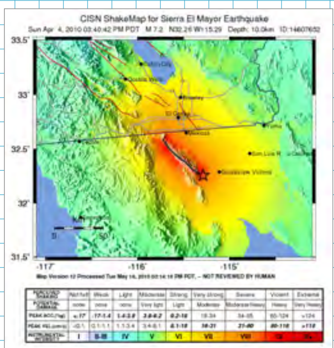
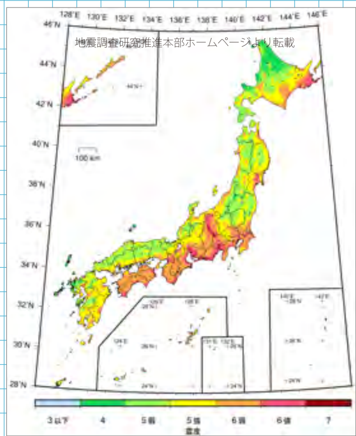
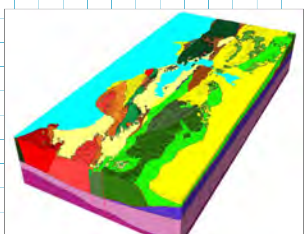
8th U.S./Japan Natural Resources Panel
on Earthquake Research
Field Trip Guidebook

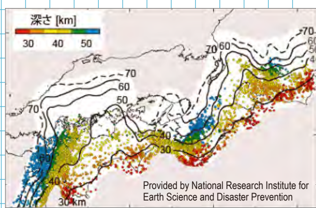
Date: October 20, 2010



ShakeMap for Sierra El Mayor Earthquake courtesy of the U.S. Geological Survey




3-D Models of the San Francisco Bay Region courtesy of the U.S. Geological Survey



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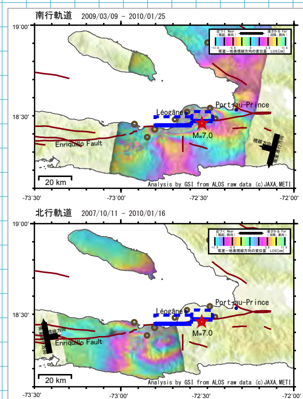
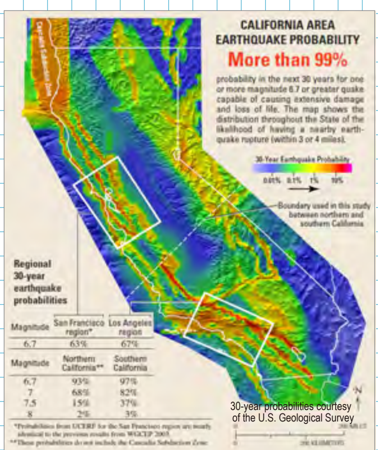
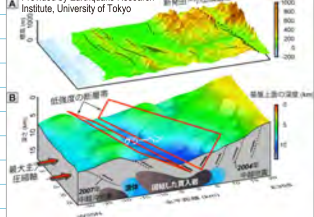




30-year probabilities courtesy of the U.S. Geological Survey


Provided by Earthquake Research Institute, University of Tokyo


Landslides caused by the Mid Niigata earthquake in 2004

UJNR

Nagaoka, Niigata, Japan
October 20-22, 2010

Field Trip Guidebook for the 8th U.S./Japan Natural Resources Panel on Earthquake Research

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Special thanks to:

NIIGATA UNIVERSITY

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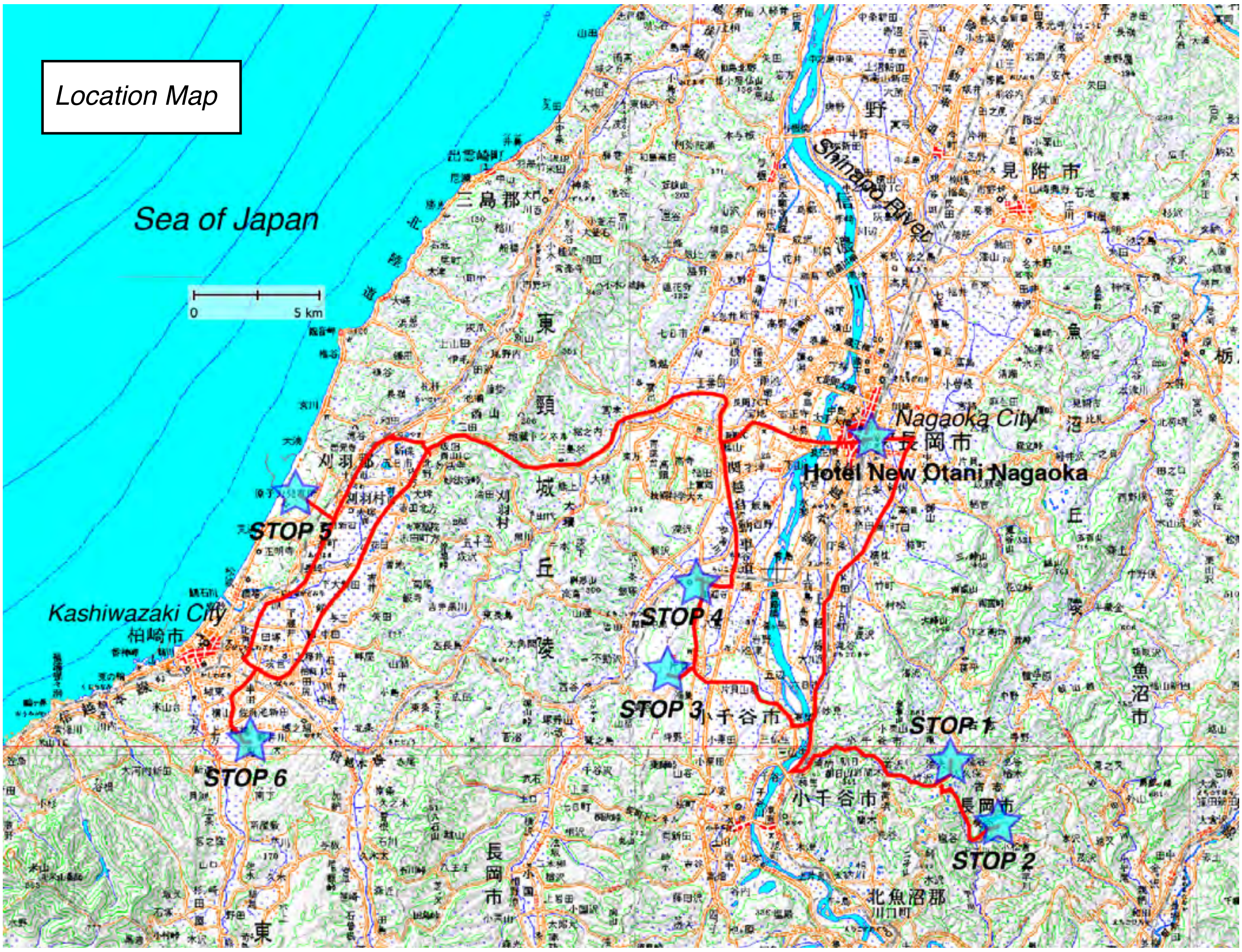


Itinerary of the field trip

08:30 Meet in a lobby of Hotel New Ohtani Nagaoka

|

STOP 1: Nagaoka City Yamakoshi Hall

|

STOP 2: Kogomo village, Yamakoshi Higashi-takezawa district

|

STOP 3: Outcrops of the Katakai Fault, Ojiya City

|

STOP 4: Lunch at *Momiji-en* (Maple tree garden), Nagaoka City

| via Kan'etsu Expressway, Hokuriku Expressway

STOP 5: Kashiwazaki-Kariwa Nuclear Power Station of TEPCO

|

STOP 6: Niigata Institute of Technology (Deep borehole drilled by JNES), Kashiwazaki City

| via Hokuriku Expressway, Kan'etsu Expressway

17:50 Return to Hotel New Ohtani Nagaoka

Overview of tectonic setting of the Japanese islands and the *Chuetsu* area

The Japanese islands are located at a plate boundary where the North America, Amurian, Philippine Sea, and Pacific plates all converge (Fig. 0-1). Most of large earthquakes occur in the subduction zone below the Pacific Ocean. However M~7 earthquakes sometimes occur in the interior of Japan, and cause serious damage and disruption to society. Most geologists and geophysists believe that two continental plates, that is, the North American and Amurian plates are bounded by the Itoigawa-Shizuoka Tectonic Line (ISTL), which is a major geological boundary in central Japan. However, GPS studies suggest that contemporary deformation is concentrated in a northeast-southwest trending zone called the Niigata-Kobe Tectonic zone (NKTZ) [Sagiya et al., 2000].

The *Chuetsu* (Mid-Niigata) area in the northern part of the NKTZ is one of the most active tectonic regions, in which a fold-and-thrust belt is well developed. Geological studies [Okamura et al., 1995; Ikeda et al., 2002; Sato et al., 2004] suggest that thick sediments accumulated in a rift system which formed in an extensional stress regime during back-arc spreading. These sediments are related to the opening of the Sea of Japan from 25–13 Ma BP. Normal faults formed at this stage have been subsequently activated as reverse faults during shortening in the eastern margin of the Japan Sea in the past 3.5 Ma. The 2004 *M*=6.8 Mid-Niigata Prefecture (*Chuetsu*) and the 2007 *M*=6.8 *Niigataken Chuetsu-oki* earthquakes ruptured such reverse faults. **(See also supplemental figures in Appendix 1)**

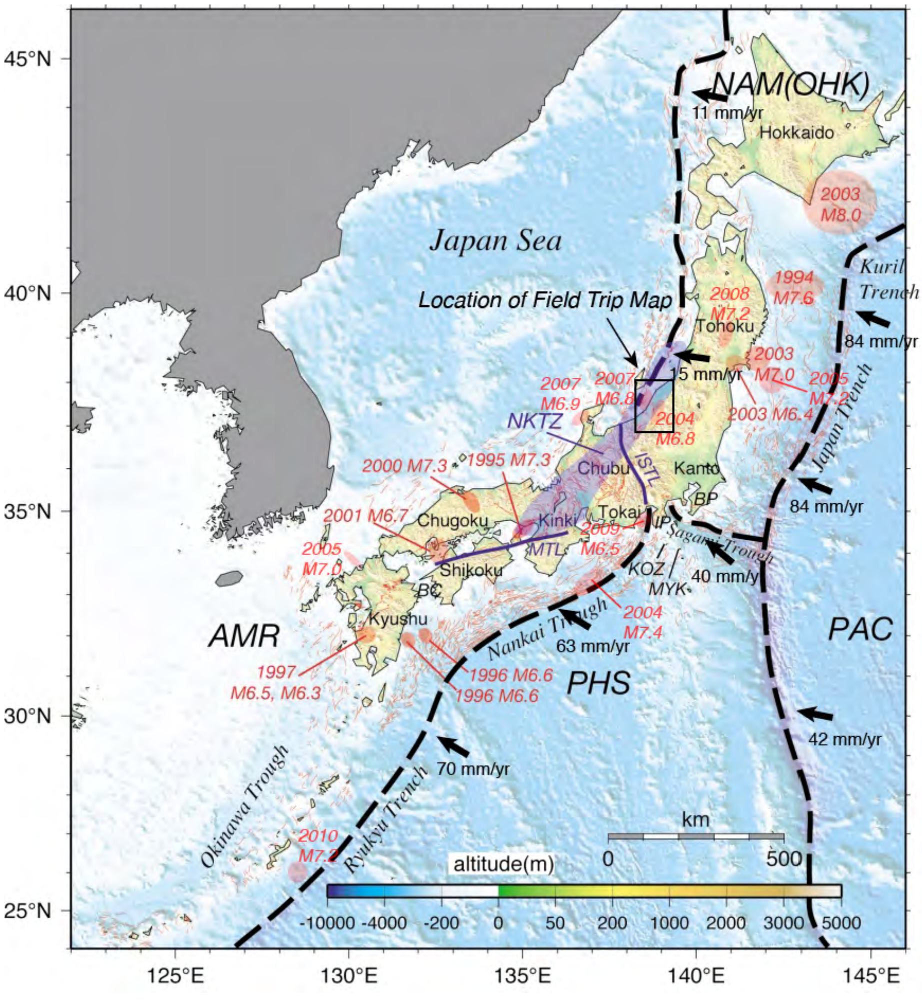


Fig. 0-1 Tectonic setting and large earthquakes of the Japanese islands [modified from Sagiya(2004)]. Arrows show relative plate motions based on REVEL 2000 [Sella et al., 2002]. Red areas show the epicentral areas of large earthquakes after 1994.

STOP 1: Nagaoka City Yamakoshi Hall

STOP 2: Kogomo village, Yamakoshi Higashi-takezawa district

The 2004 Mid Niigata Prefecture Earthquake (*M* 6.8) with a recorded seismic intensity of 7 (*JMA* scale) caused huge damage in the *Chuetsu* region. A massive landslide occurred on the left bank of the Imo River displacing a huge soil mass, and blocked the river in the Yamakoshi Higashi-takezawa district. The water level of the river rose and flooded houses in the upstream Kogomo village (Fig. 1-1).

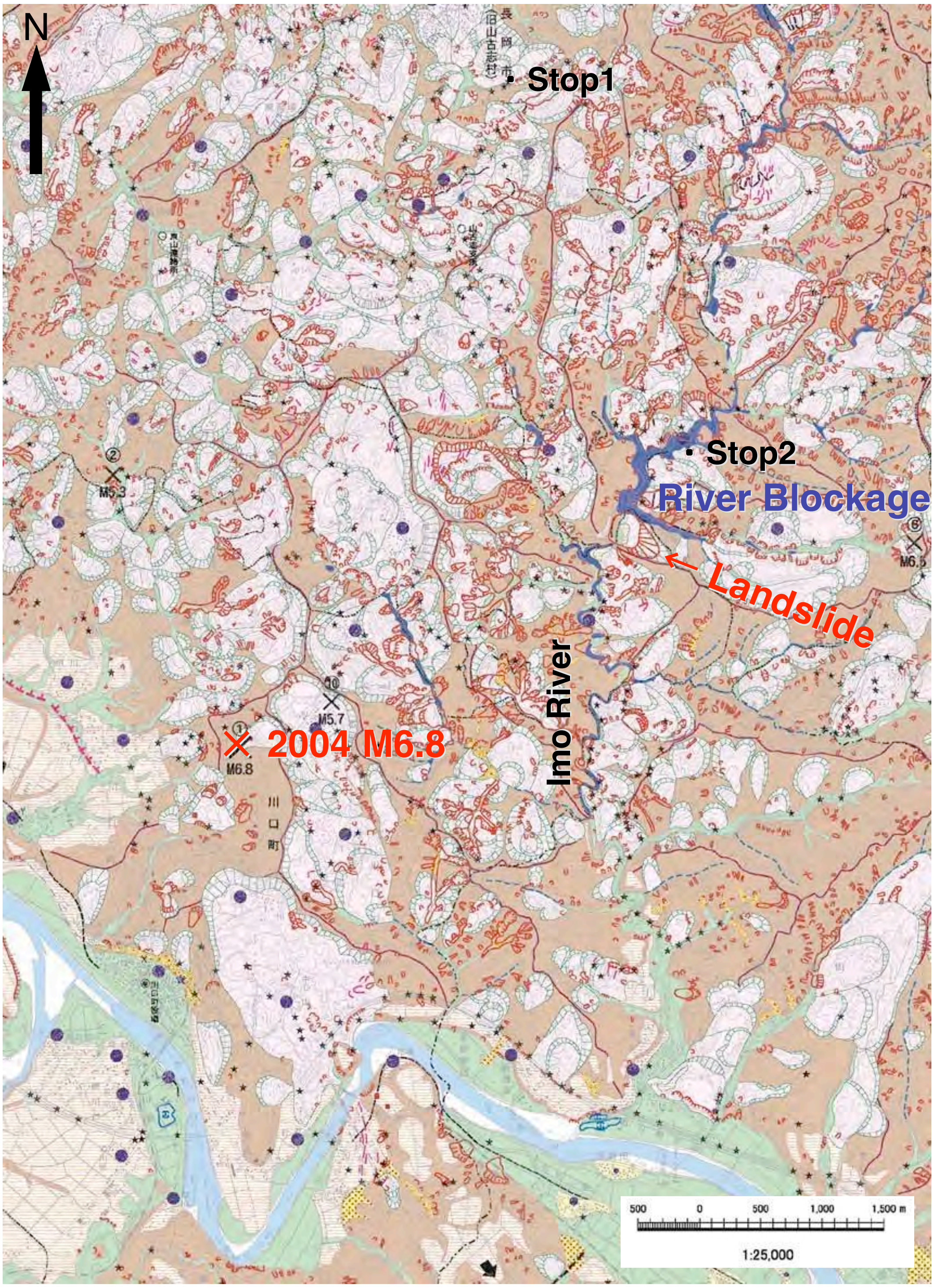


Fig. 1-1 Locations of landslide and river blockage on the Imo River. After Geographical Survey Institute (2005).

STOP 3: Outcrop of the Katakai Fault, Ojiya City

Nagaoka-heiya-seien fault zone is a well-known major Neogene thrust and fold belt in Japan. Deformed fluvial terraces and fault scarps along the western margin of the Echigo Plain (Nagaoka-heiya) provide a good record of recent tectonic activity along the fault zone [e.g. Ota, 1969]. Katakai fault is one of the components of the fault zone, developed along the eastern limb of the Tokimizu anticline.

Main blind thrust is assumed at the base of the eastern limb of the Tokimizu anticline (Fig. 3-1). Terrace deposits of ca. 130-150ka are deformed along flexure scarp of 60 m in height, vertical slip rate of over 0.4 m/ka is estimated. Four faults (F1, F2, F3 and F4) cut the terrace deposits and underlying early Pleistocene Uonuma Formation [Suzuki et al., 2008]. These faults are considered as a back thrust (F1) truncating the structure of the Uonuma Formation with a vertical slip rate of 0.1 m/ka, and as fold-related secondary (flexural slip) faults (F2, F3 and F4) along the bedding plane of the Uonuma Formation with vertical slip rates of under 0.1 m/ka.

We will observe high angle reverse faults (F2 and F3) cutting beds of volcanic ash and terrace grevel whch are dipping about 10˚E (Fig. 3-2). Underlying Uonuma Formation consists of gravel, sand and silt layers (Fig. 3-3), has a vertical dip. Incohesive narrow fault gouge zones which are gray or greenish gray in color can be defined along the F2 and F3 faults.

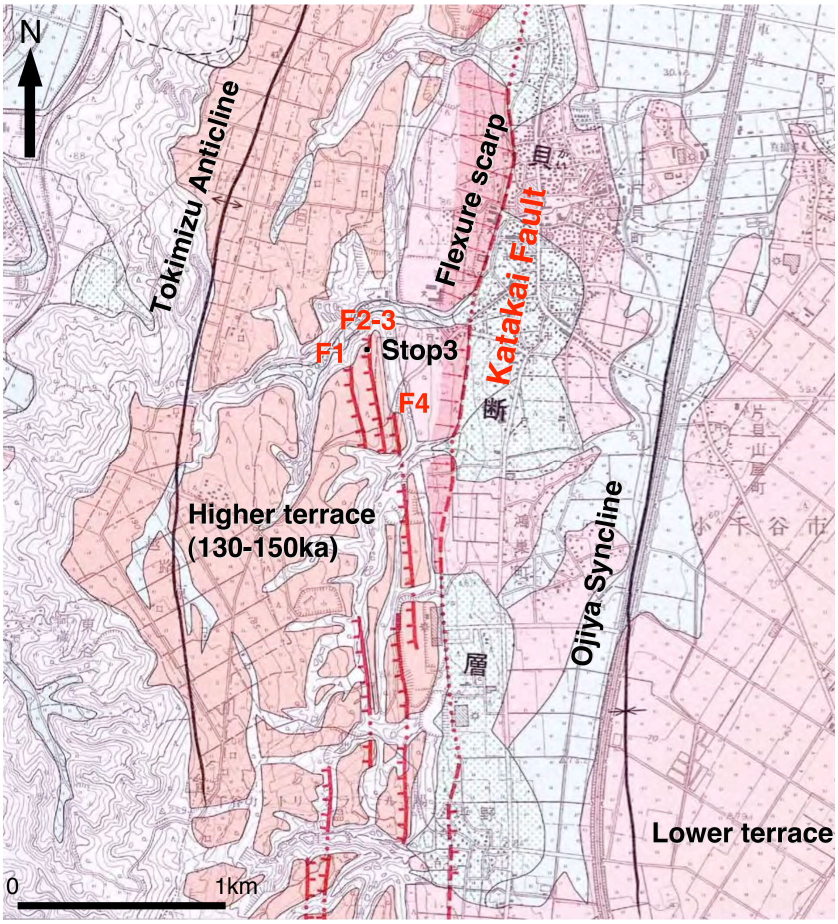


Fig. 3-1 Landforms of Katakai area, location of fault outcrop (Stop 3). After Geographical Survey Institute (2001).

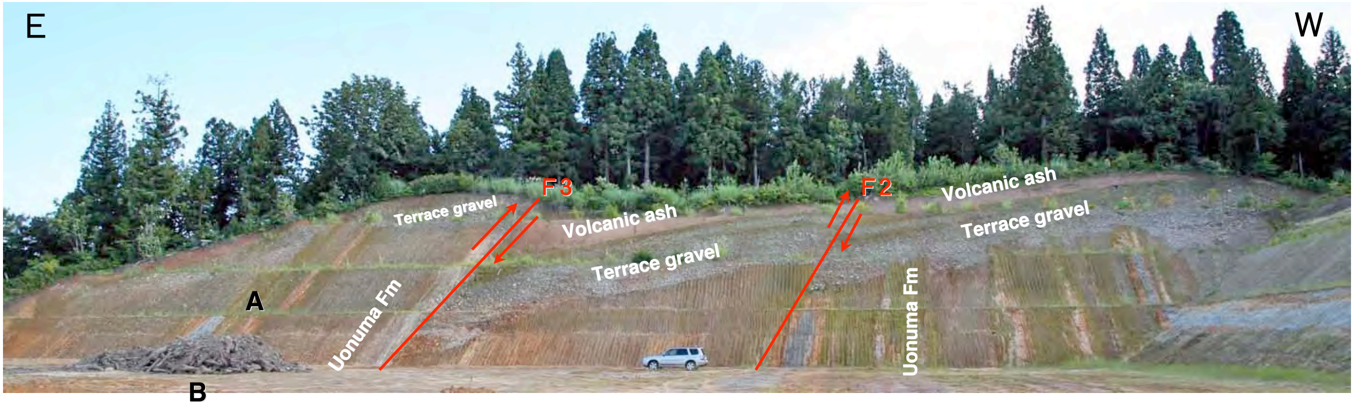


Fig. 3-2 Outcrop of the Katakai fault, Ojiya City.

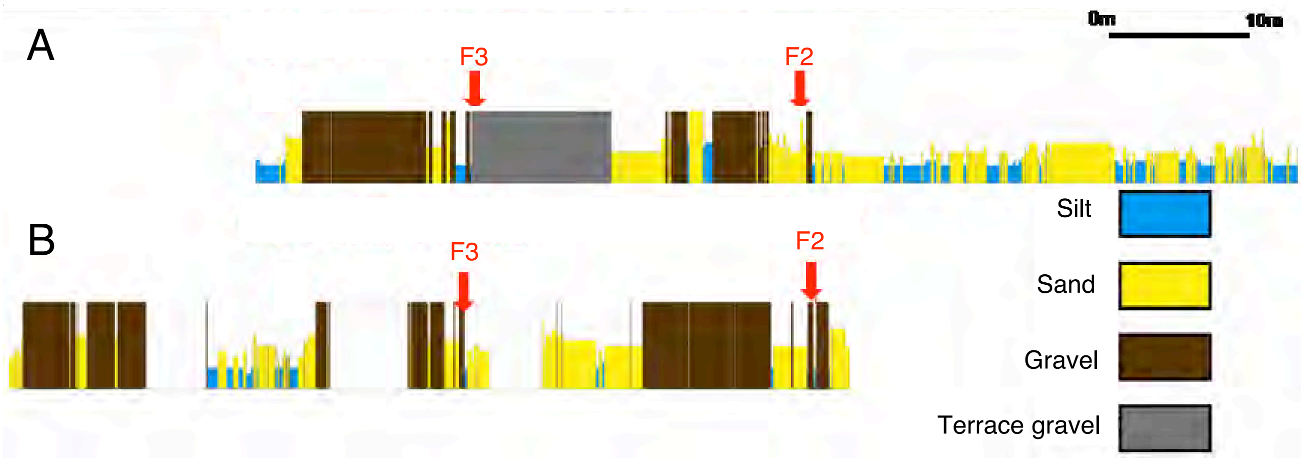


Fig. 3-3 Lithological feature at the outcrop.

STOP 4: ***Momiji-en*** **(Maple tree garden), Nagaoka City**

Momiji-en (Maple tree garden) and *Tomoegaoka-Sanso* was a country house built by a large landowner, the Takahashi family, around 1897. The garden is about 4000 square meters in area. Many trees including maple trees, wild cherry trees, and azaleas are planted. Some of the maple trees of the garden are quite rare in the Niigata area. The Takahashi family appear to have brought them from Kyoto (Translated from http://www.city.nagaoka.niigata.jp/kankou/miru/kouen/momiji.html).

We will have lunch here. A salad, sandwiches, and cold drinks will be distributed. Enjoy the Japanese garden, and traditional architecture of the house. The maple trees should become red in early November.

Fig. 4-1 Photo of *Momiji-en* in fall (http://www.city.nagaoka.niigata.jp/kankou/miru/kouen/momiji.html).

STOP 5: Kashiwazaki-Kariwa Nuclear Power Station of the Tokyo Electric Power Company

Kashiwazaki Kariwa Nuclear Power Station began operation in September, 1985. In 1997 all 7 units were in commercial operation with a total capacity of 8,212 MW, and as a result, this power station has the largest capacity of any nuclear power station in the world. It is located in the Niigata Prefecture, approximately 220 km northwest of Tokyo along the coast of the Sea of Japan. The site covers an area of about 4.2 square-kilometers including land in Kashiwazaki City and Kariwa village (Cited from http://www.tepco.co.jp/en/challenge/energy/nuclear/plants-e.html).

On July 16, 2007, the 2007 Chuetsu-oki earthquake struck the Power Station. The station suspended operations for 22 months. After various measures to retrofit for earthquakes and an intensive investigation of the local geology, power generation started again in May, 2009.

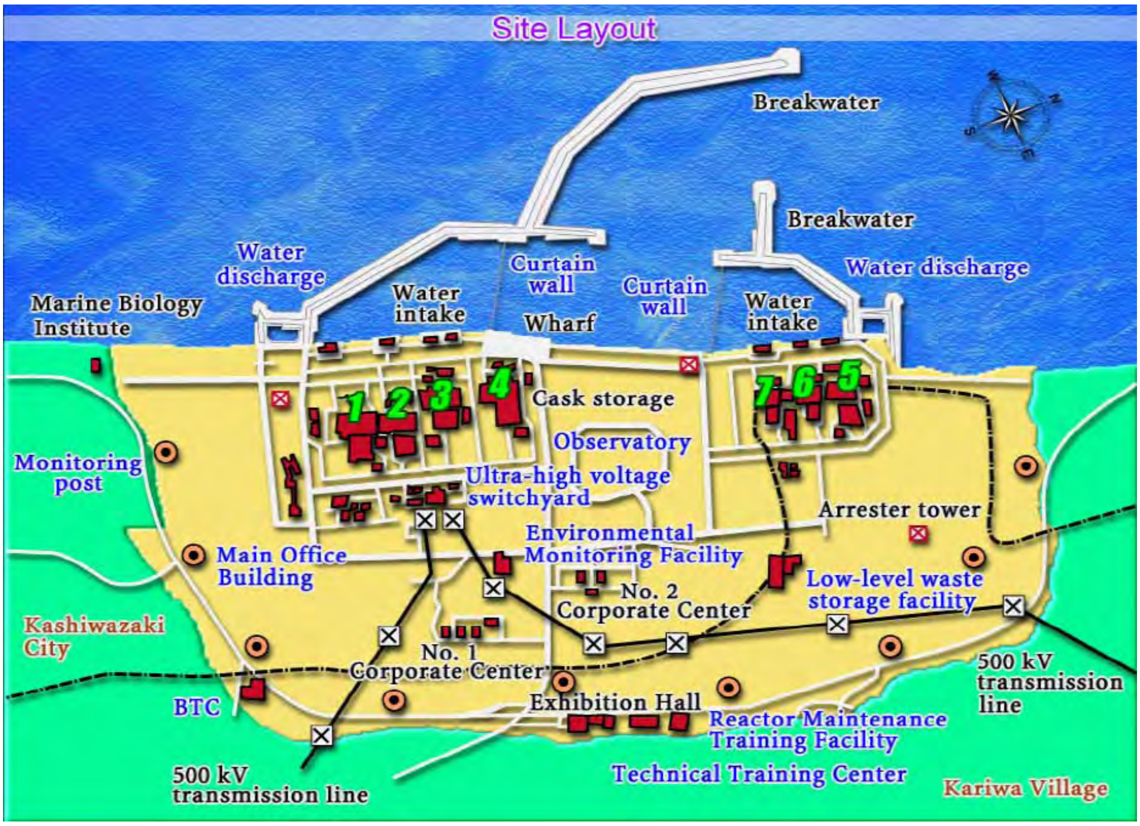


Fig. 5-1 Map showing layout of plants of the Kashiwazaki-Kariwa Nuclear Power Station (Courtesy of the Tokyo Electric Power Company).

At this spot, we will enter the Power station by bus and see some facilities for seismic observations. Next, we will go to an Exhibition Hall to listen to a description of the Power station, what occurred during the Chuetsu-oki earthquake, and a summary of seismic observations at the site by a representative from the Tokyo Electric Power Company (TEPCO).

STOP 6: Niigata Institute of Technology

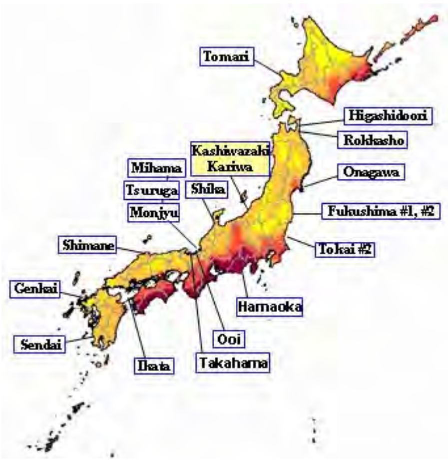
-Project on Seismic Observation in Deep Borehole and its Application-

1. Background and purpose of the project

1.1 Background of the project

Observed ground motion from the 2007 Chuetsu-oki earthquake was much larger than the predicted earthquake ground motion set under previous regulatory guidelines. The analysis so far theorizes that the existence of 3D irregular structures in the deep underground around the Nuclear Power Plant (NPP) site are thought to be a cause of amplified ground motion levels by the focusing of seismic wave energy to the site. In addition, the existence of thick sedimentary layers up to 5-7 km cause large impedance of seismic velocity amplified ground motion.

On the other hand, propagation characteristics of ground motion at hard rock sites such as Wakasa Bay have yet to be determined. Uncertainty of attenuation characteristic largely affects the estimation of ground motion.



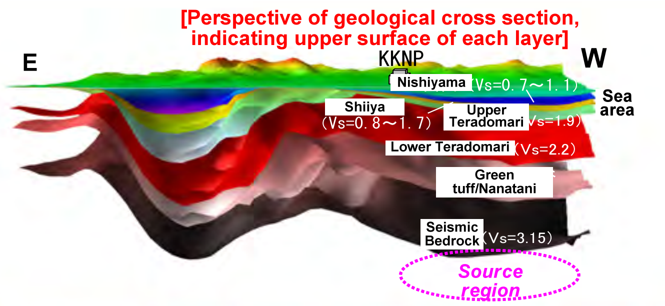


Fig. 6-2 3D geological structure under Kashiwazaki NPP.

Fig. 6-1 NPP sites in JAPAN.

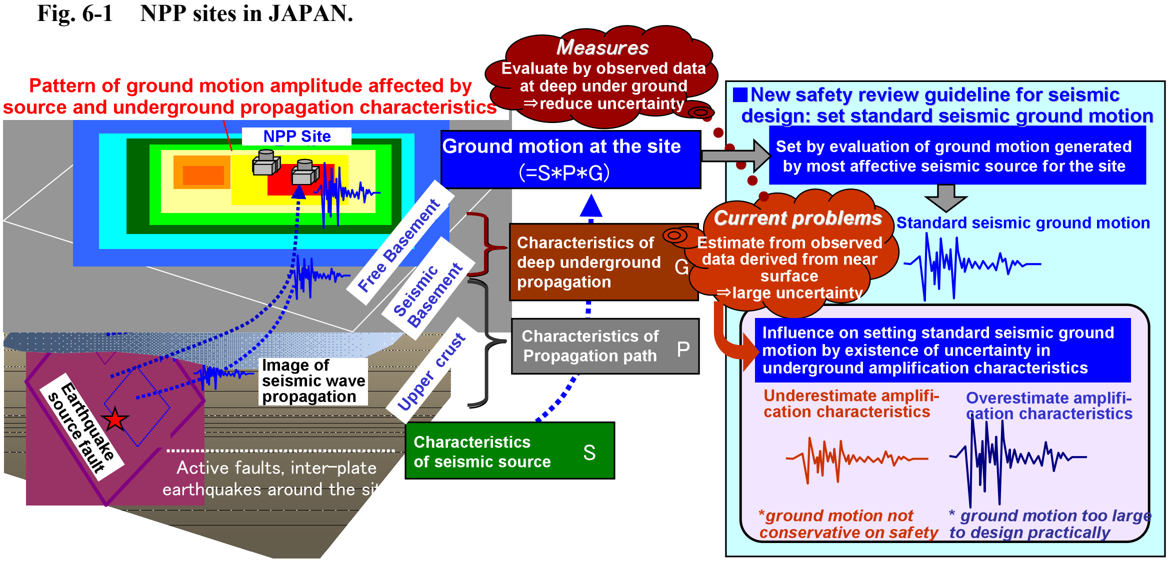


Fig. 6-3 Principal factors controlling ground motion and issue with standard seismic ground motion.

1.2 Purpose of the project

To apply for seismic safety inspection of all NPP in Japan, we need to understand ground motion propagation characteristics of typical plants installed at soft and hard rock sites. Therefore, detailed information on deep underground characteristics for both types of sites are needed to evaluate precise ground motion (Kashiwazaki area is a rare case for having much data from oil explorations by Japan Nation Oil Corporation).

JNES (Japan Nuclear Energy Safety Organization) needs to prepare evaluation scheme (technique and information) of deep ground motion propagation characteristics by supplying model and data to verify, because each power company plans to conduct deep boring investigations and seismic observations (High-temp. and pressure endure seismic observation system, specification of boring investigation etc.).

Therefore, JNES conduct deep boring investigation and analyze data from installed vertical seismic array combine with survey from ground surface to get deep underground physical properties and wave propagation characteristics.

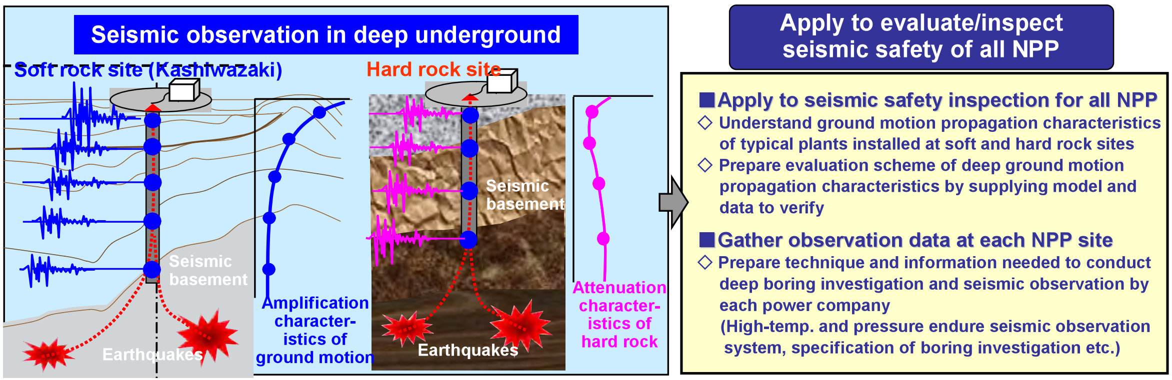


Fig. 6-4 Schematic illustrations comparing effect of amplifications at soft and hard rock sites.

2. Plan for implementing deep boring and observation system around NPP site

JNES is conducting the following plans to get deep underground physical properties and wave propagation characteristics.

(1) Implement vertical seismic array which maximum depth able to reach the level of seismic basement (Vs =3,000m/s).

(2) Planning to install the system at 2 types of sites.

1) Soft rock site (Kashiwazaki) : to analyze wave amplification characteristics of sediment layers. --- Under preparatory work for drilling

2) Hard rock site: to analyze attenuation characteristics of hard rock, source characteristics (e.g. f-max) ---- Under consideration

(3) Develop high temperature/pressure endurable borehole seismometer and multi-depth seismic observation system.

(4) Establish observation system as a model that could be installed to all NPP sites by power companies.

2.1 Overview of boring investigation and vertical seismic observation at Kashiwazaki

Drilling site: at the ground of Niigata Institute of Technology

The ground of Niigata Institute of Technology is suitable for conducting 3,000m class deep boring and seismic observation at depth. We decided the boring site for following reasons;

(1) Nature of deep underground structure is similar to that of the Kashiwazaki NPP site.

⇒ The trend of upper surface of seismic basement is inclined from the anticline axis toward the sea so that seismic propagation properties observed might be verified.

(2) Relatively shallow depth (around 3,000m) is expected for reaching seismic basement.

⇒ Detailed data for all sedimentary layers in the Kashiwazaki area is expected to be covered.

(3) Good conditions for setting boring equipments

⇒ Sufficient area is available for boring work.

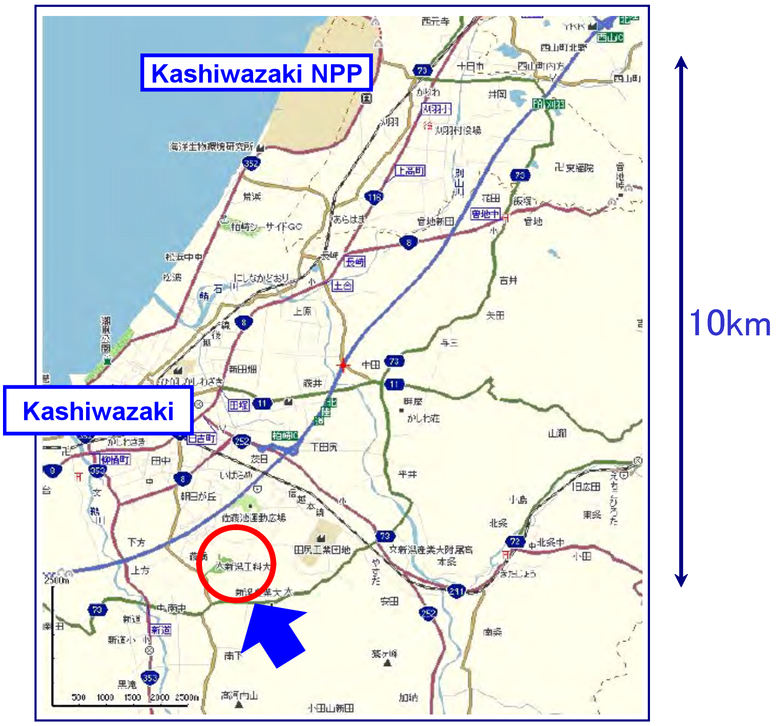


Fig. 6-5 Location of Niigata Institute of Technology

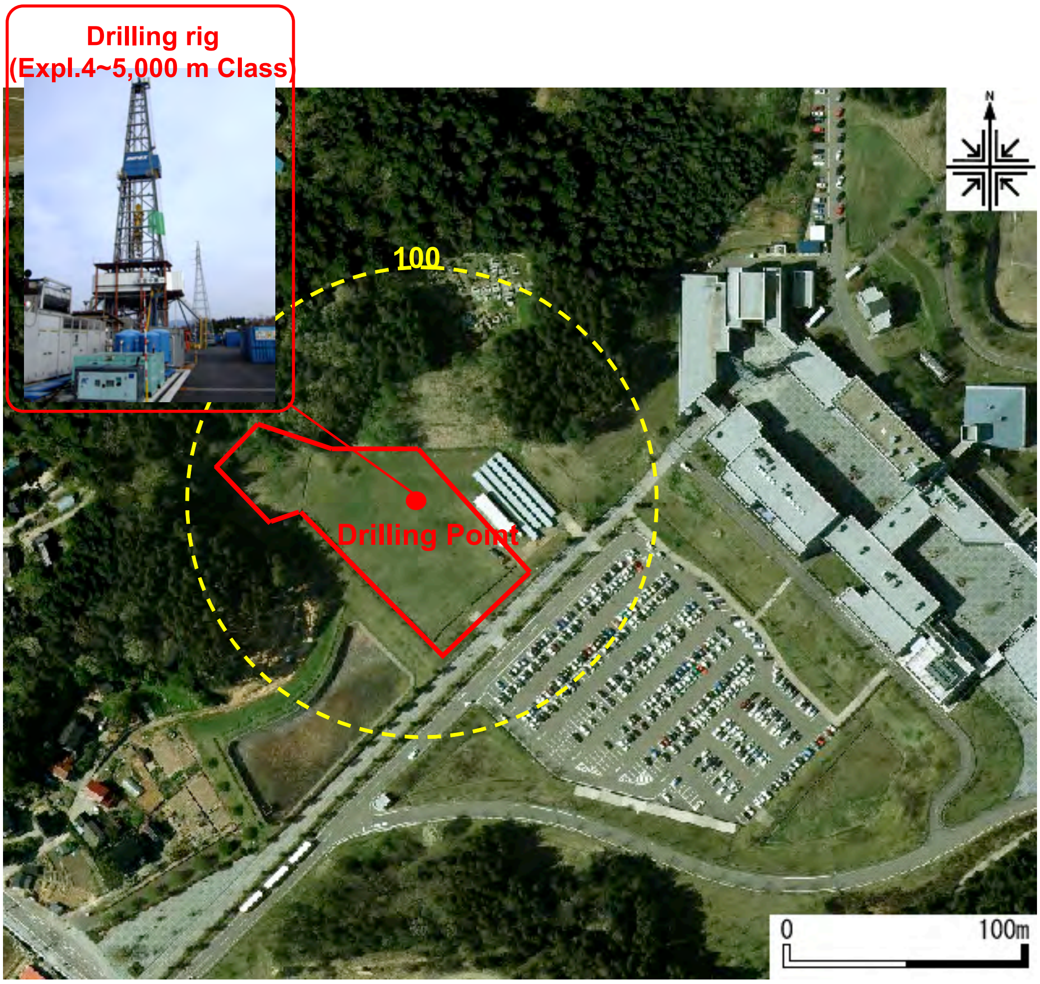


Fig. 6-6 Aerial photo of drilling site

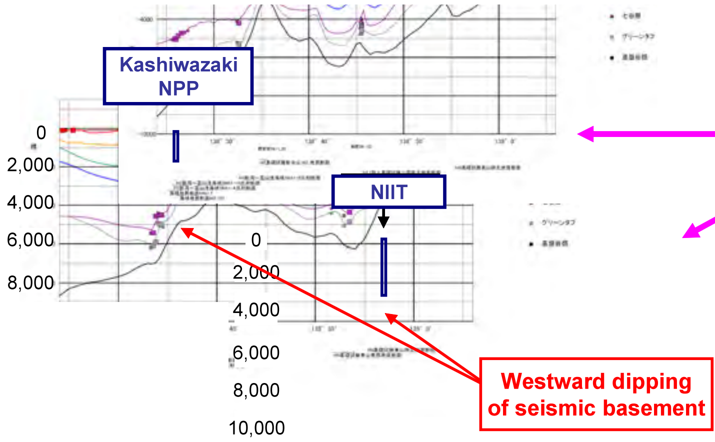


Fig. 6-7 Comparing geological formations at Kashiwazaki NPP site and at NIIT site. Each geological formation are shown on E-W cross section.

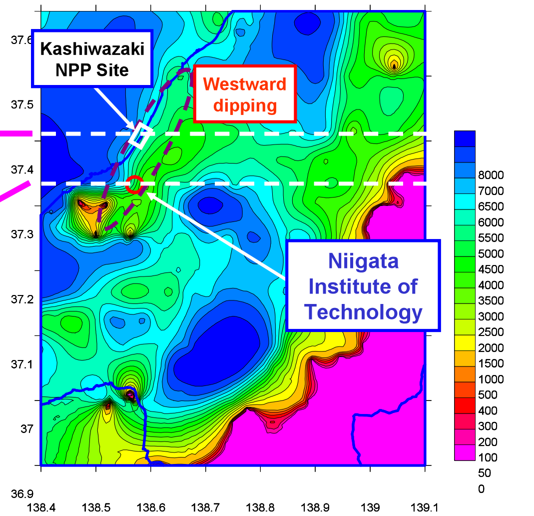


Fig. 6-8 Map showing depth of upper surface of seismic basement around Kashiwazaki area

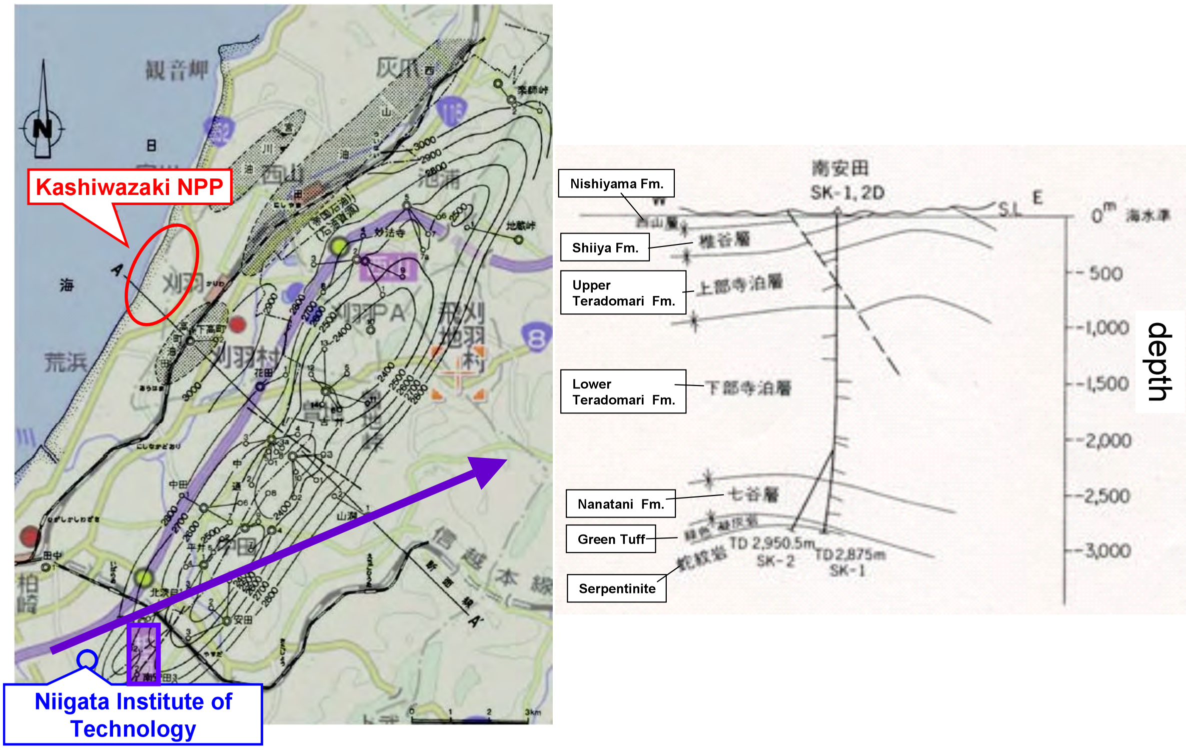


Fig. 6-9 Geological structure around Kashiwazaki. Map is modified from Haruya Nakata (2009) 「地上環境に配慮した開発技術等について」 in Japanese.

2.2 Progress schedule for project on seismic observation in deep boring well at Kashiwazaki

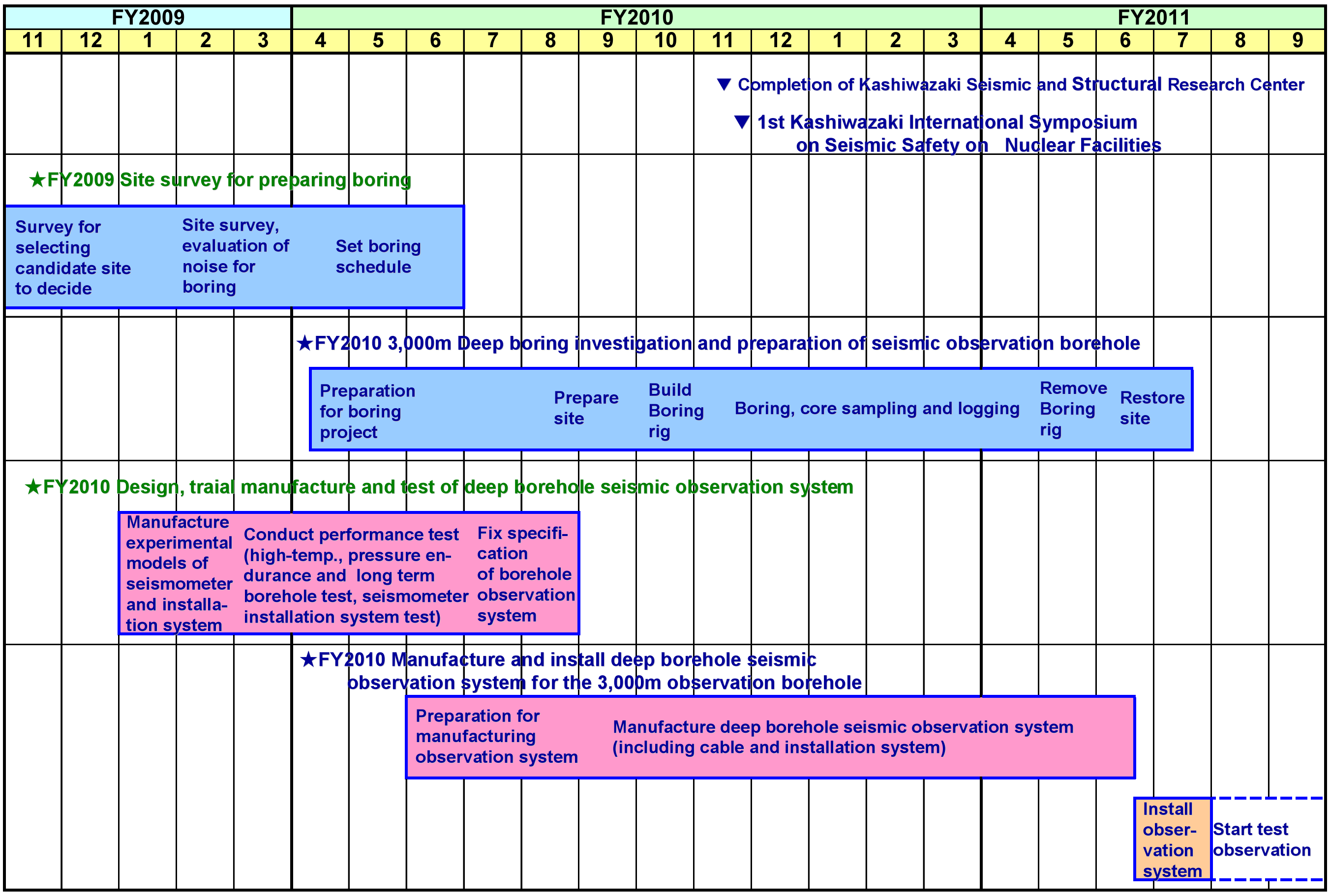


Fig. 6-10 Progress schedule for this project.

2.3 Examine the consistency between attenuation characteristic in deep structure by analyzing seismic observation data and by getting Q value

Boring investigation, logging, underground structure survey around Kashiwazaki site (seismic observation point) will help with the following:

- Understand geological structure by 3000 m drilling investigation.
- Understand structure by logging data with borehole.
- Understand deep attenuation characteristic by Q value with borehole.
- Construct 3D underground structure models from the results of the underground structure survey and existing data, and examining the effects of 3-D irregular structures from the deep underground on ground motion propagation.

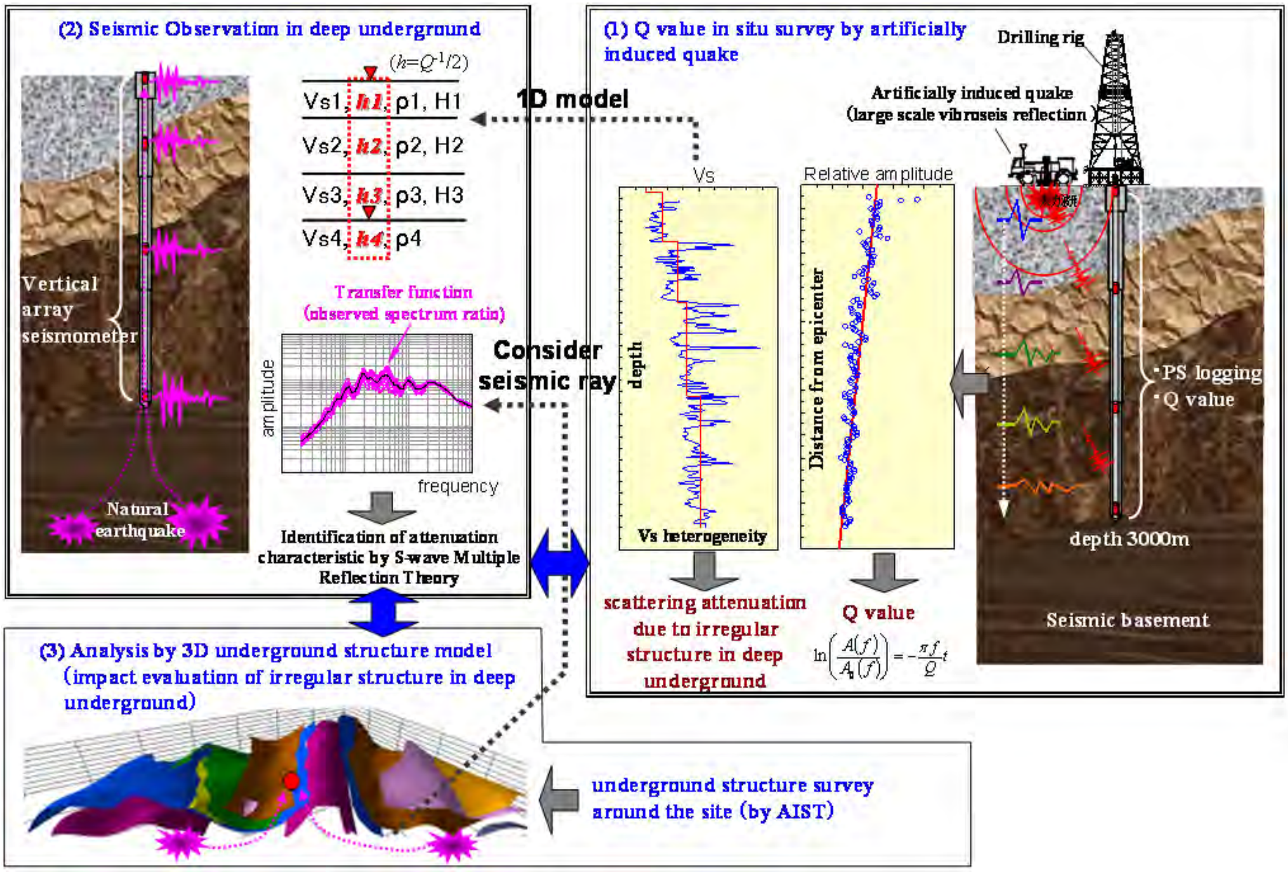


Fig. 6-11 Schematic illustrations showing observation, investigation and estimation plan in this project.

2.3.1 Q value in situ survey by artificially induced quake (Overview of Fig. 6-11(1))

Here we show the details of investigations and estimations described on the previous page.

(1) Boring investigation

JNES will estimate the depth of stratum boundaries by analyzing core samples, cuttings and logging data, and deciding the installation depth of borehole seismometers. Stratigraphic division around the site and planned installation depth of seismometers are referred to in the following table.

- Core sampling (Nishiyama Fm., Shiiya Fm., Upper Teradomari Fm., Lower Teradomari Fm., Nanatani Fm. and Green tuff)
- Cuttings (sampled by every 10m depth)
- Laboratory test, Physical characteristic test, Strength characteristic test

Table. 1 Stratigraphic division around drilling site

Upper plane of stratum	Lower plane of stratum	Stratigraphy
Surface	120-130m	Uonuma Fm.
120-130m	180-190m	Hidzume Fm.
180-190m	300m	Nishiyama Fm.
300m	370-600m	Shiiya Fm.
370-600m	800m	Upper Teradomari Fm.
800m	2,300-2,400m	Lower Teradomari Fm.
2,300-2,400m	2,900m	Nanatani Fm.
2,900m		Green Tuff

■Installation depth of seismometers (planning depth)

- Upper Teradomari Fm. (approximately 400 m in depth)
- Lower Teradomari Fm. (approximately 1000 m in depth)
- Neogene period (approximately 3000 m in depth)

※Borehole seismometer will be installed around stratum boundary.

(2) Estimating deep underground structure by PS logging, Q value in situ survey, and density logging with artificially induced quake on surface ground (Overview of Fig. 6-11(1))

PS logging (elastic wave velocity), Q value (attenuation constant), density log

(3) Quantitative understanding of S-wave scattering attenuation due to irregular structure in deep underground

PS logging (elastic wave velocity), density logging, resistivity logging, laboratory test (wet density test, permeability test, ultrasonic wave test), horizontal seismic array etc.

(4) Creating dipping strata model

Offset VSP survey (stratum dip, sequence of strata)

Fig. 6-12 Photos of Seismic vibrators (Vibroseis) for PS loggin and VSP survey

2.3.2 Analysis by 3D underground structure model (Overview of Fig. 6-11(3))

Here we show the details of investigations and estimations on previous pages (see page 13).

JNES will construct 3D underground structural model by conducting reflection surveys around the NPP site and combining results of prior surveys. JNES will evaluate amplification characteristics due to 3D irregular structure by using the 3D underground structural models developed above. Underground surveys we plan to conduct are listed below, to create a database associating with underground structure and 3D underground structural models.

(1) Deep structure investigation by seismic survey

- reflection survey: P-wave reflection survey (survey line length: 56 km)
- natural earthquake observation and seismic array observation of micro-tremor:
  at about 5-km intervals along survey line (a total of 12 points)

(2) Deep resistivity structure investigation by Magneto-telluric (MT) methods

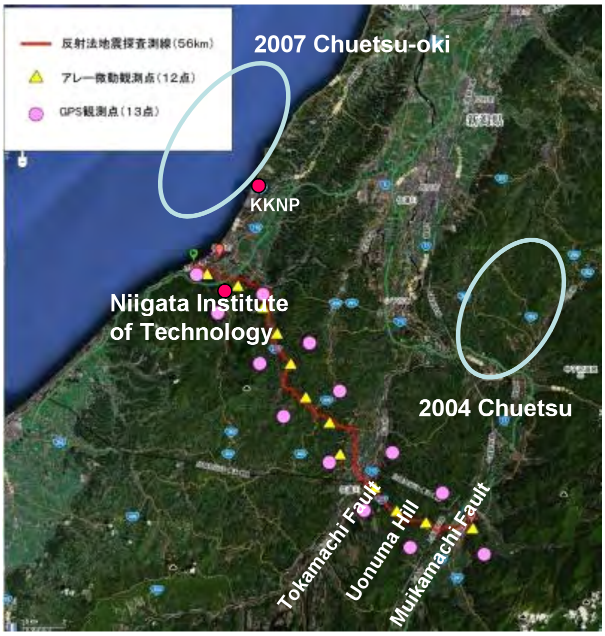
- MT methods: at about 1-km intervals along survey line

(3) Observation for stable characteristic of key strata

- strain field investigation in folds by GPS observation:
  2 lines at about 5-km intervals along survey line (a total of 13 points)

(4) Integration

- Creation of a Database, development of 3D underground structural models



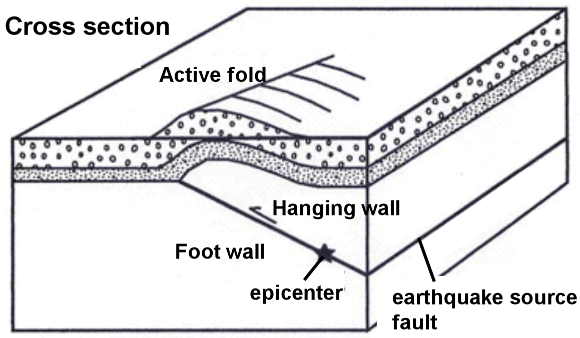
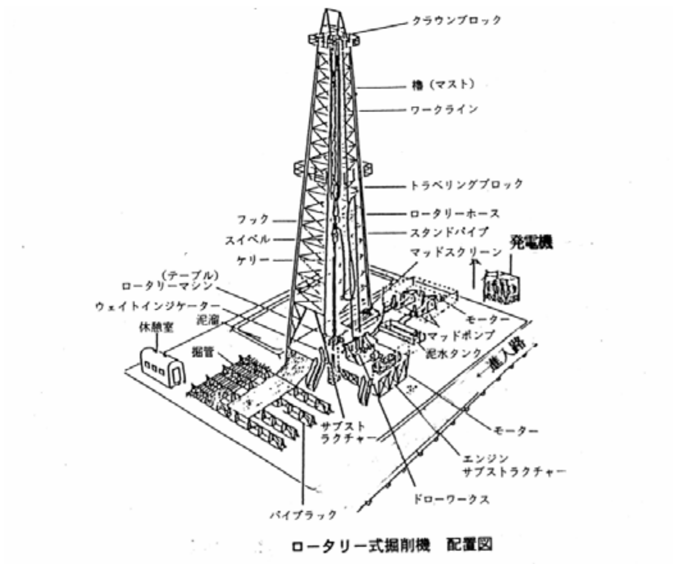


Fig. 6-13 Locations of several geophysical observations (left) and typical underground structure at an observation field (right).

3. Outline of 3,000m class boring

JNES will conduct 3000 m depth boring survey to a depth of seismic basement to measure seismic velocity, density and to collect boring cores. After the survey, JNES will conduct vertical array seismic observations by installing borehole seismometers to 4 depth levels within the borehole. (0 m, 400 m, 1000 m and 3000 m). Incline of the borehole will be limited within 5 degrees at depths of seismometer installation to keep precise operation of the seismometer.



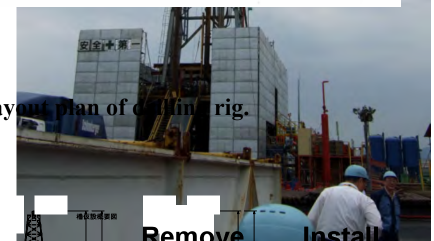


Fig. 6-14　Example of drilling rig.

Fig. 6-15 Layout plan of drilling rig.

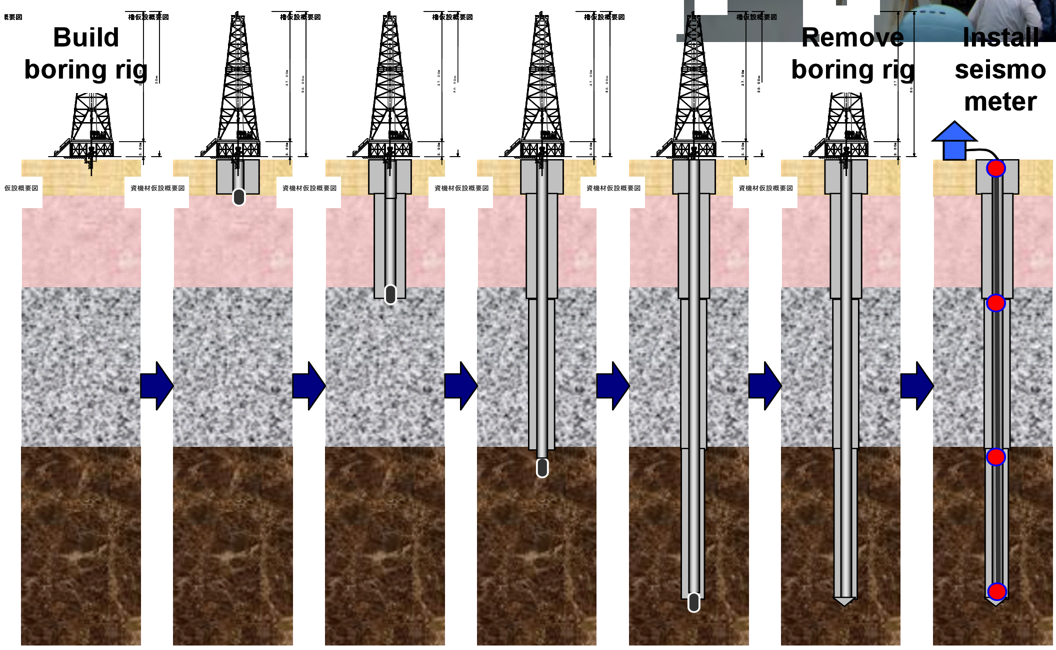


Fig. 6-16　Construction plan of drilling rig.

4. Develop high temperature resist borehole seismometer

4.1 Required specifications of seismometer for seismic observation in deep underground

The principal objective of this project is to record strong ground motion, microtremor and signals from regional micro to intermediate earthquakes. In addtion, JNES will investigate high-frequency cutoff (fmax) etc. Following specifications will therefore be required for the seismometer.

- Sensitivity: approximately 10μ kine (microtremor) ~ approximately 2G (strong ground motion)
- Frequency range: approximately 0.1Hz (microtremor) ~ approximately 50Hz (high-frequency cutoff)
- High temperature tolerability: approximately 150ºC (around 5 years)
- High pressure tolerability: approximately 40 MPa (around 5 years)

4.2 Design of seismometer under developing and testing (servo type seismometer with optical fiber sensing technique)

JNES has screened many pre-existing technologies which could be used to make seismometers which satisfy the above specifications. As a result, JNES selected servo type seismometers with optical fiber sensing technique (see Fig. 6-17). This sensor can provide velocity and acceleration signal outputs simultaneously. It has adequate sensitivity to observe micro earthquakes for velocity output and can observe strong acceleration signals as well (as would normally be recorded only by strong motion seismometers).

The Optical/Electronic servo seismometer: It detects the micro tremor by the optical fiber sensor and control the parallel beam collimator of the servo system for improving the detection accuracy of the micro tremor.

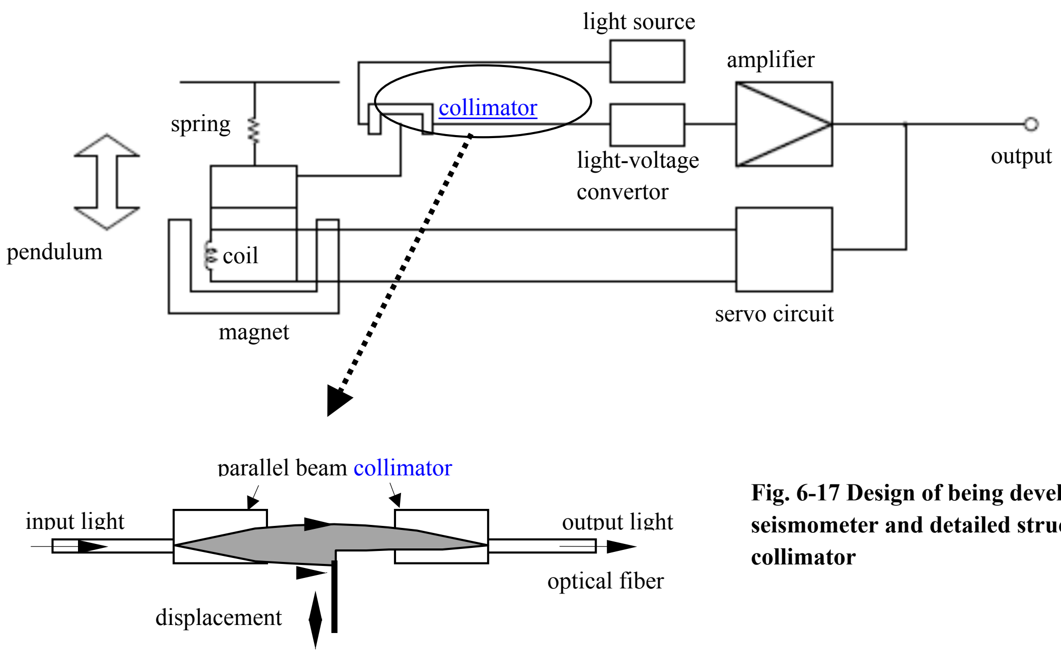


Fig. 6-17 Design of being developed seismometer and detailed structure of collimator

Table 6-2　Specifications of seismometer (APS355)

Model	APS-355
Type	Optical/Electrical Borehole type servo seismometer
Components	3 components
Output	Accelerometer / High sensitivity velocity simultaneous output
Frequency	Accelerometer 0.1 to 100Hz Velocity 0.1 to 70Hz
Range	Accelerometer ±2,000gal Velocity ±4Kine
Sensitivity	Accelerometer 5mV/gal Velocity 250V/m/s
Resolution	Accelerometer 1mgal Velocity Approx. 10μgal
Maximum output voltage	±10V
Dynamic range	Approx. 135dB
Maximum Tilt angle	±5 degree
Temperature range	-10℃ to 200℃
Maximum pressure	40Mpa (Approx. 4,000 atm)
Transverse sensitivity	0.03G/G
Temperature coefficient	Sensitivity 0.01% / ℃ Zero point shift 0.1% / ℃
Maximum cable length	Approx. 3,000m
Dimension	φ119 x 1,545mm
Extension cable	Optical 12 cores (SM) metal 6 core cable
Material of seismometer case	Titanium

4.3　Examination of cable

・Cable specification

JNES have chosen the cable unit containing optical fiber and electrical wire for the developing seismometer.

・The roles of optical fiber and conducting wires:

---optical fiber → get signal from optical sensor in seismometer

---electrical wire → supply operational power to servo circuit

- cable length : 3,000ｍ
- withstand support tensional load : about 800 kg
- 3 types of diameters of cable unit for 3 depth ranges
- Durability of cable against corrosion under high temperature and pressure condition

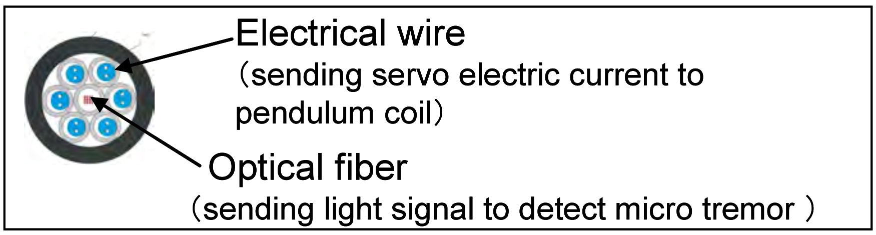


Fig. 6-18 Cross section of the cable unit

4.4 Performance testing

Improvement point

Improvement for high temperature and pressure

⇒ Use of heat-resistant optical sensing parts

⇒ Performance testing under high temperature and Pressure, long-term performance test

(1) Frequency characteristic

Shaking test for 0.1~50Hz band width

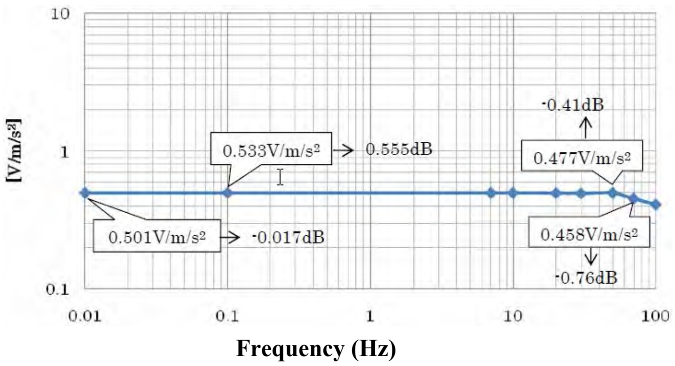


Fig. 6-19 Acceleration output: less than ±3dB at DC - 70Hz

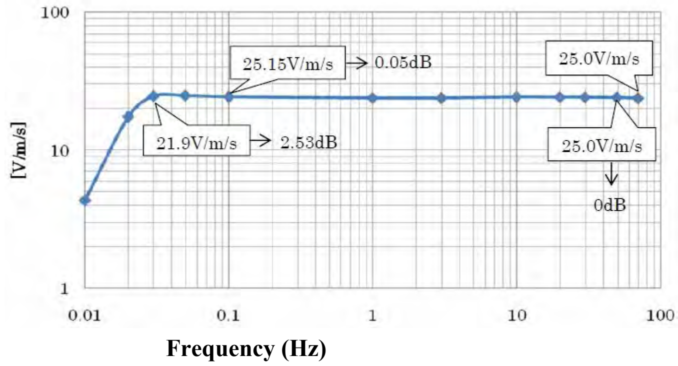


Fig. 6-20 Velocity output less than ±3dB at 0.03～70Hz

(2) Resolution level

Fig. 6-21 shows result of resolution test for developing seismometer APS355 at very silent environment. Resolution clears the required resolution level at low frequency band and is being improved at high frequency band.

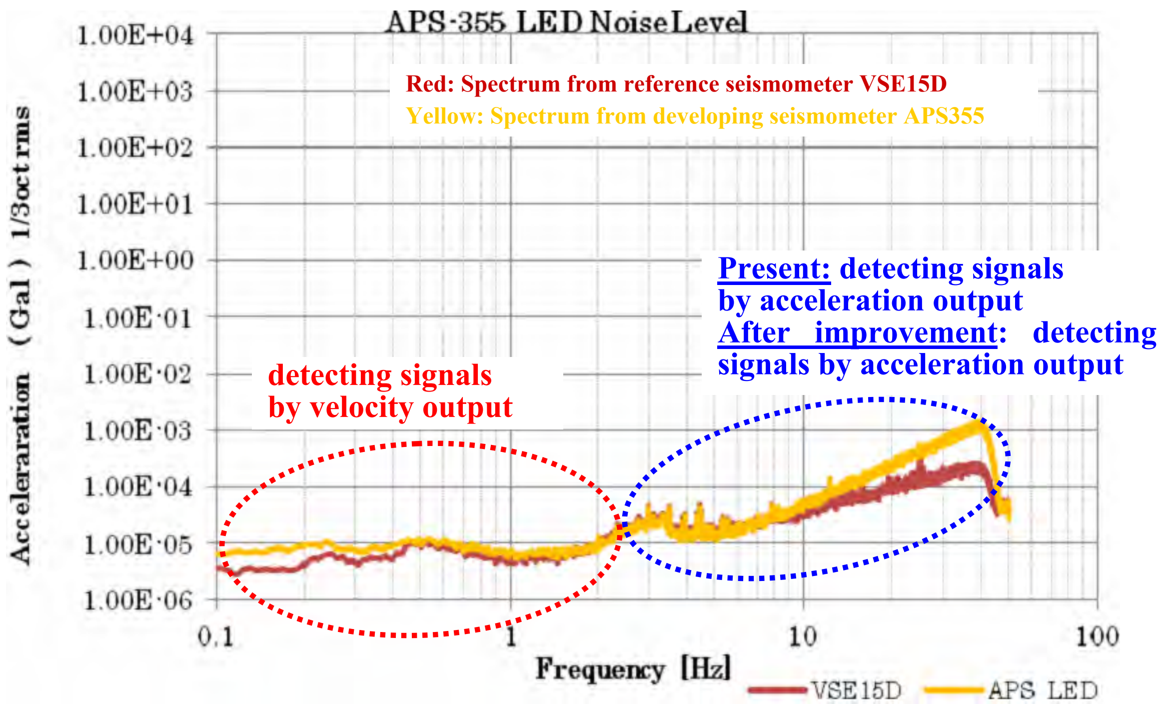


Fig. 6-21 Spectrum of micro tremors by developing seismometer APS355 and reference VSE15D

(3) Max observation level

Shaking test over 2,000 gal amplitude

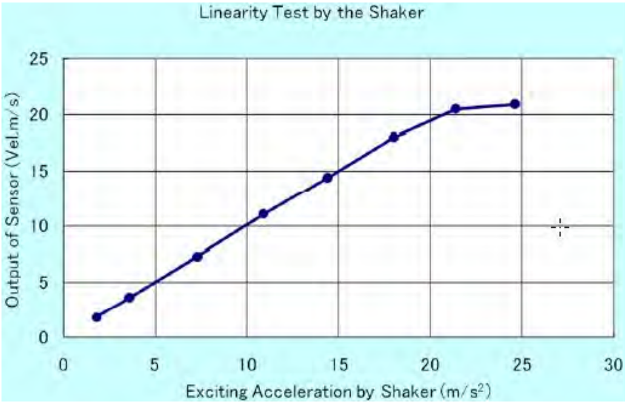


Fig. 6-22 Confirm linearity of output till about 2,000 gal

(4) High-temp/pressure resistance

- High-temperature acceleration test

  • Heat seismometer up to 200 degrees C and keep the condition for days by an electric furnace to test influence of high temperature on its characteristics.

  • Observe microtremor at the inside of furnace to check after heating.

- High-pressure acceleration test

  • Check the sealing capability of connector between cable and pressure vessel under high pressure (40MPa).

- Long-term test of installing seismometer in a deep borehole (Test is being continuously performed)

  • Install a test seismometer into an existing borehole with high temperature (> 100 degrees C) and high pressure (depths of around 1,000 m). Test endurance performance for several months or more, by conducting test observation.

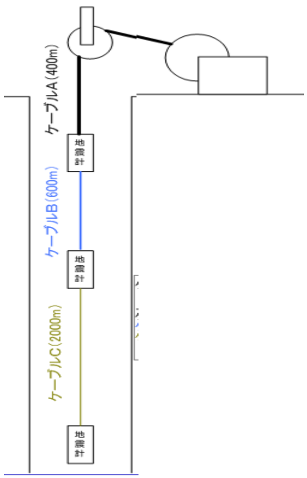


Fig. 6-23 Cable composition in depth

Fig. 6-24 Photo of winch.

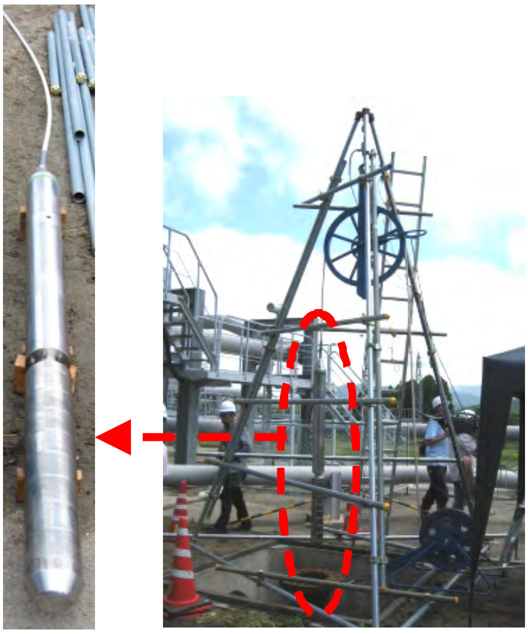


Fig. 6-25 Seismometer and endurance test in borehole at geothermal site.

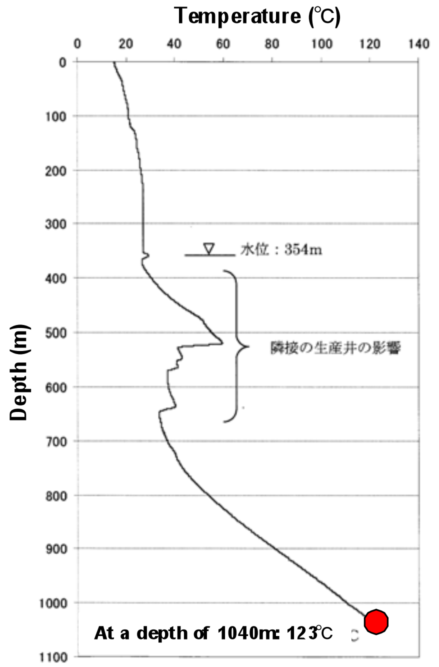


Fig. 6-26 Temperature profile of the borehole use for various tests

4.5 Comparison of micro earthquake seismograms and their spectra from JNES's developing seismometer (APS355) and the reference seismometer (VSE150).

During the comparison test of seismometers, the signals from natural earthquakes were recorded by both seismometers. The origin of the earthquake is given below.

Time: 2:15, 15 Aug. 2010,

Epicenter: 36.5ºN, 140.7ºE (Ibaraki pref. offshore)

Depth: 80 km

M_{JMA}3.0

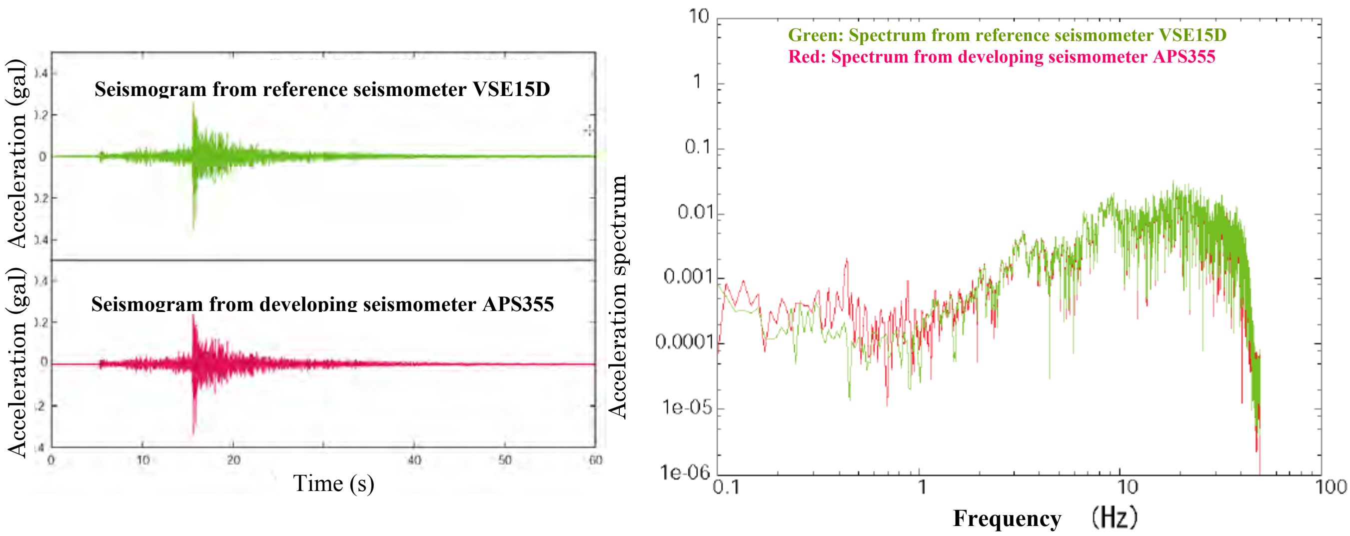


Fig. 6-27 Example of micro earthquake seismograms and their spectra

References:

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Appendix 1

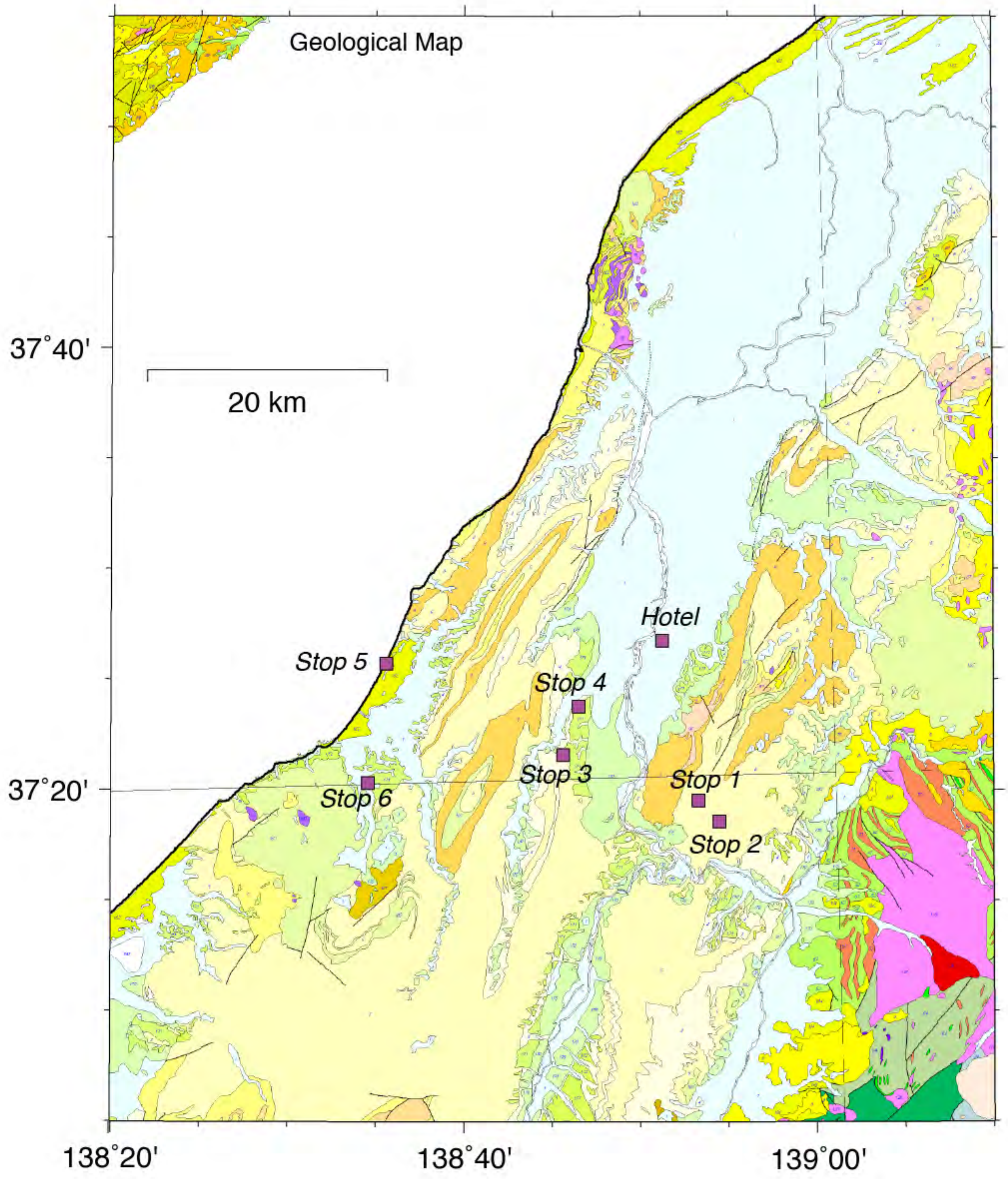


Fig. A1 Geological Map of Niigata Prefecture (Geological Survey of Japan, 2010).

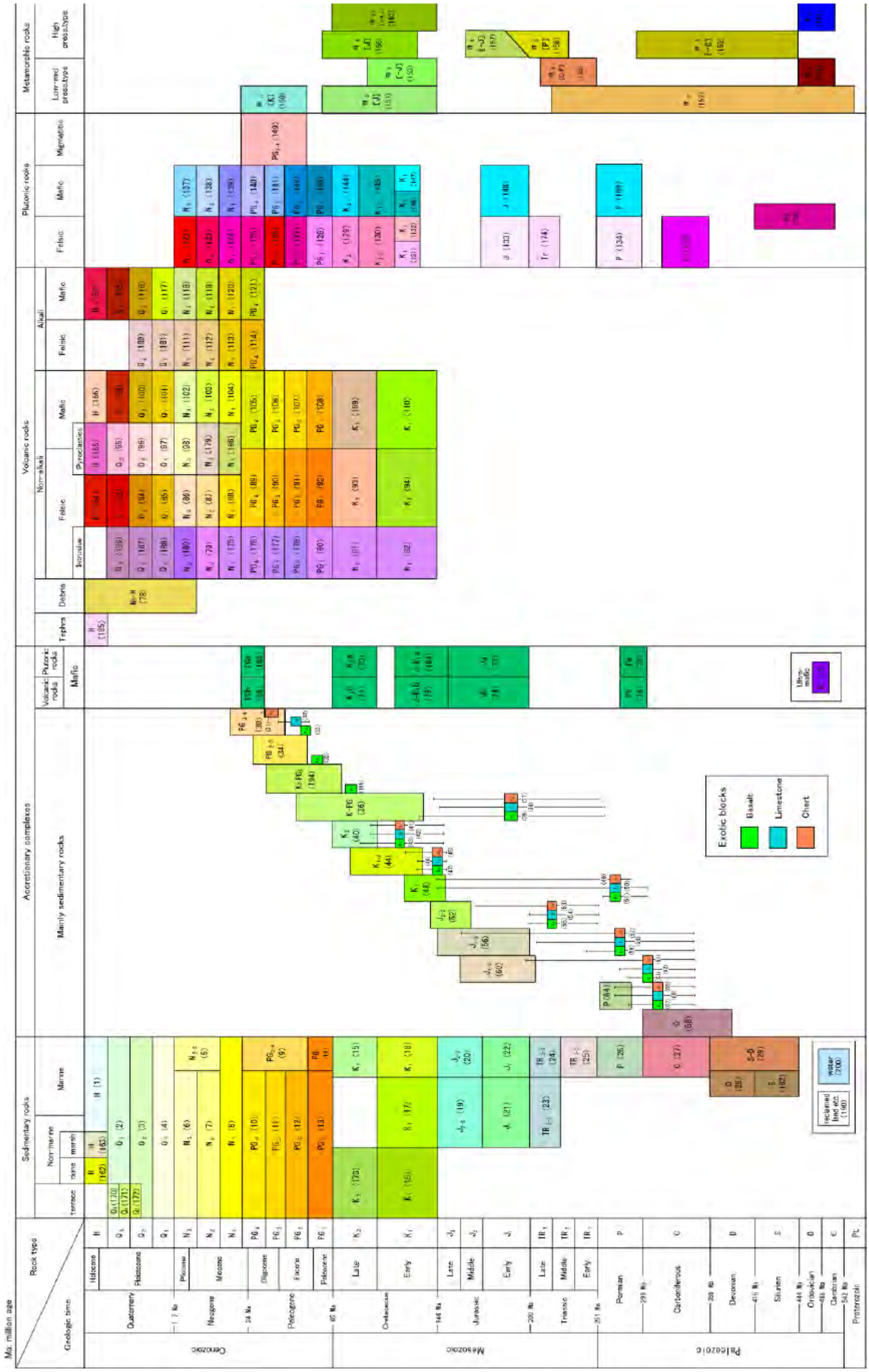


Fig. A1 (Continue)

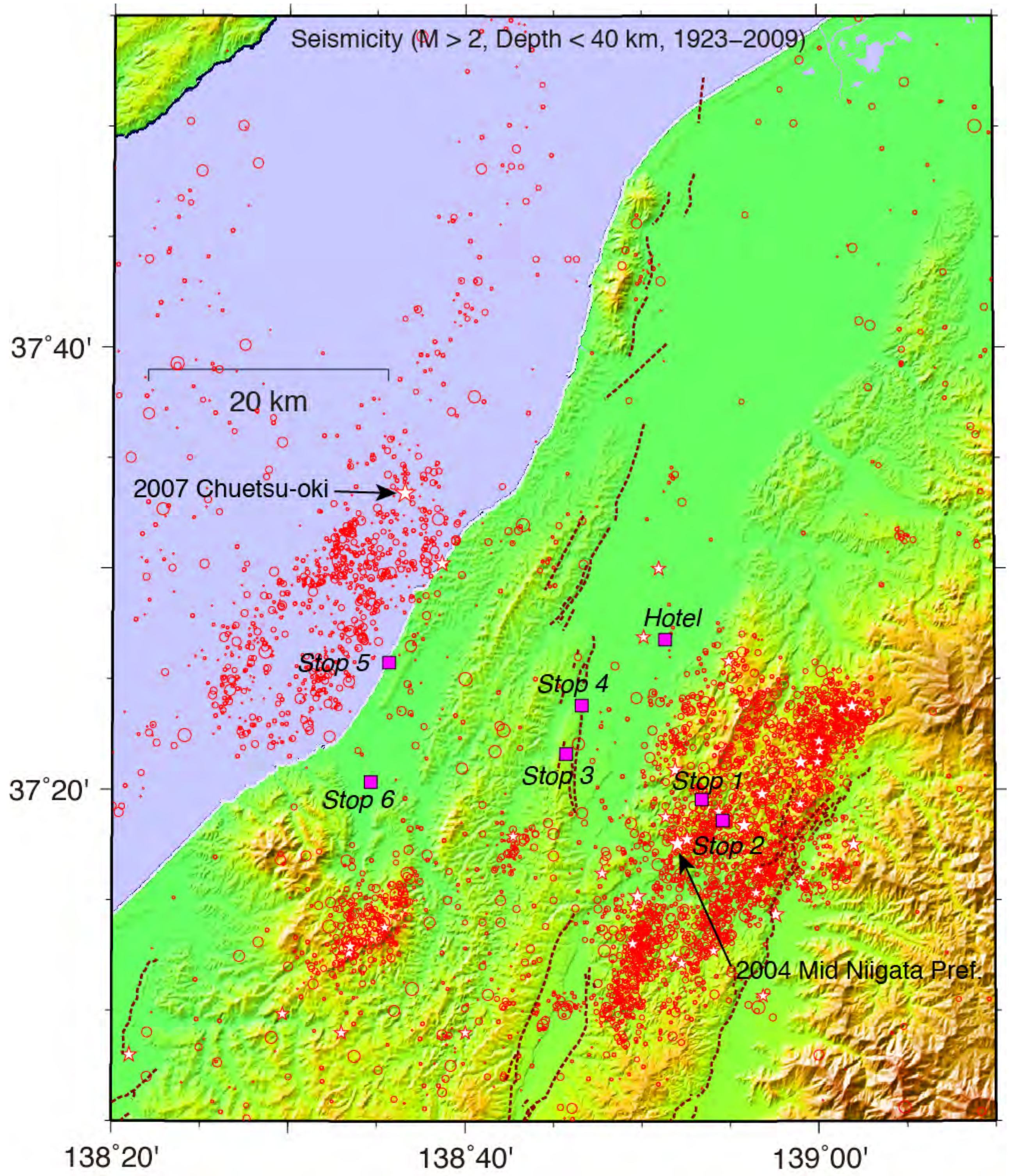


Fig. A2 Topographic map showing regional seismicity for 1923- 2009. Circles and stars represent epicenters with $2 \leq M_{JMA} < 5$ and $M_{JMA} \geq 5$, respectively. Broken lines represent surface traces of major active faults. Data of active faults and seismicity are proveided by the Headquaters of Earthquake Research Promotion and the Japan Meteorological Agency, respectively.

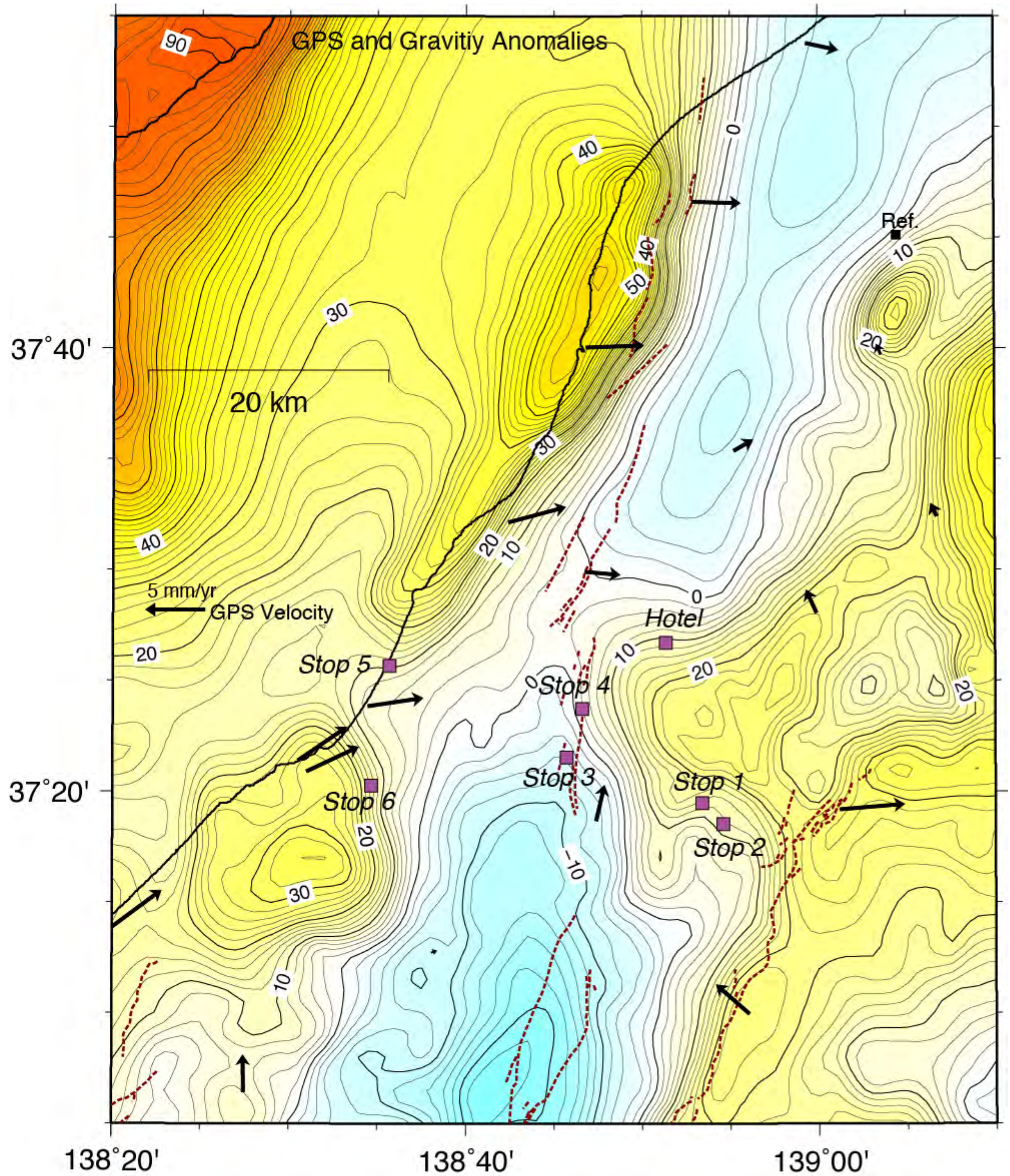
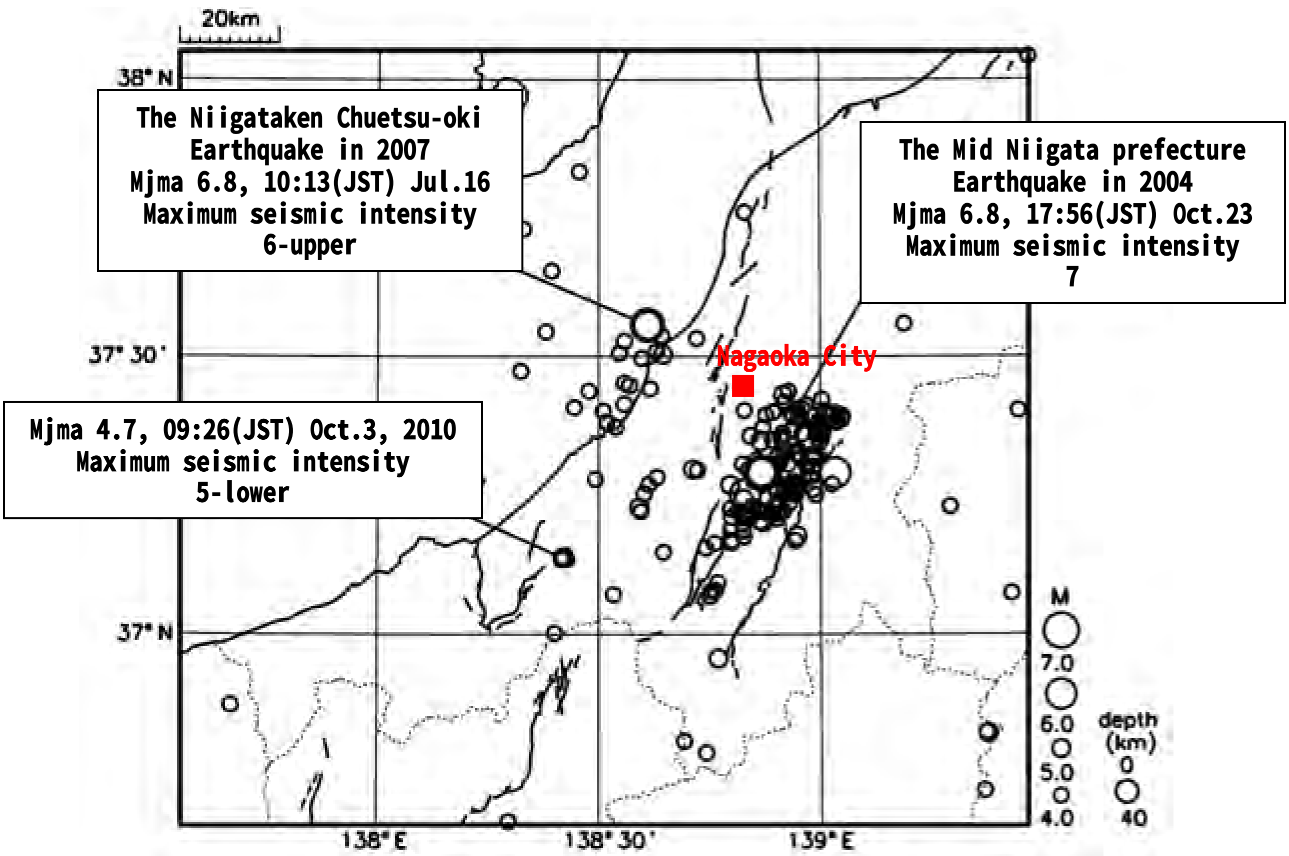


Fig. A3 Horizontal GPS Velocity and Bouguer gravity anomalies. The GPS veloctity is esteimated using daily coordinates of the GEONET GPS stations from October, 2002 to September 2004. Density of 2.67 g/cm^3 is assumed to calculate Bouger anaomalies. A contour interval of Bouger anomalies is 2 gal. Data of Bouguer anomalies are provided by the Geologial Survey of Japan, AIST (2004).

Summary
of The Mid Niigata prefecture Earthquake in 2004 and The Niigataken Chuetsu-oki Earthquake in 2007



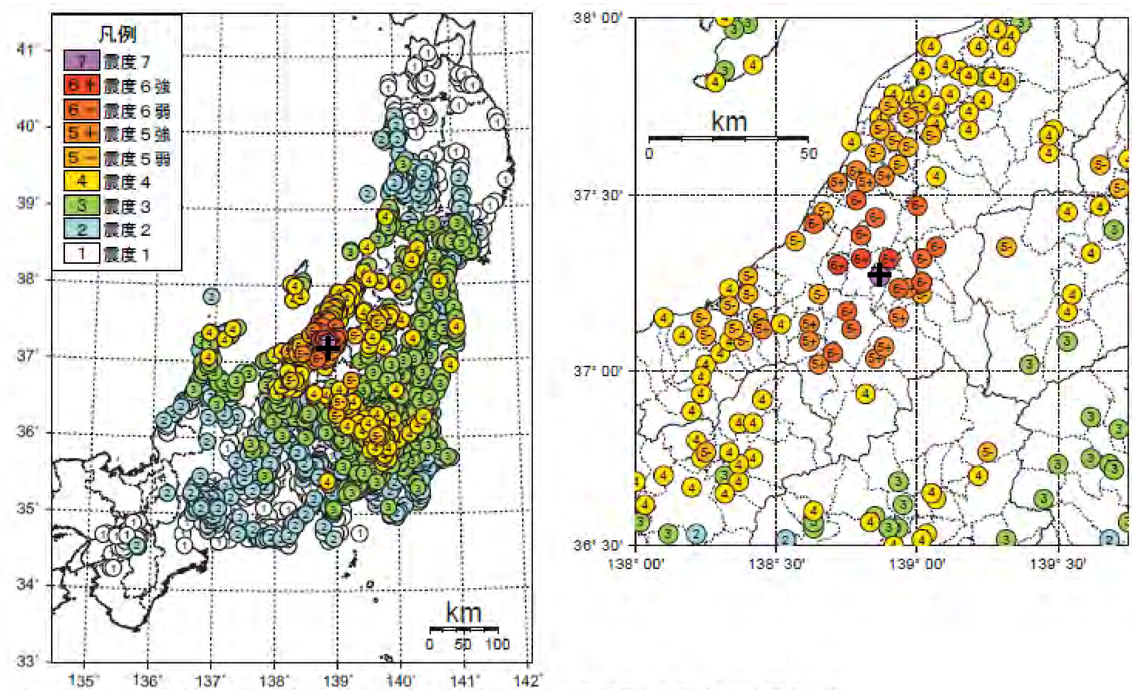
Epicenter distribution of the middle part of Niigata prefecture.
(Oct.1, 1997 - Oct.3, 2010, hypocentral depth≦40km, M≧4.0)

Japan Meteorological Agency

The Mid Niigata prefecture Earthquake in 2004

A large earthquake (Mjma 6.8) occurred in the Chuetsu region in Niigata prefecture at 17:56 on October 23, 2004 (JST). The Japan Meteorological Agency (JMA) located the hypocenter at 37°17.5′N, 138°52.0′E, at a depth of 13km.

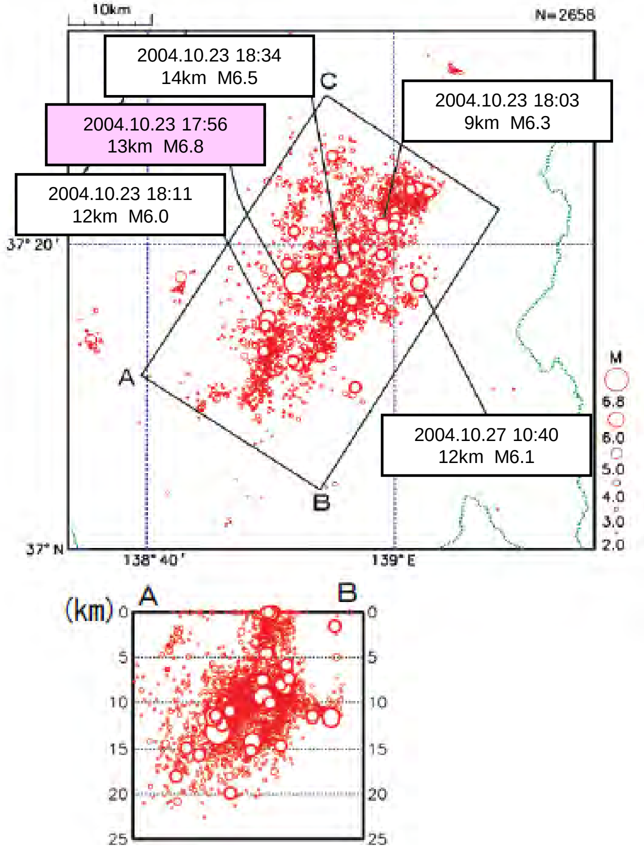
A maximum seismic intensity of 7 (7 is the highest intensity of the JMA scale) was observed at Kawaguchi town in Niigata prefecture, and the strong motion caused tremendous damage in and around the focal area. Due to this serious damage, JMA named this earthquake "The Mid Niigata prefecture Earthquake in 2004."



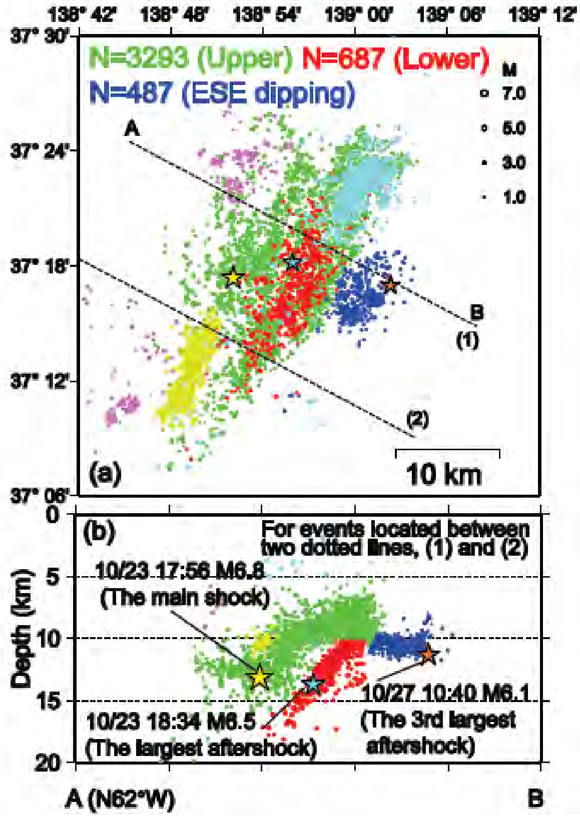
Observed Seismic Intensity Distribution

The seismic intensity of 7 in Kawaguchi town was the first to be instrumentally observed since JMA deployed seismic intensity meter and started instrumental observation in 1996. The maximum acceleration exceeding 2,500gal was observed in Kawaguchi town, caused by the largest aftershock(Mjma 6.5, 18:34 23 Oct.2004).

The mainshock and the subsequent aftershocks caused 68 deaths, 4,805 injuries, and 16,985 damaged houses including 3,175 total collapses(by Fire and Disaster Management Agency, as of Oct.21,2009).



Distribution of the mainshock and aftershocks. Events from 17:00 Oct.23, 2004 to 24:00 Aug.31, 2005 are shown.

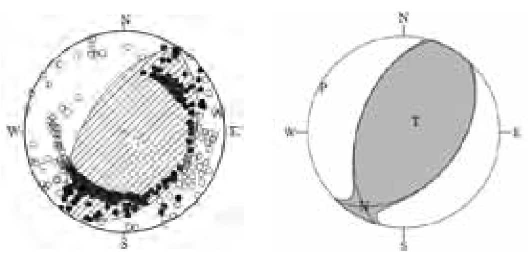


Distribution of relocated hypocenters by DD method. Events from 17:56 Oct. 23 to 24:00 Nov. 30, 2004 are shown. Green, red, and blue circles denote hypocenters of the upper plane, the lower plane, and the ESE dipping plane, respectively.

(a): Map viewing of hypocenter distribution.

(b): Vertical cross section along A-B for events located between two dotted lines.

Shigeki Aoki, “Complicated fault geometries of shallow destructive inland earthquakes with high aftershock activity -the Mid Niigata Earthquake in 2004 and the Mikawa Earthquake in 1945”, UJNR2010 Abstracts.



Focal mechanism of the mainshock.

Left : focal mechanism obtained from P wave initial motion

Right: focal mechanism obtained from CMT solutions

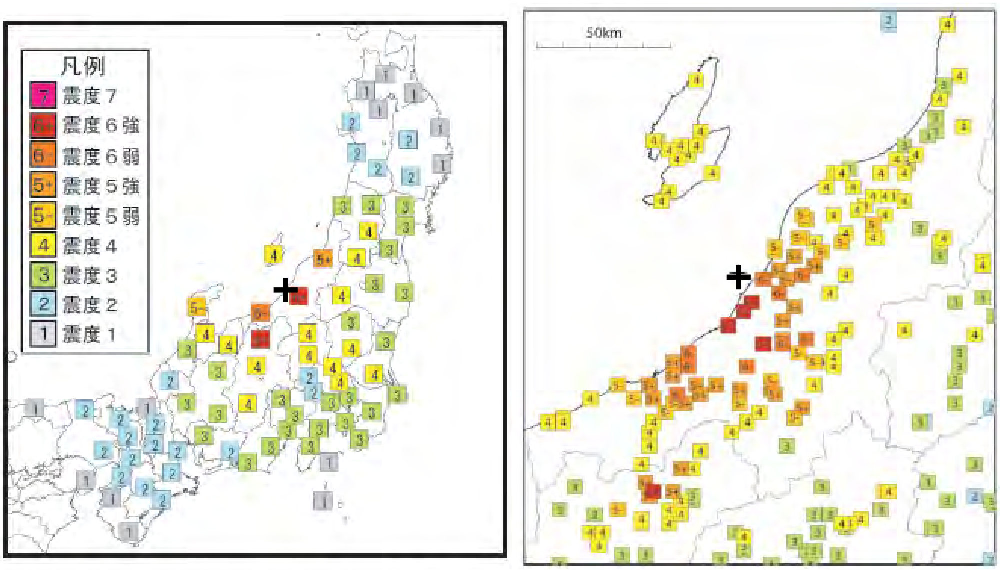
The focal mechanism was of a reverse fault type with a compression axis in the WNW-ESE direction.

A number of large aftershocks followed the mainshock with a magnitude of 6.8, including four with Mjma 6.0 or larger, which were unusually large for the magnitude of the mainshock. The frequent occurrence of large aftershocks was the main characteristic in this sequence. Aftershocks occuered across 30km-wide area, in a NNE-SSW direction. Some of these aftershocks created new fault planes, which generated many secondary aftershocks, and were one of the causes of the high aftershock activity.

The Earthquake Research Committee of the Headquarters of Earthquake Rsearch Promotion assessed that “According to the aftershock distribution, there is a possibility of activity on the northern part of the fault zone located in the western margin of the Muikamachi Basin.”

The Niigataken Chuetsu-oki Earthquake in 2007

A large earthquake (Mjma 6.8) occurred to the west of Niigata Prefecture’s coastline at 10:13 on July 16, 2007 (JST). The hypocenter was located at 37°33.4′N, 138°36.5′E and at a depth of 17 km. A maximum seismic intensity of 6-upper on the JMA scale was observed in Kashiwazaki city, Kariwa village and Nagaoka city in Niigata prefecture, and Iizuna town in Nagano prefecture. The quake’s strong motion caused serious damage in and around Niigata prefecture. Due to the extent of this damage, JMA gave the earthquake an official name, calling it “The Niigataken Chuetsu-oki Earthquake in 2007”.



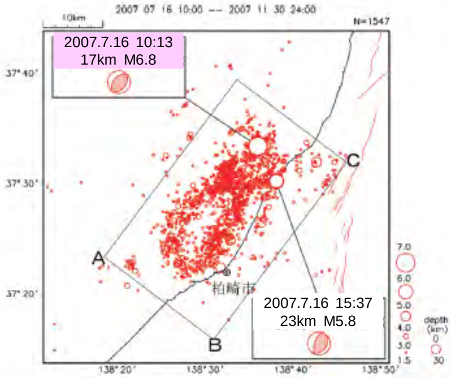
Observed Seismic Intensity Distribution

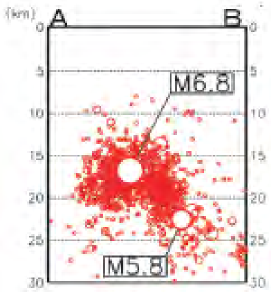


The mainshock and the subsequent aftershocks caused 15 deaths, 2,346 injuries, and 7,040 damaged houses including 1,331 total collapses(Fire and Disaster Management Agency, as of Oct.15,2009).

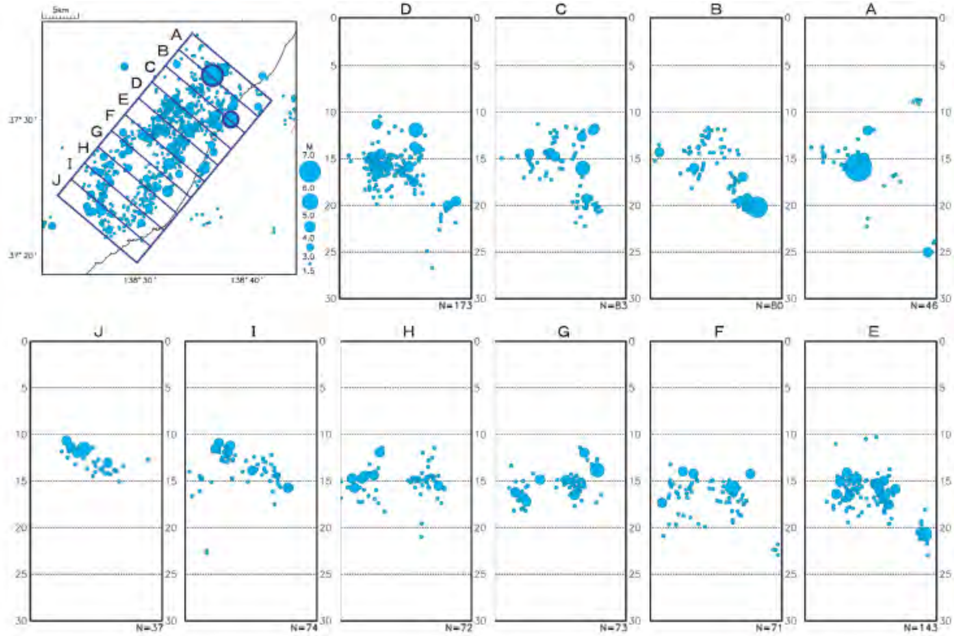
Tsunamis were observed over the region along the Sea of Japan coast from Akita prefecture to Ishikawa prefecture. The highest tsunami height was 32cm observed by a tide gauge in Kashiwazaki City.

As early as 3.8 seconds after the detection of the earthquake, JMA issued Earthquake Early Warnings to several hundred registered users. At 10:14, one minute after the onset of the mainshock, JMA also issued a tsunami advisory for coast lines of Niigata prefecture and Sado island using the earthquake’s magnitude and location determined by the Earthquake Early Warning systems. The tsunami advisory was cancelled at 11:20 after the wave had gradually attenuated.

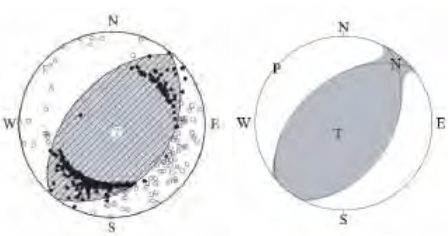




Distribution of the mainshock and aftershocks.
Events from 10:00 Jul.16,2007 to 24:00 Nov.30,2007 are shown.

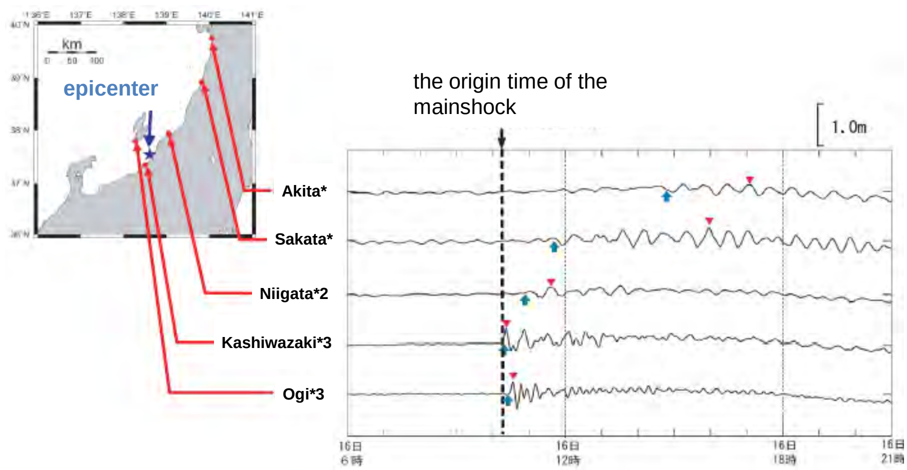


Distribution of relocated hypocenters by DD method.
Events from 10:00 Jul.16,2007 to 24:00 Nov.30,2007 are shown.
A-J: Vertical cross section along NW-SE for events located in each rectangular region from A to J.



Focal mechanism of the mainshock.
Left : focal mechanism obtained from P wave initial motion
Right : focal mechanism obtained from CMT solutions

The focal mechanism was of a reverse fault type with a compression axis in the NW-SE direction.



Location of tide gauges (left) and observed tsunami wave data (right). Blue arrows show the arrivals of initial waves, and red triangles show that maximum tsunami heights were observed. Tsunami wave data whose maximum tsunami heights were 5cm or more are shown in this figure.

*) Tide gauge of Tohoku regional bureau, Ministry of Land, Infrastructure, transport and Tourism (MLIT)
*2) Tide gauge of Hokuriku regional bureau, MLIT
*3) Tide gauge of Geospatial Information Authority of Japan, MLIT

The inactivity of aftershocks was characteristic as compared with The Mid Niigata prefecture Earthquake in 2004. Aftershocks occuered over an area 30km long and 15km wide with a NE-SW strike. These were approximately distributed on a plane that inclines to the SE, which is generally considered the source region of the mainshock. However, some aftershocks were distributed on a conjugate plane with a NW inclination.

The Earthquake Research Committee of the Headquarters of Earthquake Rsearch Promotion assessed the fault plane of the mainshock as follows: "From a comprehensive perspective, the mainshock was caused by the rupture of a reverse fault with a SE inclination, along with the rupture of a conjugate fault with a NW inclination in the northeastern part of the focal region."