The 35th International Geological Congress, Cape Town, South Africa (Aug. 28-Sep. 2, 2016)
Monday, Aug. 29, 2016, Session T8.2, “Geohazards and societal benefits: coping with reality / Risk evaluation and management in the 21st Century”, Hall 4B2, 17:00-17:15, #2221. Ver. 7

Japan’s Nuclear Regulation Standards against Natural Hazards after Fukushima

（日本の福島後の原子力新規制基準の自然災害への対応）

Akira ISHIWATARI

Commissioner of Nuclear Regulation Authority, Japan (D.Sc., Geologist)

（石渡　明（原子力規制委員会委員））

The slides were slightly corrected and edited after the presentation.

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NRA's New Regulation Standards against Natural Hazards after Fukushima accident (Mar. 11, 2011)

- More stringent standards on tsunami
- Clarification of requirements for fault displacement
- More precise methods to define design basis ground motion (DBGM) by earthquake
- Assessment & monitoring of volcanic activity
- An example: Sendai Nuclear Power Plants (NPPs), Kyushu Electric Power Co.

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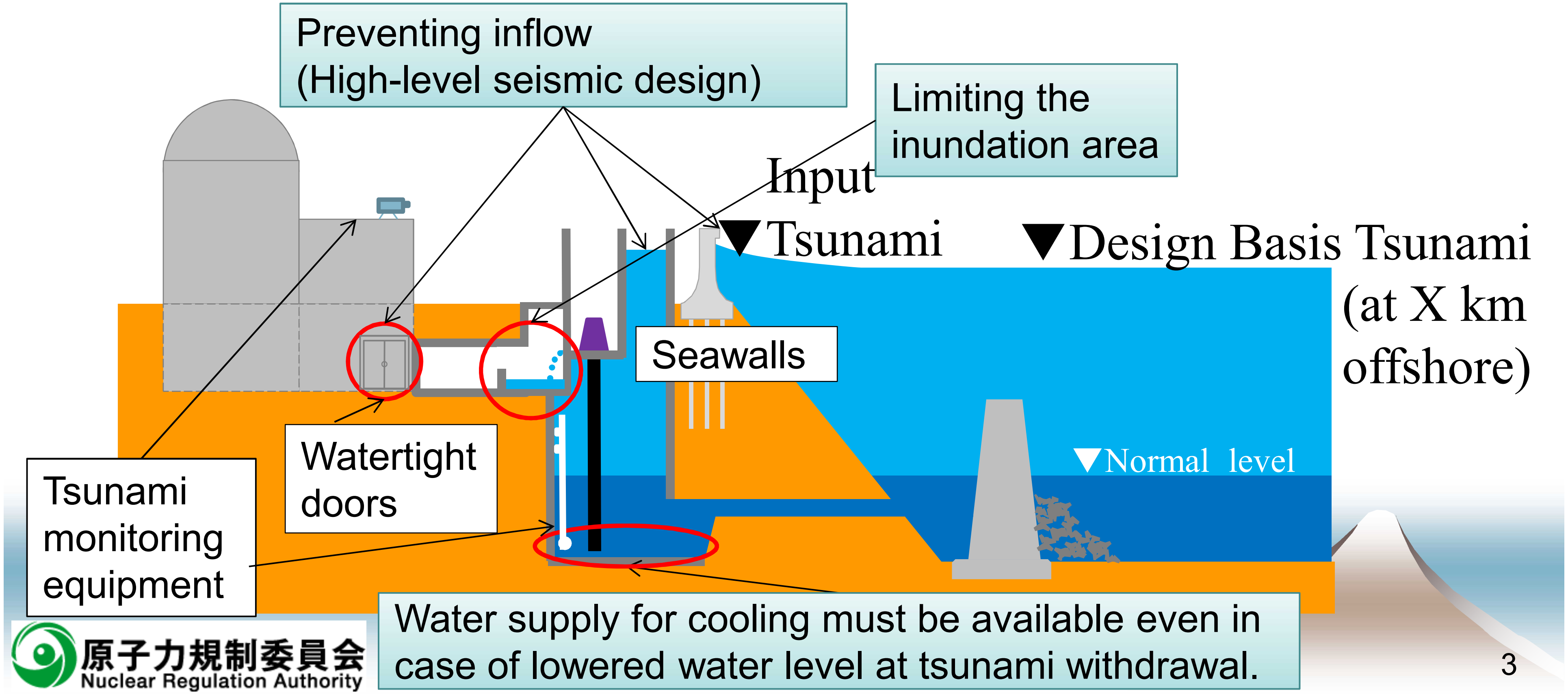
(NRA was established on Sep. 19, 2012)

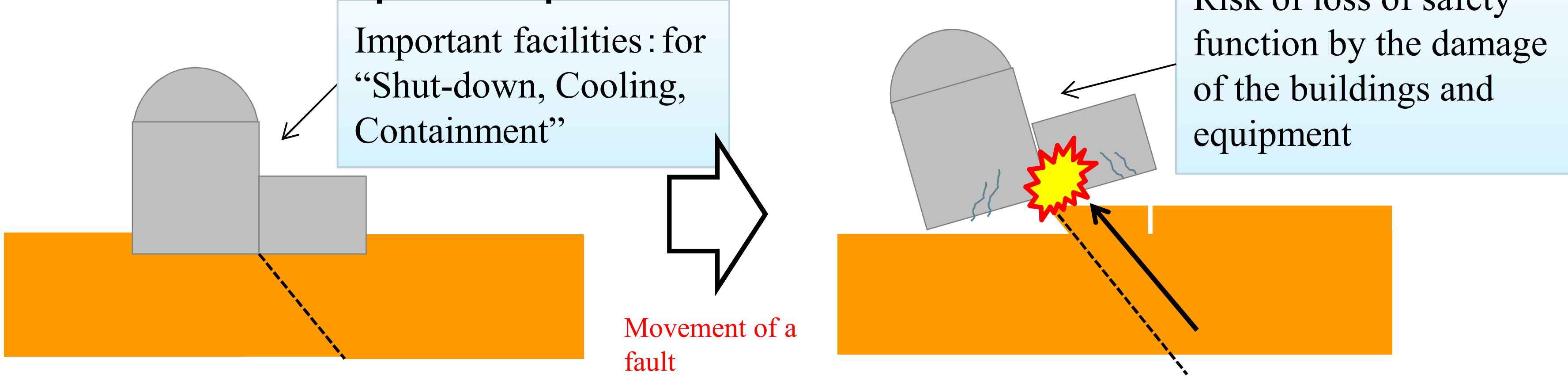
More stringent Standards on Tsunami

- Define "Design Basis Tsunami" that exceeds the largest in the historical records
- Requirements for multiple protective measures



Clarification of requirements for fault displacement

- “Capable faults” need to be determined as those whose activities since the late Pleistocene (approx.120,000 to 130,000 years ago or later) cannot be denied
- Important facilities have to be constructed on the ground without outcrop of capable faults



○Movement of the fault under important facilities like Reactor Building may result in the concentration of deadweight onto the spot and cause damage of the building.

○Even in case damage of the building is avoided, safety function can be lost due to the deformation of the facilities or damages of the internal equipment.

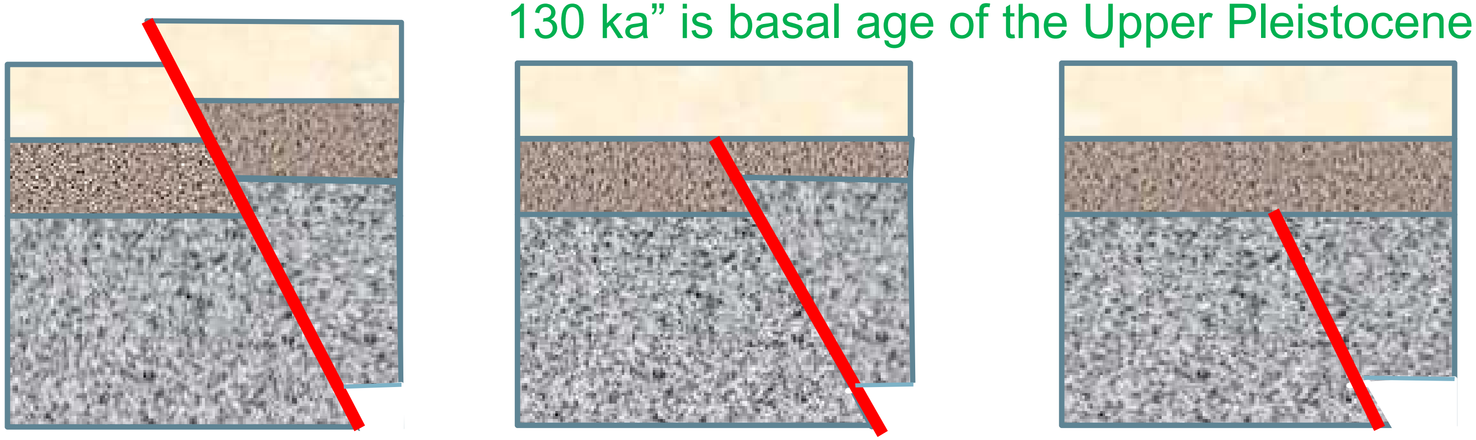
How to find a capable fault?

"Capable fault" is the official term for "active fault" that is defined in IAEA Safety Standards Series No. SSG-9 "Seismic hazards in site evaluation for nuclear installations". The "120-130 ka" is basal age of the Upper Pleistocene.

1. Covering Bed Method

Geological age of bed

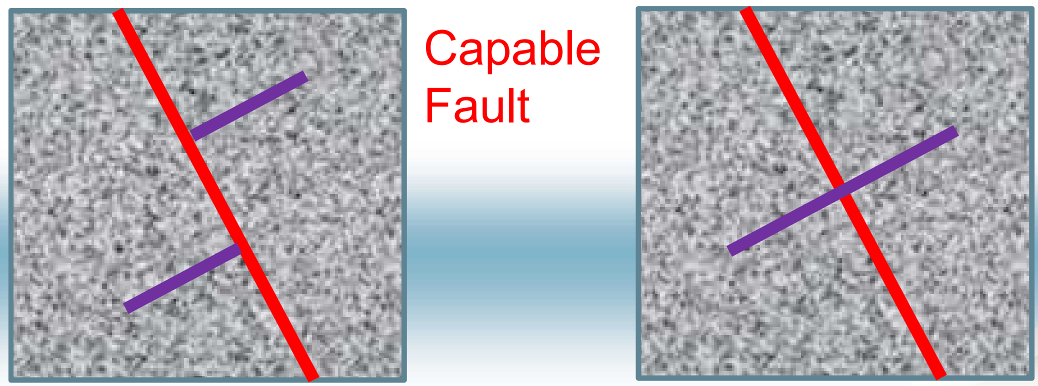
- younger
- 120-130 thousand years(ka)
- older



Judge: Capable Fault | Capable Fault | Not Capable Fault

2. Crossing Vein Method

— 120-130 ka dike or vein



Capable Fault | Not Capable Fault

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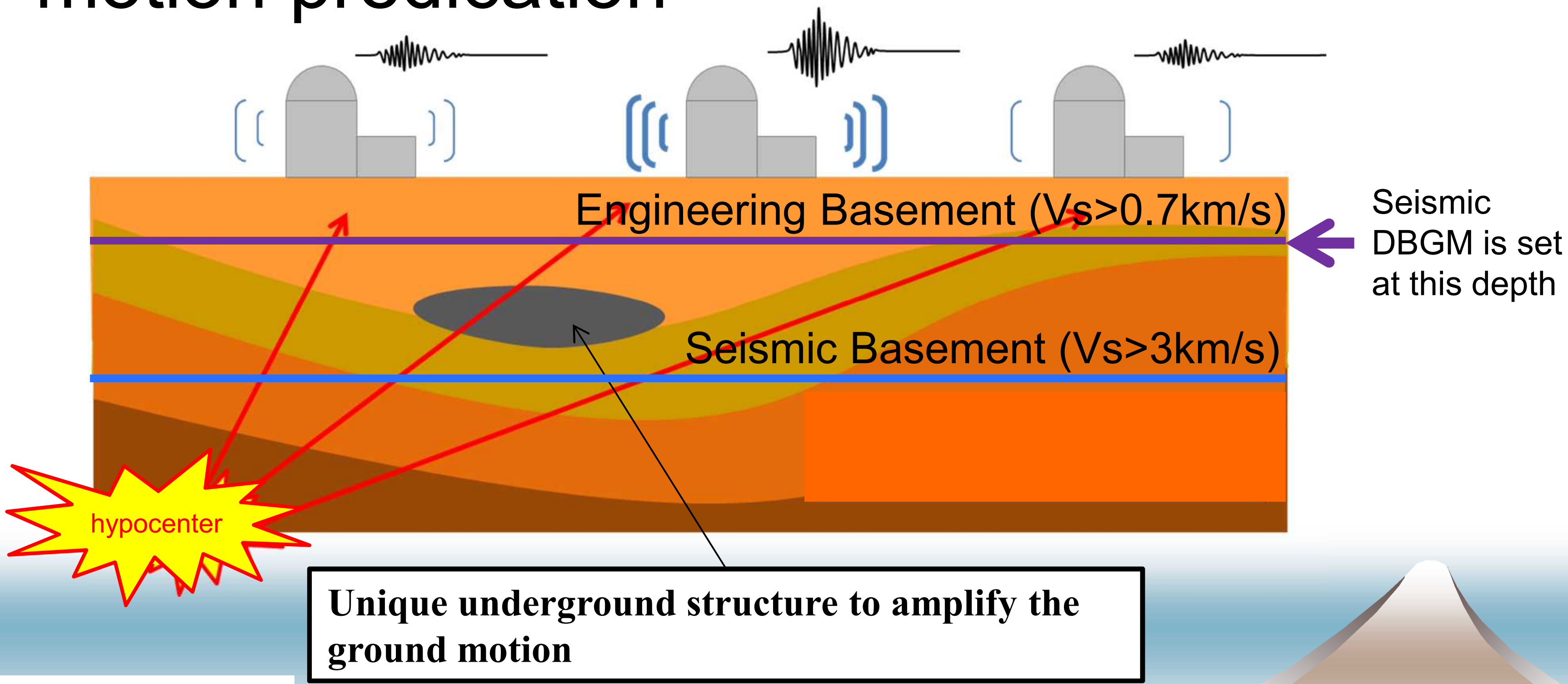
More precise methods to define Design Basis Ground Motion (DBGM)

- Survey 3D geological structure of the site
- Take into consideration of seismic ground motion predication



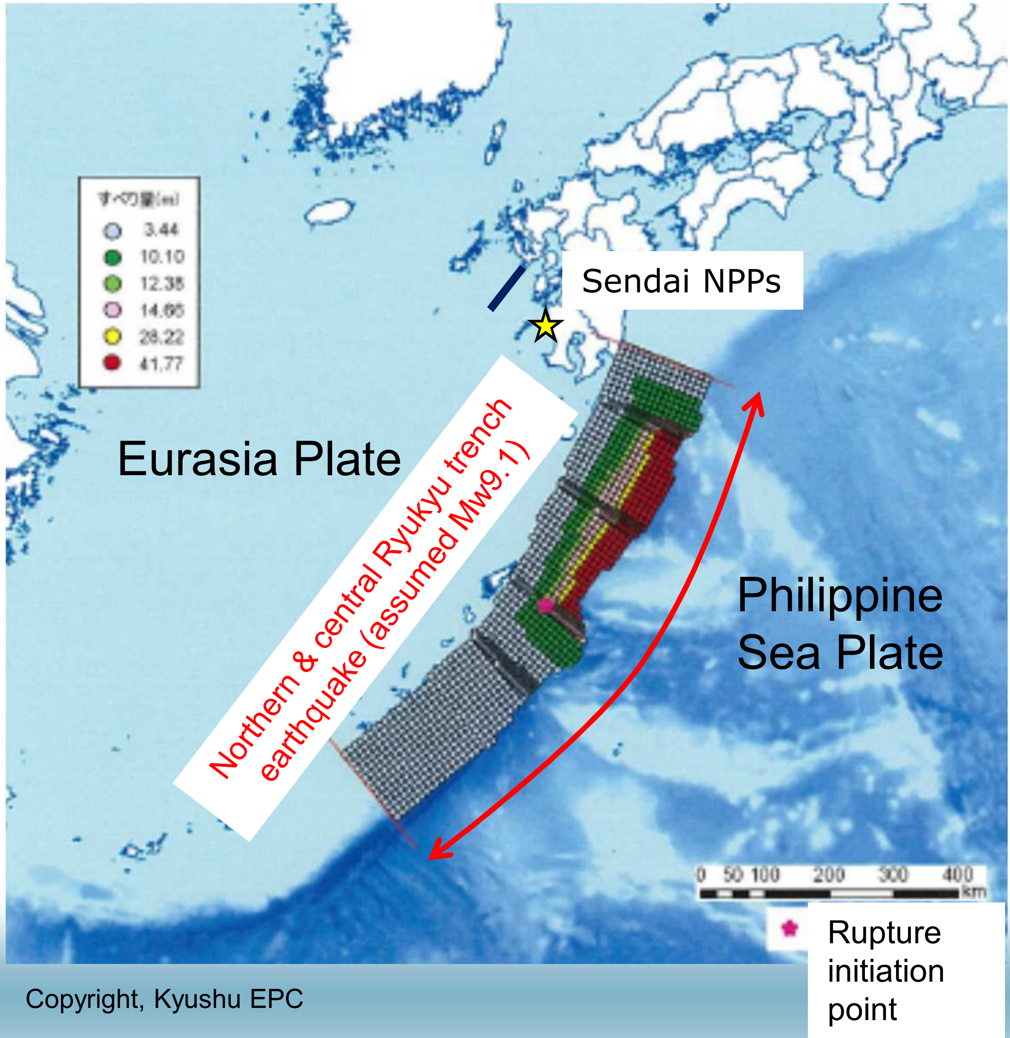
Reassessment of Sendai Nuclear Power Plants (NPPs): an example

- Owned by Kyushu EPC
- 2 PWRs, 890,000kW each
- About 30 years operation
- Front onto East China Sea (not to plate boundary)

Time sequence of reassessment

Jul. 8, 2013
  Back-fit safety assessment completed
Jul. 16, 2013
  Examination by NRA commissioners and secretariats started.
  >60 times open-to-public meetings
  ~700 times closed meetings
  Revision after public comments
Sep. 10, 2014
  Permission for basic design decided.
Sep. 10, 2015 and Nov. 17, 2015
  Commercial operation of Reactors #1 and #2 restarted, respectively. Both reactors are currently on operation.

Tsunami sources



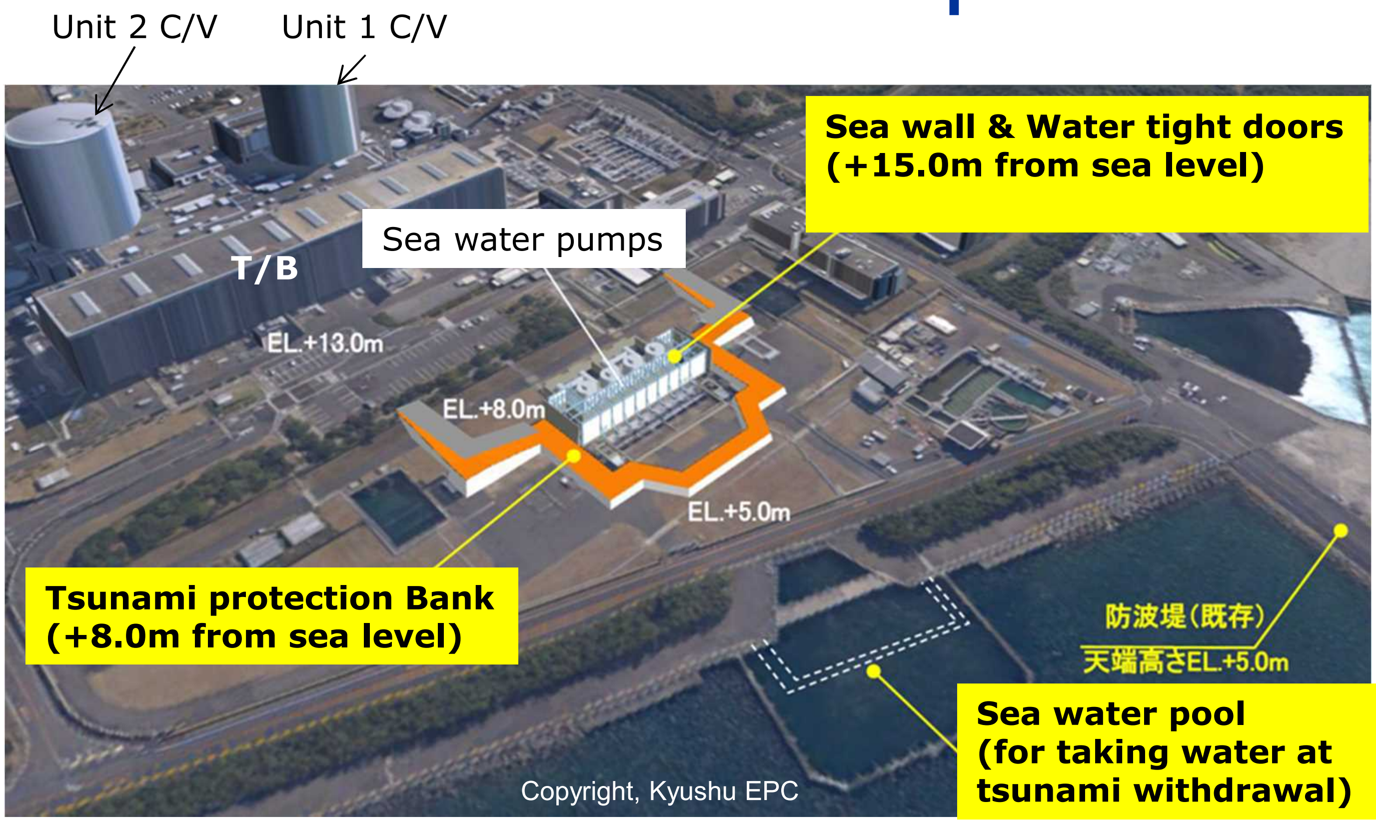
Nagasaki spur fault (length:86km, Mw7.6)

Northern and central part of Ryukyu trench (length:approx.900km, Mw9.1)

NRA required to estimate the tsunami height caused by northern and central part of Ryukyu trench*

* Any tsunami caused by this wide area have never been recorded, but the possibility to break several segment simultaneously, as in case of the Great East Japan Earthquake, should be considered.

Tsunami protection



Design Basis Tsunami Height of Sendai NPPs is calculated at the point 8 km offshore and 50 m water depth.

Input Tsunami Height is the maximum at the site waterfront.

Site Elevation is the ground height where reactors are placed.

NPPs	Tsunami Height	Input Tsunami	Site Elevation
Sendai	2.0m	7.0m	13m
Ikata	1.9m	8.7m	10m
Takahama	1.7m	6.7 m	3.5m

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Capable faults on site?

Geological Map of the Sendai Nuclear Power Plant site

Mar. 19, 2014, Assessment Meeting #95, Doc. 2-1, p. 81, Sendai NPPs, Fault (Kyushu EPC)

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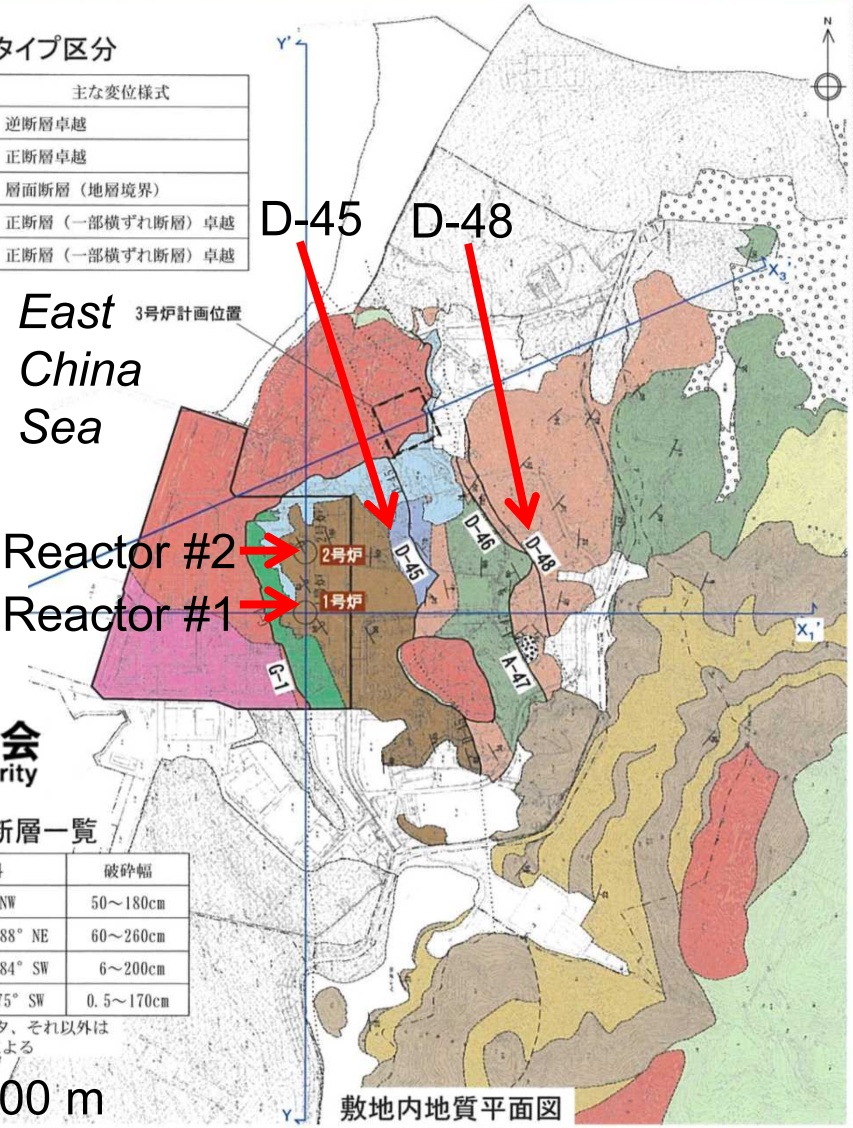
断層タイプ区分

断層タイプ	走向・傾斜	主な変位様式
A	NS系低角度	逆断層卓越
B	EW系低角度	正断層卓越
C	—	層面断層（地層境界）
D	NS系高角度	正断層（一部横ずれ断層）卓越
E	EW系高角度	正断層（一部横ずれ断層）卓越



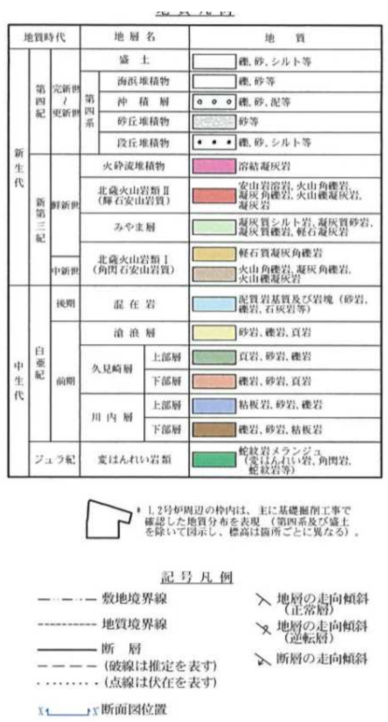
敷地東部の断層一覧

断層番号	走向・傾斜	破砕幅
A-47	N10° E/35° NW	50～180cm
D-45	N13～16° W/84～88° NE	60～260cm
D-46	N25～45° W/54～84° SW	6～200cm
D-48	N1～8° W/68～75° SW	0.5～170cm

＊ A-47断層はトレンチデータ、それ以外は3号炉調査試掘坑データによる

Two reactors are built on the Cretaceous conglomerate bed.

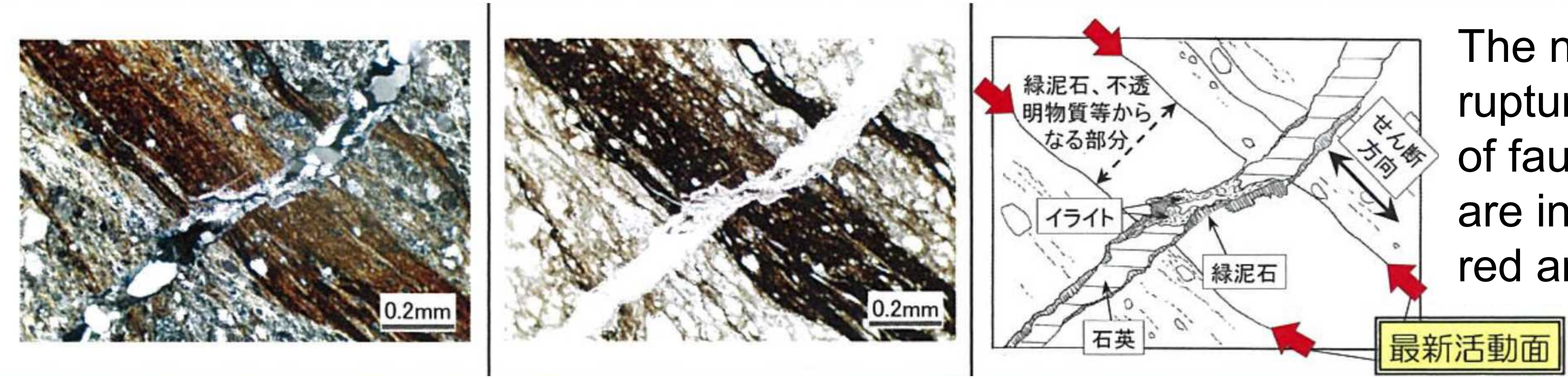
The longest and youngest faults (e.g. D-45 and D-48) are selected for detailed assessment.



81

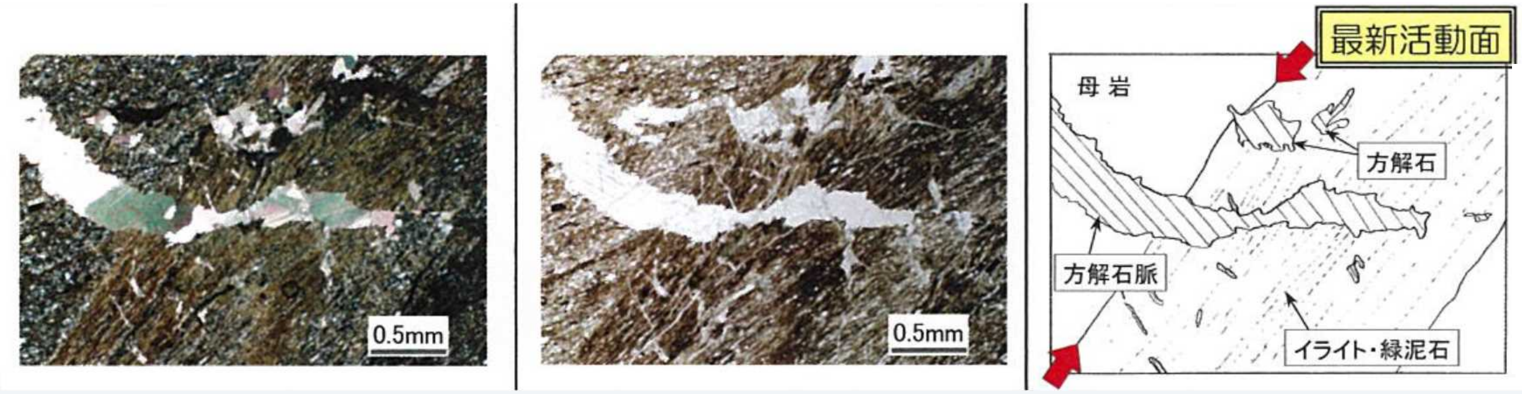
Mineral veins cutting fault zones

D-45 fault zone is cut by a quartz vein including chlorite and illite (p.109)



The newest rupture planes of fault zones are indicated by red arrows.

D-48 fault zone is cut by calcite veins (p. 117)



Chlorite and illite are also present in the fault zones.

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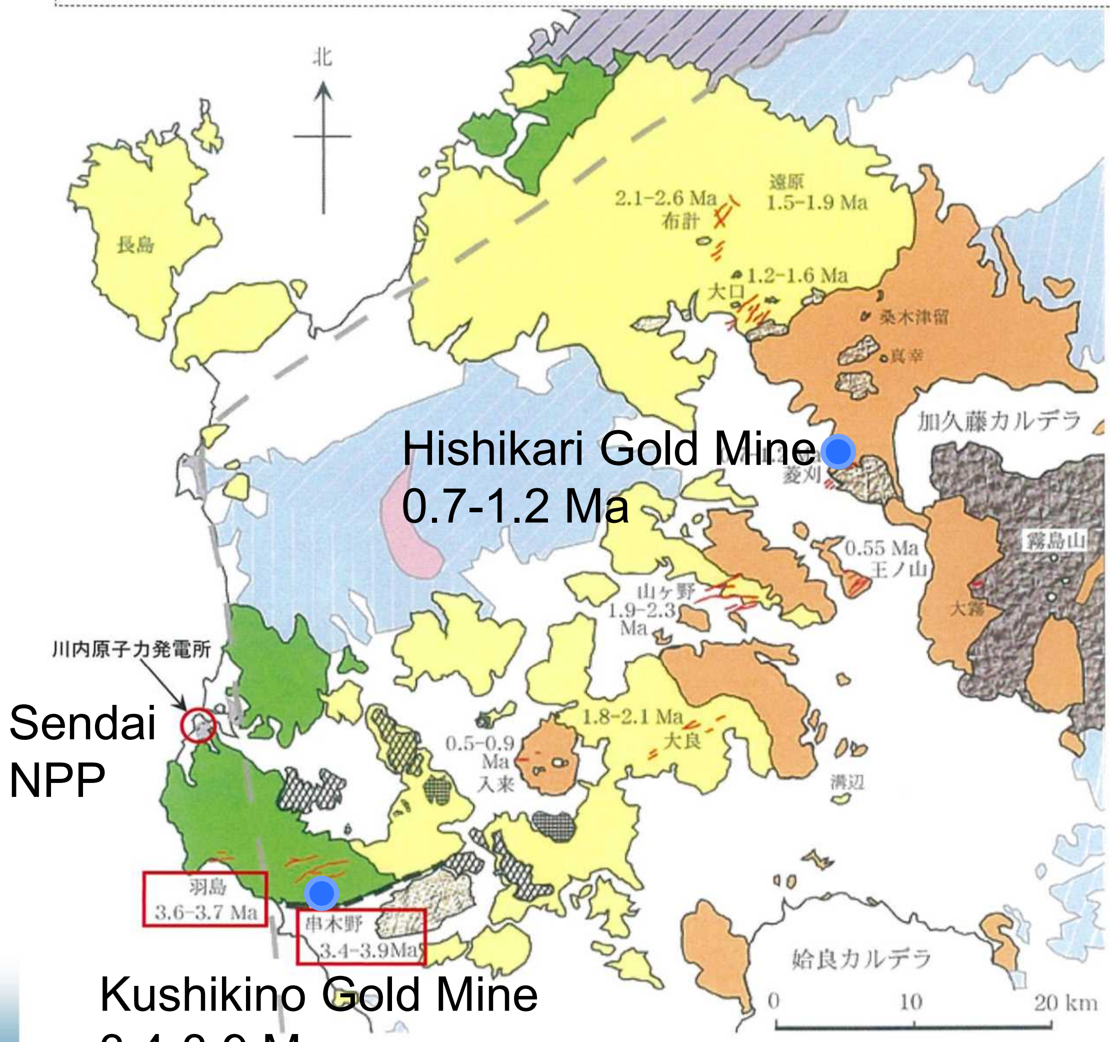
Mar. 19, 2014, Assessment Meeting #95
Doc. 2-1, Sendai NPPs (Kyushu EPC)

Age of hydrothermal veins: 3 Ma in the Sendai-Kushikino area

○ 敷地内の熱水変質活動の年代については、井澤 (2004)*に基づき、3〜4Maと判断している。

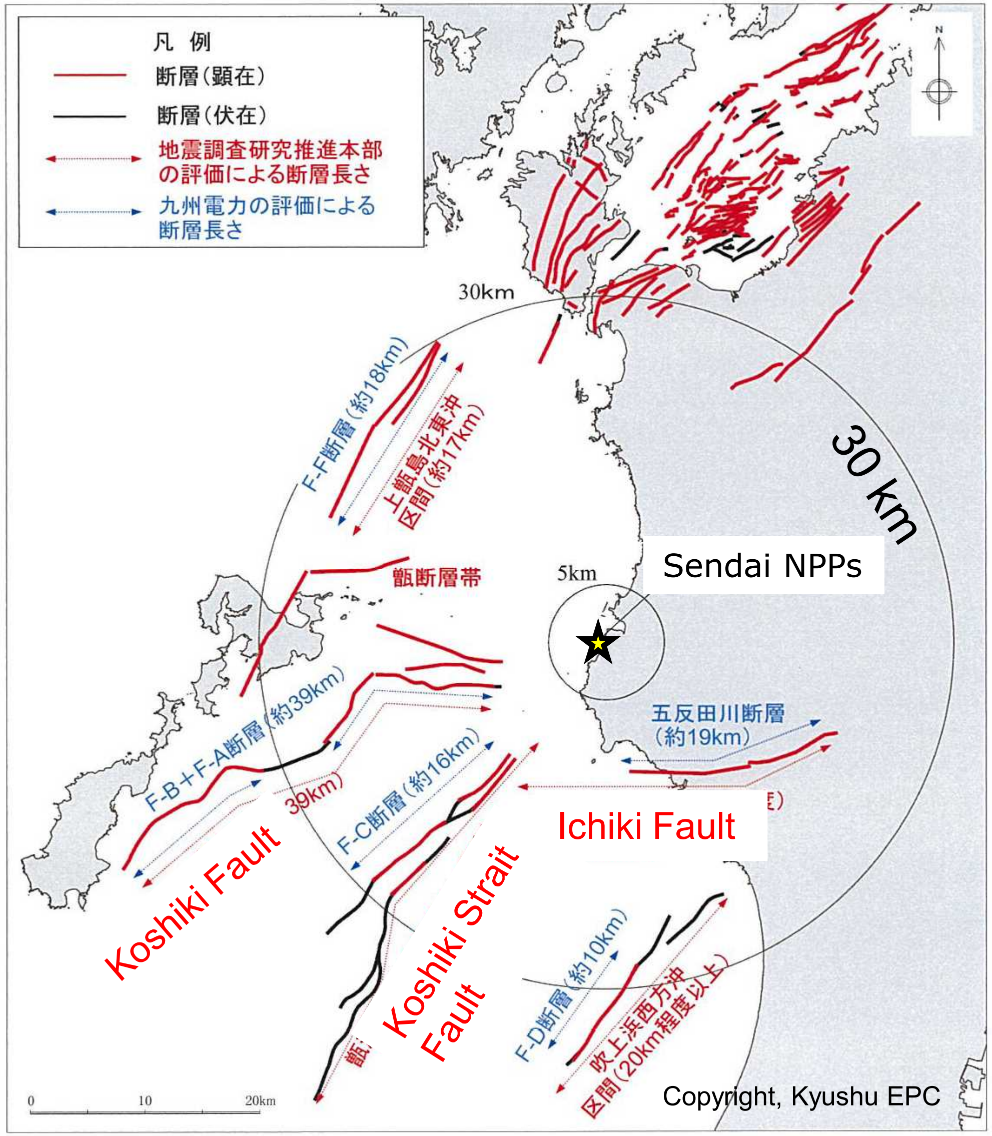


北薩地域の火山岩と金鉱床の分布（井澤,2004に加筆）

On-site faults of Sendai NPPs formed before (or geologically at the same time with) the 3 Ma hydro-thermal activity. Thus **they are not capable faults**.

Izawa, E. (2004) Chishitsu News, 599, 49-54 (in Jpn.).

Capable faults (near site <30km)



Blue: Fault length assessed by Kyushu EPC

Red: Fault length assessed by the Headquarter for Earthquake Research Promotion (HERP)

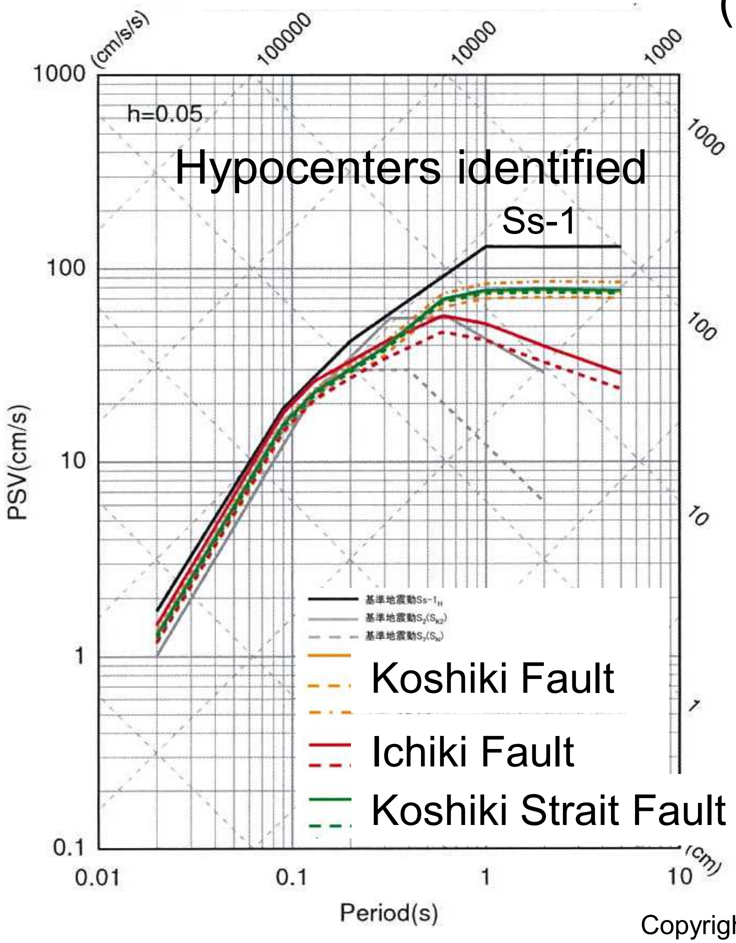
NRA required to extend the length of faults to fit the length assessed by HERP

The nearest faults are used for calculation of Design Basis Ground Motion (DBGM)

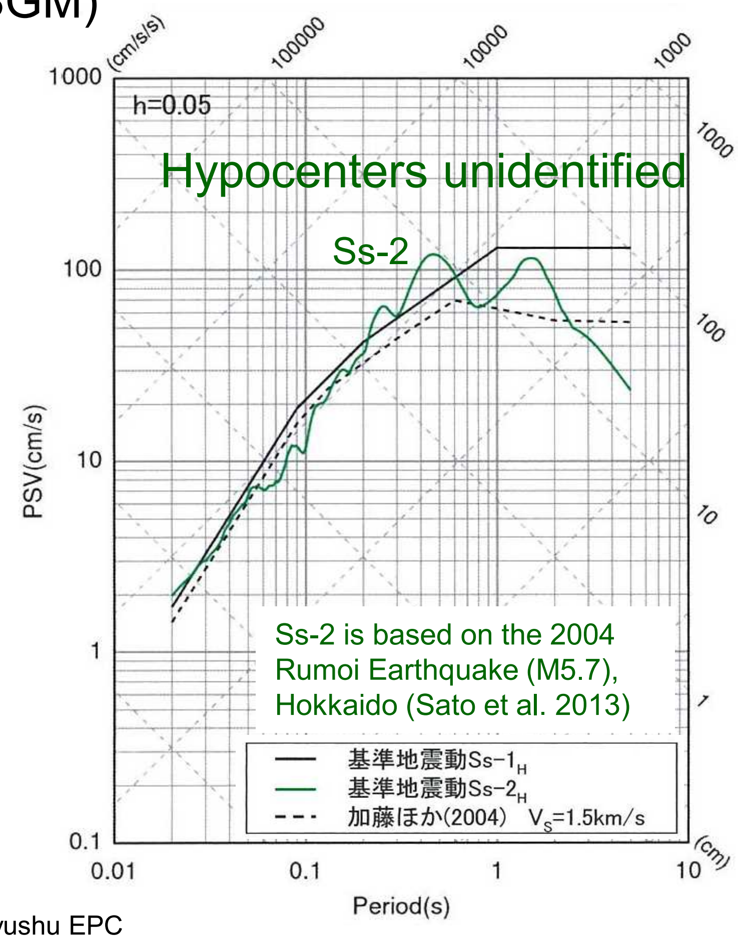
(Mar. 12, 2014 Assessment Meeting #92. Copyright: Kyushu EPC)

Design Basis Ground Motion of Sendai NPPs

(DBGM)



Horizontal movement



Horizontal movement

Ss-1 and Ss-2 are DBGMs for Sendai NPPs.

The Ss-2 “hypocenters-unidentified” earthquake is assumed to occur in the earth’s crust just beneath the NPPs.

The Ss-2 is larger than the Ss-1 in some periods.

Seismic accelaration of DBGM: (gal = cm/s^2)

Sendai: 540 gal (Appl.) >>> 620 gal (Reassess.)
Ikata: 570 gal (Appl.) >>> 650 gal (Reassess.)
Takahama: 550 gal (Appl.) >>> 700 gal (Reassess.)

Calculation is based on Irikura and Miyake (2001; *J. Geogr.*, **110**, 849-; 2011; *Pure Appl. Geophys.*, **168,** 85-)

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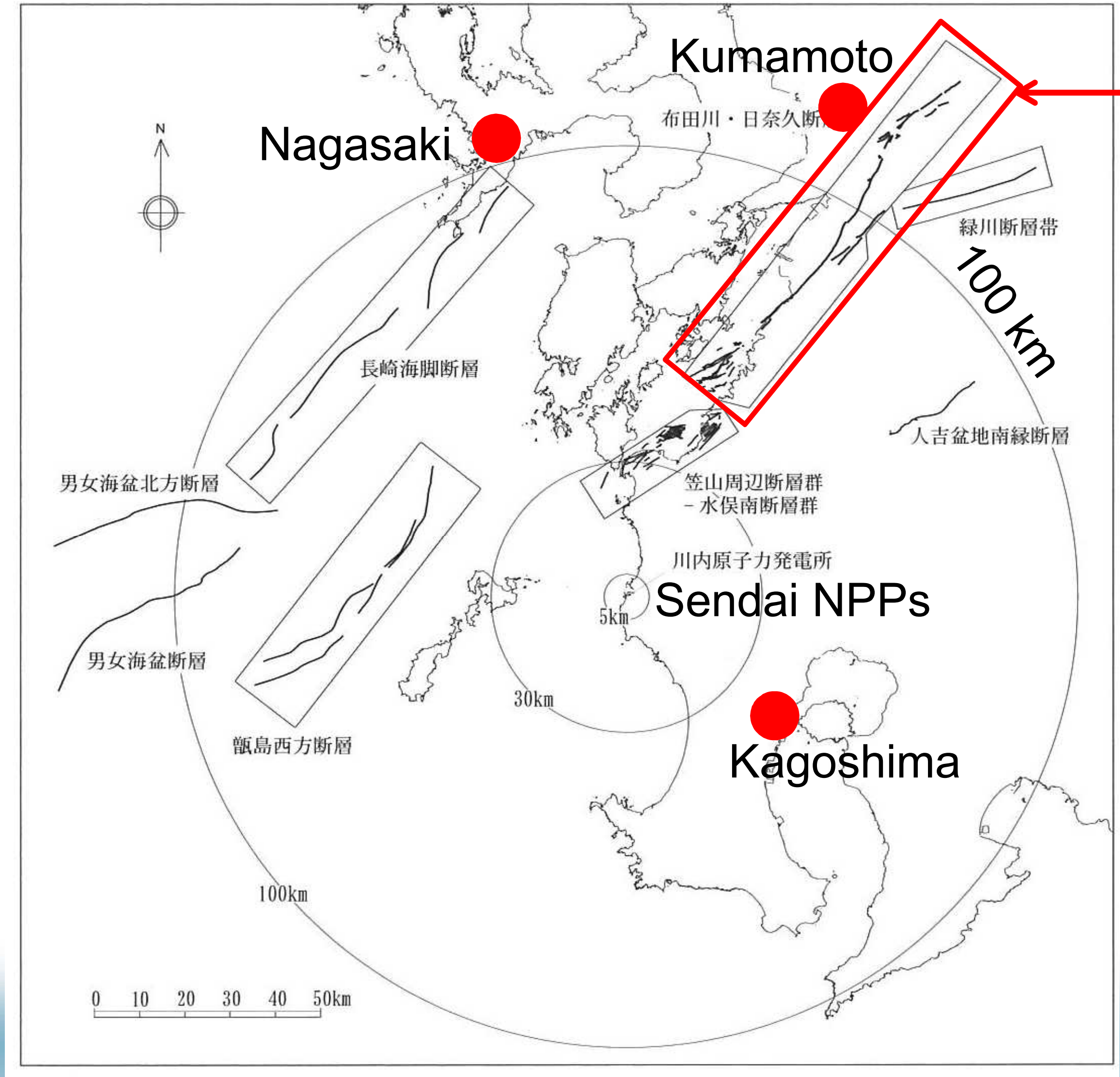
Capable faults (near site <100km)



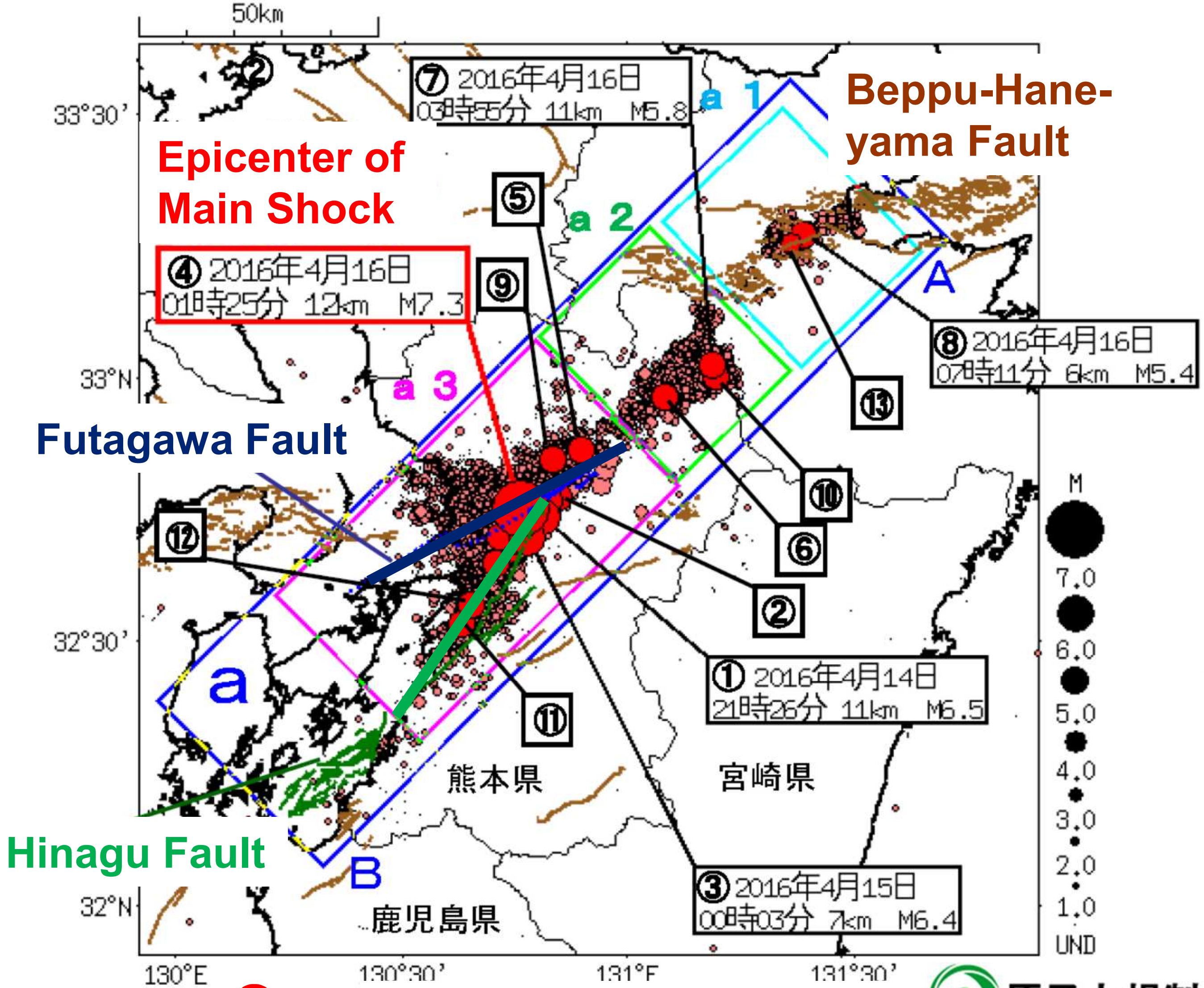
Kyushu EPC's evaluation of Futagawa-Hinagu Fault is 93 km long and M8.1, assuming a full-length rupture. Equivalent epicenter distance from Sendai NPPs is 104 km.

The Futagawa-Hinagu Fault caused M7.3 Kumamoto earthquake on Apr. 16, 2016 and associated numerous disastrous earthquakes.

(Mar. 12, 2014 Assessment Meeting #92. Copyright: Kyushu EPC)

2016 Kumamoto Earthquake

Apr. 14, M6.5 and Apr. 16, M7.3; 50 deaths, >2,000 injuries and >180,000 evacuees.



Sendai NPP●

Japan Meteorological Agency

Surface Fault Trace:
Futagawa: 28 km
Hinagu: 6 km

Fault Length by Satellite-based Ground Movement:
Futagawa E: 5 km
Futagawa W: 20 km
Hinagu: 10 km
(Data from Japan Meteorological Agency)

Kyushu EPC's evaluation of the Futagawa-Hinagu Fault in the Sendai NPP Reassessment:
93 km, M8.1

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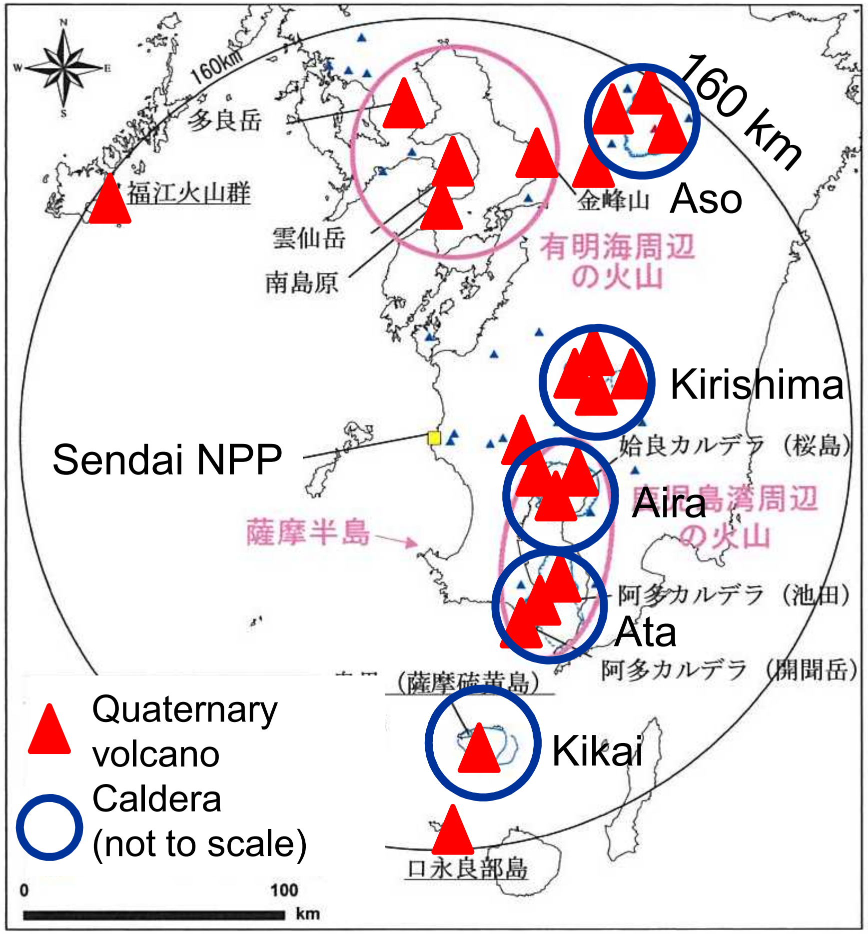
Protection of NPPs from volcanic hazards

Utility companies should survey Quaternary volcanoes within 160 km from the NPP, and assess their eruption histories, geothermal activities, distribution of lavas, pyroclastic flows and ash, etc.

In case if a pyroclastic flow reached the NPP site in the geologic past, the company should conduct seismic and geodetic monitoring of the source caldera volcano. This is the case for Sendai NPPs.



Evaluation of volcanic ash to be deposited in the NPP site during its operation:

NPP	Ash
Sendai	15 cm
Ikata	15 cm
Takahama	10 cm

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Conclusion (Principal aims of NRA)

- Protect human life & environment – our goal
- Independent scientific & technical decisions
- Field-based, effective regulation
- Open & informed regulation processes
- Professional moral & ability by daily studies
- Immediate & organized action at crisis

Thank you for your kind attention.

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