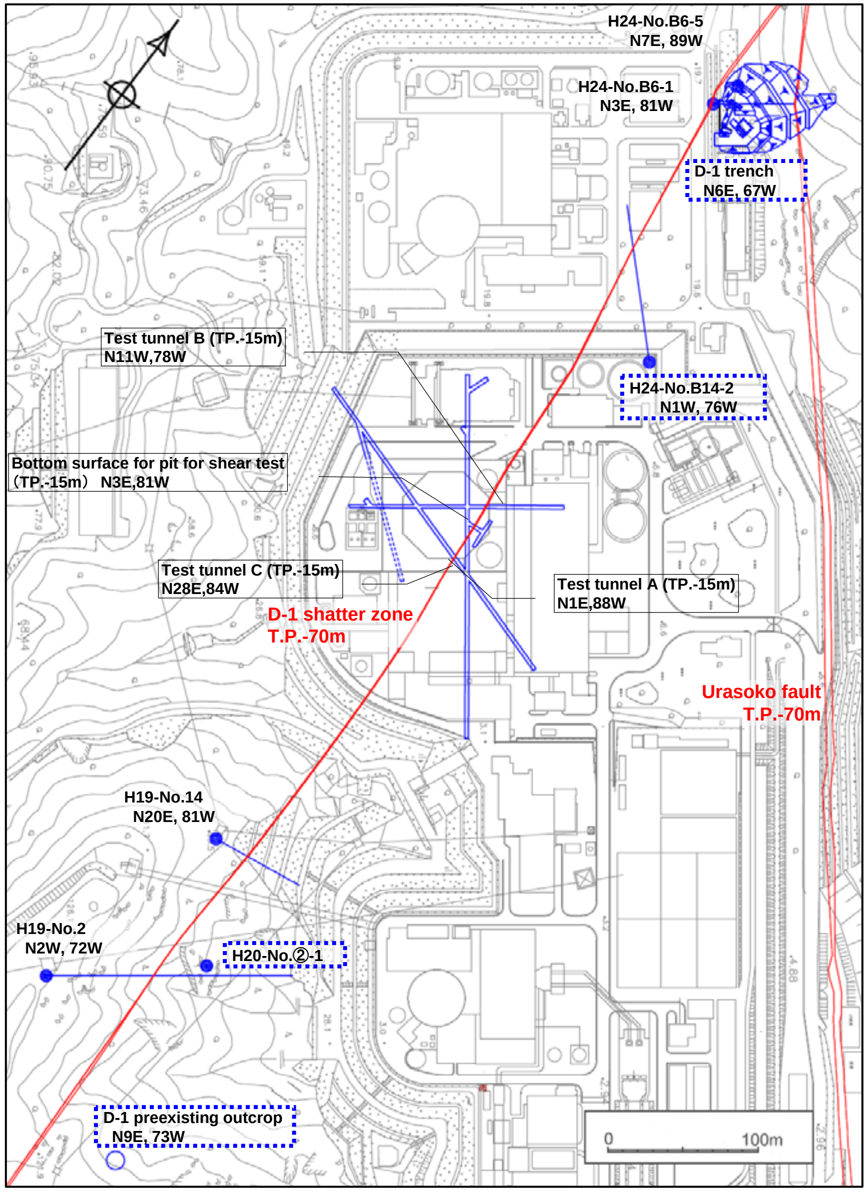
Result of evaluating continuity of D-1 shatter zone

Material newly presented after December 10, 2012



Position where the sense of displacement of normal fault was confirmed

- The shatter zones identified as D-1 shatter zone run roughly in a direction of N-S, are high-angle westerly dip, and have excellent continuity. Both consist of cataclasite and fault gouge.
- Observation of fault gouges of the last slips reveals that D-1 shatter zone and G fault have the sense of normal fault. On the other hand, K fault is a reverse fault, showing a reverse sense of displacement.
- Thus, we judge that the K fault is different from D-1 shatter zone and G fault and D-1 shatter zone compose of a series of shatter zones.

Flow of evaluation employing numerical analysis

・Simultaneous activity (future activity) of the shatter zones and Urasoko fault was evaluated with employing numerical analysis
・In conducting numerical analysis, conditions of study were organized. Based on the “elasticity theory of dislocation,” “basic study” and “study taking uncertainty into account” were conducted.
・In study of the “elasticity theory of dislocation,” the conditions of study that would produce the severest results in evaluation of bearing capacity of the ground we studied with using a Finite Element Method (FEM) model.

[Organization of the conditions of study] * Organization of basic parameters and margin of uncertainty
・Geometric shape of fault (length of fault, width of fault, dip angle, depth of the top of fault)
・Slip of fault (slip angle, slip volume)
・Ground model (ground structure, Poisson’s ratio)

↓

Elasticity theory of dislocation

[Basic study with assuming the ground as an elastic body]
・Conduct calculation with basic parameters
・Decide the slip direction of fault that produces the maximum result (inclination, etc.)

[Basic study with assuming the ground as an elastic body and taking uncertainty into account]
・Study the above slip direction with taking into account the uncertainty of computational parameters

↓ Severest result of study for reactor facility

FEM

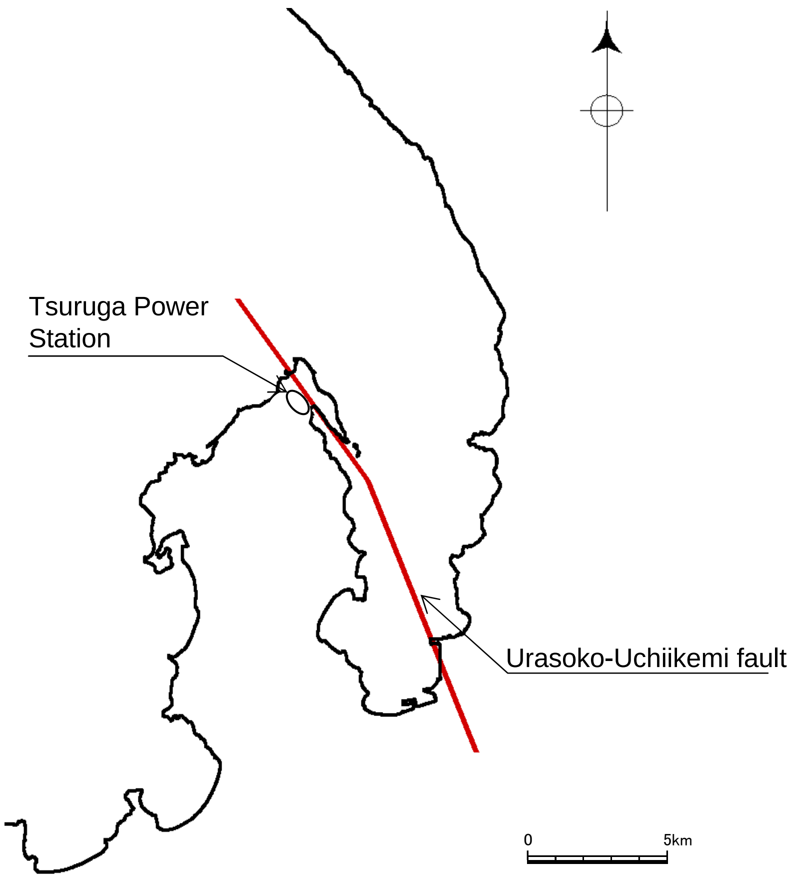
[Study with taking into account the ground’s non-homogeneity and non-linear characteristics]
・Detailed modeling of the ground near fault (reflecting rock classes, shatter zones, etc.)
・Of the results of study based on the elasticity theory of dislocation, the case producing the severest result was studied (vertical and horizontal directions)

Flow of evaluation employing numerical analysis

Modelled fault to be analyzed

- 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 fault.
- We set the conditions of study with using the concept of Tsunami Evaluation Method* as a reference.
- 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.

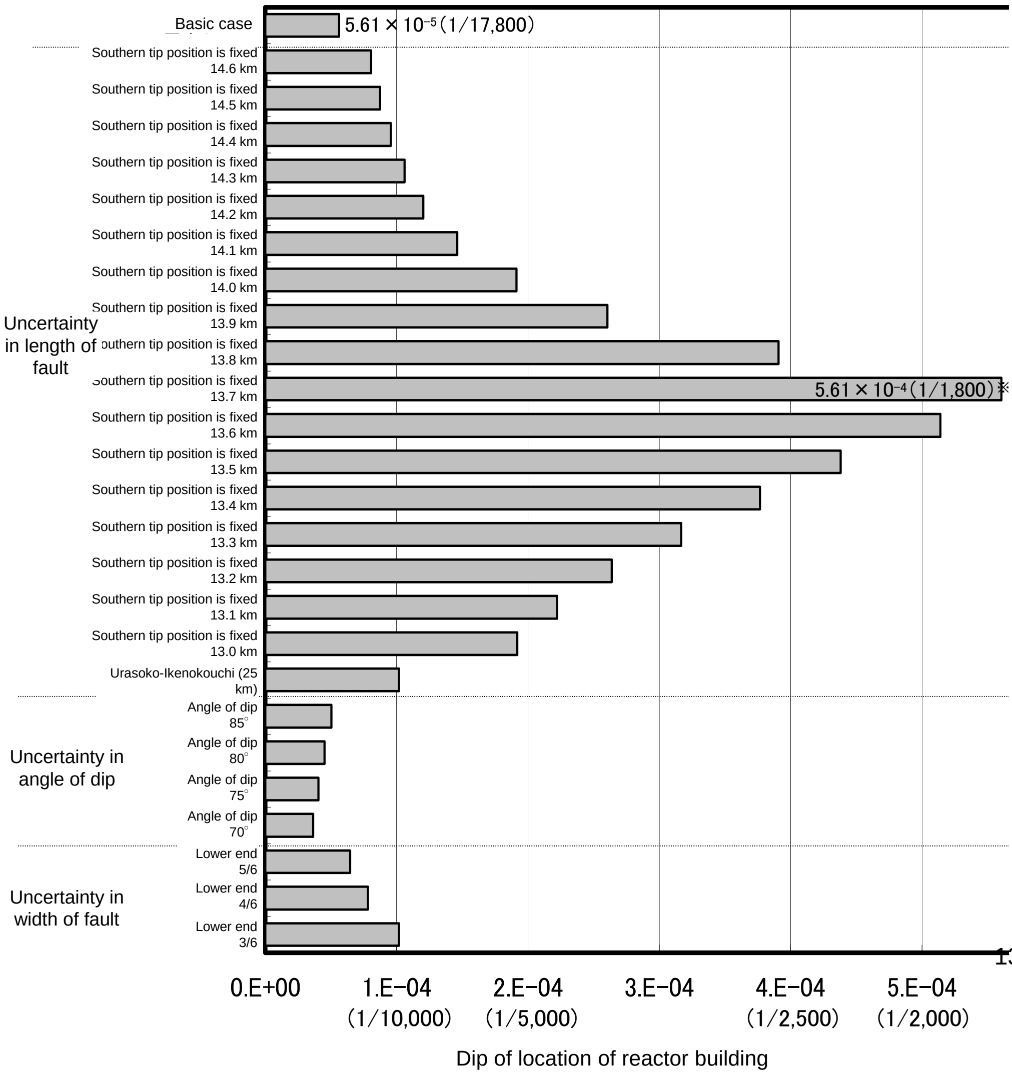
* Tsunami Evaluation Subcommittee, Nuclear Civil Engineering Committee, Japan Society of Civil Engineers (2002)



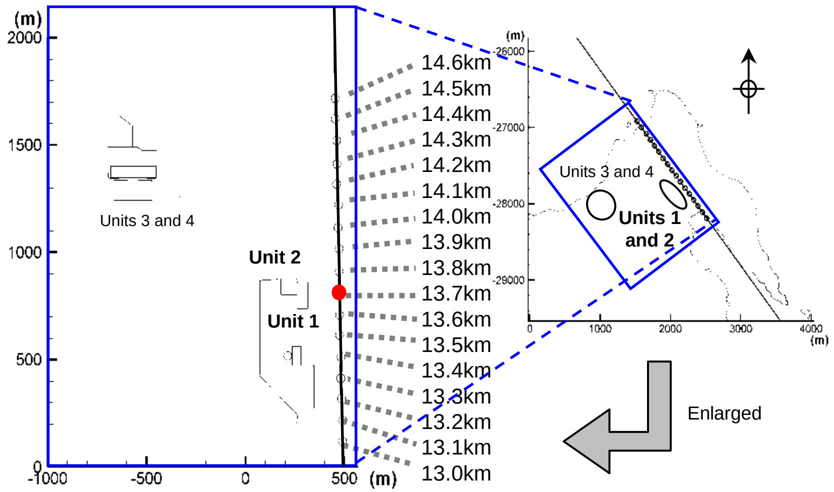
Modelled fault to be analyzed

Result of analysis based on elasticity theory of dislocation (dip of location of reactor building: Unit 2 reactor building)

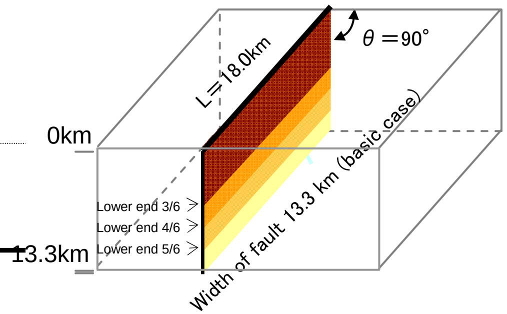
- In basic study, as for the case of p-axis = 90° that represents the maximum dip, we carried out the study with taking into account uncertainties of length of fault, angle of dip and width of fault.
- As a result, a dip becomes maximum in the case of 13.7 km (the southern tip position is fixed), and is about 1/1,800 at Unit 2 reactor building.



* Dip in the direction of maximum dip is 5.61 x 10⁻⁴ (1/1,800)



As Tsuruga Power Station is located in the north of Urasoko-Uchiikemi fault, a length of fault (slip volume) becomes larger by fixing the location of the southern end of the fault with changing the location of the northern end. Thus, study was done with fixing the location of the southern end of the fault.

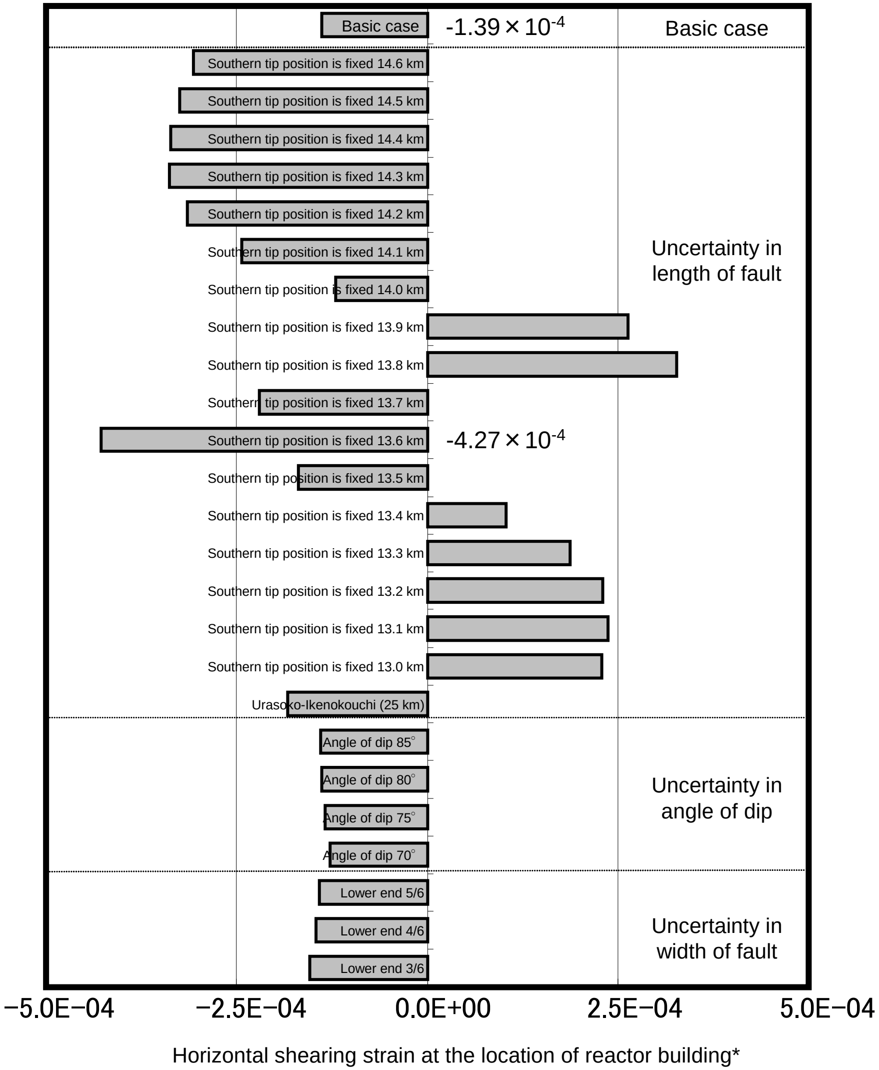


Width of fault W 13.3 km (basic case)
① 5/6 W = 11.1 km
② 4/6 W = 8.9 km
③ 3/6 W = 6.7 km

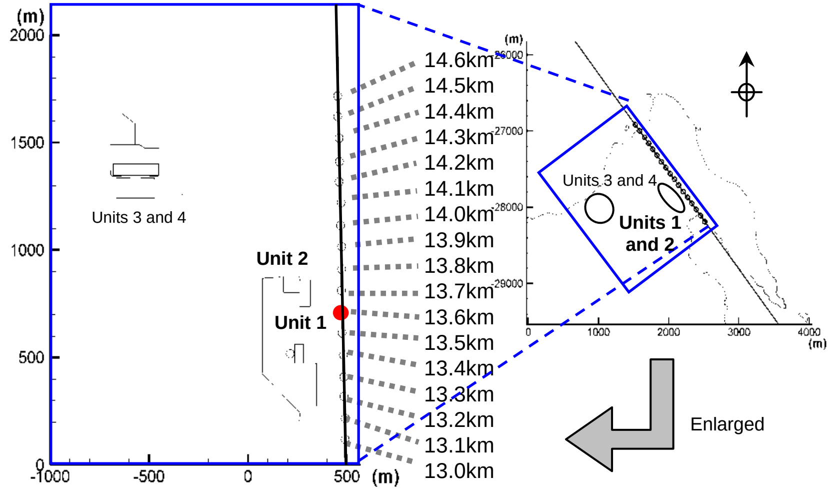
Dip with taking uncertainty into account (Unit 2 reactor building)

Result of analysis based on elasticity theory of dislocation (horizontal shearing strain at location of reactor building: Unit 2 reactor building)

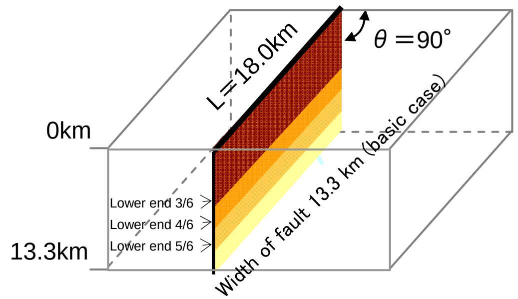
- In basic study, as for the case of p-axis = 115° that represents the maximum shearing strain, we carried out the study with taking into account uncertainties of length of fault, angle of dip and width of fault.
- As a result, a shearing strain becomes maximum in the case of 13.6 km (the southern tip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



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



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.



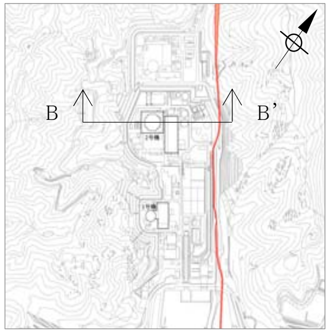
Width of fault W 13.3 km (basic case)
① 5/6 W = 11.1 km
② 4/6 W = 8.9 km
③ 3/6 W = 6.7 km

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

Result of analysis using vertical two-dimensional FEM model (local safety factors of shatter zone: profile of Unit 2)

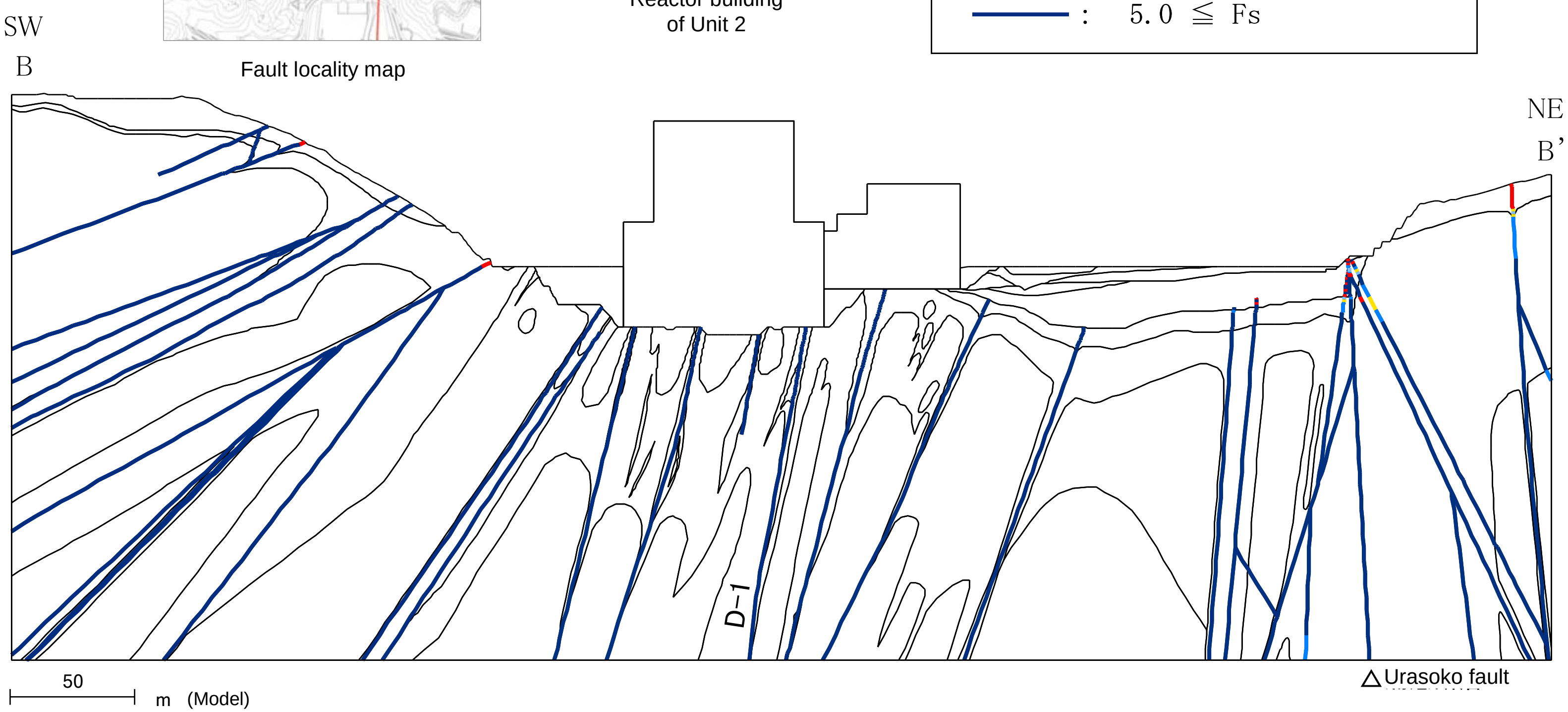
In the result of study based on the “elasticity theory of dislocation,” we performed an analysis of the case that a dip at the location of reactor building becomes maximum.

[The case of maximum dip at the location of Unit 2’s R/B]
P axis: 90° length of fault: 13.7 km



Fault locality map

- : Elememt developing tensile stress (red)
- : Elememt reaching shear strength (yellow)
- : 1.0 ≦ Fs < 2.0
- : 2.0 ≦ Fs < 5.0
- : 5.0 ≦ Fs



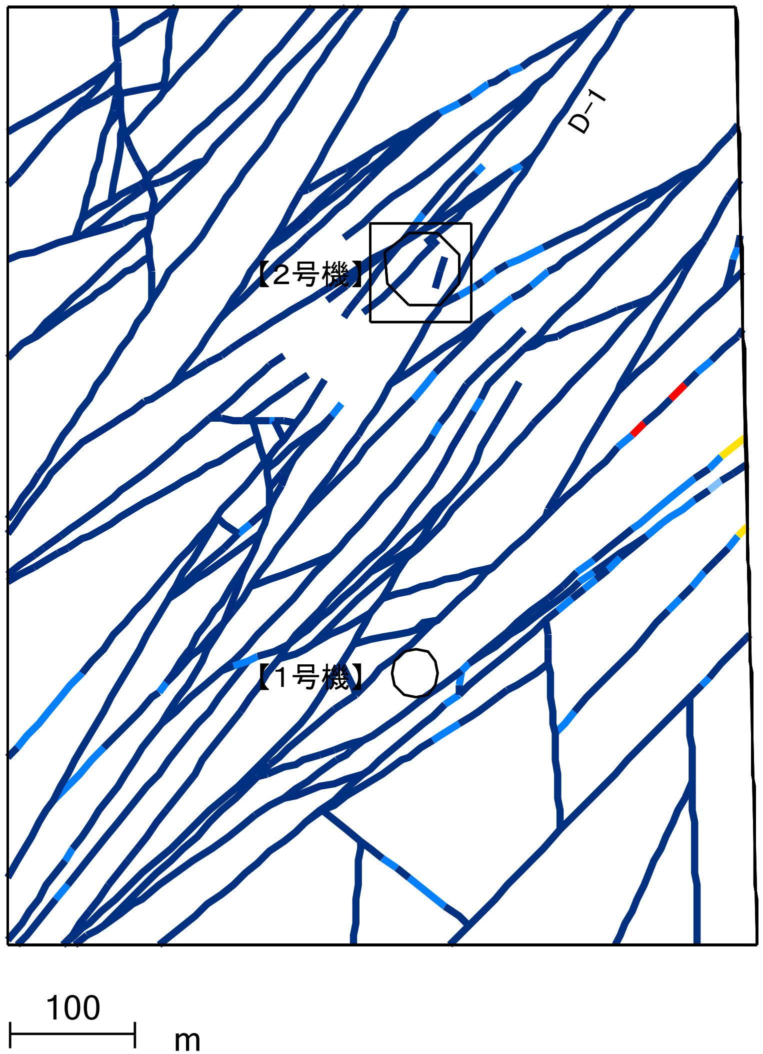
Distribution of local safety factors of shatter zone (profile of Unit 2)

Developments of shear fracture and tensile stress are seen in the shatter zone near Urasoko fault. But, as such area is limited and the local safety factors near the reactor building show enough margin of safety, the ground is believed to have enough bearing capacity.

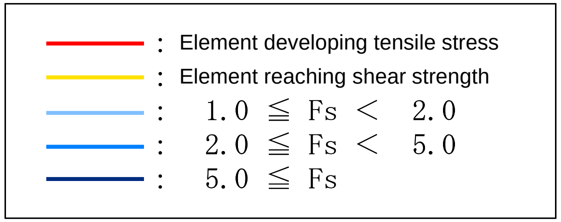
Result of analysis using horizontal two-dimensional FEM model (local safety factors of shatter zone)

In the result of study based on the “elasticity theory of dislocation,” we performed an analysis of the case that a horizontal shear strain at the location of reactor building becomes maximum.

[The case of maximum horizontal shear strain at the location of Unit 2’s R/B]
P axis: 90° length of fault: 13.7 km



Distribution of local safety factors of shatter zone



Developments of shear fracture and tensile stress are seen in the shatter zone near Urasoko fault. But, as such area is limited and the local safety factors near the reactor building show enough margin of safety, the ground is believed to have enough bearing capacity.

Comprehensive evaluation of D-1 shatter zone and K fault

◆ K fault is not D-1 shatter zone and does not extend to the reactor building of Unit 2.

(Thin section observation)

・The displacement sense of K fault is different from that of D-1 shatter zone (including G fault)

K fault: displacement sense of reverse fault
D-1 shatter zone (including G fault): displacement sense of normal fault

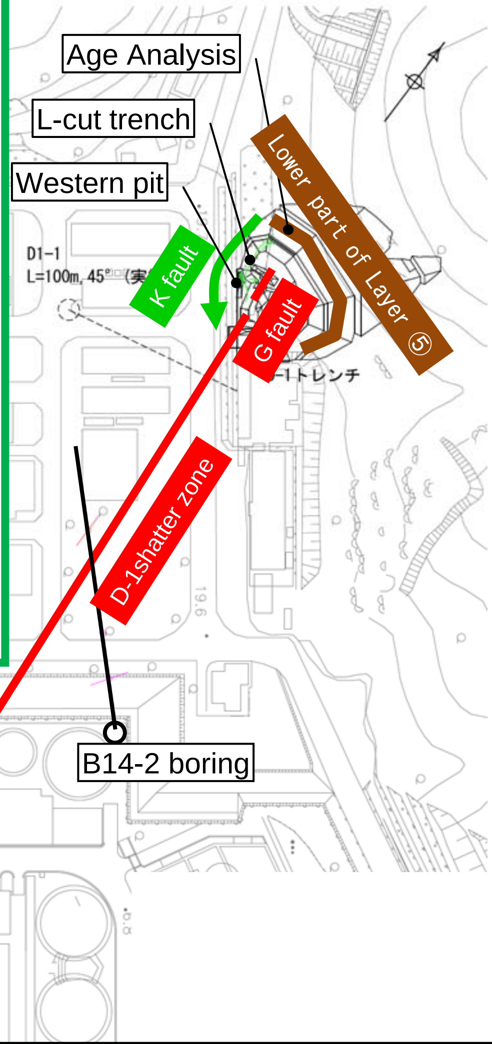
(Additional geologic observation of L-cut pit and western pit)

・K fault reaches to basement rock and the direction of its strike changes from N-S to NNW-SSE in D-1 trench. It is suggested that K fault does not extend to the reactor building of Unit 2.

(Additional thin section observation of B14-2 drilling)

・At B14-2, which is located to the south of D-1 trench, three fault gouges are found. However each of them does not have reverse fault sense, which is a characteristic of K fault, but has normal fault sense.

・Accordingly, It is judged that K fault does not extend to southern direction at least from B14-2 boring location.



◆ G fault is D-1 shatter zone.

・Strike and dip is similar to each other

(Additional thin section observation)

・Additional thin section observations were performed on the facture segments that is considered to be D-1 shatter zone (D-1 outcrop, drillings and D-1 trench)

・So both of D-1 shatter zone and G fault have displacement sense of normal fault that G fault is D-1 shatter zone.

◆ D-1 shatter zone (including G fault) and K fault were not active in and after the Late Pleistocene.

(Additional dating of D-1 trench)

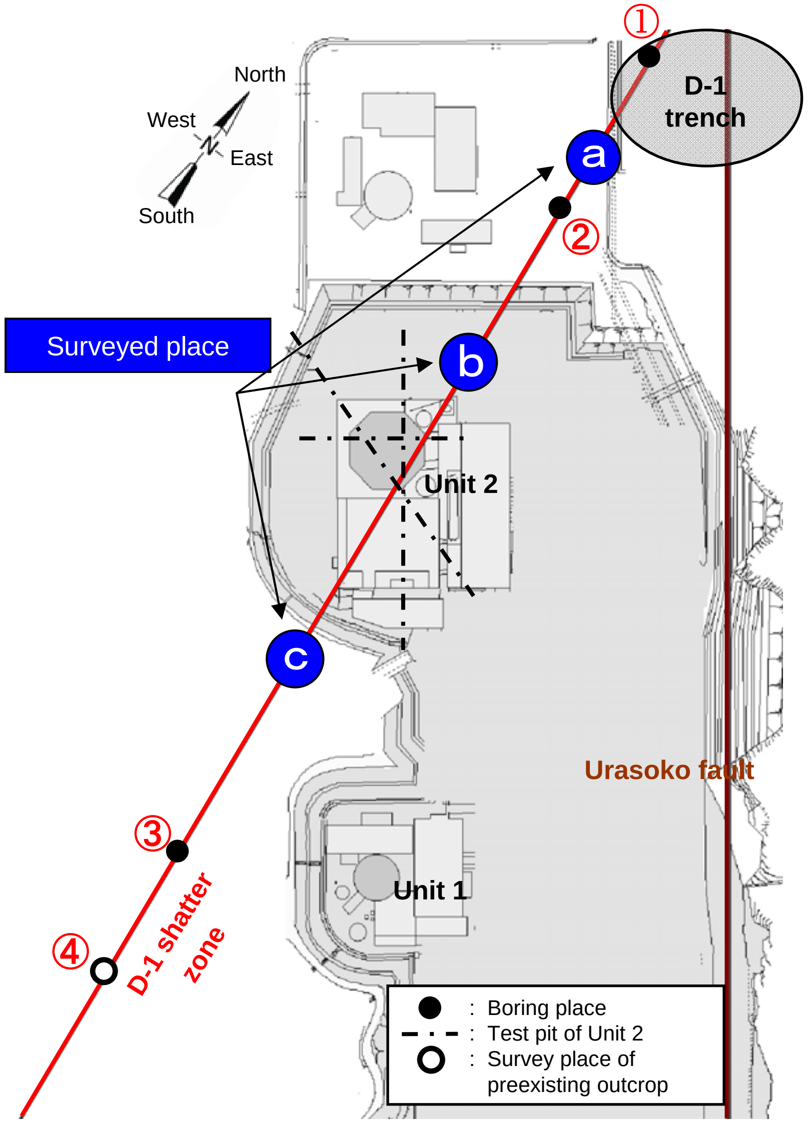
・Both of D-1 shatter zone (including G fault) and K fault is covered by lower part of Layer ⑤. (Both of them have not been active since deposition of lower part of layer ⑤)

・From the results of additional dating on the lower part of layer ⑤, it is judged that the lower part of layer ⑤ was deposited about 120,000 – 130,000 years ago. (Miahama-tephra was detected.)

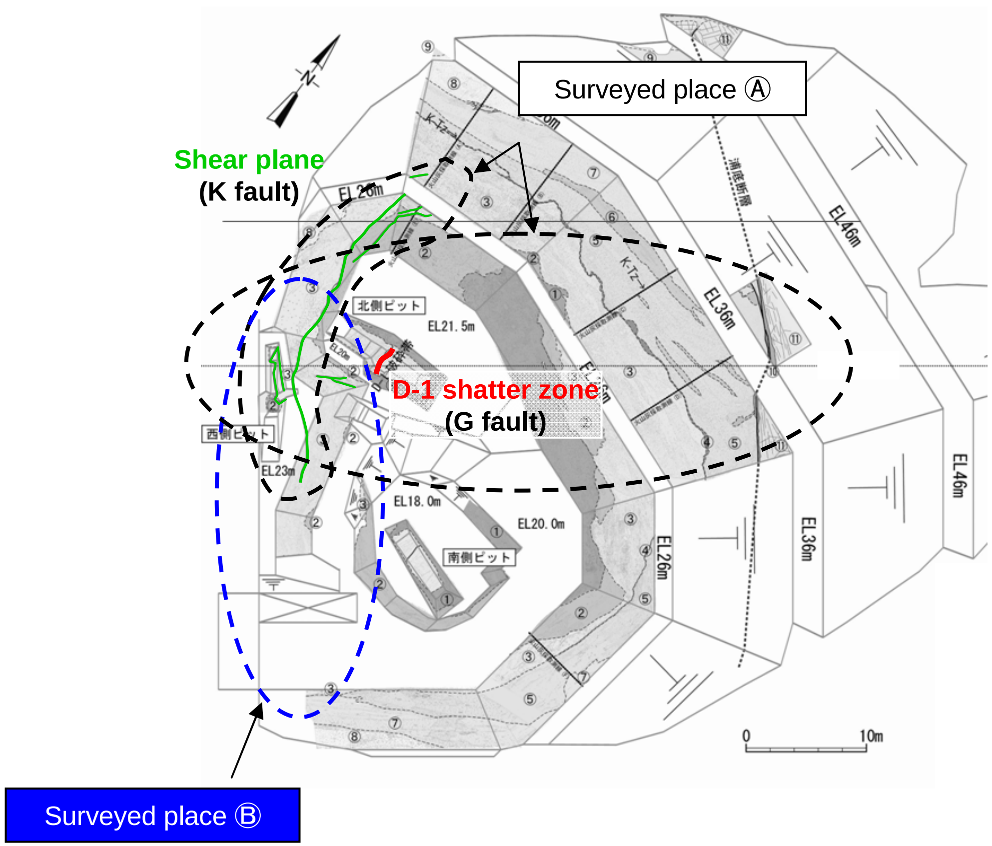
・Accordingly, both of D-1 shatter zone (including G fault) and K fault, which are covered by lower part of Layer ⑤, have not been active since about 120,000 – 130,000 years ago.

D-1 shatter zone and K fault were not active in and after Late Pleistocene. Therefore D-1 shatter zone and K fault are not active faults that should be taken into consideration for the seismic design.

Survey plan



Positional relations between power station and D-1 shatter zone (Image)



Enlarged view of D-1 trench