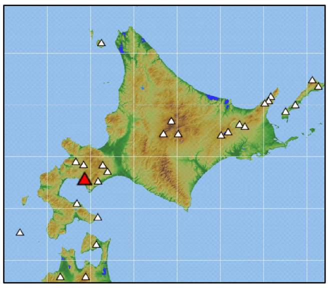
15.Usuzan



Continuously Monitored by JMA

Latitude: 42°32'38" N, Longitude: 140°50'21" E, Elevation: 733 m (Usuzan) (Elevation Point)

Latitude: 42°32'33" N, Longitude: 140°51'52" E, Elevation: 398 m (Showashinzan) (Elevation Point)

Latitude: 42°32'39" N, Longitude: 140°49'51" E, Elevation: 669 m (Usushinzan)

(Triangulation Point - Usudake)

Overview of Usuzan taken from south side on March 16, 2012 by the Japan Meteorological Agency

Summary

Usuzan is a group of stratovolcanoes and lava domes which was formed on the south wall of the Toya caldera approximately 10,000 to 20,000 years ago. It is composed of a basalt-basaltic andesite stratovolcano with a somma with a diameter of approximately 1.8 km, a flank volcano (the Donkoroyama scoria cone), 3 dacite lava domes (Ko-Usu, O-Usu, and Showashinzan), and many cryptodomes (Nishiyama, Konpirayama, Nishimaruyama, Meijishinzan, Higashimaruyama, Ogariyama, Usushinzan, and the 2000 uplift area, etc.). The summit collapsed between 7,000 and 8,000 years ago, causing a debris avalanche to the south (the Zenkoji debris avalanche). After a long period of dormancy, volcanic activity resumed in 1663. Since then, summit eruptions have repeatedly ejected rhyolite-dacite magma pumice and volcanic ash. Pyroclastic flows and pyroclastic surges occurred. After 1910, phreatomagmatic and phreatic eruptions occurred at the foot of the volcano as well, and volcanic lahar flowed from the crater. The activity frequently included the rise of highly viscous magma, forming lava domes and cryptodomes. A high number of felt-earthquakes and prominent crustal deformation have been notable as precursors of eruptions (Soya et al., 2007). The SiO_2 content is between 49.3 and 73.1 wt %.

Photos

I-crater viewed from southwest on May 10, 2011 by the Japan Meteorological Agency

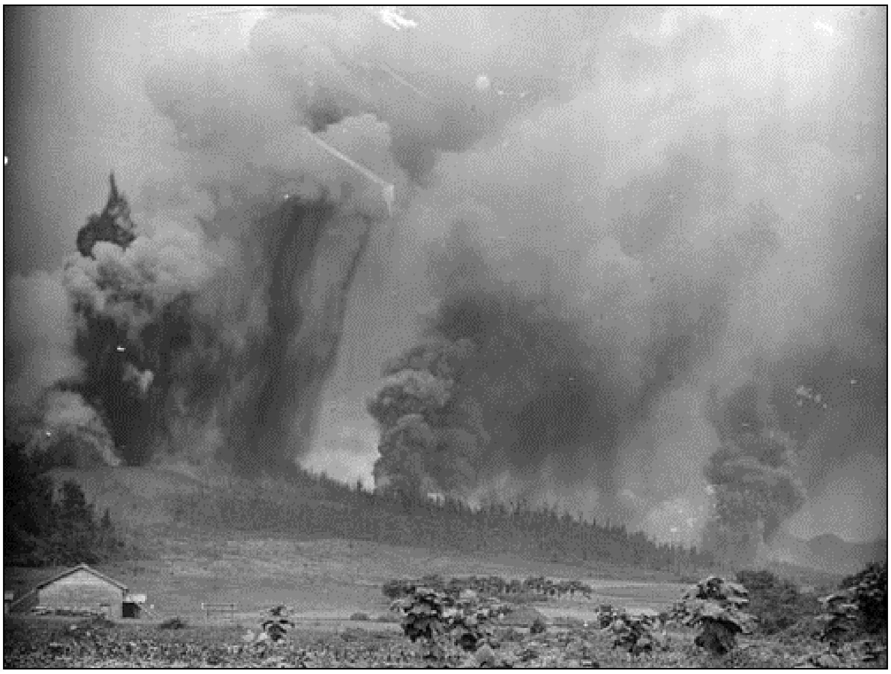
K-A crater (slightly above center) and K-B crater (Left), taken from northeast side on July 19, 2011 by the Japan Meteorological Agency

N-B Crater (Center), taken from northeast side on July 19, 2011 by the Japan Meteorological Agency

Gin'numa Crater, taken from Ogariyama to northeast On May 10, 2011 by the Japan Meteorological Agency

Showashinzan, taken from southwest side on May 22, 2007 by the Japan Meteorological Agency

Old National Road 230 Graben, taken from northeast side on July 2, 2000 Courtesy of C. Inaba



Eruption on August 2, 1910, taken from Lake Toya (Omori, 1911)

Eruption on July 3, 1944 (Minakami et al., 1951)

Eruption on August 7, 1977, taken from Sobetsu to the northeast by the Japan Meteorological Agency

Eruption on March 31, 2000, taken from southwest side

Courtesy of Asia Air Survey Co., Ltd.

Topography around the Crater

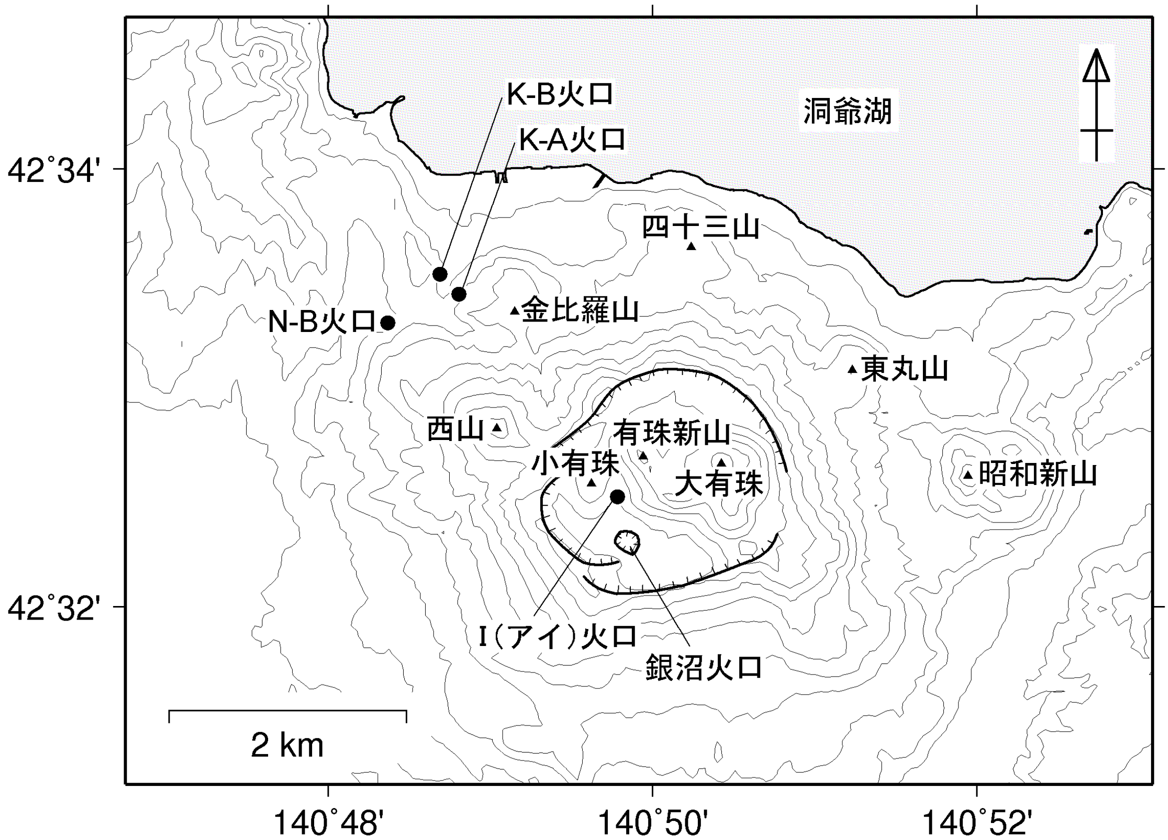


Figure 15-1 Detailed topography of the crater area.

Red Relief Image Map

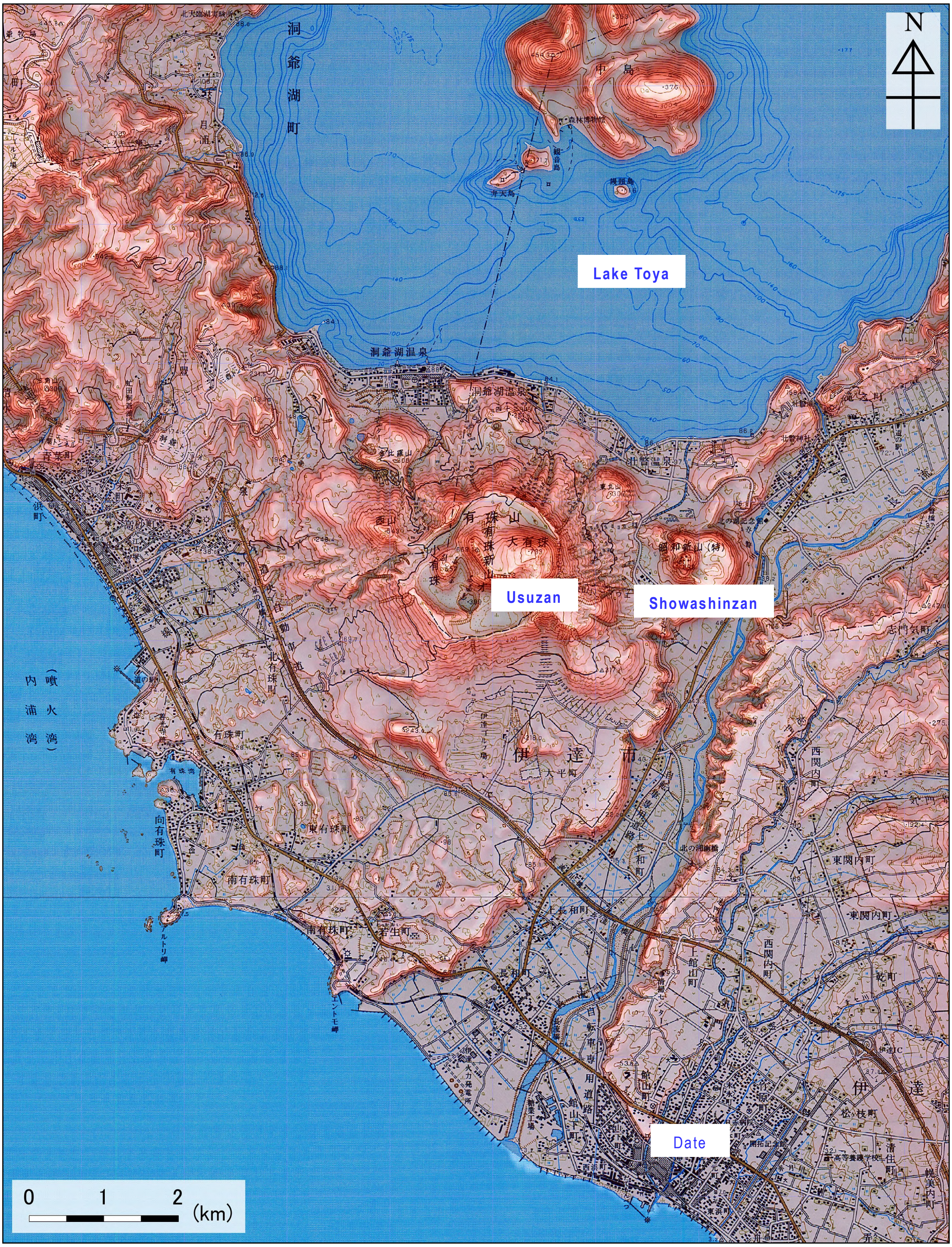


Figure 15-2 Topography of Usuzan.
1:50,000 scale topographic maps (Date and Toyako Onsen) and digital map 50 m grid (elevation) published by the Geospatial Information Authority of Japan were used.

Geological Map

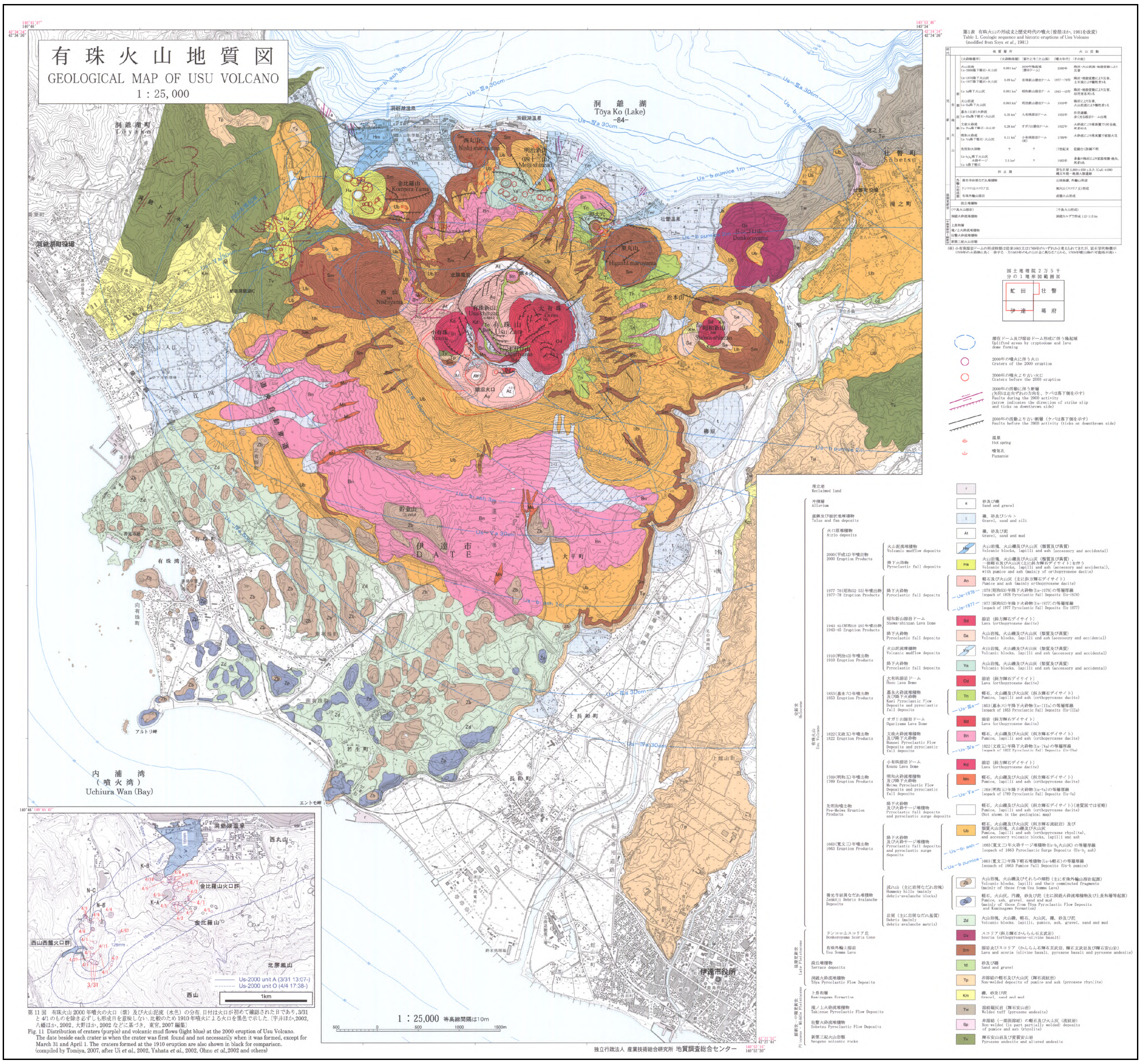


Figure 15-3 Geological map of Usuzan (Soya et al., 2007).

Chronology of Eruptions

・Volcanic Activity in the Past 10,000 Years

A large summit collapse occurred between 7,000 and 8,000 years ago, causing a debris avalanche to the south (the Zenkoji debris avalanche). This was followed by a long period of dormancy, with activity resuming from 1663. The 1663 eruption (Kanbun eruption) was a large plinian one, producing a large amount of pyroclastic material to the east. Plinian eruptions occurred during the volcanic activity of the end of the 17th century (several dozen years after the 1663 eruption), 1769, 1822, 1853, and 1977. Pyroclastic flows occurred for all of these activity periods, except the end of the 17th century and 1977. Phreatomagmatic and phreatic eruptions occurred in 1910, 1943 to 1945, and 2000. During these periods of activity, high viscosity magma rose, forming lava domes and cryptodomes (Nakagawa et al., 2005; Soya et al., 2007).

Period	Area of Activity	Eruption Type	Main Phenomena / Volume of Magma
10←→7ka	Near summit	Magmatic eruption	I to VII type somma lava eruption: 7 main eruptions ejected basalt-basaltic andesite lava and scoria, forming a stratovolcano.
10←→7ka	Eastern foot of Usuzan, Donkoroyama	Magmatic eruption	Donkoroyama air-fall scoria eruption: Scoria eruption and pyroclastic flow at northeastern foot, forming flank volcano (Donkoroyama scoria cone).
8←→7ka	Summit	(Collapse)	An eruption at the summit caused a collapse, and a debris avalanche to the south formed an irregular hummocky topography at the foot of the volcano (Zenkoji debris avalanche deposits).

* Reference documents have been appended with reference to the catalog of eruptive events during the last 10,000 years in Japan, database of Japanese active volcanoes, and AIST (Kudo and Hoshizumi, 2006) for eruptive period, area of activity and eruption type. All years are noted in calendar years. "ka" within the table indicates "1000 years ago", with the year 2000 set as 0 ka.

A←→B: Eruption events taking place at some point between year A and year B

・Historical Activity

Year	Phenomenon	Activity Sequence, Damages, etc.
1663 (Kanbun 3)	Large: Magmatic eruption	Frequent earthquakes and rumbling from August 13. A phreatomagmatic eruption at the summit began on August 16, reaching its climax on August 17 with a pumice eruption (plinian eruption) (Usu b air-fall pyroclastic deposits). Both earthquakes and eruptions were severe, and accompanied by volcanic lightning. A large amount of ash fell, with thick deposits floating approximately 5 km off the southwest coast. The eruption column could be seen as far as the Tsugaru area, and the air shock could be felt as far as the Shonai area (Yamagata Prefecture). Following the pumice eruption, volcanic blocks and volcanic ash were repeatedly ejected, and several pyroclastic surges reached the foot of the volcano. The strata thickness of the deposits was between 1 to 3 m at the foot of the volcano, and several dozen meters thick on the flanks. The eruption continued until late August. Houses were covered or burned by tephra fall, resulting in 5 deaths. Total ejecta: 2.78 km^3. Magma eruption volume: 1.1 km^3 DRE. (VEI 5)
1663←→1769	Moderate: Magmatic eruption	Meiwa eruption: A pumice eruption occurred at the summit. This was accompanied by a pyroclastic surge. The Ko-Usu lava dome was formed. Total ejecta: 0.001 km^3. Magma eruption volume: 0.0004 km^3 DRE. (VEI 2)

Year	Phenomenon	Activity Sequence, Damages, etc.
1769 (Meiji 5)	Large: Magmatic eruption	An earthquake preceded the eruption. On January 23 a pumice eruption (plinian eruption) began at the summit. Pumice and volcanic ash air-falls were followed by a pyroclastic flow (Meiwa pyroclastic flow) which caused fires, burning down all homes at the southeastern foot of the volcano. The Ogariyama cryptodome was formed. The strata thickness of deposits at the foot of the volcano was 30 to 50 cm. Total ejecta: 0.11 km^3. Magma eruption volume: 0.04 km^3 DRE (volume of air-fall pyroclastic material only). (VEI 4)
1822 (Bunsei 5)	Large: Magmatic eruption	Earthquakes began on March 9, gradually growing in frequency. A pumice eruption (plinian eruption) began on March 12. The eruption grew gradually stronger. The first pyroclastic flow occurred on March 15. The largest pyroclastic flow occurred on March 23 (the Bunsei pyroclastic flow), burning down the entire forest from the southeastern foot to the western foot. It also burned down Abuta, a coastal village (near the current Irie), resulting in many deaths (according to Mimatsu and Tada (2003) there were 103 deaths; according to the O-Usuzanshoho Record there were 82 deaths; according to Yokoyama et al. (1973) there were 50 deaths). The strata thickness of deposits was 30 cm at the western foot of the volcano and almost 1 m at the eastern foot. The Ko-Usu lava dome was formed. The eruption continued for at least 4 more months. Total ejecta: 0.28 km^3. Magma eruption volume: 0.11 km^3 DRE (volume of air-fall pyroclastic material only). (VEI 4)
1853 (Kaei 6)	Large: Magmatic eruption	Earthquakes and rumbling began on April 12, growing gradually stronger. On April 22 a pumice eruption (plinian eruption) began on the east side of the summit. On April 29 a strong eruption occurred, continuing until approximately May 4. On May 5, formation of the O-Usu lava dome began. The strata thickness of deposits was 30 cm at the western foot of the volcano and 50 to 100cm at the eastern foot. A pyroclastic flow occurred during the latter part of the eruption (the Kaei pyroclastic flow or Tateiwa pyroclastic flow). Formation of the O-Usu lava dome continued, with its elevation being measured in 1889 at 595 m, in 1905 at 692 m, and in 1911 at 740 m. Total ejecta: 0.35 km^3. Magma eruption volume: 0.14 km^3 DRE (volume of air-fall pyroclastic material only). (VEI 4)
1903 (Meiji 36)	Rumbling	Rumbling from May to June. [21]
1910 (Meiji 43)	Moderate: Phreatic eruption	Earthquakes became frequent from July 21, growing gradually stronger. On July 24 an M5 earthquake occurred, partially destroying 15 houses in Abuta. On the night of July 25, when seismic activity had relatively decreased, an eruption started at Konpirayama. The eruption occurred intermittently in a 2.7 km long area running from the west-northwest to the east-southeast, from Konpirayama to the west side of Higashimaruyama. Approximately 15 explosion craters, large and small, were formed by August 2, and a total of 45 by November. A volcanic plume extended as high as approximately 700m, and volcanic blocks fell within an area 300 m from the crater. Hot volcanic lahar (hot lahar) flowed directly from 6 craters into Lake Toya, killing 1 person. The east side of Nishimaruyama was lifted approximately 155 m by November 10, forming the Meijishinzan (Yosomiyama) cryptodome. There was extreme ground deformation in the area, causing damage to houses, mountain forests, and agricultural land. Magma intrusion caused hot springs to well up around the shore of Lake Toya immediately after the activity. Total ejecta: 0.003 km^3. (VEI 2)

Year	Phenomenon	Activity Sequence, Damages, etc.
1943 to 1945 (Showa 18 to 20)	Magmatic eruption	(1) Pre-eruption period (December 28, 1943, to June 22, 1944) On December 28 earthquakes occurred across the entire Usuzan area, with almost 20 felt-earthquakes in a single day at the northern foot. The number of earthquakes decreased slightly at the start of 1944, and the hypocenters became increasingly concentrated at the eastern foot. A ground uplift began at Yanagihara, reaching 16 m in April. From mid-April, the center of the uplift moved to Fukaba, to the north (now the site of the east portion of Showashinzan), reaching as high as 50 m. Earthquakes grew in intensity, with 250 felt-earthquakes on June 22. (2) Explosion period (June 23, 1944, to October 31, 1944) On June 23, a phreatic eruption began in agricultural land in Higashikyumantsubo (now the site of the center of Showashinzan), in the west of Fukaba. From July 2, the explosions grew more powerful, with several dozen prominent explosions by the end of October. The explosions on July 2 and July 3 were particularly large, ejecting a large volume of volcanic blocks and volcanic ash, causing significant crop damage, and tephra fall on Tomakomai and Chitose to the east. The July 11 explosion produced a low temperature (60 to 70 °C) pyroclastic surge which destroyed a protected forest and homes. 1 person was injured, and crops were damaged. On August 26, 1 small child was killed, and a house burned down. A series of explosions created a ring of 7 craters on the south side of Matsumotosan, and ground uplift continued, forming the Yaneyama cryptodome approximately 100 m tall. (3) Lava dome formation period (early November, 1944, to September, 1945) From mid-November, new lava appeared from the center of the ring-shaped group of explosion craters in the center of the roof mountain, and the rise continued, resulting in a slight protuberance on the west side. In September, 1945, the number of earthquakes fell and lava dome formation ended, with the peak of the lava dome standing at 406.9 m. The formed lava dome was named "Showashinzan". Total ejecta: 0.11 km^3(including cryptodome). Magma eruption volume: 0.44 km^3 DRE. (VEI 1)

Year	Phenomenon	Activity Sequence, Damages, etc.
1977 to 1978 (Showa 52 to 53)	Moderate: Magmatic eruption	A large number of felt-earthquakes occurred from 03:30 on August 6. On August 7, at 09:12, a dacite magma pumice eruption (plinian eruption) began from the summit crater floor (the southeastern foot of Ko-Usu). An hour later, the volcanic plume had reached a height of 12,000 m, but the eruption stopped temporarily after just under two and a half hours. Over 10 intermittent eruptions then occurred, including large pumice eruptions, leading up to the early morning of August 14. During the first stage eruption that occurred over the course of the week, craters No. 1 through No. 3 were formed at the eastern foot of the Ko-Usu lava dome, the No. 4 crater was formed to the north of the crater floor, and a large amount of pumice and volcanic ash was deposited around the craters. tephra fall destroyed a house at the foot of the volcano, and caused damage to crops and forests. From August to September rain caused secondary lahar damage at the western foot. The first stage eruption ejected 83,000,000 m^3 of ejecta. After this first stage of activity, the remaining magma continued to rise and, accompanied by seismic activity, the crater floor rose, forming a fault from the northeastern foot of Ko-Usu, through Ogariyama, to O-Usu, as well as a new cryptodome (Usushinzan). A graben measuring 100 to 250 m wide formed on the southwestern side of the fault, and the summit of Ko-Usu continued to subside. Two and a half months after the start of the eruption, the new mountain had risen 40 to 50 m, and the northeastern wall of the Usu somma swelled outwards, with a lateral displacement of 48 m. The prominent effects of crustal deformation at the summit extended to the northern foot, causing severe damage to roads, buildings, and sewer and water mains, etc. From November 16, a phreatic eruption began at the summit crater floor (second stage eruption). 1978 From July to September phreatomagmatic eruptions were frequent, and eruptive activity continued until October 27. During this time, the A-N crater was formed on the south side of the fault. It eventually connected to the J-N crater, forming the Gin'numa crater. The second stage eruption produced approximately 7,500,000 m^3 of magma, only 1/10 that of the first stage eruption. However, on October 16 and October 24 rain caused a secondary lahar across Usuzan, resulting in 2 deaths, 1 missing person, 2 slight injuries, damage to 196 houses, damage to 9 other buildings, and damage to agricultural, civil engineering, sewerage, and other facilities. The new mountain uplift continued until March, 1982, accompanied by seismic activity. An uplift of approximately 180 m occurred in Ogariyama and the eastern foot of Ko-Usu, as well as a reduction in the distance between the northern somma and the shore of Lake Toya of approximately 180 m. Total ejecta: 0.09 km^3. Magma eruption volume: 0.04 km^3 DRE. (VEI 3)

Year	Phenomenon	Activity Sequence, Damages, etc.
2000 (Heisei 12)	Small-scale: Phreatomagmatic eruption	Gradual increase in earthquakes from the afternoon of March 27. On March 28, at approximately 01:31, the first felt-earthquake occurred (felt in the Lake Toya Onsen area). From March 30 to March 31, faults and fissures were formed at the summit and the northwestern foot of the volcano, and gradually grew larger. On March 31, seismic activity reached its peak, and at 13:07 a phreatomagmatic eruption began at the western foot of Nishiyama. Volcanic blocks were ejected near the crater. The volcanic plume rose several hundred meters straight up, and then blew to the northeast, reaching a height of 3,500m. Ash fell downwind, to the northeast. A small amount of tephra fall was detected at Chitose, 75 km away. The March 31 eruption ejected 240,000 tons of ejecta. On April 1, at approximately 11:30, an eruption began from the northwestern foot of Konpirayama. Small phreatic eruptions occurred repeatedly until mid-April, and a total of 65 craters were formed at the western foot of Nishiyama and around Konpirayama. Hot lahars occurred from the western foot of Nishiyama from April 1 to April 2, and from Konpirayama from April 2 to April 10. From mid-April, activity was confined to 4 craters (the N-B crater and N-C crater at the western foot of Nishiyama, and the K-A crater and K-B crater at the northwestern foot of Konpirayama). Magma intrusion at the western foot of Nishiyama caused an uplift with a maximum height of approximately 80m, forming a cryptodome. From August, the uplift at the western foot of Nishiyama subsided, and activity at each crater gradually lessened. At the K-B crater, volcanic blocks, etc., continued to be ejected accompanied by air shocks. 2001 No K-B crater air shocks or volcanic ash emission were observed since September. The area of activity included some residential areas at the foot of northwest, so despite eruptions being small, roads, sewer pipes, and water mains were cut, and 850 homes were damaged. Total ejecta: 0.0009 km^3 (small amount of magma discharge). (VEI 1)

* Reference documents have been appended with reference to the catalog of eruptive events during the last 10,000 years in Japan, database of Japanese active volcanoes, and AIST (Kudo and Hoshizumi, 2006) for eruptive period, area of activity and eruption type.
A←→B: Eruption events taking place at some point between year A and year B

Whole Rock Chemical Composition

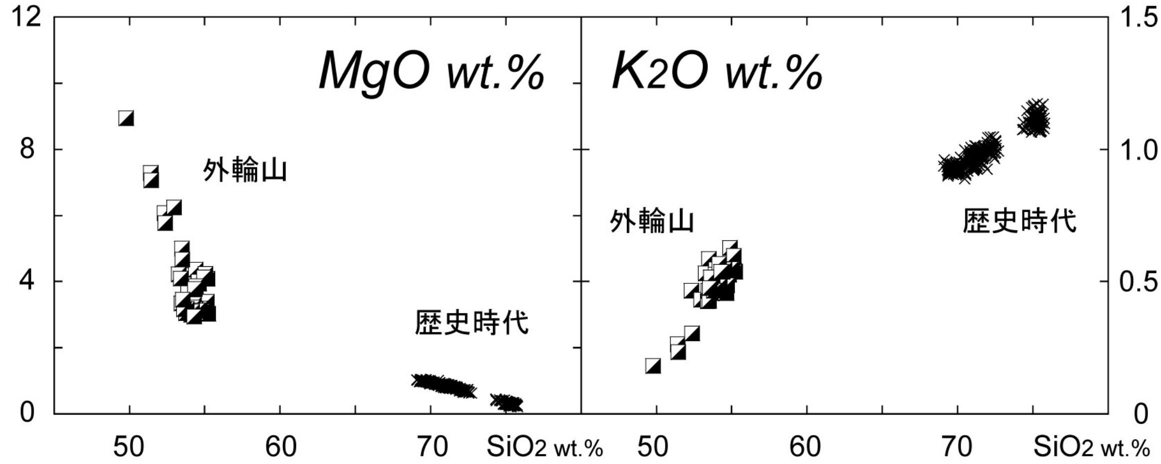


Figure 15-4 Whole rock chemical composition by Harker diagrams of ejecta within prehistoric period (somma) and historic period (Matsumoto and Nakagawa, 2010).

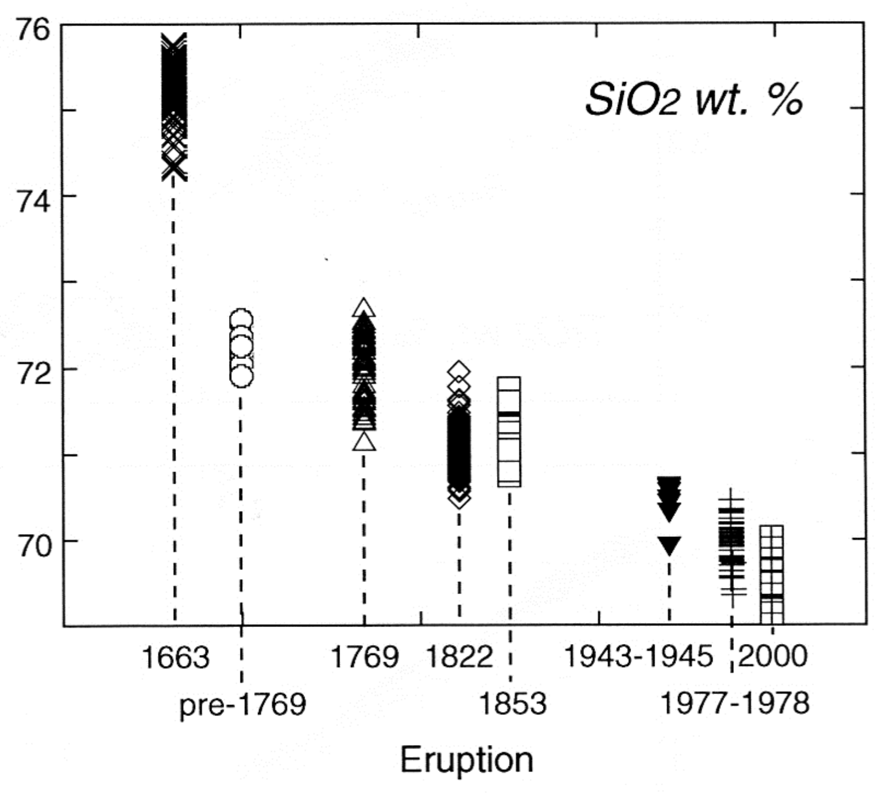


Figure 15-5 Time series of whole rock chemical composition of SiO_2 wt % within historical period. (Nakagawa et al., 2005; Matsumoto and Nakagawa, 2010)

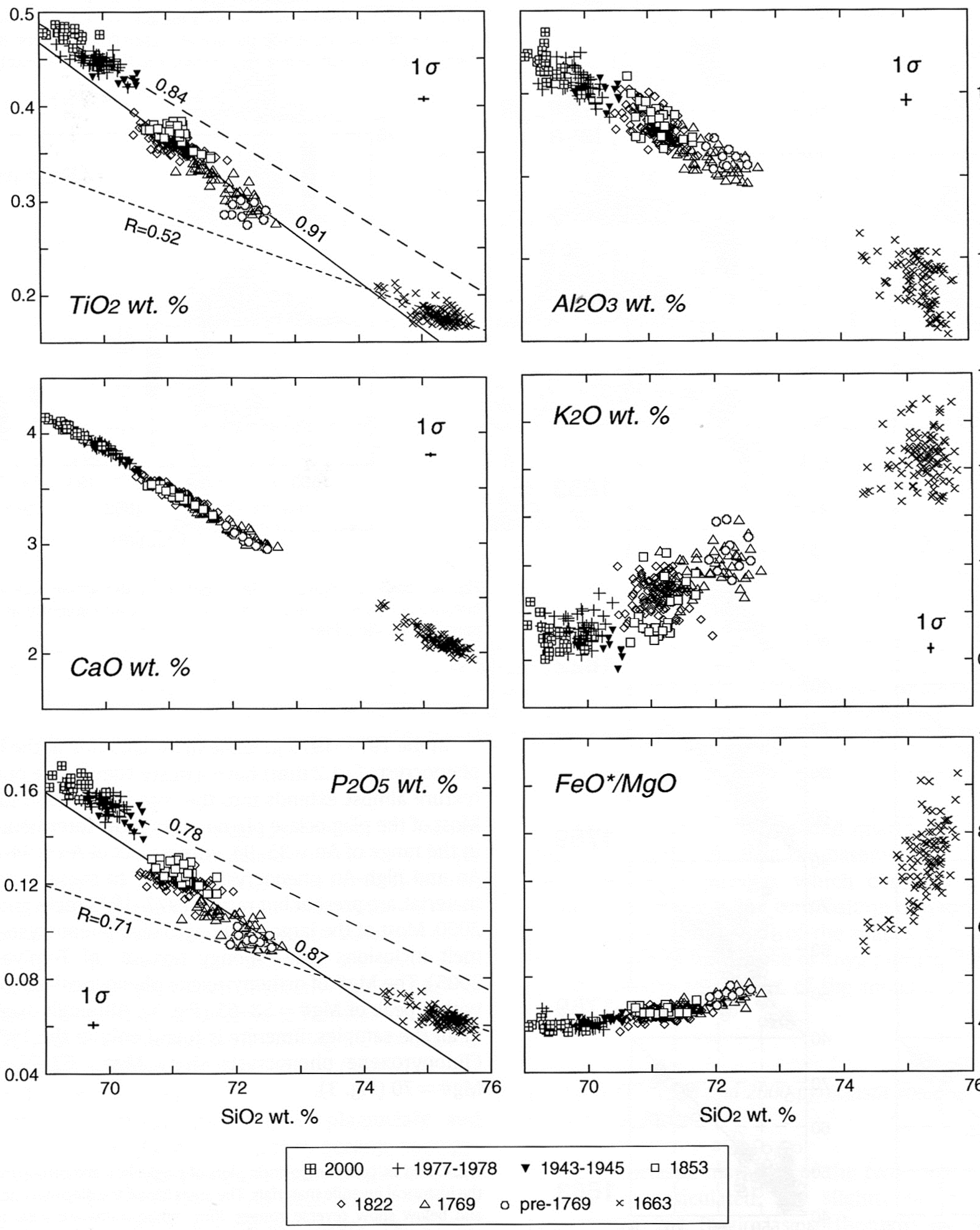
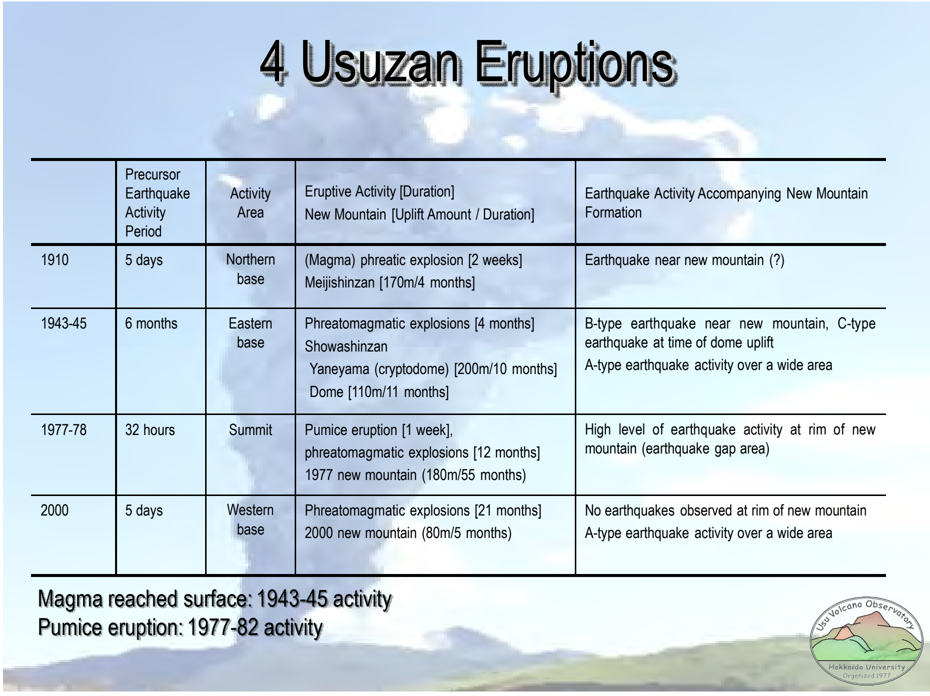


Figure 15-6 Whole rock chemical composition by Harker diagram of ejecta within historical period (Matsumoto and Nakagawa, 2010).

Major Volcanic Activities



4 Usuzan Eruptions

	Precursor Earthquake Activity Period	Activity Area	Eruptive Activity [Duration] New Mountain [Uplift Amount / Duration]	Earthquake Activity Accompanying New Mountain Formation
1910	5 days	Northern base	(Magma) phreatic explosion [2 weeks] Meijishinzan [170m/4 months]	Earthquake near new mountain (?)
1943-45	6 months	Eastern base	Phreatomagmatic explosions [4 months] Showashinzan Yaneyama (cryptodome) [200m/10 months] Dome [110m/11 months]	B-type earthquake near new mountain, C-type earthquake at time of dome uplift A-type earthquake activity over a wide area
1977-78	32 hours	Summit	Pumice eruption [1 week], phreatomagmatic explosions [12 months] 1977 new mountain (180m/55 months)	High level of earthquake activity at rim of new mountain (earthquake gap area)
2000	5 days	Western base	Phreatomagmatic explosions [21 months] 2000 new mountain (80m/5 months)	No earthquakes observed at rim of new mountain A-type earthquake activity over a wide area

Magma reached surface: 1943-45 activity
Pumice eruption: 1977-82 activity

Figure 15-7 Summary of the recent 4 eruptive activity at Usuzan.

・1910 Eruption

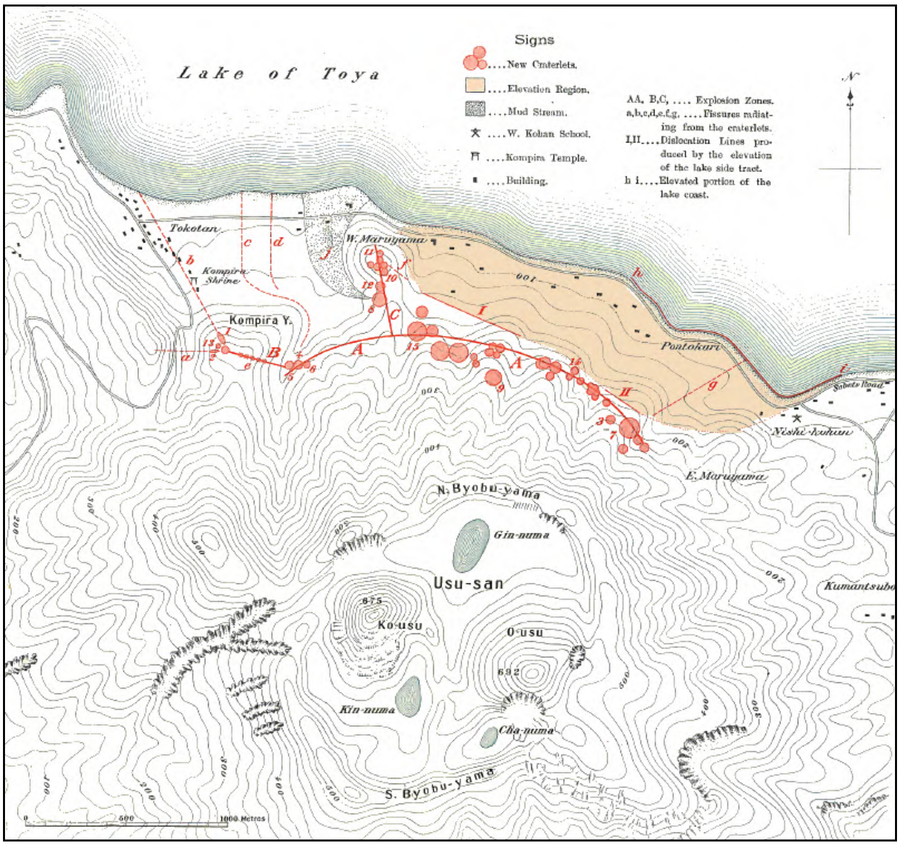
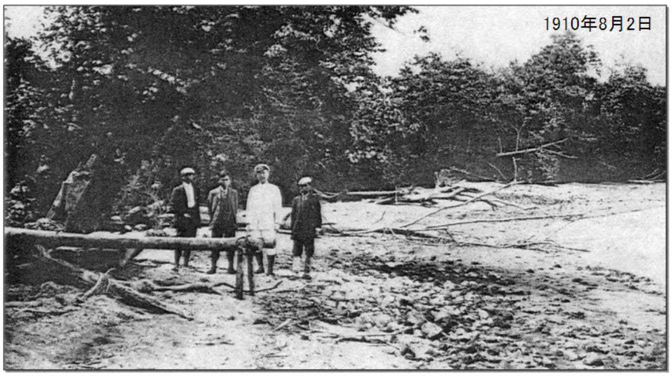


Figure 15-8 Distribution of explosion craters, cracks, and faults (Omori, 1911, revised).



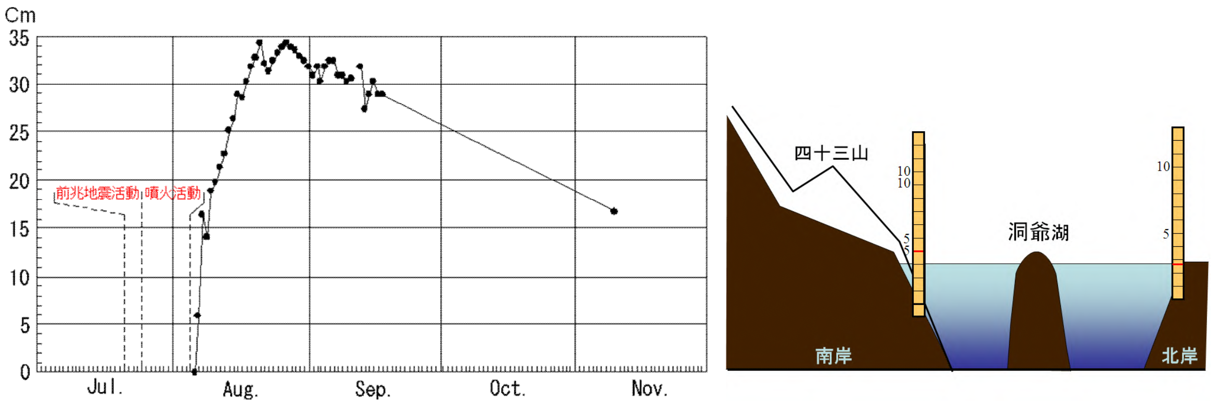


Figure 15-9 Change in the height of the shore of Lake Toya after the 1910 eruption (diagram based on Omori, 1911)
・Uplift and subsidence at the south shore of Lake Toya were confirmed by the observation of water level.

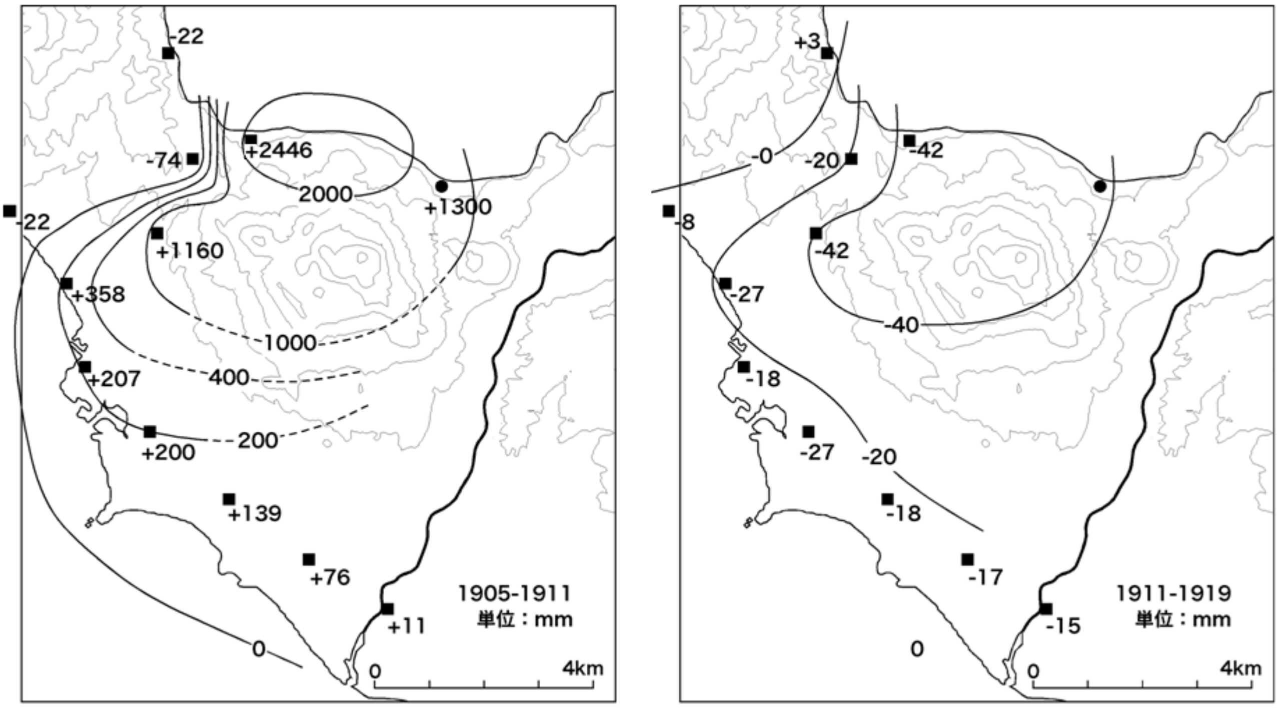


Figure 15-10 Changes in the relative heights at each bench mark (revision based on Omori, 1913, 1920).

・1943-1945 Eruption

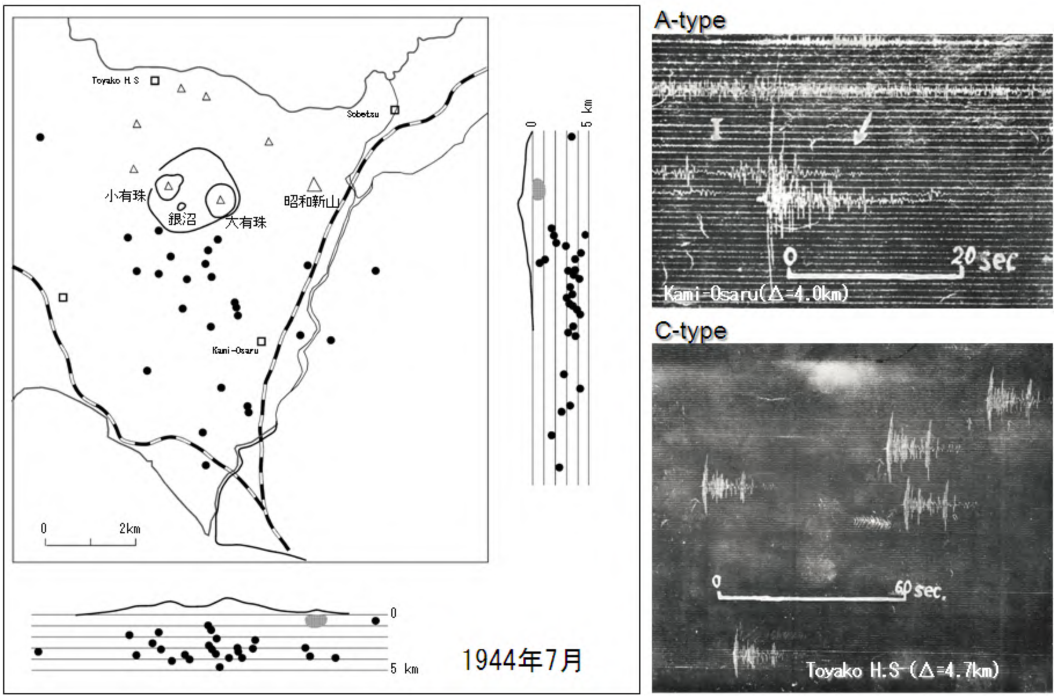


Figure 15-11 Distribution of A-type earthquake hypocenters and examples of earthquake records for 1944 eruption (Minakami et al., 1951).
・The gray area in the cross-section indicates the hypothesized hypocenters of the B-type earthquake near Showashinzan.

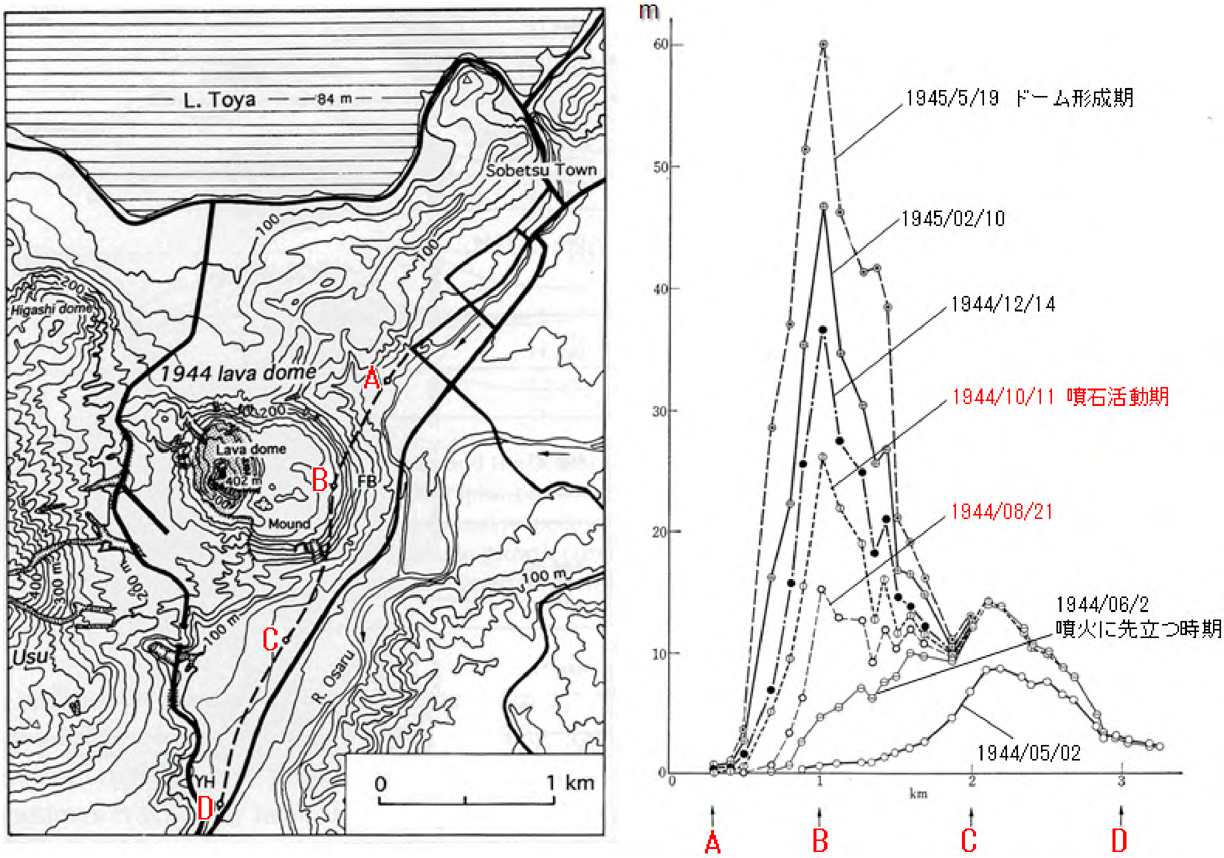


Figure 15-12 Uplift oat the eastern foot of Usuzan (modification of Minakami, 1947a).
・Before the eruption, uplift at C point was prominent. After the eruption, uplift at B point was prominent.

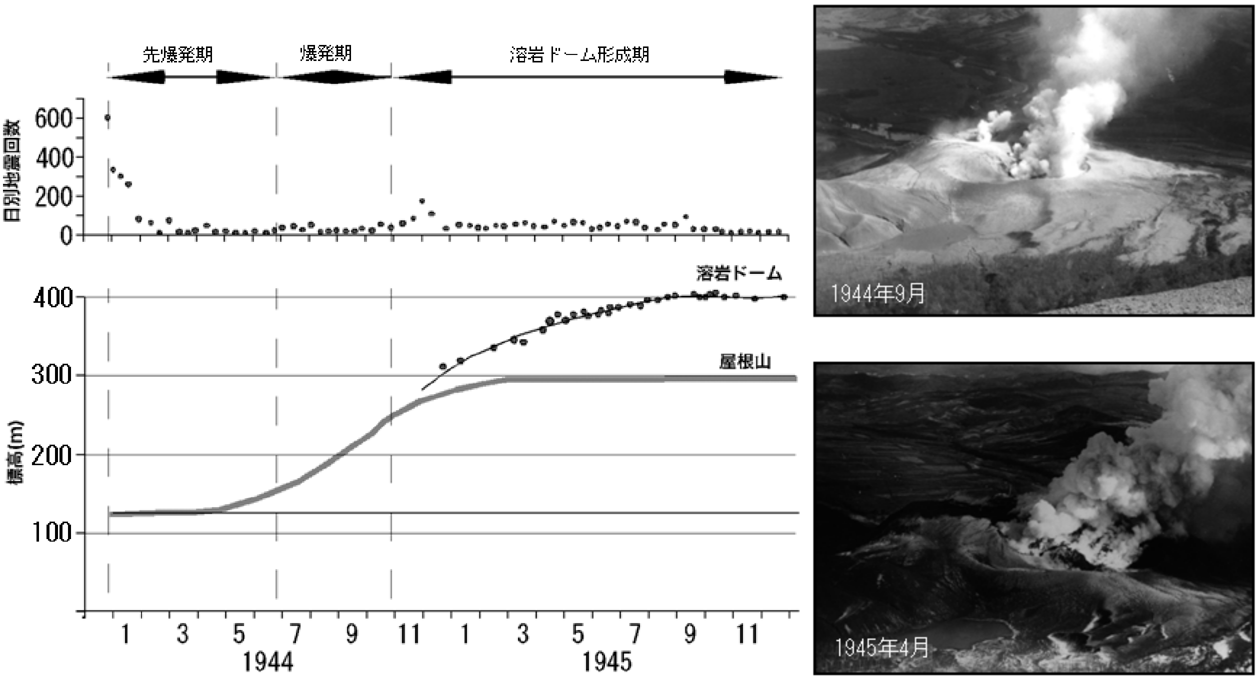


Figure 15-13 Growth of the 1944-1945 lava dome (based on Fukutomi, 1946).

・1977-1978 Eruption

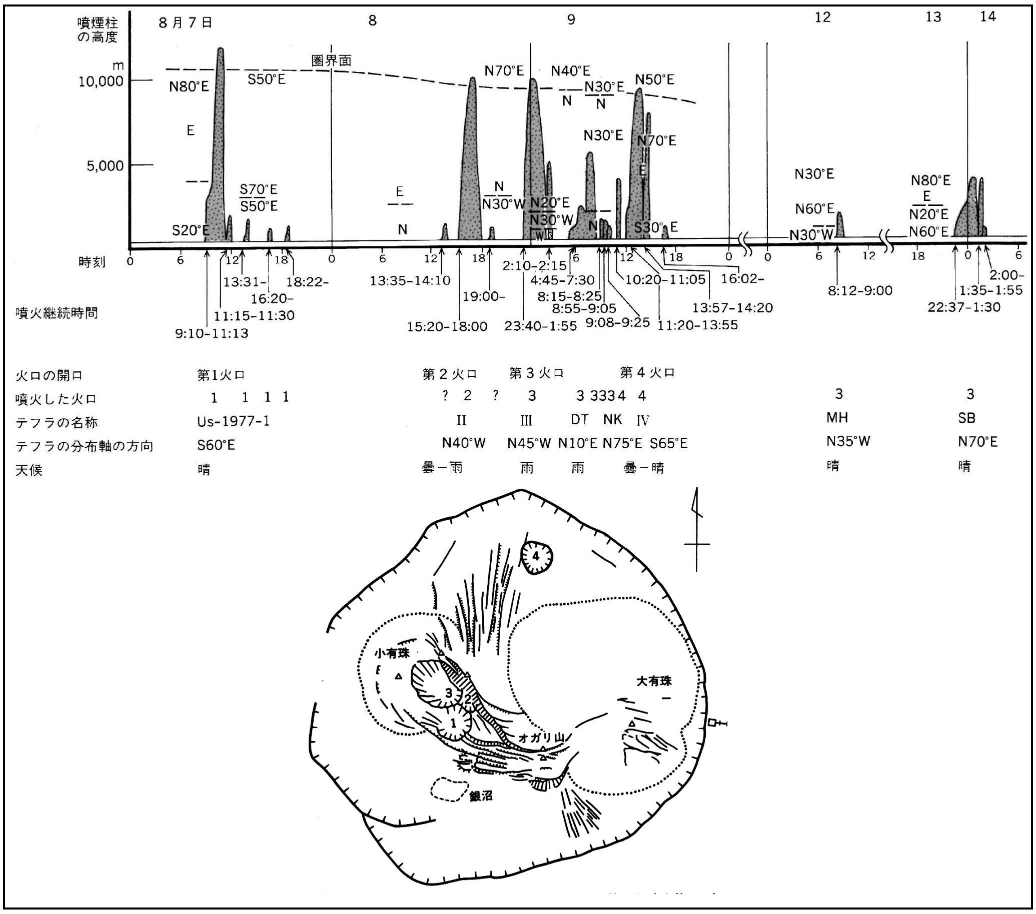
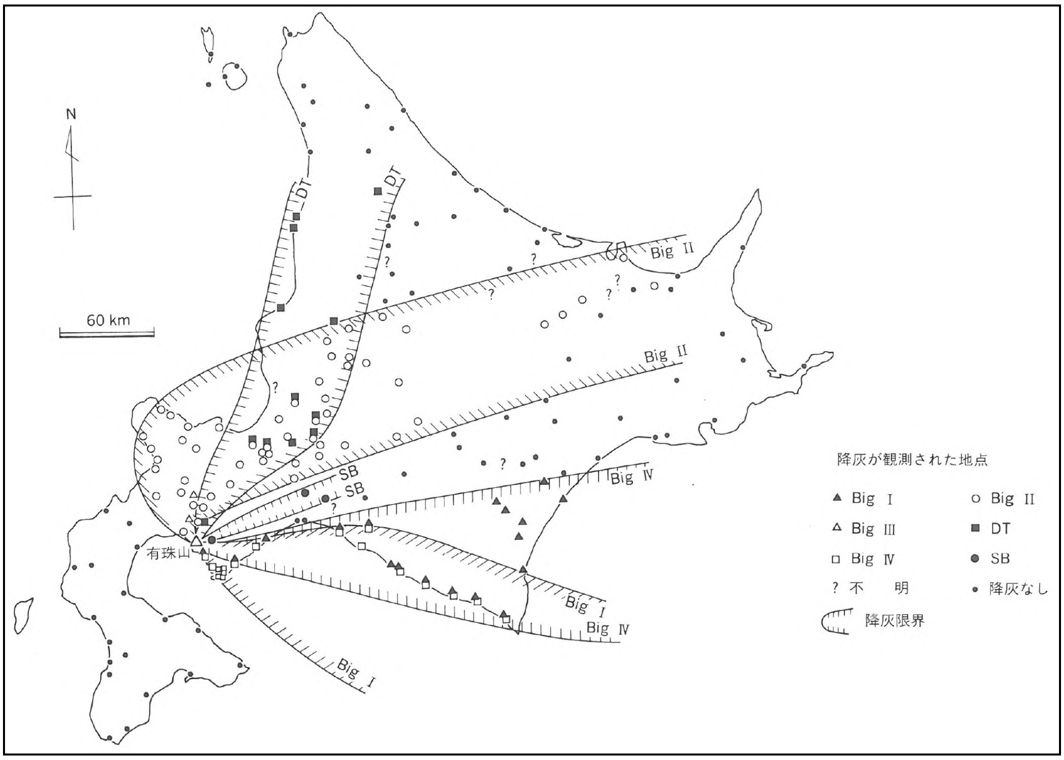


Figure 15-14 Time series of 1977 eruption, and locations of eruption craters (Katsui et al., 1988).



. 15-15 Ash fall area of the 1977 eruption (Katsui et al., 1988)

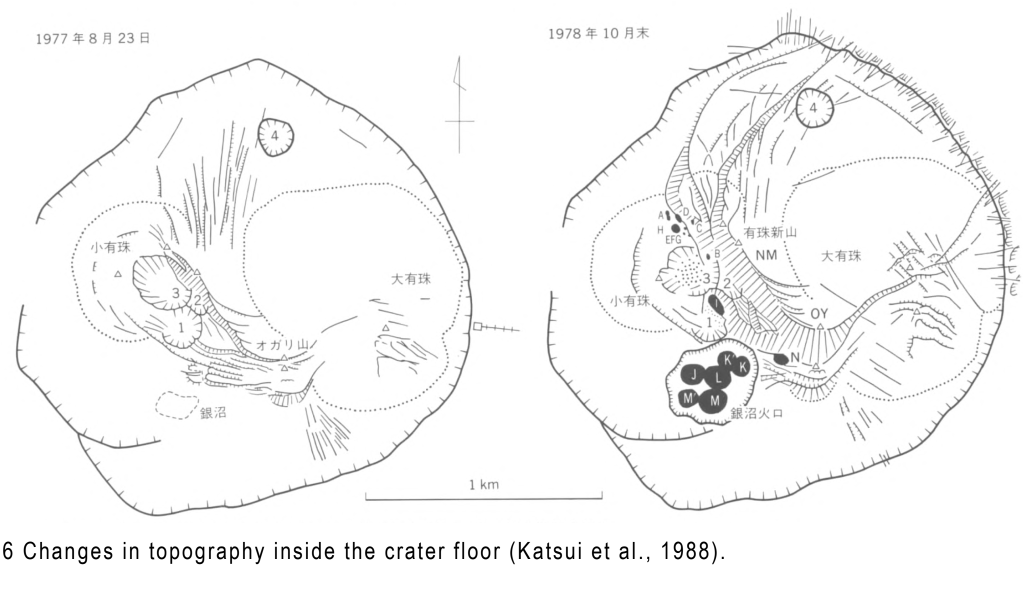


Figure 15-16 Changes in topography inside the crater floor (Katsui et al., 1988).

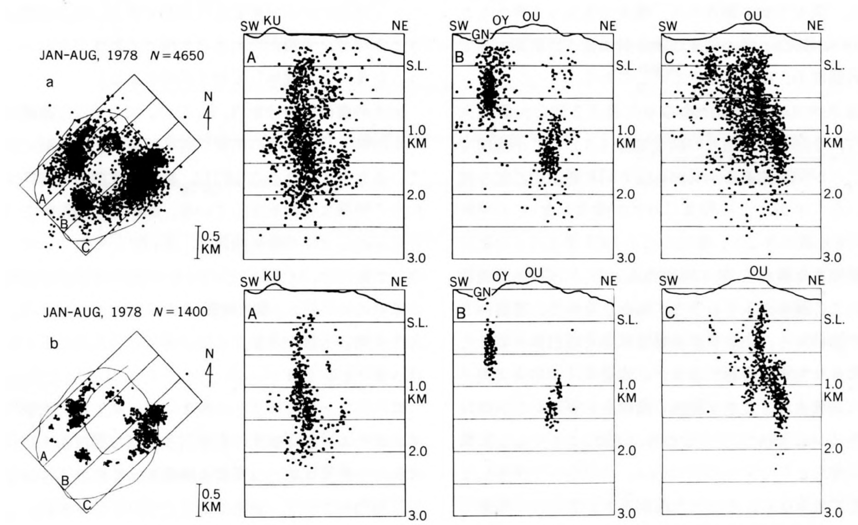


Figure 15-17 Distribution of hypocenters of volcanic earthquakes in shallow summit area, related to formation of Usushinzan (Nishimura and Okada, 1987).

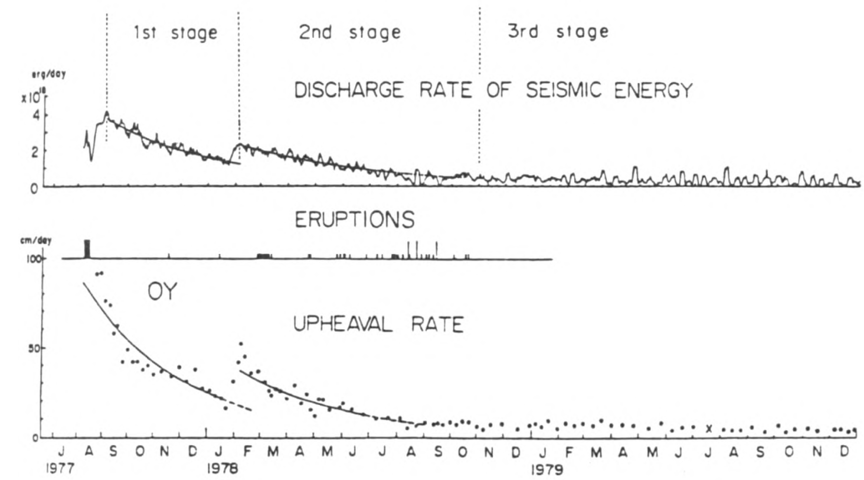


Figure 15-18 Rate of seismic energy discharge during activity from 1977 to 1979 (erg/day), and change in upheaval rate of Ogariyama (cm/day) (Yokoyama, 1993).

Figure 15-19 Topographic change as seen in photographs from before and after the 1977-82 eruption (Courtesy of S. Mimatsu).

・2000 Eruption

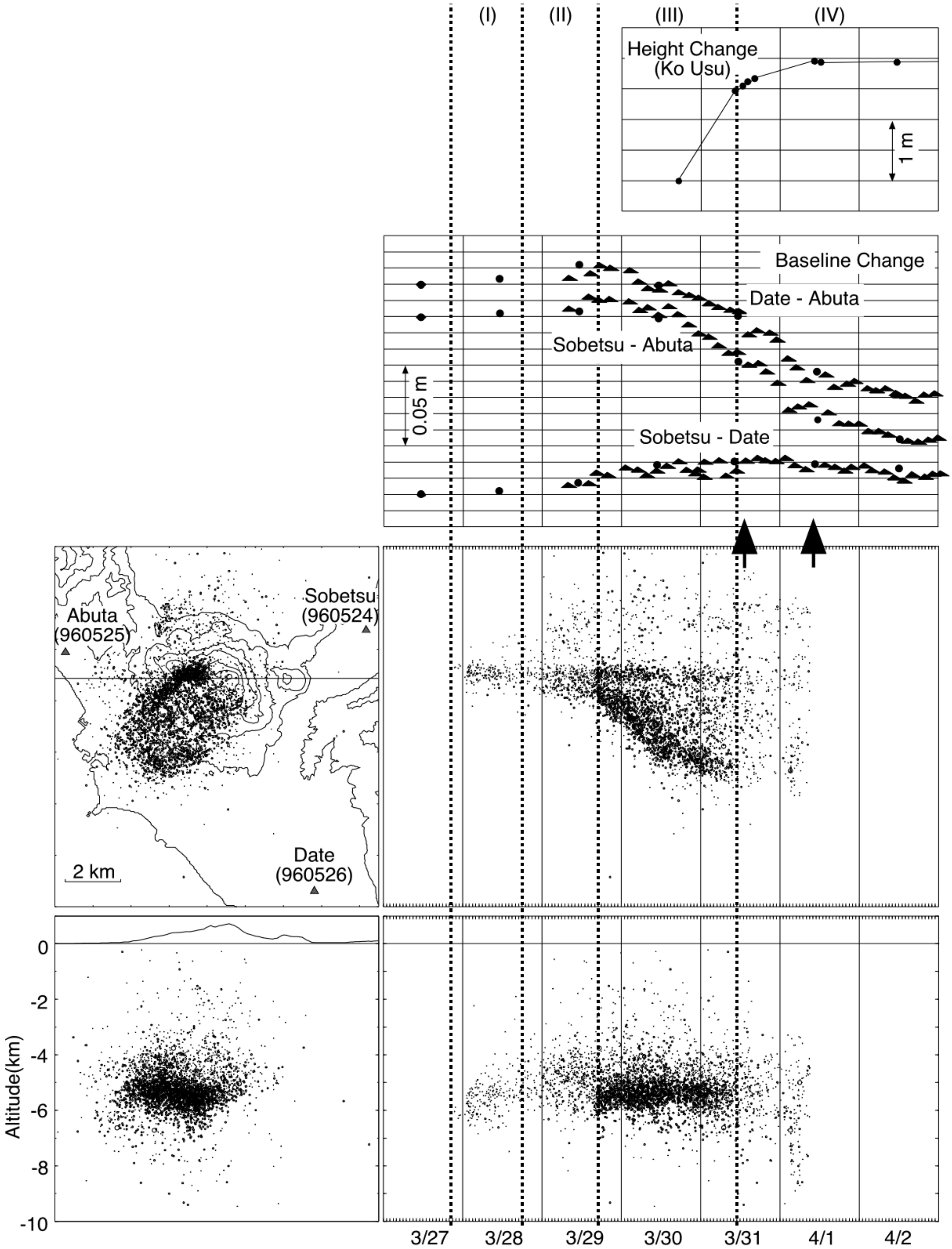


Figure 15-20 Distribution of hypocenters around the start of 2000 eruption, and corresponding crustal deformation (Oshima and Ui, 2003).
Left arrow: Start of eruption at the western foot of Nishiyama (crater group), Right arrow: Start of eruption at Konpirayama

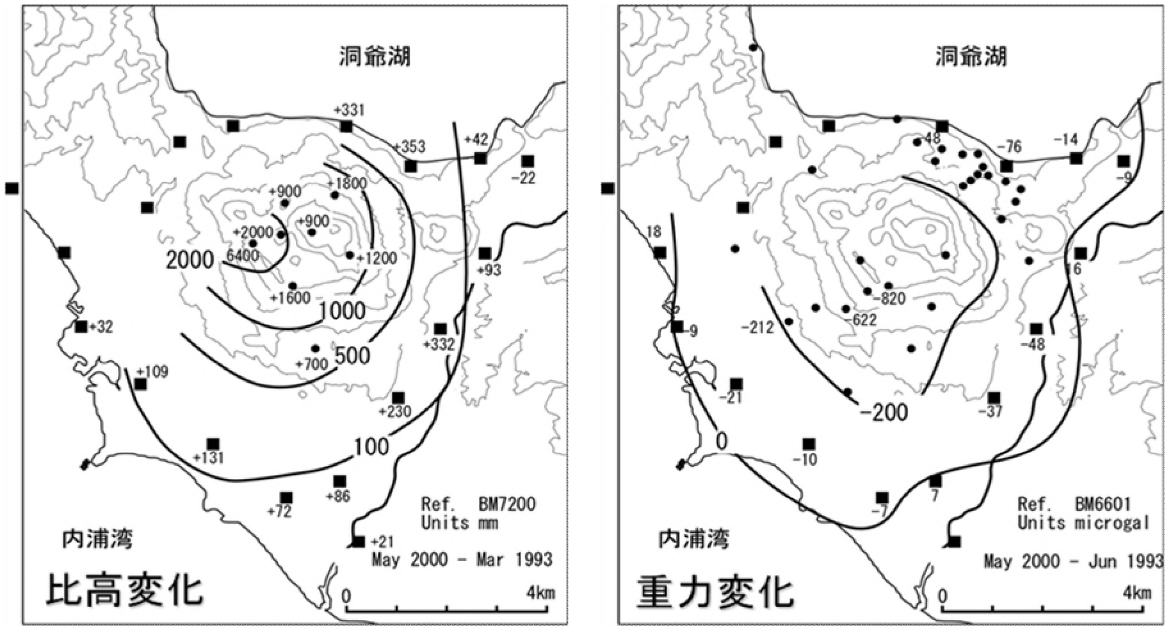


Figure 15-21 Changes in relative height and gravity around 2000 eruption (Oshima and Ui, 2003).

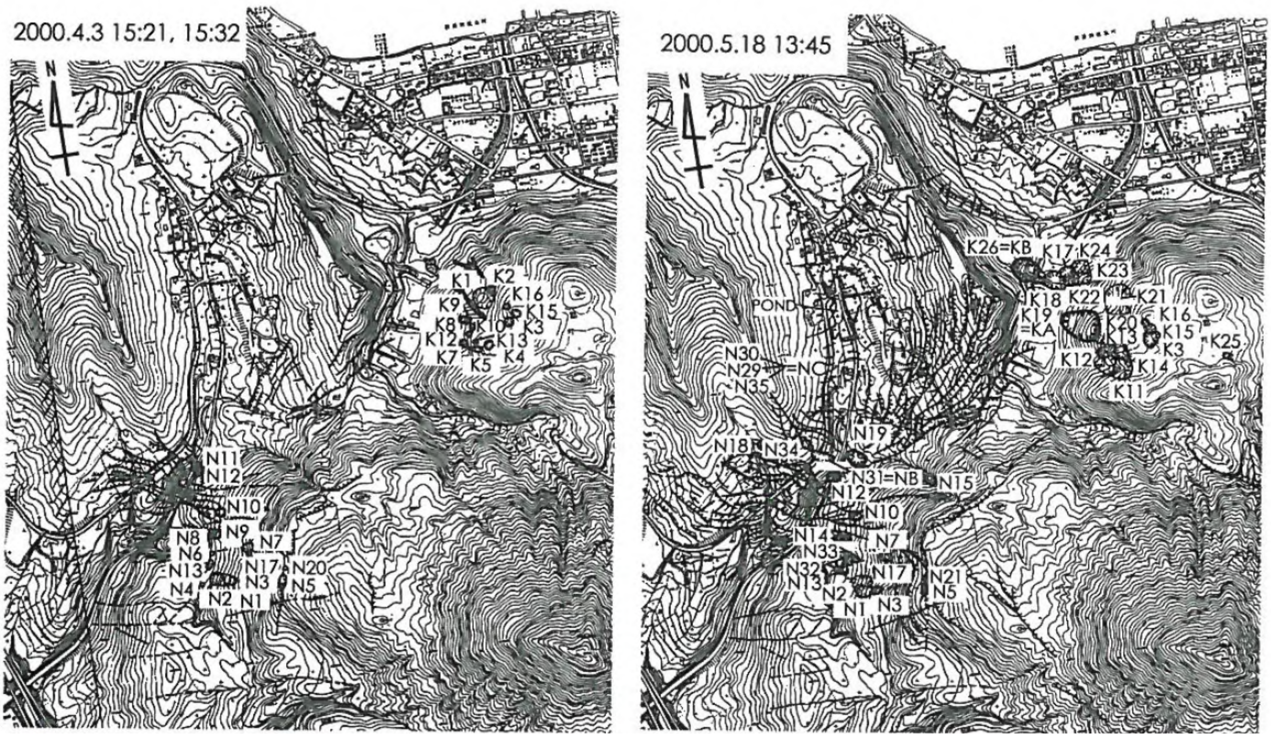


Figure 15-22 Topograhic changes by Usuzan 2000 eruption (Ui et al., 2002).
Newly formed craters and faults were confirmed on April 3 and May 18

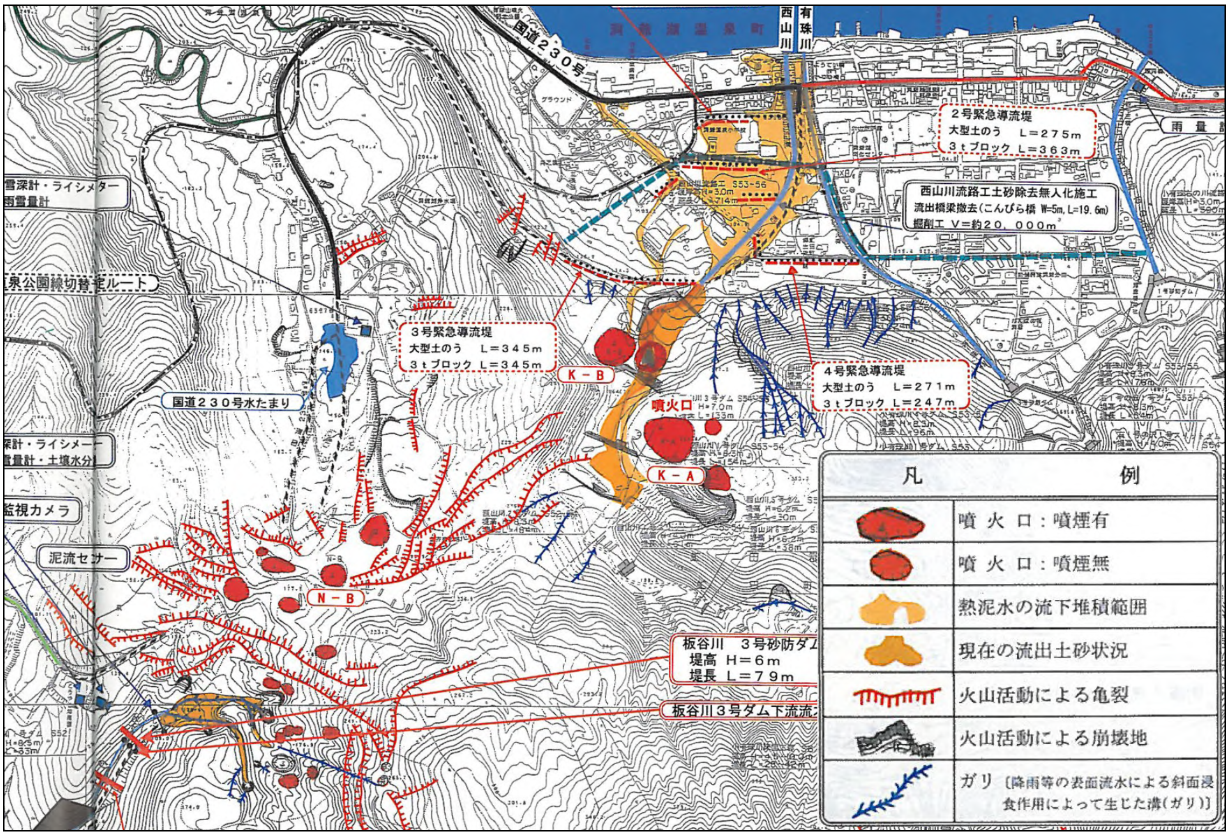


Figure 15-23 Distribution of hot lahar at 2000 eruption (Hokkaido Department of Construction, 2001).

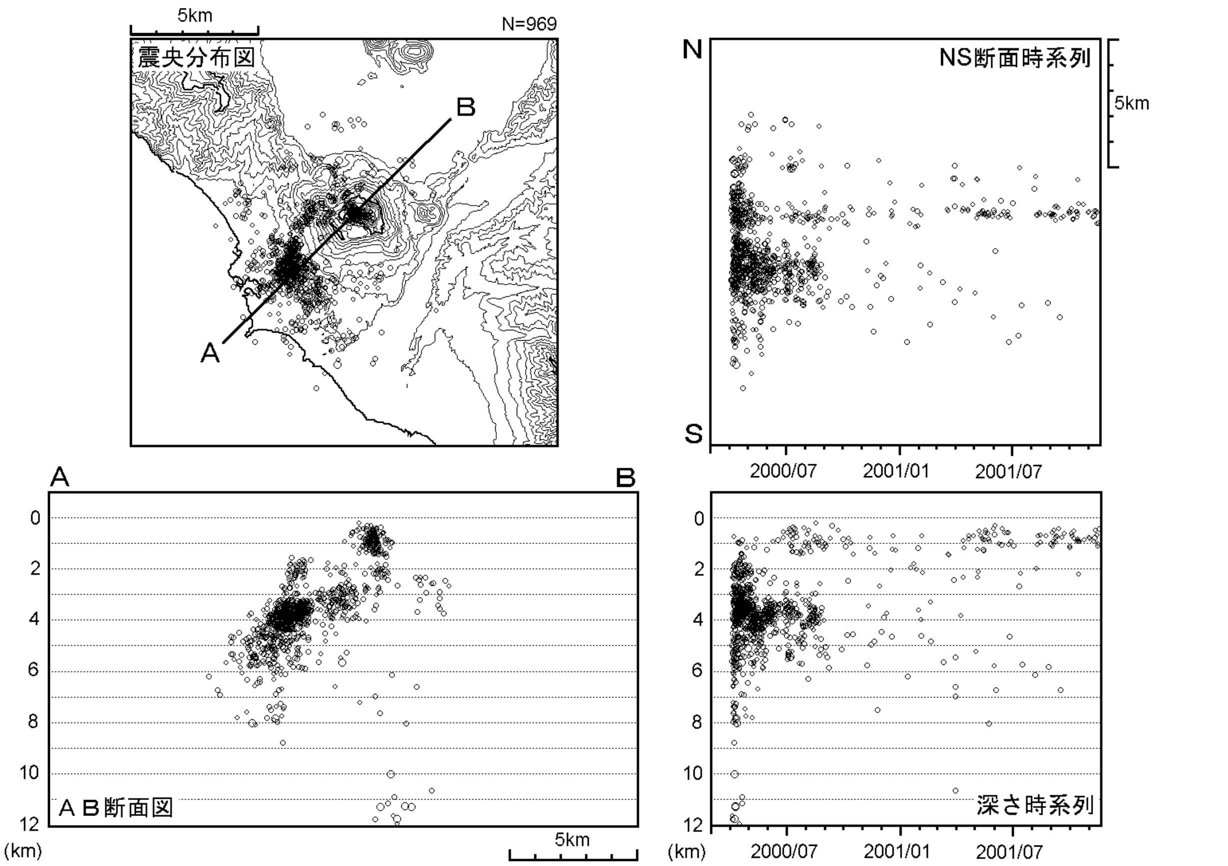


Figure 15-24 Distribution of volcanic earthquakes around the start of 2000 eruption (Japan Meteorological Agency, 2003).

Precursory Phenomena

Historical eruptions was preceded by prominent felt-earthquake swarms at several dozen hours to several days before the eruption, as well as cracking at the summit or foot of the volcano, the formation of faults, or other prominent crustal deformations. Underground water levels changed around the volcanic edifice for several days to several months before the eruption, and predominant frequencies in waveforms became lower immediately before the eruption.

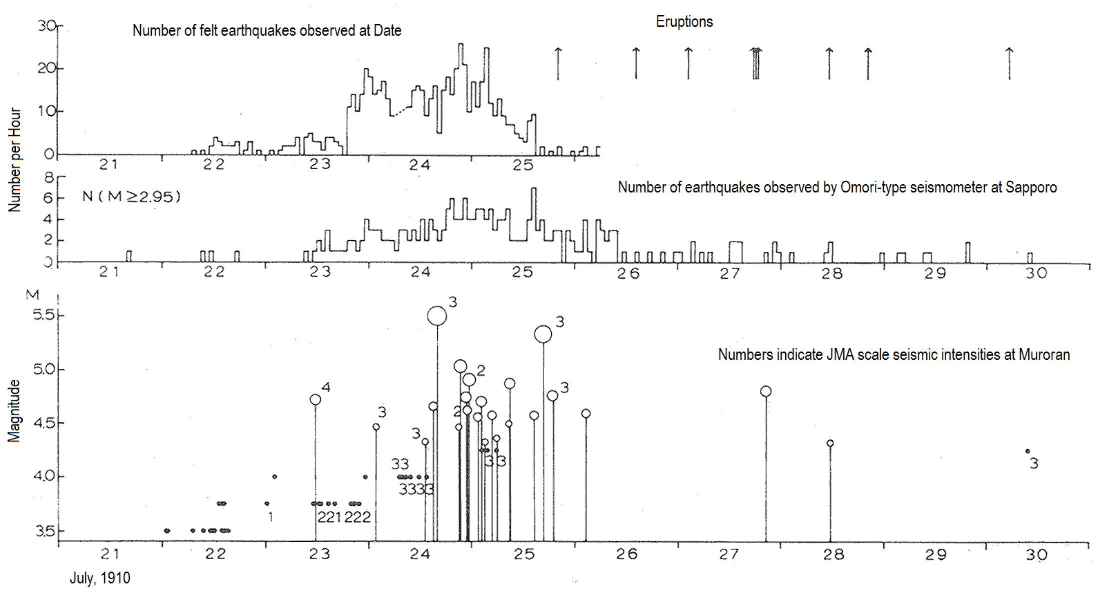


Figure 15-25 Precursor of seismic activity before the1910 eruption (modification of Okada, 1982).

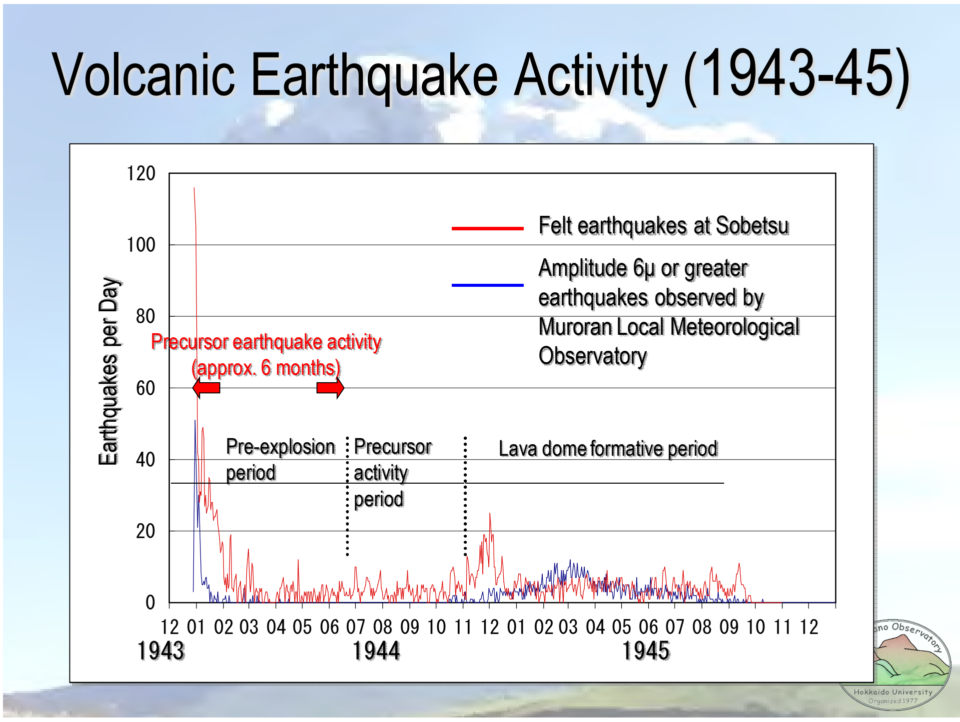


Figure 15-26 Precursor seismic activity for the 1943-45 eruption.
(based on Minakami, 1949b and Kizawa, 1957)

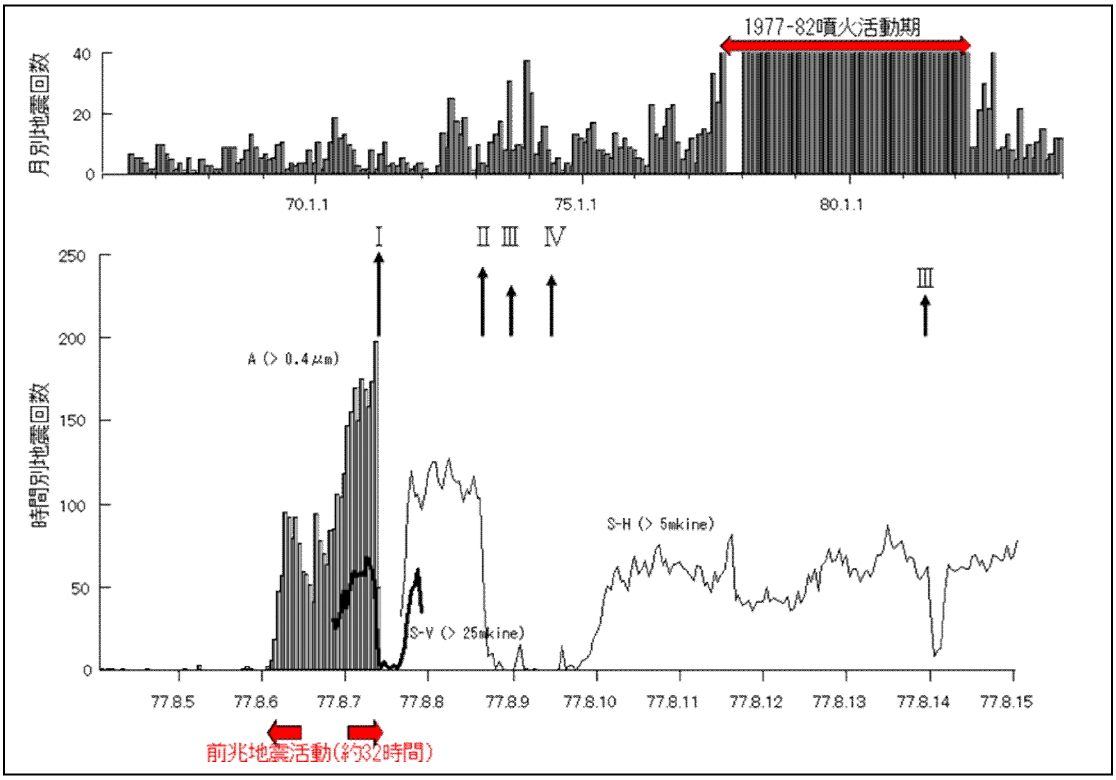


Figure 15-27 Precursor seismic activity for the 1977-78 eruption (number of earthquakes at A-station by Japan Meteorological Agency (current "Minamisanroku" station) and Sobetsu temporal observation point).
(based on Japan Meteorological Agency, 1980)

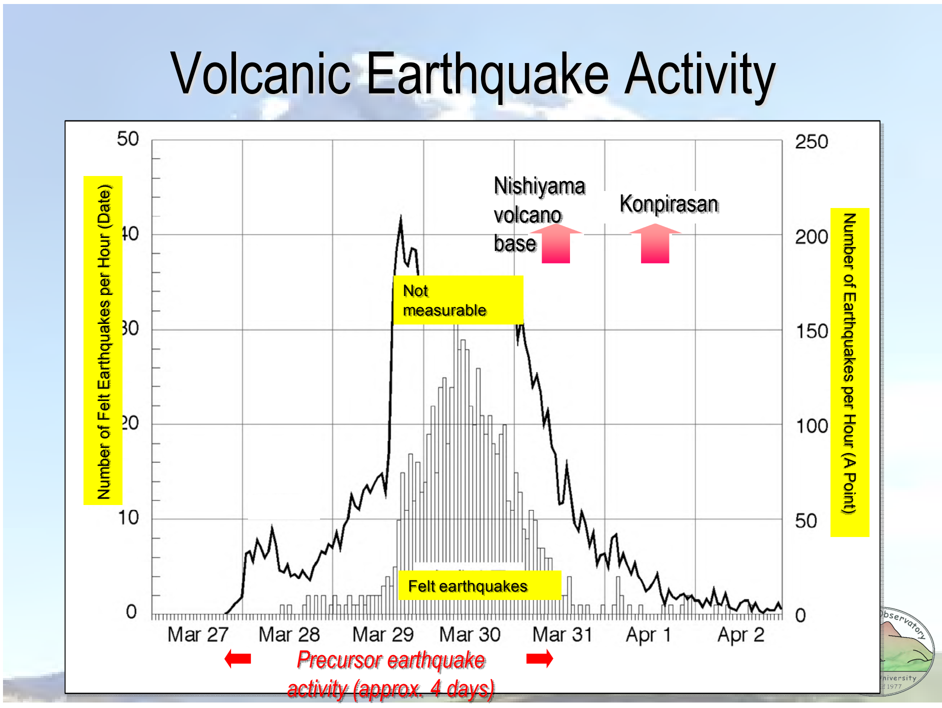


Figure 15-28 Seismic activity for the 2000 eruption (based on Japan Meteorological Agency, 2003).

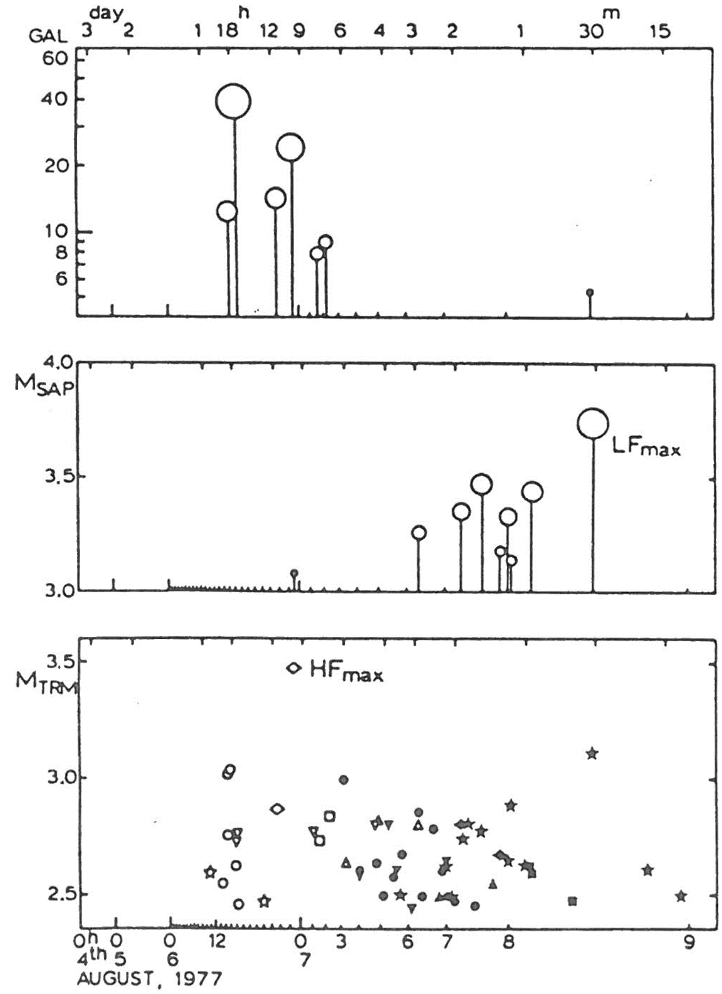


Figure 15-29 Changes in waveform of precursor earthquakes of the 1977-78 eruption (high frequency → low frequency) (Okada, 1985).

Top: Acceleration amplitude (Date)

Middle: Displacement amplitude (Sapporo)

Bottom: Acceleration amplitude (Tarumaesan)

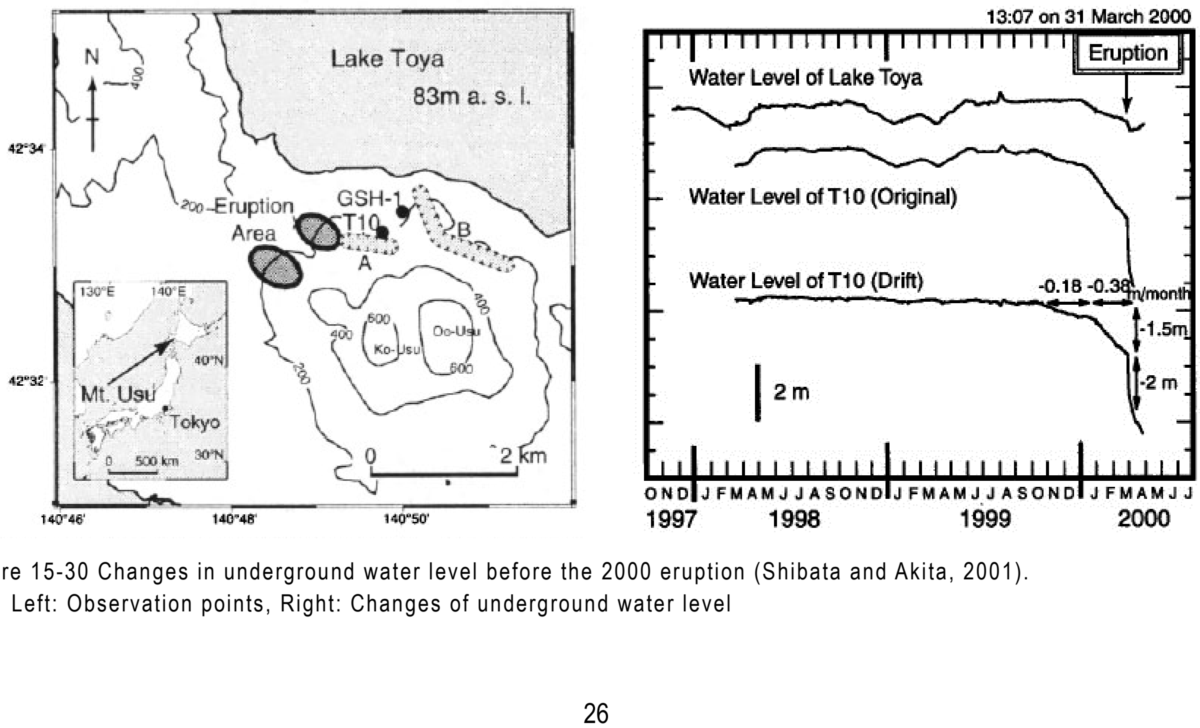


Figure 15-30 Changes in underground water level before the 2000 eruption (Shibata and Akita, 2001).

Left: Observation points, Right: Changes of underground water level

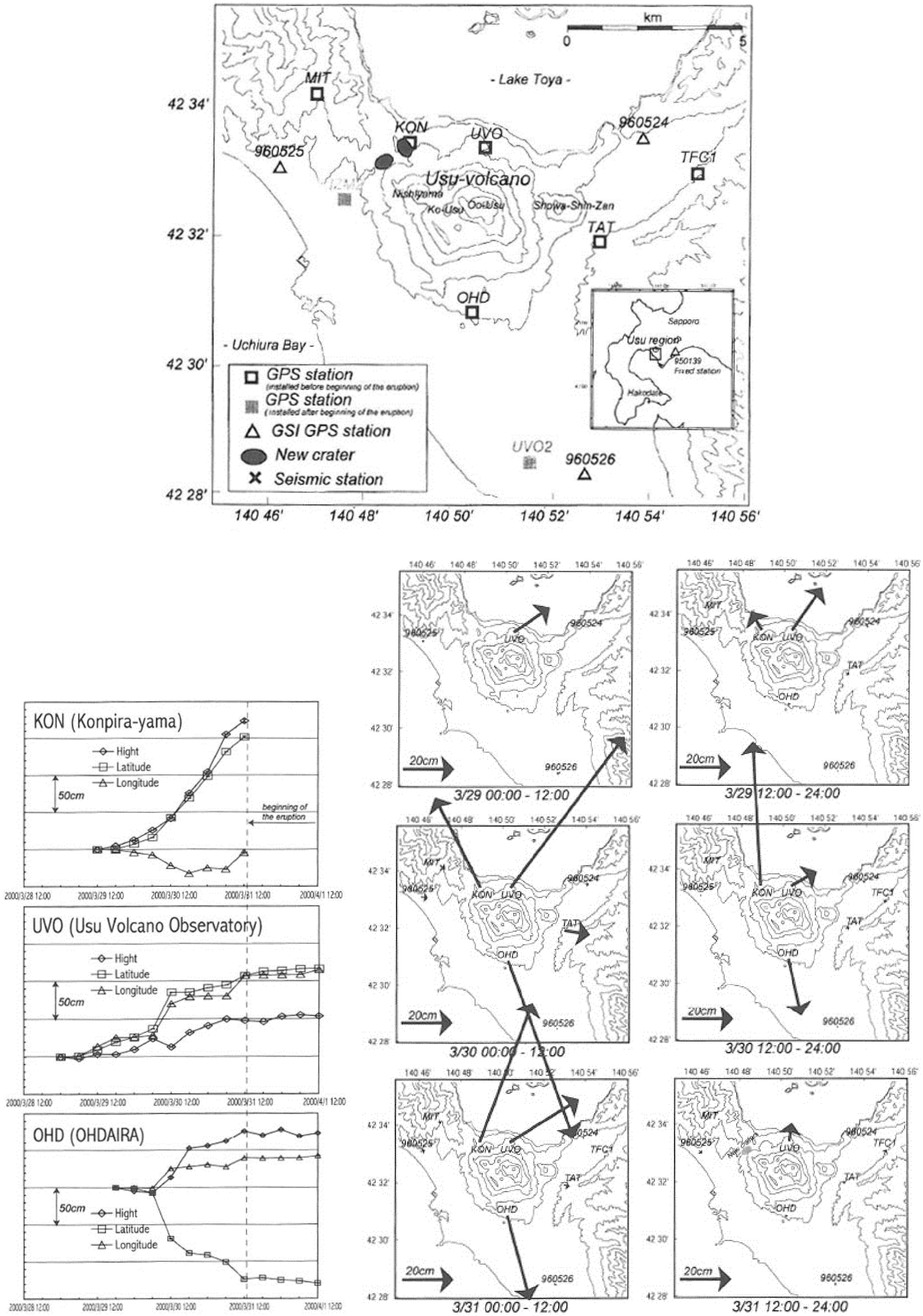


Figure 15-31 Precursor crustal deformation observed by GPS measurement for the 2000 eruption (Takahashi et al., 2002).

Top: Observation points

Bottom left: Change in baseline length, Bottom right: Lateral displacement from March 29 to March 31.

Recent Volcanic Activity

・Activity Chronograms

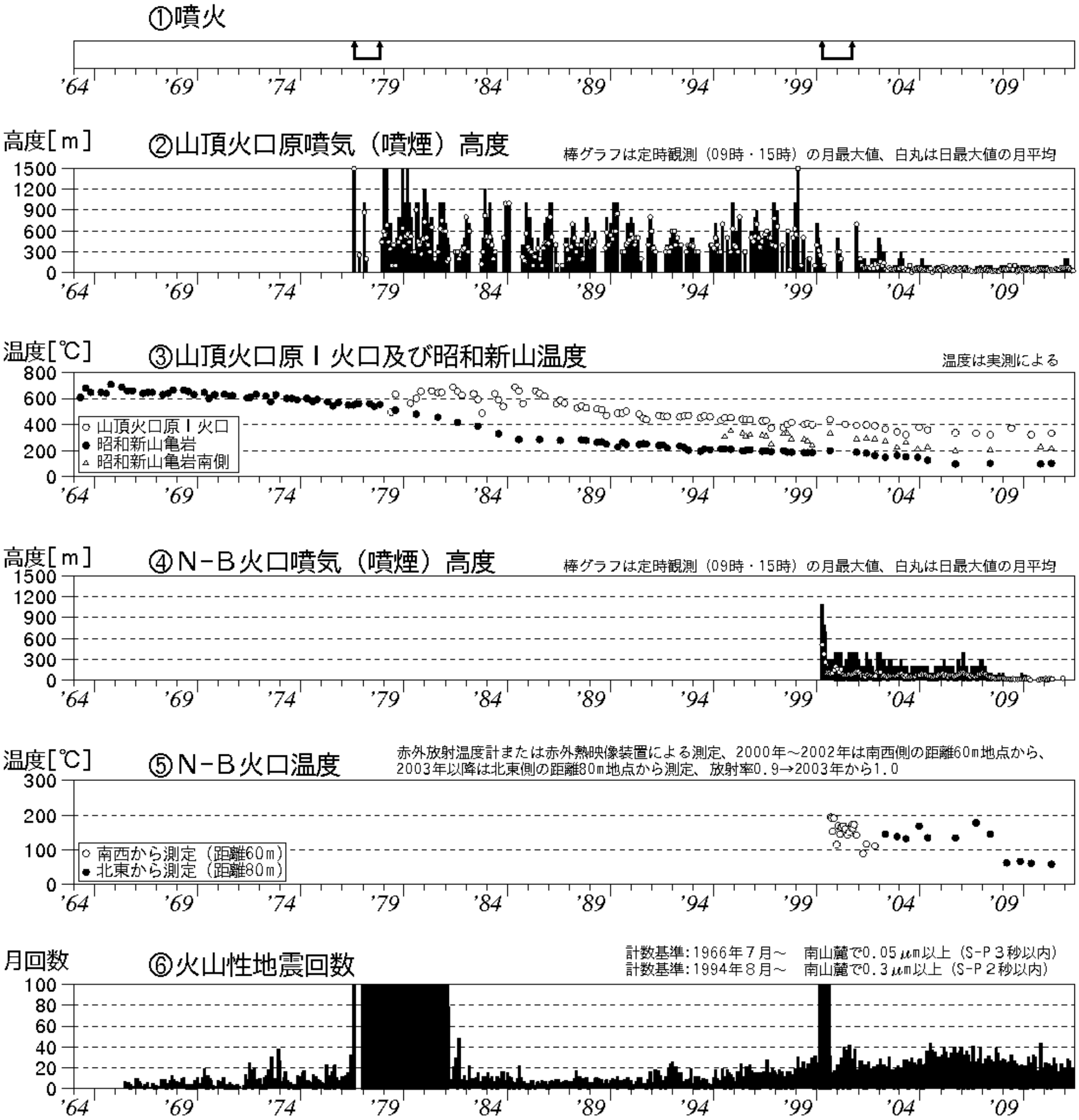


Figure 15-32 Volcano activity (1964 to June, 2012).

①Eruptions

②Fume heights at the summit floor

③Temperature at I-crater and Showashinzan

④Plume heights at N-B crater

⑤Temperature at N-B crater

⑥Number of volcanic earthquakes

・Volcanic Earthquake Epicenter Distribution

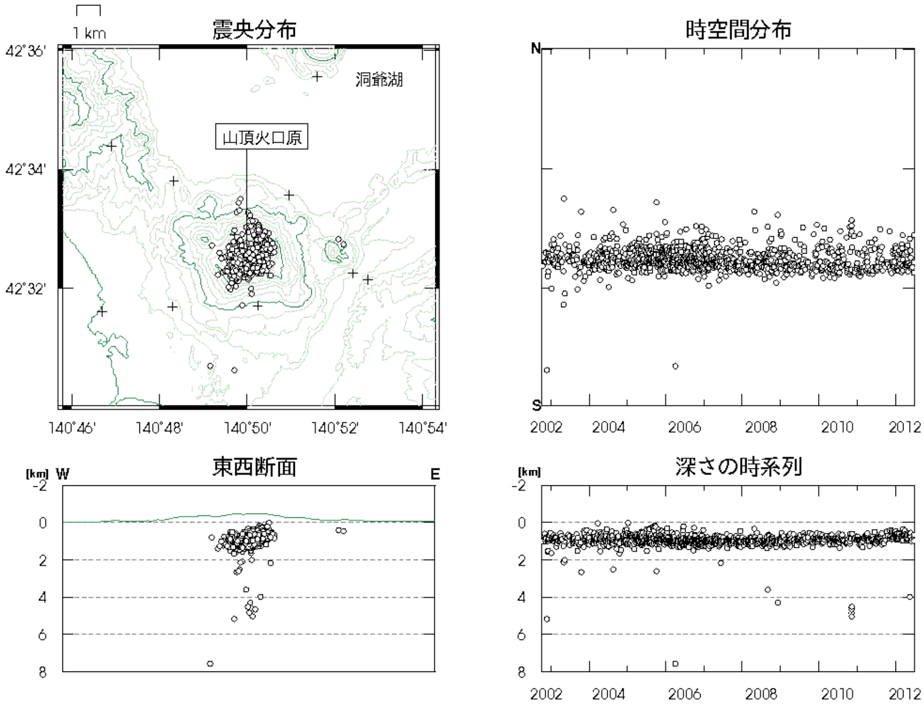


Figure 15-33 Distribution of volcanic earthquakes (October, 2002, to June 30, 2012).
+ symbols indicate earthquake observation points
①Epicenter distribution
②Space-time plot
③E-W cross-section
④Depth time series

・Seismic Activity

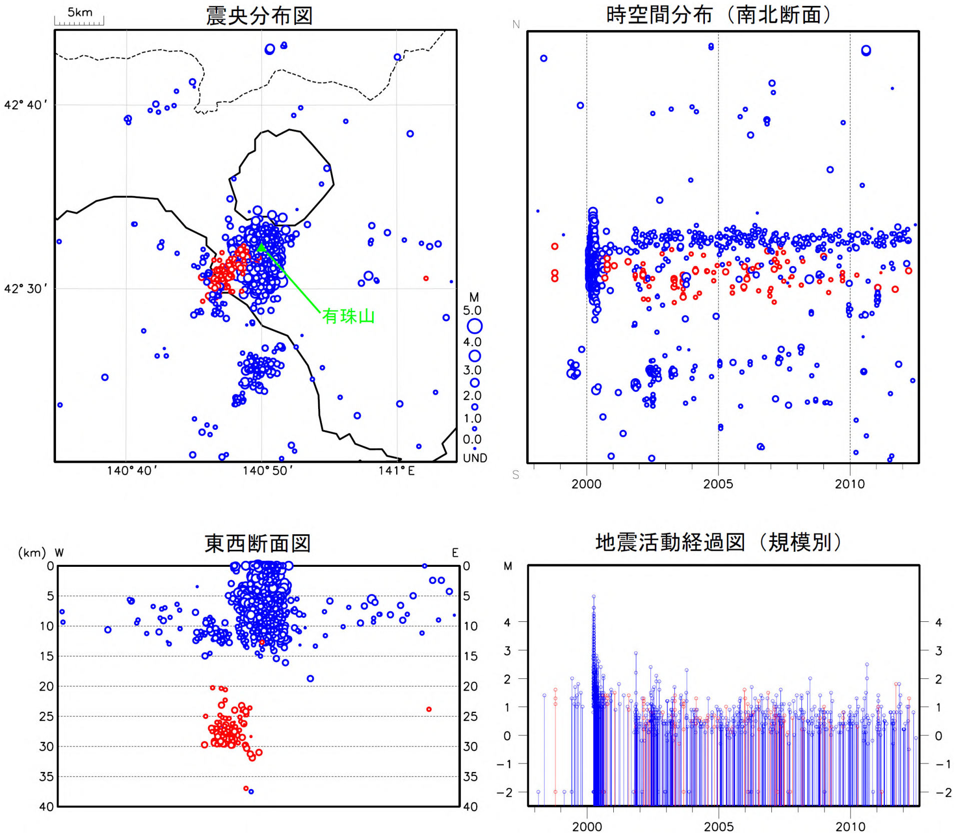


Figure 15-34 Activity of shallow VT earthquakes (blue circles) and deep low-frequency earthquakes (red circles) observed by a regional seismometer network (October 1, 1997, to June 30, 2012). Epicenter distribution (upper left), space-time plot (N-S cross-section) (upper right), E-W cross-section (lower left) and magnitude-time diagram (lower right).

・Usuzan Shallow Area Crustal Deformation

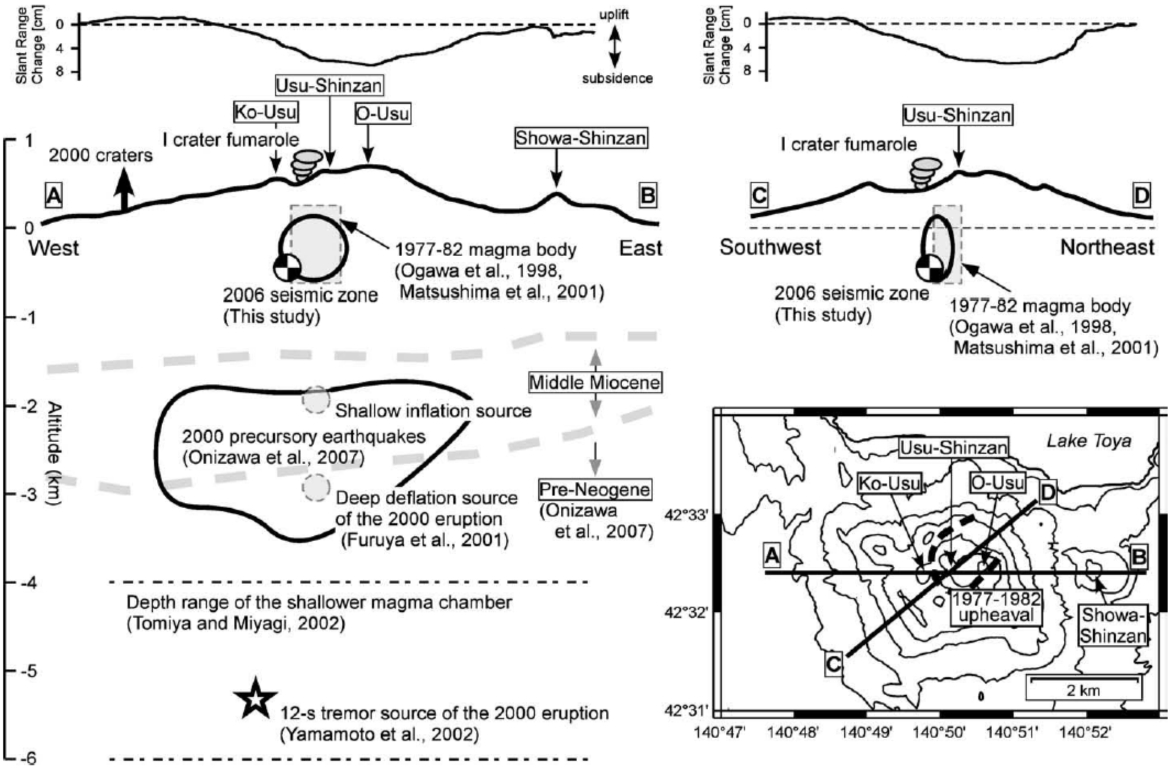


Figure 15-35 Cross-sectional image of crustal activity under Usu volcano (Aoyama et al., 2009).

・Interior Structure

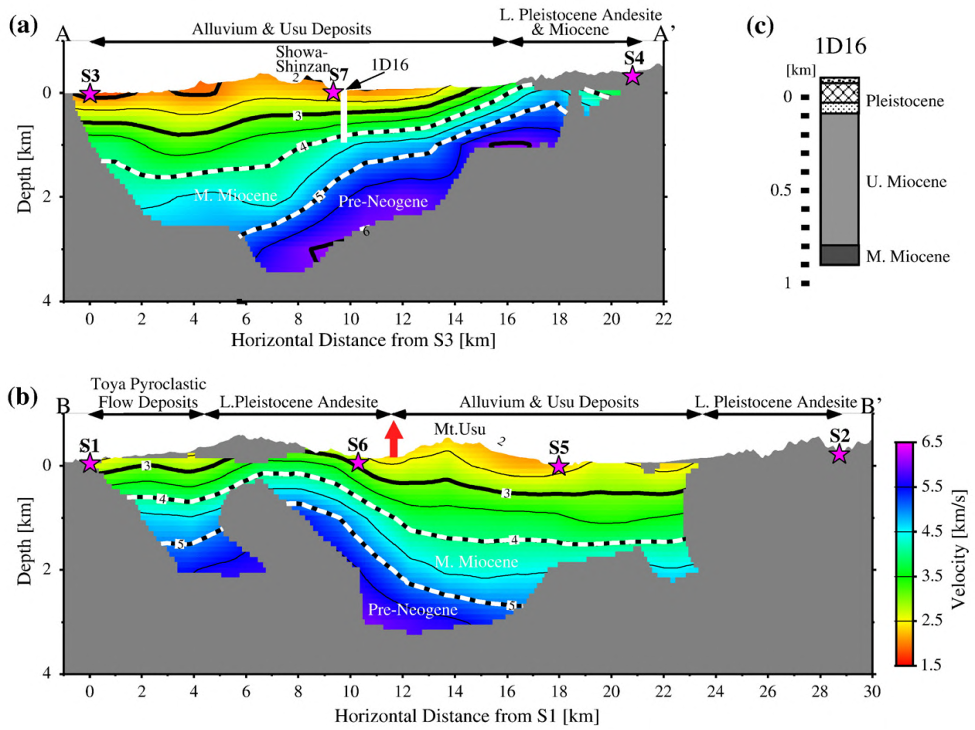


Figure 15-36 Cross sections of the P-wave velocity model determined by the 2001 active seismic survey (Onizawa et al., 2007).

(a) Southwest-northeast cross-section (b) Northwest-southeast cross-section

(c) Geological column of borehole located at Showashinzan

Information on Disaster Prevention

①Hazard Map

Usuzan Volcano Disaster Prevention Map (Wide Area Version) March, 2002 - Published by the Date Office of Disaster Prevention, Abuta Usuzan Eruption Disaster Restoration Initiative Office, Sobetsu Department of General Affairs, Toyoura Planning and Coordination Department, and Toya General Affairs Department, Editorial supervision by the Hokkaido Disaster Prevention Committee Earthquake and Volcano Countermeasure Department Volcano Countermeasure Expert Committee

http://www.city.date.hokkaido.jp/soumu/n96bln0000008f27.html

②Volcanic Alert Levels (Used since June 9, 2008)

有珠山の噴火警戒レベルと必要な防災対応

この図は、国土地理院発行20万分の1地勢図「室蘭」を使用して作成しています。

■噴火地点が特定されない段階

レベル5：赤線内からの避難
レベル4：赤線内で避難準備
レベル3：入山規制や山麓での営林作業の中止等
レベル2：火口周辺への立入規制

■噴火地点が特定された段階

噴火地点や噴火様式が特定された段階で、その影響の及ぶ可能性がある範囲に対してレベル5（避難）やレベル4（避難準備）等を適用します。

このレベルは地元市町等と調整して作成したものです。

図の凡例

- 赤線：噴火により火砕流・火砕サージや大きな噴石の影響を受ける可能性がある区域
- 橙色点線：噴火の起こる可能性のある区域

（有珠山火山防災マップ（平成14年2月）の山頂噴火及び山麓噴火の危険区域予測図に基づき設定した）

Volcanic Alert Levels for the Usuzan Volcano (Valid as of June, 2008)

Warning and Forecast	Target Area	Levels & Keywords	Expected Volcanic Activity	Actions to be Taken by Residents and Climbers	Expected Phenomena and Previous Cases
Eruption Warning	**Residential areas and areas closer to the crater**	**5 Evacuate**	**Eruption or imminent eruption causing significant damage to residential areas**	**Evacuate from the danger zone**	●An eruption from the summit or foot of the volcano is imminent due to further seismic activity or observed prominent crustal deformation. Past Examples March 29, 2000, and August 7, 1977 (early morning): Many felt-earthquakes. ●Eruption at the summit, with volcanic blocks, pyroclastic flow, and pyroclastic surge reaching residential areas. Past Examples August 7, 1977, 09:12; April 22, 1853; March 12, 1822; January 23, 1769: Eruptions from the summit crater floor. Volcanic blocks were scattered approximately 4km from the summit crater, pyroclastic flows and pyroclastic surges covered a wide area, reaching up to 10km from the summit crater (except in the case of the 1977 eruption), deposits of large amounts of pumice and volcanic ash over a wide area. ●Eruption at the foot of the volcano, with volcanic blocks and pyroclastic surge reaching residential areas. Past Examples March 31, 2000, 13:07; June 23, 1944; July 25, 1910: Eruptions from the foot of the volcano. Volcanic blocks scattered up to approximately 2km from the crater, and pyroclastic surge reached up to 3km from the crater (July, 1944 eruption).
		4 Prepare to evacuate	**Forecast of eruption causing significant damage to residential areas (increased probability).**	**Those within the alert area should prepare for evacuation. Those requiring protection in the event of an disaster must be evacuated.**	●High probability of summit or foot eruptions due to increased seismic activity and increased incidence of felt-earthquakes. Past Examples March 28, 2000; August 6, 1977, approximately 04:00: Increase in felt-earthquakes.
Crater Area Warning	**Non-residential areas near the volcano**	**3 Do not approach the volcano**	**Eruption or prediction of eruption causing significant damage to areas near residential areas (entering area is life threatening).**	**Residents can go about daily activities as normal (paying close attention to volcanic activity). When necessary, evacuation preparations should be performed for those requiring protection in the event of a disaster. Access restrictions for dangerous areas, including mountain climbing and mountain access prohibitions, etc.**	●An eruption from the summit or foot of the volcano is forecast due to increased seismic activity. Past Examples March 28, 2000 (early morning); August 6, 1977, approximately 03:30; December 28, 1943: Many small earthquakes, some of which could be felt.
	Crater area	**2 Do not approach the crater**	**Eruption or prediction of eruption affecting area around crater (entering area is life threatening).**	**Residents can go about daily activities as normal (paying close attention to volcanic activity). Access to crater area restricted, etc.**	●Increase in small earthquakes which cannot be felt. Past Examples March 27, 2000; August 6, 1977, approximately 02:00: Increase in very small earthquakes ●Very small eruptions from existing fumaroles and geothermal areas, scattering volcanic blocks in area. Past Examples No observed examples
Eruption Forecast	**Inside the crater**	**1 Normal**	**Little or no volcanic activity. Volcanic ash may be discharged within the crater as a result of volcanic activity (entering area is life threatening).**	**Access to interior of and area around crater restricted as necessary, etc.**	●Little or no volcanic activity. Possibility of discharge of volcanic ash, etc. which may affect summit crater interior and nearby area.

Note 1) Eruptions points (craters) cannot be identified at Usuzan during the initial stages when precursory phenomena occur. Eruption level 2 (Do Not Approach the Crater) requires crater access restrictions, etc. Eruption level 3 (Do Not Approach the Volcano) requires mountain access restrictions and the suspension of forestry activities at the foot of Usuzan, etc.

Note 2) The volcanic blocks mentioned in this table refer mainly to blocks large enough that their trajectories are not affected by wind.

Social Circumstances

①Populations

- Date City: 36,670 (17,747 households) (as of March 31, 2011)
- Toyako Town10,041 (5,120 households) (as of October 31, 2011)
- Sobetsu Town: 2,833 (1,306 households) (as of October 31, 2011)
- Toyoura Town: 4,443 (2,279 households) (as of October 31, 2011)

②National Parks, Quasi-National Parks, Number of Climbers

Shikotsu-Toya National Park (Shikotsu, Jozankei, Noboribetsu areas)

- Lake Toya Usuzan area certified as "Japanese Geopark" in December, 2008.
- Lake Toya Usuzan area certified as "Global Geopark" in August, 2009.
- Lake Toya Onsen area, Lake Toya estimated number of sightseers per year: 2,461,541 (in 2010)
- Sobetsu Onsen area, Sobetsu estimated number of sightseers per year: 1,131,000 (in 2010)
- Date area, Date estimated number of sightseers per year: 2,211,900 (in 2010)

③Facilities

- Date City:

  Date Firefighting and Disaster Prevention Center
- Toyako Town:
  - Lake Toya Visitor Center

  Volcano Science Museum
- Sobetsu Town:

  Sobetsu Information Center "i"

  Mimatsu Masao Memorial Museum

  Usu Volcano Observatory, Hokkaido University

Monitoring Network

Wide Area * Monitoring sites with multiple observation instruments are indicated by small black dots, and other symbols indicate types of monitoring.

1:200,000 scale regional maps (Sapporo, Iwanai, Tomakomai and Muroran) published by the Geospatial Information Authority of Japan were used.

Legend

(JMA)
- seismometer(SP)
- GPS
- tiltmeter
- infrasonic microphone
- visual camera
- seismic intensity meter

(GSI)
- GPS

(NIED)
- V-net(SP)
- V-net(broadband)
- V-net(tiltmeter)
- K-NET
- GPS

(AIST)
- water thermometer
- waterlevel gauge

(Hokkaido Univ.)
- seismometer(SP)
- infrasonic microphone

(Municipalities)
- seismic intensity meter

Figure 15-37 Reigional monitoring network.

In and Around the Summit

* Monitoring sites with multiple observation instruments are indicated by small black dots, and other symbols indicate types of monitoring.

1:50,000 scale topographic maps (Date, Toyoura and Toyako Onsen) published by the Geospatial Information Authority of Japan were used.

Legend

(JMA)
- seismometer(SP)
- GPS
- tiltmeter
- infrasonic microphone
- visual camera
- seismic intensity meter

(GSI)
- GPS

(NIED)
- V-net(SP)
- V-net(broadband)
- V-net(tiltmeter)
- K-NET
- GPS

(AIST)
- water thermometer
- waterlevel gauge

(Hokkaido Univ.)
- seismometer(SP)
- infrasonic microphone

(Municipalities)
- seismic intensity meter

Figure 15-38 Local monitoring network.

Bibliography

Aoyama, H., et al. (2009): J. Volcanol. Geotherm. Res., **187**, 203–217.

Niida, K., et al. (1982): Bull. Volcanol. Soc. Jap., 27, 97-118 (in Japanese with English Abstract).

Fukutomi, K. (1946): Kagaku, 16, 3-8 (in Japanese).

Ishikawa, T. (1950): J. Fac. Sci., Hokkaido Univ., Ser. 4, **7**, 237-260 (in Japanese).

Katsui, Y., et al. (1978): J. Fac. Sci., Hokkaido Univ., Ser. 4, **18**, 385-408.

Katsui, Y., et al. (1985): J. Fac. Sci., Hokkaido Univ., Ser. 4,, **21**, 339-362.

JMA (1980): Meteorological Research Institute, **99**, 203p (in Japanese with English Abstract).

JMA (2003): Meteorological Research Institute, **124**, 247p (in Japanese with English Abstract).

Kizawa, T (1957): Meteorological Research Institute, **8**, 150-169.

Matsumoto, A. and Nakagawa, M. (2010): J. Volcanol. Geotherm. Res., **196**, 185-207.

Matsumoto, A. and Nakagawa, M. (2011): Abstract of Conference of Volcanol. Soc, Jap., 97 (in Japanese).

Mimatsu, M. (1993): Museum of Mimatsu Masao, 225p (in Japanese).

Minakami, T. (1947a): Bull. Earthq. Res. Inst., **25**, 65-69.

Minakami, T. (1947b): Bull. Earthq. Res. Inst., **25**, 71-75.

Minakami, T (1949a): Bull. Earthq. Res. Inst., **27**, 123-128.

Minakami, T (1949b): Bull. Earthq. Res. Inst., **27**, 129-134.

Minakami, T (1950a): Bull. Earthq. Res. Inst., **28**, 143-152.

Minakami, T (1950b): Bull. Earthq. Res. Inst., **28**, 123-128.

Minakami, T., et al. (1951): Bull. Volcanol., **11**, 45-157 (in Japanese with English Abstract).

Miura, D. and Niida, K. (2002): Bull. Volcanol. Soc. Jap., **47**, 119-130 (in Japanese with English Abstract).

Nakagawa, M. et al. (2005): Bull. Volcanol. Soc. Jap., **50**, 39-52 (in Japanese with English Abstract).

Nakamura Y. et al. (2005): J. Geograph., **114**,549-560 (in Japanese with English Abstract).

Nakada, S.(2001): Bull. Earthq. Res. Inst., **76**, 203-214 (in Japanese with English Abstract).

Nishimura, Y. and Okada, H. (1987): Geophys. Bull. Hokkaido. Univ., **49**, 23-30 (in Japanese with English Abstract).

Niida, K., et al. (1980): J. Fac. Sci. Hokkaido Univ., Ser. 4, **19**, 357-394 (in Japanese).

Oba, Y. (1966): J. Fac. Sci. Hokkaido Univ., Ser. 4, **13**, 185-236 (in Japanese).

Okada, H. (1982): Geophys. Bull. Hokkaido. Univ, **41**, 53-63 (in Japanese with English Abstract).

Okada, H. (1988): Hokkaido Univ. Press (in Japanese).

Okada, H., et al. (1981): J. Volcanol. Geotherm. Res. **9**, 311-334.

Okada, H. et al. (2002): Hokkaido Disaster Prevention Council, 58 (in Japanese with English Abstract).

Okazaki, N. (2002): Bull. Volcanol. Soc. Japan., **47**, 547-557 (in Japanese with English Abstract).

Omori, F. (1911): Bull. Imperial Earthquake Investigation Committee, **5**, 1-38.

Omori, F. (1913): Bull. Imperial Earthquake Investigation Committee, **5**, 101-107.

Omori, F. (1920): Bull. Imperial Earthquake Investigation Committee, **9**, 41-76.

Onizawa, S., et al. (2007): J. Volcanol. Geotherm. Res., **160**, 175–194.

Ono, M. et al. (2002): Bull. Volcanol. Soc. Jap., **47**, 619-643 (in Japanese with English Abstract).

Oshima, H. and T. Ui (2003): Bull. Volcanol. Soc. Jap., **48**, 22-31.

Shibata, T. and F. Akita (2001): Geophys. Res. Lett., **28**, 1799-1802.

Soya, T. et al., (1981): Geol. Surv. Japan (in Japanese with English Abstract).

Soya, T. et al. (2007): Geol. Surv. Japan (in Japanese with English Abstract).

Takahashi, H. et al. (2002): Bull. Volcanol. Soc. Jap., **47**, 161-166 (in Japanese with English Abstract).

Takarada, S. et al. (2002): Bull. Volcanol. Soc. Jap., **47**, 645-661 (in Japanese with English Abstract).
Tomiya, A. and Takahashi, E. (2005): J. Petrol., **46**, 2395-2426.
Tomiya, A., et al. (2010): J. Petrol., **51**, 1333-1354.
Ui, T. et al. (2002)Bull. Volcanol. Soc. Jap., **47**, 105-117 (in Japanese with English Abstract).
Ui, T. et al. (2002)Bull. Volcanol. Soc. Jap., **47**, 325-332 (in Japanese with English Abstract).
Yahata, M. (2002)Bull. Volcanol. Soc. Jap., **47**, 263-278 (in Japanese with English Abstract).
Yokoyama I. (1993)Gekkan Chikyu, Special Vol. 7 (in Japanese).
Yokoyama, I. et al. (1973) Hokkaido Disaster Prevention Council, 254p (in Japanese).
Yoshida, M. (1995) Bull. Volcanol. Soc. Jap., **40**, 249-262 (in Japanese with English Abstract).

(Matsumoto, A., and Nakagawa, M.)