1st Kashiwazaki International Symposium on Seismic Safety of Nuclear Facilities

Determination of DBGM in Japan

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Introduction

- On September 19th 2006, the Nuclear Safety Commission (NSC) of Japan had revised "Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities" (originally authorized on May 27th 1978).

The seismic reevaluation (back-checks) on existing NPPs was started based on the revised regulatory guide .

Before completion of the seismic reevaluation for KKNPP

July 16th 2007
Niigataken Chuetsu-oki (NCO) earthquake (M_{JMA}6.8)

- The seismic reevaluation for Kashiwazaki-Kariwa Nuclear Power Plant (KKNPP) is conducted following policy:

•The lessons learned from the NCOEQ are reflected on the evaluation.

•Uncertainty factors are taken into account
(Fault interlocking, conservative evaluation of the fault length)

Introduction

Contents of this presentation:

1. Basic policy for DBGM determination based on regulatory guide in Japan

2. Determination of DBGM at Kashiwazaki-Kariwa Nuclear Power Plant

1. Basic policy for DBGM determination based on regulatory guide in Japan

1. Process of determining Design Basis Ground Motion Ss

- Design Basis Ground Motion Ss is to be formulated for each NPP site.
- Important facilities shall be designed to bear the seismic force from DBGM Ss and maintain their safety function.

Geological survey and active faults evaluation

↓

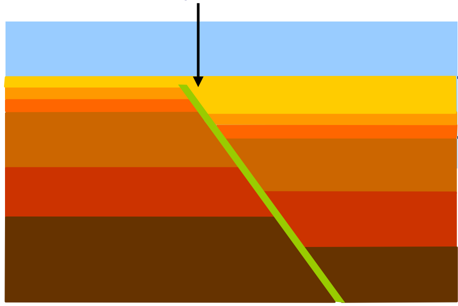
Investigate the earthquakes which may affect the site

↓

Evaluate the ground motion at the site:
Determination of DBGM Ss

2. Criteria for evaluation of active faults

- The active faults to be considered in the seismic design shall be identified as the one whose activities since the late Pleistocene epoch can not be denied.

<table>
<tr><th></th><th>Fault</th><th>Folding</th></tr>
<tr><td>Active</td><td>


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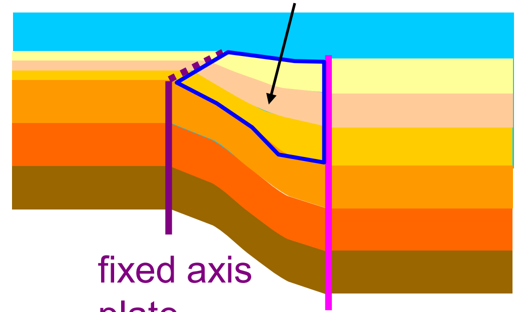

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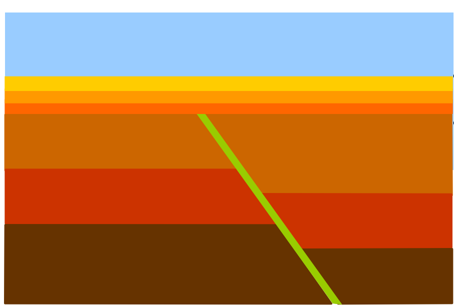
<tr><td>Not Active</td><td>


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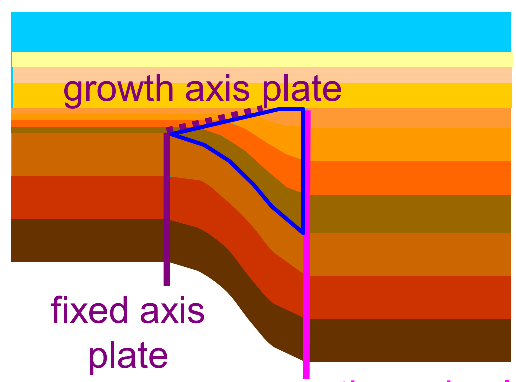

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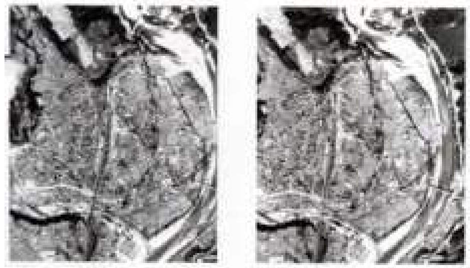
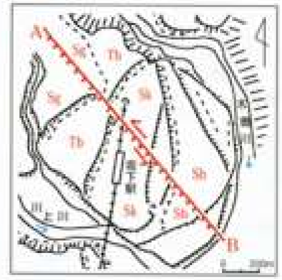
3. Methodology of geological investigation

(a) Topographical approach

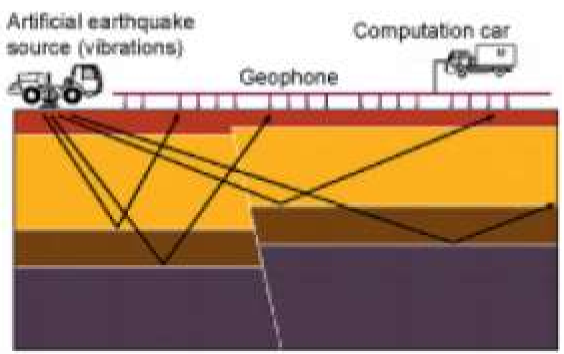




(b) Geological approach

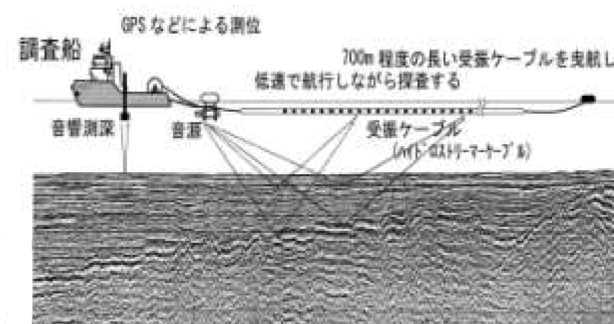
(c) Geo-physical approach

Onshore



Conception diagram of seismic reflection survey

Offshore



4. Methodology for evaluating the Design Basis Ground Motion

- Based on the survey results, DBGM Ss is determined following these procedure.

Selection of the sources: "Earthquakes to be examined"

- Inter-plate Earthquakes
- Shallow Inland Earthquakes
- Intra-plate Earthquakes

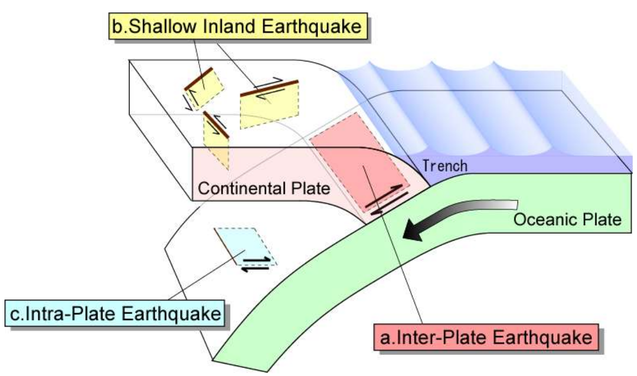
Ground motion Evaluation

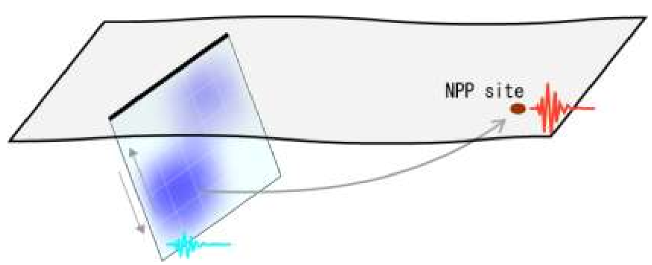
- Site-specific Ground motion with specific sources
- Ground motion with unidentified sources

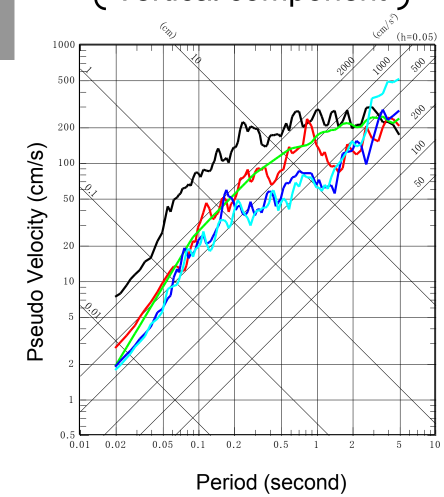
Determination of Ss

Design Basis Ground Motion **Ss**

(Both Horizontal and Vertical component)

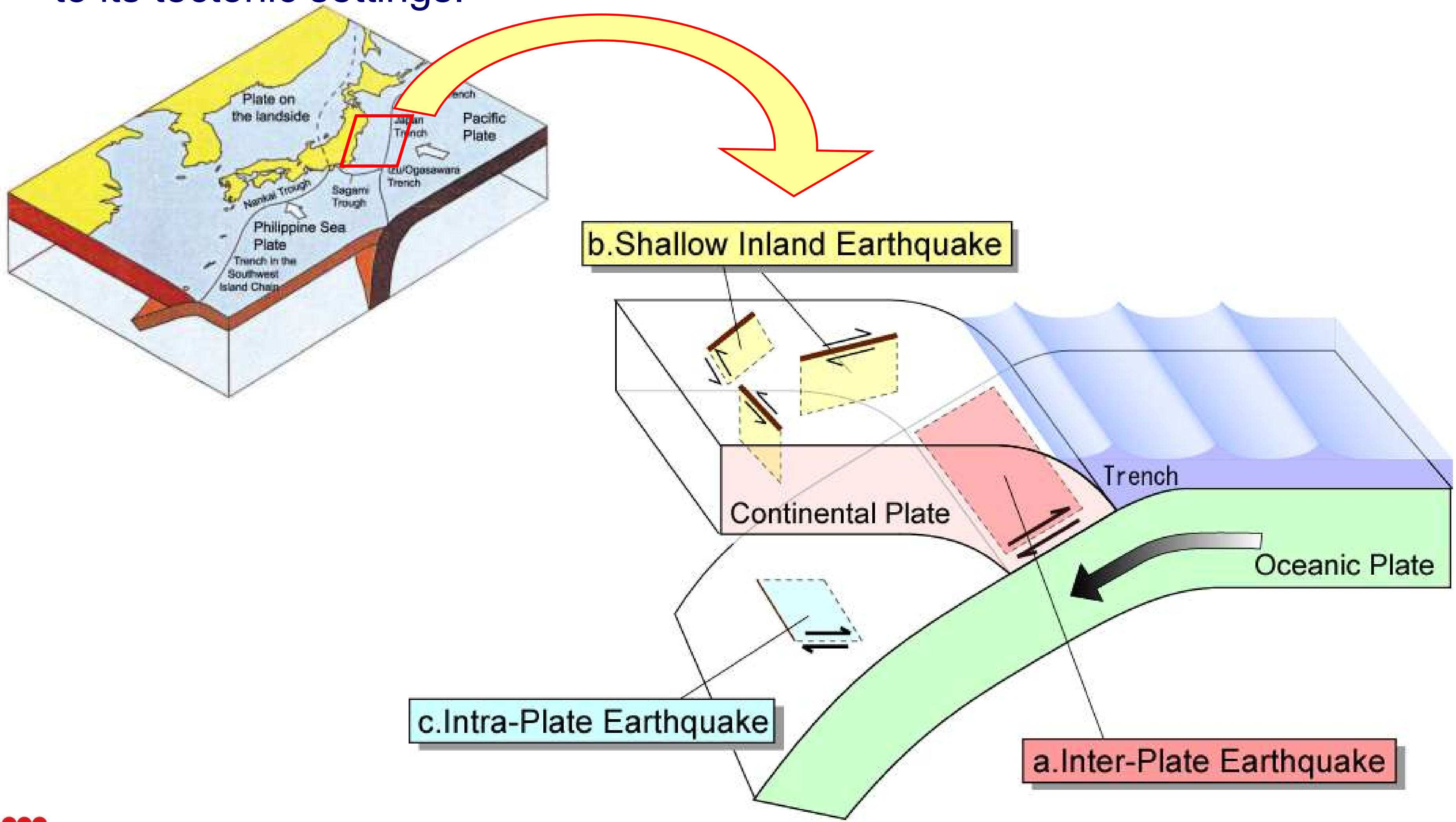






5. Selection of the sources for examination according to their tectonic settings

- The characteristics of the earthquake vary according to its tectonic settings. Therefore, The earthquake sources should be selected to be examined, as to its tectonic settings.



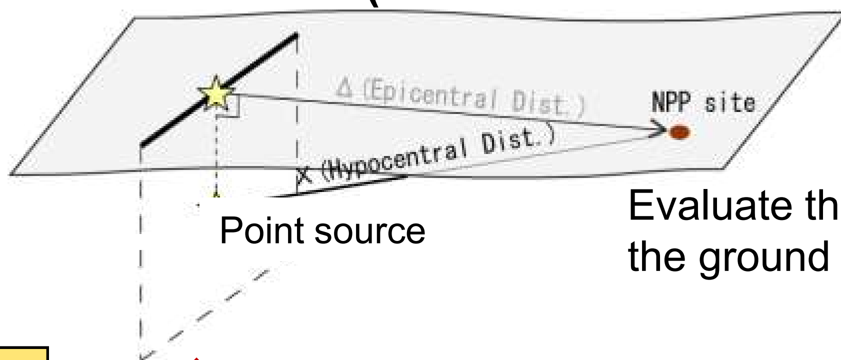
6. Ground motion evaluation using both empirical and numerical method

■ Two method is used to evaluate the ground motion by the specific sources.

Empirical

◆ **Empirical evaluation method**

(based on the attenuation relation)

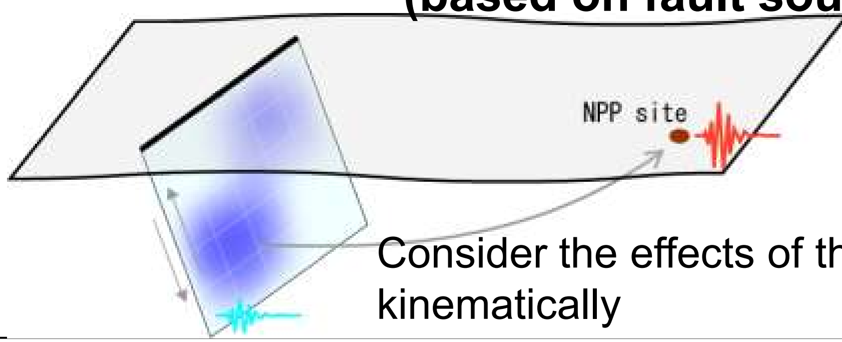


Evaluate the response spectrum for the ground motion

Numerical

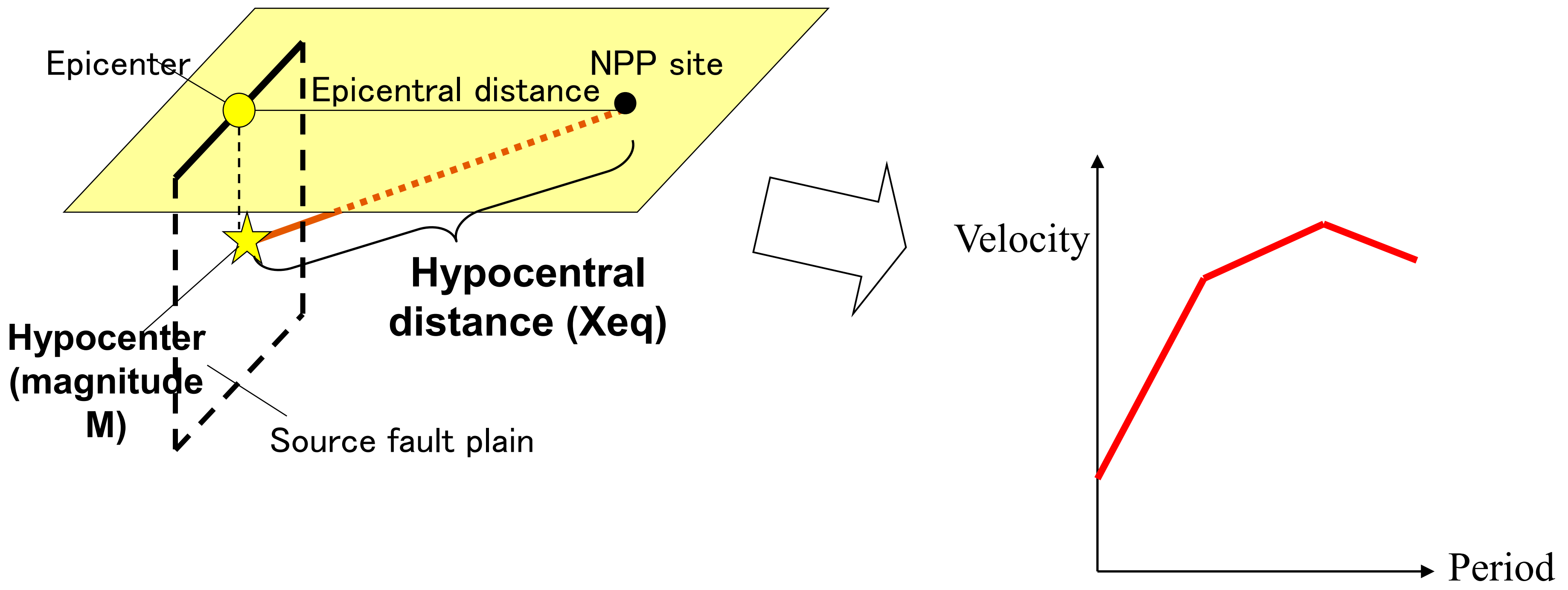
◆ **Numerical calculation method**

(based on fault source model)



Consider the effects of the source fault's rupture kinematically

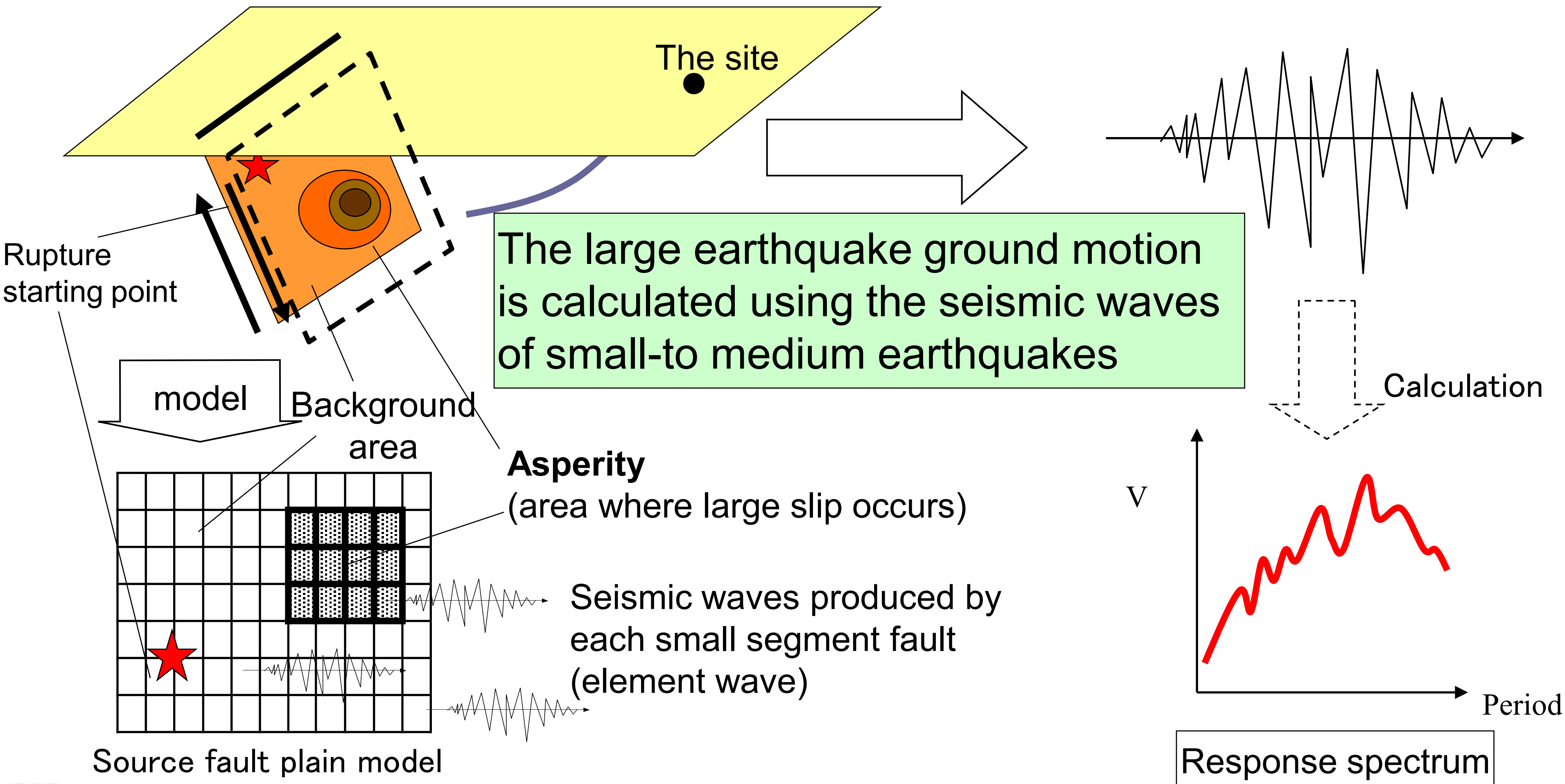
- In empirical evaluation method, the ground motion is given using response spectrum at the site, which is based on the regional attenuation relation.



Response spectrum

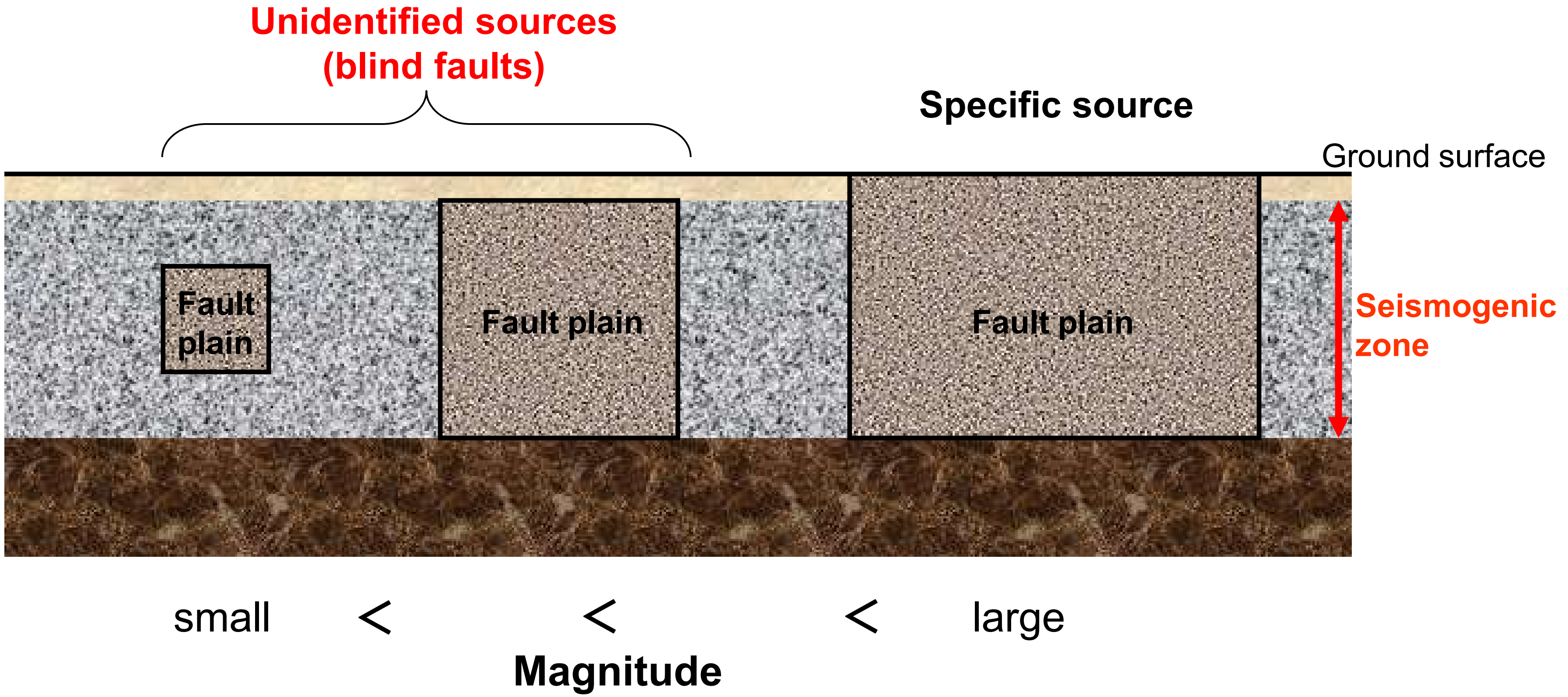
6-b. Ground motion evaluation based on numerical method

- In numerical method, the ground motion is evaluated using numerical way based on the source fault model.



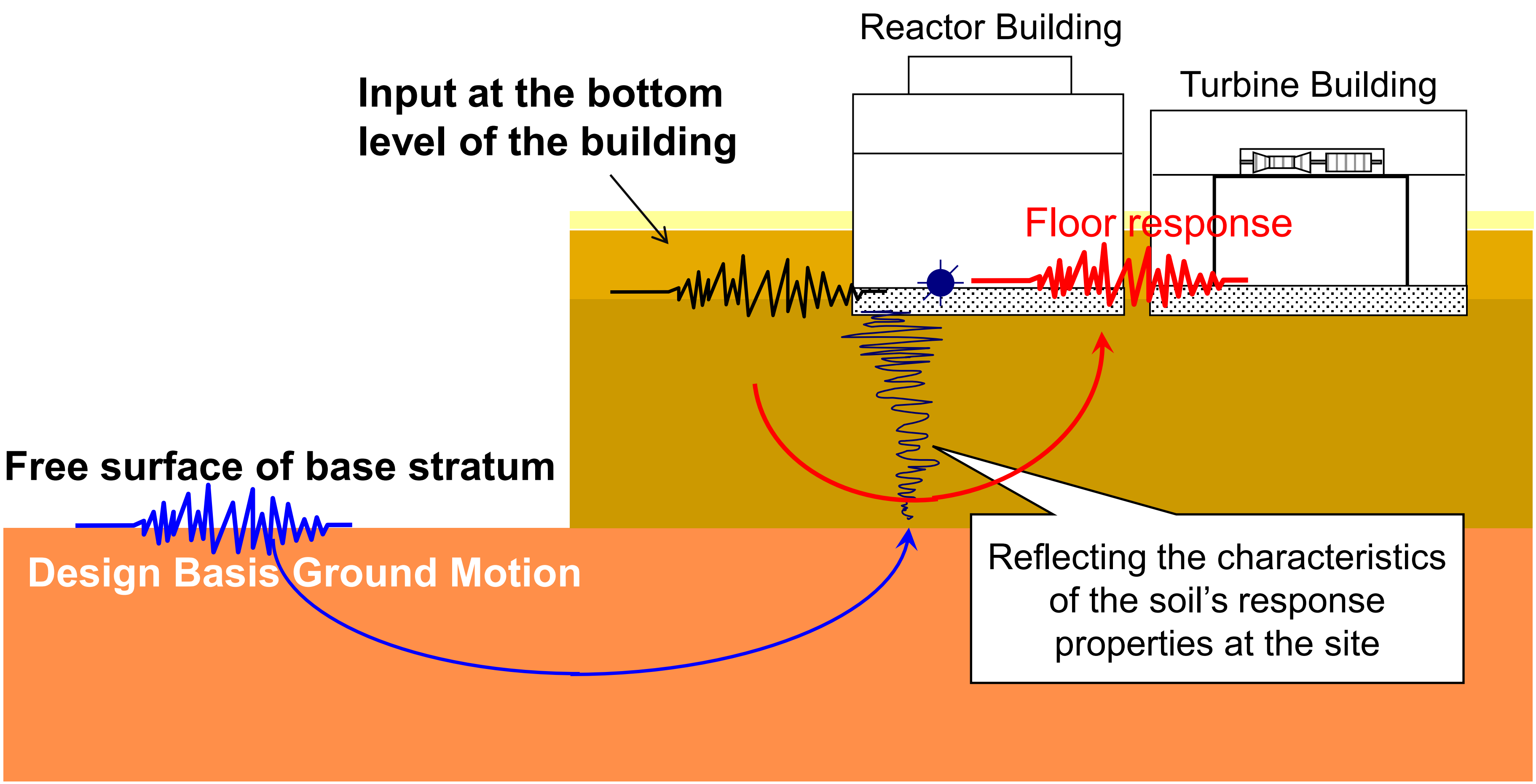
7. Consideration of the ground motion with unidentified sources

- If the fault plane is small and its magnitude is not fully large ,we may miss the existence of fault plane even by precise survey.
  Therefor, the ground motion with unidentified sources should be considered to determine Design Basis Ground Motion Ss.
- The level of the ground motion with unidentified sources can be evaluated by collecting the observation records near the source which couldn't be identified before the event.



8. Ground Motion evaluation on free surface of the base stratum

- DBGM is defined on free surface of the base stratum (Vs ≧ 700m/s)



2. Determination of DBGM at Kashiwazaki-Kariwa Nuclear Power Plant

1.Policy on determining Ss for KKNPP

■ DBGM for Kashiwazaki-Kariwa NPP defined based on the regulatory guide

(1) Geological survey and active fault evaluation

(2) Determination of Design Basis Ground Motion Ss

Seismic hazard by specific source

Selection of sources for examination

Seismic hazard evaluation by response spectrum (empirical)

Seismic hazard evaluation using source model (numerical)

Seismic hazard with unspecified source (blind faults)

design basis ground motion Ss

★Knowledge from the Niigataken-Chuetsu-Oki Earthquake to be considered

★Items in the new regulatory guideline to be considered

Uncertainty factors are taken into account.

(Fault interlocking, conservative evaluation of the fault length etc,)

1-1.Knowledge from the Niigataken-Chuetsu-Oki Earthquake(1)

Items to be reflected

(1) Intensity of offshore events

With respect to the offshore events, observation records at the site was larger than the average ground motion estimated by JEA spectrum.

(2) Difference of ground motions between the offshore events and the inland events

With respect to the inland events, the difference mentioned above is not observed.

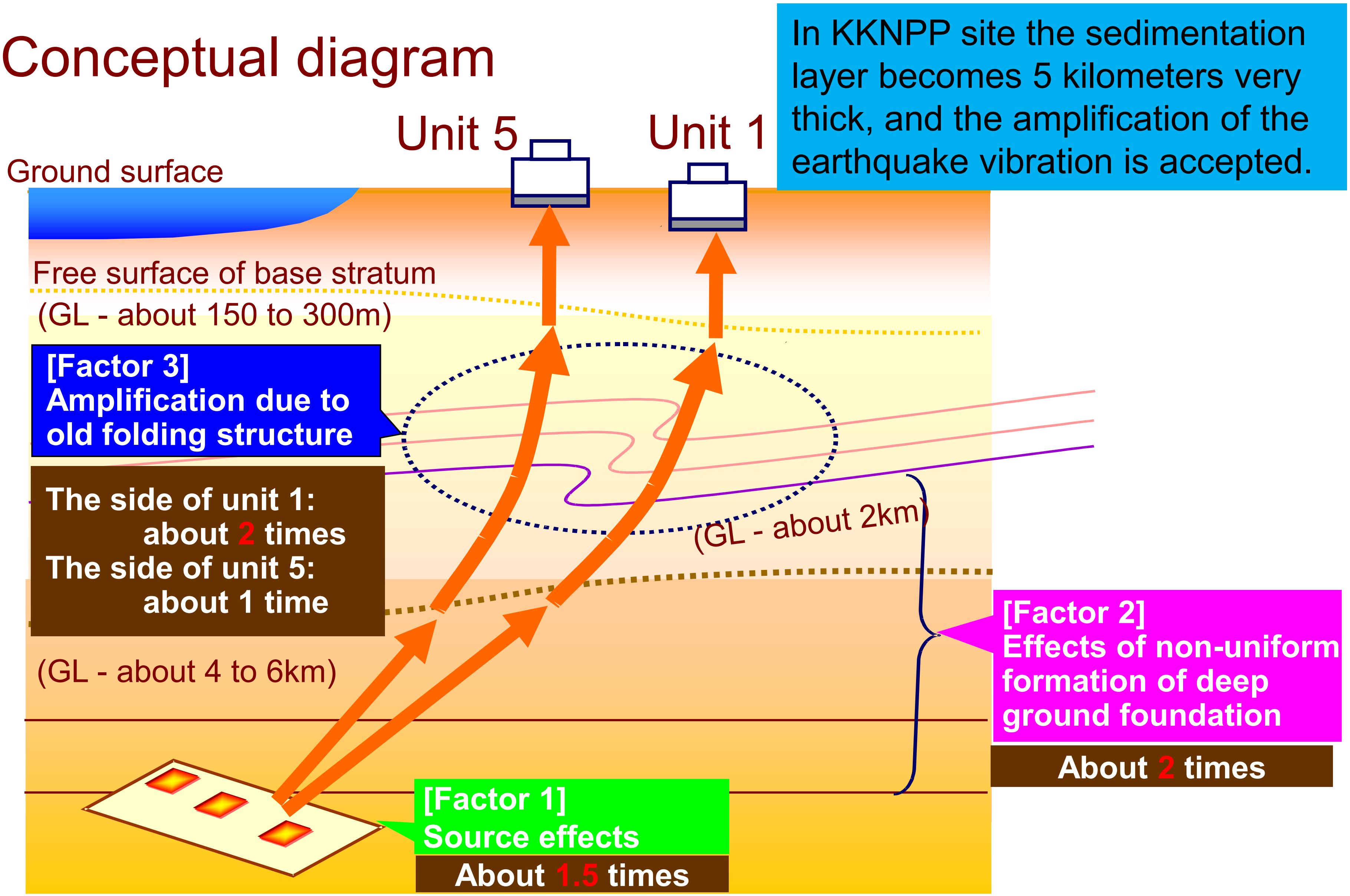
Therefore, DBGM are defined for offshore faults and inland faults separately.

(3) Difference of ground motions in offshore events between the Arahama side (Units 1-4) and the Ominato side (Units 5-7)

The ground motion of the Arahama side is about two times larger than that of the Ominato side.

Therefore, DGBM by offshore faults are defined for the Arahama side and the Ominato side separately.

● Conceptual diagram



2. Survey of active faults near the site

(Area1:Inland survey area)

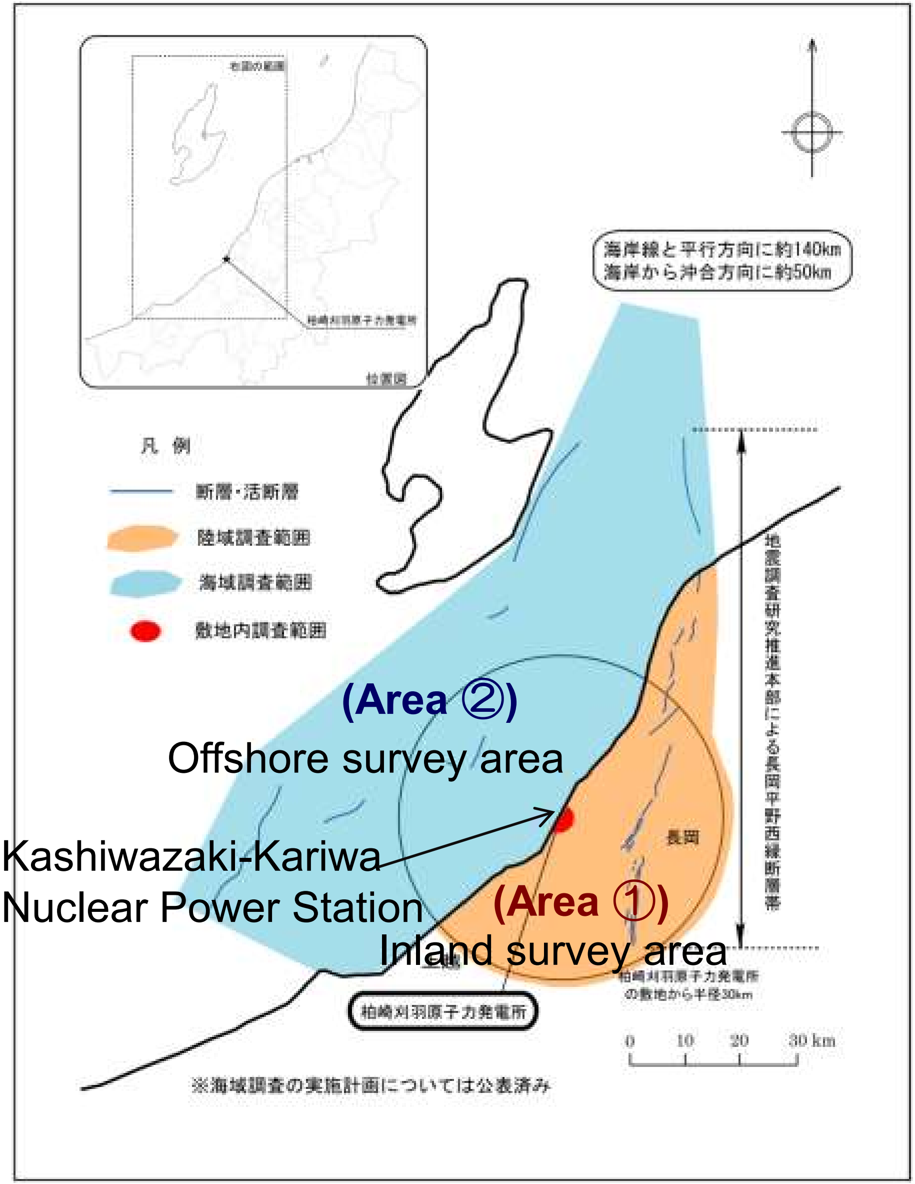
Tectonic geomorphological survey,
Surface geological survey,
Ground probing (seismic reflection profiling),
Boring survey
were conducted on the land area within 30km radius from the power station.

The same set of surveys was also conducted along main faults beyond the radius.

(Area2:Offshore survey area)

Marine sonic prospecting and record analysis,
Submarine geological survey
were conducted in the 50km sea band along a 140km stretch of coastline extending from the power station.

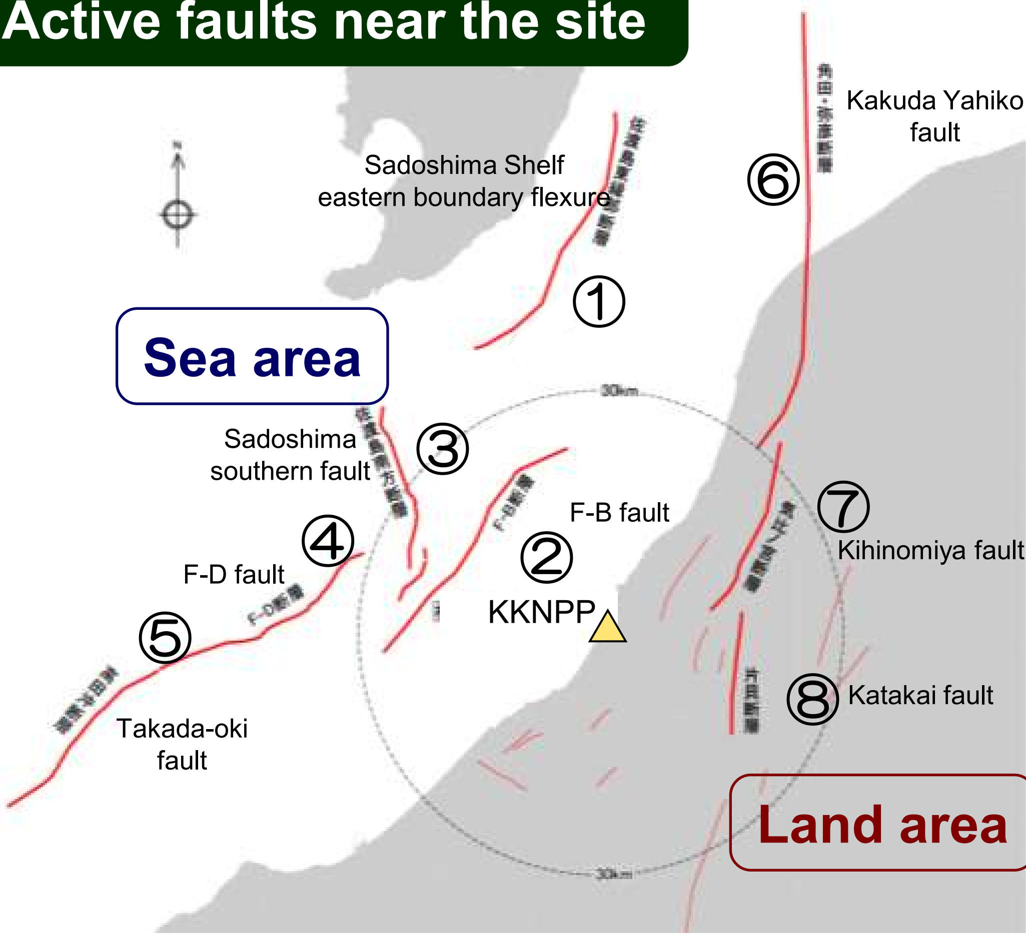
Marine sonic prospecting records from other organizations were also analyzed.



4. Selection of active faults to be considered

■Comparisons of active faults by the empirical evaluation method were conducted, and those which have a major impact on the KKNPP site were selected.

Active faults near the site



Major active faults

	Fault name	Fault length
Sea area	(1) Sadoshima Shelf eastern boundary flexure	Approx. 37km
	(2) F-B fault	Approx. 36km＊
	(3) Sadoshima Southern fault	Approx. 29km
	(4) F-D fault	Approx. 30km
	(5) Takada-oki fault	Approx. 25km
Land area	(6) Kakuda Yahiko fault	Approx. 54km
	(7) Kihinomiya fault	Approx. 22km
	(8) Katakai fault	Approx. 16km

＊This fault is 27km long according to the TEPCO survey, and is assessed to have the length of 36km for the purpose of safety evaluation.

5. Evaluation of seismic hazard by the earthquake to be considered

Selection of Earthquakes

Finally two sources are selected for dominant events.

Offshore active fault

Earthquake caused by F-B fault(L=36Km*Mj=7.0*)
（NCO：L=27Km *Mj=6.8*）

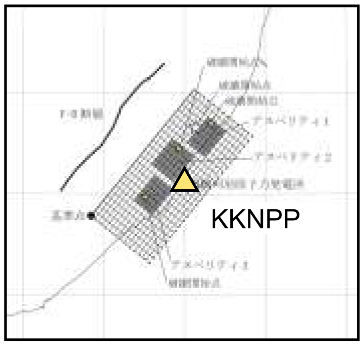
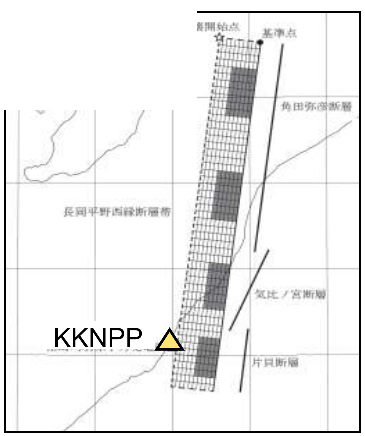
Fault location and fault length are defined on the basis of geological survey , and the length of the F-B fault is increased from 27km(NCO) to 36 km.

Inland active fault

Earthquake caused by Nagaoka Plain WBFA (Western boundary Fault Zone)*Mj=8.1*

Fault location and fault length are defined on the basis of geological survey result ,and the length of this zone is evaluated 91km considering fault interlocking of three segment faults(Kakuda-Yahiko fault, Kihinomiya fault, Katakai fault).

5. Evaluation of seismic hazard by the earthquake to be considered

	Empirical evaluation method	Source fault model
F-B fault 	■Site correction for offshore events, calculated from observation records of NCO earthquake (as a representative of offshore events) was adopted.	■Defined based on the result of source inversion of NCO earthquake ■Inner parameters were set presuming that the fault length of F-B fault was extended from 27km to 36 km
Nagaoka Plain West Boundary Fault Zone 	■Site correction for inland events, calculated from observation records of 2004 Niigataken Chuetsu earthquake's aftershocks (as representatives of inland events) was adopted.	■Defined based on the evaluation by HERP (the Headquarters for Earthquake Research Promotion)

5-1. F-B fault (Formulating source model)

Policy on source fault formulation

- Fault location and fault length are defined on the basis of geological survey result and presuming that length of the F-B fault is increased from 27km to 36 km.

- Fault dipping angle is defined as 35 degree according to the hypocentral distribution of the NCO aftershock, the same as seismic source inversion.

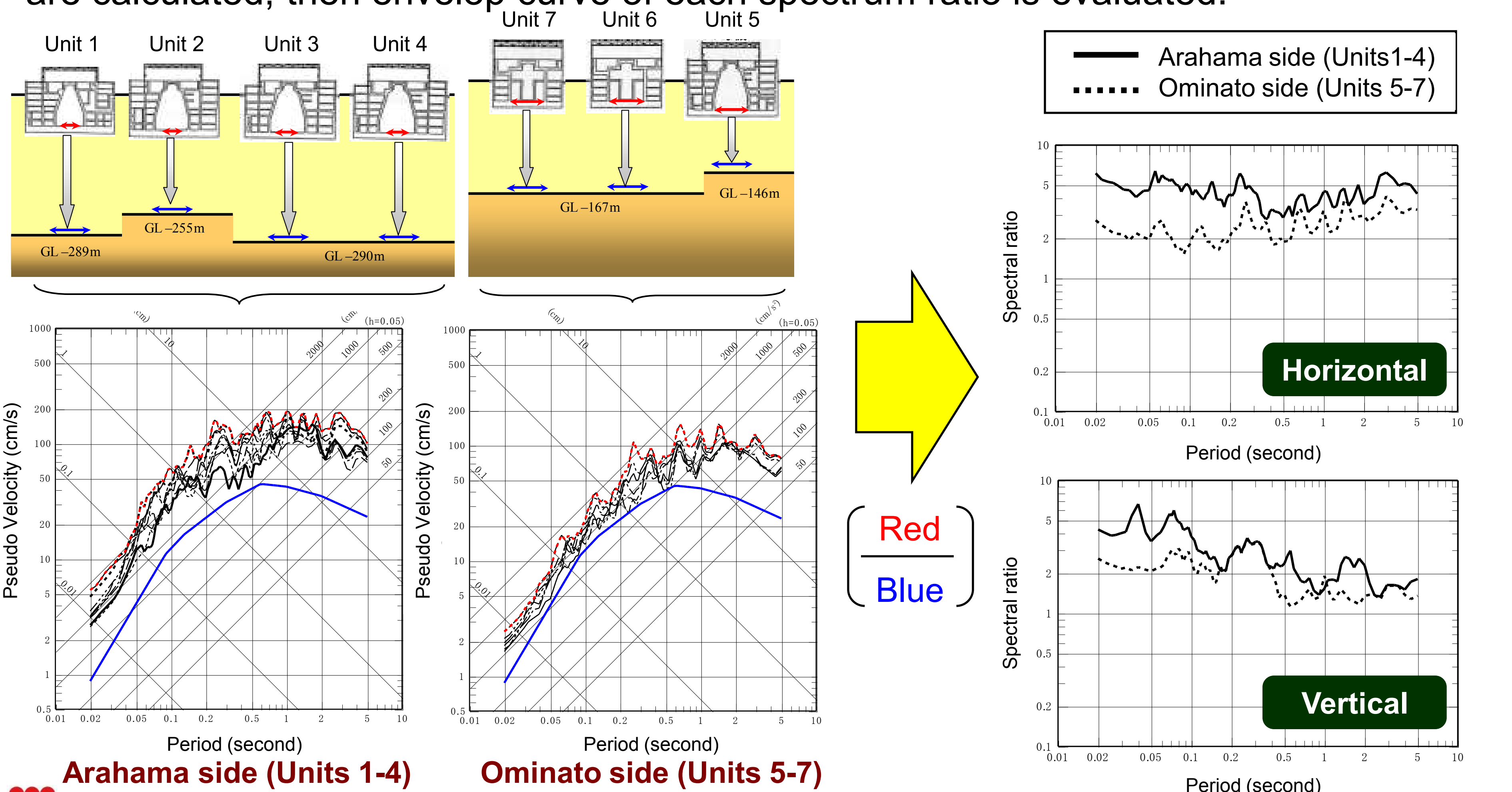
- Seismogenic zone is defined from 6km deep through 17km deep, according to the hypocentral distribution of microearthquakes around the site.

- Fault width is defined as 20km from the dipping angle of fault plain and the thickness of seismogenic zone, so as to saturate the seismogenic zone.

- Inner source fault parameters are defined based on the result of source inversion analysis.

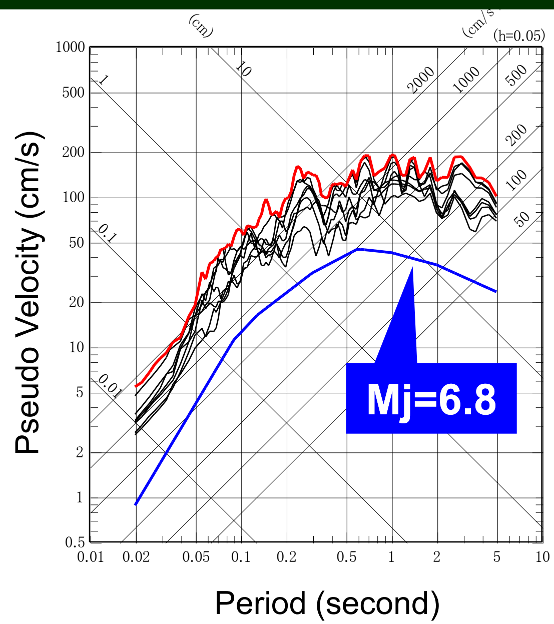
5-1. F-B fault (Empirical evaluation method with Site correction)

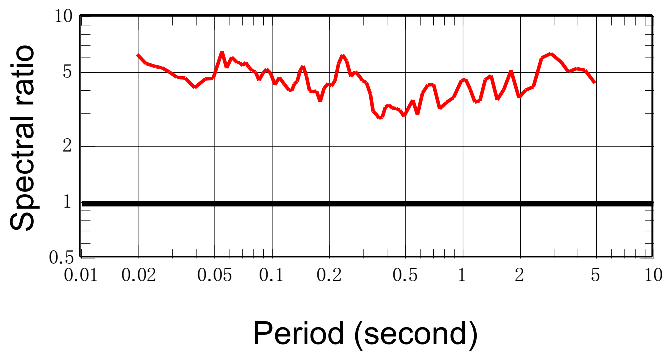
The intensity of ground motions of NCO earthquake differs between Arahama side and Ominato side, therefor site correction should be evaluated for each side respectively. The spectrum ratio of the NCO earthquake and JEA spectrum(Mj=6.8) for every plants are calculated, then envelop curve of each spectrum ratio is evaluated.



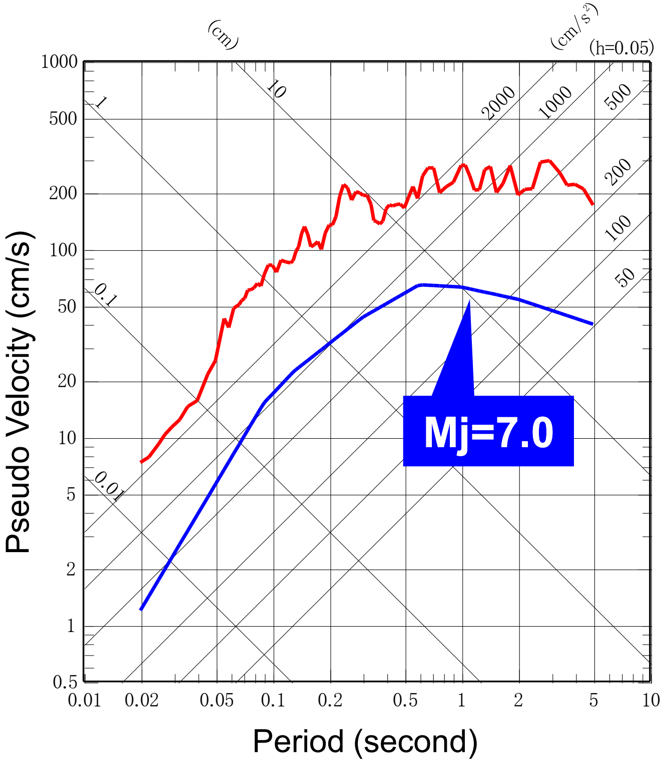
5-1. F-B fault (Empirical evaluation method with Site correction)

Site correction for F-B fault





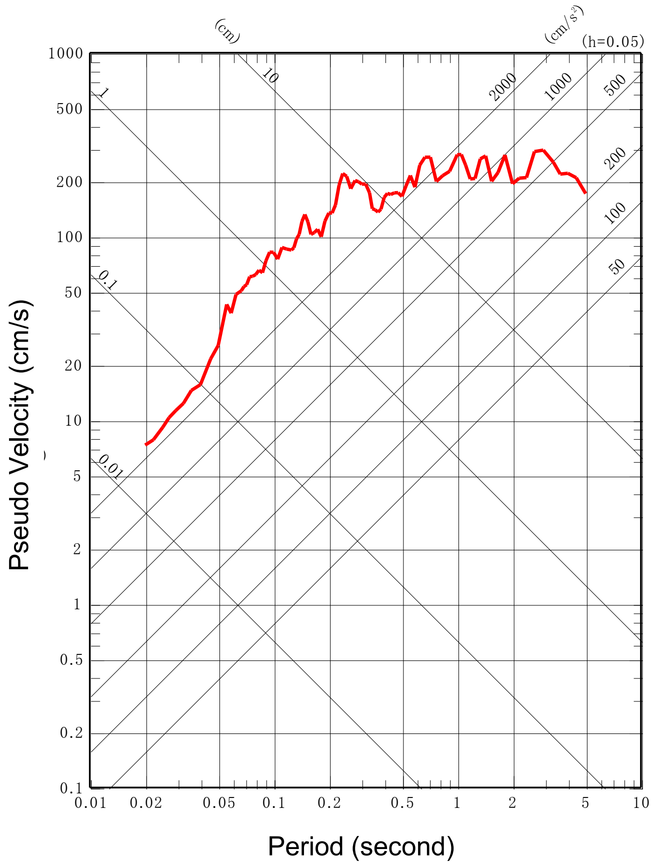
Site correction ratio based on NCO earthquake is adopted to JEA spectrum for F-B fault (Mj=7.0)



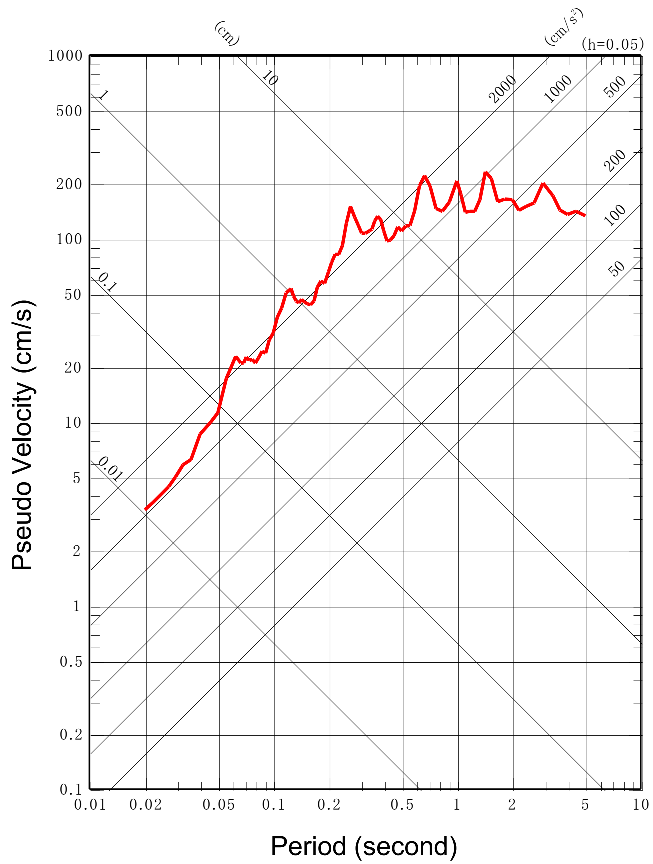
5-1. F-B fault (Ground motion evaluation by response spectrum method)

Horizontal

JEA spectrum



Arahama side (Units 1-4)

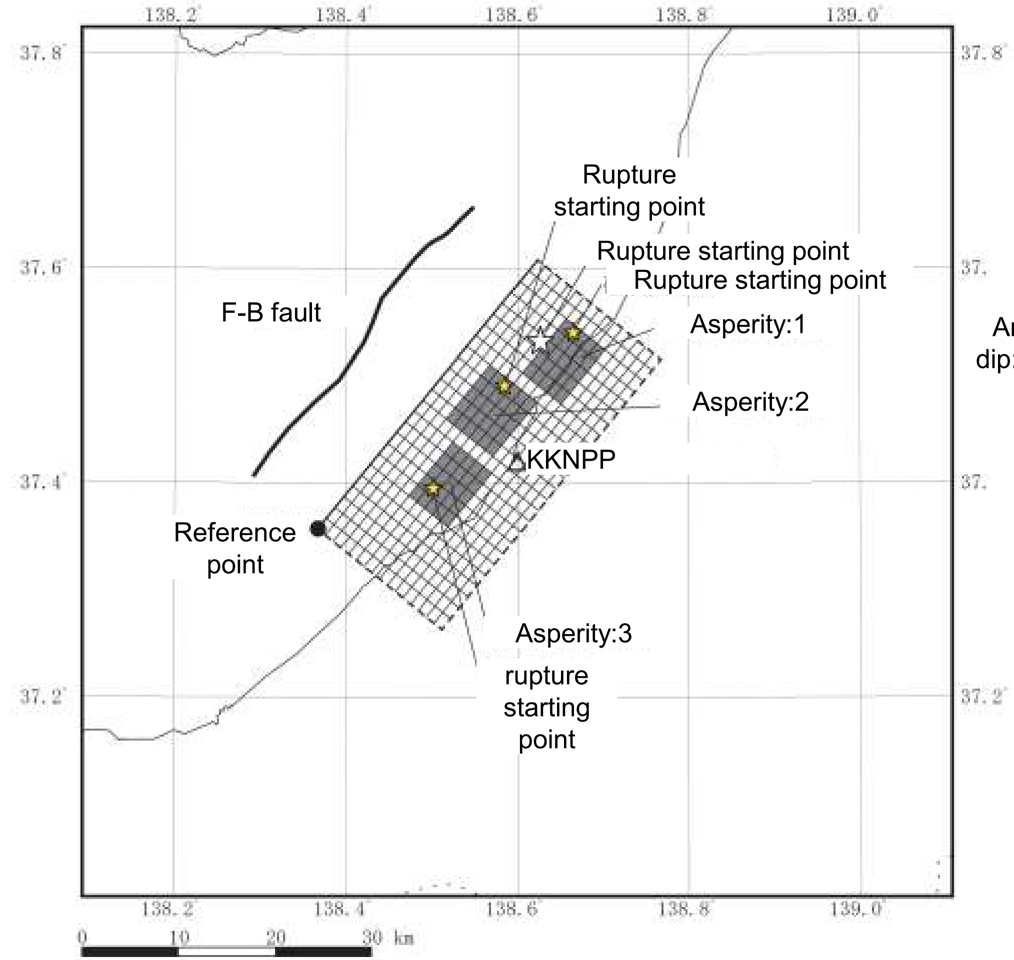


Ominato side (Units 5-7)

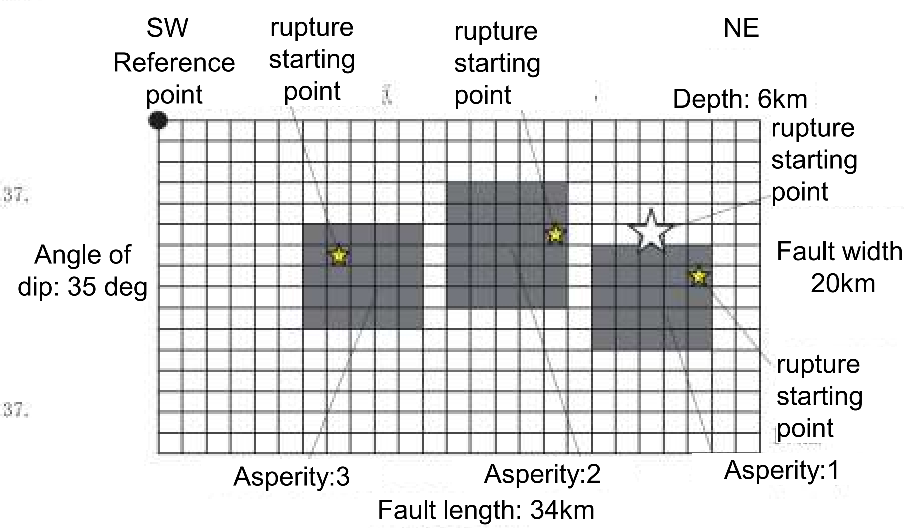
5-1. F-B fault (Formulating source model)

Source fault model (fault length: 36km)

Plan



Cross section diagram



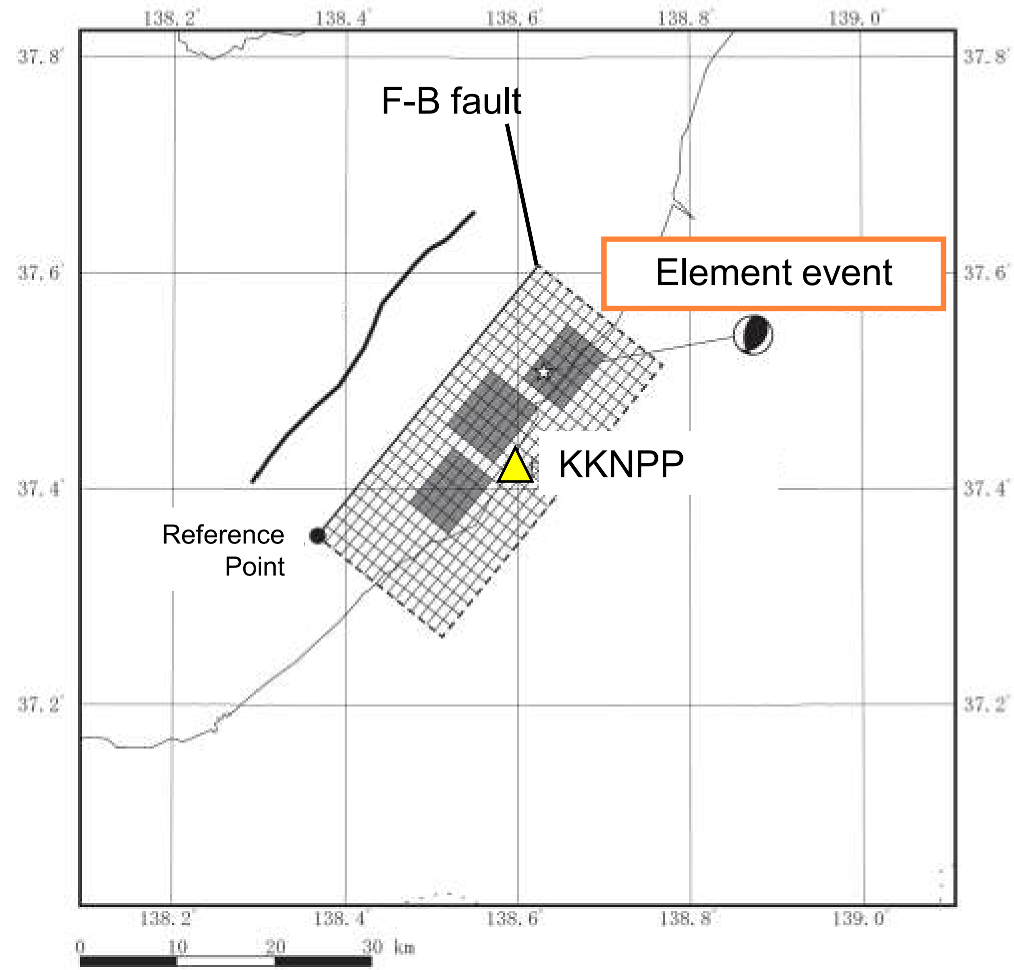
(Main specification)
Fault length: 36km
Fault width: 20km
Angle of dip: 35 deg
(east dipping)
Number of asperity: 3

5-1. F-B fault (Choosing an element event for the EGF)

- An aftershock of the NCO EQ was selected to be used as an element event for the empirical Green's function (EGF)
  [element event] 2007/7/16, 21:08(M4.4)

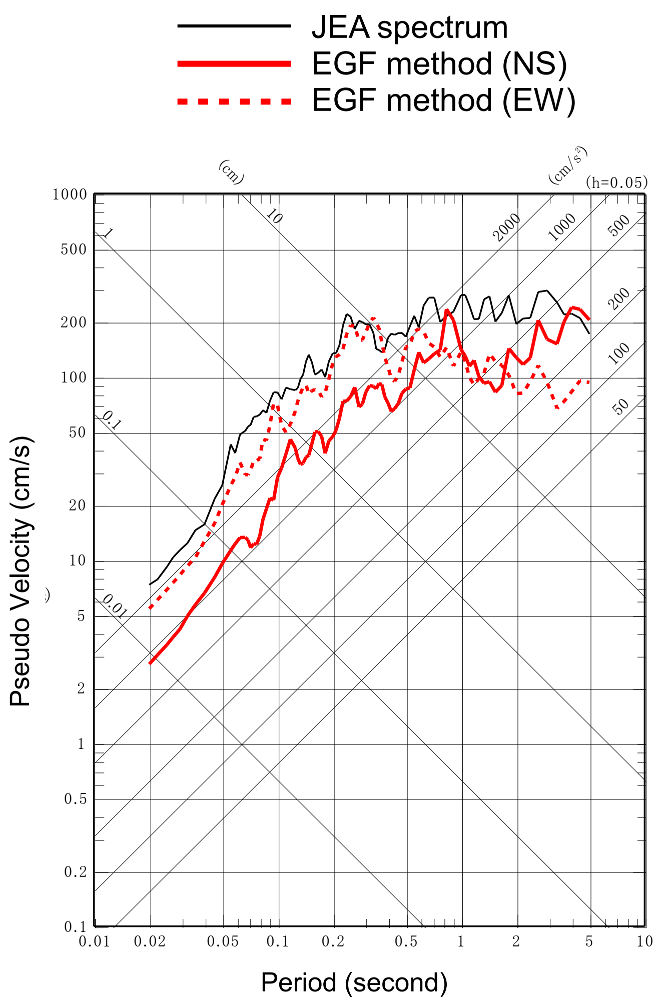
Source parameters

Date & Time		2007.7.16,21:08
M_{JMA}		4.4
Location	Longitude (deg)	37.509
	Latitude (deg)	138.630
	Depth (km)	13.6
	Strike (deg)	187;39
	Dip (deg)	54;41
	Rake (deg)	70;115
Seismic moment	(Nm)	5.21×10^{16}
Critical freq.	(Hz)	1.65
Fault length	(km)	1.40
Fault width	(km)	1.40
Avg. slip	(cm)	8.0
Effective stress	(MPa)	4.6
Rigidity	(N/m^2)	3.31×10^{10}
S-wave velocity	(km/s)	3.5
Unit weight	(g/cm^3)	2.7

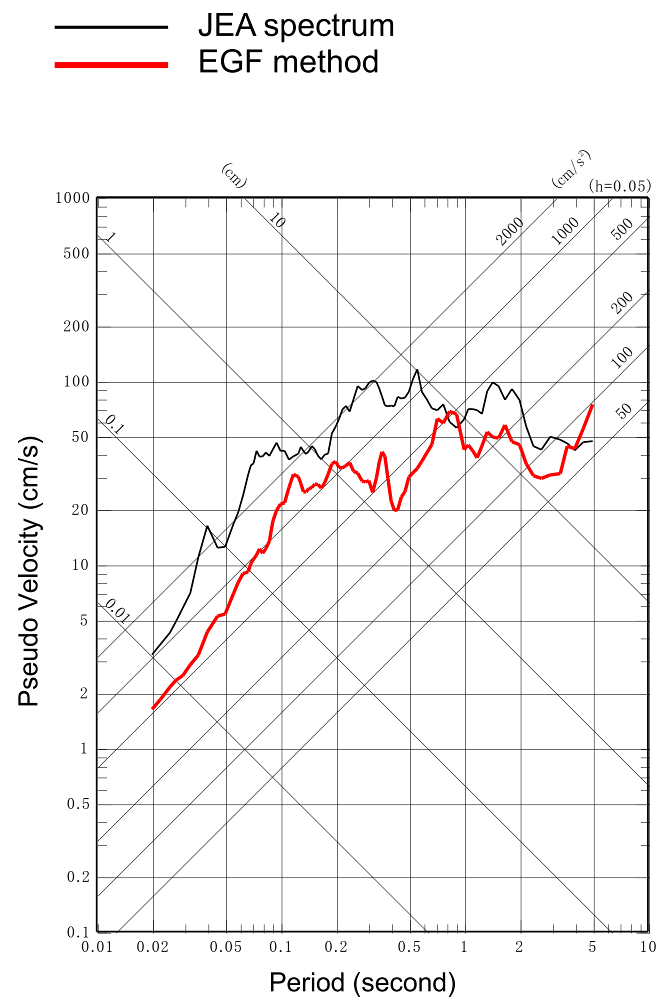


5-1. F-B fault (Ground motion evaluation by source fault model method)

Arahama side (Units 1-4)



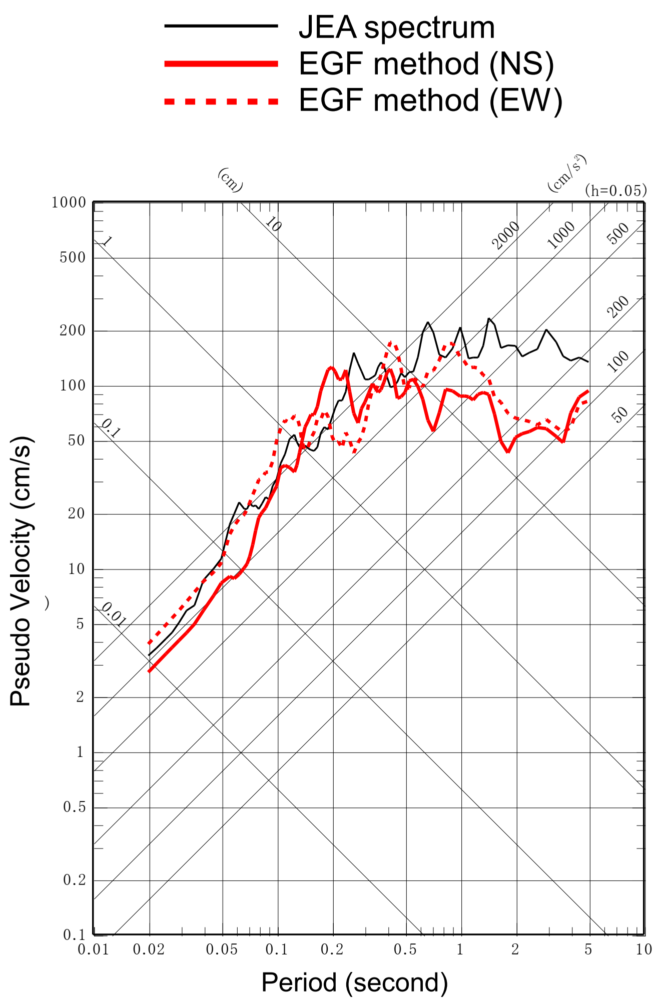
Horizontal



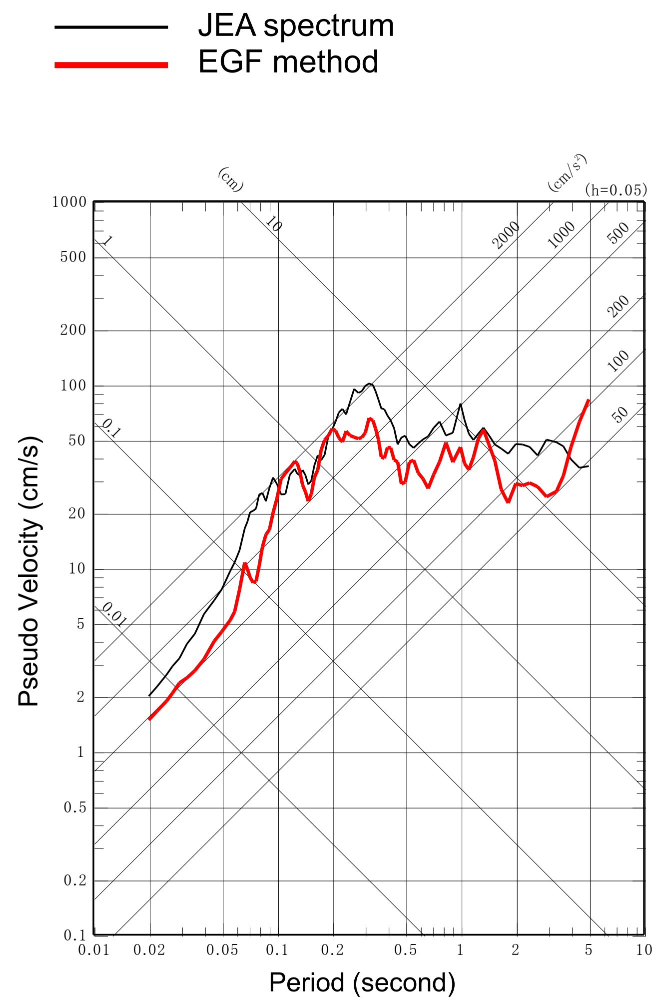
Vertical

5-1. F-B fault (Ground motion evaluation by source fault model method)

Ominato side (Units 5-7)



Horizontal



Vertical

5-2. Nagaoka Plain WBFZ (formulating source model)

Policy on source fault formulation

- Fault location and fault length are defined on the basis of geological survey result.

- Fault dipping angle is defined based on the evaluation of Nagaoka Plain WBFZ by HERP (2004), and fault width is defined so as to saturate the seismogenic zone in the same manner as F-B fault.

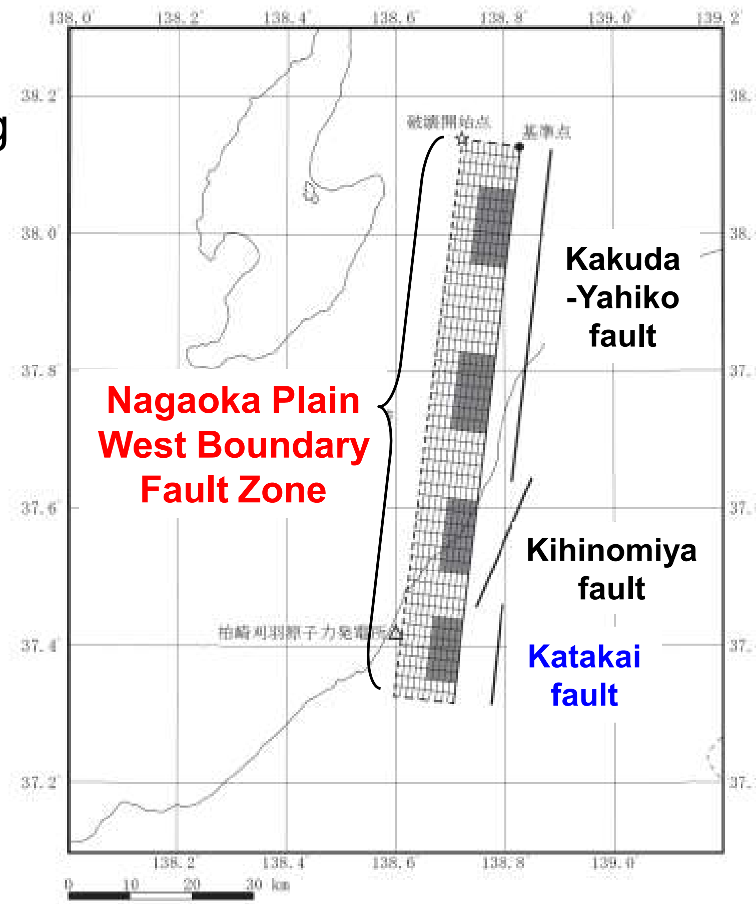
- Inner source fault parameters are basically defined based on the recipe for strong motion prediction by HERP (2008), but considering its long fault length, stress drop for whole source fault plain is calculated using formula for the vertical dipping surface fault with infinite fault length.

- Stress drop of the asperities and effective stress of background area are applied 1.5 times larger value than that defined by the recipe, reflecting the knowledge from the NCO EQ.

5-2. Nagaoka Plain WBFZ (consideration of uncertainties)

Parameters to be considered with uncertainty

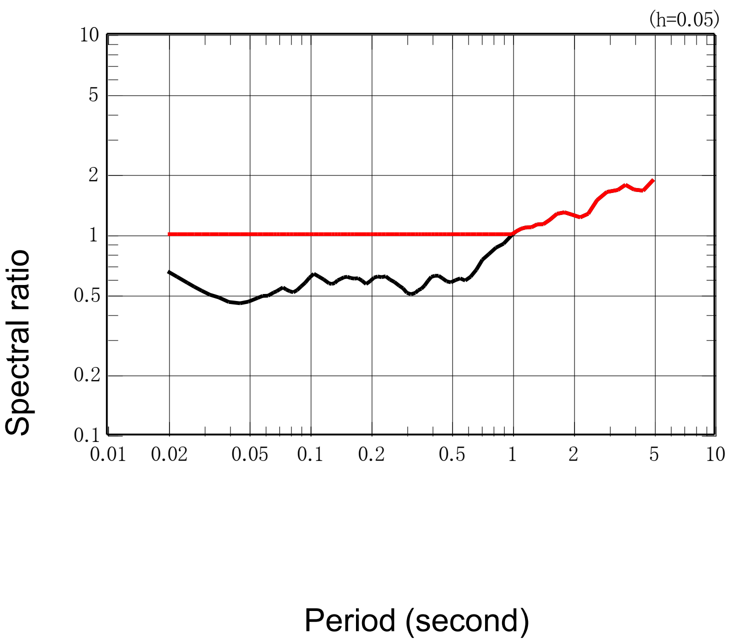
- **Fault length**
  Activity of Katakai fault is standard case, and consider fault interlocking with its surrounding faults (Kihinomiya fault, Kakuda-Yahiko fault)
- **Fault dipping angle**
  50 deg. Is the standard case according to the evaluation of HERP, and 35 deg. is also taken into account as an uncertainty.
- **The number & location of asperity**
  Upper-center position of the fault plain is the standard case, and lower-center is also considered.
- **The amount of stress drop & avg. slip**
  1.5 times larger than recipe is considered.

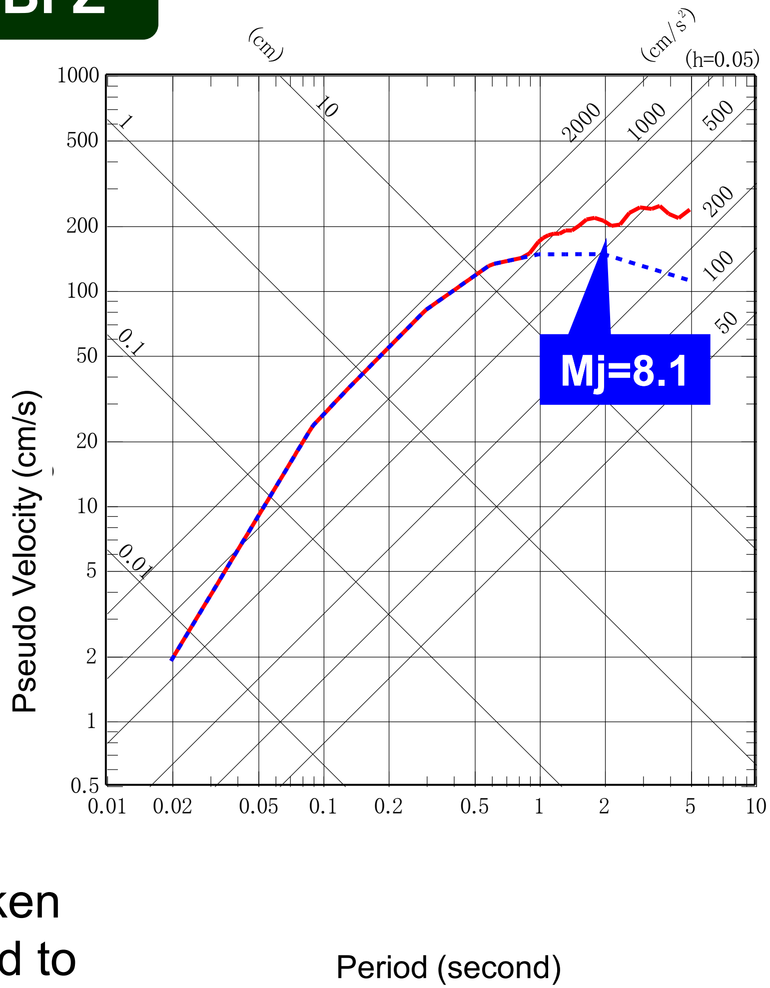


- **Rupture starting point**
  Place which rupture proceed toward the site is the standard case, and boundary of asperity is also considered as an uncertainty

5-2. Nagaoka Plain WBFZ (site correction for response spectrum evaluation)

Site correction for Nagaoka Plain WBFZ





Site correction ratio based on 2004 Niigataken Chuetsu earthquake's aftershocks is adopted to JEA spectrum for Nagaoka Plain WBFZ (Mj=8.1)

5-2. Nagaoka Plain WBFZ (Standard source model and consideration of uncertainties)

- As a more conservative evaluation, ground motion evaluation considering uncertainties of the fault length & stress drop simultaneously, which have larger impact, is conducted.

No.1 The case considering 1.5 times larger stress drop for NPWBFZ

- Furthermore, ground motion evaluation considering uncertainties of the fault length & dipping angle simultaneously is also conducted based on the discussion at the WG of NISA.

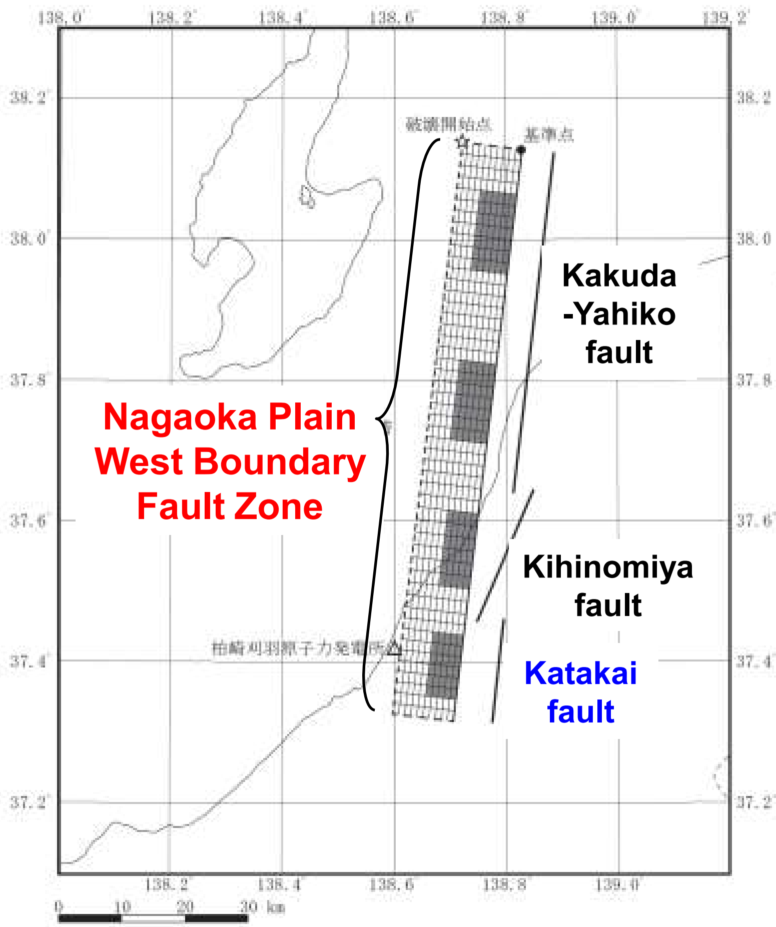
No.2 The case considering 35 degree of dipping angle for NPWBFZ

No.	Case	Length L	Width W	Dip δ	Rupture starting point	The location of asperity	Stress drop
1	Considering uncertainty about the fault length and stress drop	91km	15km	50°	Boundary of the source plain	Upper-center	1.5 times of Recipe
2	Considering uncertainty about the fault length and dipping angle	91km	20km	35°	Boundary of the source plain	Upper-center	Recipe

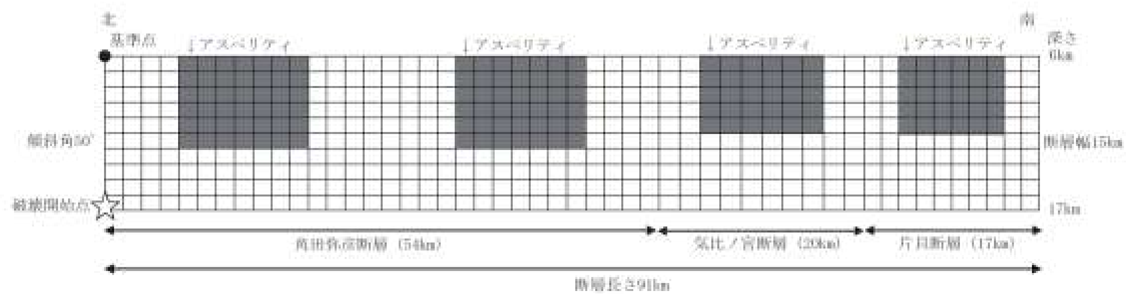
5-2. Nagaoka Plain WBFZ (formulating source model)

■Source model for the case No.1.

Plan



Cross-section diagram



(Main specification)
Fault length:91km
Fault width: 15km
Angle of dip: 50 deg
(west dipping)
Number of asperity: 4

6. Outline of the design basis ground motion Ss

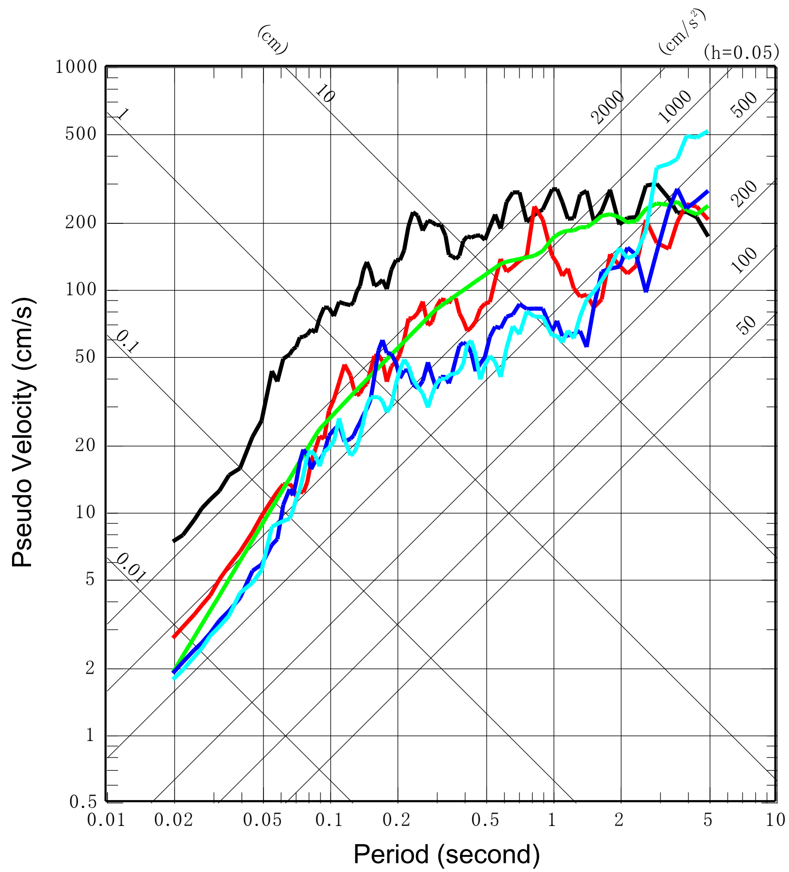
- Each result of the ground motion evaluation on the earthquake for examination is defined as design basis ground motion Ss.

design basis ground motion	Examination earthquakes	ground motion evaluation method
Ss—1	Earthquake caused by F-B fault (M7.0)	JEA spectrum [Noda et al.(2002)]
Ss—2		Fault model [Empirical Green's Function method]
Ss—3	Earthquake caused by the Nagaoka plain western boundary fault zone (M8.1)	JEA spectrum [x1.5 stress drop + 50deg. dipping] [avg. stress drop + 35deg. dipping]
Ss—4		Fault model [x1.5 stress drop + 50deg. dipping]
Ss—5		Fault model [avg. stress drop + 35deg. dipping]

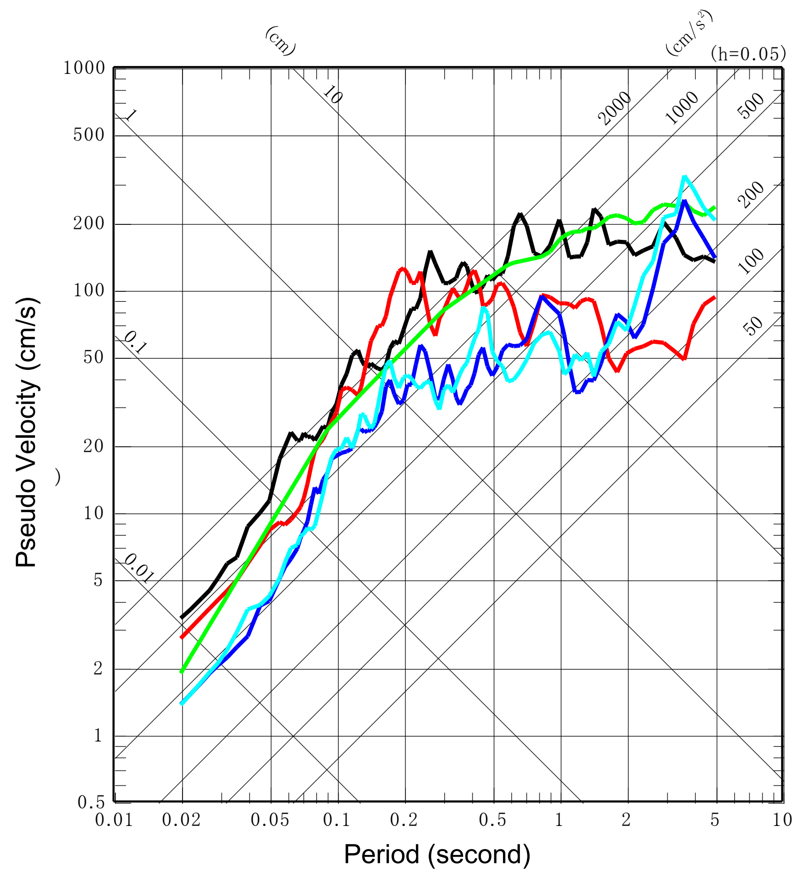
6. Outline of the Ss (pseudo velocity response spectra)

design basis ground motion Ss-1H
design basis ground motion Ss-2NS
design basis ground motion Ss-3H
design basis ground motion Ss-4NS
design basis ground motion Ss-5NS

NS



Arahama side (Units 1-4)

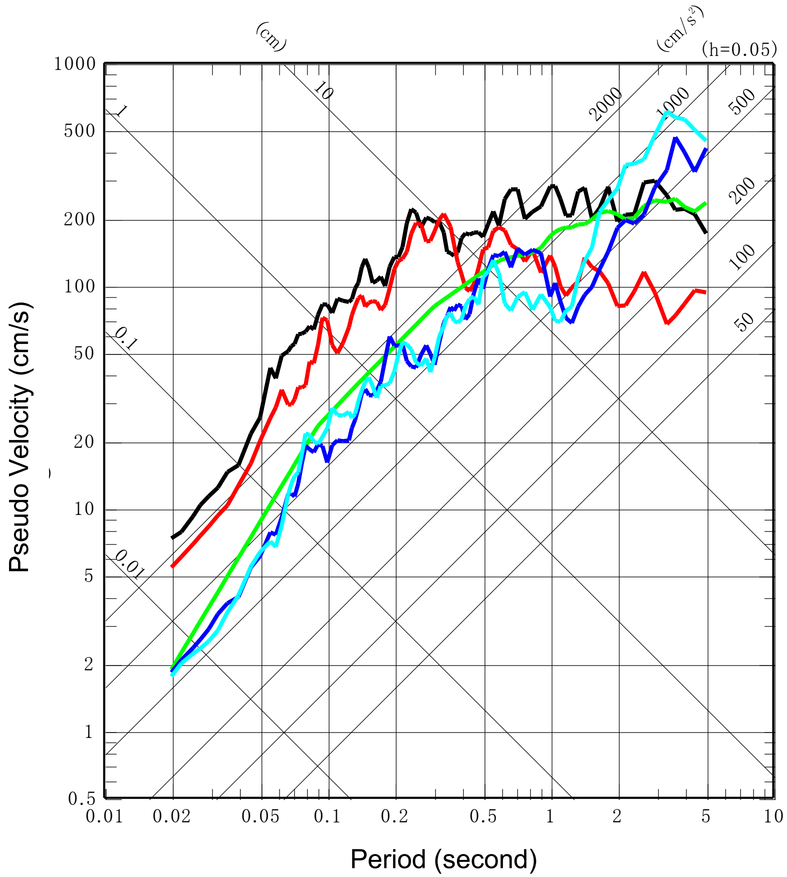


Ominato side (Units 5-7)

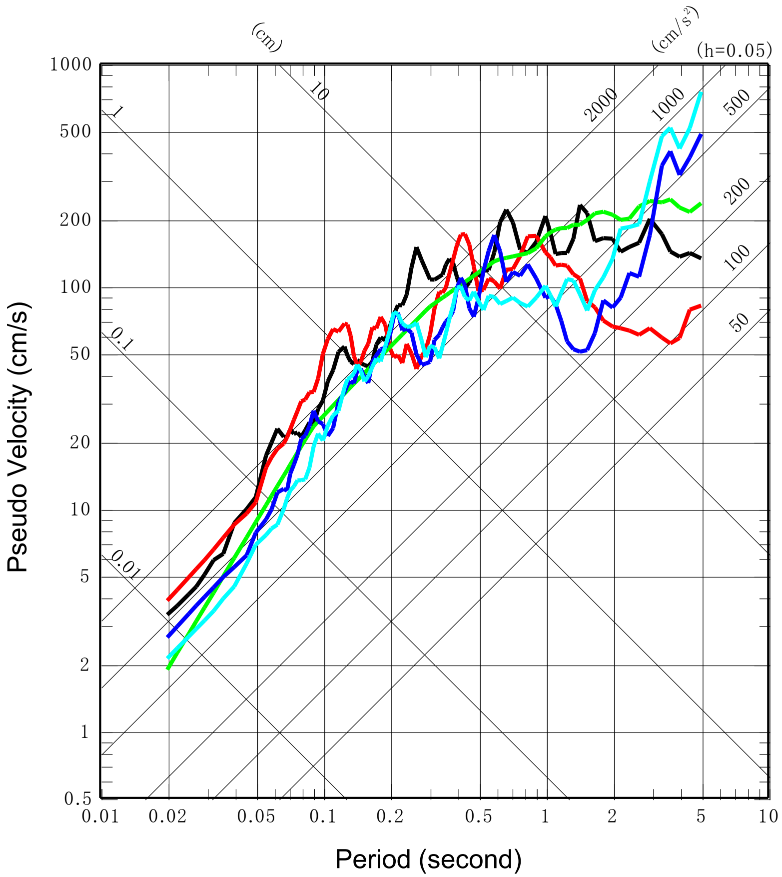
6. Outline of the Ss (pseudo velocity response spectra)

EW

design basis ground motion Ss-1H
design basis ground motion Ss-2EW
design basis ground motion Ss-3H
design basis ground motion Ss-4EW
design basis ground motion Ss-5EW



Arahama side (Units 1-4)

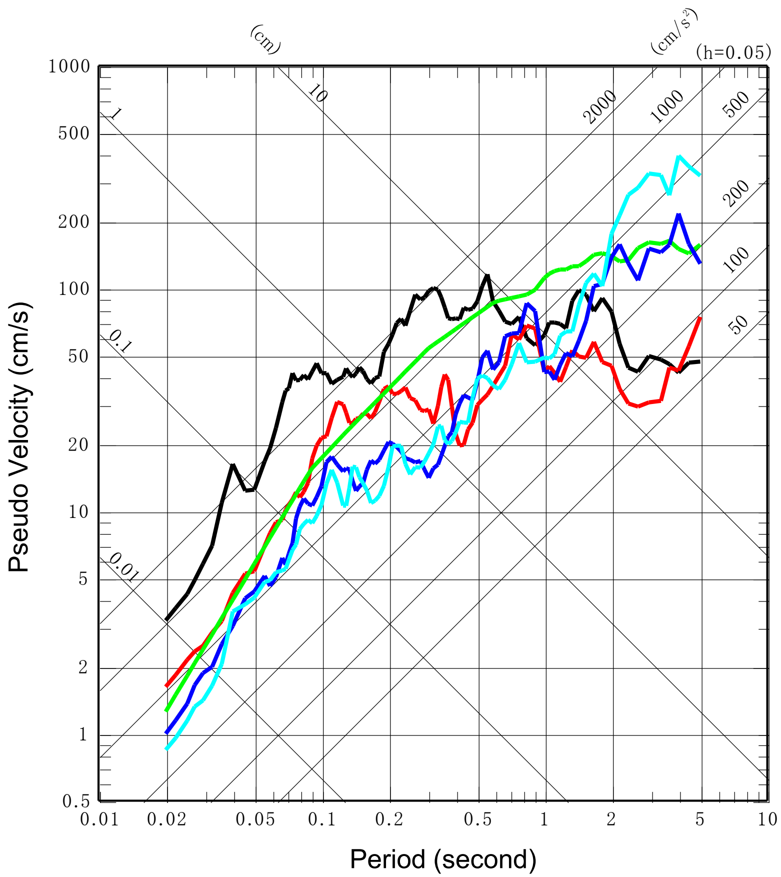


Ominato side (Units 5-7)

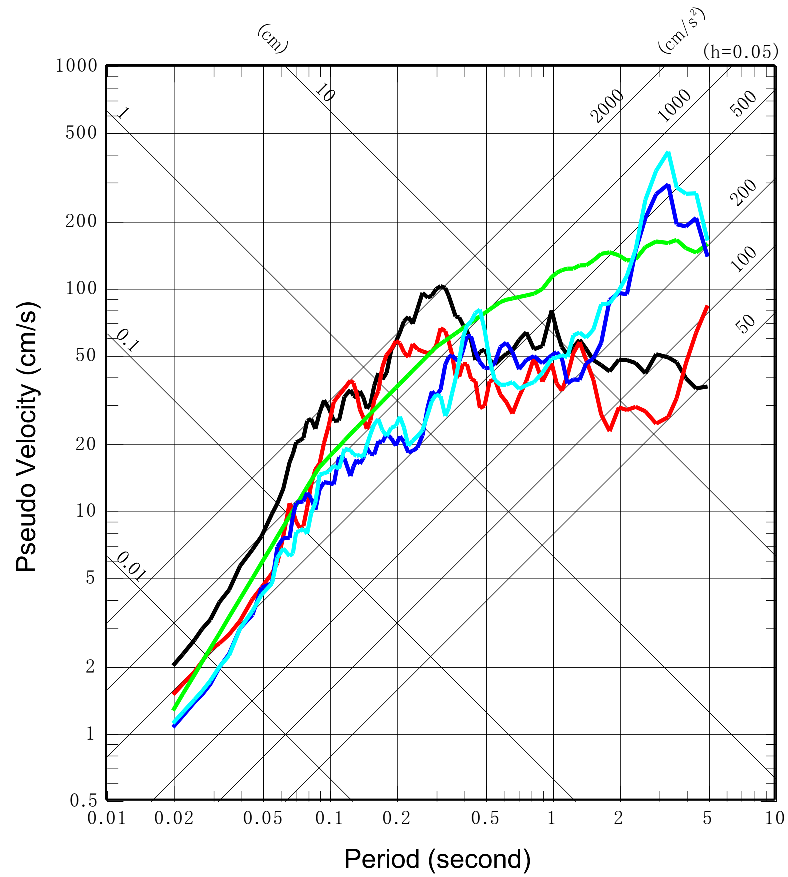
6. Outline of the Ss (pseudo velocity response spectra)

UD

design basis ground motion Ss-1V
design basis ground motion Ss-2UD
design basis ground motion Ss-3V
design basis ground motion Ss-4UD
design basis ground motion Ss-5UD



Arahama side (Units 1-4)



Ominato side (Units 5-7)

6. Outline of the Ss (Acceleration time history)

Acceleration time history of Ss-1

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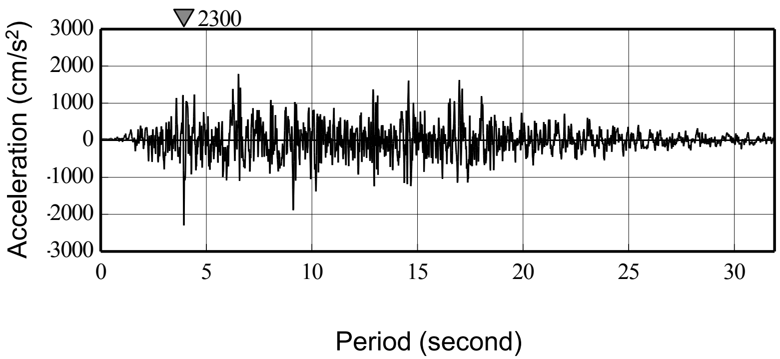
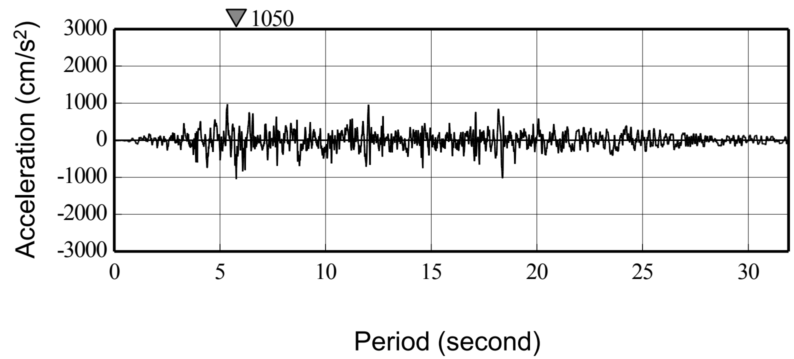
<tr><th></th><th>Arahama side (Units 1-4)</th><th>Ominato side (Units 5-7)</th></tr>
<tr><td>Horizontal</td><td>
</td><td>
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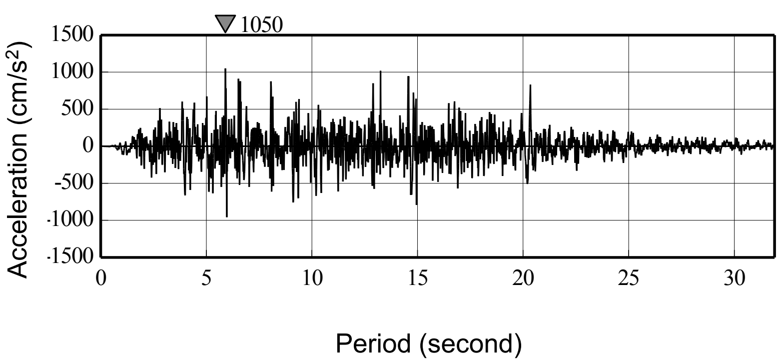
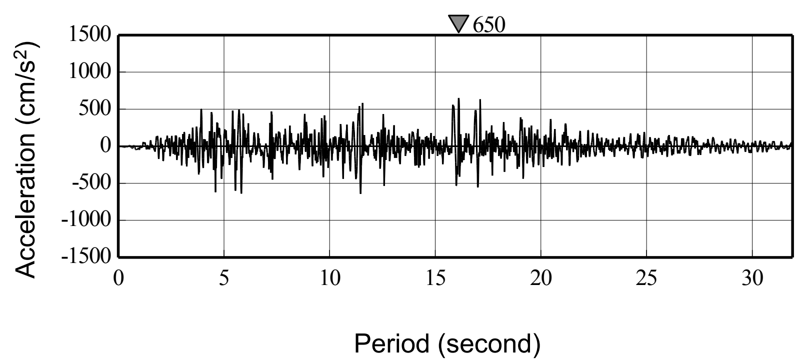
<tr><td>Vertical</td><td>
</td><td>
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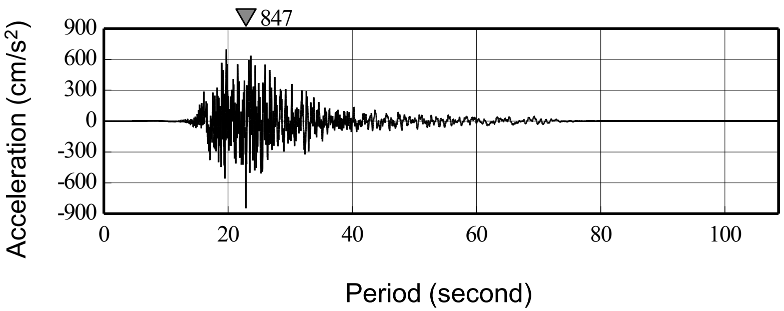
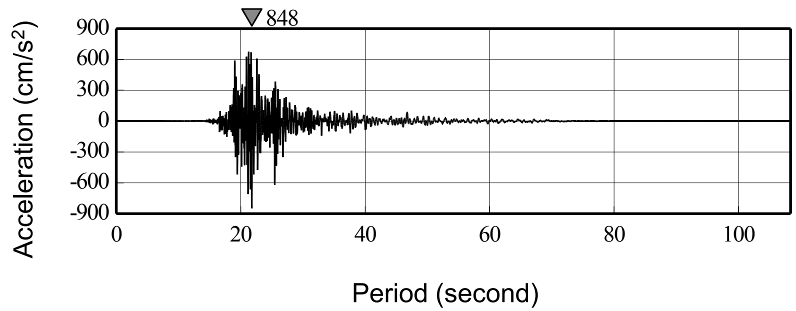
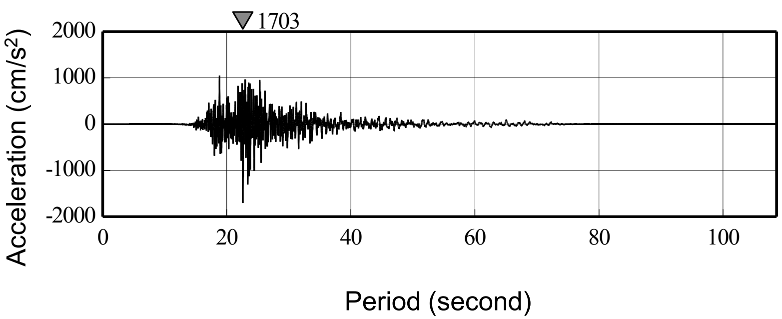
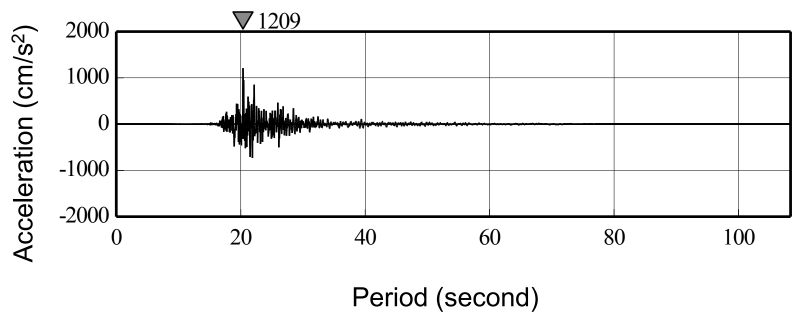
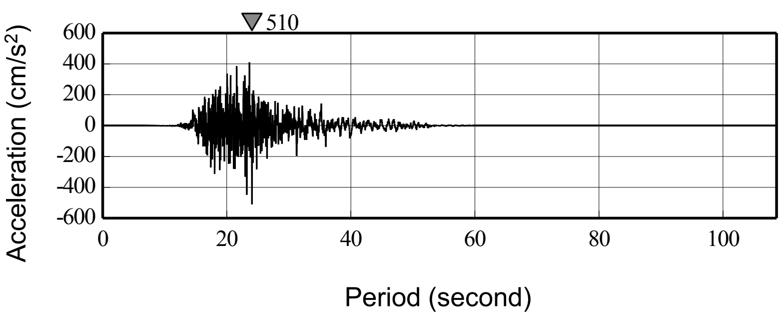
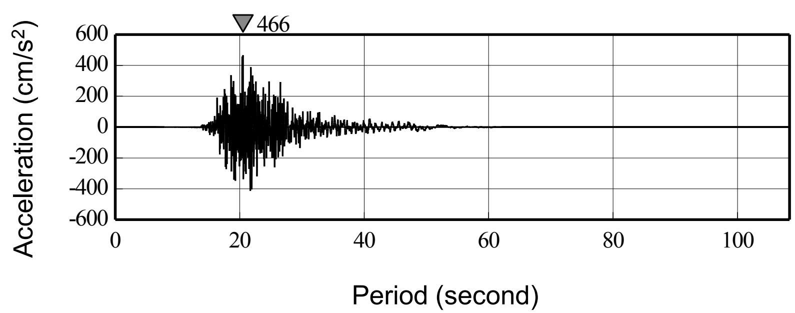
6. Outline of the Ss (Acceleration time history)

Acceleration time history of Ss-2

	Arahama side (Units 1-4)	Ominato side (Units 5-7)
NS		
EW		
UD		

6. Outline of the Ss (Maximum peak acceleration value)

(Unit: Gal)

design basis ground motion	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Ss—1 (F-B fault / JEA spectrum)	Horizontal: 2300 Vertical: 1050				Horizontal: 1050 Vertical: 650		
Ss—2 (F-B fault / Empirical Green's function)	NS: 847 EW: 1703 UD: 510				Ns: 848 EW: 1209 UD: 466		
Ss—3 (Nagaoka plain western boundary fault zone / JEA spectrum)	Horizontal: 600 Vertical: 400						
Ss—4 (Nagaoka plain western boundary fault zone / Empirical Green's function)	ＮＳ：589 ＥＷ ：574 UD：314				ＮＳ：428 ＥＷ：826 UD：332		
Ss—5 (Nagaoka plain western boundary fault zone / Empirical Green's function)	ＮＳ：553 ＥＷ ：554 UD：266				ＮＳ：426 ＥＷ：664 UD：346		

Determination of the Design Basis Ground Motion Ss

Summary

- Active faults are categorized into Sea area and Land area, considering the knowledge obtained from the NCO Earthquake, and the earthquake for examination are selected based on the comparisons of their impact on the site.

  (earthquakes for examination)

  the earthquake by F-B fault

  the earthquake by Nagaoka Plain WBFZ

- Standard source model and consideration about uncertainties of the earthquakes for examination are taken into account, and ground motion evaluation are conducted by both response spectrum method and the empirical Green's function.

  5 design basis ground motions Ss are defined based on those results.

Thank you for your attention