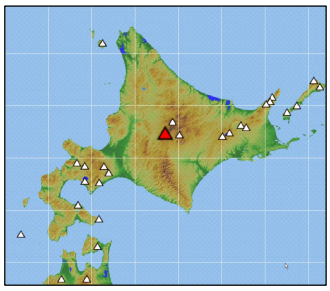
10.Tokachidake



Continuously Monitored by JMA

Latitude: 43°25'04" N, Longitude: 142°41'11" E, Elevation: 2,077 m
(Tokachidake) (Elevation Point)

Overview of Tokachidake, taken from northwest (Bougakudai) on July 13, 2010 by the Japan Meteorological Agency

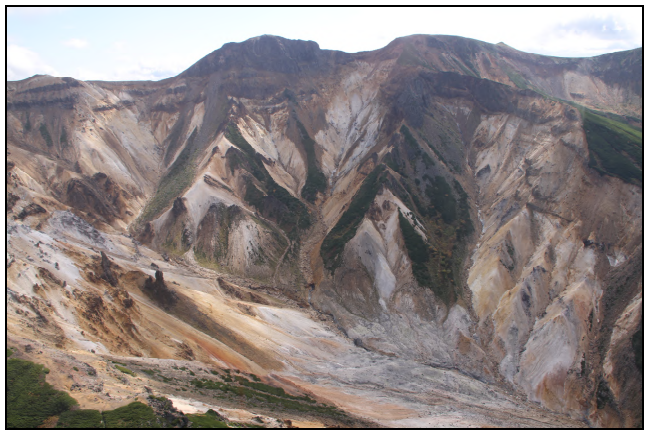
Summary

This volcano group consists of multiple basalt and andesite volcanic edifices (The SiO_2 content is between 46.8 and 66.5 wt %). It can be divided into old, intermediate, and new volcano groups. The highest point (Tokachidake) is the last lava dome, formed during the intermediate stage. Ground crater, central cone, and Suribachi cone etc. are located to its northwest. Fumarolic activity is high both at the Taisho crater (formed during the 1926 eruption) and the 62-2crater (formed during the 1962 eruption) (Katsui et al., 1963; Ishizuka et al., 2010).

In the last 10,000 years, eruptions mainly consisted of air-fall pyroclastic emissions and lava flows by strombolian and subplinian eruptions, but when accompanied by collapse or the emission of hot water, melted snow lahar flows are common, due to the fact that snow season is long (Fujiwara et al., 2007, 2009; Uesawa, 2008; Ishizuka et al., 2010).

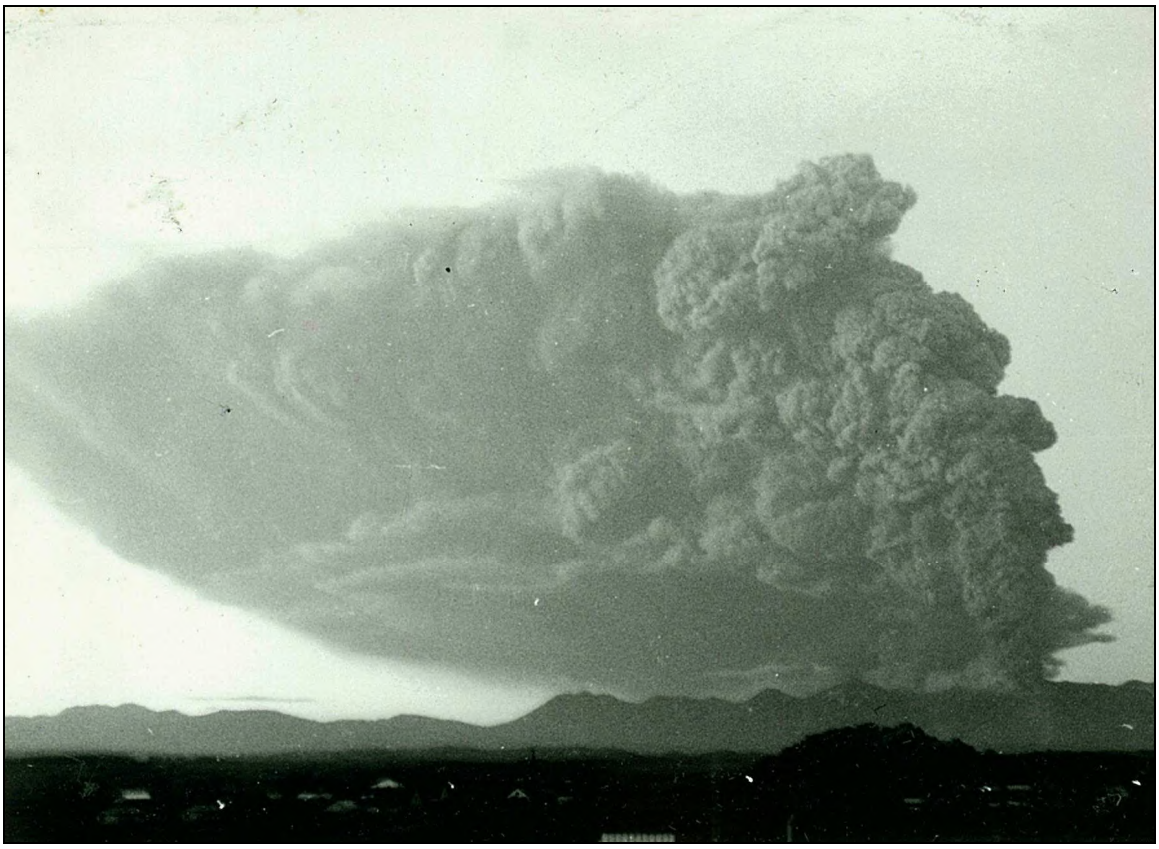
Photos

62-2 Crater and Taisho Crater, taken from southwest side on September 26, 2011 by the Japan Meteorological Agency



Old Eruption Crater taken from northwest side on September 26, 2011 by the Japan Meteorological Agency

Camera image at Bougakudai on December 2, 2011 by the Japan Meteorological Agency



,Eruption on June 30,1962, taken from Biei Town Hall, to northeast by the Japan Meteorological Agency

Eruption on July 1, 1962, taken from northwest Bougakudai , taken by the Japan Meteorological Agency

Eruption on July 3, 1962, taken from northwest side, taken by the Japan Meteorological Agency

Pyroclastic Flow by the Eruption on December 25, 1988, at the 62-2 Crater, taken from northwest Bougakudai by the Japan Meteorological Agency

Topography around the Crater

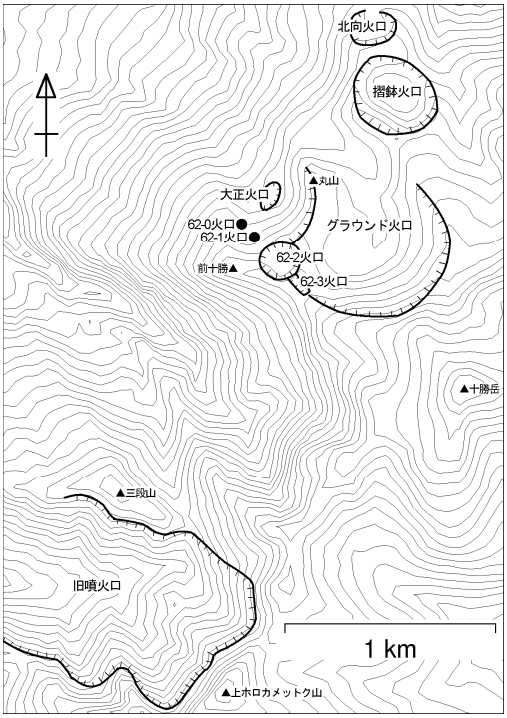
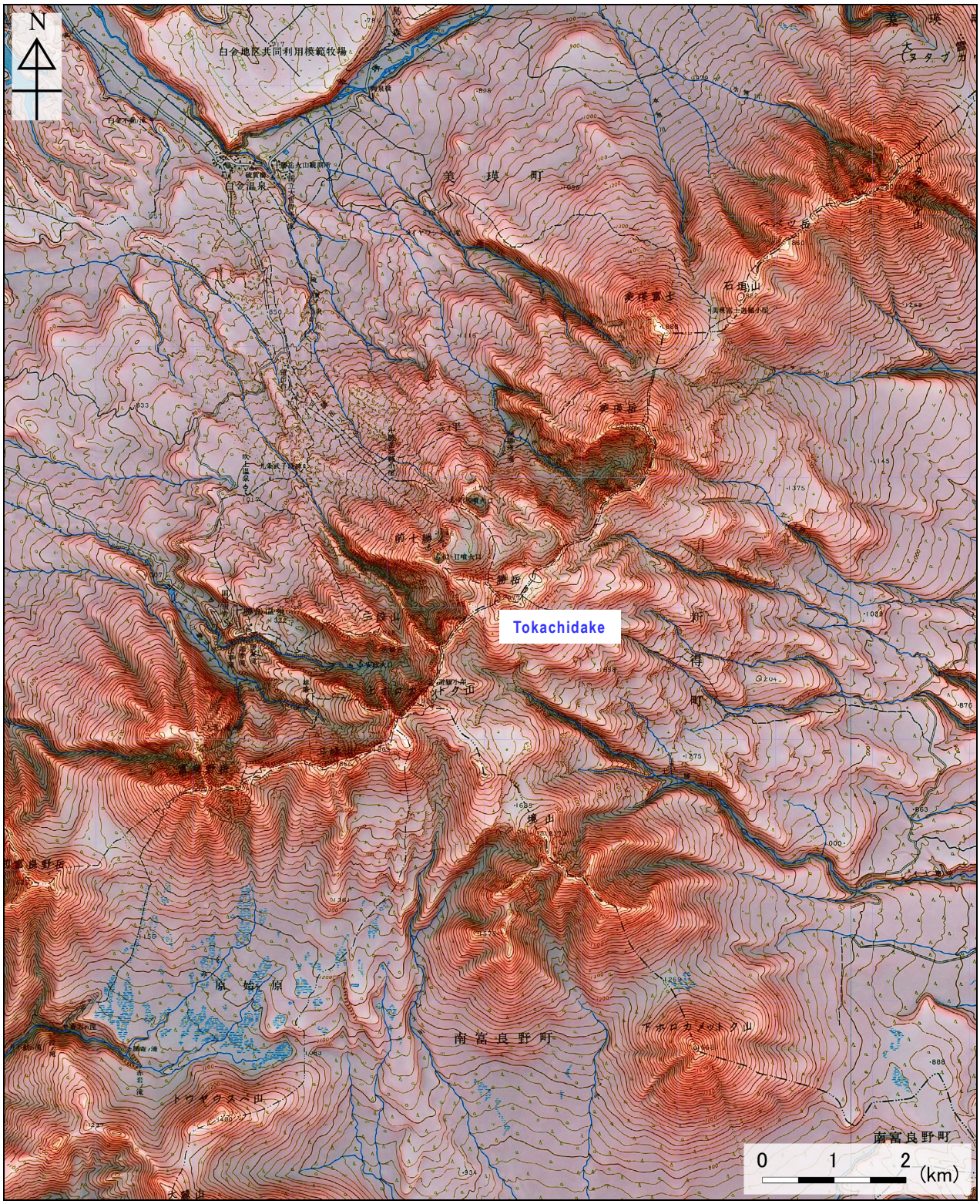


Figure 10-1 Crater topology.

Red Relief Image Map



1:50,000 scale topographic maps (Tokachidake and Tokachi Gawa Joryu) and digital map 50 m grid (elevation) published by the Geospatial Information Authority of Japan were used.

Geological Map

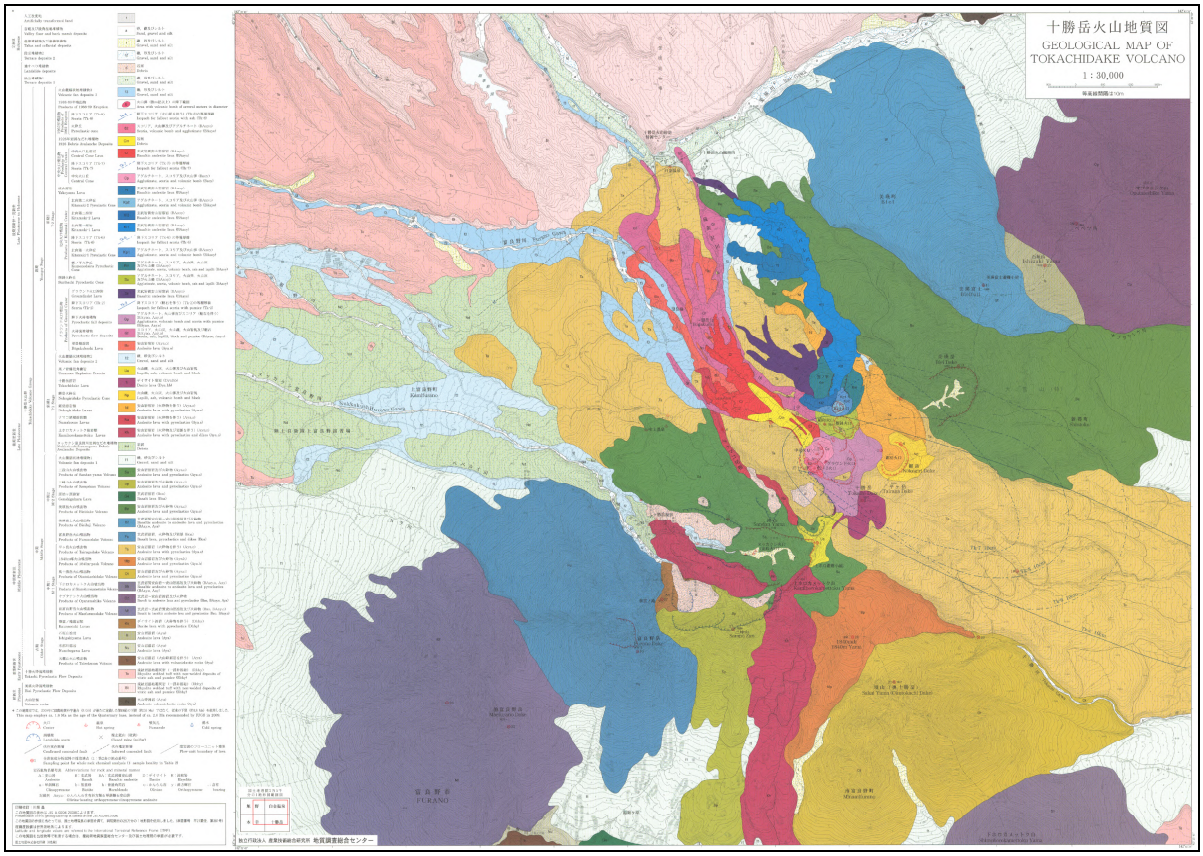


Figure 10-3 Tokachidake geological map (Ishizuka et al., 2010).

Chronology of Eruptions

・Volcanic Activity in the Past 10,000 Years

Eruptions mainly occurred on the northwest flank of Tokachidake, forming multiple craters. The peak of activity was 3,300 to 4,700 years ago, with repeated collapses and explosive eruptions, producing pyroclastic flows. Then, the Ground crater was formed. A lava flowed at the end of the activity. The pyroclastic flow flowed downstream beyond Shirogane Onsen, and lava flow reached Shirogane Onsen. Approximately 1,000 years ago subplinian eruptions occurred repeatedly at the northwest of the Ground crater, forming multiple pyroclastic cones. Some small phreatomagmatic eruptions occurred. Also, a lava flow almost reached Shirogane Onsen at the end of this activity,. The activity at Central cone began approximately 500 years ago, forming a pyroclastic cone and emitting lava. The lava flow reached almost to the Bougakudai. The central cone maintained small scale activity even in the 19th century, and 3 magmatic eruptions occurred in the 20th century. The 1926 eruption produced a large amount of lahar (Ishikawa et al., 1971; Fujiwara et al., 2007, 2009; Uesawa, 2008; Ishizuka et al., 2010).

Period	Area of Activity	Eruption Type	Main Phenomena / Volume of Magma
8.4←→8.3ka		(Lahar produced)	Lahar
		Magmatic eruption	Lava flow
4.8←→4.5ka	Ground crater	Phreatomagmatic eruption (producing lahar)→magmatic eruption	Tk-1 Ground crater pyroclastic flow deposit “0 “eruption: Tephra fall, lahar, pyroclastic flow. Magma eruption volume = 0.004 km^3 DRE. (VEI 3)

Period	Area of Activity	Eruption Type	Main Phenomena / Volume of Magma
3.4ka<		(Lahar produced)	Lahar
		(Lahar produced)	Lahar
3.4ka	Ground crater	Magmatic eruption (producing lahar)	Lower Ground crater / upper pyroclastic flow deposit eruption: Pyroclastic flow, pyroclastic surge, tephra fall, lahar. Magma eruption volume = 0.022 km^3 DRE. (VEI 3)
3.4ka>	Ground crater northern slope	Magmatic eruption	Ground crater lava flow eruption: Lava flow. Magma eruption volume = 0.018 km^3 DRE.
2.7ka<	Near old eruption crater	Phreatic eruption	Tephra fall
2.2←→1.9ka		(Lahar produced)	Lahar
		(Lahar produced)	Lahar
2←→1.9ka	Near old eruption crater	Phreatic eruption	Tephra fall
2.2←→1.8ka		(Lahar produced)	Lahar
1.9←→1.8ka		Phreatic eruption	Tk-3 eruption: Tephra fall
1.9←→1ka	Suribachi crater	Magmatic eruption, phreatomagmatic eruption	Suribachi crater pyroclastic deposit eruption: Tephra fall, pyroclastic surge. Magma eruption volume = 0.0017 km^3 DRE. (VEI 2)
1.3←→0.9ka		(Lahar produced)	Lahar[1]
1←→0.9ka	Kumonotaira pyroclastic cone	Magmatic eruption	Kumonotaira pyroclastic deposit eruption: Tephra fall, pyroclastic surge. Magma eruption volume = 0.0084 km^3 DRE. (VEI 3)
0.8ka	Kitamuki crater	Magmatic eruption	Kitamuki No. 1 pyroclastic deposit eruption: Pyroclastic fall. Magma eruption volume = 0.012 km^3 DRE. (VEI 3)
0.8←→0.7ka	Kitamuki crater	Magmatic eruption	Kitamuki No. 1 lava flow eruption: Lava flow. Magma eruption volume = 0.0094 km^3 DRE.
	Yakeyama crater	Magmatic eruption (producing lahar)	Yakeyama lava flow eruption: Lava flow, lahar. Magma eruption volume = 0.0036 km^3 DRE.
0.8←→0.5ka	Kitamuki crater	Magmatic eruption	Kitamuki No. 2 lava flow eruption: Lava flow. Magma eruption volume = 0.0014 km^3 DRE.
			Kitamuki No. 2 pyroclastic flow deposit eruption: Pyroclastic fall. Magma eruption volume = 0.00022 km^3 DRE (VEI 1)
0.7ka	Near old eruption crater	Phreatic eruption	Pyroclastic fall.
0.5ka	Central crater	Magmatic eruption	Central crater pyroclastic deposit eruption: Pyroclastic fall. Magma eruption volume = 0.0073 km^3 DRE. (VEI 3)
		(Lahar produced)	Lahar
	Central crater	Magmatic eruption	Central crater lava flow eruption: Lava flow. Magma eruption volume = 0.011 km^3 DRE.
0.261←→0.254ka	Sandanzan northern slope	(Collapse)	Debris avalanche
		(Lahar produced)	Lahar

* 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

A<: Eruption event before year A.

A>: Eruption event after year A.

・Historical Activity

Year	Phenomenon	Activity Sequence, Damages, etc.
1857 (Ansei 4)	Eruption	On May 20 (solar calendar), central cone eruption: Sulfuric activity around Yakeyama (by Mr. Matsuda). On June 14 (solar calendar), "Lava poured out from the side of the mountain, and a black volcanic plume rose into the sky." (by Mr. Matsuura)
1887 (Meiji 20)	Eruption	Eruption from the central cone. Pyroclastic fall. Tephra fall in nearby area (Mr. Obinata).
1923 (Taisho 12)	Molten sulfur emission	In June, a molten sulfur pool appeared, And the temperature rose and volume of water increased at Maruya Onsen (near the current" Bougakudai"). In August, molten sulfur was sprayed 7 to 8m high.
1925 (Taisho 14)	Eruption	On December 23 an eruption occurred from Obuki, inside the central cone crater. Rumbling.
1926 (Taisho 12)	Moderate: Phreatic eruption (producing lahar) → (collapse and lahar production) → magmatic eruption, phreatic eruption	Eruption from the central cone. Tephra fall and lahar → debris avalanche and lahar → air-fall pyroclastic material. After mid-February, lapilli were ejected from the Obuki crater. A small eruption occurred on April 5 and 6. Tephra fall from the Obuki crater, and a fire column mid-way through the eruption. Rumbling on May 4 and 5. A small eruption occurred on May 7. Fire column, volcanic blocks, tephra fall. New crater formation. Felt-earthquakes on May 13 and 14. Earthquakes could be felt at the foot of the mountain. Rumbling and volcanic plume from May 13 to 17: Continuous rumbling began on May 13, calming gradually on May 15, but the amount of volcanic plume increased. Rumbling on May 22: Could also be felt at the foot of the mountain. Lapilli were ejected from the Obuki crater. May 24 eruption: Eruption at approximately 12:11, with small lahar flow. At approximately 14:00, small rumbling and eruption. At around 16:18, an eruption occurred, and the west side in the central cone was partially collapsed. Hot debris avalanche melted snow, creating a large amount of lahar (average speed: approximately 60kmh), covering two towns (Kamifurano and Biei). 144 dead or missing, approximately 200 injured. 372 buildings damaged, 68 livestock killed, and mountain forest farmland damaged. Created u-shaped crater opening to northwest (450x300 m). Total ejecta: $4x10^4$ m^3. Collapse material: 2 to $4x10^6$ m^3. Magma eruption volume = $1x10^3$ m^3 DRE. (VEI 1) September 8 eruption: Occurred at approximately 16:33. A volcanic plume rose up to 4,600 m. Eruption left 2 people missing. A small eruption on September 9 occurred at approximately 15:40. Small eruptions on September 10 occurred at approximately 09:37, 15:48, and 18:50. Small eruptions occurred from September 11 to 21: Repeated small eruptions. Eruptive activity in September left oval crater in area that collapsed on May 24 (Taisho crater: 130x50 m, 30 m deep) Small eruption on December 10: Small amount of lahar was produced. Volcanic plume on December 17: Small, black volcanic plume. Volcanic plume on December 25: Black volcanic plume (rose up to 500 m).
1927 (Showa 2)	Phreatic eruption	Multiple small eruptions and black volcanic plume from January to April, and June to September.
1928 (Showa 3)	Eruption	Volcanic plume on January 16. Volcanic plume and ash fall on March 5. May 23 eruption: Black volcanic plume.
	Phreatic eruption	Rumbling accompanied by eruption on December 4 (final eruption at Taisho stage). The area of activity was the Taisho crater.
1936 (Showa 11)	Molten sulfur emission	Sulfur emitted from February to autumn.
1947 (Showa 22)	Fume	Increase in fume in old eruption crater.
1952 (Showa 27)	Phreatic eruption	Showa crater was formed on August 17 (30 mx15 m). Fumarole with 50 cm in diameter was confirmed inside the crater. Fumarole possibly appeared around 18:00.
1954 (Showa 29)	Phreatic eruption	Small explosions at Showa crater in September. Sulfur emitted from Taisho crater.
1956 (Showa 31)	Phreatic eruption	Small explosions at Showa crater in June.
1957 (Showa 32)	Fumarole formed	New fumarole formed at Showa crater in February.

Year	Phenomenon	Activity Sequence, Damages, etc.
1958 (Showa 33)	Phreatic eruption	Small explosions at Showa crater on October 4. New fumarole (58-1) was formed in Showa crater.
1959 (Showa 34)	Phreatic eruption	Small explosions at Showa crater 58-1 fumarole in August and November. Small-scale lahar in November.
1961 (Showa 36)	Fume	At Taisho crater, fume activity from June to July, as well as natural sulfur fires.
	Phreatic eruption	Weak phreatic explosion at old crater on August 14, making water of Nukkakushi Furano River grey (according to Aida).
1962 (Showa 37)	Moderate: Magmatic eruption, phreatomagmatic eruption	Tephra fall from March to June. Increased fumarolic activity at Taisho crater. Felt-earthquakes began from May to June, gradually growing in frequency. Eruption on June 29. Eruption occurred from the south side of central cone (near Yunuma), at approximately 22:40. Sulfur mining office at edge of Taisho crater damaged by volcanic blocks. 5 dead, 11 injured. Eruption from approximately 2:45 on June 30. High level of emission of volcanic projectiles and volcanic ash. A volcanic plume rose up to 12,000 m. Tephra fall in direction of Shiretoko and Minami-Chishima. Explosion sound could be heard 190 km away. Eruption, accompanied by fire column, continued until approximately July 5. This eruption formed craters 62-0, 62-1, 62-2, and 62-3 along the southwest wall of the Ground crater, and the formation of a scoria cone around the 62-2 crater. Total ejecta: 7.1×10^7 m^3. Magma eruption volume: 0.028 km^3 DRE. (VEI 3)
1968 (Showa 43)	Earthquake and volcanic plume	Earthquake swarm in May and December: Volcanic earthquake swarm occurred after the Tokachi Oki Earthquake (M7.9 earthquake on May 16). Increase in volcanic plume at 62-2 crater in May.
1969 (Showa 44)	Earthquake	Earthquake swarms from January to August: Peak month for earthquakes was March, with 3344 earthquakes (2 of which were Felt-earthquakes). Seismic activity gradually lessened after April.
1971 (Showa 46)	Fume	Activity ceased at Showa crater in June.
1974 (Showa 49)	Fume	Fumarolic activity resumed and grew in intensity between May and July 62-1 crater.
1975 (Showa 50)	Fume	Volcanic fume decreased at 62-1 crater.
1983 (Showa 58)	Earthquake	Earthquake swarms in February and May. The area of discoloration in east wall of 62-1 crater grew in September.
1984 (Showa 59)	Fume	Fumarolic activity at 62-1 crater intensified between June and September, with fumarole temperatures exceeding 300 °C. During September the temperature of the wall was 475 °C.
1985 (Showa 60)	Mud ejection	Hot mud ejection: Hot mud jet with approximately 5 m tall was ejected from east wall of 62-1 crater on May 29. Depression with 10 m long at widest point (85-1 fumarole) was confirmed.
	Phreatic eruption	Very small-scale eruption: A black/gray volcanic plume was emitted from 62-1 crater on June 19, with small amount of tephra fall in nearby area. Red-hot glow from June 19 to 22: Red-hot glow at 62-1 crater (natural sulfur fire). Volcanic tremors on September 1.
1986 (Showa 61)	Earthquakes, volcanic tremors	Felt-earthquakes on August 31. JMA scale seismic intensity 1 at Shirogane Onsen. Temperature increase in October: Maximum temperature of 529 °C at east wall of 62-1 crater. Felt-earthquakes on December 3. JMA scale seismic intensity 1 at Shirogane Onsen. Volcanic tremors on December 20.
1987 (Showa 62)	Volcanic tremors	Tremors in February, March, July, and August.

Year	Phenomenon	Activity Sequence, Damages, etc.
1988 (Showa 63)	Earthquake, volcanic tremor, pyroclastic flow, pyroclastic surge, lahar	Earthquakes of JMA scale seismic intensity 1 or 2 at Tokachidake Onsen in February and June, with hypocenters at very shallow parts of the old eruption crater. Earthquake swarm in September: Increase in earthquakes after late September. Volcanic tremors on October 4. Felt-earthquakes in October. Felt-earthquakes in November. Maximum JMA scale seismic intensity of 3. Very small eruptions on December 10, 11, 13, 14, and 15: Eruptions from 62-2 crater. Eruption on December 16: Small eruptions from 62-2 crater. Accompanied by explosion sound and explosive earthquake (JMA scale seismic intensity 3 at Shirogane Onsen). Tephra fall up to approximately 80km southeast. Small eruptions on December 18 and 19: Fire column, pyroclastic surge, small lahar, and tephra fall up to approximately 150 km east-by-northeast. Small eruption on December 24: Fire column and pyroclastic surge. Small eruption on December 25: Fire column, volcanic lightning, volcanic blocks, pyroclastic surge, small pyroclastic flow, and small-scale lahar. Small eruption on December 30: Explosion sound and explosion earthquake (JMA scale seismic intensity 1 at Fukiage Onsen).
1988 to 1989 (Showa 63 to Heisei 1) December 10 to March 5	Small-scale: Phreatic eruption, phreatomagmatic eruption	Tephra fall→pyroclastic surge, pyroclastic flow, tephra fall, and lahar. Total ejecta: 7.4×10^5 m^3. Magma eruption volume: 5×10^4 m^3 DRE. (VEI 1)
1989 (Heisei 1) January 1 to March 5	Pyroclastic flow, pyroclastic surge, lahar, earthquake, volcanic tremor	17 eruptions. Fire column, pyroclastic surge, pyroclastic flow, volcanic blocks, lahar, glowing, tephra fall extending 140 km (total of 28 phreatic and phreatomagmatic eruptions from December 1988 to March 1989). Harmonic tremors on January 13 and 21.. Earthquake swarms from June to August. Volcanic tremors in July. Volcanic tremors in December.
1990 (Heisei 2)	Volcanic tremors	Volcanic tremors in January, February, and June.
1991 (Heisei 3)	Volcanic tremors	Volcanic tremors in February.
1992 (Heisei 4)	Earthquake	Felt earthquake on March 17. JMA scale seismic intensity 1 in some parts of Shirogane Onsen.
1994 (Heisei 6)	Volcanic tremors	Volcanic tremors in April.
1995 (Heisei 7)	Earthquakes, volcanic tremors	Increased earthquakes from July to December, and volcanic tremors in August.
1996 (Heisei 8)	Earthquake	Increase in earthquakes in May and June.
1997 (Heisei 9)	Earthquake, fume, volcanic tremor	Increase in earthquakes in May. The increase on fumaroles temperature at Furikozawa was detected by field observation in June. Fumarolic activity resumed in September (first time since 1993). Volcanic tremors in January, February, March, May, September, and October.

Year	Phenomenon	Activity Sequence, Damages, etc.
1998 (Heisei 10)	Earthquake, fume mud ejection, crater glow, volcanic tremor	Volcanic earthquake on April 17, accompanied by infrasonic wave. Later aerial observation confirmed evidence of surface phenomena. Increased earthquakes from June to August. Field observation on June 23 and June 24 found the formation of new fumarole inside the northwest wall of 62-2 crater. Fumarole temperature 414 °C (measured via infrared radiation thermometer at a distance of approximately 40 m). Fumarolic activity resumed in 62-3 crater (first time since September, 1992). Temperature increases and expansion of geothermal and discoloration areas at 62-0 crater, 62-1 crater, and Furikozawa fumarole. Volcanic gas released in September. Broadleaf tree leaf withering at foot of volcano. Hot mud ejection on September 29: Hot mud was ejected to a height of approximately 2 m from bottom of 62-2 crater, and a new fumarole was formed inside the west wall. Hot mud was confirmed on October 5 as well. On October 9, night brightness in the area around the 62-2 crater was confirmed by high-sensitivity cameras. This was observed occasionally thereafter. Increased volcanic plume activity on October 12: Black volcanic plume was emitted twice from 62-2 crater. The 62-2 crater was confirmed to have stopped ejected hot mud on October 13. The hot mud had been ejected from a hollow approximately 5 m in diameter, and a large white volcanic plume was emitted from its center. Temperature of fumaroles inside the northwest wall of 62-2 crater was 460 °C. Tremors in January, February, May, July, and September.
1999 (Heisei 11)	Earthquake	Volcanic earthquake on May 27, accompanied by an infrasonic wave, whose source was hypothesized to be near 62-2 crater. No surface phenomena.
2000 (Heisei)12)	Volcanic tremor, fume, earthquake, mud ejection	Approximately 18 minutes of volcanic tremors were observed on January 1. Geothermal activity on February 24: New fumarole confirmed via visual observation on northwest slope of Maetokachi. Felt-earthquakes on June 21 and 25: On June 21, at 11:09, Japan Meteorological Agency personnel engaged in field observation felt a quake with a JMA scale seismic intensity of approximately 1 (not felt at foot of volcano). Felt earthquake at Shirogane Onsen on June 25. Hot mud ejection on July 23: Hot mud ejection confirmed at bottom of 62-2 crater. Temperature of fumarole inside the northwest wall was 507 °C.
2002 (Heisei 14)	Volcanic tremors	Volcanic tremors occurred in January, March, May, and September.
2003 (Heisei 15)	Volcanic tremors	Relatively large volcanic tremors observed on February 8 (duration of approximately 37 minutes), followed in mid-June by 6 additional tremors, gradually decreasing in scale. No surface phenomena or other anomalies were observed in any of the tremors.
2004 (Heisei 16)[14]	Phreatic eruption	Very small eruption from February 25 to 26. On April 19 colored volcanic plume, mixed with volcanic ash, was emitted from the 62-2 crater, accompanied by small amplitude volcanic tremors. Volcanic tremors with small amplitudes also occurred on April 9 and April 12. Volcanic tremors occurred in November.
2005 (Heisei 17)	Volcanic tremors	Volcanic tremors in June, July, and September.
2006 (Heisei 18)	Volcanic tremors	Volcanic tremors in February.
2007 (Heisei 19)	Crustal deformation, volcanic tremors	June field observation confirmed localized inflation in shallow areas of 62-2 crater, which continued afterwards. Volcanic tremors in July.
2008 (Heisei 20)	Volcanic tremors	Volcanic tremors in June and July.
2009 (Heisei 21)	Volcanic tremors	Volcanic tremors in April, May, July, and October.
2010 (Heisei 22)	Fume, volcanic tremor	Slight increase in fumarole activity at Taisho crater from May. Volcanic tremors in February, May, and July.
2011 (Heisei 23)	Volcanic tremors	Volcanic tremors occurred in January, February, August, and November.

Year	Phenomenon	Activity Sequence, Damages, etc.
2012 (Heisei 24)	Crater glowing, volcanic tremor	June 30: High-sensitivity cameras observed that the Taisho crater appeared bright at night. This continued until the night of July 4. The cause is concluded to have been the emission of high temperature volcanic gas and/or the burning of sulfur, etc. No evidence of ejecta was found by aerial observation on July 1. Relatively high levels of SO_2 (approximately 600 t/day) were observed on the same day. SO_2 emissions gradually decreased thereafter. Volcanic tremors in January and July.
	Earthquake	Temporary increase in earthquakes on December 2. An earthquake with a seismic intensity of 1 on JMA scale is estimated to have occurred in the Shirogane Onsen area and Tokachidake one at 13:37, and an earthquake with a seismic intensity of 1 on JMA scale occurred in the Shirogane Onsen area at 13:49.

* 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.

Whole Rock Chemical Composition

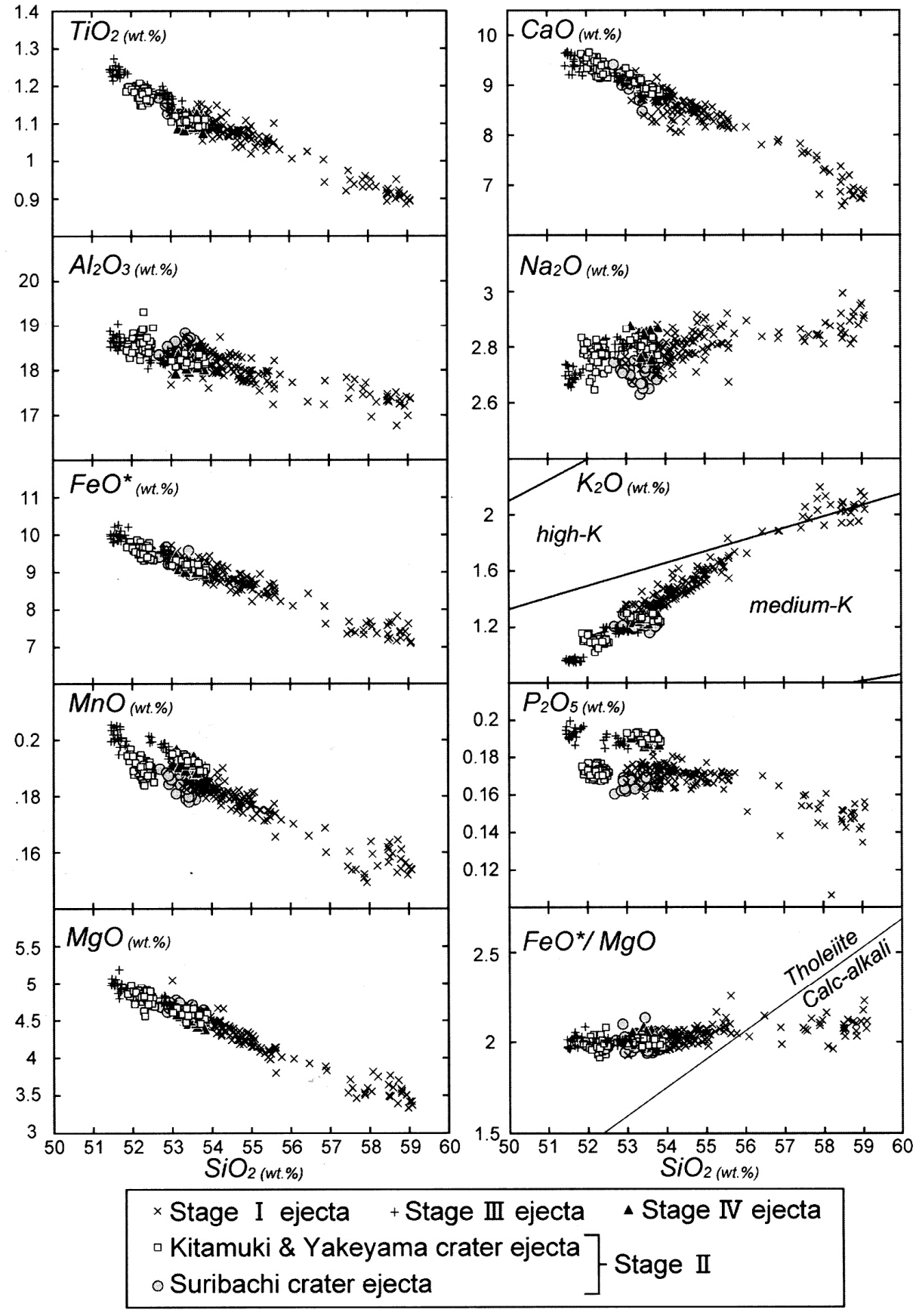


Figure 10-4 Whole rock chemical composition of ejecta within the past 3,300 years by Harker diagram (Fujiwara et al., 2007).

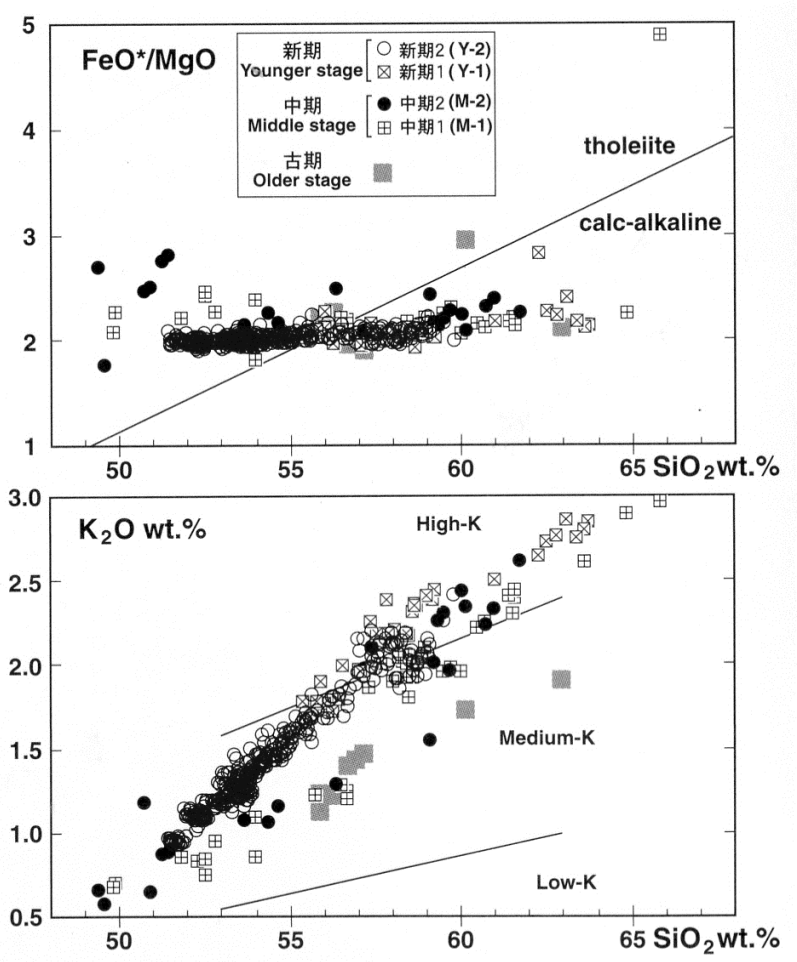


Figure 10-5 Whole rock chemical composition of Tokachidake volcano group by Harker diagram (Ishizuka et al., 2010).

Period - Cumulative Magma Volume

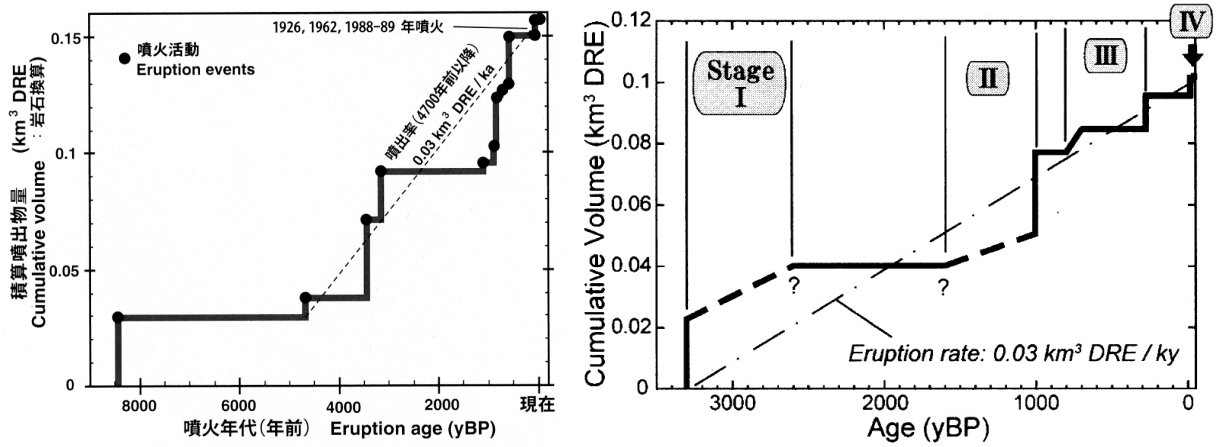


Figure 10-6 Change in cumulative magma emission over time in Holocene epoch (left) and last 3,300 years (right) (Fujiwara et al., 2007; Ishizuka et al., 2010).

Stage I: Activity period in which Ground crater was formed,

Stage II: Activity period in which Suribachi, Kitamuki, and Yakeyama craters were formed,

Stage III: Activity period in which central cone was formed,

Stage IV: Activity period since 1926

Major Volcanic Activities

・1926 Eruption

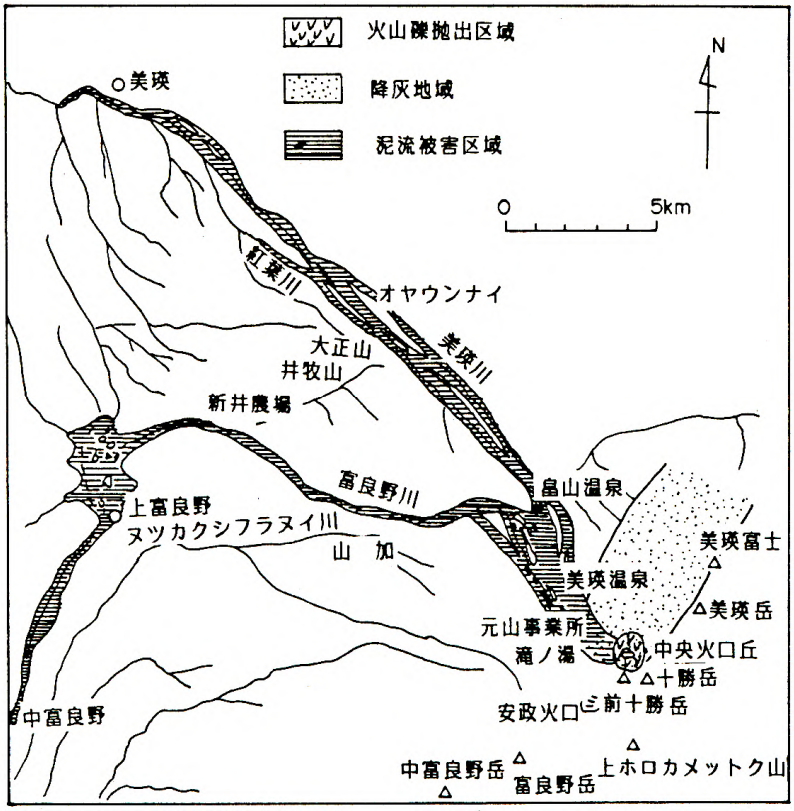


Figure 10-7 Distribution of ejecta and lahar produced by the 1926 eruption (Tada and Tsuya, 1927).

・1962 Eruption

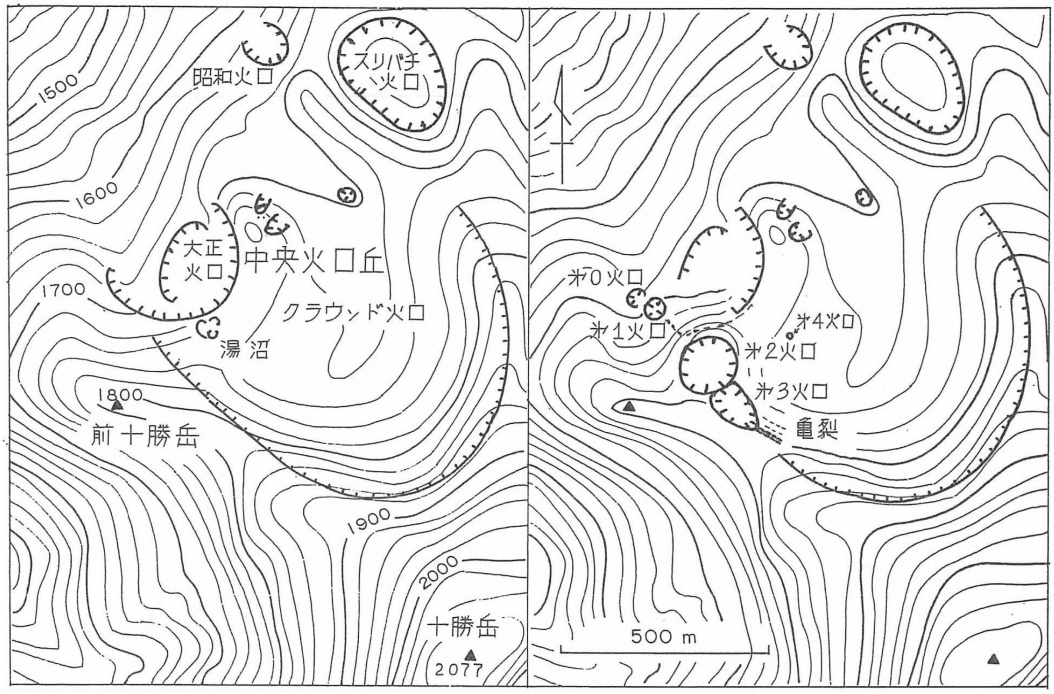
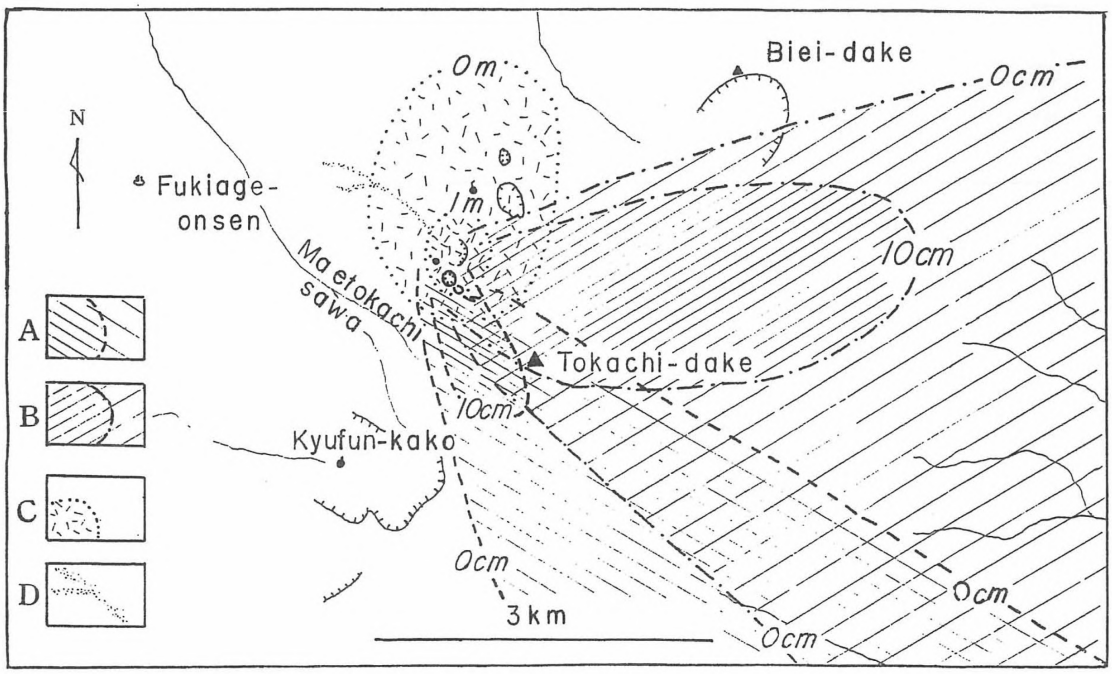


Figure 10-8 Topographic changes around crater before (left) and after (right) the 1962 eruption (Ishikawa et al., 1971).



A： 第１回目噴火の火山灰　　B： 第２回目噴火の火山灰
C： 火山弾，スコリア，火山岩塊　　D： 泥流

Figure 10-9 Distribution of ejecta in and around Tokachidake from June 29 to June 30, 1962 (Ishikawa et al., 1971).

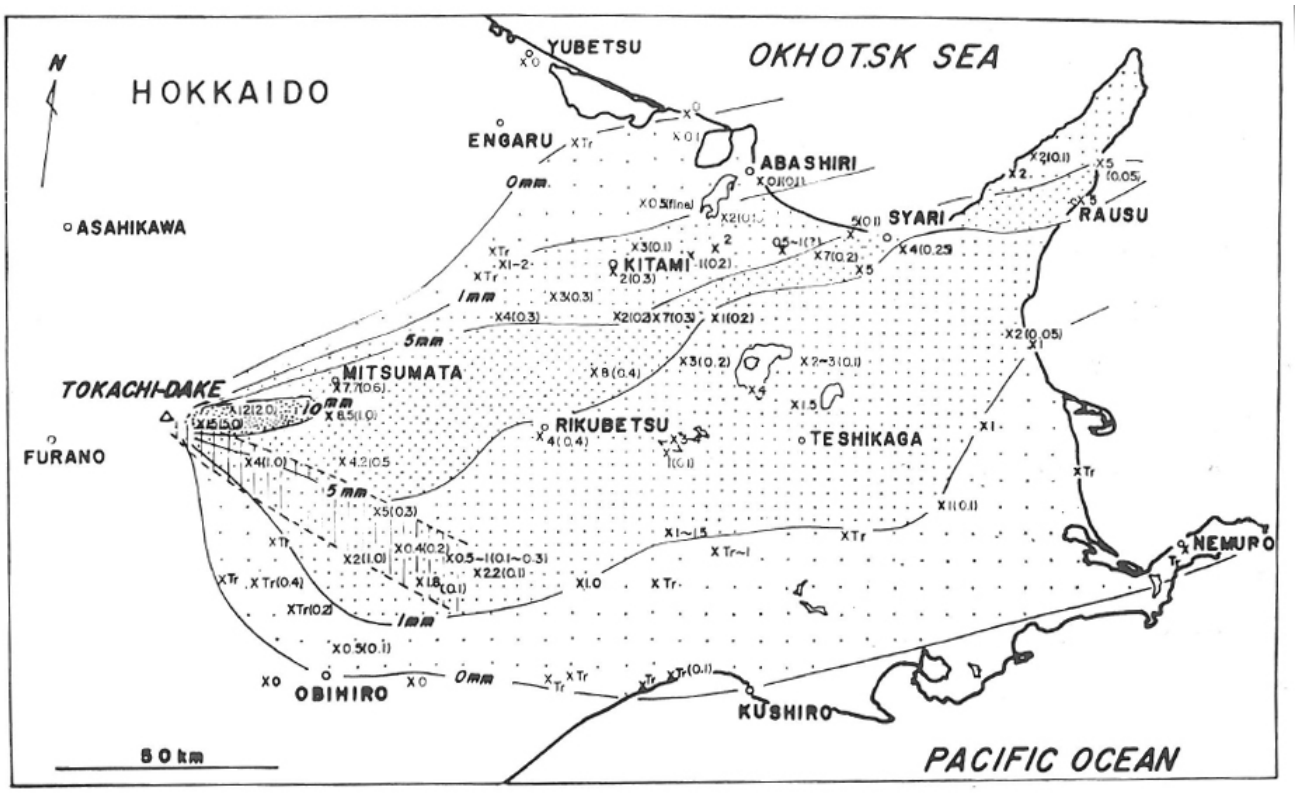


Figure 10-10 Distribution of ejecta in wide area from June 29 to June 30, 1962 (Ishikawa et al., 1971).

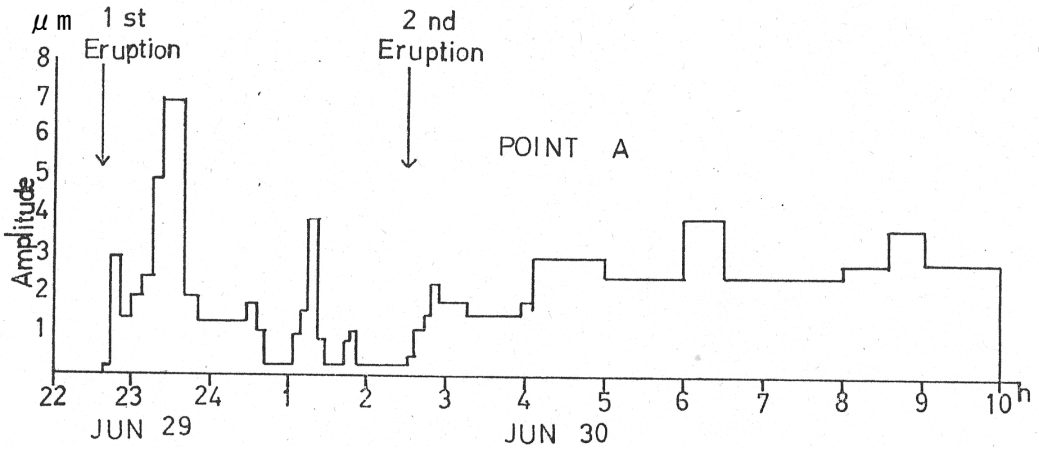


Figure 10-11 Changes in volcanic tremor amplitudes by the eruption on June 29 to June 30, 1962, measured at short-period seismometer (M-station, approximately 1.2km from crater) (Sapporo District Meteorological Observatory, 1971).

・1988-89 Eruption

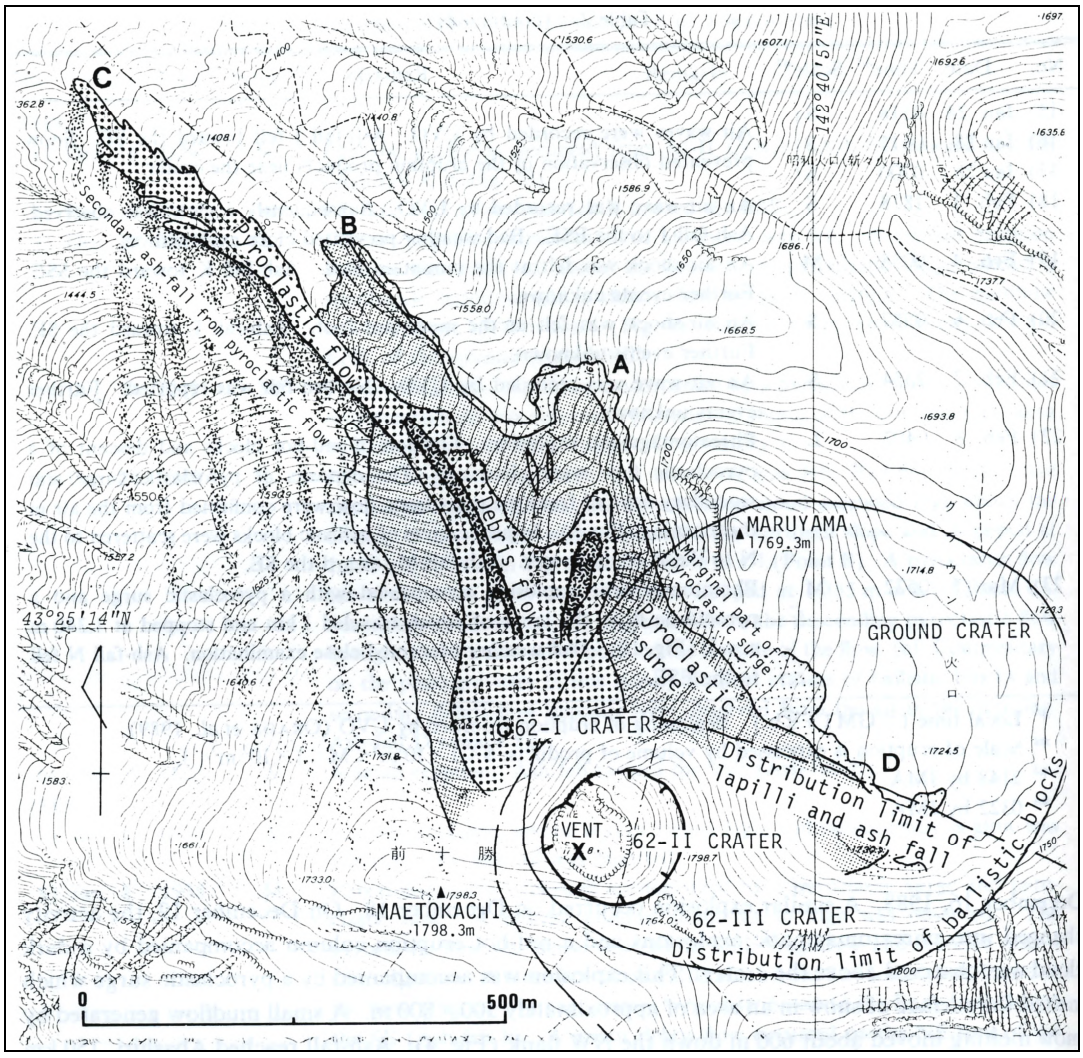
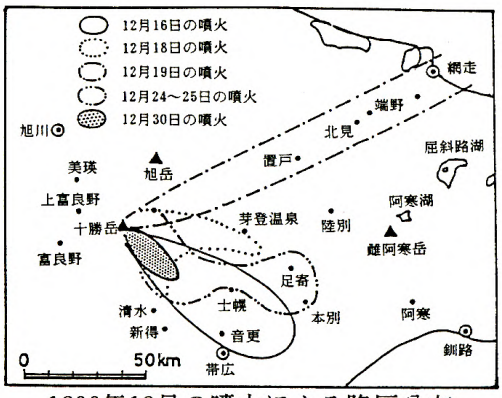
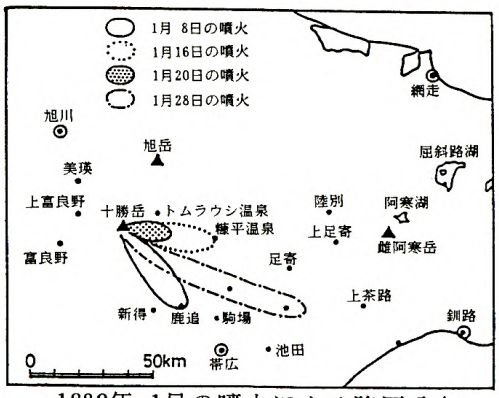


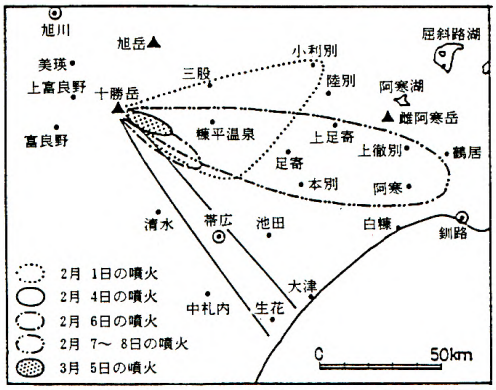
Figure 10-12 Distribution of ejecta around the crater by the eruption on December 25, 1988 (Katsui et al., 1990).



1988年12月の噴火による降灰分布



1989年 1月の噴火による降灰分布



1989年 2～ 3月の噴火による降灰分布

Figure 10-13 Distribution of ash fall on December 1988, January 1989, and February to March, 1989. (Sapporo District Meteorological Observatory, Asahikawa Local Meteorological Observatory, 1990)

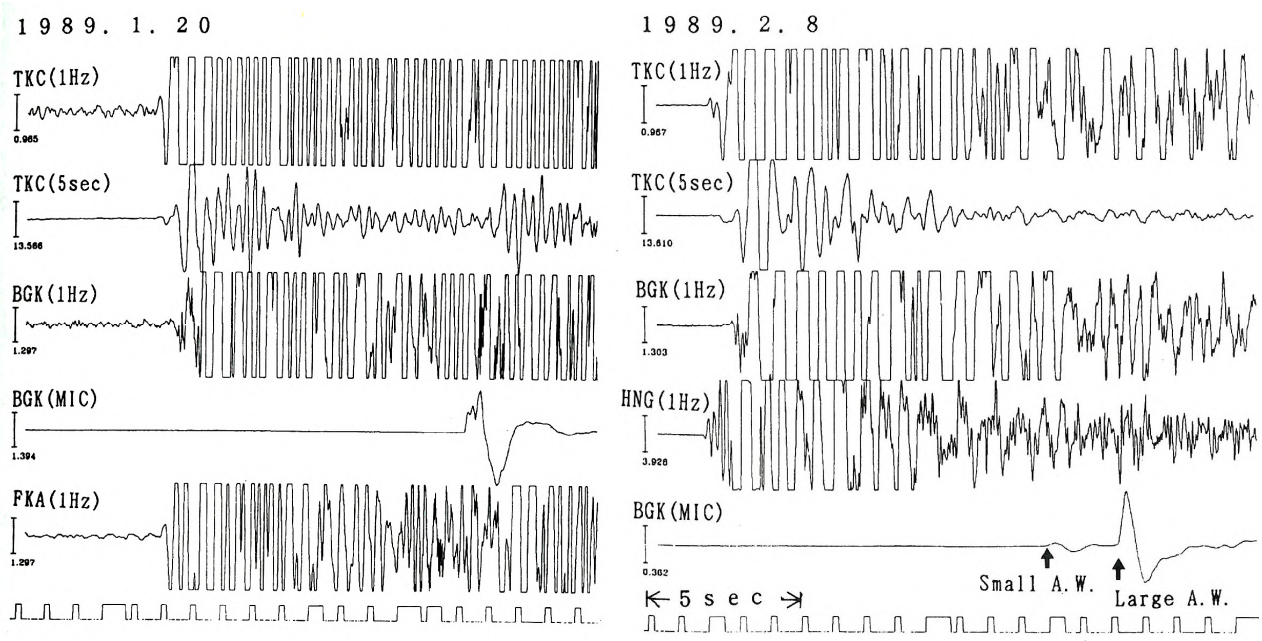


Figure 10-14 Explosive earthquakes and infrasonic waves for eruptions on January 20, 1989 and February 8, 1989 (Okada et al., 1990).

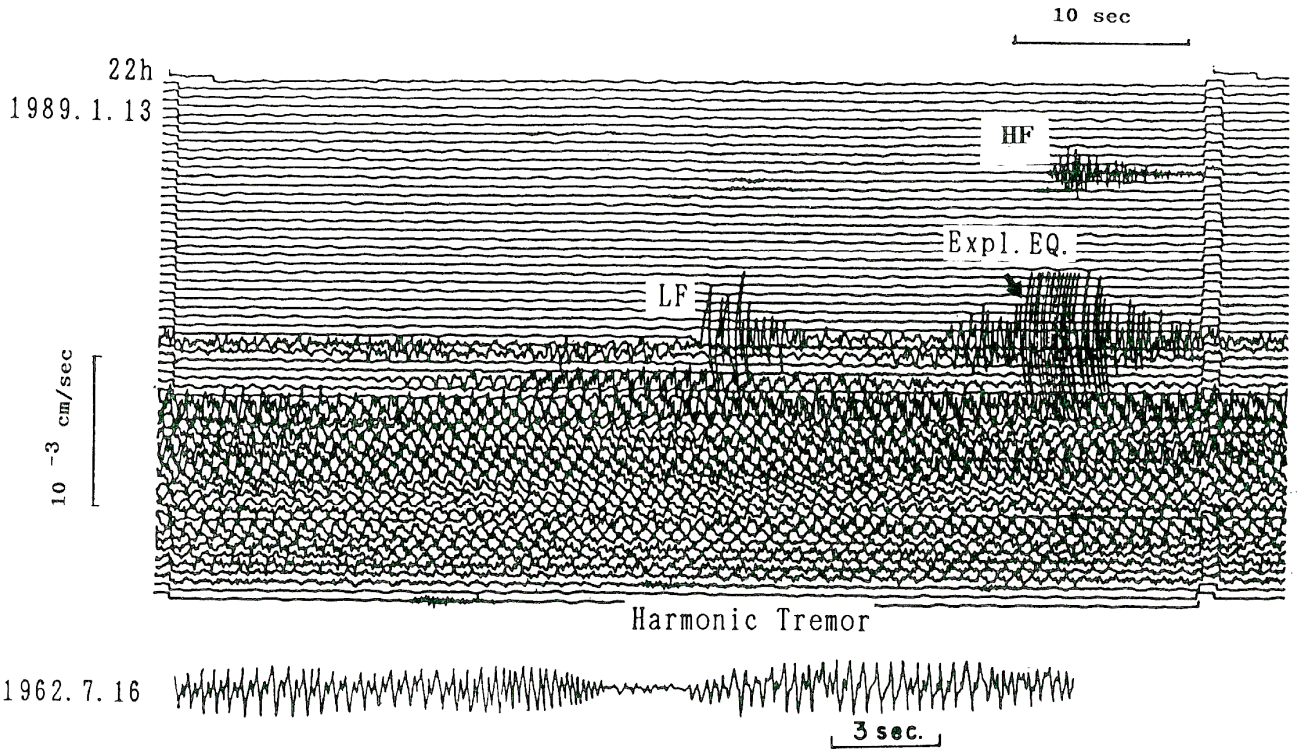


Figure 10-15 Records by short-period seismometer immediately before and after January 13, 1989 eruption (Okada et al., 1990).
HF: high-frequency earthquake, LF: low-frequency earthquake. Expl.EQ: explosive earthquake

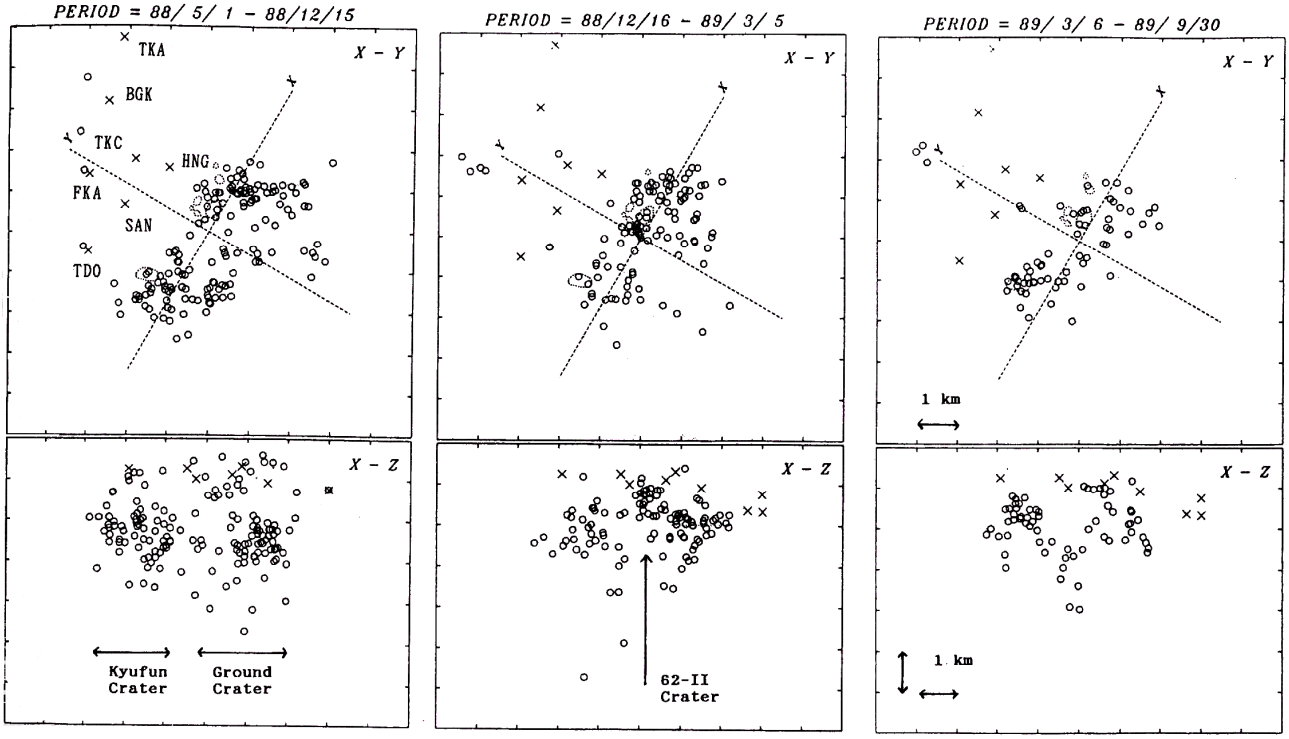


Figure 10-16 Hypocenter distribution of volcanic earthquake before and after eruptions of 1988-89 (Okada et al.,1990).
Left: Before eruption, Middle: During eruption, Right: After eruption

- During the eruptive activity, a notable increase in earthquakes was observed in the area around the Ground crater
- The hypocenter distribution showed that almost all were high-frequency earthquakes.

Table 10-1 List of eruptions from 1988 to 1989 (Okada et al., 1990)

No.	Date YR MO DY	Time HR MI	Expl. Earthq. micron	Air Wave mb	Ejecta 10^4 m^3	Pyrocl. Surge	Pyrocl. Flow	Tremor	Immed. Precursor	Tidal Correl.	Remarks
1	88. 12. 16	05 : 24	12.9	—	1.4	no	no	39 m aft Short	LF, TR	+sP	phreatic
2	88. 12. 18	08 : 38	13.6	—	6.1	no	no	Large Short	HF–LF	+sP	phreatic
3	88. 12. 19	21 : 47	16.1	—	8.4	yes	no	V. Large	sHF–sLF	+P	mgt. −phr.
4	88. 12. 24	22 : 12	5.6	1.10		yes	no	Small	Clear sHF–sLF	+P	mgt. −phr.
5	88. 12. 25	00 : 49	22.0	0.99	18.6	yes	yes	V. Large	sLF, Im. LF	+P	mgt. −phr.
6	88. 12. 30	05 : 27	6.9	1.25	0.1	?	no	Small	Clear sHF–sLF	+sP	
7	89. 01. 01	02 : 12	none	none		no	no	none	none	D	
8	89. 01. 08	19 : 38	21.2	0.94	4.3	yes	yes	Medium	Im. LF	I	high Cl/S
9	89. 01. 13	22 : 29	—	0.07			no	Harmonic T.	Im. LF	D	high Cl/S
10	89. 01. 16	18 : 55	11.9	2.68	10.1	yes	yes	Medium	none	+P	mgt. −phr.
11	89. 01. 20	03 : 21	14.7	3.75	2.0	yes	no	Large Short		+P	magmatic
12	89. 01. 22	00 : 14	0.4	0.31			no	Weak		+P	
13	89. 01. 23	12 : 17	—	0.04		no	no	none		+sP	
14	89. 01. 27	01 : 44	26.8	3.67		?	no			+sP	?
15	89. 01. 28	05 : 18	4.9	0.67			no	none	sHF–sLF	0	
16	89. 01. 28	06 : 11	14.7	0.42	2.1 ?		no	Weak	sLF	0	
17	89. 01. 28	07 : 00	12.8	0.33			no	Weak		0	
18	89. 02. 01	18 : 18	12.6	0.58	0.5		no	4 m aft Lg	sHF–sLF	+P	
19	89. 02. 04	00 : 38	36.9	0.71	5.5	yes ?	yes	V. Large	Clear sHF–sLF	+P	mgt. −phr.
20	89. 02. 06	09 : 37	8.4	0.76	1.6		no	41 m aft Lg St	sHF–sLF	−P	
21	89. 02. 07	23 : 54	10.1	0.64			no	V. Weak	sLF	+P	
22	89. 02. 08	04 : 02	31.9	0.89	7.7	yes	yes	V. Large	sHF–sLF	+P	mgt. −phr.
23	89. 03. 05	05 : 22	21.5	0.77	4.9	yes	yes	Large	sLF, Im. LF	−P	mgt. −phr.

Expl. Earthq.: Maximum explosion earthquake amplitude measured by Japan Meteorological Agency at station A (current Iozawa) (in microns, at Bougakudai)
Air Wave: Maximum amplitude of infrasonic wave measured at Bougakudai (mb)
Ejecta: Total amount of volcanic ash, pyroclastic flow, pyroclastic surge, and volcanic block ejecta (x10^4 m^3), measured by Miyaji (private correspondence)
Pyrocl. Surge: Pyroclastic surge
Pyrocl. Flow: Pyroclastic flow
Tremor: Volcanic tremor conditions V: Very large, Lg: Large, St: Short, m: Minutes, aft: After
Immed. Precursor: Immediate precursor HF: high-frequency earthquake, LF: low-frequency earthquake, TR: volcanic tremor, sHF: Small high-frequency earthquake, sLF: Small low-frequency earthquake, Im: Immediately after
Tidal Correl.: Earth tide (corrected for gravity) +P: Maximum tide (inflation) -P: Minimum tide (deflation) +sP: Small peak, D: Maximum deflation rate, I: Maximum inflation rate, o: Near zero
Remarks: Phreatic: Phreatic eruption, mgt. -phr: Phreatomagmatic eruption, high Cl/S: High Cl/S ratio, magmatic: Magmatic eruption

Precursory Phenomena

Eruptive activity in recent years is characterized by increased fumarolic and thermal activity, such as rising ground temperatures and increased volcanic gas emissions, for several years before eruptions, with increased seismic activity several months before the eruptions. Eruptions are immediately followed by further increases in seismic activity, such as large earthquakes, and crustal deformation, such as cracking around craters. Explosive eruptions are immediately preceded by inflation belowthe crater, and increased low-frequency earthquakes.

1926 Eruption				1962 Eruption				1988 to 1989 Eruption			
Date	Until Start of Eruption		Phenomenon	Date	Until Start of Eruption		Phenomenon	Date	Until Start of Eruption		Phenomenon
	(Months)	(Days)			(Months)	(Days)			(Months)	(Days)	
				08/1952	-118		Showa crater formed				
				09/1954	-93		Small explosions at Showa crater				
				1954			Increased Taisho crater fumarolic activity and emission of molten sulfur				
				06/1956	-72		Small explosions at Showa crater	2/1983	-70		Increase in volcanic earthquakes
								5/1983	-67		Increase in volcanic earthquakes
				02/1957	-64		New Showa crater fumarole formed	9/1983	-63		Number of 62-1 crater fumaroles increased, east wall ground temperature rose
								6/1984	-54		Cracks (10 to 15m long) appeared in 62-1 crater east wall , ground temperature 360°C
								9/1984	-51		62-1 crater east wall ground temperature of 475°C

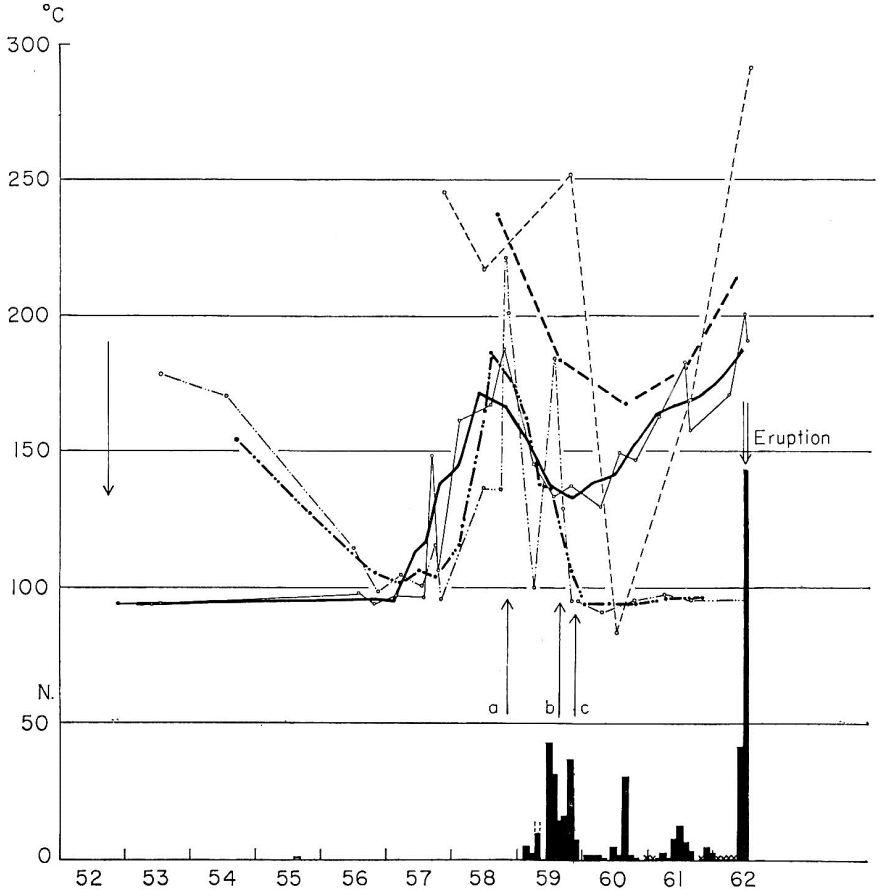
				10/1958	-44		Small eruption at Showa crater, new fumarole formed		-43		Hot mud was ejected (approx. 5m high) from east wall of 62-1 crater, and a new fumarole was formed
									-42		A black volcanic plume was emitted from 62-1 crater, and from 20th, red-hot glow occurred as result of burning sulfur
									-41		Jet of hot mud ejected from east wall of 62-1 crater (approx. 10m high)
06/1923	-35		Molten sulfur pool appears in Yunuma, and sulfur production increased Temperature and flow volume of Maruya Onsen spring rose	06 to 10/1959	-36		Increase in volcanic tremors				
08/1923	-34		7 to 8m high spray of molten sulfur at Yunuma	08/1959	-34		Small explosions at Showa crater				
				11/1959	-31		Small explosions at Showa crater, 100m long lahar flow				
								8/1986	-28		Felt earthquake (JMA scale seismic intensity 1 at Shirogane Onsen)
								1/1986	-26		62-1 crater east wall ground temperature of 529°C
								12/1986	-24		Felt earthquake (JMA scale seismic intensity 1 at Shirogane Onsen), volcanic tremor
								2 to 3/1987	-22		Volcanic tremors

								7/1987	-17		Volcanic tremors
								9 to 10/1987	-15		Temporary decrease in volcanic plume from 62-1 and 62-2 craters
					-12		Natural sulfur fire at east wall of Taisho crater				
					-10		Weak phreatic explosion in old eruption (according to Mr. Aida)		-10		Increase in Furikozawa fumaroles, forming nodules
									-10		Felt earthquake (JMA scale seismic intensity 1 to 2 at Tokachidake Onsen)
12/1925	-5		Central cone central crater becomes active, Obuki						-6		Felt earthquake (JMA scale seismic intensity 2 at Tokachidake Onsen)
			crater formed		-3		Increased fumarole activity at Taisho crater, maximum temperature of 170°C		-3		Gradual increase in volcanic earthquakes from late in month
2/1926	-3		Sand gravel ejected from Obuki		-2		Taisho crater too hot to measure temperature (300°C or more)		-2		2 Felt-earthquakes (JMA scale seismic intensity 1 at Fukiage Onsen and Shirogane Onsen), 2 volcanic tremors
					-2		(M7.1 earthquake in Hiro Oki)				
4/1926	-1		Ash fall from Obuki, natural sulfur fire, fire column		-1		5 Felt-earthquakes (JMA scale seismic intensity 2 at Shirogane Onsen)		-1		4 Felt-earthquakes (maximum JMA scale seismic intensity 3 at Shirogane Onsen, Fukiage Onsen, and Tokachidake Onsen)

					0	-25	2 Felt-earthquakes (JMA scale seismic intensity 1 at Shirogane Onsen)				
5/4/1926	0	-20	Rumbling			-20	2 Felt-earthquakes (JMA scale seismic intensity 1 at Shirogane Onsen)				
						-19	Felt earthquake near crater (JMA scale seismic intensity 1)				
5/7/1926		-17	Explosion, fire column, new crater formed, and volcanic blocks and ash fall near crater			-16	Natural sulfur fire at Taisho crater				
						-15	Increase in volcanic plume from Taisho crater, increase in volcanic tremors				
5/13/1926		-11	Increased volcanic plume activity, Felt-earthquakes and rumbling at foot of volcano						0	-11	Increased volcanic plume activity (snow appeared blackened)
5/15/1926		-9	Rumbling gradually calms, but volcanic plume production remains active								
										-6	Black volcanic plume emitted from 62-2 crater
						-5	Increase in volcanic tremors			-5	Gray volcanic plume emitted from 62-2 crater, accompanied by volcanic tremors
5/22/1926		-2	Rumbling which could be felt as far away as Kamifurano, accompanied by single boom			-2	Increase in cracking of east wall of Taisho crater			-3	Ash fall near 62 crater (new hole in 62-2 crater)
			Heated stones ejected from Obuki			-1	2 Felt-earthquakes (JMA scale seismic intensity 2 at Shirogane Onsen)				

5/23/1926		-1	South wind with cloudy skies, work does not progress, so miners come down from mountain in afternoon Followed by rain, so conditions unknown								
5/24/1926		0	Large rocks rain down from Obuki during morning 12:11 Explosion. Explosion sound could be heard at foot of mountain. Lahar occurs. Earthquake record at Asahikawa weather station (Ohmori scale magnification = 50) Approx. 14:00 Small-scale rumbling and eruption After 16:17, large explosion occurred. central cone northwest section collapsed. Large scale lahar. 16:17:55 Earthquake recorded by Asahikawa weather station Taisho crater formed on northwest side of central cone			0	Cracks discovered in Maetokachi ridge in morning 22:40 First eruption (phreatic explosion) 02:45 Second eruption (subplinian eruption) A volcanic plume rose 12,000m, craters 62-0 to 62-3 formed			0	05:24 Eruption from 62-2 crater (accompanied by explosion sound and explosion earthquake) Explosive eruptions occur repeatedly until March 5, 1989

Table 10-2 Change over time in immediately preceding three magmatic eruptions, and recent volcanic activity (Japan Meteorological Agency, updated in 2012)



……；旧噴火口（安政火口）
————；新噴火口（大正火口）
—·—·—；新々噴火口（昭和火口）
棒グラフ　56型地震計による月別地震回数

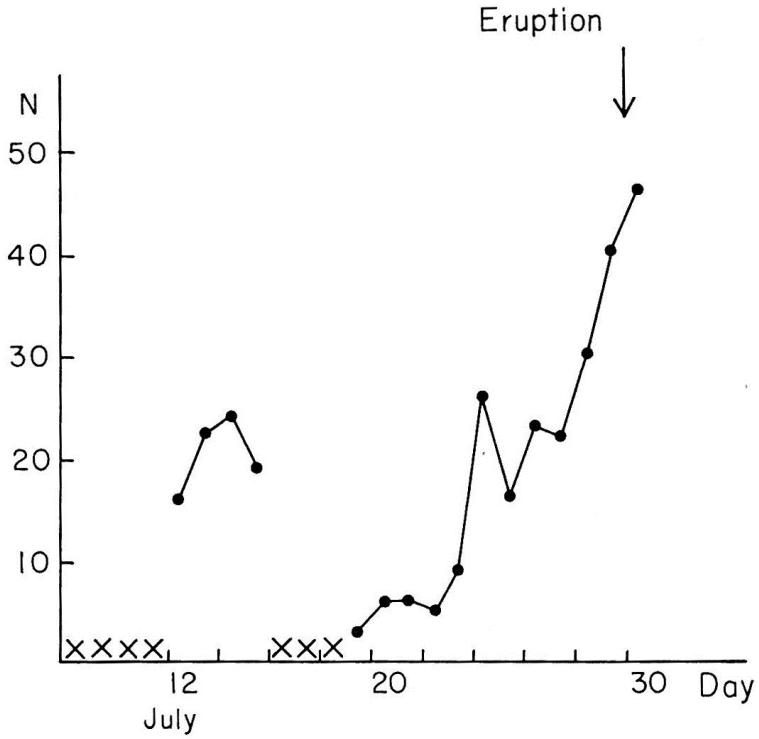


Figure 10-17 Changes in crater temperatures and number of earthquakes before the 1962 eruption (Ishikawa et al., 1971).

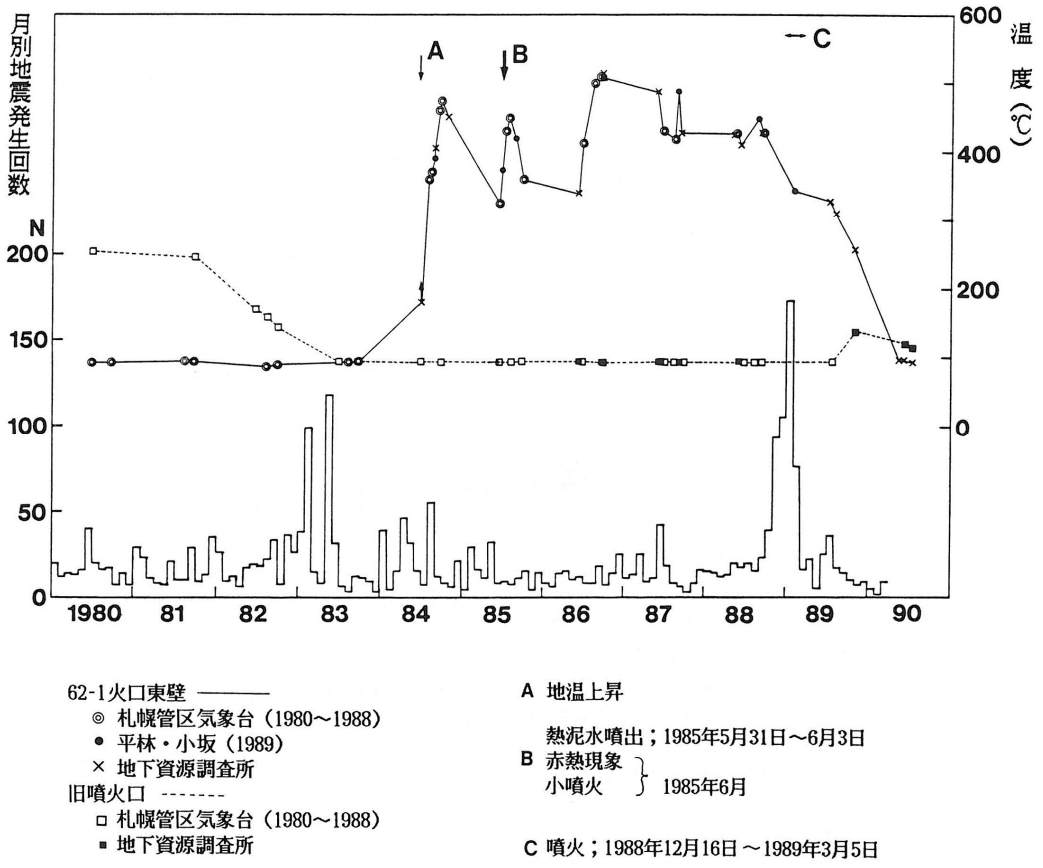


Figure 10-18 Changes in temperatures at 62-1 crater and old crater, and number of earthquakes per month (Akita et al., 1991).

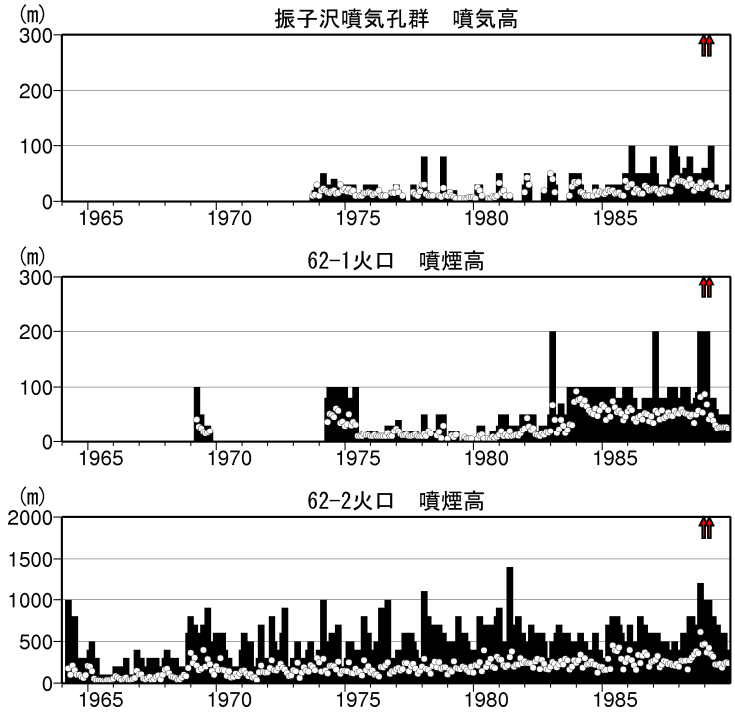


Figure 10-19 Changes in heights of volcanic plumes released ateach crater before the 1988 eruption.

1. Fume heights at Furikozawa
2. Plume height at 62-1 crater
3. Plume height at 62-2 crater

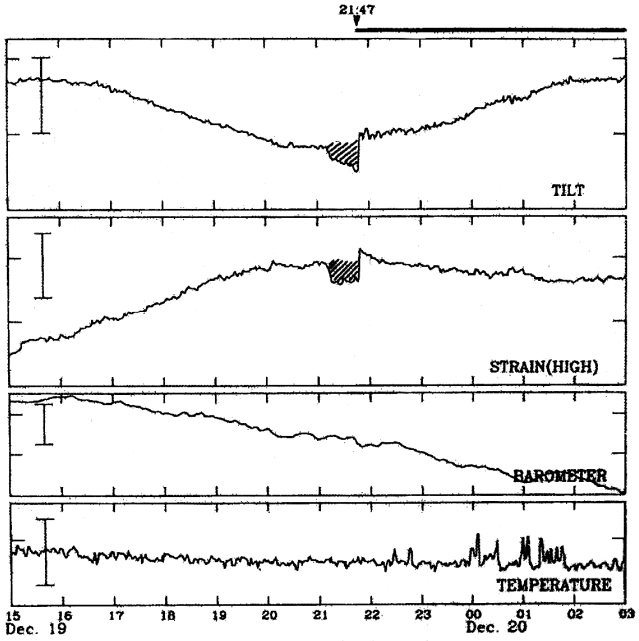


Figure 10-20 Changes in tiltmeter and strainmeter just before the eruption on December 19, 1988 (Miyamachi et al., 1990).

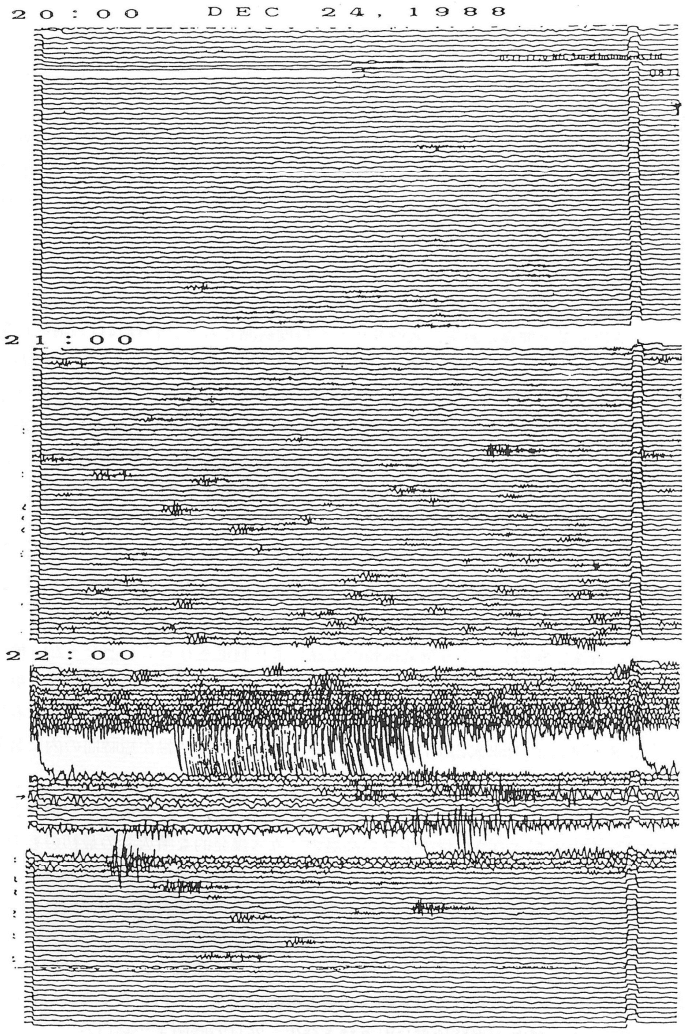


Figure 10-21 Changes in waveforms just before December 24, 1988, eruption (Okada et al., 1989).

Recent Volcanic Activity

・Activity Chronograms

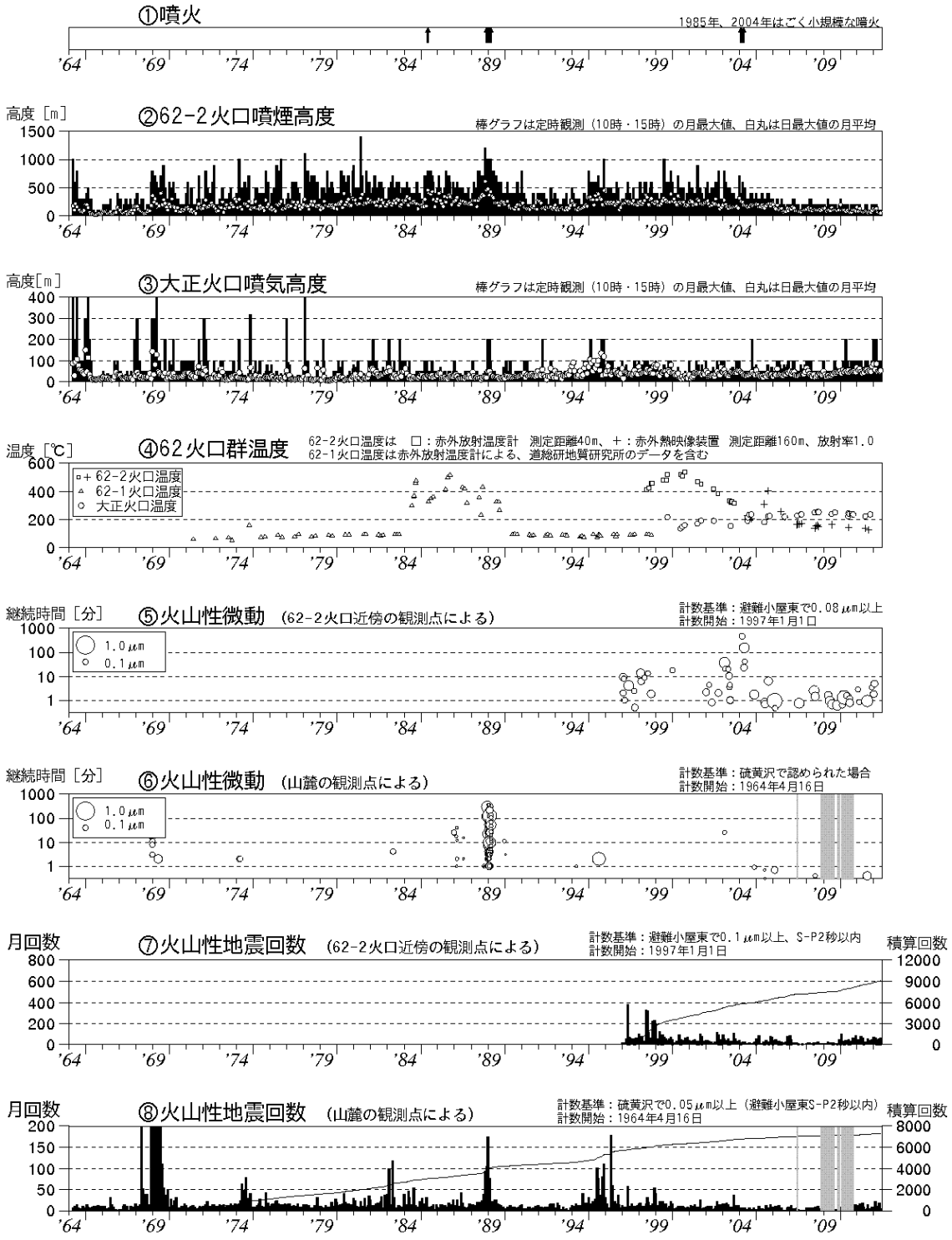


Figure 10-22 Volcano activity (1964 to June, 2012).

⑥⑧: Gray areas show the period due to equipment failures

① Eruptions, ②Plume heights at 62-2 crater, ③Fume heights at Taisho crater, ④Temperatures of 62-crater group

⑤ Volcanic tremors (Observed at the foot of volcano)

⑥ Volcanic tremors (Observed at the foot of volcano)

⑦ Number of volcanic earthquakes (Observed at the foot of volcano)

⑧ Number of volcanic earthquakes (Observed at the foot of volcano)

・Volcanic Earthquake Hypocenter Distribution

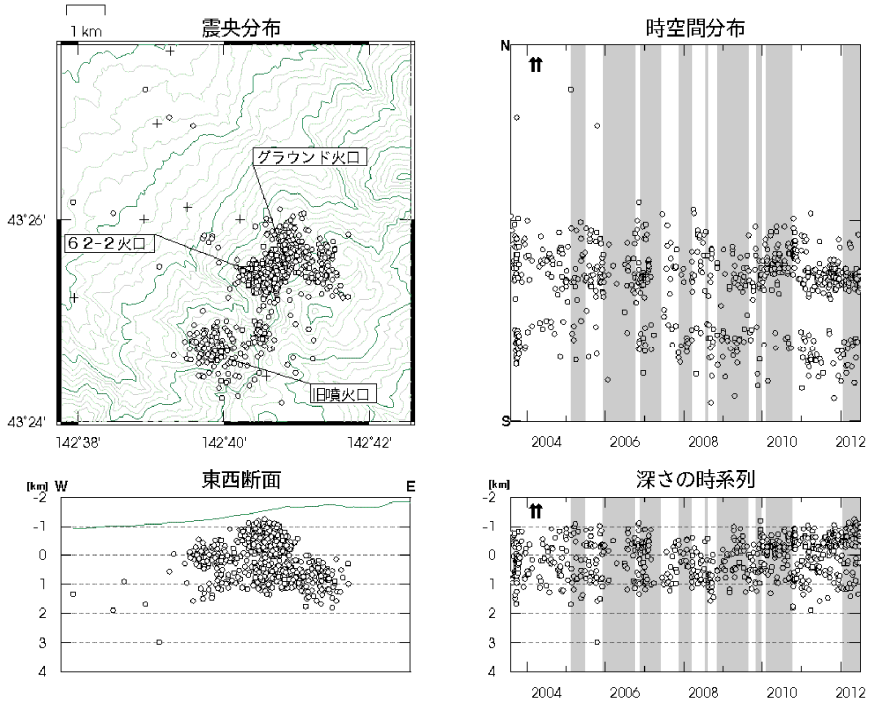


Figure 10-23 Distribution of volcanic earthquakes (August 2003 to June 30, 2012).
Crossess indicate observation points, ↑ symbols indicate eruptions
・Periods indicated in gray represent the ones when dateare partly lacking, resulting in a decrease in number of identified hypocenters and resulting reduction in accuracy.
①Epicenter distribution, ②Space-time plot, ③E-W cross-section, ④Depth time series

・Seismic Activity

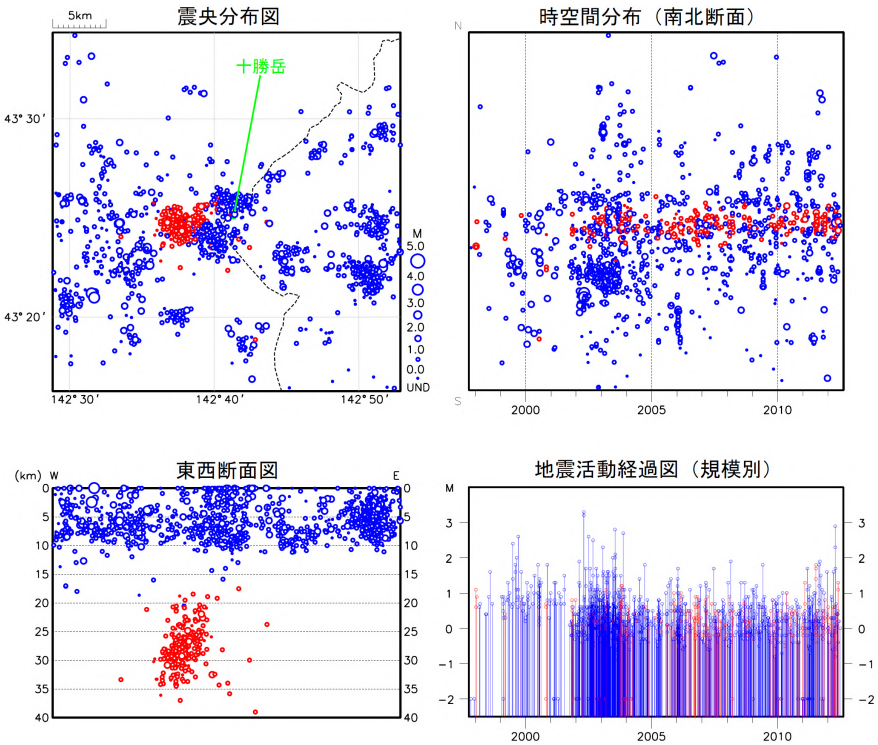


Figure 10-24 Activity of shallow VT earthquakes (blue circles) and deep low-frequency earthquakes (red circles) observed by a regional seismometer network (October 1, 1997, to June 30, 2012). Epicenter distribution (upper left), space-time plot (N-S cross-section) (upper right), E-W cross-section (lower left) and magnitude-time diagram (lower right).)

・Crustal Deformation in Shallow Area below 62-2 Crater

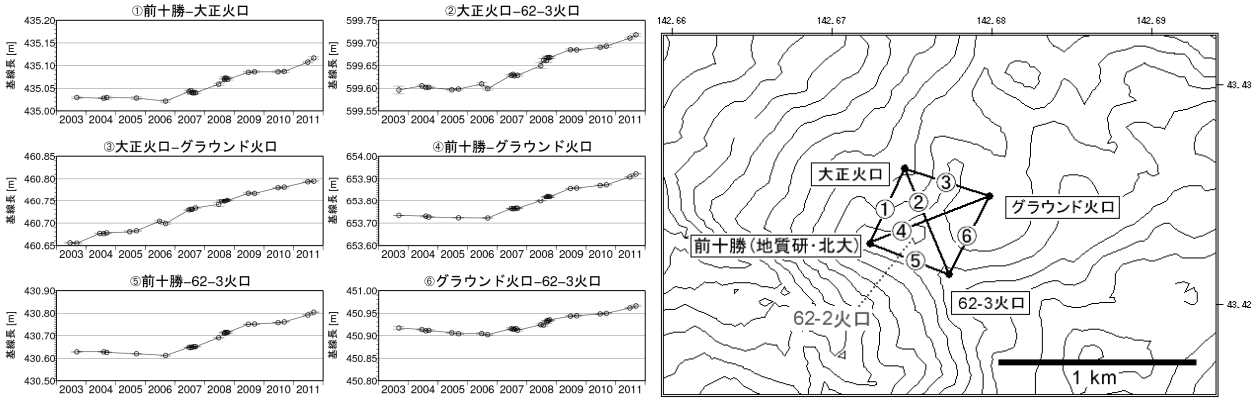


Figure 10-25 Crustal deformation in shallow area below 62-2 crater, observed by repeated GPS campaigns (2003 to 2011). (Japan Meteorological Agency, 2011)

・Thermal Demagnetization in Shallow Area below 62-2 Crater

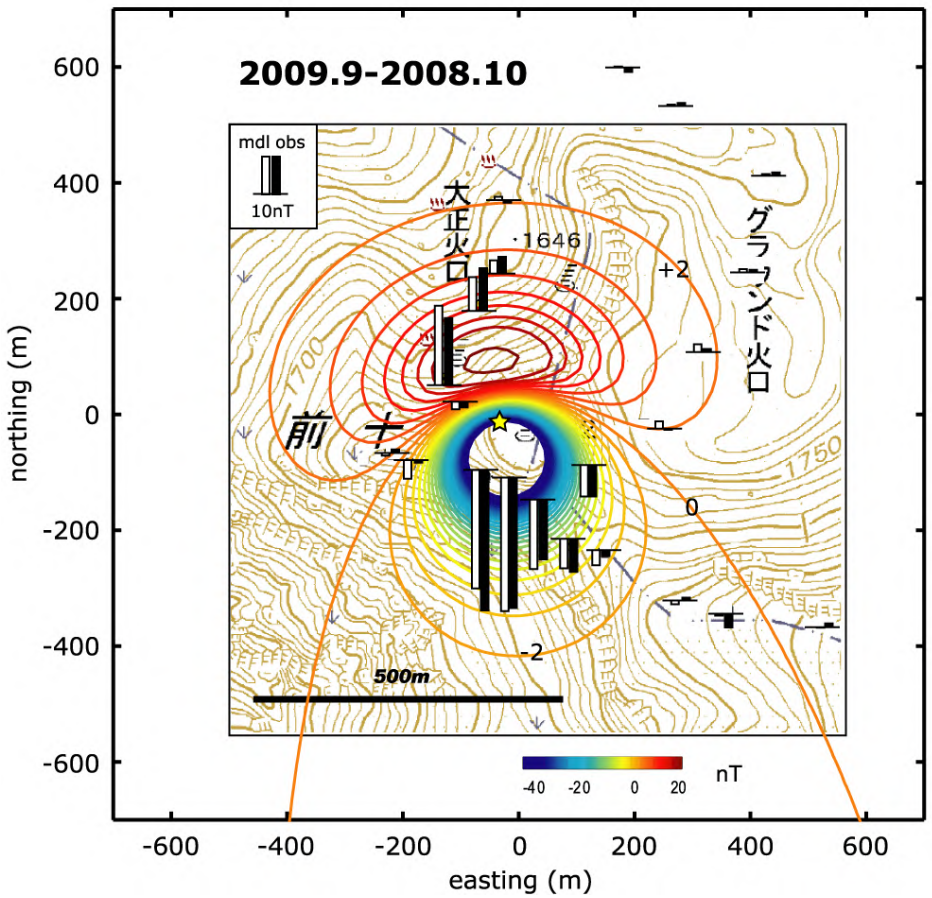


Figure 10-26 Changes of total magnetic force changes during 2008 to 2009. Illustrated are the best-fit model (white bars) and observation (black bars) values. Thermal demagnetization in shallow area directly beneath 62-2 crater is suggested. (Hashimoto et al., 2010).

- The change distribution shows a clear decrease south of the 62-2 crater, and an increase to north. A spherical demagnetization is hypothesized to exist at 1,600 m in elevation (at a depth of 150 m) on west edge of 62-II crater. Demagnetization moment is 1.3×10^6 Am^2.

・3D Electric Resistivity Structure Around 62-2 crater

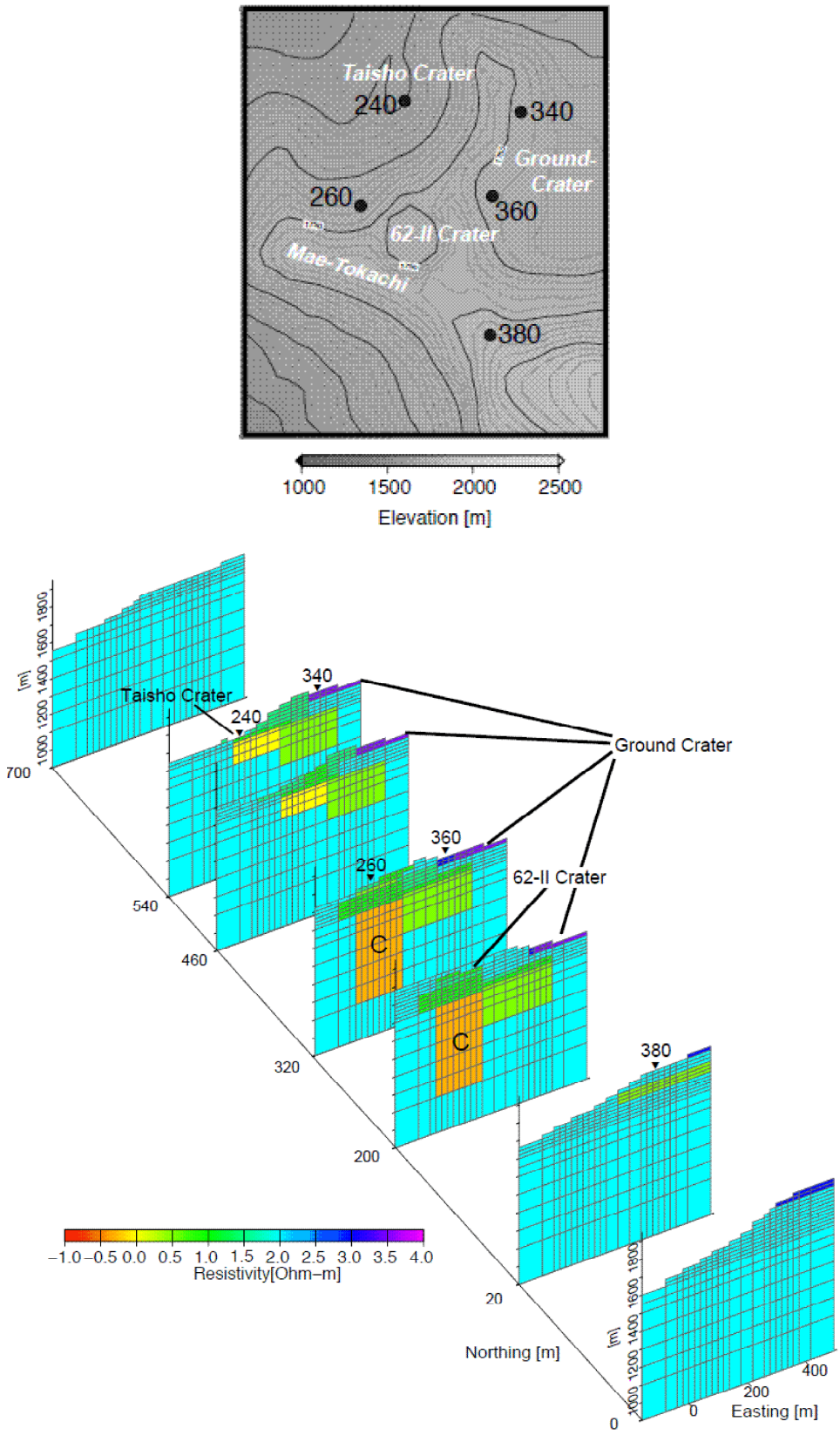


Figure 10-27 3D resistivity structure, determined via forward modeling (bottom) and observation point (top) (Yamaya et al., 2010).

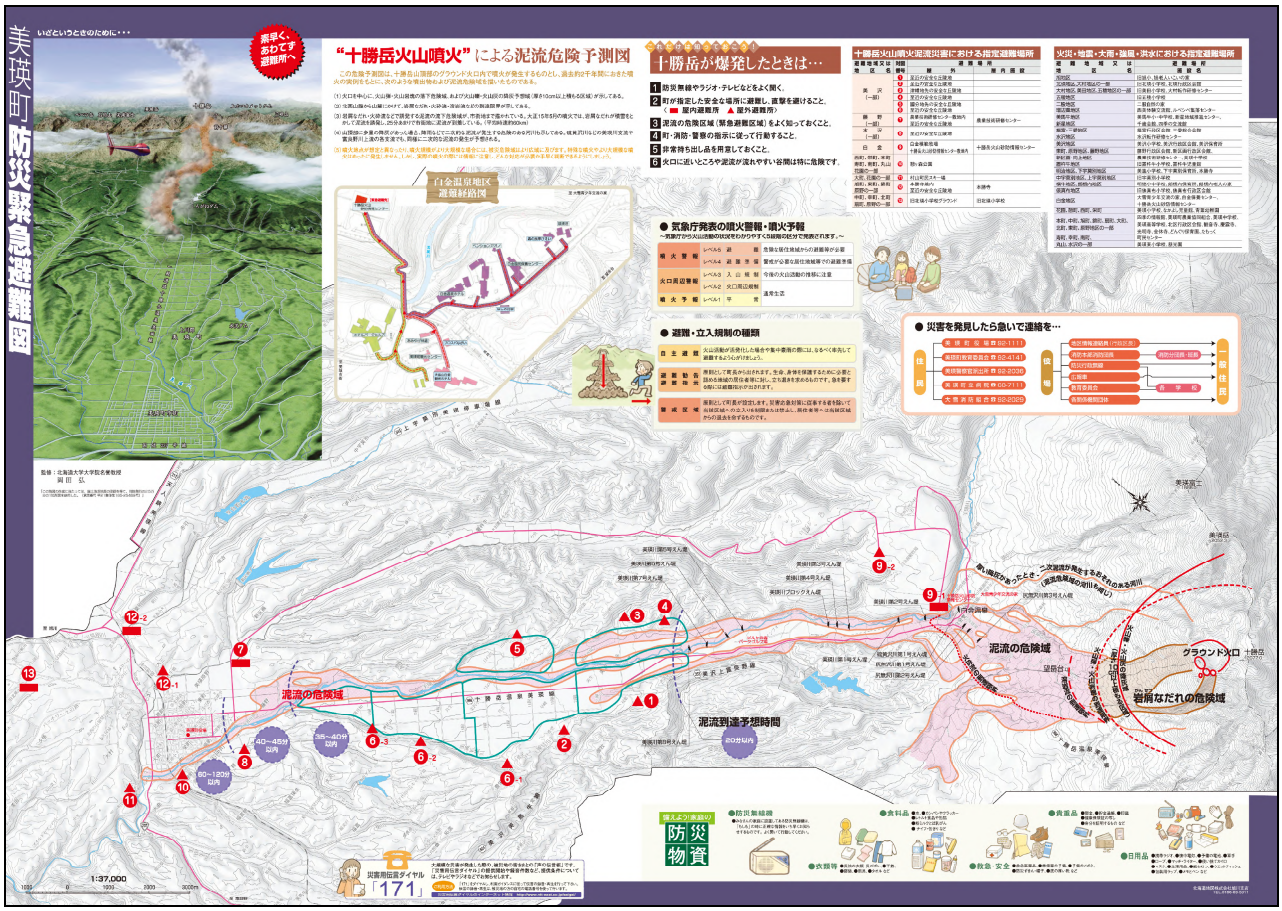
・Significantlow resistivity area(0.5Ωm) was estimated at elevation of 1100m to 1600m near 62-2 crater (indicated by “C” in figure).

Information on Disaster Prevention

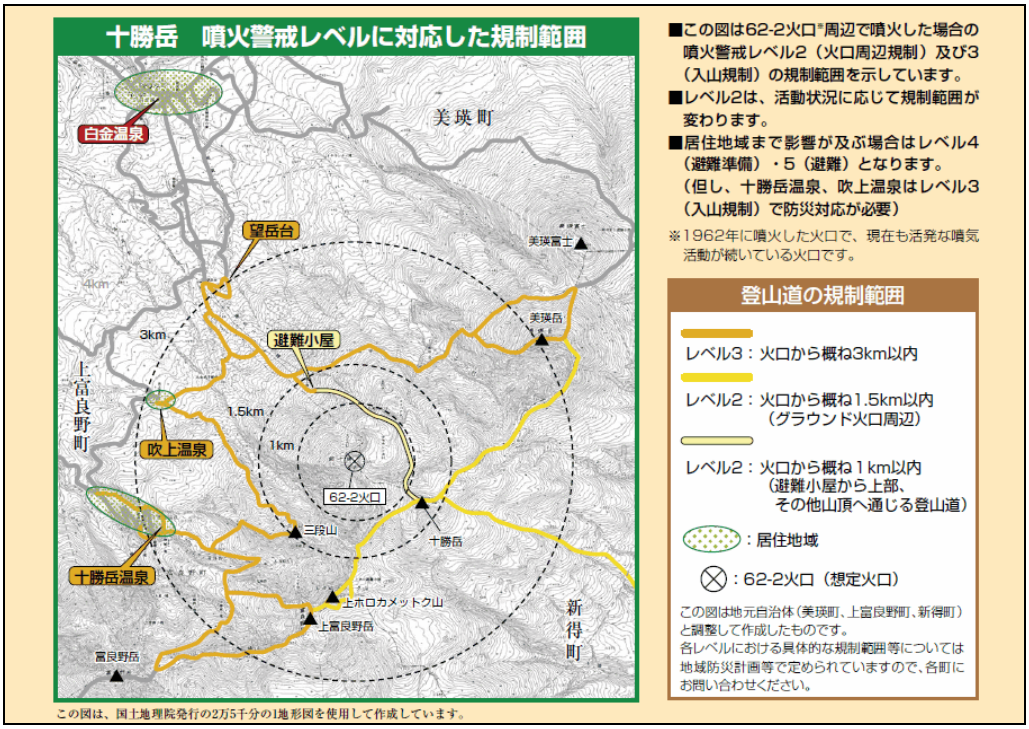
①Hazard Map

Tokachidake Volcano Disaster Prevention Map March, 2006 Kamifurano
http://www.town.kamifurano.hokkaido.jp/contents/01soumu/0110soumu/bosai/map.pdf

Tokachidake Volcano Eruption Hazard Map March, 2009 Biei
http://www.town.biei.hokkaido.jp/modules/d3downloads/index.php?page=visit&cid=4&lid=472



②Volcanic Alert Levels (Used since December 16, 2008)



Volcanic Alert Levels for the Tokachidake Volcano (Valid as of December, 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	●Eruption or imminent eruption accompanied by debris avalanche during periods when snow has accumulated, and forecast of large scale melted snow volcanic lahar. Past Examples May 24, 1926, after 16:17: Eruption caused collapse of central crater cone, causing large lahar flow. At 12:11, a phreatic explosion occurred in advance of the collapse. ●Eruption or imminent eruption accompanied with forecast of pyroclastic flow reaching residential areas. In the event that pyroclastic flow occurs during periods when snow has accumulated, large scale melted snow volcanic lahar are forecast. Past Examples Eruption approximately 3,300 years ago
		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.	●Increase in earthquake and thermal activity, and increased crustal deformation, result in increased likelihood of large-scale eruption. Past Examples No observed examples ●Medium-sized eruption occurs, or small eruption occurs during periods when snow has accumulated. Past Examples June 30, 1962, 02:45: Medium-sized eruption December 16, 1988 to March 15, 1989: Repeated small-scale explosive eruptions
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.	●Increase in seismic activity and frequent Felt-earthquakes and volcanic tremors result in eruption forecasts. Past Examples Late September, 1988: Increase in volcanic earthquakes begins October to December, 1988, and May to June, 1962: Number of Felt-earthquakes and tremors increases May, 1962 : Frequent Felt-earthquakes and tremors May, 1926: Rumbling, and Felt-earthquakes from 10 days before eruption ●Small eruptions during snow-free periods, and volcanic blocks scattered 1 to 2km. Past Examples No observed examples
	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.	●Temporary increase in small but perceptible seismic activity and/or volcanic tremors. Increased thermal activity such as more active volcanic plume production. Forecasts for very small eruptions. Past Examples June 19, 1985: Very small eruption from 62-1 crater February and May, 1983: Increase in very small earthquakes 1954: Increased Taisho crater fumarolic activity, emission of molten sulfur August 17, 1952: Showa crater formed December, 1925: New crater (Dai-Fun) formed inside central cone crater.
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) The volcanic blocks mentioned in this table refer mainly to blocks large enough that their trajectories are not affected by wind.

Note 2) Large eruptions refer to eruptions with volcanic plumes extending 11,000m or more, and which in some cases cause pyroclastic flows extending to residential areas, accompanied by melted snow lahars in periods when snow has accumulated.

Note 3) Moderate eruptions refer to eruptions with volcanic plumes extending several thousand to 10,000m or more, scattering volcanic blocks 2 to 3km, and, in some cases, causing pyroclastic flows.

Note 4) Small eruptions refer to eruptions with volcanic plumes extending less than 1,000m scattering volcanic blocks 1 to 2km, and causing small pyroclastic flows and/or melted snow lahars.

Social Circumstances

①Populations

- Kamifurano Town: 11,838 (As of September 30, 2010)
- Biei Town: 10,921 (As of September 30, 2010)

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

- Daisetsuzan National Park

  Number of sightseers per year: Approx. 350,000

  (Estimated number of sightseers to Tokachidake area, according to 2010 survey by Biei and Kamifurano)

  Number of mountain-climbers per year: Approx. 15,000

  (Kamikawa Chubu District Forest Office and Kamikawa Nanbu District Forest Office, 2010)

③Facilities

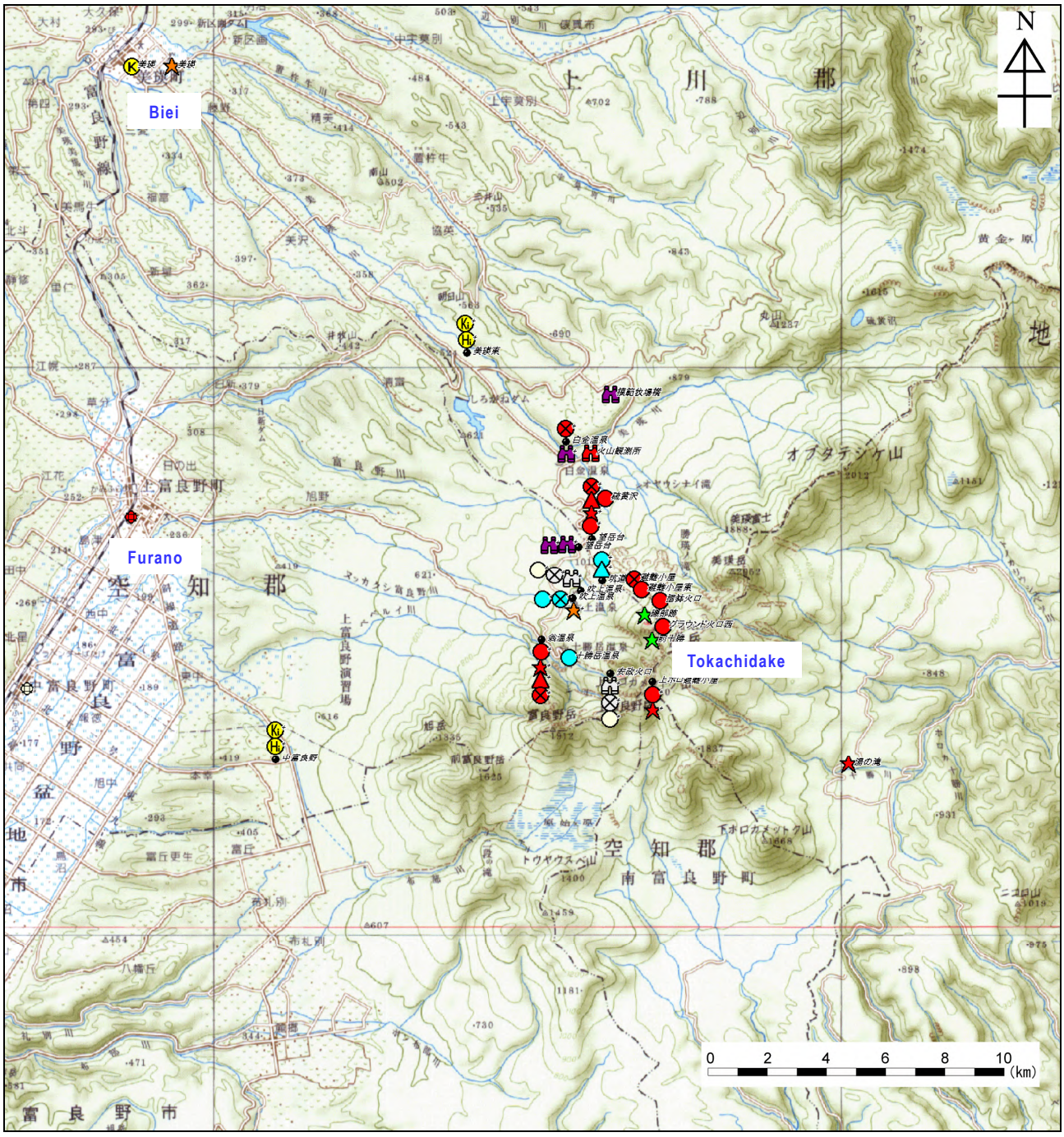
- Biei Shirogane

  Mt. Tokachidake Volcanic Sabo Information Center

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 (Kitami, Obihiro, Asahikawa and Yubaridake) 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)
Hi-net
K-NET
KiK-net

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

(MLIT)
visual camera

(Hokkaido Govt.)
seismometer(SP)
infrasonic microphone
visual camera

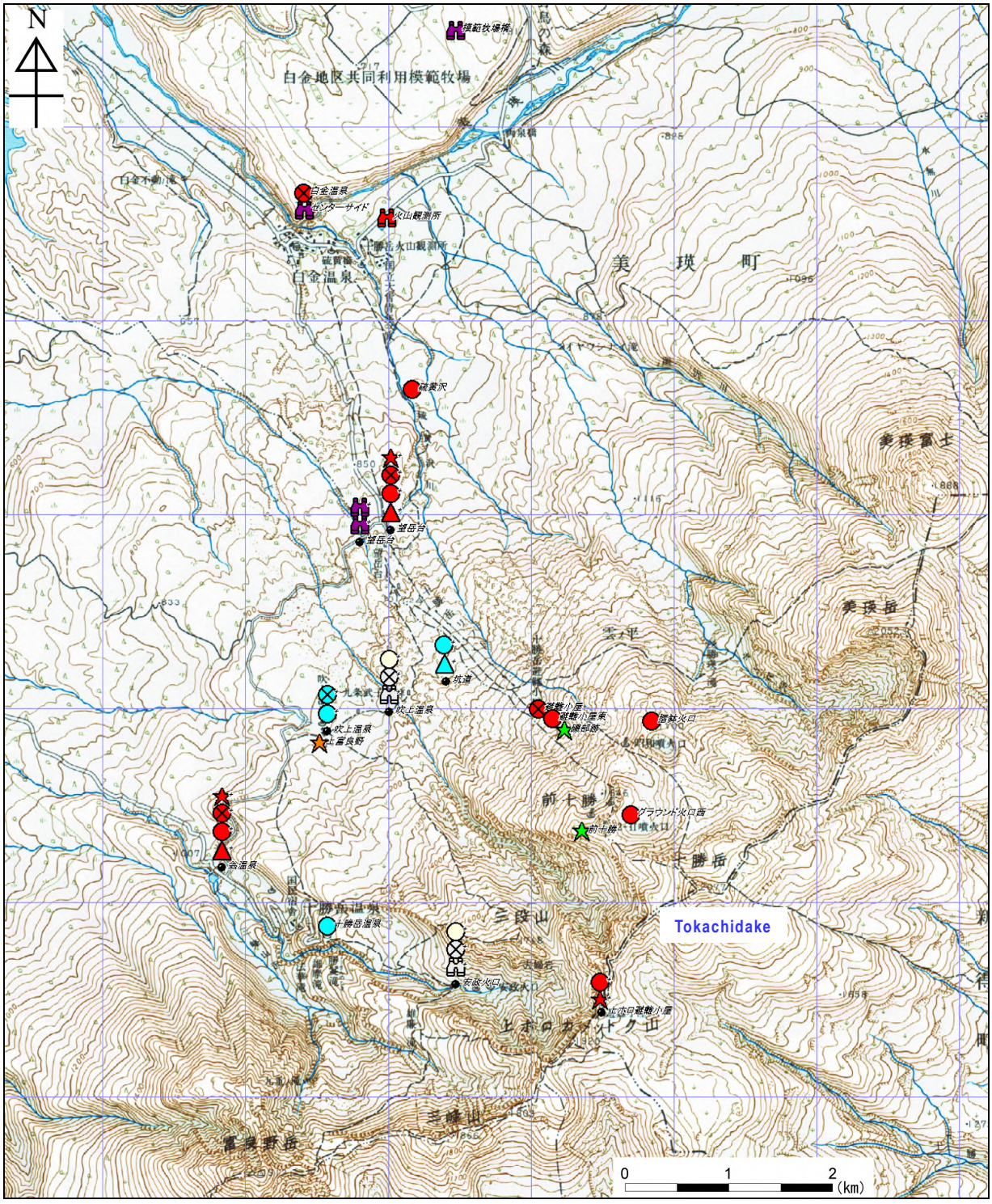
(GSH)
GPS

(Municipalities)
seismic intensity meter

Figure 10-28 Regional 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 map (Tokachidake) published by the Geospatial Information Authority of Japan was used.

Legend

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

(GSI)
- GPS

(NIED)
- Hi-net
- K-NET
- KiK-net

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

(MLIT)
- visual camera

(Hokkaido Govt.)
- seismometer(SP)
- infrasonic microphone
- visual camera

(GSH)
- GPS

(Municipalities)
- seismic intensity meter

Figure 10-29 Local monitoring network.

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