault width	Fault slope	Slip
Tsunami Evaluation Technique (2002)	20km	13.3km	90°	1.66m
Matsuda (1975) ※1	f20km	No examination	No examination	1.59m
Sato (1989) ※2	20km	10.0km	No examination	0.60m
Model for seismic evaluation	20km	16.0km	90°	0.509m (Average slip <i>D</i>) (information) 1.022m (Asperity) 0.398m (Background field)

 Basic study

Tsunami Evaluation Technique (2002)

$$D = M_0 / (\mu \cdot S)$$

D : Slip

*M*₀ : Seismic Moment

μ : Modulus of Rigidity ※3

S : Section of Fault

(Calculate *M*₀ from Takemura(1998)※4 and Kanamori(1997)※5)

Matsuda (1975)

$$\log L = 0.6M - 2.9$$

$$\log D = 0.6M - 4.0$$

D : Slip (*m*)

M : Seismic Scale (Magnitude *M*)

L : Length of Fault (*km*)

Sato (1989)

$$\log L = 0.5M - 1.88$$

$$\log D = 0.5M - 3.40$$

D : Slip (*m*)

M : Seismic Scale (Magnitude *M*)

L : Length of Fault (*km*)

Model for seismic evaluation

$$D = M_0 / (\mu \cdot S)$$

D : Average Slip

*M*₀ : Seismic Moment

μ : Modulus of Rigidity

S : Section of Fault

※1 Matsuda Tokihiko, Seismic scale and cycle of earthquake caused by active fault, Jishin 2nd vol.28(1975), pp.269-283.

※2 Sato Ryosuke, The handbook of seismic fault in Japan(1989)

※3 Using 3.5×10^{10} N/m² based on Tsunami Evaluation Technique(2002)

※4 Takemura Masayuki, Scaling rule of distrophism earthquake in Japan –A influence of fault and relation to damage-, Jishin 2nd, vol.51(1998), pp.211-228

※5 Kanamori, H(1997) : The energy release in great earthquakes, Journal of Geophysical Research, Vol.82, No.20, pp.2981-2987

5. Examination based on the elasticity theory of dislocation (4) Dip (taking account of uncertainty)
 Case⑥ Uncertainties of ground model

Table Ground Model for deciding of basic seismic ground motion in Tsuruga Power Station

E.L. (m)	layer	thickness (m)	density ρ (t/m ³)	Vs (m/s)	Vp (m/s)	Poisson's ratio
-9						
-44	1	34	2.6	1,450	3,700	0.41
-130	2	86	2.6	1,760	4,300	0.40
-200	3	70	2.6	2,200	4,600	0.35
-630	3'	430	2.6	2,200	4,600	0.35
-1400	4	770	2.6	2,800	5,130	0.29
-4000	5	2600	2.6	3,100	5,310	0.24
	6	—	2.7	3,600	6,270	0.25

$$V_p/V_s = \sqrt{\frac{2(1-\sigma)}{1-2\sigma}} \quad \sigma : \text{Poisson's ratio}$$

- In order to study for uncertainties of ground model, the result using basic study (Single-layer model) have been compared with the result using Multi-layer model in the ground structure.
- Physical properties of the ground in Multi-layer model have been similar to the analysis model in seismic evaluation using fault model, and the elasticity theory of dislocation (Multi-layer model) Wang *et al.* have been examined.
- The result of Single-layer model have not been different from the Multi-layer model hardly.
- In studies of uncertainties, therefore, Single-layer model is determined to apply for ground structure in principle.

Table Dips of building (Unit 1) with Single-layer and Multi-layer model

Case	Vertical dislocation (m)	Dip
Single-layer (basic study)	-0.55	5.49×10^{-5} (1/18,200)
Multi-layer	-0.55	5.65×10^{-5} (1/17,700)

Table Dips of building (Unit 2) with Single layer and Multi-layer model

Case	Vertical dislocation (m)	Dip
Single-layer (basic study)	-0.55	5.61×10^{-5} (1/17,800)
Multi-layer	-0.55	5.73×10^{-5} (1/17,500)

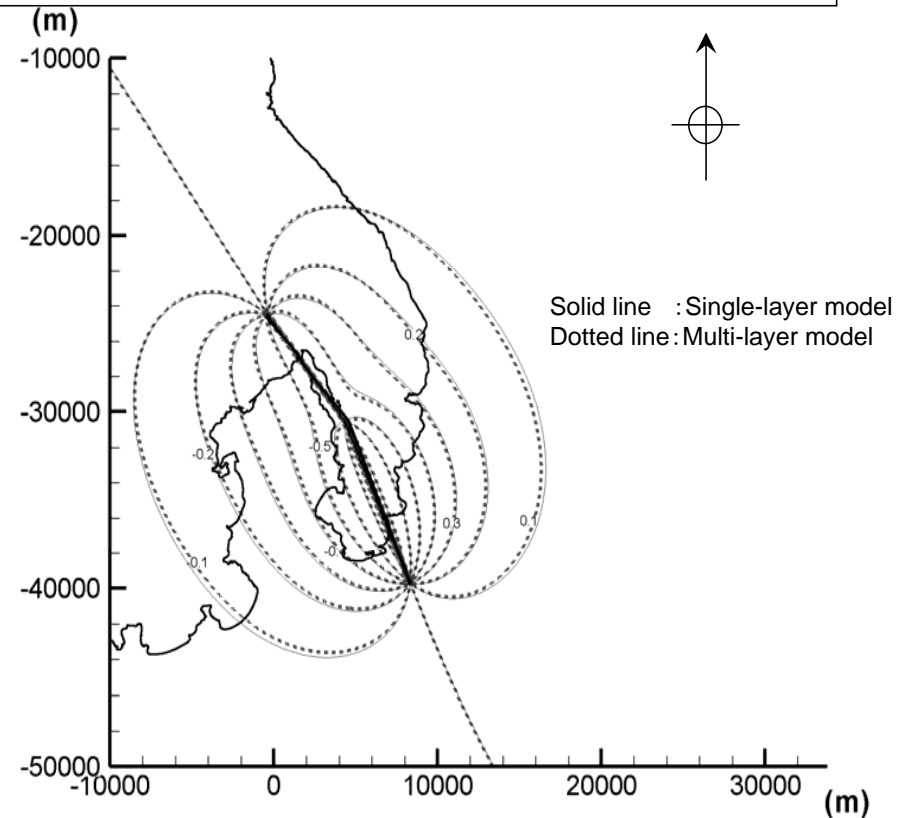


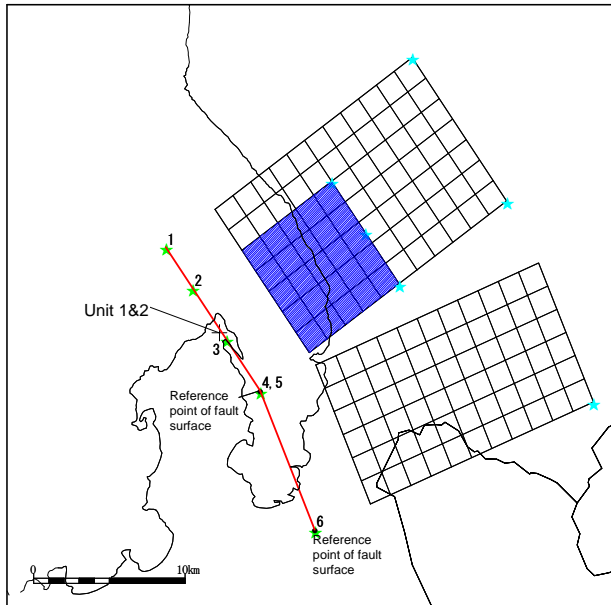
Fig. Comparison between Single-layer with Multi-layer model in distribution of vertical ground dislocation

Single-layer model : Okada(1992)
 Multi-layer model : Wang *et al.* (2003)

5. Examination based on the elasticity theory of dislocation (4) Dip (taking account of uncertainty) Case⑦ Uncertainties of ground model (Depth 4km) No.1(1)

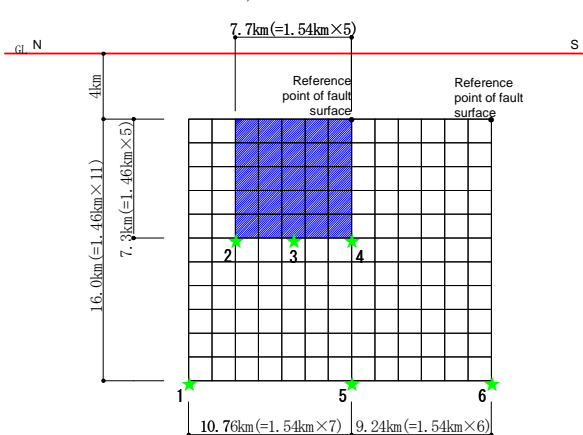
- The fault model in seismic evaluation have been examined to study for uncertainties of fault model.
- The case No.1 is depth of fault top 4km, and No.2 is 3km in fault models respectively, these are similar to the concept of seismic evaluation.
- As a result, both vertical dislocation and dip was smaller than results of basic study.

Depth of the fault top 4km



※ Drawing dip 90° as dip 0° ★: Starting point of destruction

i) Fault location



ii) Cross section

Table Parameters of the fault model using to seismic evaluation in Tsuruga Power Station (Depth of fault top 4km)

Parameters of fault	Values	Means
Fault length L (km)	20 (18)	Extending fault location
Fault angle (°)	90 (90)	The result of survey
Depth of the fault top (km)	4 (0)	Setting with reference to occurrence of minute earthquake and underground structure in order to keep scale
Depth of the fault bottom (km)	20 (13.3)	
Fault width W (km)	16 (13.3)	The same as above
Section of fault S (km ²)	320 (239.4)	Calculation from fault surface
Crack propagation pattern	Concentric circular	—
Seismic moment M ₀ (Nm)	5.70 × 10 ¹⁸	M ₀ =(S/(4.24 × 10 ⁻¹¹)) ^{2.0}
Modulus of rigidity (N/m ²)	3.5 × 10 ¹⁰	$\mu = \rho \beta^2$, $\rho = 2.7\text{g/cm}^3$, $\beta = 3.6\text{km/s}$
Average slip D (cm)	50.9	D=M ₀ /(μ S)
Average stress drop $\Delta \sigma$ (MPa)	2.4	$\Delta \sigma = (7 \pi^{1.5}/16)(M_0/S^{1.5})$
Crack propagation velocity V _r (km/s)	2.59	V _r =0.72 β
Startup time T _r (sec)	0.78	T _r =2.03 × 10 ⁻⁹ M ₀ ^{1/3}
Cutoff frequency f _{max} (Hz)	8.3	Kagawa et al.(2003)
Short-period level A (Nm/s ²)	9.47 × 10 ¹⁸	A=2.46 × 10 ¹⁷ × M ₀ ^{1/3}
Value of Q	50f ^{1.1}	Sato et al.(2007)

	Parameters of fault	Values	Means
Total asperity	Section S _a (km ²)	56.71 (not consider)	S _a = πr^2 $r=(7 \pi M_0 \beta^2)/(4AaR)$, R=(S/ π) ^{0.5}
	Average slip D _a (cm)	102.2 (166)	D _a = $\gamma_D D$, $\gamma_D=2.01$
	Seismic moment M _{0a} (Nm)	2.03 × 10 ¹⁸	M _{0a} = $\mu S_a D_a$
	Stress drop $\Delta \sigma_a$ (MPa)	13.7	$\Delta \sigma_a = (S/S_a) \Delta \sigma$
Background field	Section S _b (km ²)	263.29 (not consider)	S _b =S-S _a
	Average slip D _b (cm)	39.8 (166)	D _b =M _{0b} /(μS_b)
	Seismic moment M _{0b} (Nm)	3.67 × 10 ¹⁸	M _{0b} =M ₀ -M _{0a}
	Effective stress $\Delta \sigma_b$ (MPa)	2.7	$\sigma_b=0.2 \Delta \sigma_a$

(Note) Single-layer mode based on Okada's formula, and physical properties of ground was similar to basic study.

Parameters using to calculation based on the elasticity theory of dislocation
Inside () represents parameters on basic study

Fig. Schematic view of the fault model using to seismic evaluation in Tsuruga Power Station (Depth of fault top 4km)

5. Examination based on the elasticity theory of dislocation (4) Dip (taking account of uncertainty)
 Case⑦ Uncertainties of ground model (Depth 4km) No.1(2)

Table Vertical dislocations and dips of reactor buildings in seismic evaluation models (Depth of fault top 4km)

	Vertical dislocation [m]	Dip
Unit 1 Reactor Building	-0.01	4.41×10^{-6} (1/227,000)
Unit 2 Reactor Building	-0.01	5.74×10^{-6} (1/174,300)

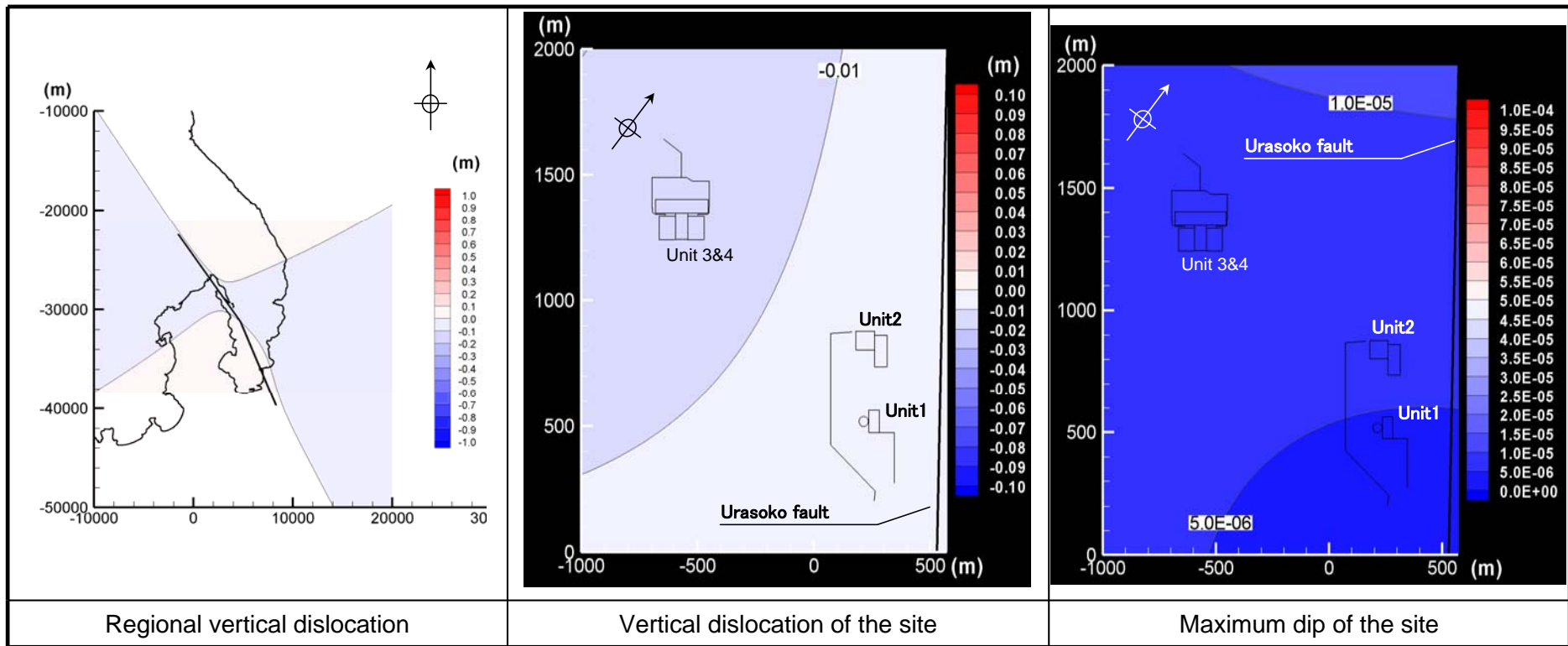
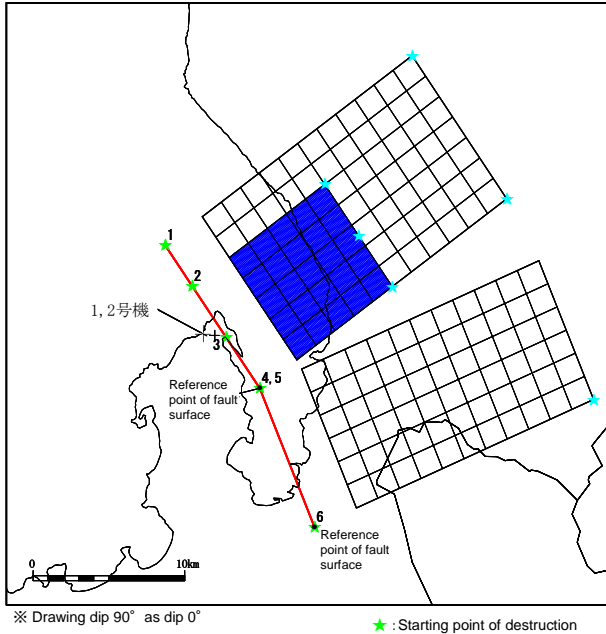


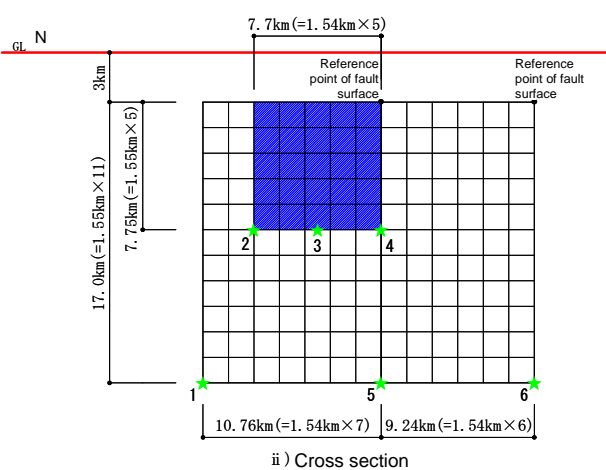
Fig. Distribution of vertical dislocation and dip (Depth of fault top 4km)

5. Examination based on the elasticity theory of dislocation (4) Dip (taking account of uncertainty) Case⑦ Uncertainties of ground model (Depth 3km) No.2(1)

Depth of fault top 3km



i) Fault location



ii) Cross section

Table Parameters of the fault model using to seismic evaluation in Tsuruga Power Station (Depth of fault top 3km)

Parameters of fault	Values	Means
Fault length L (km)	20 (18)	Extending fault location
Fault angle (°)	90 (90)	The result of survey
Depth of the fault top (km) Depth of the fault bottom (km)	3 (0) 20 (13.3)	Setting with reference to occurrence of minute earthquake and underground structure in order to keep scale
Fault width W (km)	17 (13.3)	The same as above
Section of fault S (km ²)	340 (239.4)	Calculation from fault surface
Crack propagation pattern	Concentric circular	—
Seismic moment M ₀ (Nm)	6.43 × 10 ¹⁸	M ₀ = {S / (4.24 × 10 ⁻¹¹) ^{2.0}
Modulus of rigidity (N/m ²)	3.5 × 10 ¹⁰	μ = ρ β ² , ρ = 2.7g/cm ³ , β = 3.6km/s
Average slip D (cm)	54.0	D = M ₀ / (μ S)
Average stress drop Δσ	2.5	Δσ = (7 π ^{1.5} / 16) (M ₀ / S ^{1.5})
Crack propagation velocity V _r (km/s)	2.59	V _r = 0.72 β
Startup time T _r (sec)	0.81	T _r = 2.03 × 10 ⁻⁹ M ₀ ^{1/3}
Cutoff frequency f _{max} (Hz)	8.3	Kagawa et al. (2003)
Short-period level A (Nm/s ²)	9.86 × 10 ¹⁸	A = 2.46 × 10 ¹⁷ × M ₀ ^{1/3}
Value of Q	50f ^{1.1}	Sato et al. (2007)

	Parameters of fault	Values	Means
Total asperity	Section S _a (km ²)	62.73 (not consider)	S _a = π r ² r = (7 π M ₀ β ²) / (4 A a R), R = (S / π) ^{0.5}
	Average slip D _a (cm)	108.6 (166)	D _a = γ _D D, γ _D = 2.01
	Seismic moment M _{0a} (Nm)	2.38 × 10 ¹⁸	M _{0a} = μ S _a D _a
Background field	Stress drop Δσ _a (MPa)	13.5	Δσ _a = (S / S _a) Δσ
	Section S _b (km ²)	277.27 (not consider)	S _b = S - S _a
	Average slip D _b (cm)	41.7 (166)	D _b = M _{0b} / (μ S _b)
	Seismic moment M _{0b} (Nm)	4.05 × 10 ¹⁸	M _{0b} = M ₀ - M _{0a}
	Effective stress Δσ _b (MPa)	2.7	σ _b = 0.2 Δσ _a

(Note) Single-layer mode based on Okada's formula, and physical properties of ground was similar to basic study.

Parameters using to calculation based on the elasticity theory of dislocation
Inside () represents parameters on basic study

Fig. Schematic view of the fault model using to seismic evaluation in Tsuruga Power Station (Depth of fault top 3km)

5. Examination based on the elasticity theory of dislocation (4) Dip (taking account of uncertainty)
 Case⑦ Uncertainties of ground model (Depth 3km) No.2(2)

Table Vertical dislocations and dips of reactor buildings in seismic evaluation models (Depth of fault top 3km)

	Vertical dislocation [m]	Dip
Unit 1 Reactor Building	-0.01	5.60×10^{-6} (1/178,700)
Unit 2 Reactor Building	-0.01	7.59×10^{-6} (1/131,800)

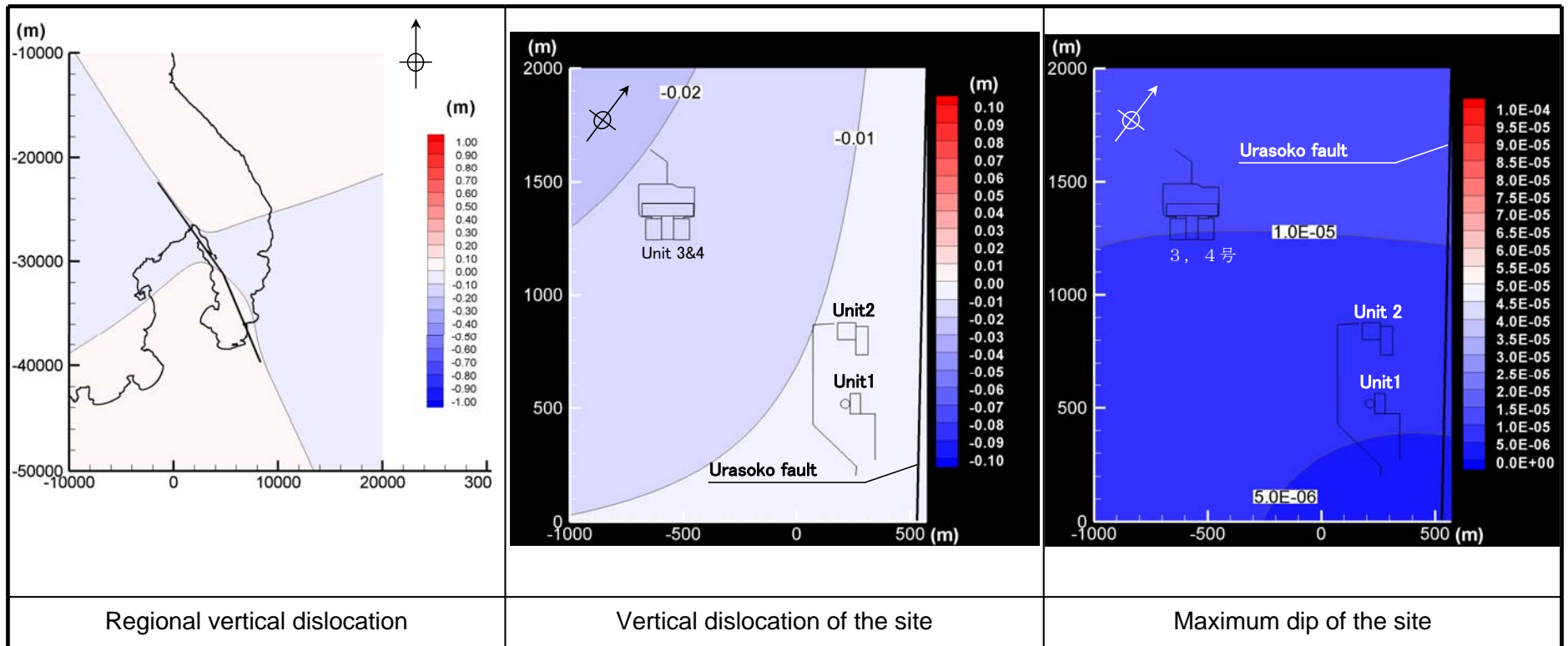


Fig. Distribution of vertical dislocation and dip (Depth of fault top 3km)

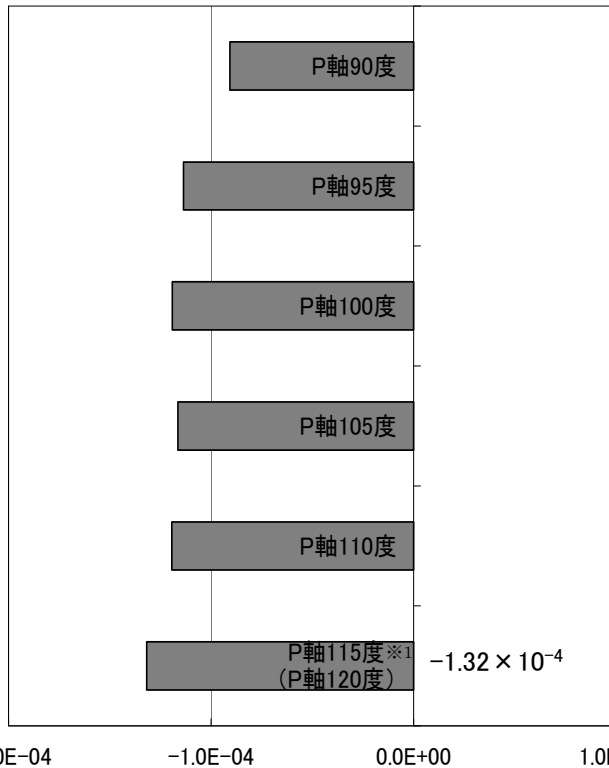
5. Examination based on the elasticity theory of dislocation, (5) Horizontal deformation of the structure (basic case)
 Study ① Parameter study on compressional axis (P-axis) in wide-area stress field

- In the basic study, parameter study on compressional axis (P-axis) in wide-area stress field was carried out. A direction of the P-axis, which maximize the deformation of the basement of reactor building, was determined.
- As a parameter of the deformation, shearing strain was selected.
- The shearing strain was calculated from the horizontal displacements of the reactor building corners.
- In the both cases of Unit 1 and Unit 2, P-axis at a 115 degrees angle maximized the shearing strain.
- Therefore in the study taking account of uncertainty, the angle of P-axis was defined as 115 degrees.

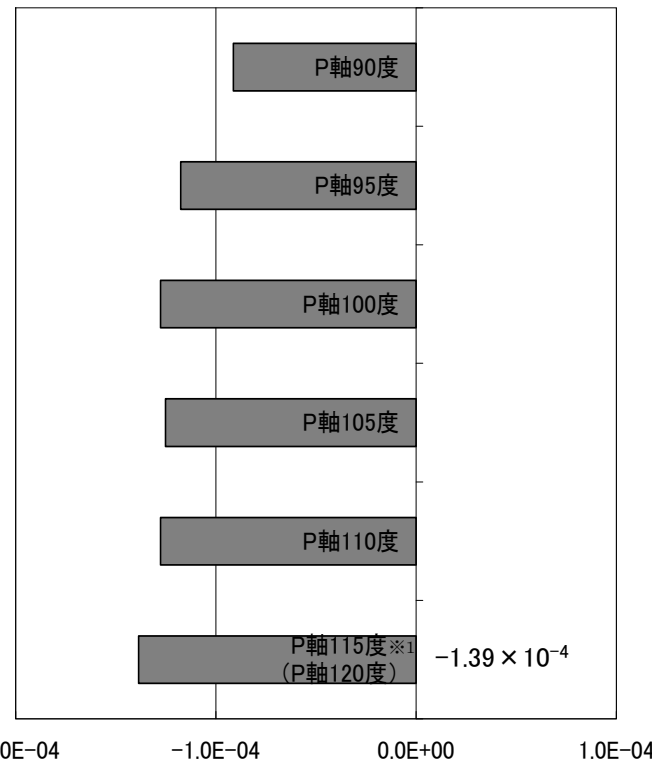
• "Regulatory Guide for Seismic Design of Nuclear Power Reactor Facilities" requests to evaluate "effect of a horizontal deformation against facilities if a fault have a lateral slip component".

• Urasoko fault has a left-lateral slip component. Therefore study on the deformation of the horizontal plane was carried out.

Horizontal shearing strain of reactor building of Unit 1 ※1, 2



Horizontal shearing strain of reactor building of Unit 2 ※1, 2



Horizontal shearing strain is the maximum shearing strains of reactor building calculated from the following formula.

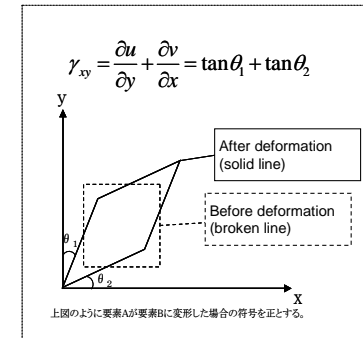
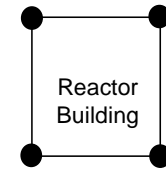


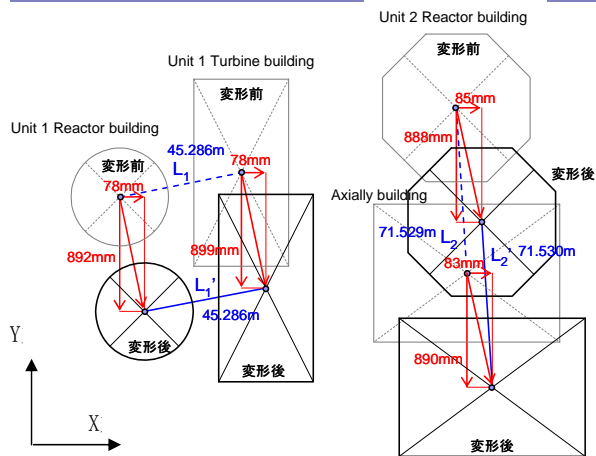
Fig. Calculation method of horizontal shearing strain of a building.

Fig. Horizontal shearing strain of reactor buildings of Unit 1 and Unit 2 (Base case)

※1 A case of P-axis at a angle of 120 degrees has only lateral slip as well as it of P-axis at a angle of 115 degrees.

※2 Scale of reactor building: Unit 1 42mx42m, Unit 2 80mx75m

5. Examination based on the elasticity theory of dislocation, (5) Horizontal deformation of the structure (basic case) Study ① Fundamental study (P-axis at an angle of 115 degrees)



【Image of relative displacement】

- Horizontal displacement and horizontal shearing strain of the basement of Unit 1 and Unit 2 are shown in the following table in the case of P-axis at an angle of 115 degrees.
- Maximum shearing strain is -1.32×10^{-4} at Unit 1 reactor building and -1.39×10^{-4} at Unit 2 reactor building.
- The locations of reactor building and surrounding ground move into a same direction with a same displacement, and the relative displacement between them is small. (For example, relative displacement between the center of reactor building and axially building is about 1mm)

Table. Horizontal shearing strain and relative displacement with 115° P-axis

Horizontal shearing strain ※1	Relative displacement between the center of reactor building and turbine building or axially building ※2
Unit 1 Reactor building: -1.32×10^{-4}	-0.2mm ($L_1'-L_1$)
Unit 2 Reactor building: -1.39×10^{-4}	1mm ($L_2'-L_2$)

※1 Scale of reactor building: Unit 1 42mx42m, Unit 2 80mx75m

※2 Direction away from each other is positive.

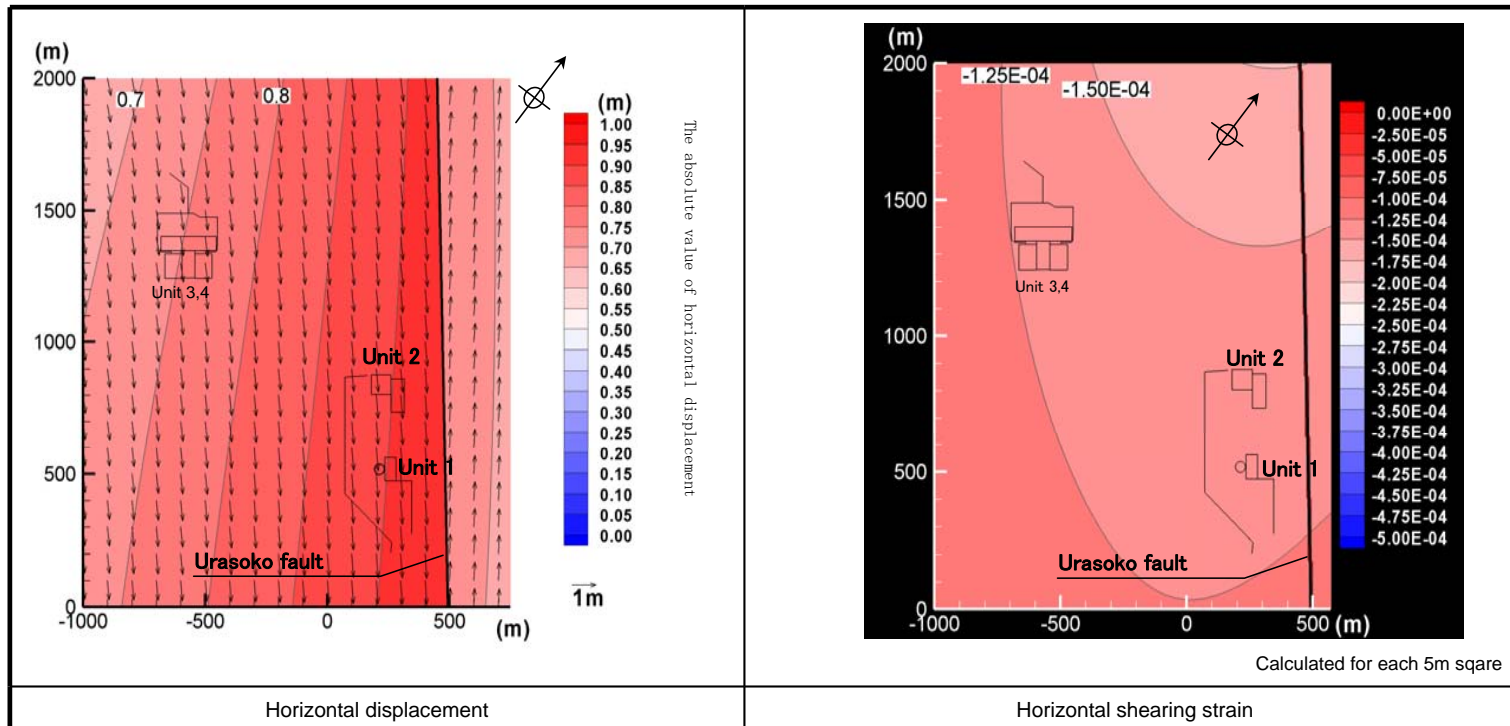
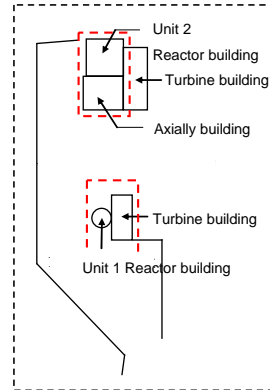
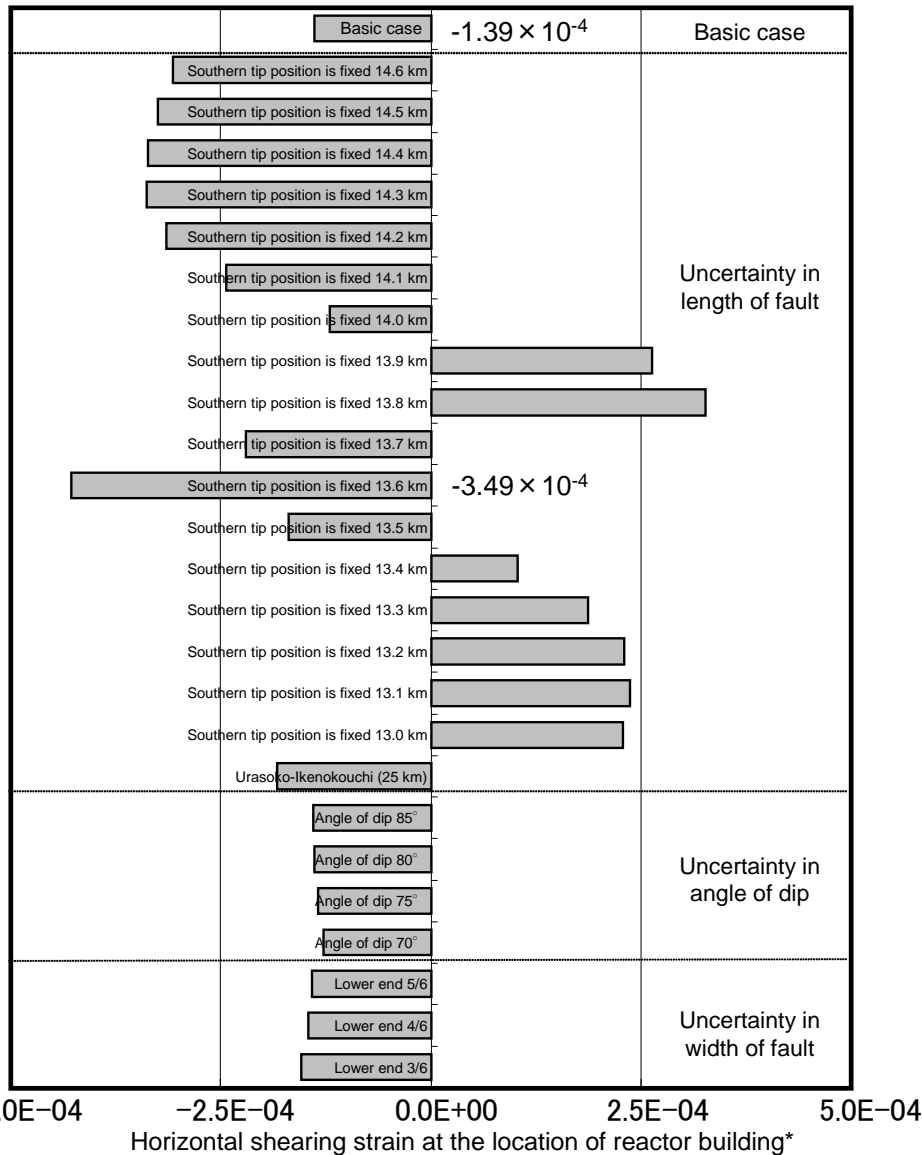
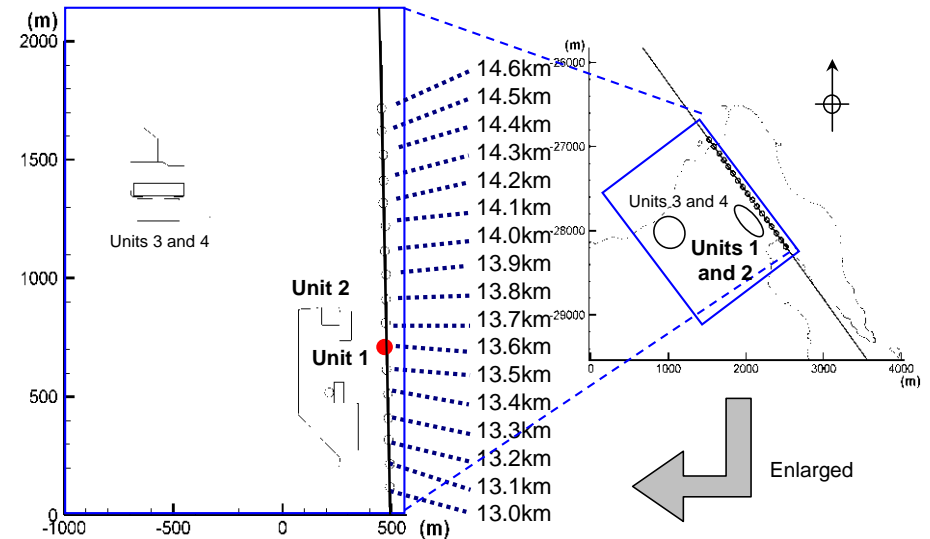


Fig. Distribution of horizontal displacement and horizontal shearing strain in the case of 115° P-axis

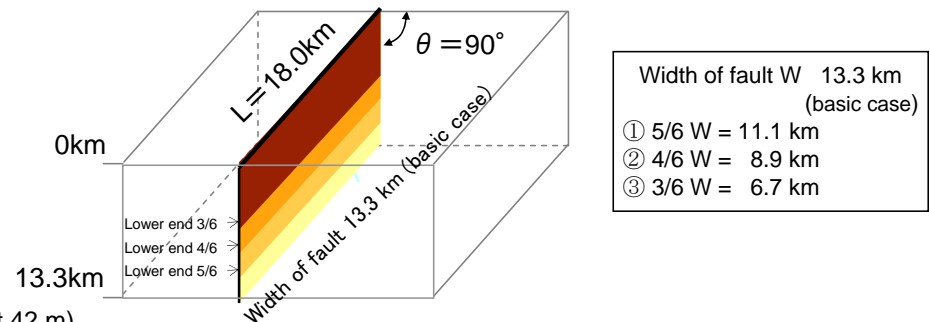
5. Examination based on the elasticity theory of dislocation, (6) Horizontal deformation of the structure (taking account of uncertainty)
 Study ①~③ Fault length, dip angle, fault width (Unit 1 reactor building)



• In basic study, as for the case of p-axis = 115° that represents the maximum shearing strain, we carried out the study with taking into account uncertainties of length of fault, angle of dip and width of fault.
 • As a result, a shearing strain becomes maximum in the case of 13.3 km (the southern tip position is fixed), and is -3.49×10^{-4} at Unit 1 reactor building.



As Tsuruga Power Station is located in the north of Urasoko-Uchiikemi fault, study was done with fixing the location of the southern end of the fault with changing the location of the northern end.

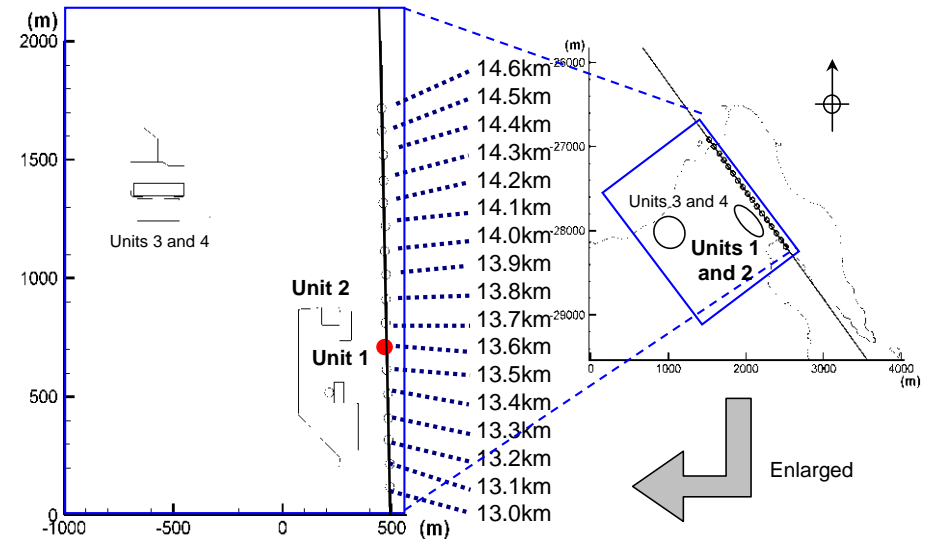
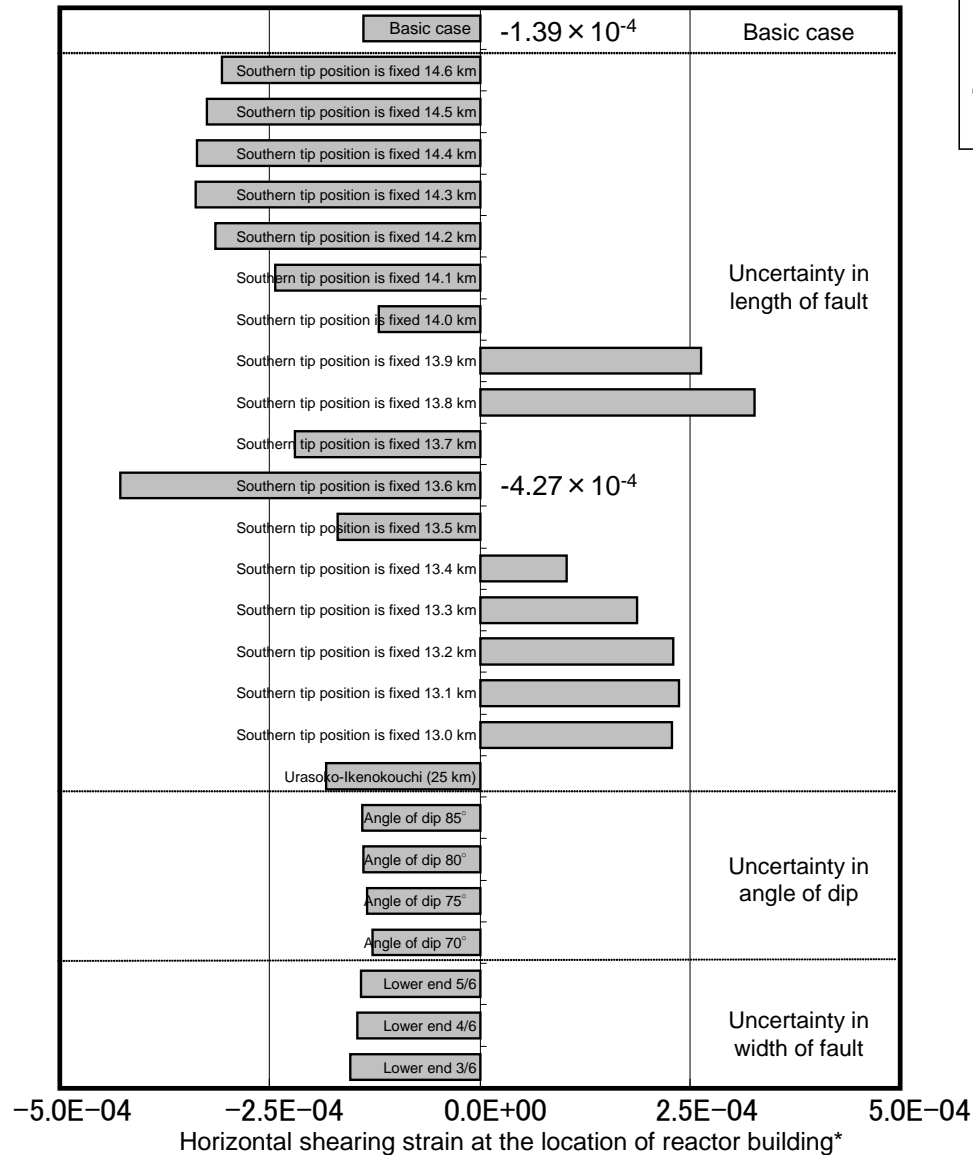


* Horizontal shearing strain acquired with a reactor building scale (Unit1: about 42 m x about 42 m)

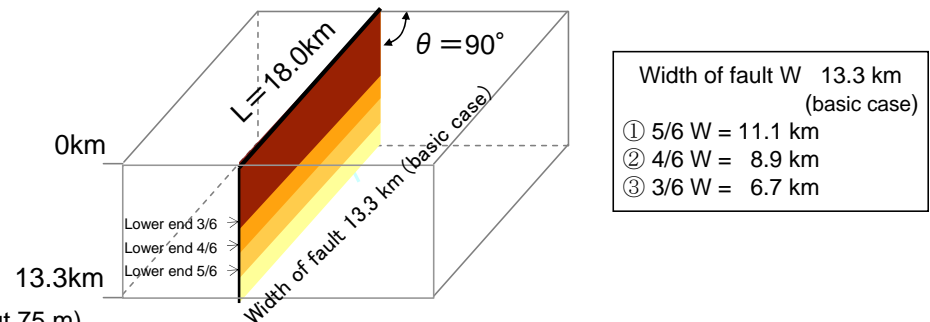
Fig. Horizontal shearing strain with taking uncertainty into account (Unit 1 reactor building)

5. Examination based on the elasticity theory of dislocation, (6) Horizontal deformation of the structure taking account of uncertainty)
 Study ①~③ Fault length, dip angle, fault width (Unit 2 reactor building)

- In basic study, as for the case of p-axis = 115° that represents the maximum shearing strain, we carried out the study with taking into account uncertainties of length of fault, angle of dip and width of fault.
- As a result, a shearing strain becomes maximum in the case of 13.6 km (the southern tip position is fixed), and is -4.27×10^{-4} at Unit 2 reactor building.



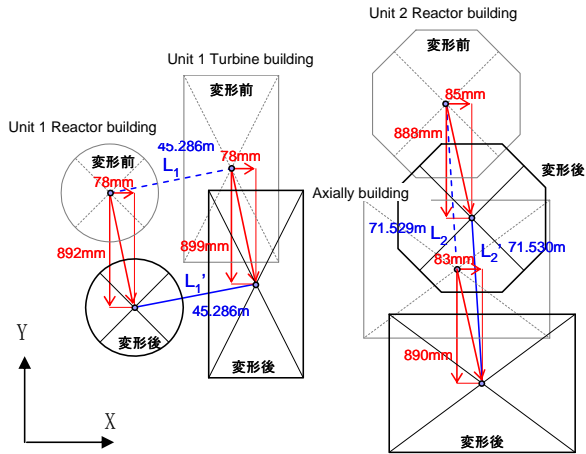
As Tsuruga Power Station is located in the north of Urasoko-Uchiikemi fault, study was done with fixing the location of the southern end of the fault with changing the location of the northern end.



* Horizontal shearing strain acquired with a reactor building scale (Unit 2: about 80 m x about 75 m)

Fig. Horizontal shearing strain with taking uncertainty into account (Unit 2 reactor building)

5. Examination based on the elasticity theory of dislocation, (6) Horizontal deformation of the structure (taking uncertainty into account)
 Study ②-④ Fault length, dip angle, fault width



【Image of relative displacement】

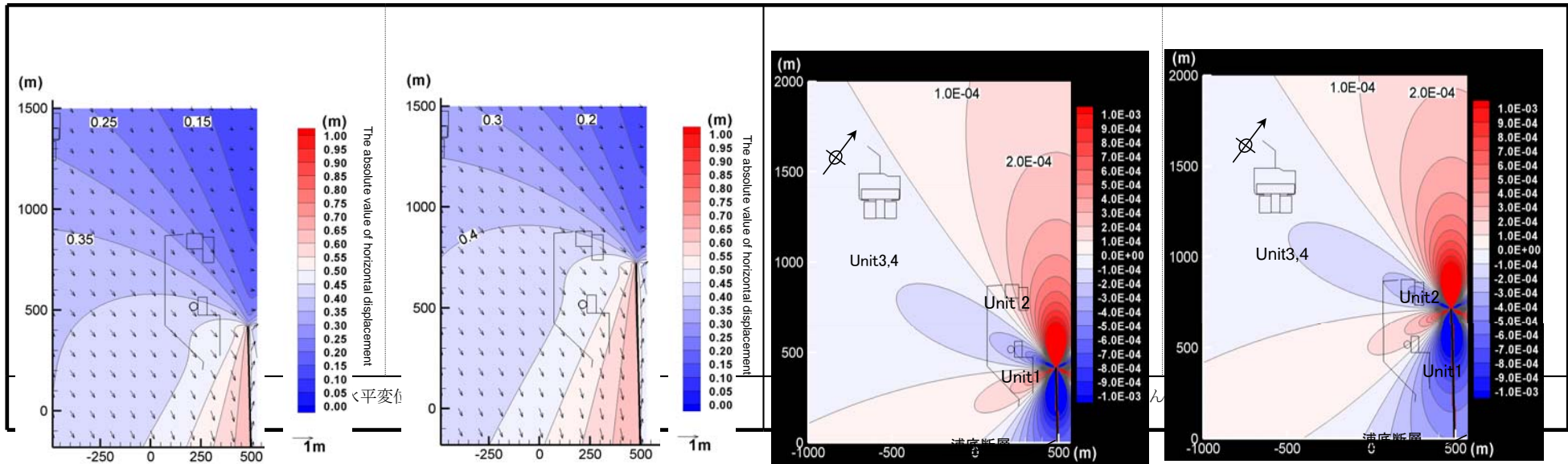
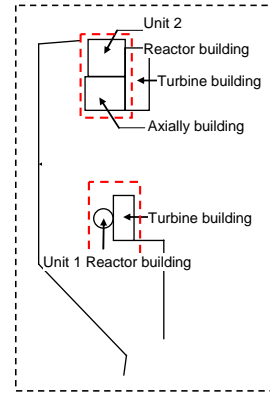
- Maximum shearing strain is -3.49×10^{-4} at Unit 1 reactor building and -4.27×10^{-4} at Unit 2 reactor building.
- The locations of reactor building and surrounding ground move into a same direction with a same displacement, and the relative displacement between them is small. (For example, relative displacement between the center of reactor building and axially building is about 19mm)

Table. Maximum horizontal shearing strain and relative displacement

Horizontal shearing strain ※1	Relative displacement between the center of reactor building and turbine building or axially building ※2
Unit 1 Reactor building: -3.49×10^{-4}	-0.1mm ($L_1'-L_1$)
Unit 2 Reactor building: -4.27×10^{-4}	19mm ($L_2'-L_2$)

※1 Scale of reactor building: Unit 1 42mx42m, Unit 2 80mx75m

※2 Direction away from each other is positive.



【Unit 1 R/B max. case】

【 Unit 1 R/B max. case 】

【Unit 2 R/B max. case】

【 Unit 2 R/B max. case 】

Horizontal displacement

Horizontal shearing strain

Calculated for each 5m square

Fig. Distribution of horizontal displacement and horizontal shearing strain of Unit 1 and Unit 2 in the case of maximum horizontal strain

6. Vertical two-dimensional FEM analysis, (1) Flow of the study

【Details to be studied】

For the detail study on vertical displacement, vertical two-dimensional FEM was carried out on the case that maximize dipping of the ground at a reactor building.

【Max. dipping case at Unit 1 reactor building】
P-axis: 90 degrees, Fault length: 13.3 km

【Max. dipping case at Unit 2 reactor building】
P-axis: 90 degrees, Fault length: 13.7 km

【Flow of the study】

1. Creating an analytical model

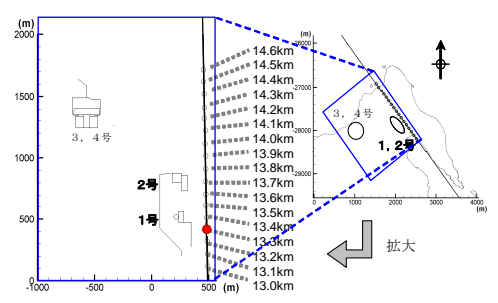
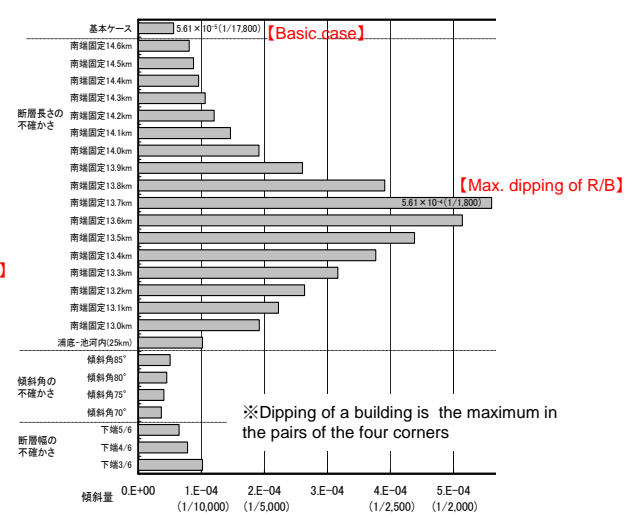
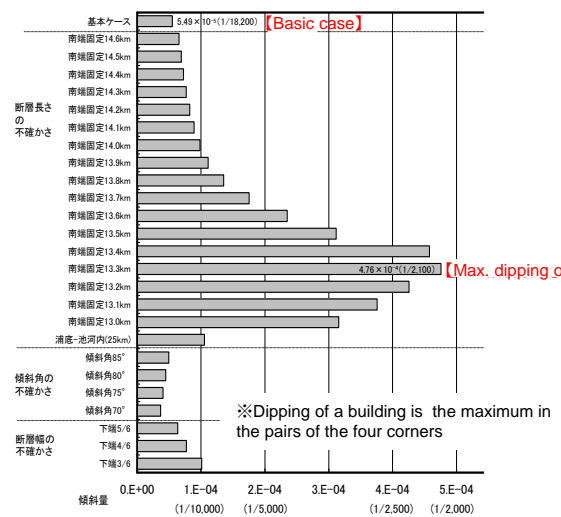
• Vertical two-dimensional model

2. FEM analysis

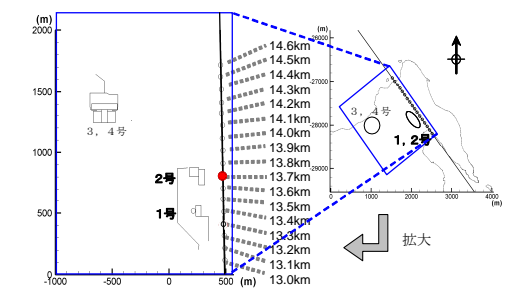
• Maximum dipping case at reactor building

3. Result

Fig. Flow of the study



【Location of northern end of the fault】



【Location of northern end of the fault】

Fig. Dipping of a reactor building taking account of uncertainty (left: Unit 1 reactor building, right: Unit 2 reactor building)

6. Vertical two-dimensional FEM analysis, (2) Analysis condition, ① Location of the cross section

Cross sections at reactor buildings perpendicular to Urasko-fault are selected to be studied. (Unit 1: A-A', Unit 2: B-B')

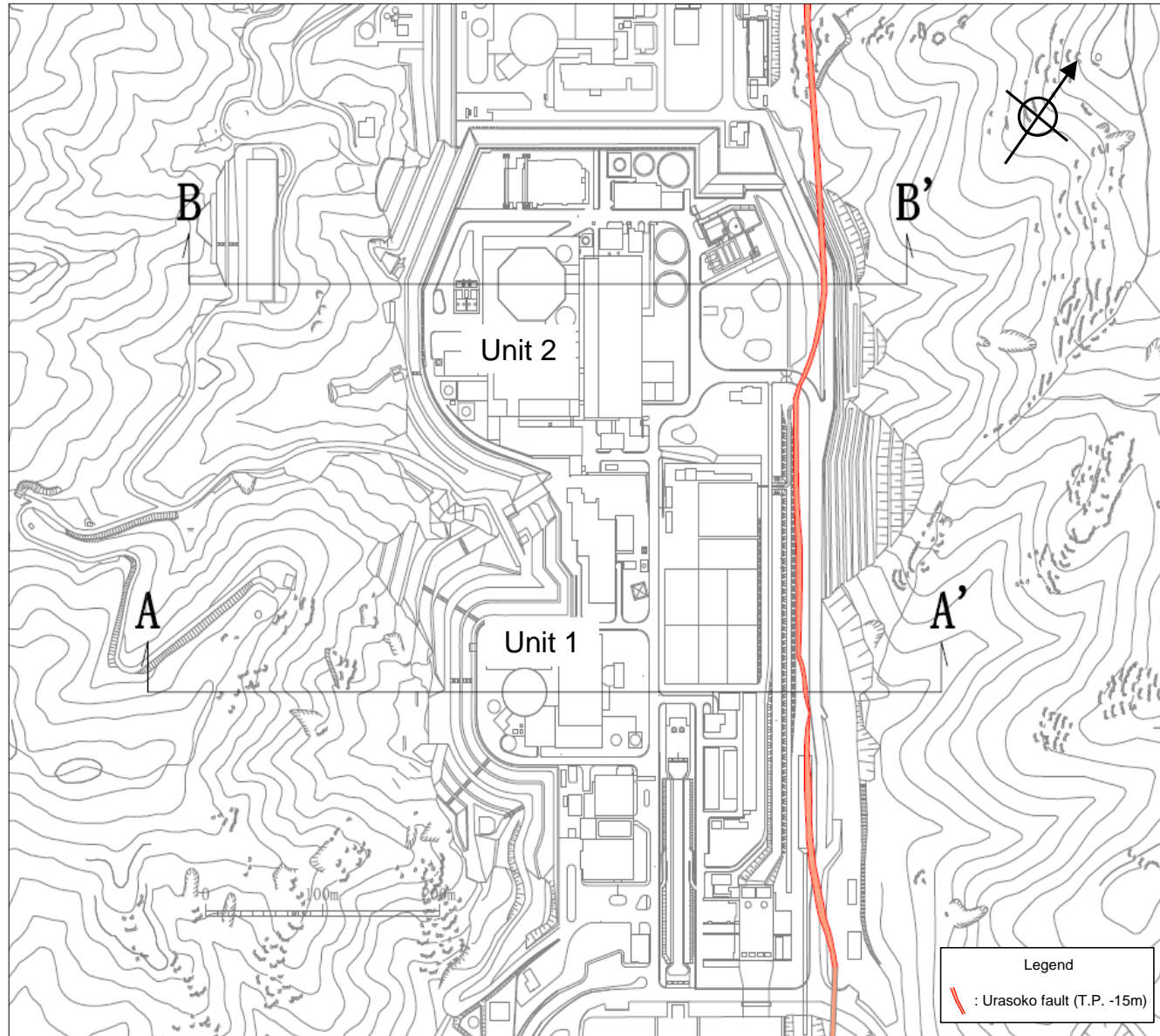
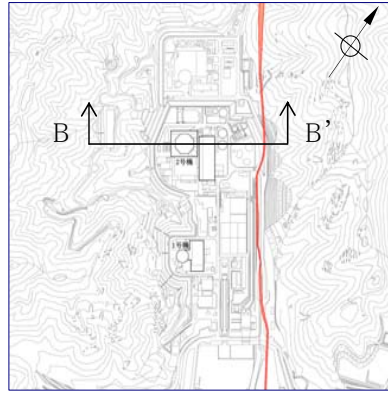


Fig. Location of the cross section

6. Vertical two-dimensional FEM analysis, (2) Analysis condition, (3) Figure of vertical rock distribution (Cross section at Unit 2: B-B' cross section)



Location of cross section

- Figure of rock distribution was made based on the geological profile of each cross sections.
- Rock distribution in depth direction is D-class rock at the earth's surface, C_L-class rock, and over C_M-class hard rock.

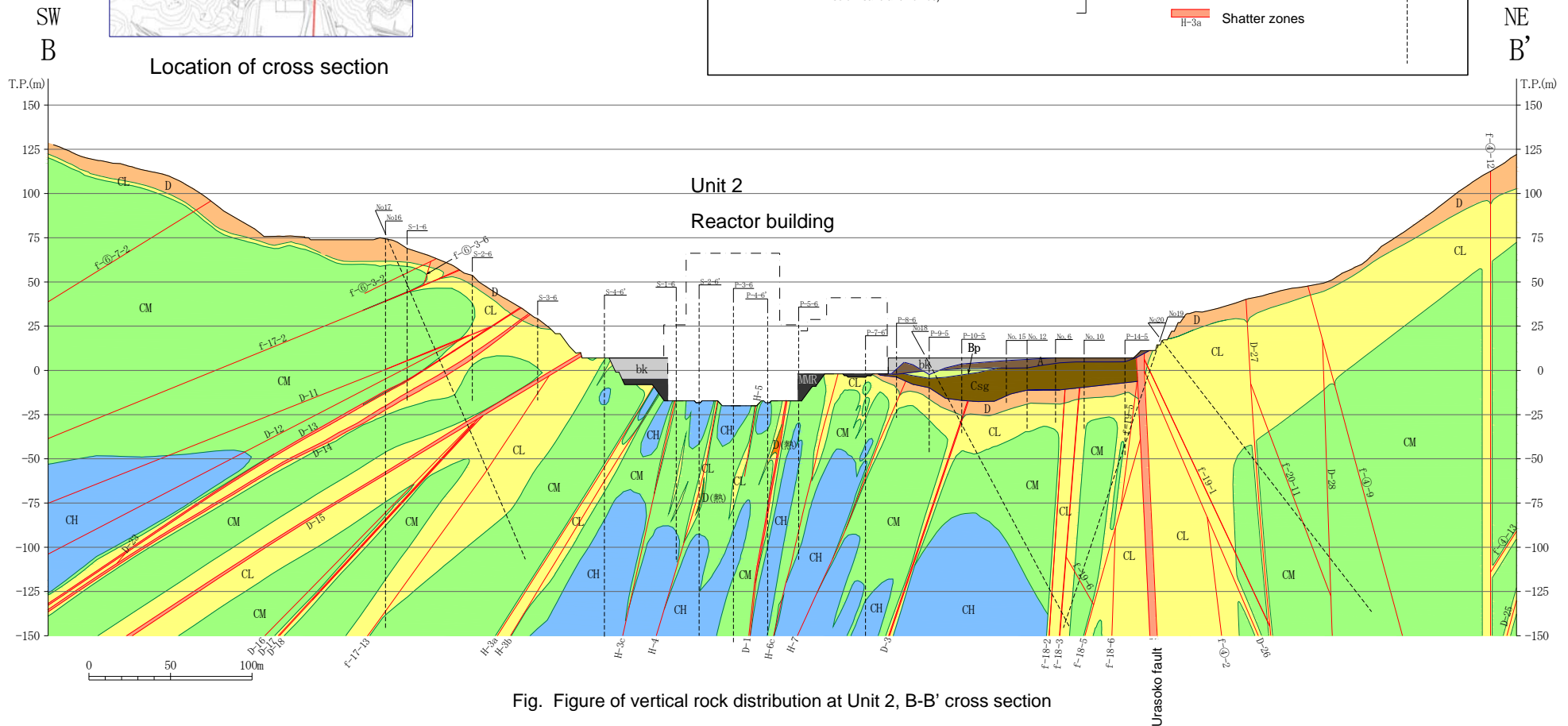
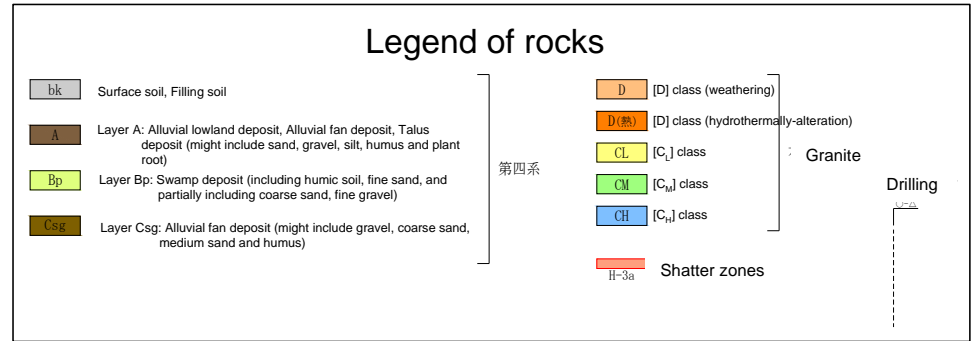


Fig. Figure of vertical rock distribution at Unit 2, B-B' cross section

6. Vertical two-dimensional FEM analysis, (2) Analysis condition, ④ Setting of physical properties for analysis

Table. Setting of physical properties for analysis

Item		Physical characteristics	Deformational characteristics		Strength characteristics		
		Wet density ρ_t (g/cm ³)	Elastic modulus E_s (N/mm ²)	Static Poisson's ratio ν_s	Shear strength τ_0 (N/mm ²)	Angle of internal friction ϕ (°)	Residual strength τ_r (N/mm ²)
Granite	CH class	Density test	Secant modulus of Plate load test	Uniaxial compression test	Same as CM class		
	CM class				Rock shear test		
	CL class				Rock shear test		
	D class (weathering)				Rock shear test		
	D class (Hydro-thermal alteration)				Rock shear test		
Shatter zone						Rock shear test	N/A
Quaternary	A		E50 of Triaxial compression test	Same as Bs class	Triaxial compression test	N/A	
	Bp						
	Bs						
	Bsm			Triaxial compression test			
	Cal						
	Csg						
Filling soil			Same as Bs class		N/A		
Man made rock (MMR)		Same as CL class			Same as CL class		

Note) Physical properties of CL class are conservatively substituted for that of MMR to decrease constraint effect for shatter zone, because MMR is just located around the buildings and has a limited depth.

6. Vertical two-dimensional FEM analysis, (2) Analysis condition, ⑤ Physical properties for analysis

Table. Physical properties for analysis

Item Classification		Physical characteristics	Deformational characteristics		Strength characteristics		
		Wet density ρ_t (g/cm ³)	Elastic modulus E_s (N/mm ²)	Static Poisson's ratio ν_s	Shear strength τ_0 (N/mm ²)	Angle of internal friction ϕ (°)	Residual strength τ_r (N/mm ²)
Granite	CH class	2.6	7,160	0.25	0.499	44	$1.31 \sigma^{0.602}$
	CM class	2.5	1,180	0.27	0.499	44	$1.31 \sigma^{0.602}$
	CL class	2.4	152	0.30	0.266	36	$0.813 \sigma^{0.554}$
	D class (weathering)	2.06	140	0.35	0.169	36	$0.792 \sigma^{0.630}$
	D class (Hydro-thermal alteration)	2.0	44	0.35	0.0697	33	$0.386 \sigma^{0.484}$
Shatter zone		2.0	44	0.35	0.0257	32	0
Quaternary	A	1.90	13.1	0.47	0.0113	25.0	0
	Bp	1.82	11.6	0.47	0.0453	23.6	
	Bs	1.94	23.4	0.47	0.0718	34.2	
	Bsm	1.97	20.8	0.47	0.0416	29.9	
	Cal	2.04	41.9	0.48	0.158	31.5	
	Csg	2.08	31.2	0.47	0.110	34.5	
Filling soil		2.07	27.0	0.47	0.156	21.5	0

Note) Physical properties of granite are based on the application for permission for establishment of Tsuruga PS

σ : normal stress (N/mm²)

Tree significant digits are basically applied.

6. Vertical two-dimensional FEM analysis, (3) Analytical model (Cross section at Unit 1)

- The ground model is made based on the figure of rock distribution. (bedrock: plane strain element, shatter zone: joint element)
- Non-linearity of each element is taken account of by decreasing stiffness depending on the generated stress.

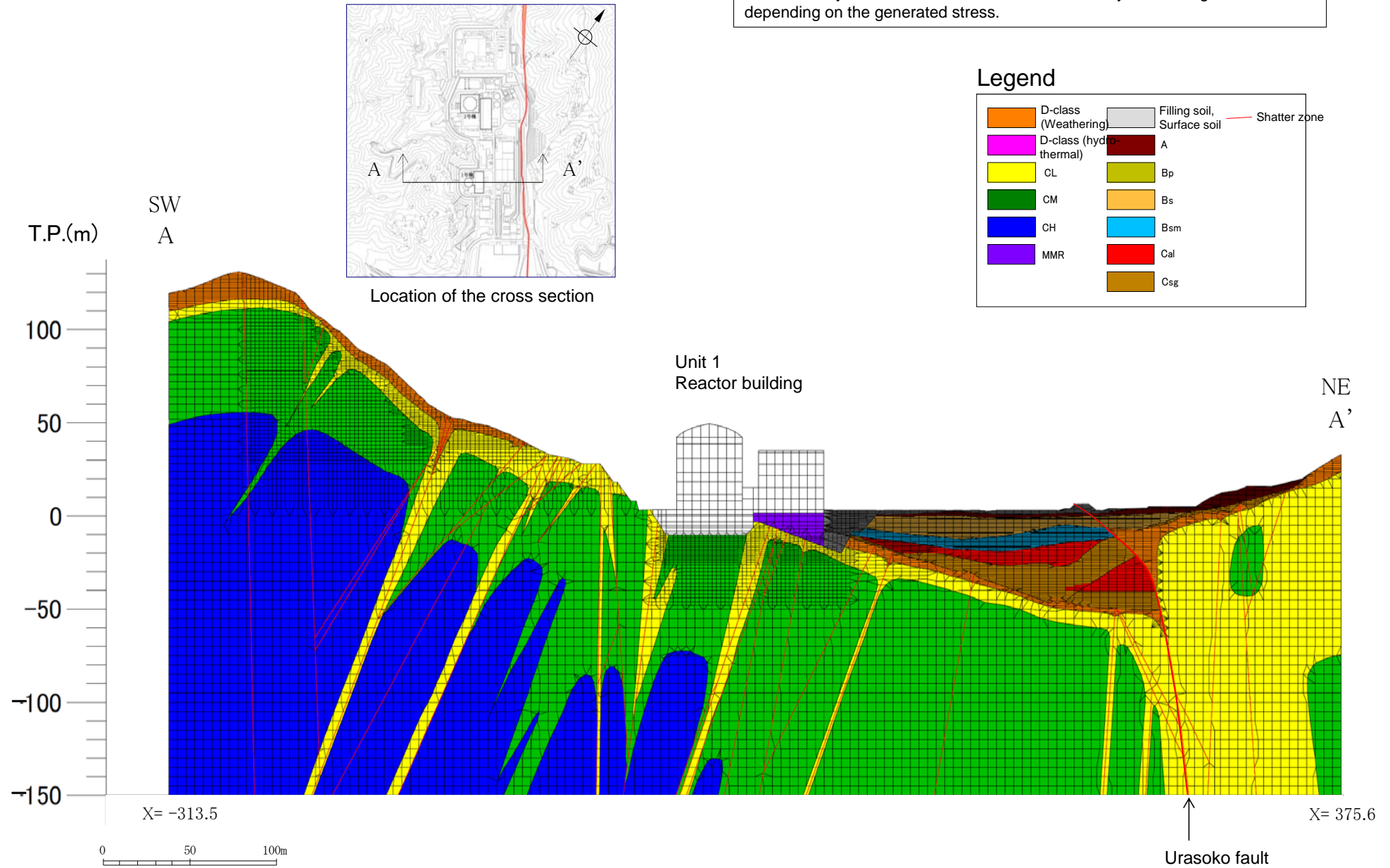


Fig. Analytical model (Unit 1 cross section)

6. Vertical two-dimensional FEM analysis, (3) Analytical model (Cross section at Unit 2)

- The ground model is made based on the figure of rock distribution. (bedrock: plane strain element, shatter zone: joint element)
- Non-linearity of each element is taken account of by decreasing stiffness depending on the generated stress.

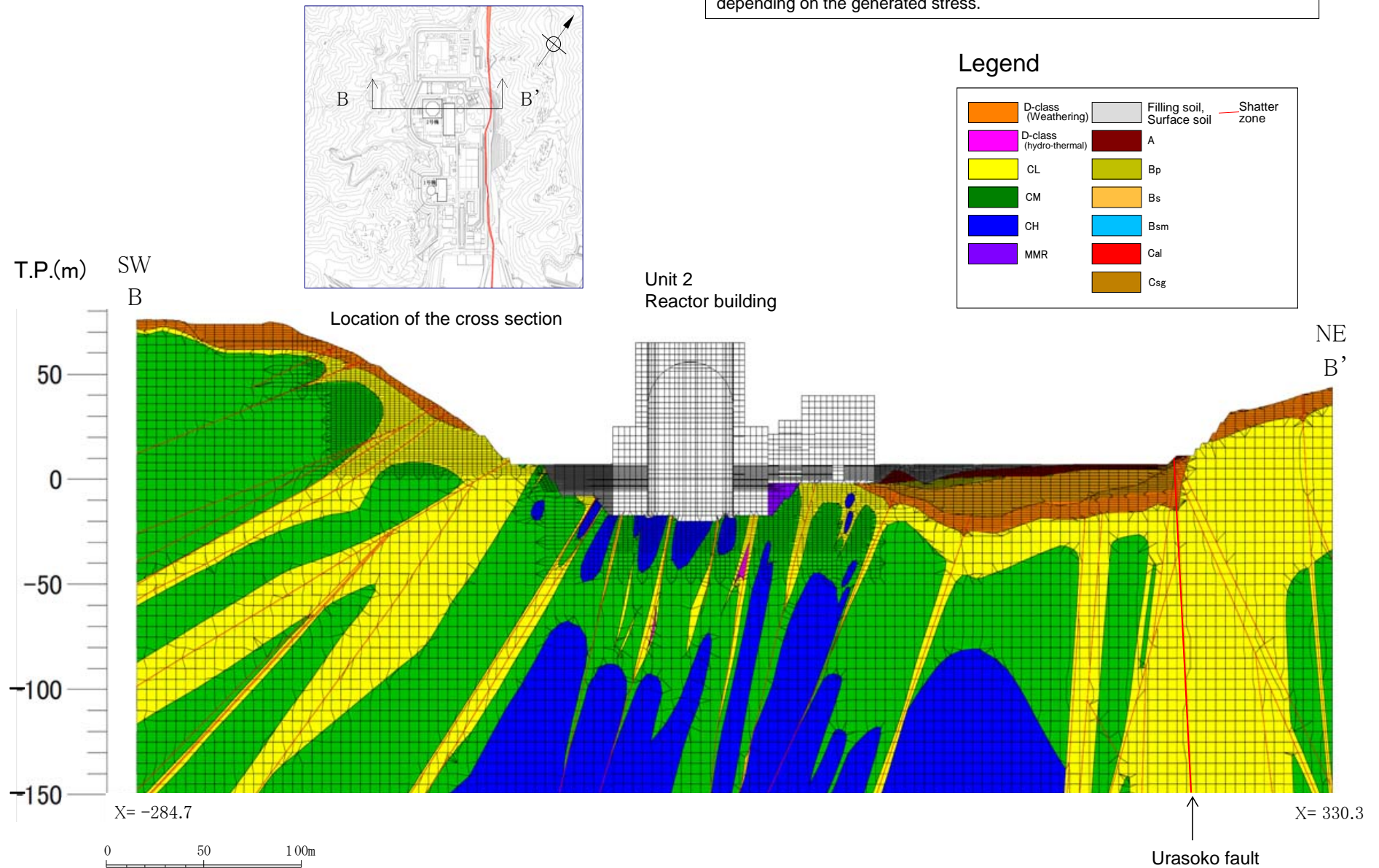
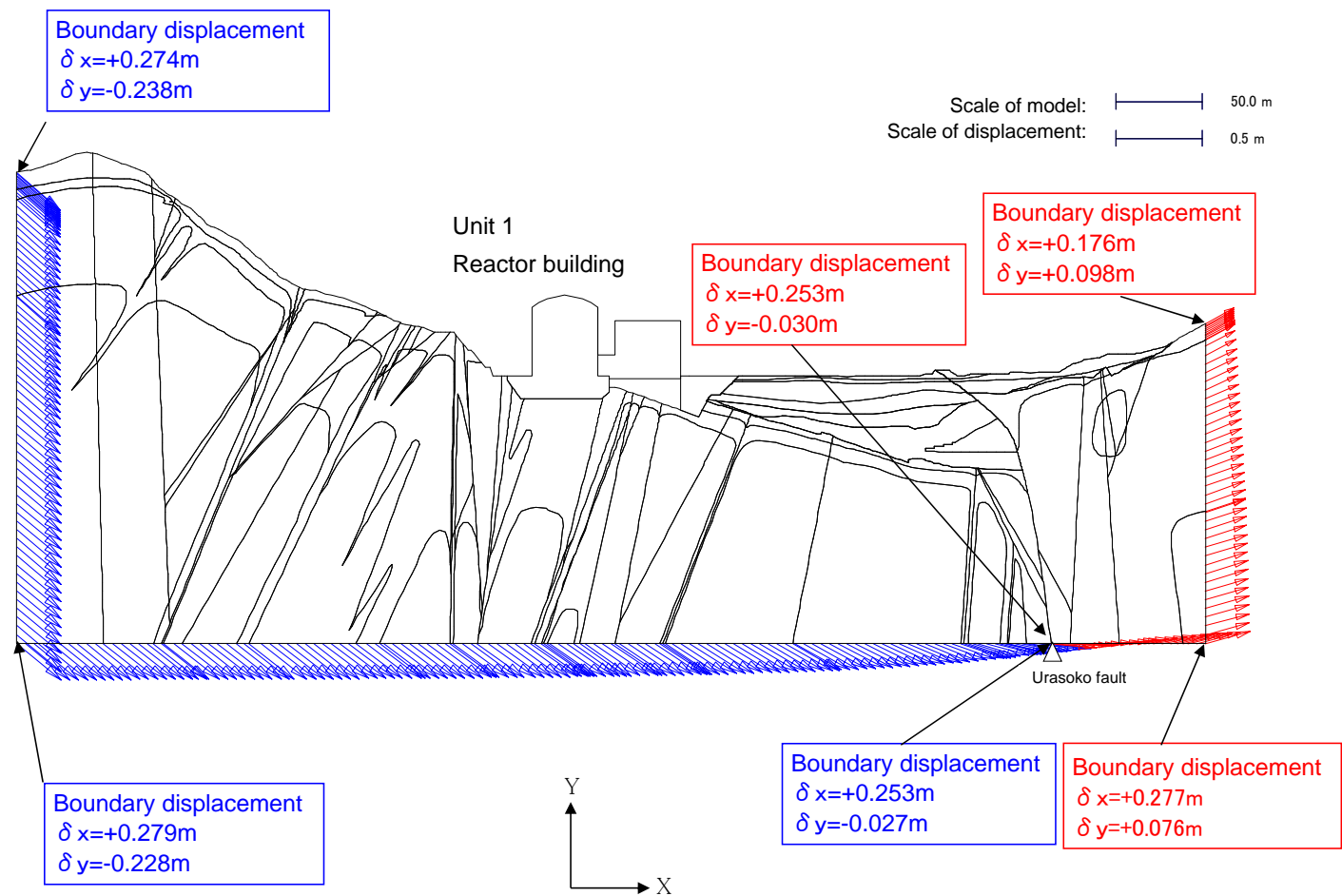


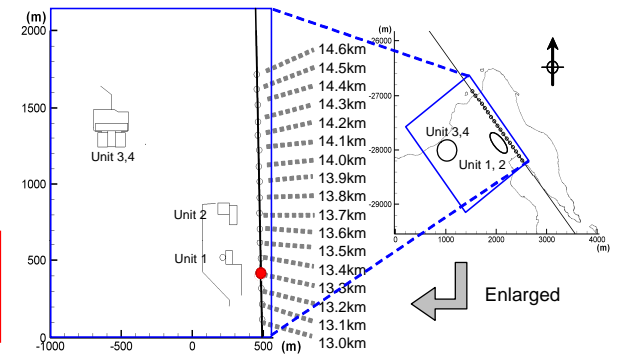
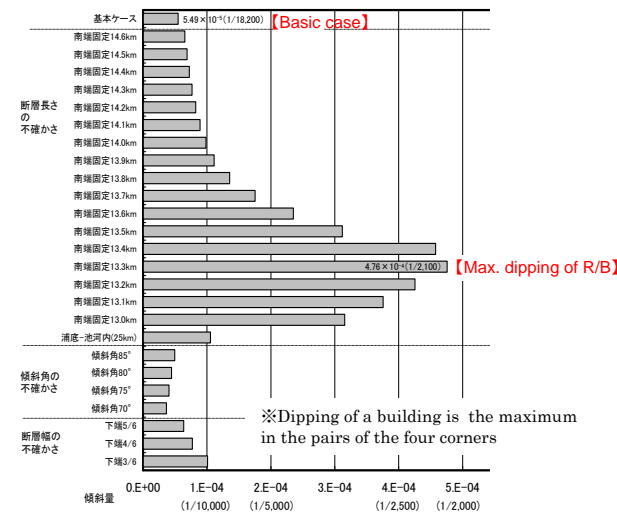
Fig. Analytical model (Unit 2 cross section)

6. Vertical two-dimensional FEM analysis, (4) Input of displacement (Unit 1 cross section)

- FEM analysis is conducted on the case that maximize the dipping of reactor building basement in the elasticity theory of dislocation.
- Displacements at boundary of the analytical model is calculated by the elasticity theory of dislocation, and that displacement data is used as enforced displacements of the boundary condition of FEM model.



[Max. dipping case at Unit 1 reactor building]
P-axis: 90 degrees, Fault length: 13.3 km



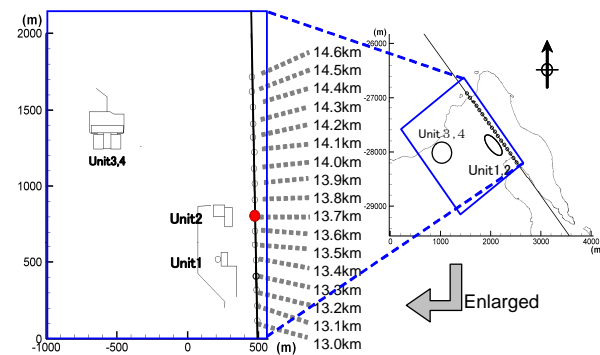
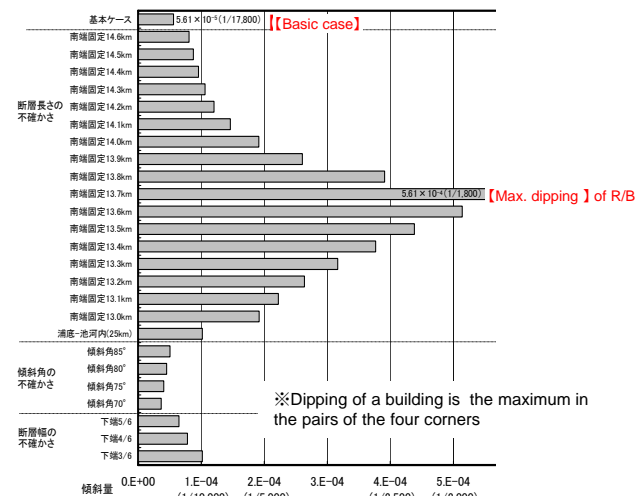
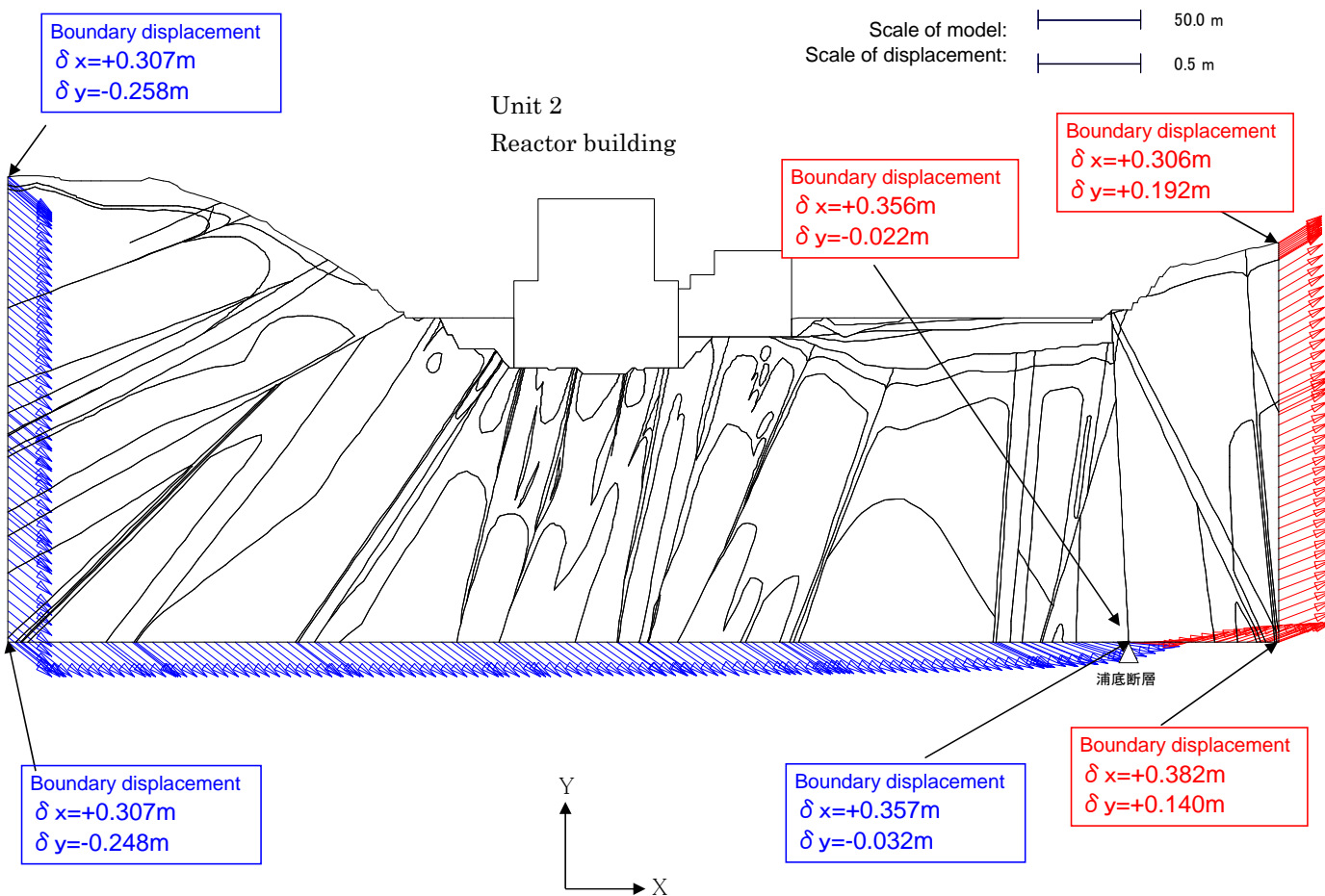
[Location of northern end of the fault]

Fig. Input of displacement (Unit 1 cross section)

6. Vertical two-dimensional FEM analysis, (4) Input of displacement (Unit 2 cross section)

- FEM analysis is conducted on the case that maximize the dipping of reactor building basement in the elasticity theory of dislocation.
- Displacements at boundary of the analytical model is calculated by the elasticity theory of dislocation, and that displacement data is used as enforced displacements of the boundary condition of FEM model.

【Max. dipping case at Unit 2 reactor building】
P-axis: 90 degrees, Fault length: 13.7 km



【 Location of northern end of the fault 】

Fig. Input of displacement (Unit 2 cross section)

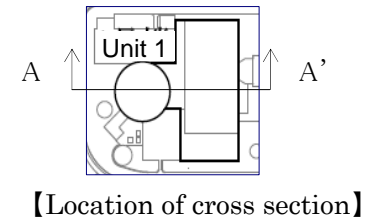
6. Vertical two-dimensional FEM analysis, (5) Analysis result
 ① Dipping of reactor building (Cross section at Unit 1)

- Maximum dipping at reactor building calculated by two-dimensional FEM is about 1/4,400.
- Dipping at reactor building calculated by two-dimensional FEM and that calculated by elasticity theory of dislocation are almost the same.

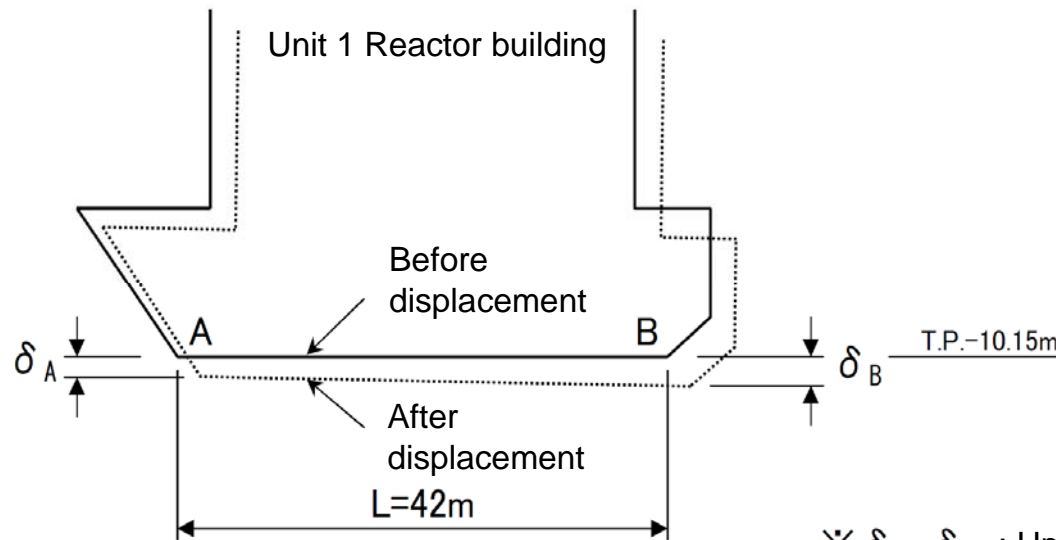
Table. Dipping at reactor building (Unit 1)

【Max. dipping case at Unit 1 reactor building】
 P-axis: 90 degrees, Fault length: 13.3 km

Analytical method	Vertical relative displacement $\delta = \delta_A - \delta_B$ (cm)	Dipping
Two-dimensional FEM	0.956	1/4,400
Elasticity theory of dislocation	0.726*	1/5,800*



※ The value at A-A' cross section of FEM analysis



※ δ_A, δ_B : Upper direction is positive

6. Vertical two-dimensional FEM analysis, (5) Analysis result

① Dipping of reactor building (Cross section at Unit 2)

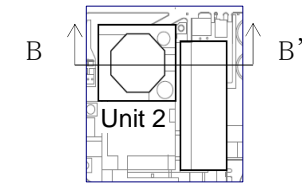
- Maximum dipping at reactor building calculated by two-dimensional FEM is about 1/10,800.
- Dipping at reactor building calculated by two-dimensional FEM and that calculated by elasticity theory of dislocation are almost the same.

Table. Dipping at reactor building (Unit 2)

【Max. dipping case at Unit 2 reactor building】

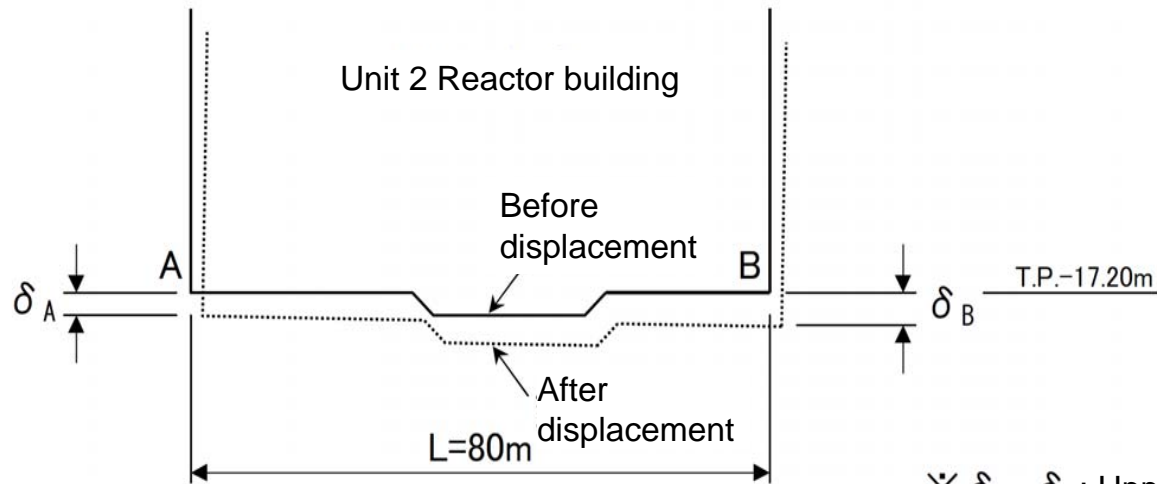
P-axis: 90 degrees, Fault length: 13.7 km

Analytical method	Vertical relative displacement $\delta = \delta_A - \delta_B$ (cm)	Dipping
Two-dimensional FEM	0.739	1/10,800
Elasticity theory of dislocation	0.786*	1/10,200*



【Location of cross section】

※ The value at B-B' cross section of FEM analysis



※ δ_A, δ_B : Upper direction is positive

6. Vertical two-dimensional FEM analysis, (5) Analysis result
 ③ Local safety factor of shatter zones (cross section at Unit 1)

Shatter zones except for Urasoko fault do not have shear failure. Tensile ruptures are limited to the earth's surface. The local safety factors near the building show enough margin.

Distribution of local safety factor of shatter zones



Location of cross section

【Max. dipping case at Unit 1 reactor building】
 P-axis: 90 degrees, Fault length: 13.3 km

- : Element developing tensile stress
- : Element reaching shear strength
- : $1.0 \leq F_s < 2.0$
- : $2.0 \leq F_s < 5.0$
- : $5.0 \leq F_s$

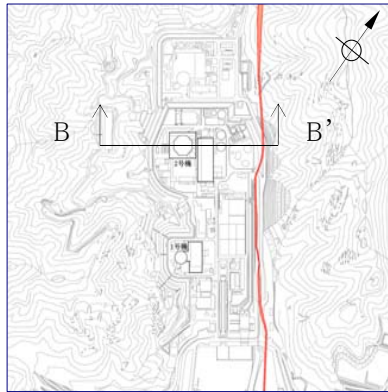


Fig. Distribution of local safety factor of shatter zones (cross section at Unit 1)

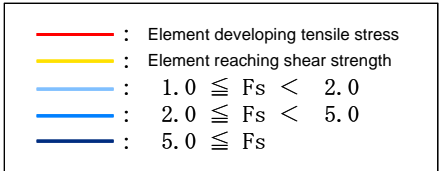
6. Vertical two-dimensional FEM analysis, (5) Analysis result
 ③ Local safety factor of shatter zones (cross section at Unit 2)

Shatter zones except for Urasoko fault do not have shear failure. Tensile ruptures are limited to the earth's surface. The local safety factors near the building show enough margin.

Distribution of local safety factor of shatter zones



【Max. dipping case at Unit 2 reactor building】
 P-axis: 90 degrees, Fault length: 13.7 km



SW
B

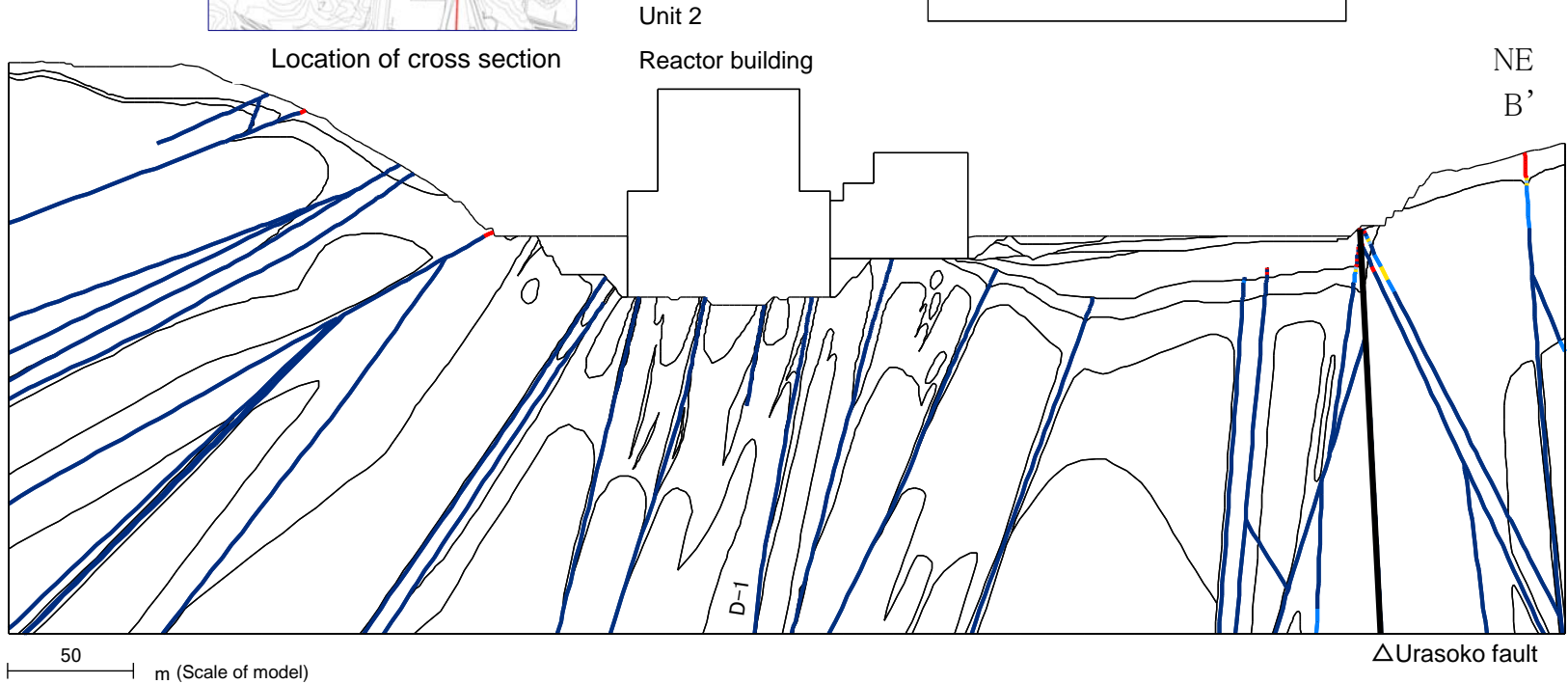


Fig. Distribution of local safety factor of shatter zones (cross section at Unit 2)

7. Horizontal two-dimensional FEM analysis, (1) Flow of the study

【Details of study】

For the detail study on horizontal displacement, horizontal two-dimensional FEM was carried out on the case that maximize horizontal shearing strain at a reactor building.

【Flow of the study】

1. Creating an analytical model

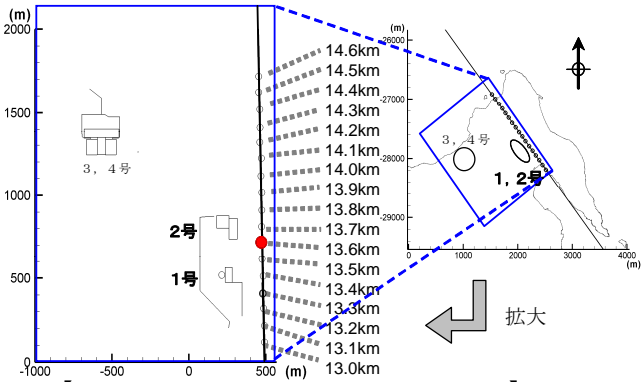
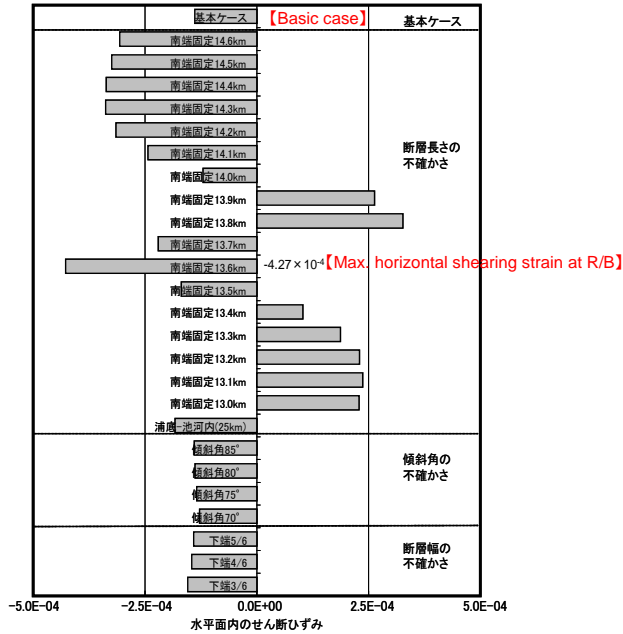
2. FEM analysis

3. Result

- Horizontal two-dimensional model
- Primly stress analysis (simple three-dimensional model)
- Maximum horizontal shearing strain case at a reactor building

Fig. Flow of the study

【Horizontal shearing strain taking account of uncertainty (Unit 2 reactor building)】



【Location of northern end of the fault】

Fig. Horizontal shearing strain at a reactor building taking account of uncertainty

7. Horizontal two-dimensional FEM analysis, (2) Rock distribution

- Physical properties of rocks are classified with CH, CM, CL, and D-class. CM-class is widely distributed around Unit 2.
- Direction of N-S to NE-SW is the dominant direction for shatter zones.
- In the NE side of power station, Quaternary is distributed.

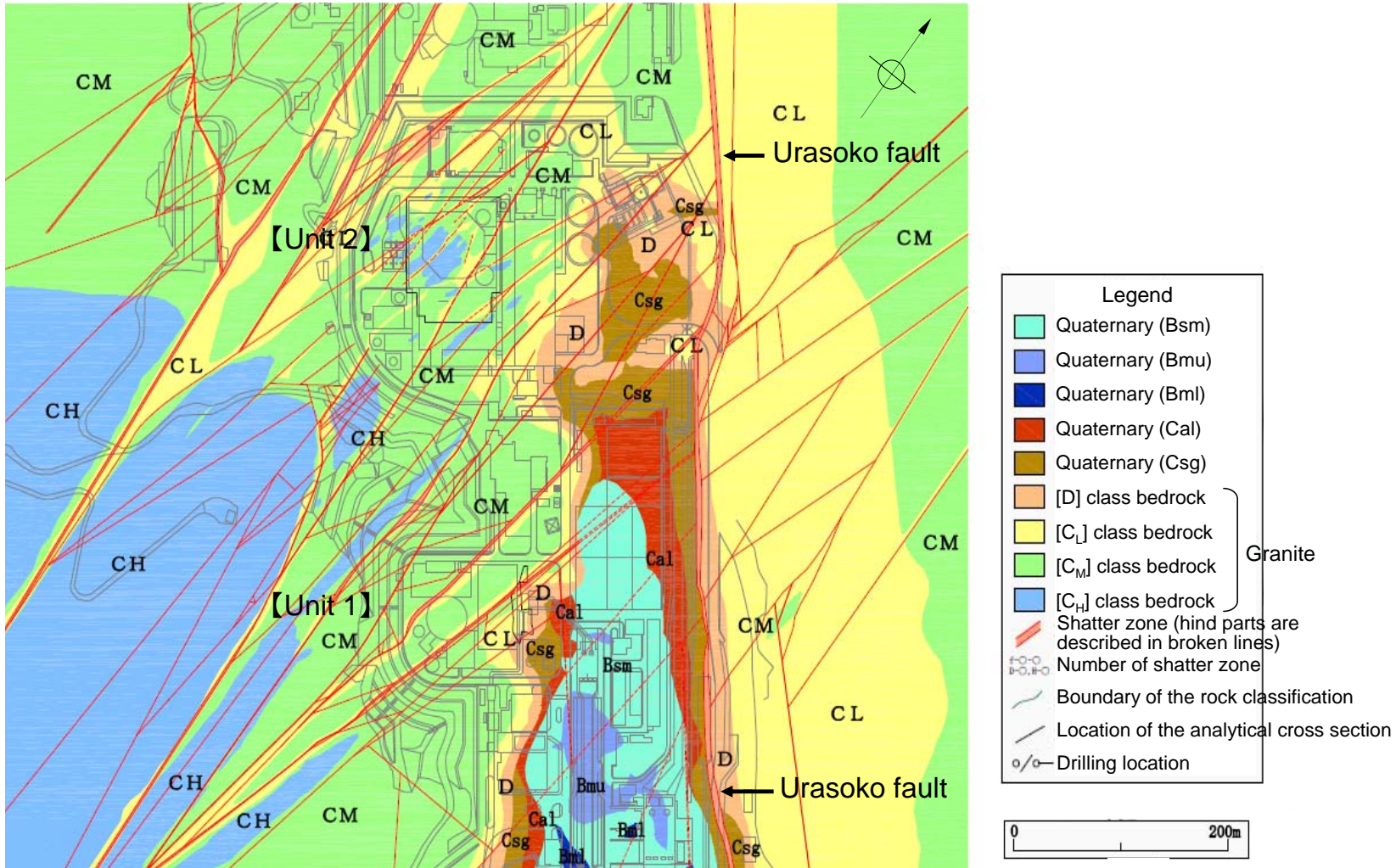


Fig. Figure of rock distribution (T.P. -15m)

7. Horizontal two-dimensional FEM analysis, (3) Analytical model

- Footwall is simulated. In order to consider the effect of rock classification and shatter zones around a reactor building, broad area is simulated.
- Same as the vertical two-dimensional FEM model, the distribution of shatter zones is simulated from the geologic map.
- Physical properties are same as that of vertical two-dimensional FEM model
- Physical properties are set according to the rock classifications (Distribution of Quaternary is limited to the depth direction, therefore quaternary is conservatively simulated as bedrock of CL-class).

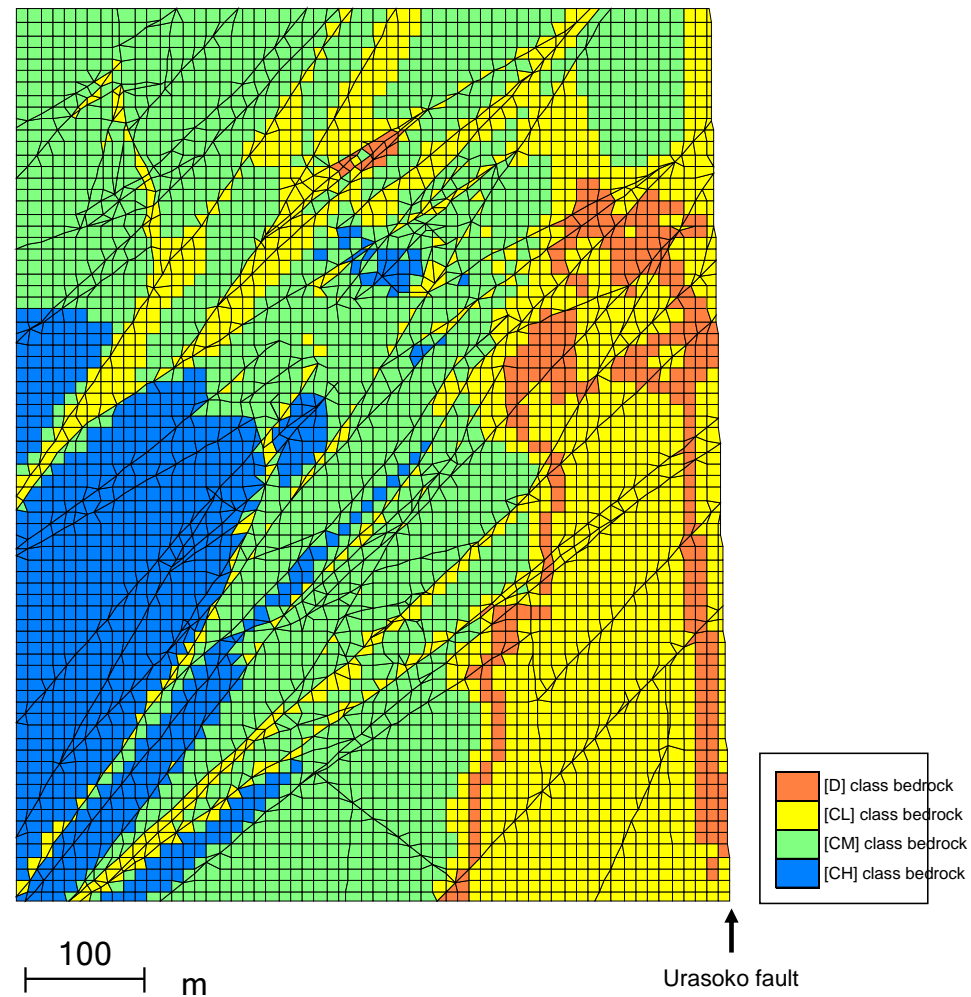


Fig. Analytical model

7. Horizontal two-dimensional FEM analysis, (5) Input of displacement

- FEM analysis is conducted on the case that maximize horizontal shearing strain of the ground at a reactor building in the elasticity theory of dislocation.
- Displacements at boundary of the analytical model is calculated by the elasticity theory of dislocation, and that displacement data is used as enforced displacements of the boundary condition of FEM model.
- Local displacement is developed around the northern end of fault, in the case that maximize horizontal shearing strain.

【Horizontal shearing strain taking account of uncertainty (Unit 2 reactor building)】

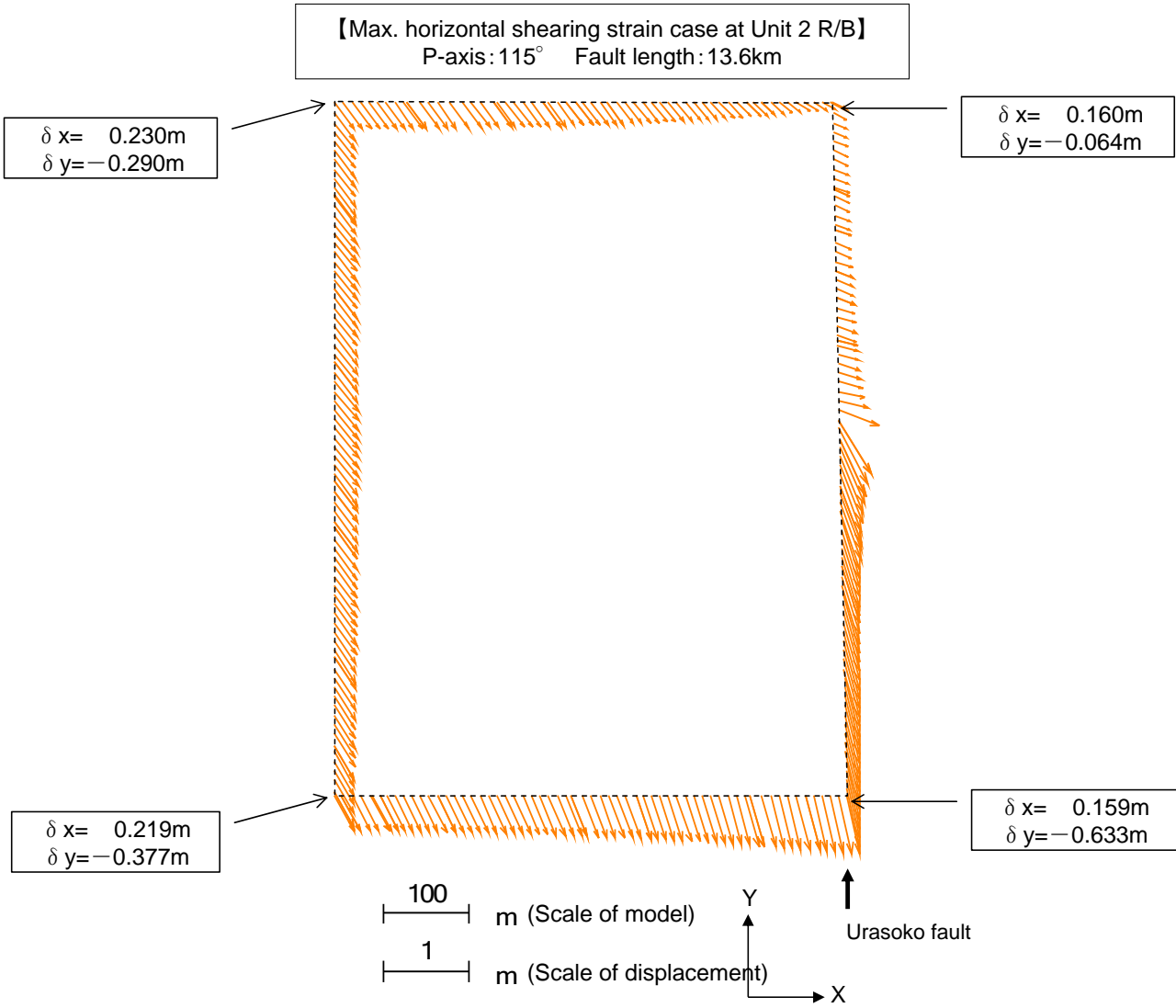
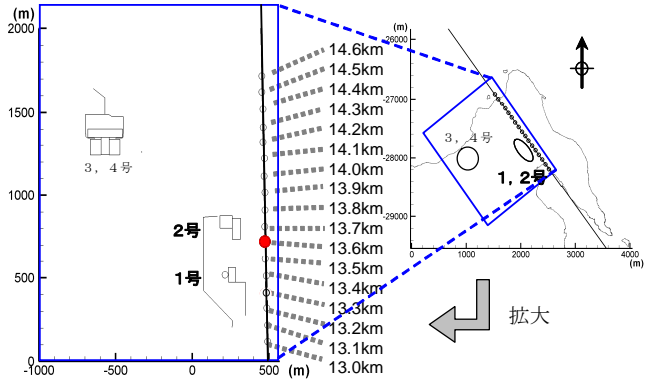
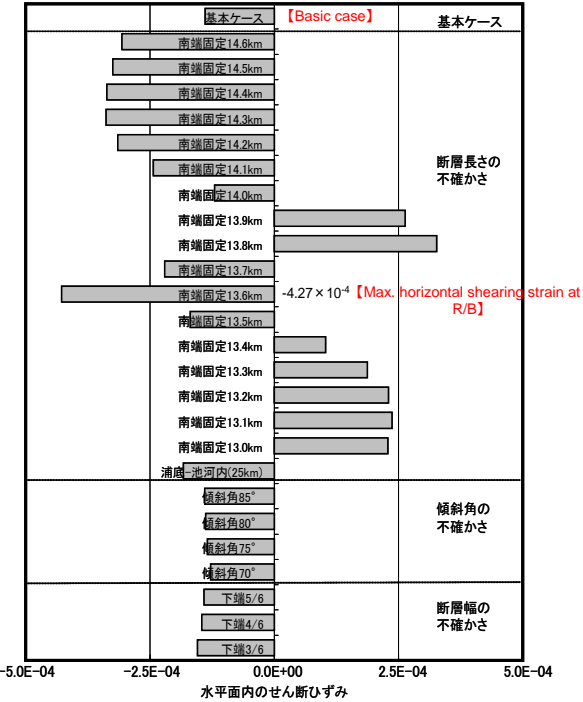


Fig. Input of displacement



【Location of northern end of the fault】

Fig. Horizontal shearing strain at a reactor building taking account of uncertainty

7. Horizontal two-dimensional FEM analysis, (6) Analysis result

① Relative displacement of reactor buildings and important facilities

• Relative displacement between a reactor building and an important facility is small (for example, relative displacement between centers of Unit 2 reactor building and auxiliary building is about 15mm)

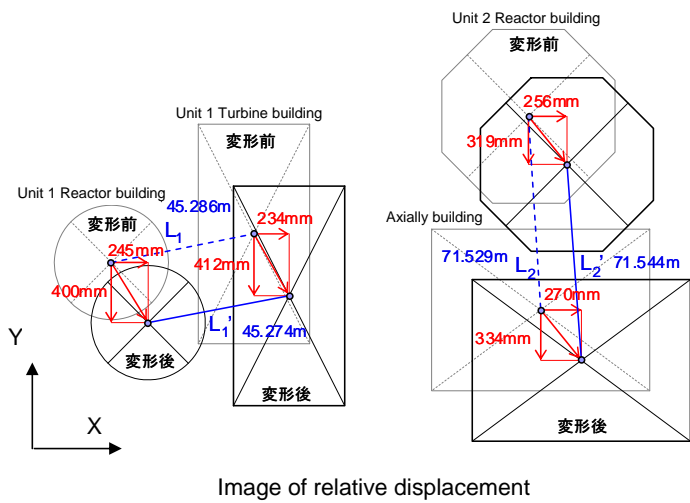
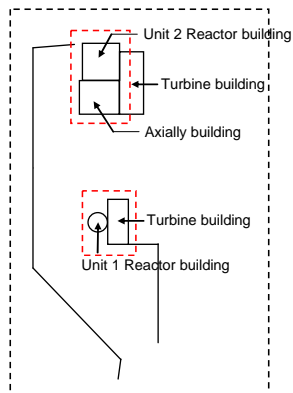


Table. Relative displacement between the centers of a reactor building and an important building

Buildings	Relative displacement
Unit 1 reactor building – Turbine building	-12mm ($L_1'-L_1$)
Unit 2 reactor building – Auxiliary building	15mm ($L_2'-L_2$)

※ Direction away from each other is positive.



7. Horizontal two-dimensional FEM analysis, (6) Analysis result

③ Local safety factor of shatter zones

Because of local displacement at the northern end of Urasoko fault, partial rapture and decrease of safety factor is developed nearby Urasoko fault. However that area is limited and safety factors near the buildings show enough margin.

Distribution of local safety factor of shatter zone

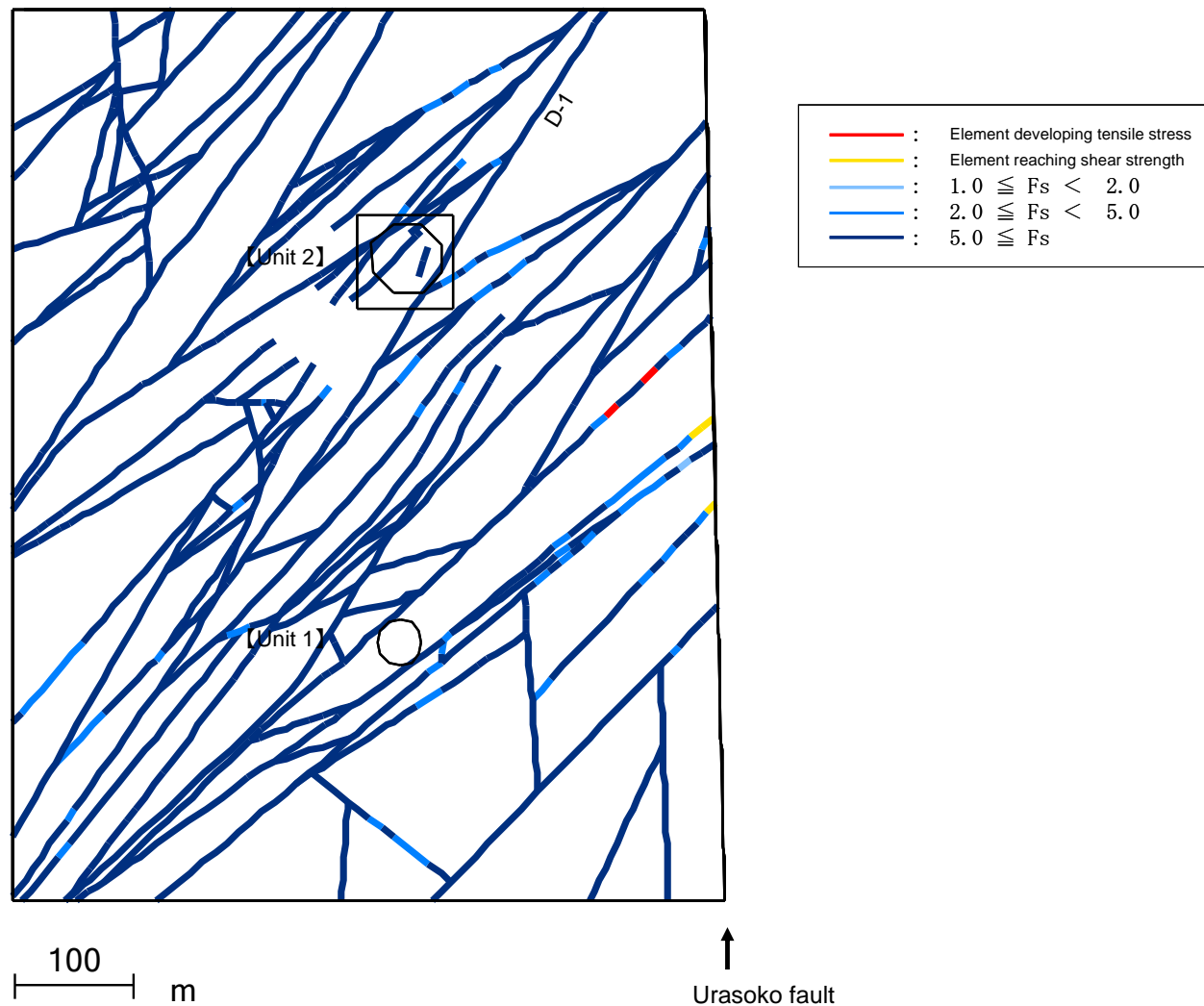
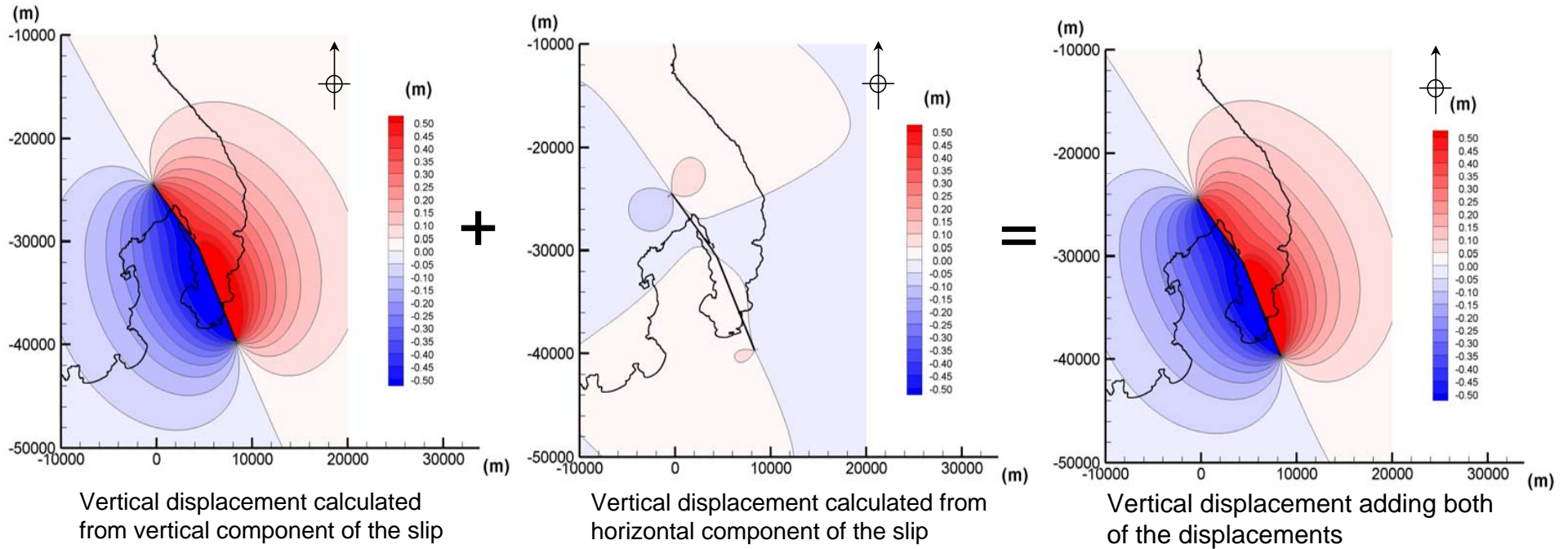


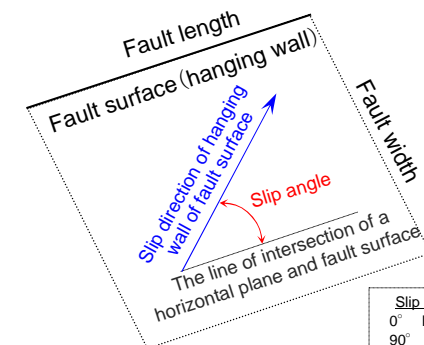
Fig. Distribution of local safety factor of shatter zones

<Reference> Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault, (1) Basic case: P-axis 90°

Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault is calculated by superimposing vertical displacement calculated from vertical component of the slip and vertical displacement calculated from horizontal component of the slip.



Slip angle (P-axis 90°)	
Northern part of Urasoko-Uchiikemi fault	39°
Southern part of Urasoko-Uchiikemi fault	64°

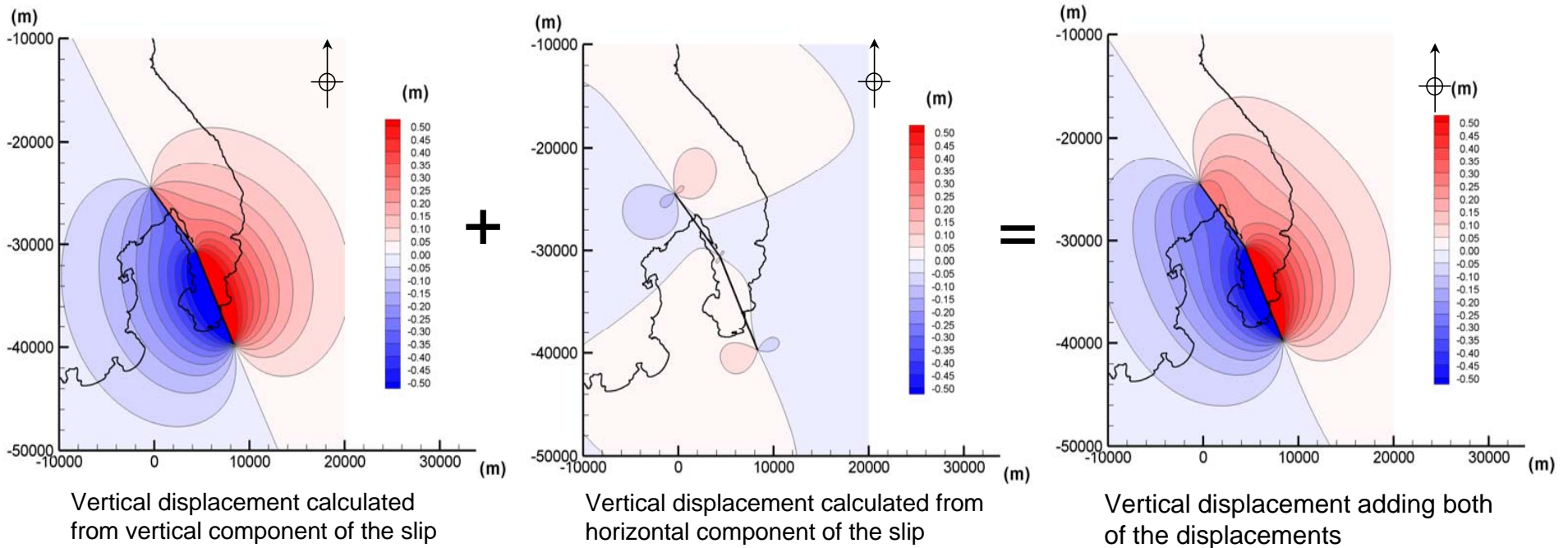


Slip angle and slip direction
 0° left-lateral slip
 90° reverse fault
 180° right-lateral slip
 270° normal fault

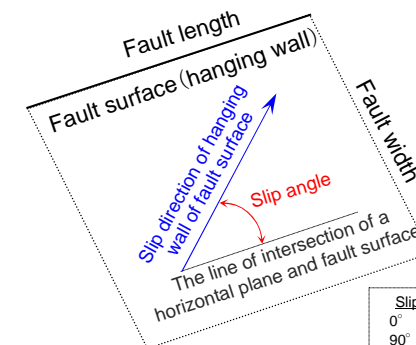
Fig. 【Reference】 Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault (basic case: P-axis 90°)

<Reference> Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault, (2) Basic case: P-axis 95°

Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault is calculated by superimposing vertical displacement calculated from vertical component of the slip and vertical displacement calculated from horizontal component of the slip.



Slip angle (P-axis 95°)	
Northern part of Urasoko-Uchiikemi fault	21°
Southern part of Urasoko-Uchiikemi fault	57°

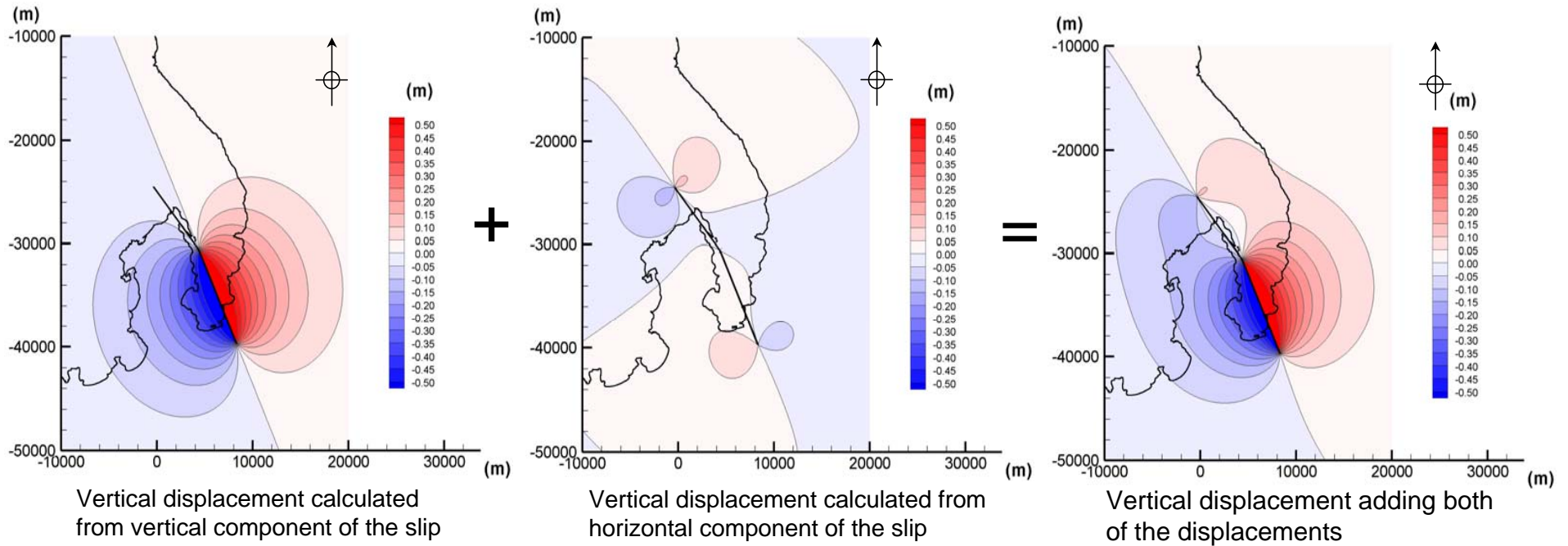


Slip angle and slip direction
 0° left-lateral slip
 90° reverse fault
 180° right-lateral slip
 270° normal fault

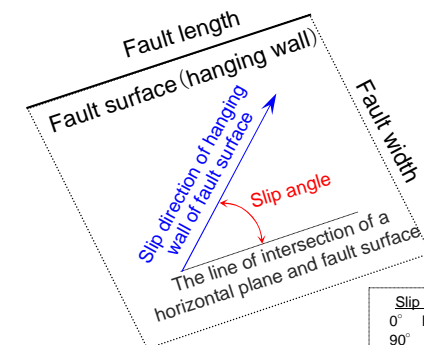
Fig. 【Reference】 Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault (basic case: P-axis 95°)

<Reference> Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault, (3) Basic case: P-axis 100°

Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault is calculated by superimposing vertical displacement calculated from vertical component of the slip and vertical displacement calculated from horizontal component of the slip.



Slip angle (P-axis 100°)	
Northern part of Urasoko-Uchiikemi fault	0°
Southern part of Urasoko-Uchiikemi fault	49°

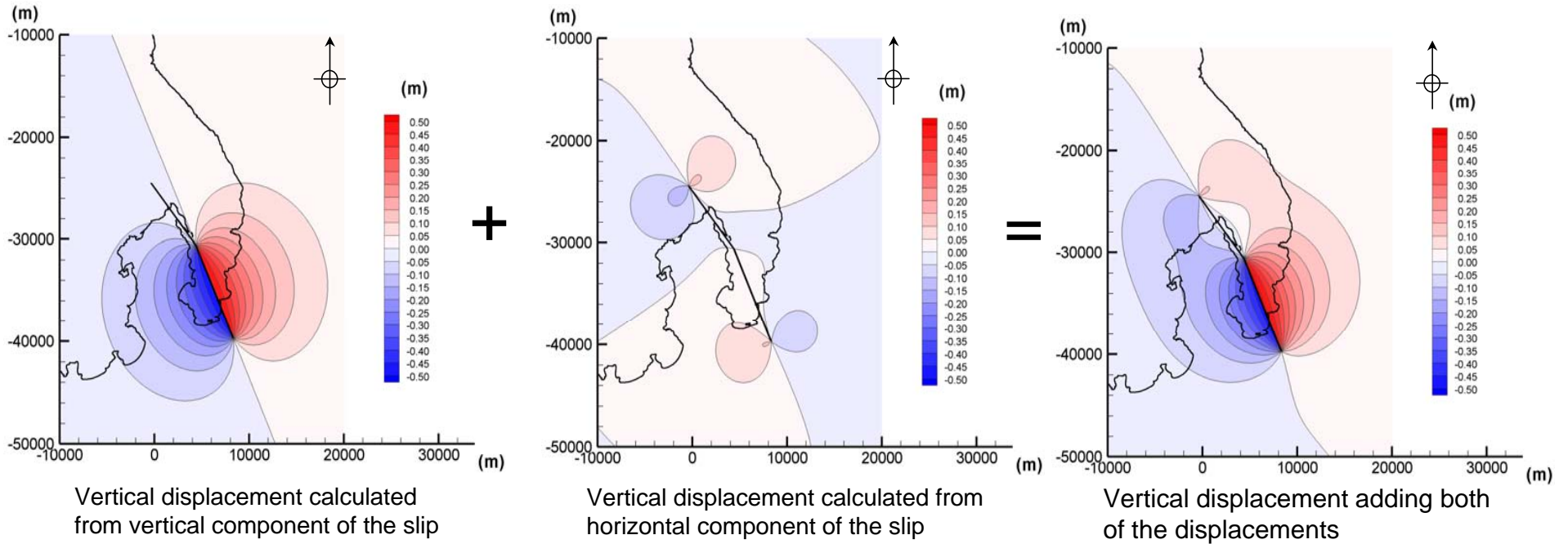


Slip angle and slip direction
 0° left-lateral slip
 90° reverse fault
 180° right-lateral slip
 270° normal fault

Fig. 【Reference】 Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault (basic case: P-axis 100°)

<Reference> Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault, (4) Basic case: P-axis 105°

Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault is calculated by superimposing vertical displacement calculated from vertical component of the slip and vertical displacement calculated from horizontal component of the slip.



Slip angle (P-axis 105°)	
Northern part of Urasoko-Uchiikemi fault	0°
Southern part of Urasoko-Uchiikemi fault	38°

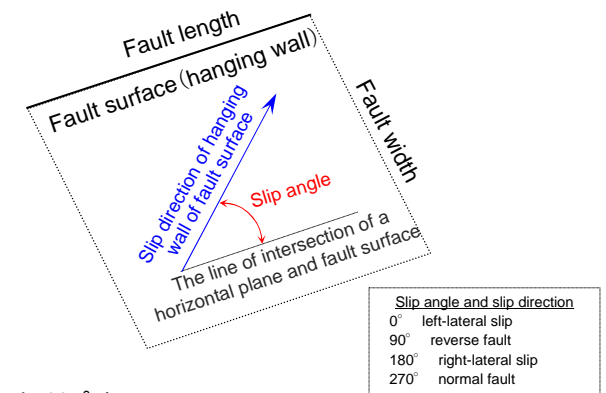
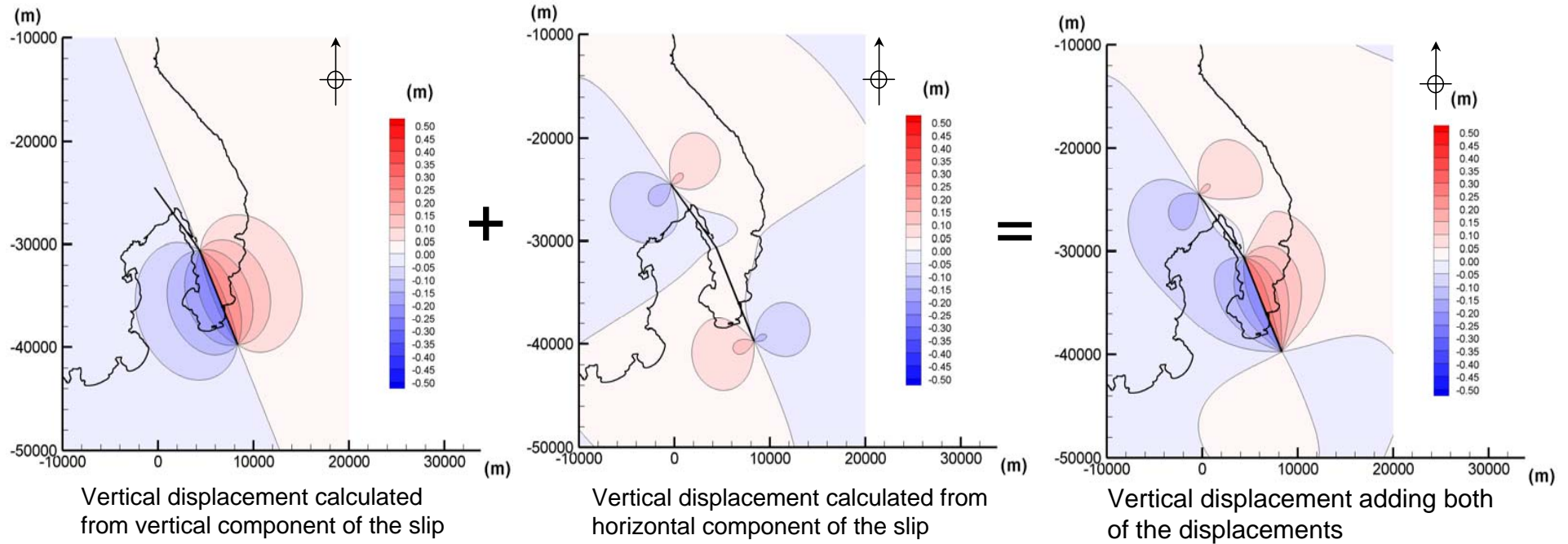


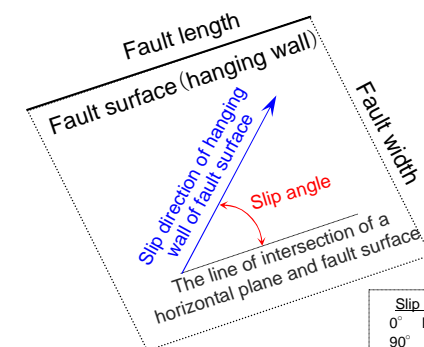
Fig. 【Reference】 Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault (basic case: P-axis 105°)

<Reference> Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault, (5) Basic case: P-axis 110°

Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault is calculated by superimposing vertical displacement calculated from vertical component of the slip and vertical displacement calculated from horizontal component of the slip.



Slip angle (P-axis 110°)	
Northern part of Urasoko-Uchiikemi fault	0°
Southern part of Urasoko-Uchiikemi fault	19°

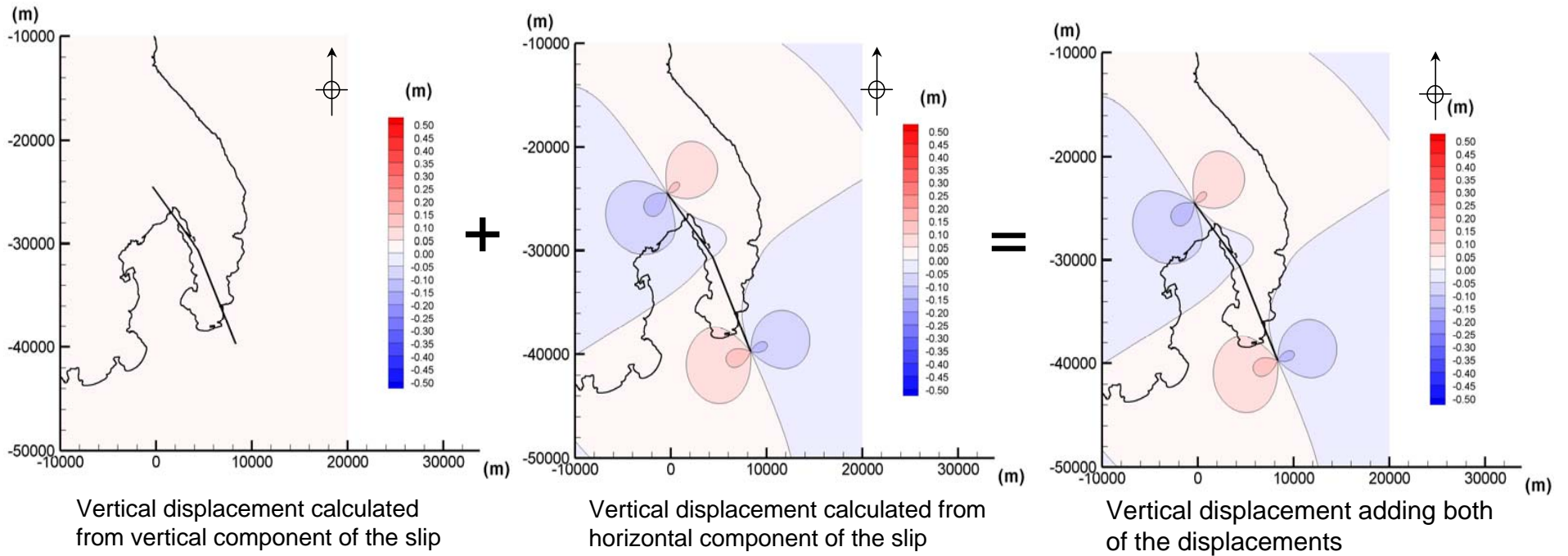


Slip angle and slip direction
 0° left-lateral slip
 90° reverse fault
 180° right-lateral slip
 270° normal fault

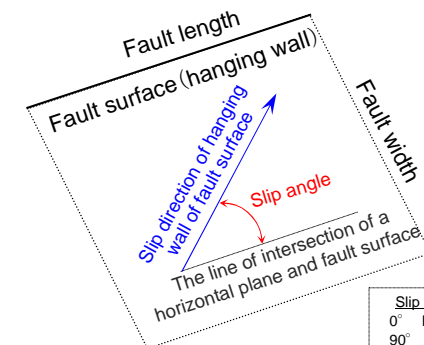
Fig. 【Reference】 Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault (basic case: P-axis 110°)

<Reference> Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault, (6) Basic case: P-axis 120°

Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault is calculated by superimposing vertical displacement calculated from vertical component of the slip and vertical displacement calculated from horizontal component of the slip.



Slip angle (P-axis 115°)	
Northern part of Urasoko-Uchiikemi fault	0°
Southern part of Urasoko-Uchiikemi fault	0°



Slip angle and slip direction
 0° left-lateral slip
 90° reverse fault
 180° right-lateral slip
 270° normal fault

Fig. 【Reference】 Vertical displacement of ground associated with the activity of Urasoko-Uchiikemi fault (basic case: P-axis 120°)

Our opinions on 'views against JAPC's claim'

(Draft) EMS's views against JAPC's claim concerning the fault evaluations of Tsuruga PS site		JAPC's opinion	Reference No.
Main texts	Arguments		
<p>【EMS views to Claim 5】 The current seismic design policies stipulate that an active fault given consideration in the seismic design is a "fault with signs of activity after the Late Pleistocene that cannot be denied." It is not stipulated that an active fault is a "fault, of which signs of activity are recognized." So, to be of concern here is a case with no data relevant to activity available (with no data available proving no activity is found whatsoever). On the occasion that the operator does not present a data accurate enough, like this time, a fault in question is to be judged as an "active fault given consideration in the seismic design." EMS also considers that <u>the operator is primarily held accountable for proving that a fault is not an active fault</u>. Thus, the operator, which conducted surveys, has a responsibility to present data relevant to fault activity (showing there is no activity whatsoever). In case a new fact emerges, this evaluation might be reviewed, if necessary. Even on that occasion, though, the operator needs to present a set of "objective data" denying any possibility that a fault under survey is not active through further surveys etc.</p>	<ul style="list-style-type: none"> • Whether the operator is primarily held accountable for having the burden of proof? 	<p>From the legal point of view, we consider as inappropriate that the operator is primarily held for having the burden of proof.</p> <p>Generally speaking, under the regulation laws, it is authorities, as an administrator of regulations, that are accountable for proving whether a subject matter in case makes up regulatory requirements. To that end, authorities are entitled to the right of collection of reports and the right to make on-site inspections. Pursuant to new backfitting rules under the Nuclear Reactor Regulation Law, the Nuclear Regulation Authority (or EMS) is authorities found relevant to the case in question and is responsible for having the burden of proof and making final explanations.</p> <p>We already presented to EMS highly accurate and objective facts and data based on surveys to prove that there are "no signs of activity." If the NRA (or EMS) tries to overturn our position, it will be held accountable for having the burden of proof, or verifying its position, and making explanations on the given data.</p>	136-138

Relevant rules on “accountability” of administrative agencies

〈 Article 23-2 (1) Administrative Case Litigation Act〉

The court, when it finds it necessary in order to clarify the matters related to the action, may make the following dispositions:

(i) request any administrative agency affiliated with the State or the public entity that stands as a defendant, or the administrative agency that stands as a defendant, to submit the whole or part of materials that clarify the content of the original administrative disposition or administrative disposition on appeal, the provisions of the laws and regulations which give a basis for the original administrative disposition or administrative disposition on appeal, the facts constituting the cause of the original administrative disposition or administrative disposition on appeal and other grounds for the original administrative disposition or administrative disposition on appeal (excluding the records of a case of request for an administrative review prescribed in the following paragraph,) which are held by the administrative agency;

(Expert commentaries)

- “The purpose of the law is to stipulate that administrative agencies shall be held accountable for clarifying the legality of disposition” (extracted from a book on the administrative law authored by Yoshikazau Shibaïke).
- “If any administrative disposition encroaches on the interests of the people, administrative bodies shall be held accountable for explaining legality of their action” (extracted from the book above).
- To support what is stipulated in Article 23-2, administrative bodies shall be primarily held accountable for explaining disposition (extracted from a book on the administrative law co-authored by Keiko Sakurai and Hiroyuki Hashimoto (third edition)).

<Administrative Procedure Act>

Article 1 (Purpose etc.) “**to advance a guarantee of fairness and progress towards transparency...”**

Article 8 (1) (Showing of Grounds) “Administrative agencies shall, in cases where they render Dispositions refusing the permission etc. sought by Applications, concurrently show the grounds for the subject Disposition.”

(Expert commentary)

The stipulation helps the subject parties bring up motion for complaint etc. (“function of accommodating judicial action”) to inhibit arbitrariness of administrative agencies by guaranteeing fairness of administrative judgment (“function of inhibiting arbitrariness”). Any dispositions without grounds shall be invalid and dispositions with flaws in presenting grounds should be nullified (extracted from a book on the administrative law co-authored by Keiko Sakurai and Hiroyuki Hashimoto (third edition)).

Act 14 (1) (Showing of Grounds for Adverse Dispositions)

“Administrative agencies, in cases where they render Adverse Dispositions, shall concurrently show the ground for the Adverse Disposition to the subject parties.”

The stipulation above is intended to inhibit arbitrariness of administrative agencies by guaranteeing the circumspection and rationality of administrative dispositions in light of predisposition of adverse dispositions, which holds the subject parties directly accountable and refuses their rights (extracted from the 2121st edition of the “Hanrei Jiho” (citation of judicial precedents) published on Jun 7 of 2011).