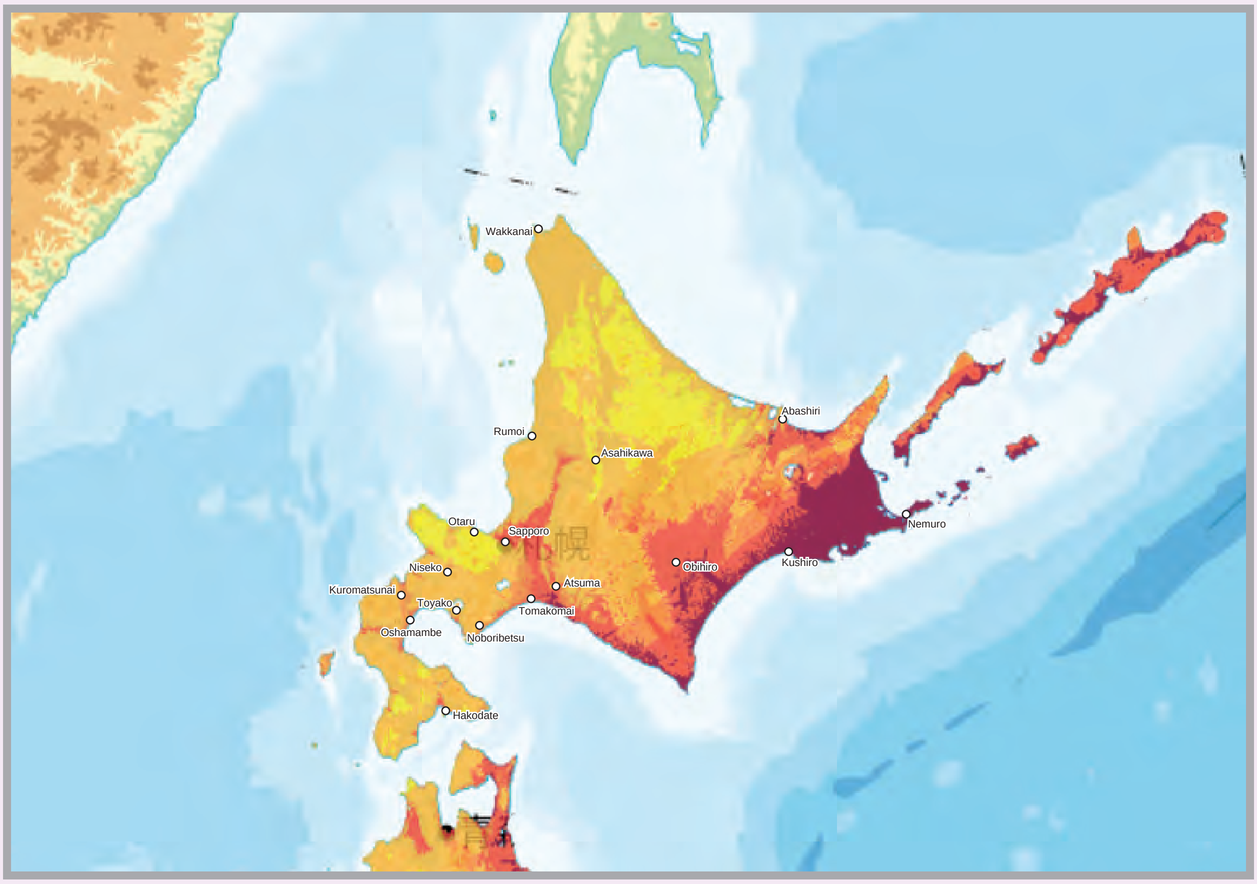
Field Trip Guide

(3, 6 and 7-8 November 2019)



The 2019 Japan-New Zealand-Taiwan Seismic Hazard Workshop

Outline of 2019 field trip in Hokkaido, Japan

Sunday: 3 November “Welcome to active Hokkaido”

[Course A]
13:30 Departure from New Chitose Airport
|
14:30 "Jigoku-dani" Noboribetsu Onsen hot spa
16:00 Departure
|
17:00 Hotel: Toyako Onsen

[Course B]
15:30 Departure from New Chitose Airport
|
17:00 Hotel: Toyako Onsen

Wednesday: 6 November “Walking on volcano”

12:00 Leave from Convention Hall
|
12:15 Showa-Shinzan
|
12:30 Lunch
|
13:30 Usu volcano
|
15:30 2000 Eruption of Usu volcano
|
17:00 Hotel

Thursday: 7 November “The highest probability active fault in Hokkaido”

08:00 Departure
|
09:00 Stop 1: Tokyo University of Science, Oshamambe Campus
|
09:30 Stop 2: Oshamambe Park
|
10:30 Stop 3: Warabitai Fault
|
11:30 Lunch at Nature Experience House of Kuromatunai (Utazai Shizen-no-ie)
|
13:30 Stop 4: Shirozumi-higashi fault
|
14:00 Stop 5: Utasutsu
|
14:30 stop at Road Station of Kuromatsunai
|
17:30 Hotel: Niseko Northern Resort Annupuri

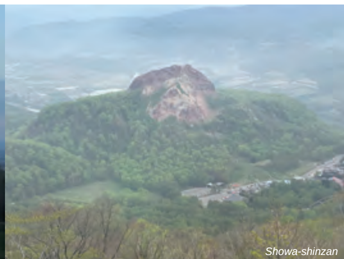
Friday: 8 November “Large landslides of 2018 Iburi-tobu Earthquake”

08:00 Departure
|
09:45 Stop 6: Lake Shikotsu
|
12:15 Stop 7: The largest Landslide of 2018 earthquake
|
13:30 Stop 8: Landslide related to tephra layers
|
15:00 New Chitose Airport

Route map of field trip


Lake Shikotsu and Tarumae volcano


Mt. Youtei


Showa-shinzan


Lake Shikotsu and Eniwa volcano


Ooyunuma, Noboribetsu


Lake Kuttara


Tephra layers, Atsima


Jigokudani, Noboribetsu


2003 Warabitai trench survey


Usu volcano


Hokkaido ramen


Japanese foods

Introduction

Tectonic Setting of Hokkaido

In Hokkaido there are various types of tectonic features, such as subduction zone, collision zone, fold-and -thrust belt, active faults and volcanoes. Hidaka collision zone divides Hokkaido into the eastern side (Kuril Arc) and the western side (Northeast Japan Arc). In the eastern side of Hidaka collision zone, there are several reverse faults and the most active zone in the Quaternary period is a blind thrust near Sapporo, which includes Ishikari-teichi-touen fault zone. Source area of the 2018 Hokkaido Eastern Iburi earthquake (M_{JMA} 6.7) was located on the southern part of Ishikari-teichi-touen fault zone, but focal depth was deeper than fault plane modeled for this fault zone. Subduction-type earthquake along Kuril Arc could be so large and is accompanied by large tsunamis.

There are many active volcanoes in Hokkaido, including large calderas, such as Toya, Shikotsu and Kussharo. Pyroclastic flow deposits from these calderas covers land widely in Hokkaido. There are high hazard of volcanic eruption, like 1977-1978 and 2000 eruptions of Usu Volcanoes.

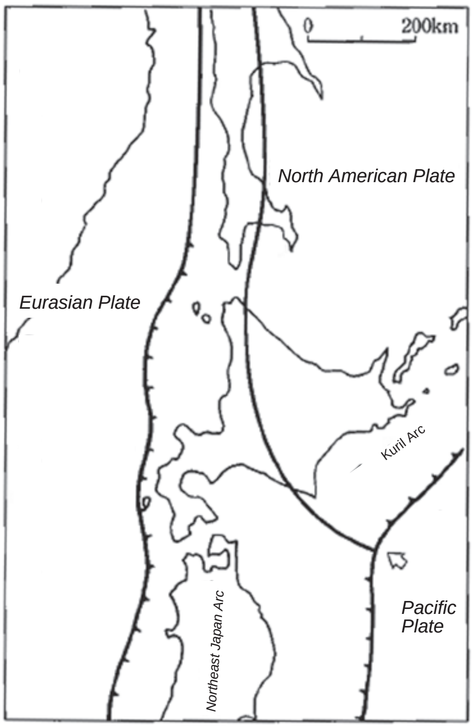


Fig. 1 Tectonic setting around Hokkaido

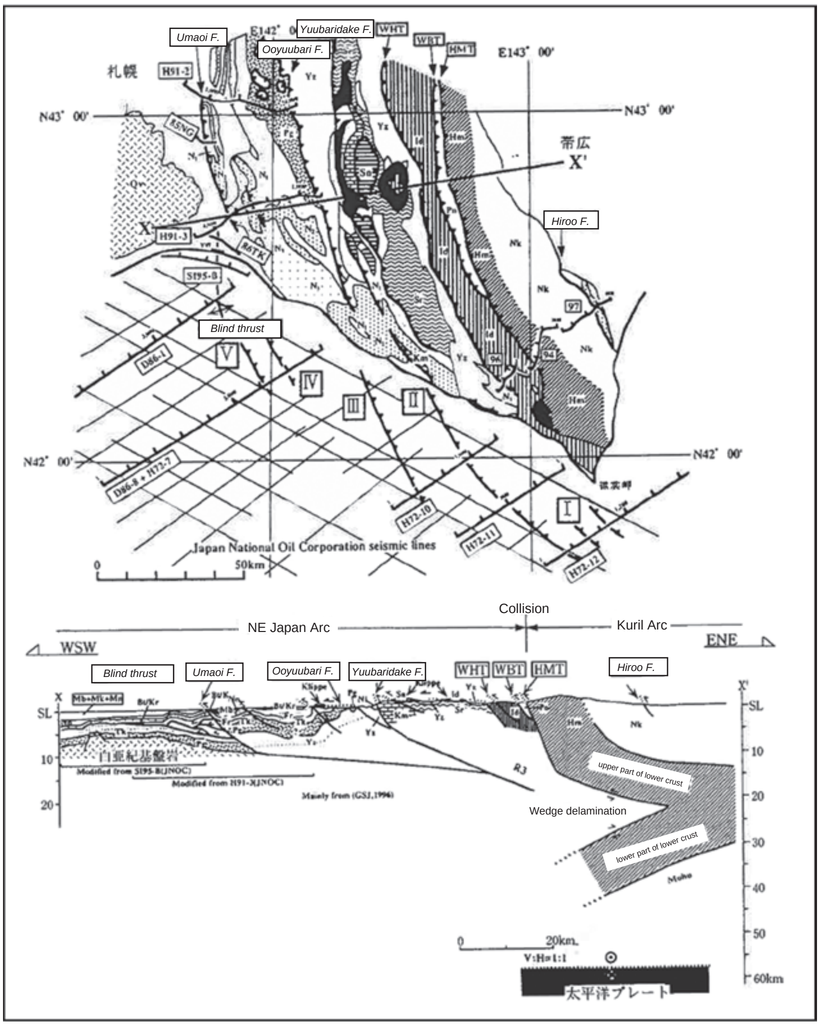
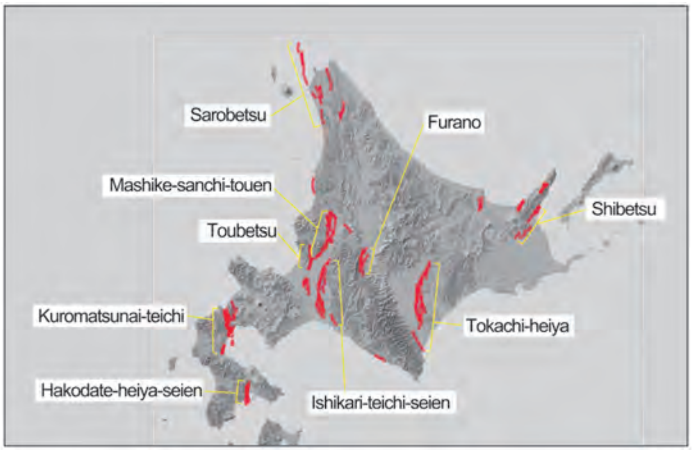


Fig. 2 Geological structure and cross section of collision zone between NE Japan and Kuril Arcs (modified from Ito, 2000)

Active faults in Hokkaido

Most of active faults in Hokkaido are reverse fault trending N-S direction. Slip-rates of them are less than 1 mm/yr. History of faulting of these faults are not known well.



Name of Fault Zone	Probability (30 years)
Shibetsu	no data
Tokachi-heiya (main)	0.1-0.2%
Tokachi-heiya (south)	0.4-0.4%
Furano	nearly 0-0.03%
Mashike-santi-touen	< 0.6%
Toubetsu	nearly 0-2%
Ishikari-teichi-touen (north)	0.05-6%
Ishikari-teichi-touen (South)	no data
Hakodate-heiya-seien	nearly 0-1%
Kuromatsunai-teichi	2-5%

Fig. 3 Active fault map of Hokkaido and probability of future earthquake for 30 years by HERP

Historical earthquakes in and around Hokkaido

Historical record in Hokkaido had covered rather shorter period than main land of Japan (since 17 Centuries) because of native people there, Ainu, has a culture without letters. Large earthquakes often occurred along the Kuril subduction zone offshore of Tokachi, Kushiro and Nemuro. Other large earthquakes occurred in offshore of Japan Sea side, such as 1993 Southwest off Hokkaido earthquake of M_{JMA} 7.8. Intra-plate earthquakes more than M 7 were rare on land.

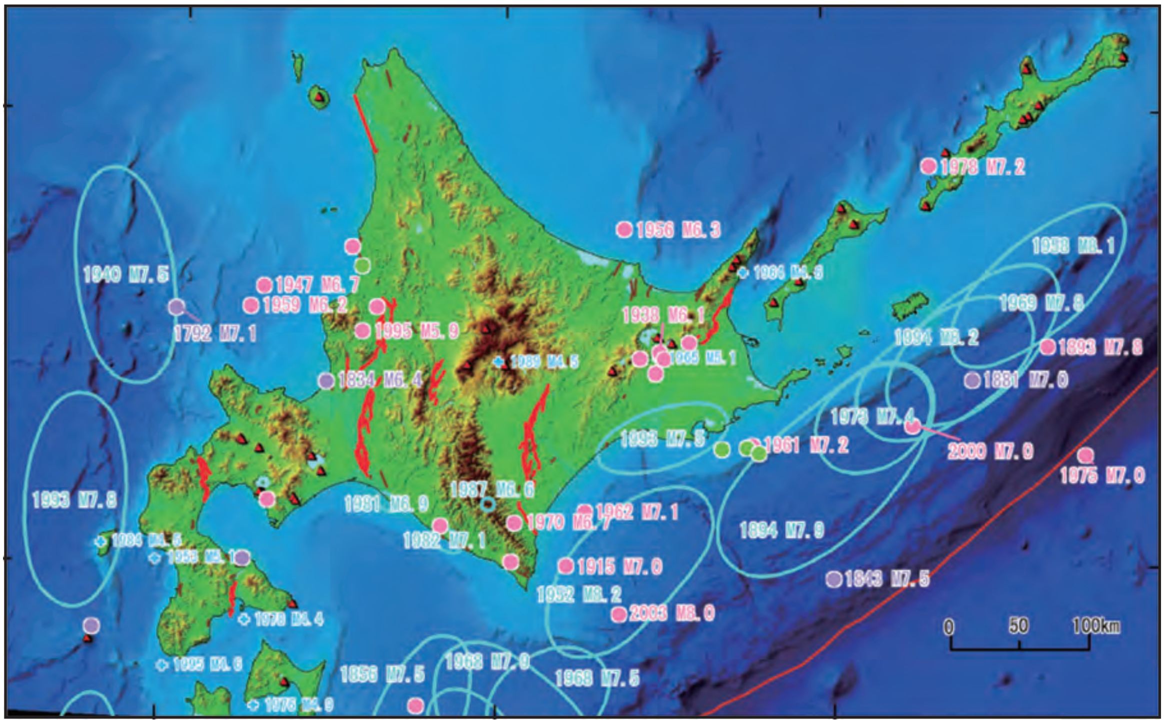


Fig. 4 Epicenters and source areas of historical and observed earthquakes in and around Hokkaido (Earthquake Research Committee of HERP, 2009)

Pre-Conference trip

Fig. 5 Route map of pre-conference trip

Jigoku-dani in Noboribetsu Hot Spa

Noboribetsu hot spa is one of the famous hot spa in Hokkaido. You can walk around "Jigoku-dani (Hell Valley)", where volcanic steams and geyser are very active. Noboribetsu hot spa is located to the west of Lake Kuttara, which was produced by caldera eruption in the late Pleistocene period.

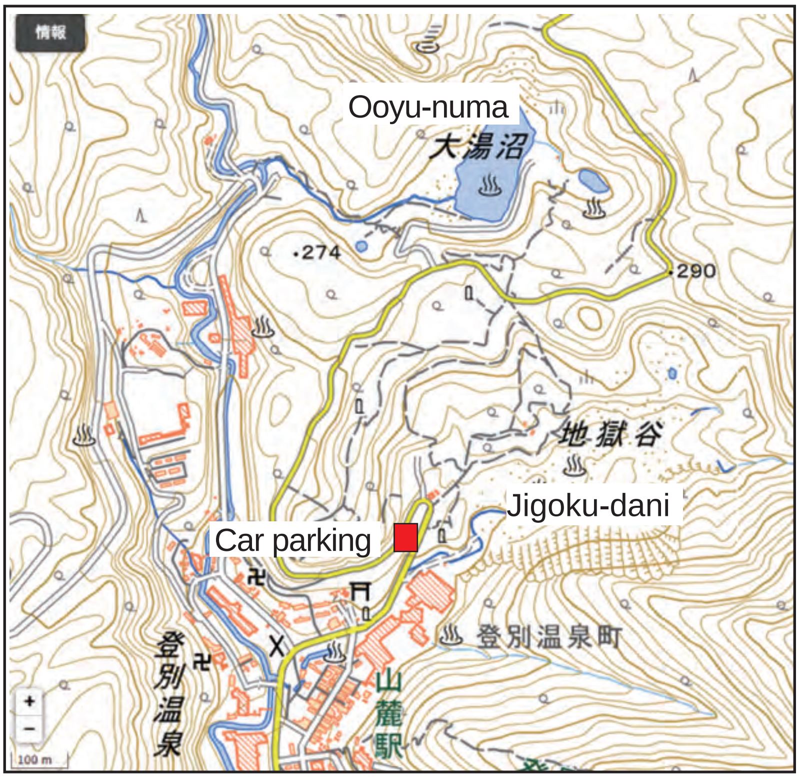


Fig. 6 Map of Jigoku-dani in Noboribetsu
(from GSI Map)

Fig. 7 Photos of Jigoku-dani (top) and Ooyu-numa
(bottom) in Noboribetsu

Kuttara Caldera

Lake Kuttara is located in the east of Noboribetsu hot spa with 2 km in diameter. It is a caldera lake created by volcanic eruption in the late Pleistocene. Several tephra layers from Kuttara Caldera are found. Kt-2 was distributed westward, whereas others were distributed eastward. Kt-2 is one of key-tephra layers in Kuromatsunai region though its age is not knows yet.

Fig. xx Photo of Lake Kuttara

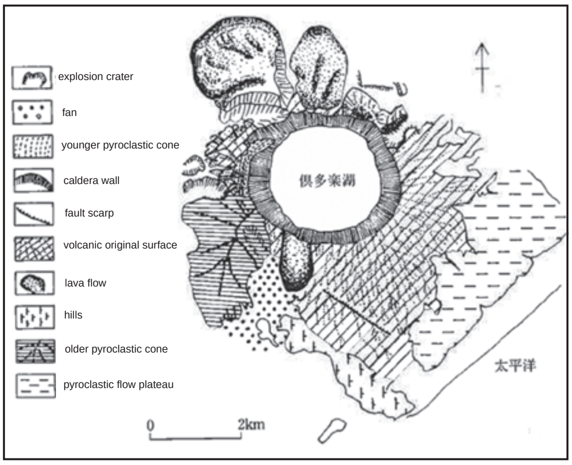


Fig. 8 Topographic map around Kuttara Caldera (Koaze et al., 2003)

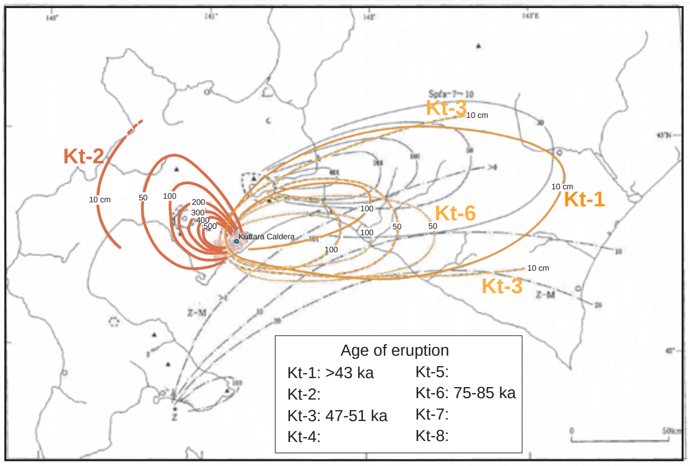


Fig. 9 Distribution and thickness of tephras from Kuttara tephra (modified from Machida and Arai, 2003)

Toya Caldera

Toya Caldera was created by huge eruption in 112-115 ka, which was accompanied with pyroclastic flow. Volcanic ash and pumice are one of the most important wide-spreading tephras covering marine deposits of MIS 5e terraces in the northeastern Japan. Pyroclastic flow deposits is called as “Neppu tuff” .

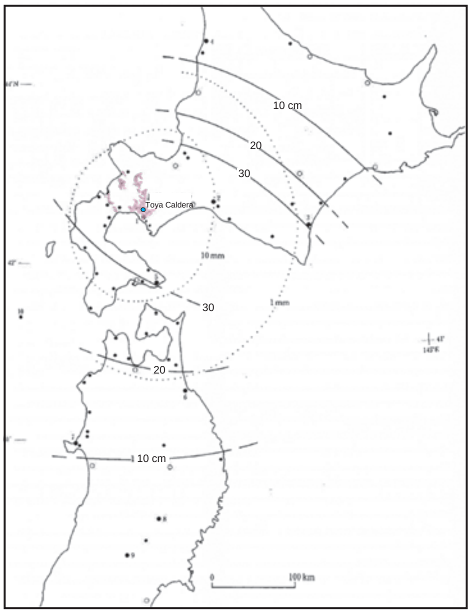


Fig. 10 Distribution and thickness of Toya tephra (Machida and Arai, 2003)

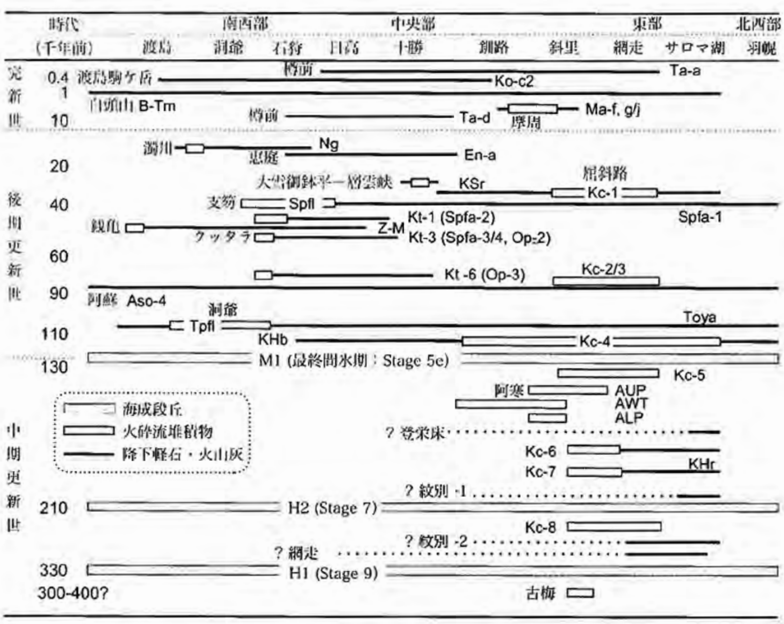


Fig. 11 Diagram of tephrochronology in Hokkaido (Machida and Arai, 2003)

Afternoon field trip “Walking on volcano” (6 November)

12:00 leave from Convention Hall
|
12:15 Showa-shinzan (A)
|
12:30 Lunch
|
13:30 Climb up to Usu-zan (B) by Ropeway
|
15:15 leave from Usu-zan
|
15:30 2000 eruption area (C)
|
16:45 departure
|
17:00 arriving at Hotel

Fig. 12 Map around Usu volcano (Base map is from GIS Map)

Showa-shinzan

Activity of volcanic earthquakes increased around Usu volcano in the end of 1943. This activity was continued until September 1945 and Showa-shinzan was created in the east foot of Usu-zan. This activity is divided into 3 stages, 1) Pre-eruption stage (28 December 1943 - 22 June 1944), 2) Explosion stage (23 June 1944 - 31 October 1944), and 3) Lava dome creation stage (November 1944 - September 1945). A chief of post office, Mr. Mimatsu, recorded a change of shape of Showa-shinzan from the window of office. It is well known as “Mimatsu Diagram” (Fig. 13).

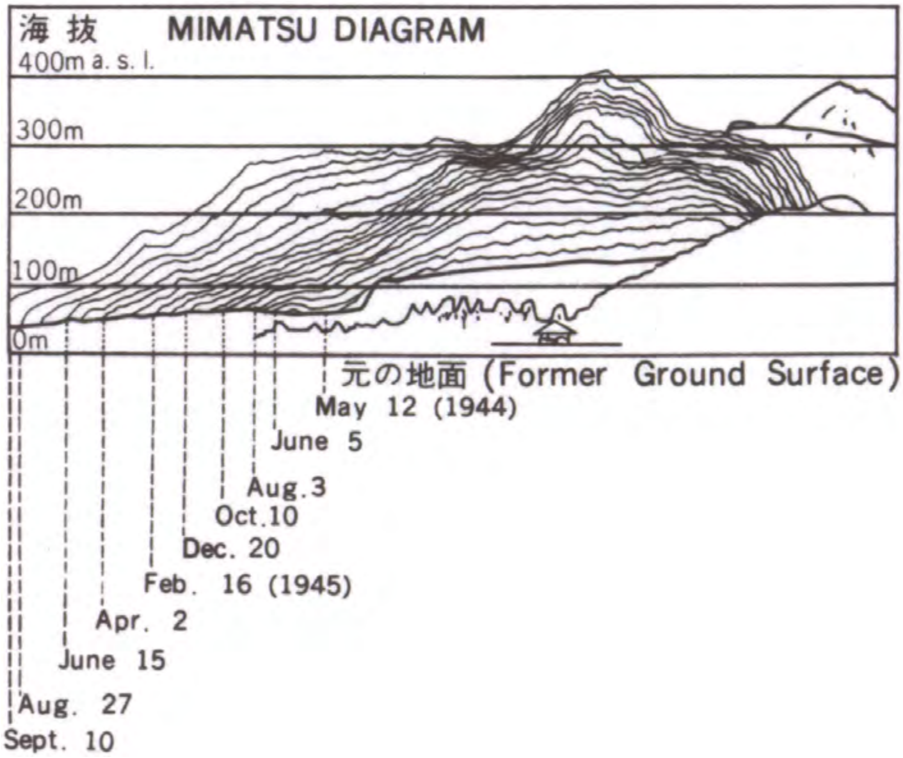


Fig. 13 Mimatsu diagram showing the growth of Showa-shinzan lava dome (Mimatsu, 1962)

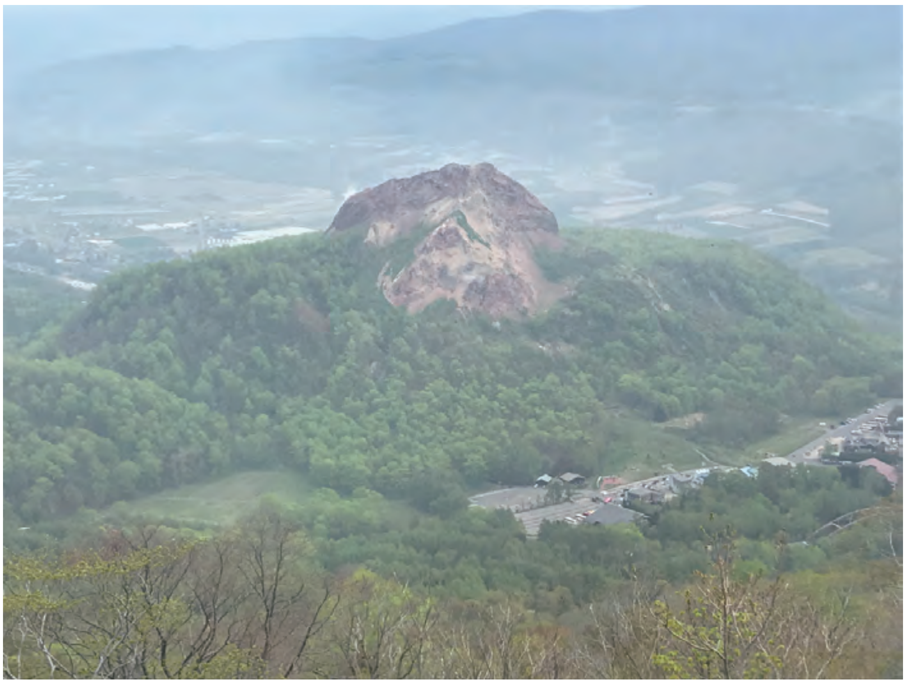


Fig. 14 Photo of Showa-shinzan

Usu-zan

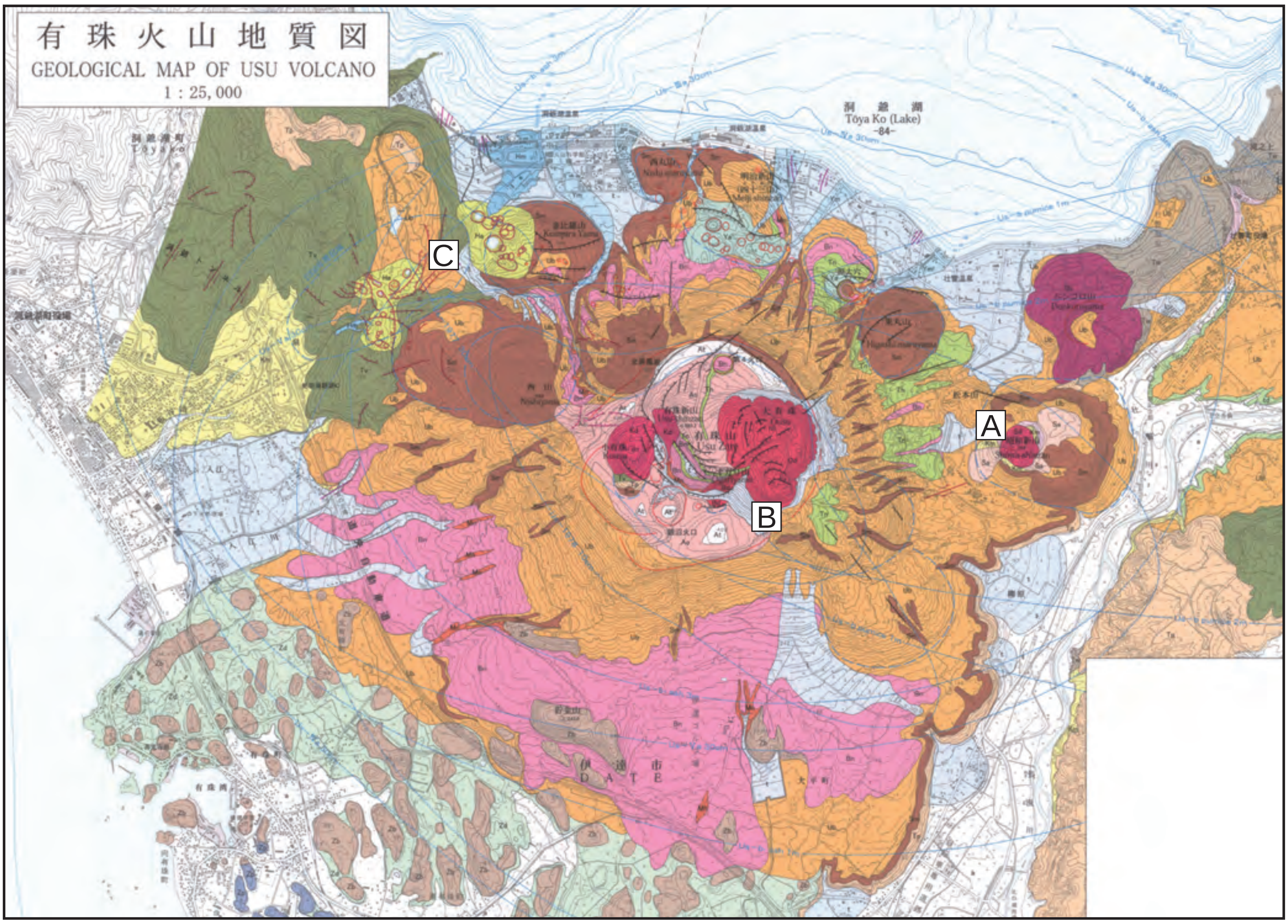


Fig. 15 Geological map of Usu volcano (Soya et al., 2004)

Fig. 16 Photo of crater of Usu-zan

1977-1978 and 2000 eruption

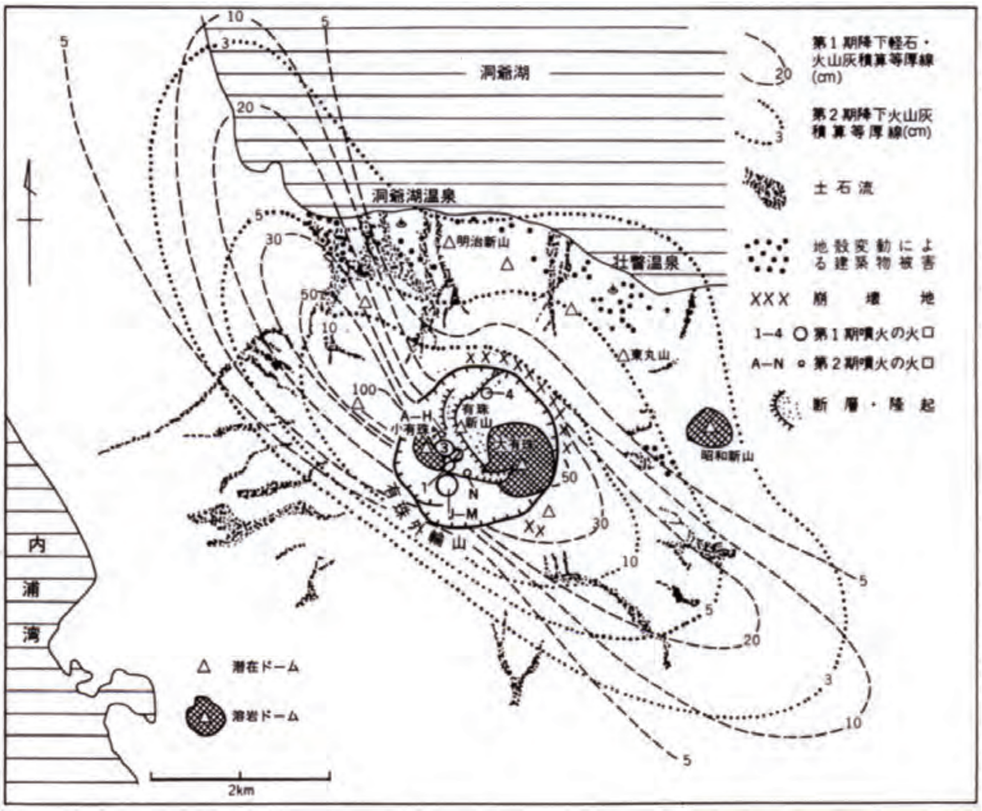


Fig. 17 Distribution and thickness of tephras by 1977-1978 eruption of Usu volcano.
(modified from Soya et al, 2007)

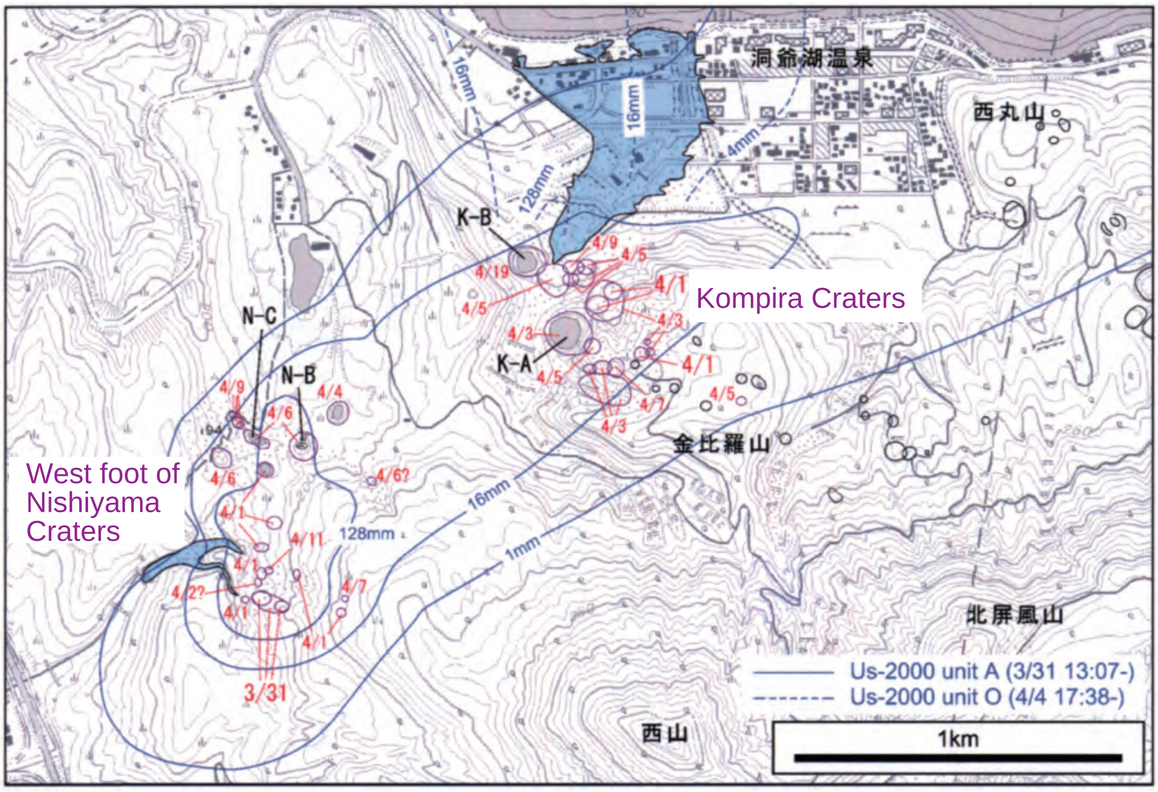


Fig. 18 Distribution of craters (purple) and volcanic mud flows (light blue) at the 2000 eruption of Usu volcano.
(modified from Soya et al, 2007)

Post-Workshop field trip

Day 1 Kuromatsunai-teichi fault zone

Kuromatsunai-teichi fault zone is located southwestern part of Hokkaido. It is 32 km in length on land and is continued to offshore. It includes several reverse faults, such as Shirozumi-higashi, Shirozumi-nishi, Neppu, Neppu-genya, Asahino, Warabitai, Chiraigawa-ugan, Oshamambe, Nakanosawa, and so on. Geological Survey of Japan conducted paleoseismological surveys in 2002-2004. HERP evaluated probability of occurrence of future activity of this fault zone as 2-5 % for next 30 years, which is the highest value in Hokkaido.

Stop 1: Tokyo University of Science, Oshamambe Campus

Tilted marine terrace, Holocene marine terraces, seismic profile, offshore fault

Stop 2: Oshamambe Park

Paleoseismological trench in 2002

Stop 3: Warabitai Fault

Paleoseismological trench in 2003 and 2004, the latest faulting event of the fault zone

Stop 4: Shirozumi-higashi fault

Paleoseismological trench in 2002 and pit survey 2003

Stop 5: Utasutsu

Northern end of the fault zone on land, other active faults around this area

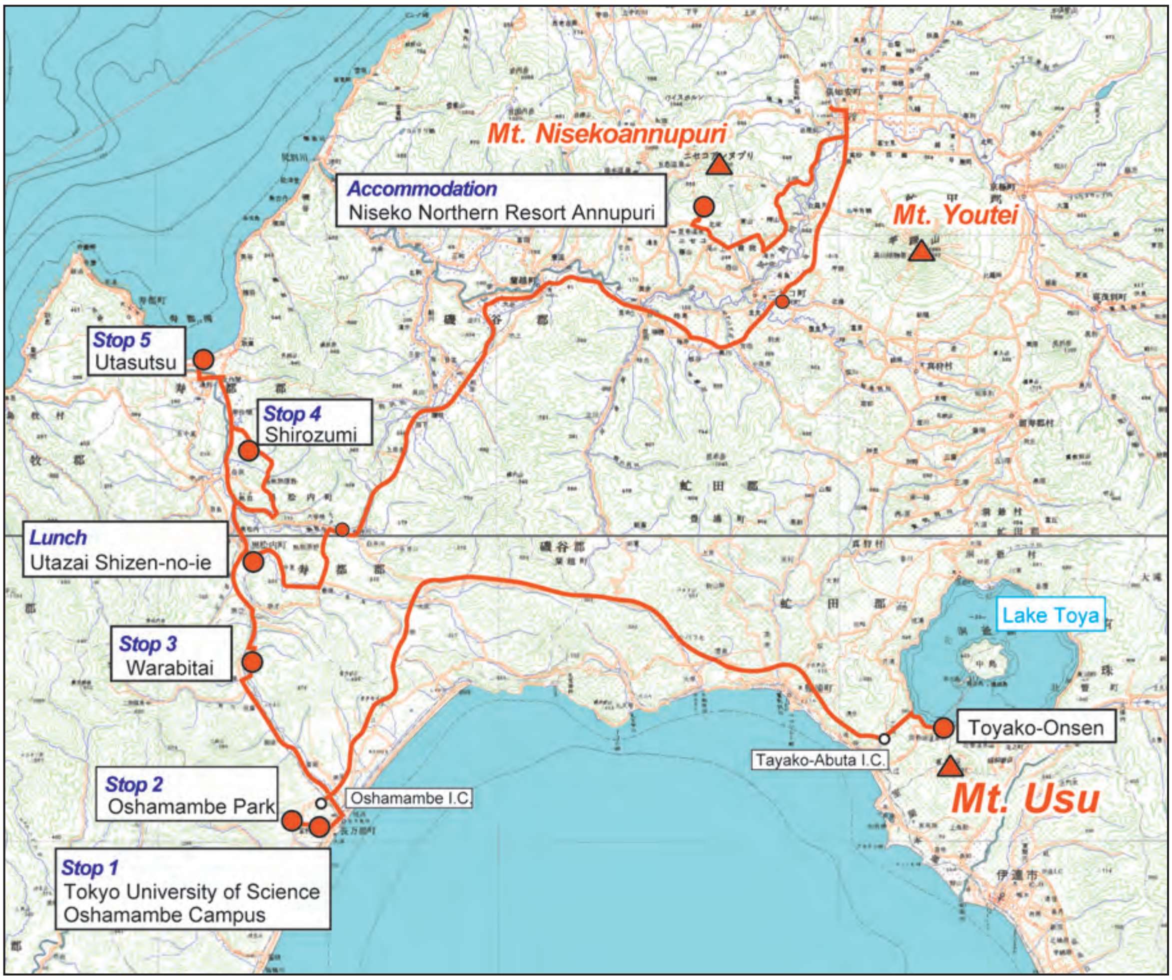


Fig. 19 Route map of Day 1

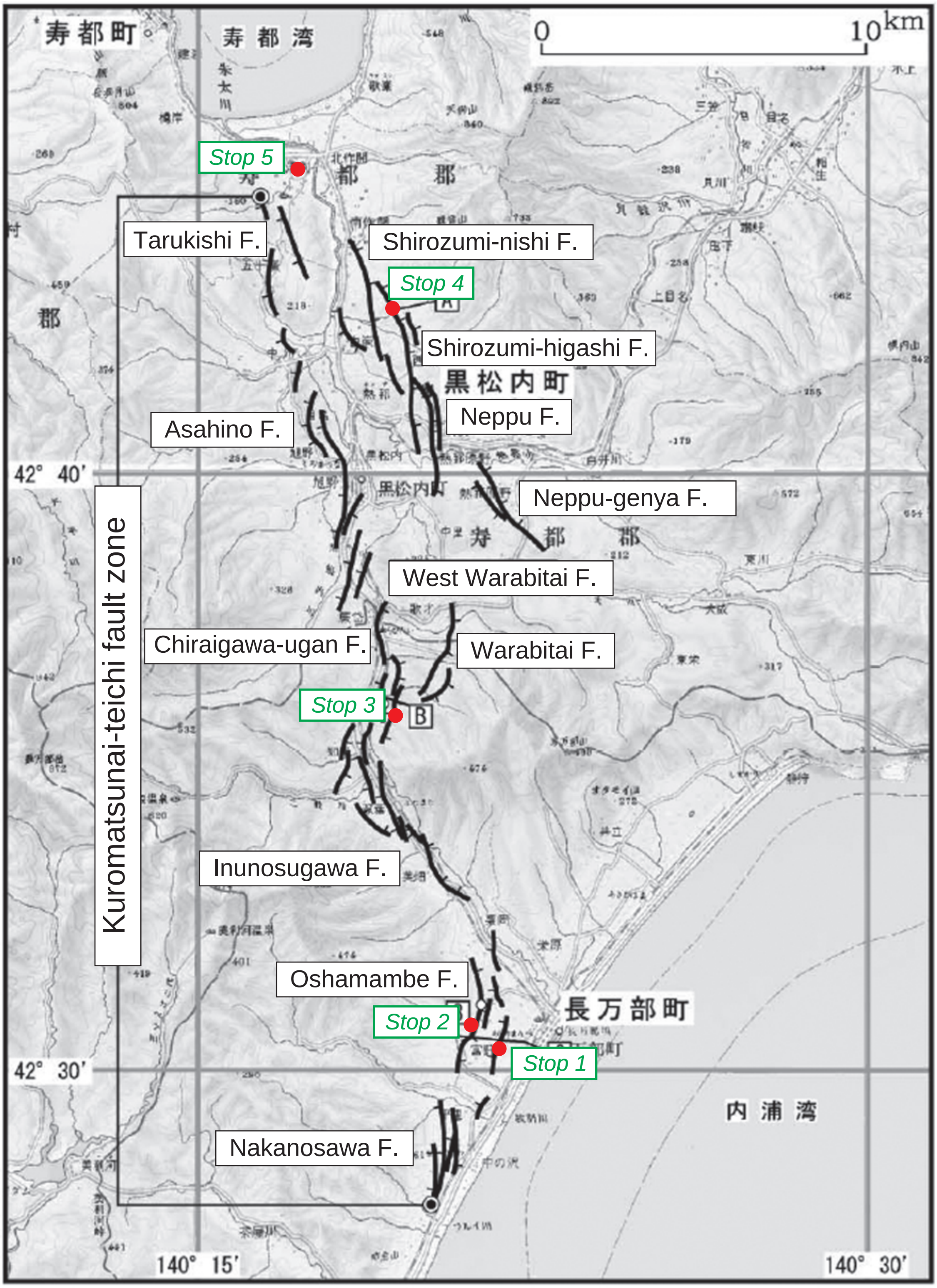


Fig. 20 Distribution of active faults of Kuromatsunai-teichi fault zone
(modified from HERP, 2005)

Stop 1: Tokyo University of Science, Oshamambe Campus

Tilted marine terraces

Late Pleistocene and Holocene terraces are distributed at Oshamambe. Late Pleistocene terraces are divided into 3 level and they are tilted toward inland (Fig. 21). Comparison of tilting angles (Fig.22) indicates this crustal movement started ca. 0.8 Ma. This tilting toward inland was caused by activity of offshore fault, which might be related to uplift of Holocene marine terraces in this area (Fig. 26).

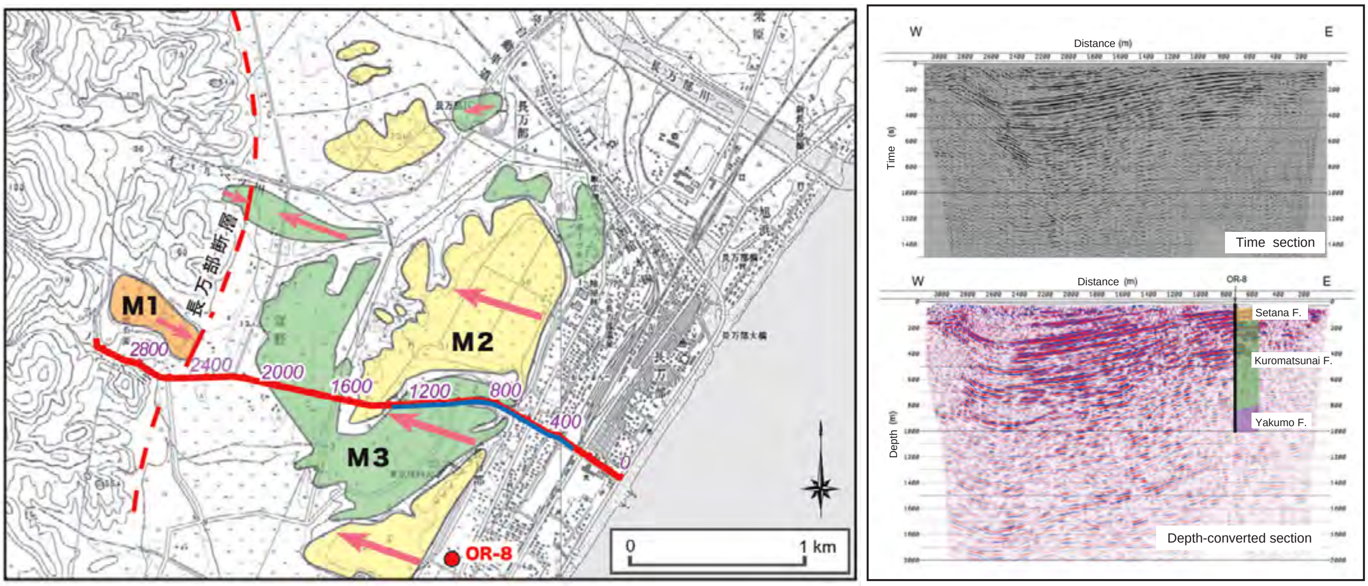


Fig. 21 Map of terrace distribution (left) and seismic profile (right) at Oshamambe
Arrows show direction of abnormal inclination of the late Pleistocene terraces.
(modified from Azuma *et al*., 2004)

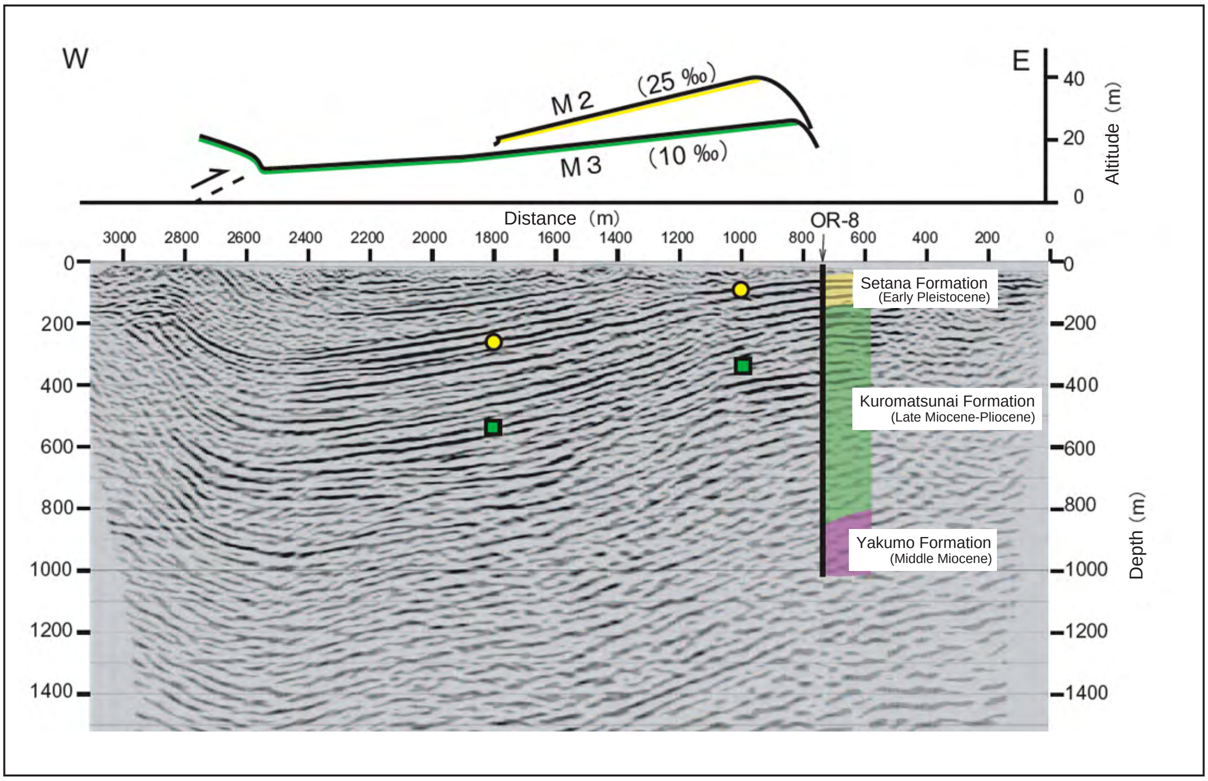


Fig. 22 Depth-converted seismic profile and projection of tilted terraces at Oshamambe
(modified from Azuma *et al*., 2004)

Offshore fault

South extension of Kuromatsunai-teichi fault zone was seemed to be continued into offshore to Yakumo to the south by the reasons of 1) it needs offshore fault to have marine terraces tilted to land-ward at Oshamambe, and 2) there are minor west-facing fault scarps on land (Nakanosawa fault). Sugiyama *et al*. (2007) showed existence of offshore faults and anticlinal axes with left stepping, although the age of the last faulting event did not consisted with a result of on-land fault at Warabitai site.

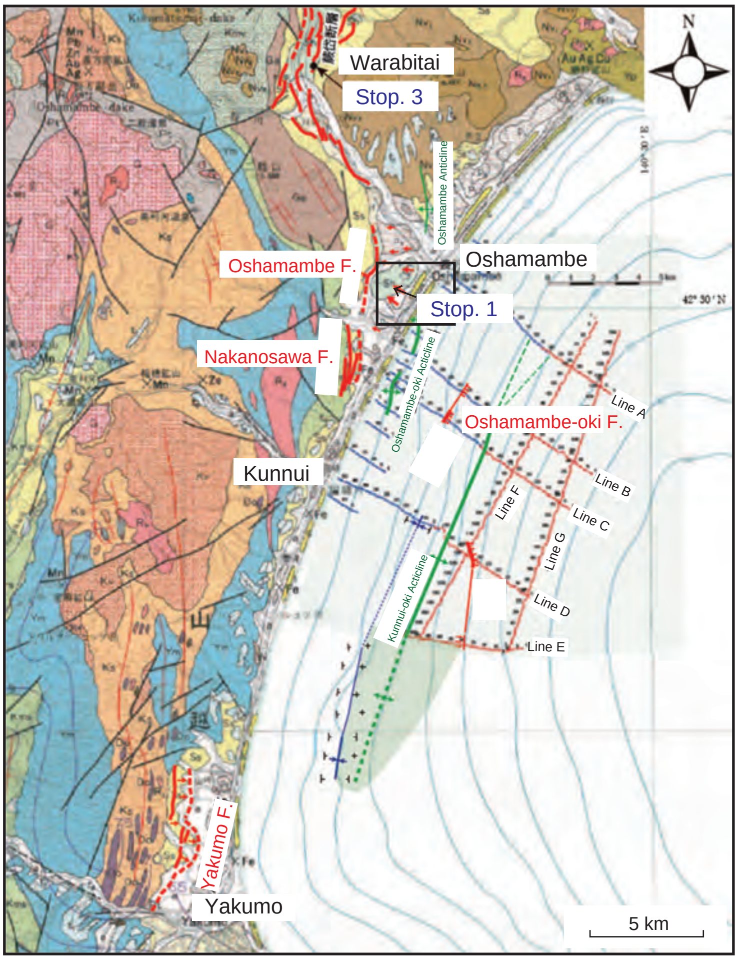


Fig. 23 Location of survey lines active faults on land and offshore around the southern end of Kuromatsunai-teichi fault zone. (modified from Sugiyama *et al*., 2007)

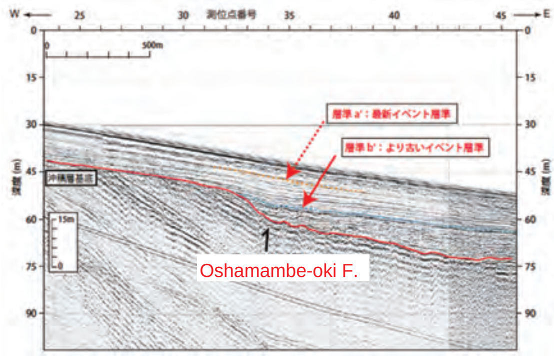


Fig. 24 Acoustic reflection profile around Oshamambe-oki fault on Line B (Sugiyama *et al*., 2007)

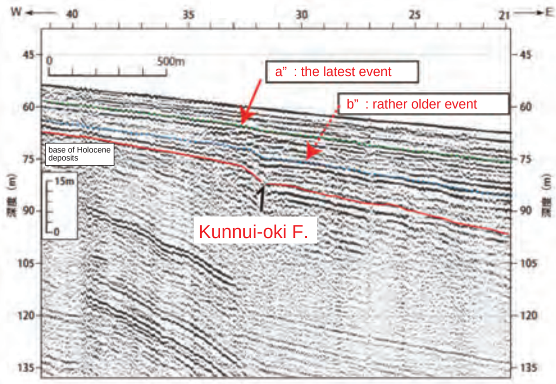


Fig. 25 Acoustic reflection profile around Kunnui-oki fault on Line D (Sugiyama *et al*., 2007)

Holocene marine terraces

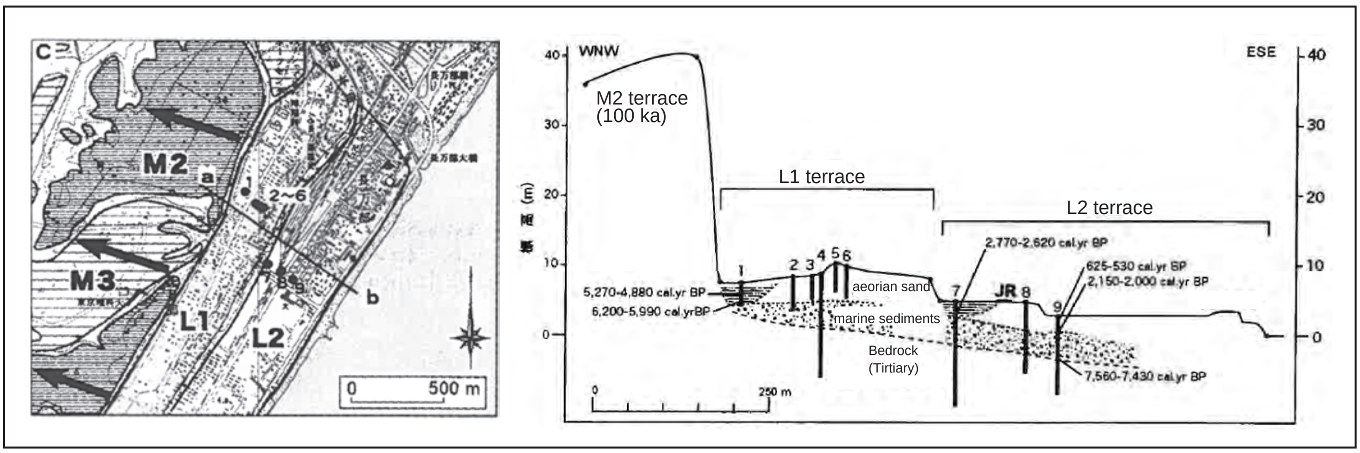


Fig. 26 Topographic and geological profile of Holocene marine terraces at Oshamambe (Azuma, 2007)

Stop 2: Oshamambe Park

Oshamambe fault is mapped by Active Fault Research Group in Japan (1991). It is a reverse fault dipping to west and is located along boundary between hills and plain in the southern part of Kuromatsunai-teichi Fault Zone. We excavated a paleoseismological trench and 3 all-core borings in 2002. Fault was not appeared on the trench walls but we observed 1) angular unconformity between layers of Holocene sediments and late Pleistocene sediments, which may indicate a growth of flexure, 2) deformation of Holocene sediments (paleo-liquiefaction), which is an evidence of occurrence of strong ground motion at that period.

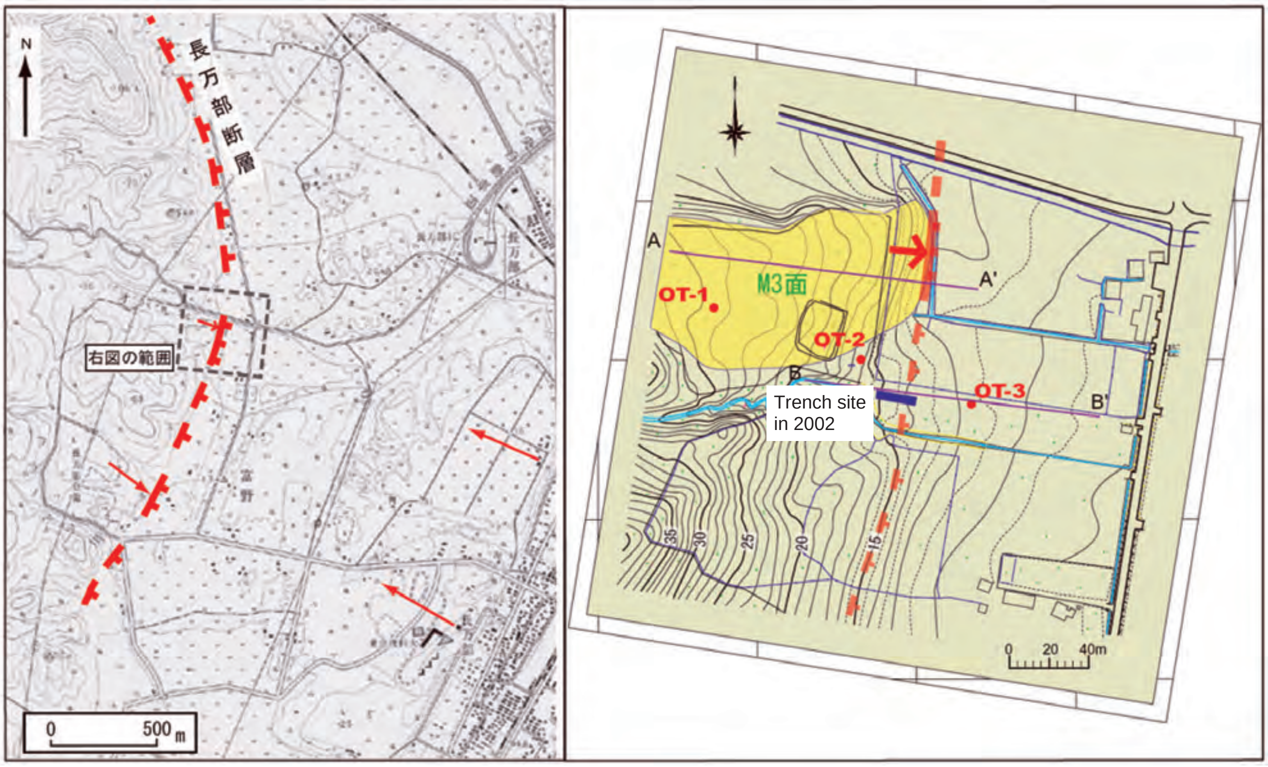


Fig. 27 Topographic map and distribution of active fault near Oshamambe Park (modified from Azuma et al., 2003)

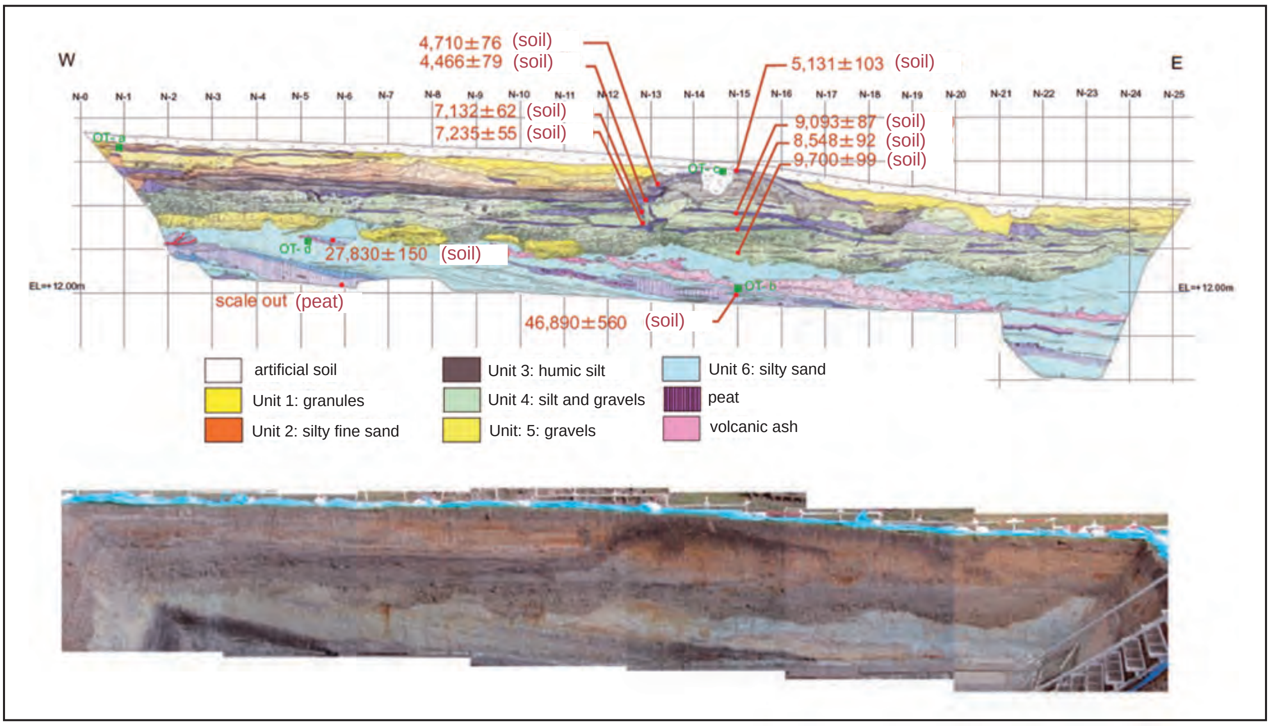


Fig. 28 Log and photo of north wall of 2002 Oshamambe trench (modified from Azuma et al., 2003)

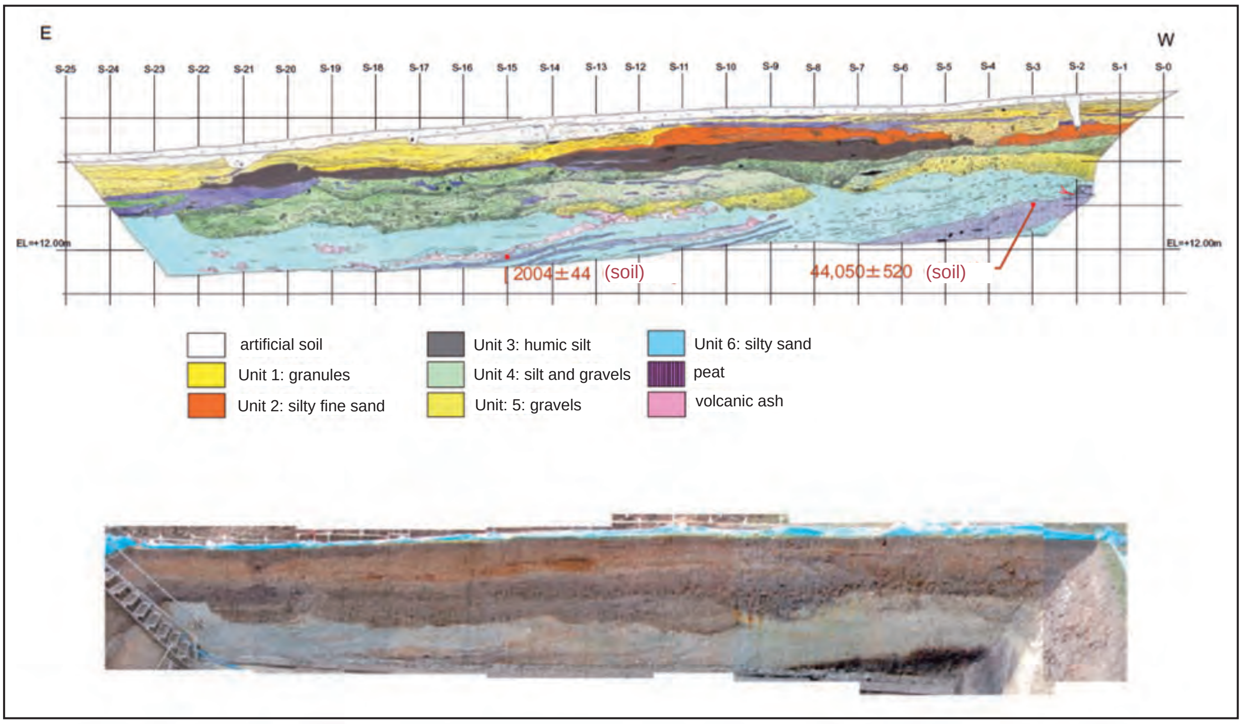


Fig. 29 Log and photo of south wall of 2002 Oshamambe trench (modified from Azuma et al., 2003)

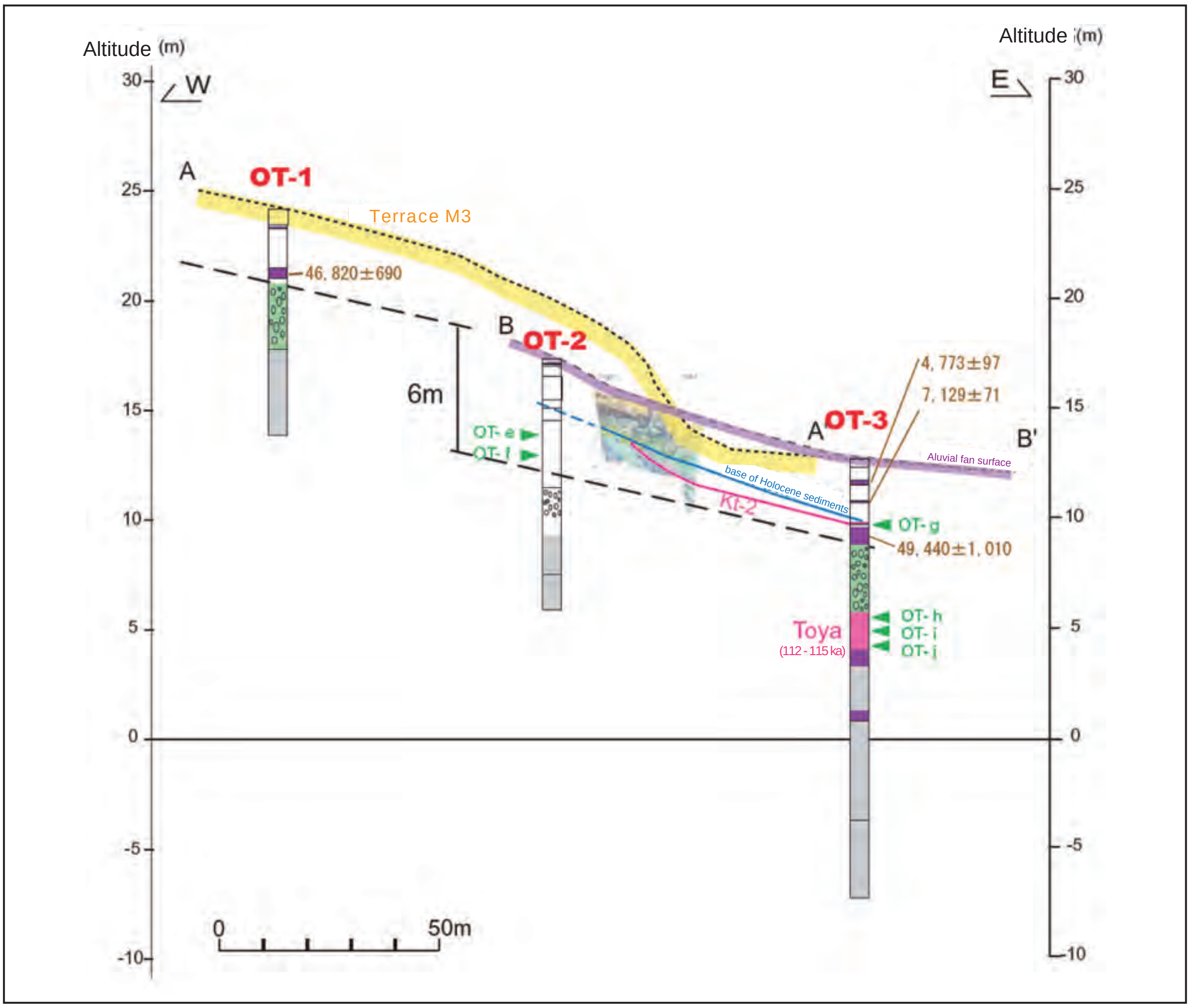


Fig. 30 Topographic and geologic section across Oshamambe fault (modified from Azuma et al, 2003)

Stop 3: Warabitai Fault

Warabitai fault and Chiragawa-ugan fault are mapped by Active Fault Research Group in Japan (1991) and are located in the central part of Kuromatsunai-teichi Fault Zone. We excavated two paleoseismological trenches in 2003 and 2004. From the result of 2003 trench, the latest faulting event occurred between 4,900-5,900 cal.yBP. Average recurrence interval of this fault zone is estimated as 3,600-5,000 years based on slip rate (0.5-0.7 m/ka in vertical) and amount of slip-per-event (2-3 m). Probability of occurrence of the future faulting event for the next 30 years is calculated as 2-5 % (HERP, 2005), which is the highest probability for active fault zone in Hokkaido.

2003 trench

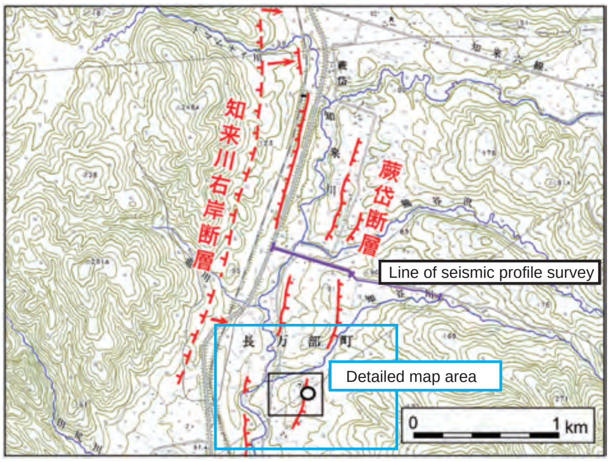


Fig. 31 Topographic map and distribution of active fault at Warabitai site (modified from Azuma et al., 2004)

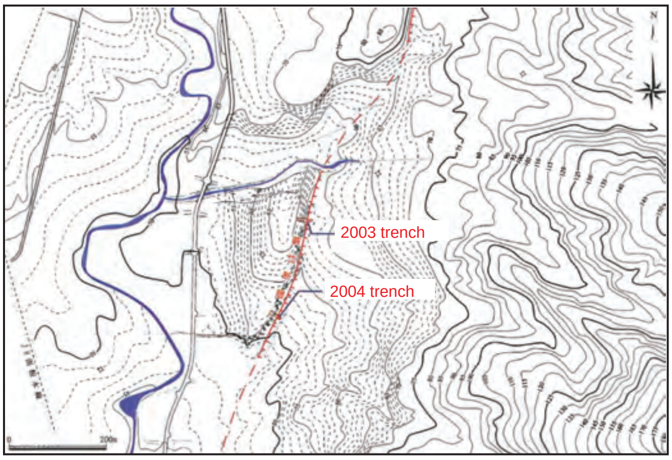


Fig. 32 Detailed topographic map around 2003 and 2004 Warabitai trench site (modified from AIST, 2005)

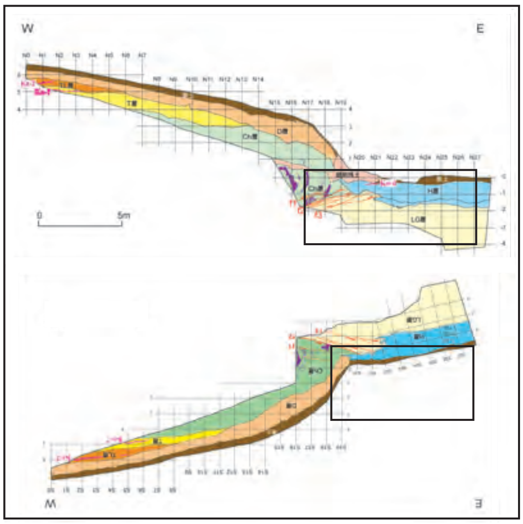


Fig.33 Logs of 2003 Warabitai trench (modified from Azuma et al., 2004)

Fig. 34 Photo of fault on south wall of 2003 Warabitai trench

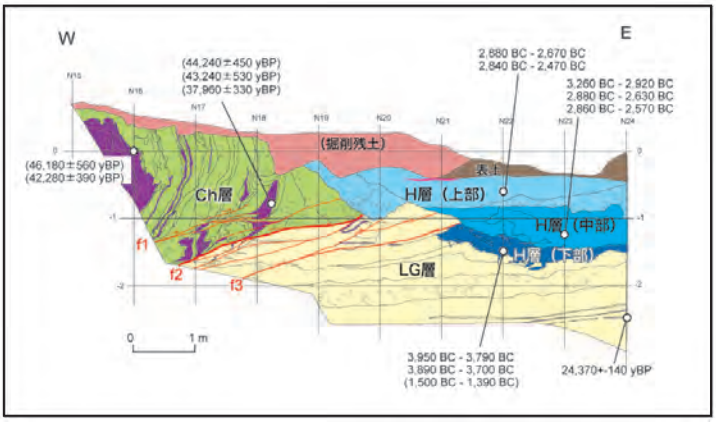


Fig. 35 Detailed log near fault on north wall and results of 14C dating of 2003 Warabitai trench (Azuma et al., 2004)

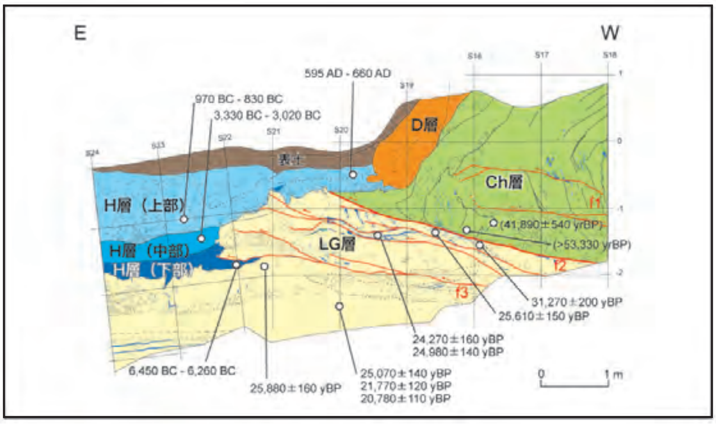


Fig. 36 Detailed log near fault on south wall and results of ^{14}C dating of 2003 Warabitai trench (Azuma et al., 2004)

2004 trench

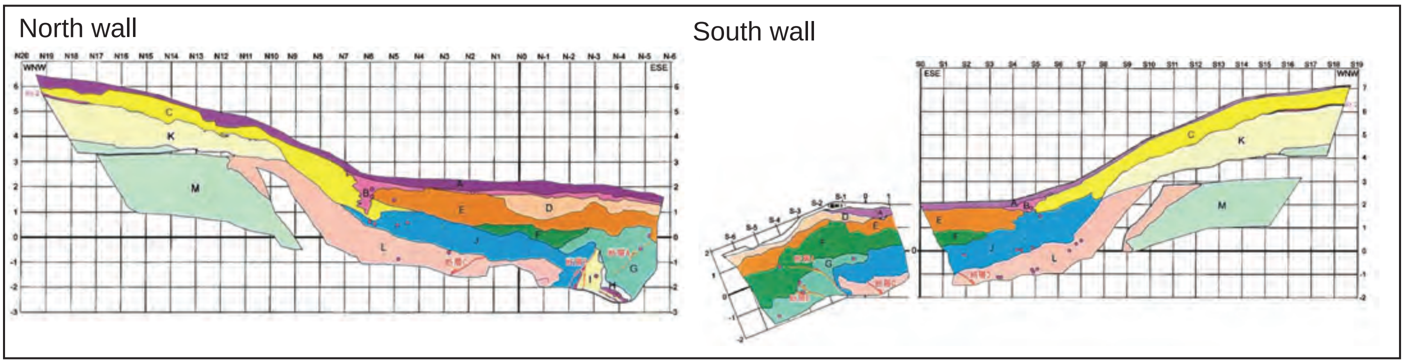


Fig. 37 Logs of 2004 Warabitai trench (modified from AIST, 2005)
Location of the trench is shown in fig.32.

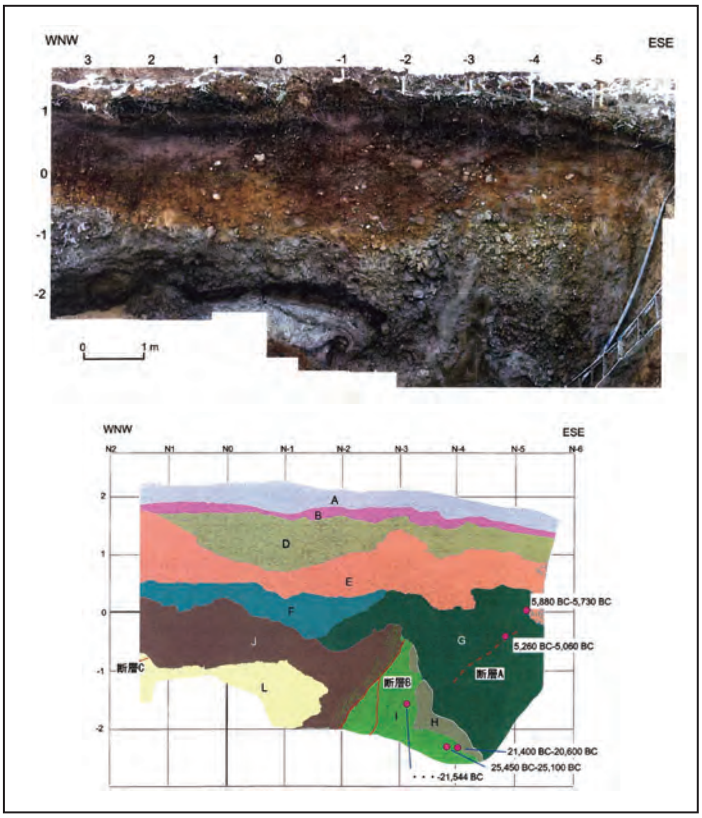


Fig. 38 Photo and log of the north wall of 2004 Warabitai trench (modified from AIST, 2005)
Results of ^{14}C dating are included.

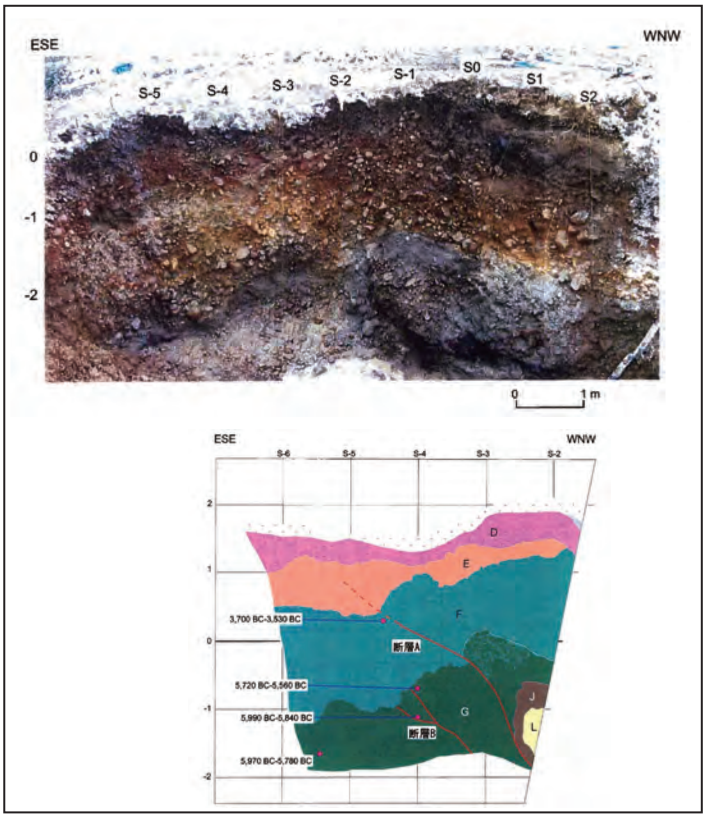


Fig. 39 Photo and log of the south wall of 2004 Warabitai trench (modified from AIST, 2005)
Results of ^{14}C dating are included.

Seismic reflection survey

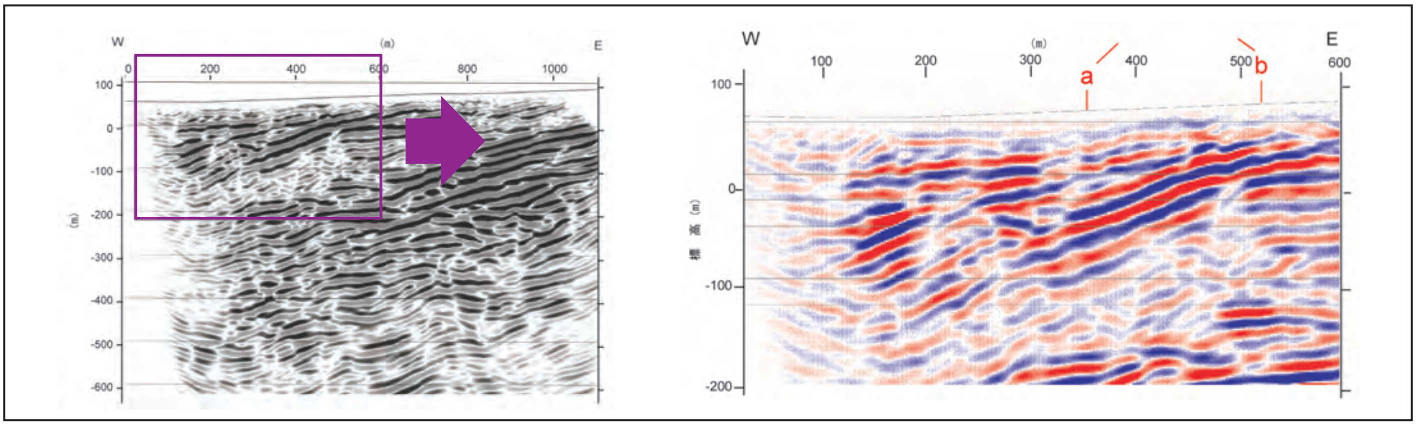


Fig. 40 Seismic profile across Warabitai fault (modified from Azuma et al., 2004)

Stop 4: Shirozumi-higashi fault

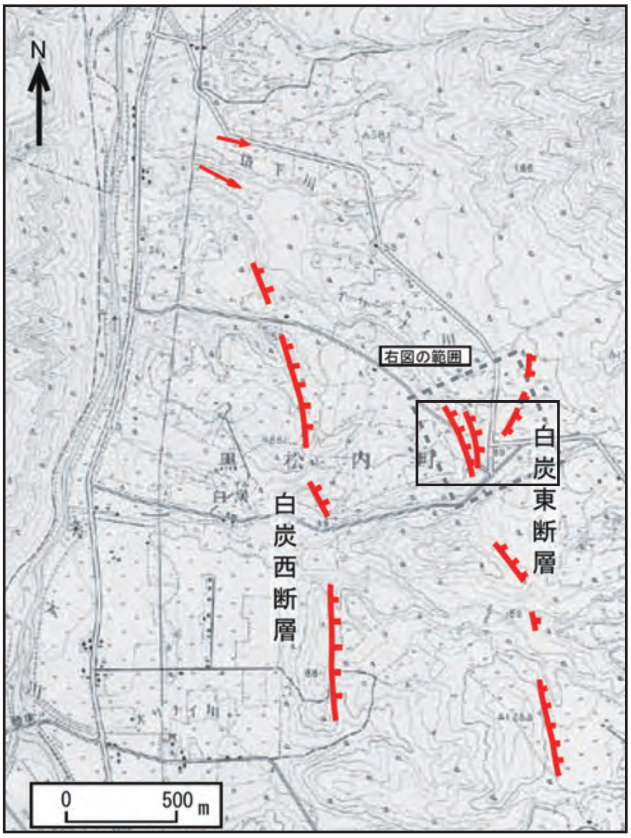


Fig. 41 Topographic map and distribution of active fault around Shirozumi site (modified from Azuma et al., 2003)

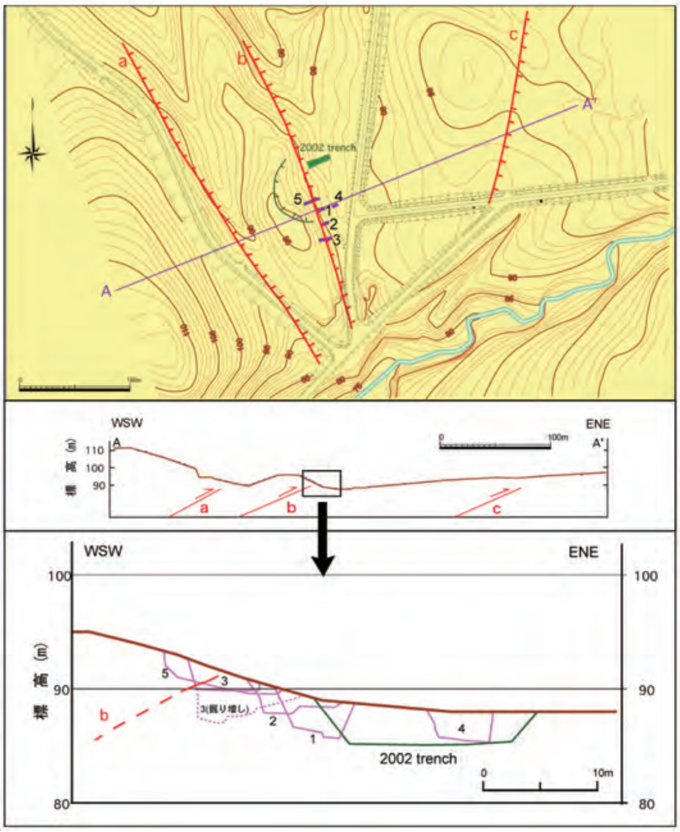


Fig. 42 Detailed topographic map and profiles of Shirozumi-higashi fault (modified from Azuma et al., 2004)

2002 trench

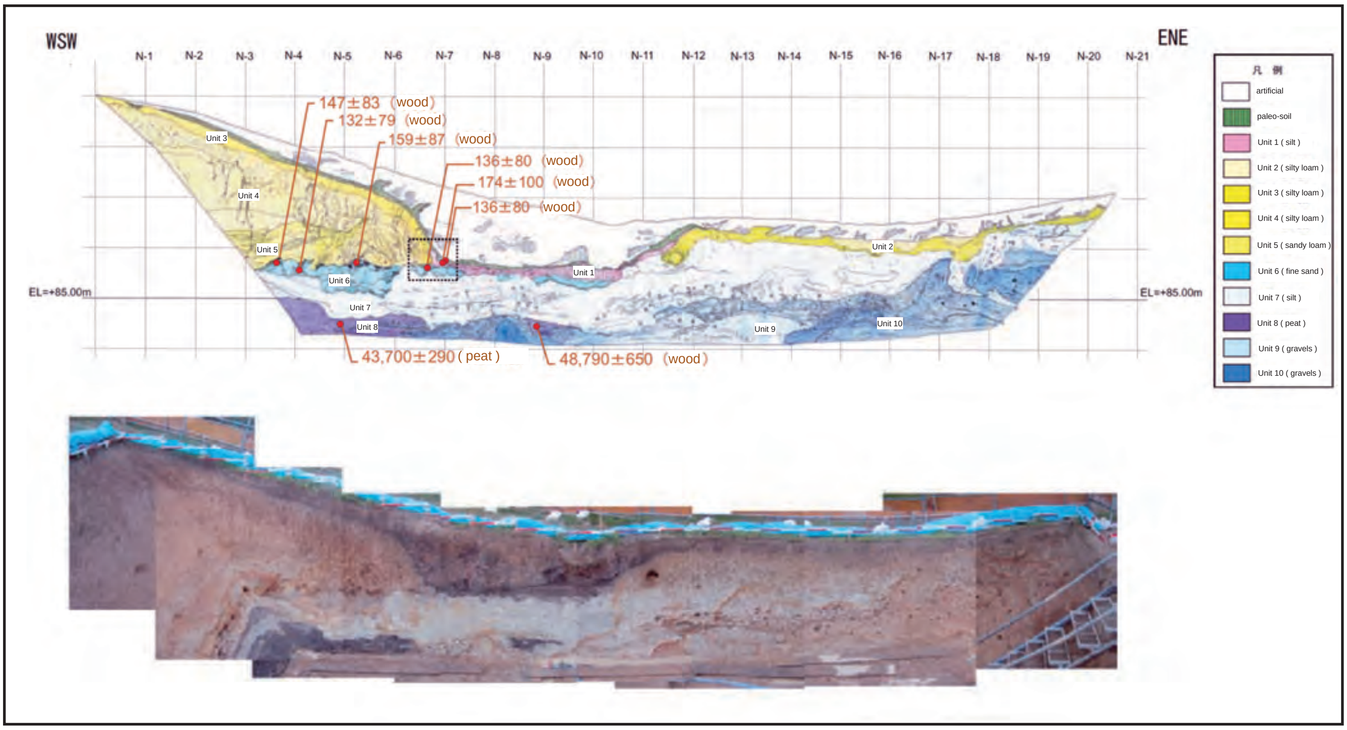


Fig. 43 Log and photo of north wall of 2002 trench at Shirozumi site (modified from Azuma et al., 2003)

2003 pit excavation survey

We conducted pit excavation survey in 2003 to find a fault of trace b of Shirozumi-higashi fault. We observed several reverse faults dipping to WSW, that cut sediments and loam. At the base of No. 3 pit, Toya pyroclastic flow deposits (112-115 ka; Machida and Arai, 2003) were observed although we could not find any samples for dating related to the age of the latest faulting event at this site.

Fig. 44 Photo of Shirozumi site before excavation

Fig. 45 Photo of the north wall of No.3 pit

Fig. 46 Photo of the south wall of No.3 pit

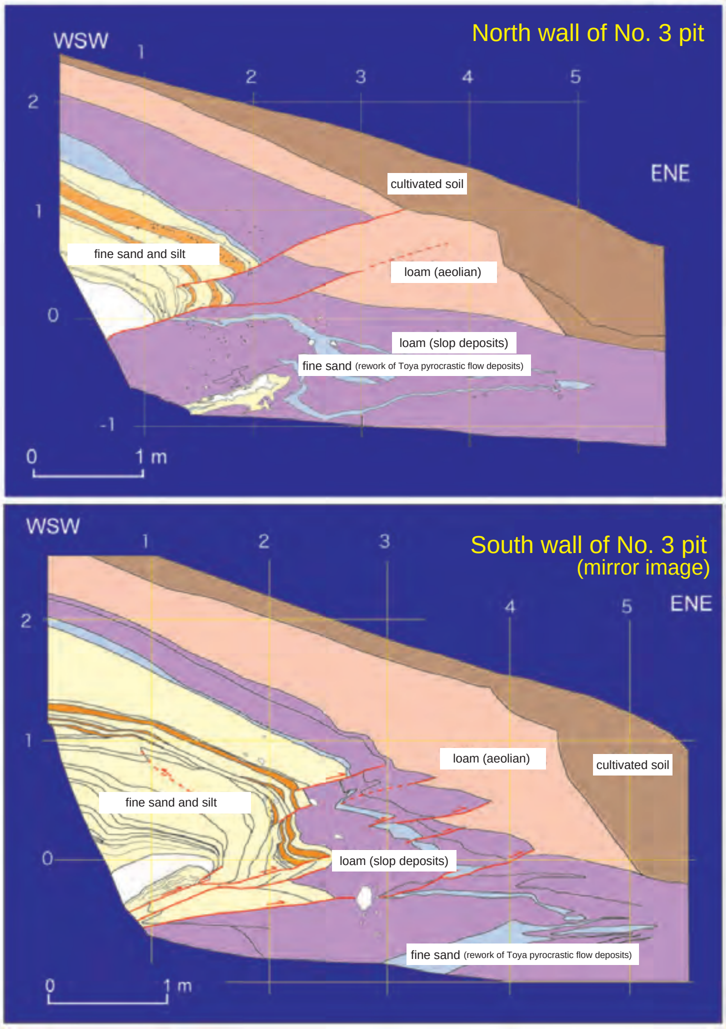


Fig. 47 Logs of No. 3 pit at Shirozumi site (modified from Azuma et al., 2004)

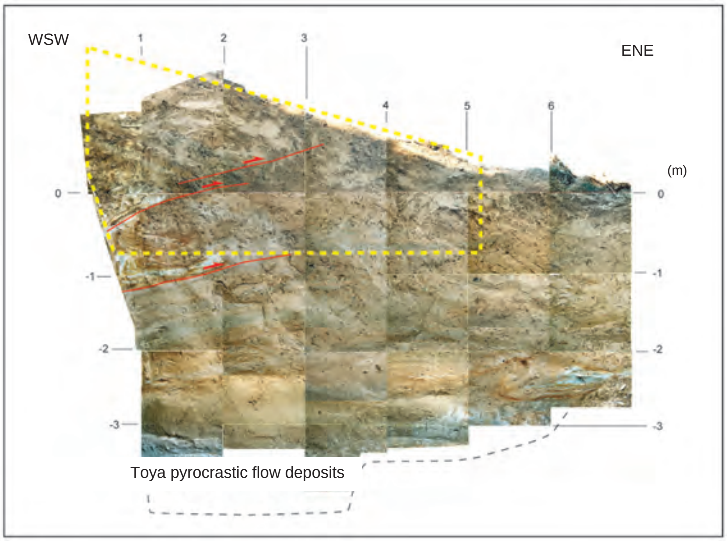


Fig. 48 Mosaic photo of deeper part of No.3 pit (modified from Azuma et al., 2004)

Stop 5: Utasutsu

Kuromatsunai-teichi fault zone is terminated at Utasutsu. On the eastern side of Suttsu plain, Utasutsu lineament is located, which is recognized as sharp end of mountain slope. On the other side of plain, there is Tarukishi fault, which formed small scarps and depressions on the mountain slope. Historical document recorded an earthquake and tsunami in AD 1792 in this area and its tsunami killed several people (Usami et al., 2013).

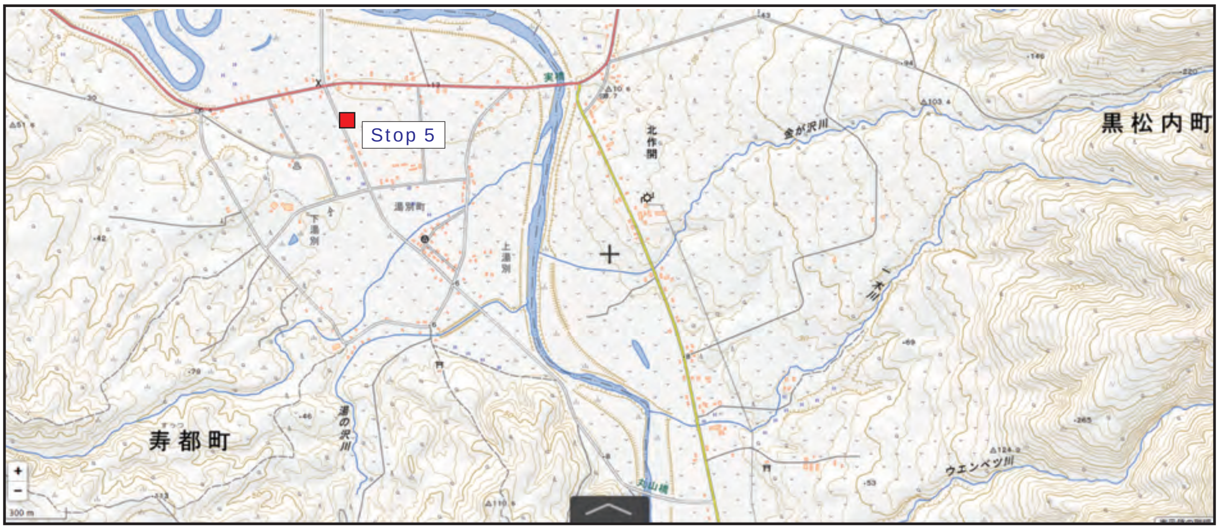


Fig. 49 Location of Stop. 5
Base map is from GSI Map

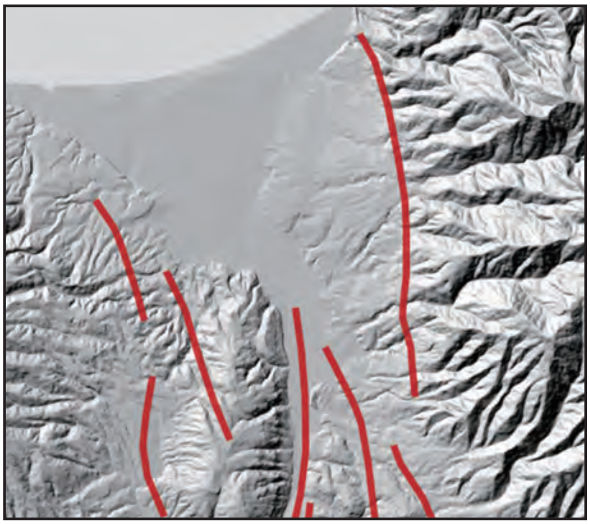


Fig. 50 Distribution of active faults around Utasutsu


Fig. 51 Photos of landscape at Utasutsu

Other active faults near Kuromatsunai

On the way to Niseko from Kromatsunai, we will pass by several faults. Shiribetsugawa fault is the most significant one and its northern end may extent to offshore. Short active faults at Mena, Akaigawa and Shiroigawa are not well surveyed yet.

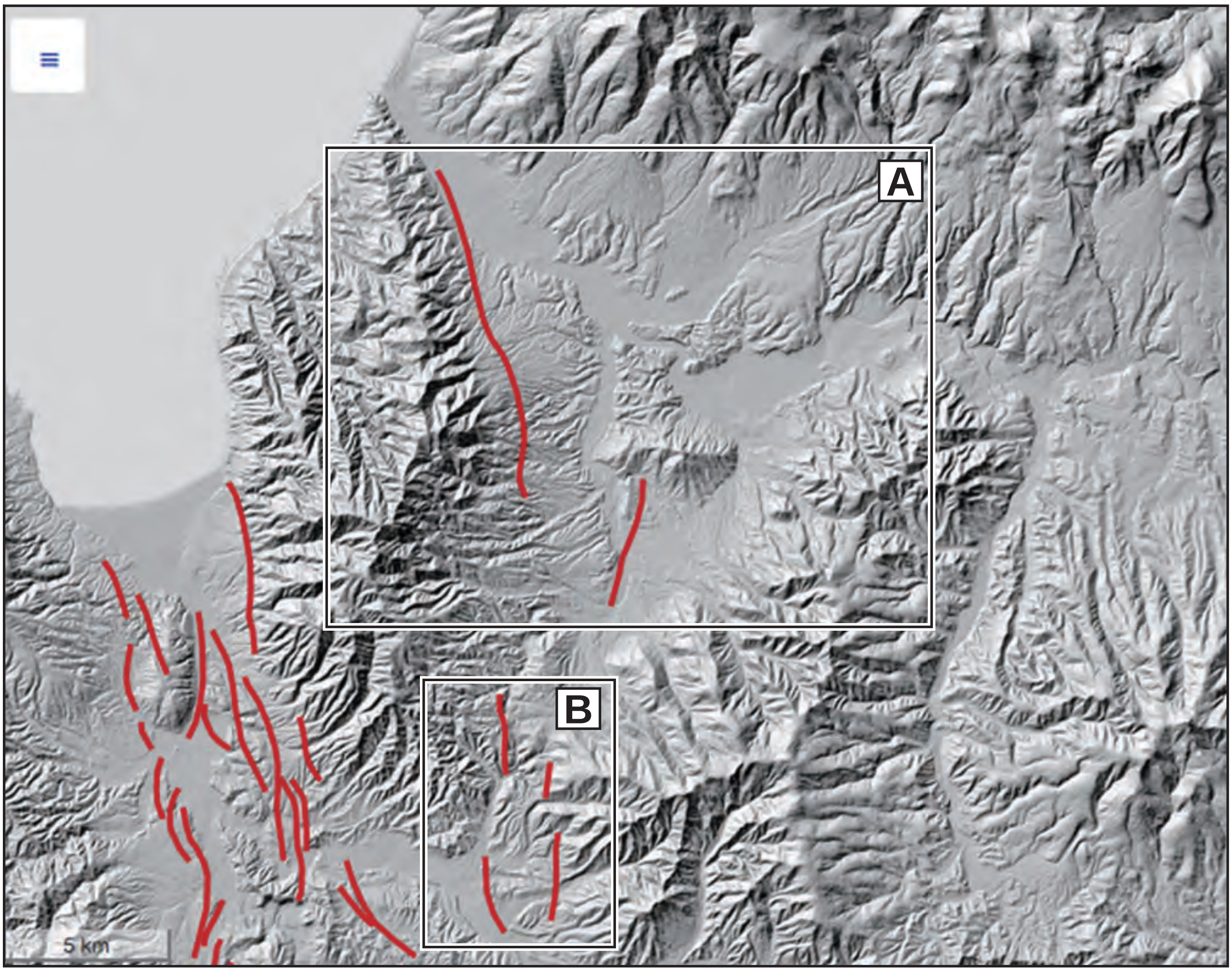


Fig. 52 Distribution of active faults in the area between Kuromatsunai and Niseko

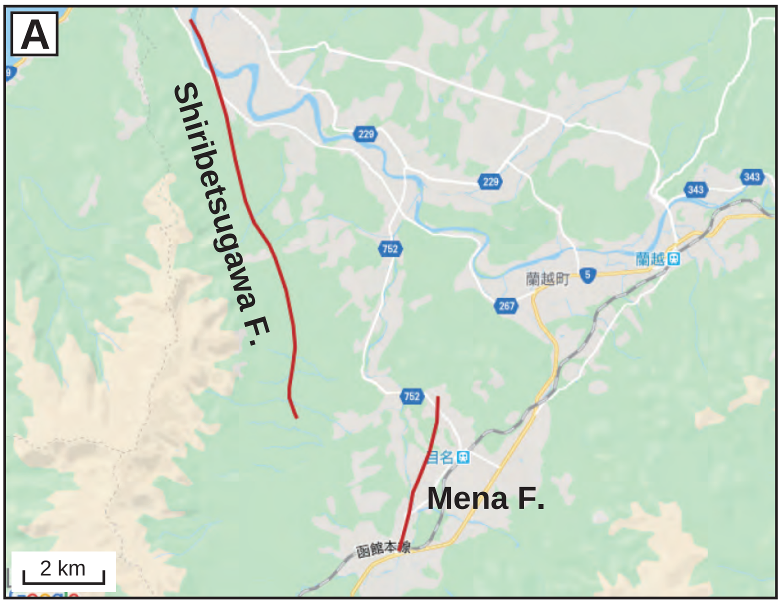


Fig. 53 Map of Shiribetsugawa fault and Mena fault

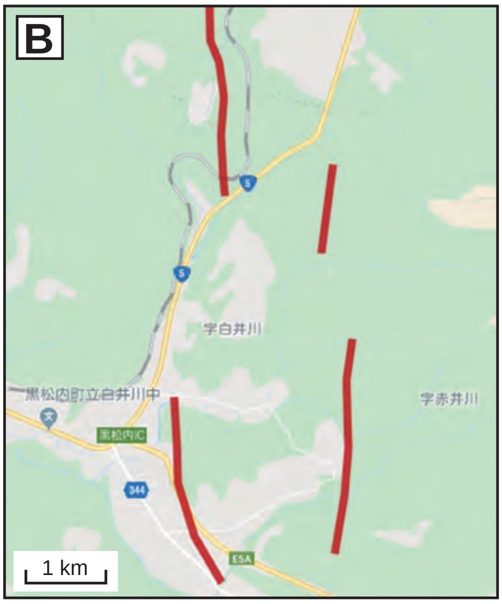


Fig. 54 Active faults in Akaigawa and Shiroigawa

Volcanoes in Niseko

Youtei volcano

Youtei volcano is one of stratvolcanoes in Hokkaido. It has another name of Ezo-Fuji, meaning Mt. Fuji in Hokkaido. Its height is 1,898 m in altitude. Most of lava flows on surface was produced by eruptions after deposition of Spfl-1 from Shikotsu Caldera in ca. 40 ka. The latest eruption seems to have occurred ca. 1,000 years ago. Lake Hangetsu on the western foot of this mountain was formed by a flank eruption.

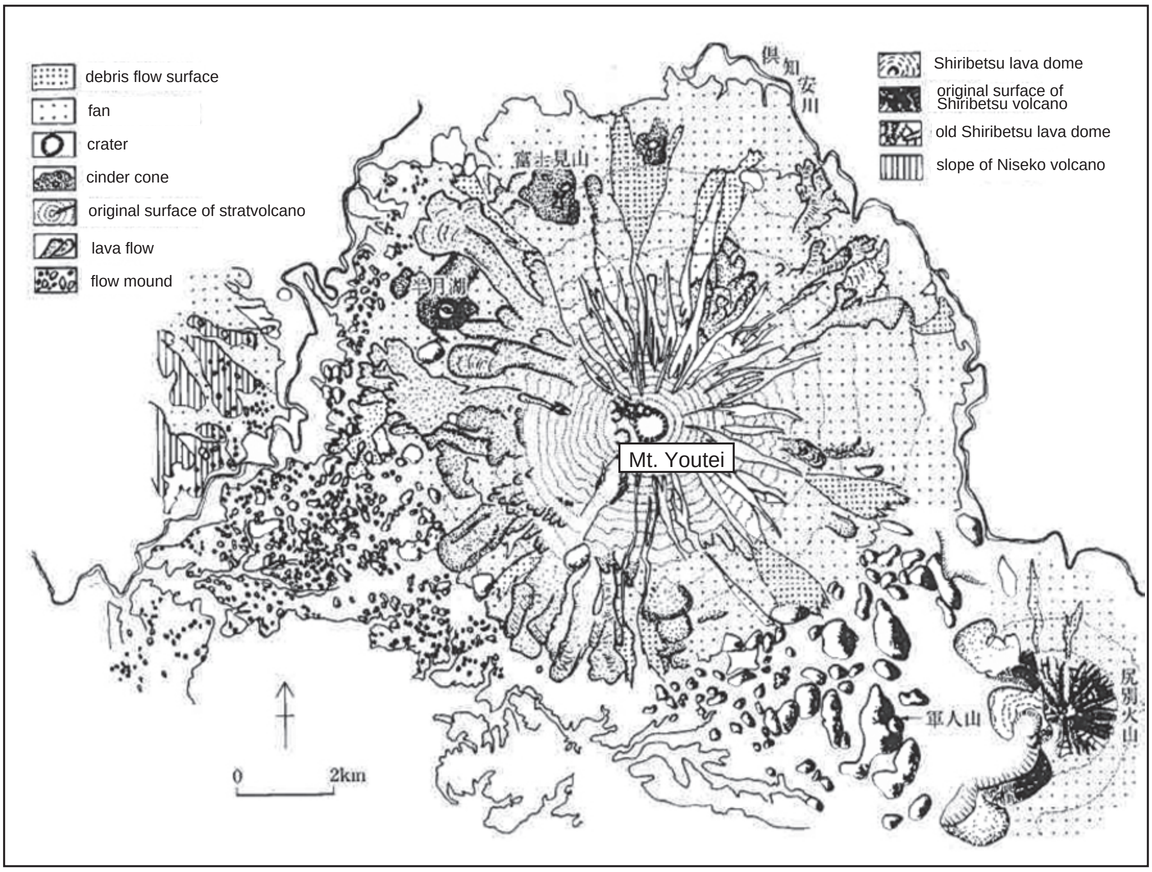


Fig. 55 Geomorphological map of Youtei volcano
(modified from Koaze et al., 2003)

Fig. 56 Photo of Youtei volcano

Nisekoannupuri volcano

Nisekoannupuri is one of the lava domes of Niseko volcanoes. Its peak is 1,212 m in height. It was accompanied by several lava flows. Nisekoannupuri is seemed is to be formed before the Last Glacial Maximum, whereas Iwaonupri formed several thousands years ago. Raiden-yama, Iwanai-dake and Mekunnai-dake were lava domes erupted during 1.4-0.49 Ma. Weisshorn is old stratovolcano during 1.4-1.0 Ma, named after a mountain in Swiss. There are good ski slopes and hot spas around Nisekoannupuri. “Nupuri” means “mountain” in Ainu language.

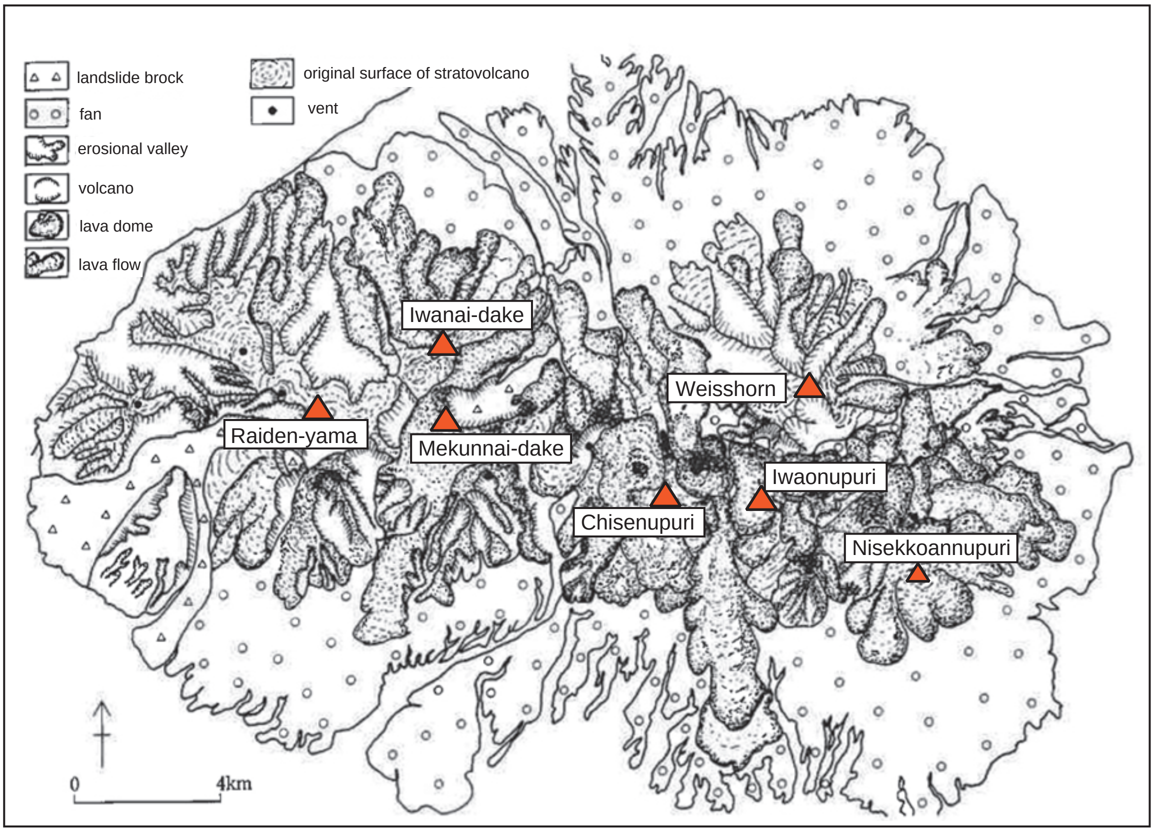


Fig. 57 Geomorphological map of Nisekoannupuri
(modified from Koaze *et al*., 2003)

Day 2 Landslides caused by 2018 earthquake

The 2018 Hokkaido Eastern Iburi earthquake (M_{JMA} 6.7, depth=37 km) occurred on 6 September 2018 in the southern part of central Hokkaido. Epicenter of this earthquake was located near the southern part of Ishikari-teishi-touen fault zone. Focal depth of tmainshock was much deeper than the fault plane of that fault zone based on seismic reflection surveys and distribution of aftershocks showed rather high angle than fault plane, which had modeled before earthquake.

This earthquake caused many landslides in and around Atsuma town. The reasons of occurrence of many of landslides were not only strong ground motion near epicenter, but also existence of thick tephra layers on the hill slope. Origins of these tephras were Mt. Tarumae and Mt. Eniwa near Lake Shikotsu, which was produced by a huge caldera eruption in ca. 40 ka.

Stop 6: Lake Shikotsu

Sources of tephras, Shikotsu Caldera, Mt. Tarumae, Mt. Eniwa

Stop 7: Huge landslide at Horonai

Collapse of bedrock

Stop 8: Landslide related to tephra layers at Sakuraoka

Landslide, En-a pumice, Ta-d pumice

Fig. 58 Route map of Day 2

The 2018 Hokkaido Eastern Iburi Earthquake

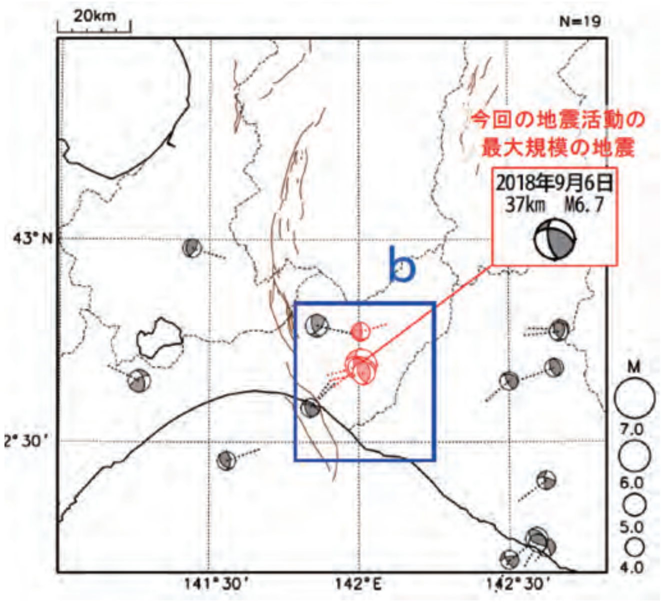


Fig. 59 Fault plane solutions of earthquakes from 1 October 1997 to 6 September 2018 around source area of the 2018 Hokkaido Eastern Iburi earthquake (reported by JMA)

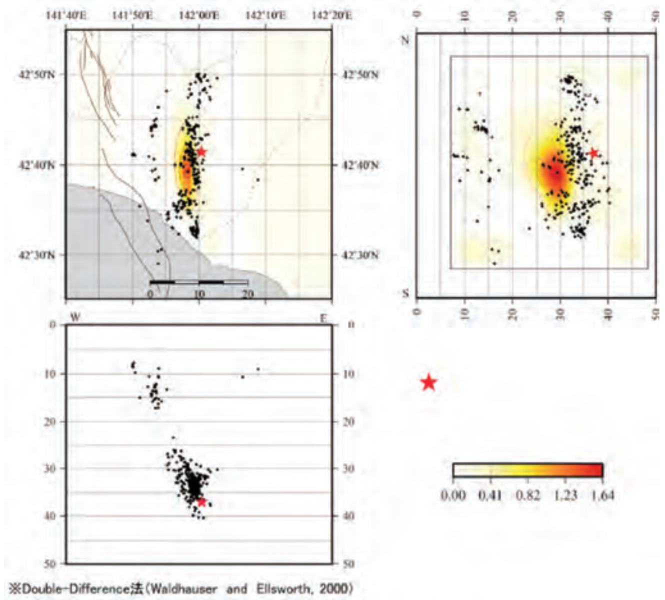


Fig. 60 Distribution of epicenters of main shock and aftershock of the 2018 Hokkaido Eastern Iburi earthquake (reported by JMA)

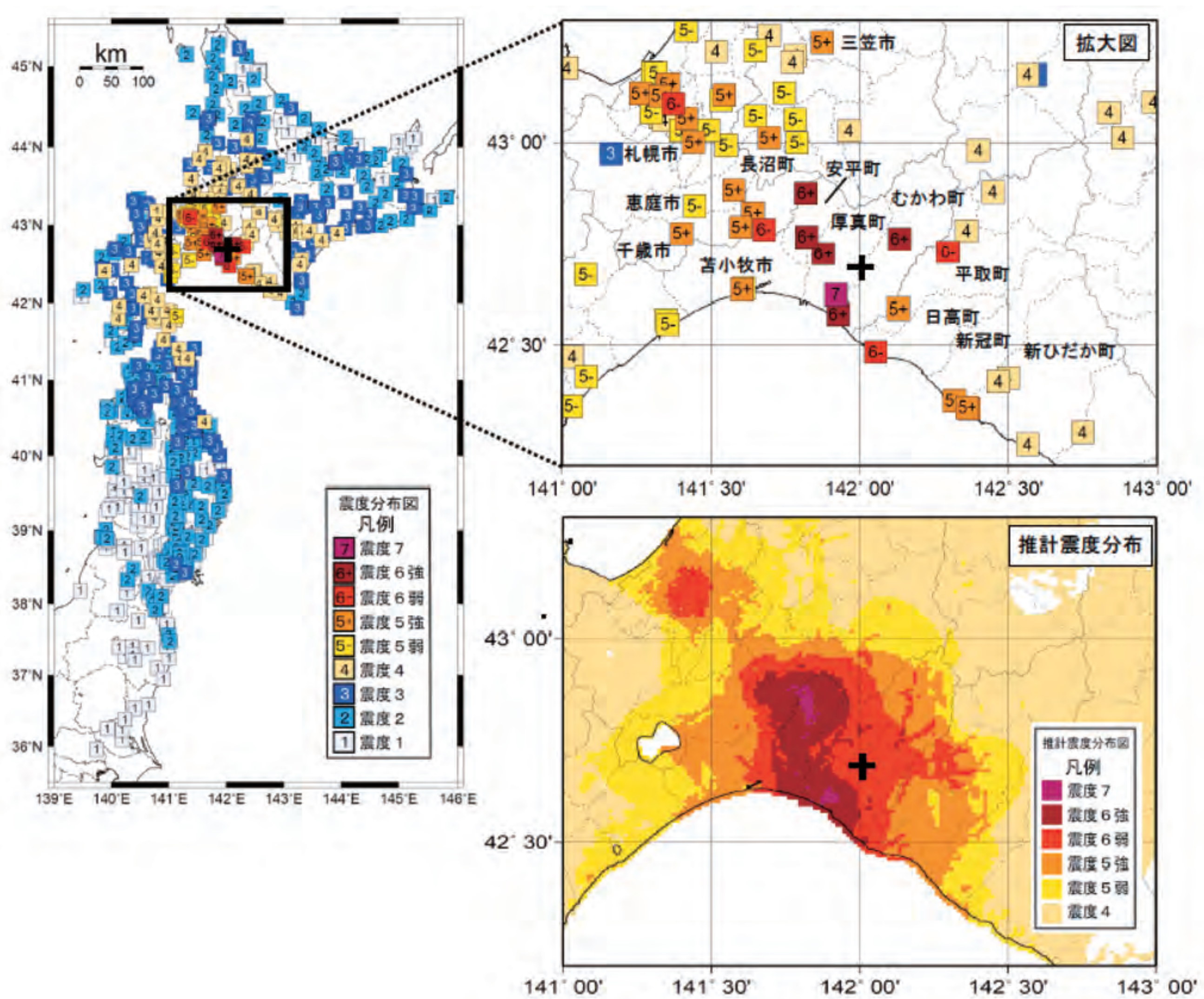


Fig. 61 Distribution of seismic intensity around source area of the 2018 Hokkaido Eastern Iburi earthquake (reported by JMA)

Stop 6: Lake Shikotsu

Lake Shikotsu is located in the south to Sapporo and in the west to Chitose. It is a part of Shikotsu-Toya National Park. On the sides of this lake, there are active volcanoes, Tarumae, Fuppushi and Eniwa. It is one of the most famous places by good views, whereas some tephras from these volcanoes caused occurrence of landslides during the 2018 Hokkaido Eastern Iburi Earthquake.

Shikotsu caldera

Lake Shikotsu is a caldera lake with 13 km in diameter and > 400 m in depth. Thick deposits of pyroclastic flow (Spfl-1), erupted in ca. 40,000 years ago, are widely distributed around this lake to near Sapporo to the north and Tomakomai to the south. Before eruption of pyloclastic flow, there was a large Plinian eruption with pumice fall (Spfa-1).

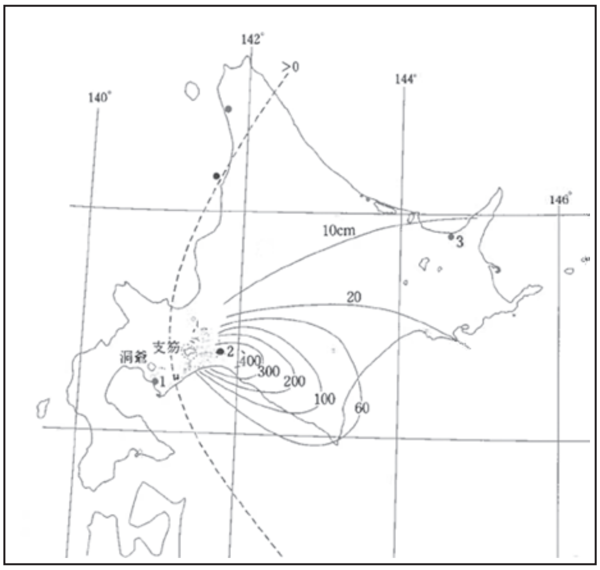


Fig. 62 Distribution and thickness of Spfa-1
(Machida and Arai, 2003)

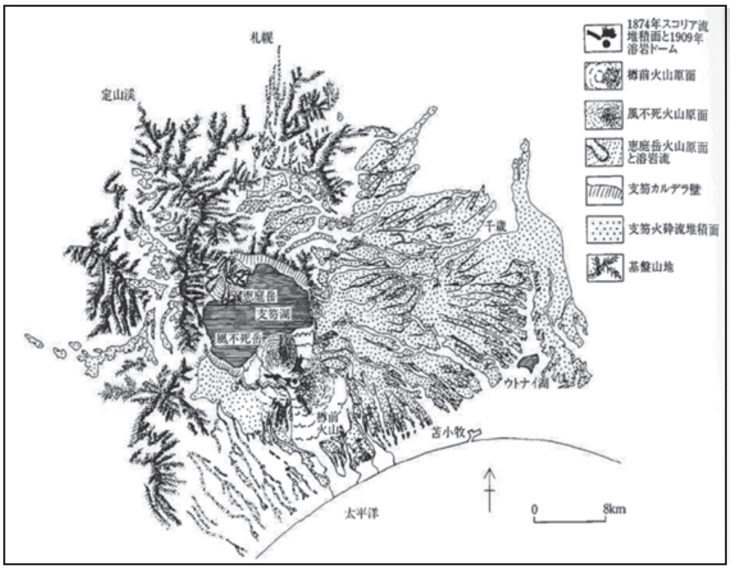


Fig. 63 Geomorphologic map around Lake Shikotsu
(Koaze et al., 2003)

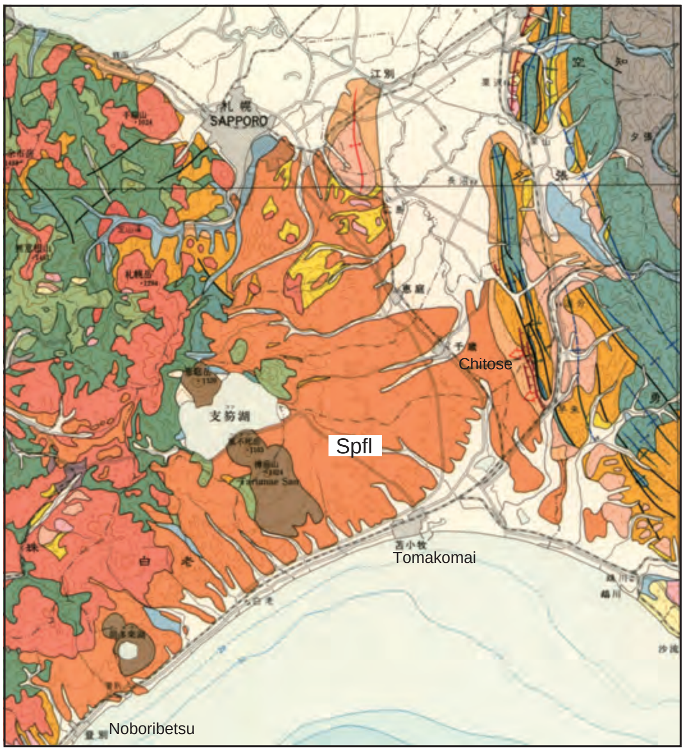


Fig. 64 Geological map around Lake Shikotsu
(Sangawa et al., 1984)

Tarumae volcano

Tarumae volcano is located in the southeast of Lake Shikotsu. Volcanic activity has started since ca. 9,000 years ago. Large eruption occurred 9 ka (Ta-d), 3 ka (Ta-c), AD 1667 (Ta-b) and 1739 (Ta-a). On the top of Tarumae, there are small caldera and lava domes, which was created in 1909. This volcano is still very active and erupted several times in the last Century. Fuppushi volcano is located in the north of Tarumae. Its activity started since ca. 30,000 years ago.

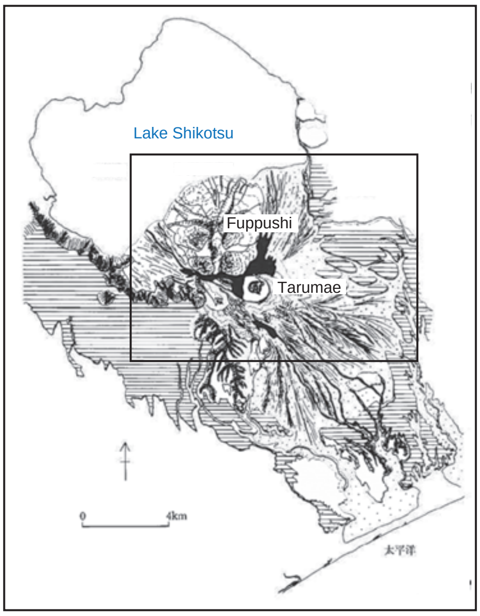


Fig. 65 Topographic map of Tarumae volcano (modified from Koaze et al., 2003)

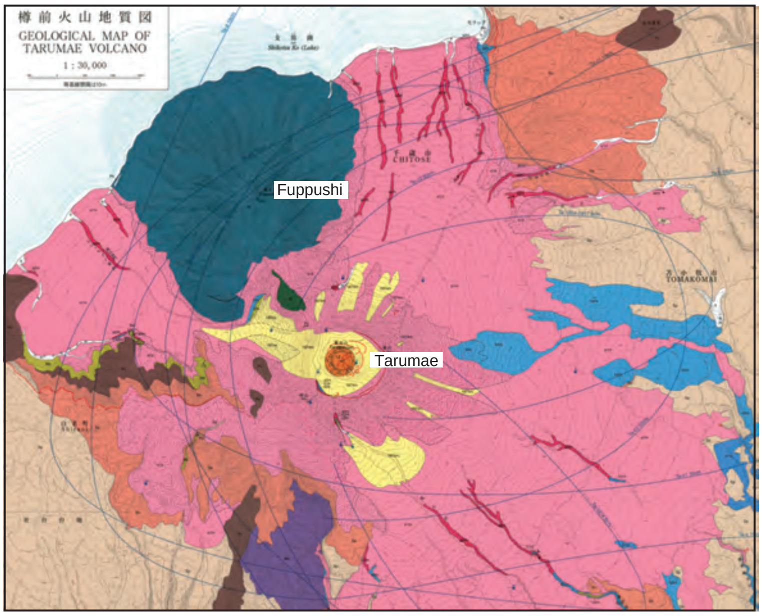


Fig. 66 Geological map of Tarumae volcano (modified from Furukawa and Nakagawa, 2010)

Eniwa volcano

Eniwa volcano is located in the northwest of Lake Shikotsu. There are many lava flows on the slope. There are several explosive craters on the top, indicating steam eruption occurred several times in the last thousands years. This volcano had a large Plinian eruption in 20 ka, which produced En-a tephra, widely distributed in Hokkaido.

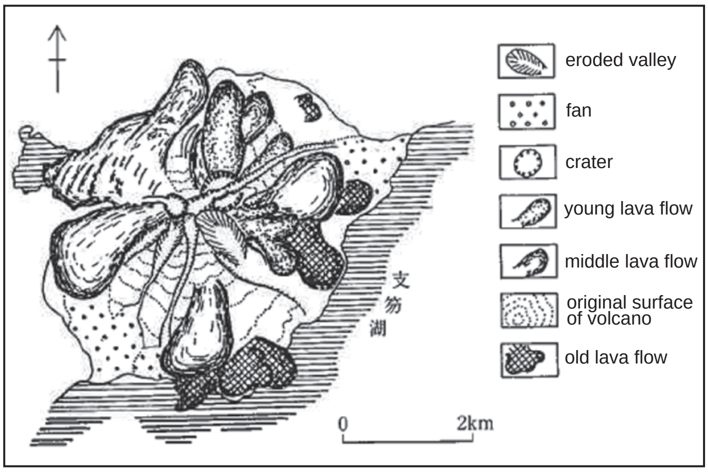


Fig. 67 Topographic map of Eniwa volcano (modified from Koaze et al., 2003)

Fig. 68 Photo of Eniwa volcano

Stop 7: Huge landslide at Horonai

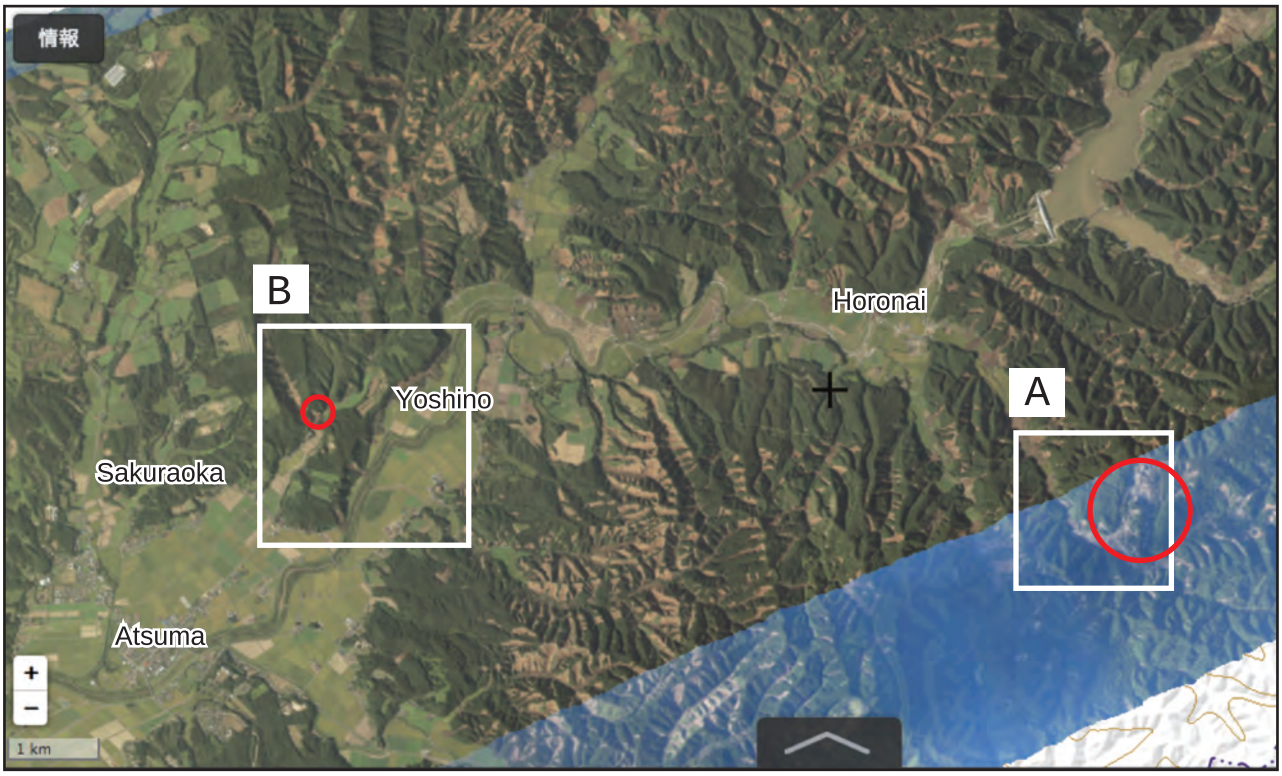


Fig. 69 Air photo in the northern part of Atsuma town, where many landslides occurred by strong ground motion (modified from GSI data)

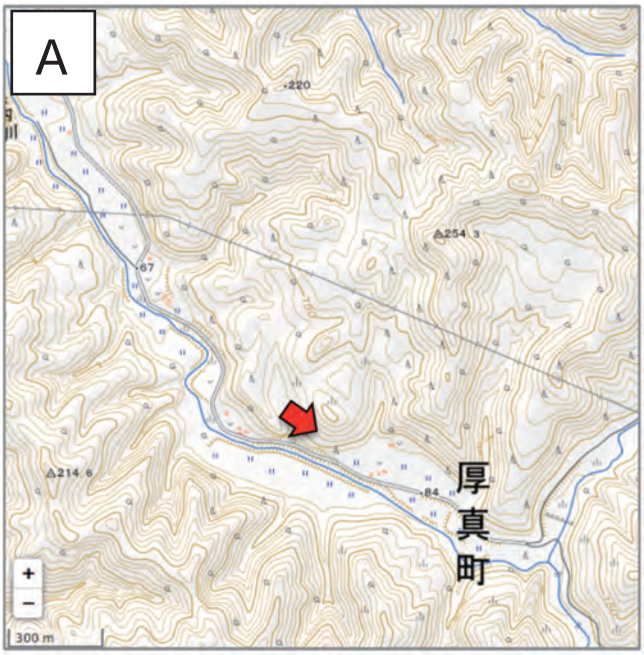


Fig. 70 Topographic map around Horonai site (modified from GSI data)

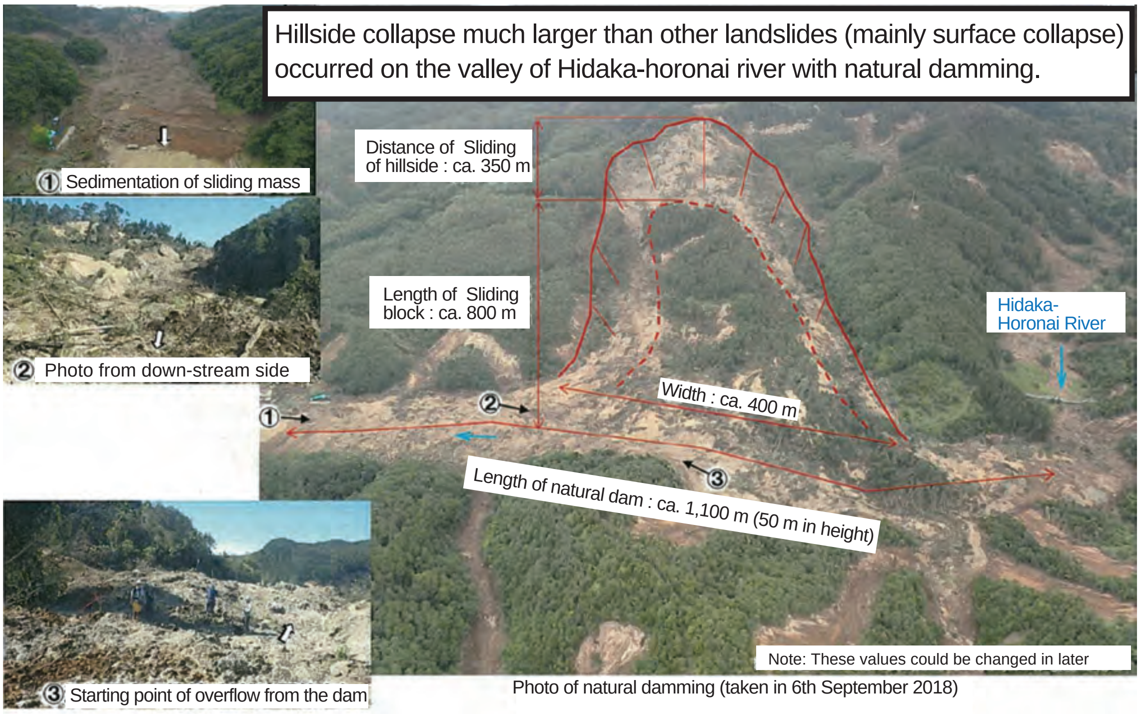


Fig. 71 Photo of the largest landslide caused by the 2018 Hokkaido Eastern Iburi earthquake (modified from a report by Hokkaido Regional Development Bureau)

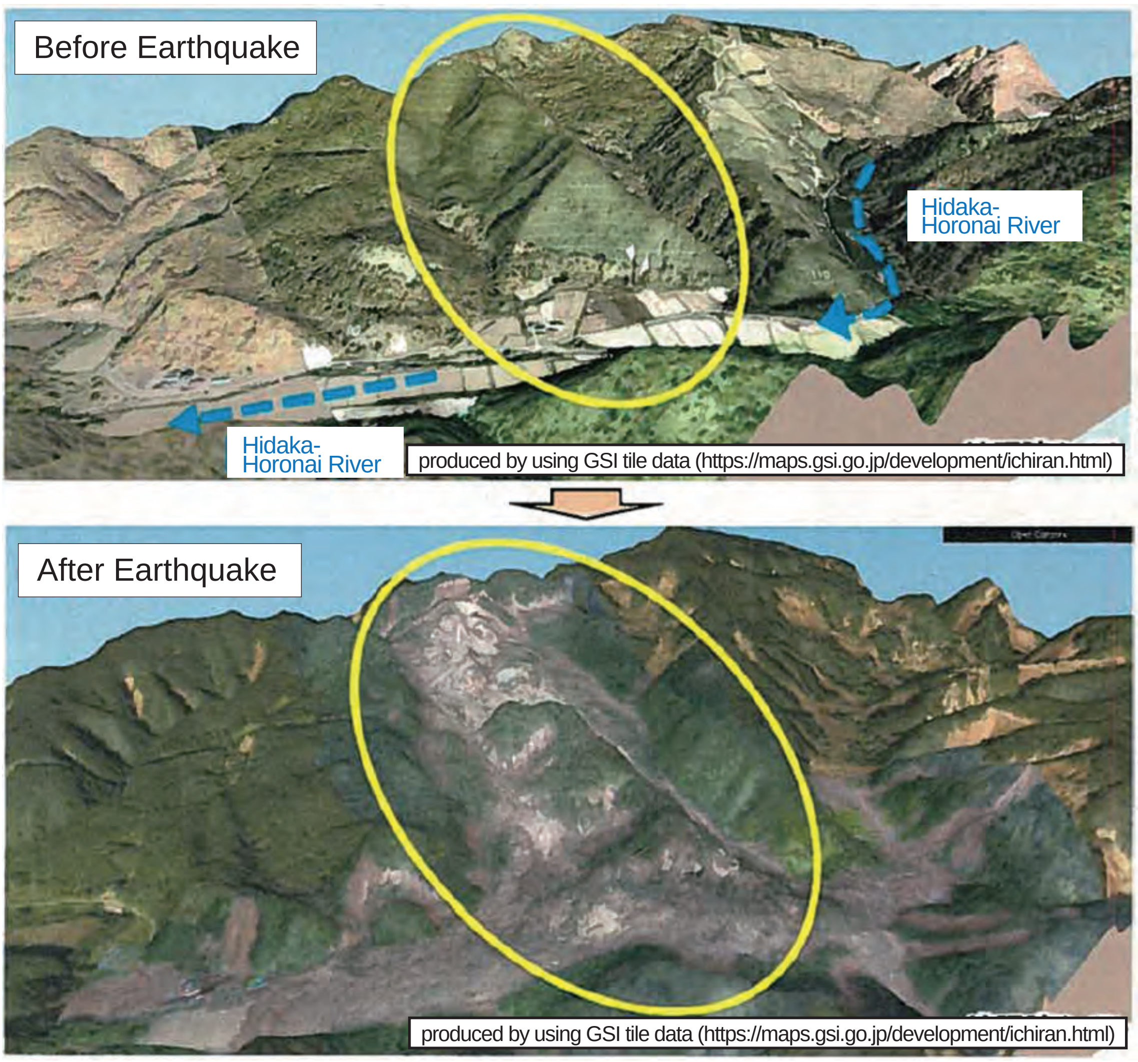


Fig. 72 Comparison of landform before and after the 2018 Hokkaido Eastern Iburi earthquake (modified from a report by Hokkaido Regional Development Bureau)

Stop 8: landslide related to tephra layers at Sakuraoka

We will stop at a large landslide near Sakuraoka in Atuma Town. This site is located close to Yoshino, where several people were killed by landslides. A landslide with ca. 100 m in width and length occurred and massed flew down about 100 m in the valley bottom. Masses slid on bottom of tephra layer of Ta-b, which was erupted from Mt. Tarumae in 9 ka. On the side walls of landslide, we can observe a series of tephras from Tarumae and humic soil (Fig. 74).

Fig. 73 Topographic map around Sakuraoka
(Base map is from GSI Map)

Fig. 74 Photo of tephra layers at Sakuraoka

Fig. 75 Photo of landslides at Sakuraoka

Landslide related to tephra layers

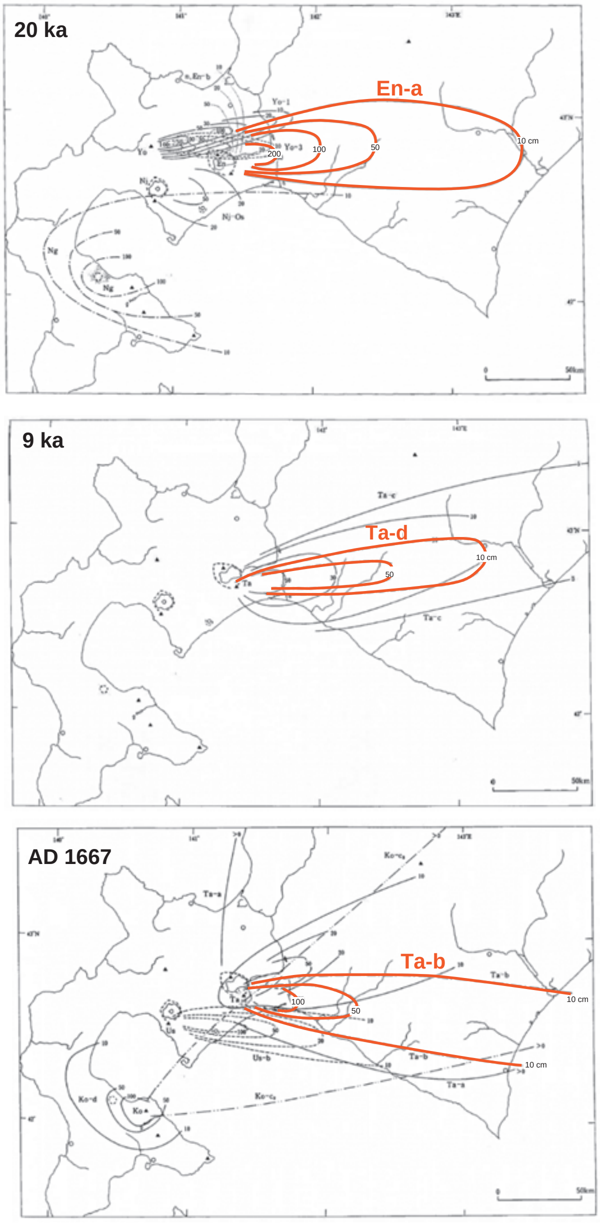


Fig. 76 Distribution and thickness of En-a, Ta-d, Ta-b tephra (Machida and Arai, 2003)

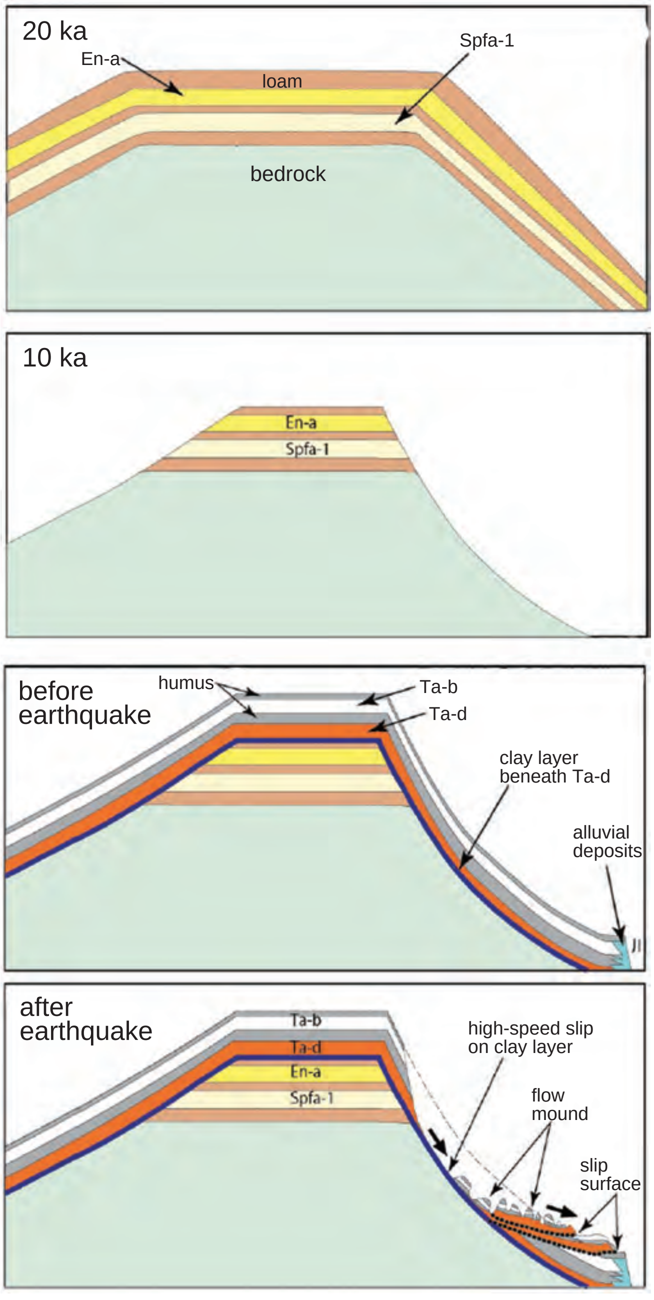


Fig. 77 Process of occurrence of landslide related tephra layers (modified from Hirose et al., 2018)

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