VOLCANOES IN HOKKAIDO, JAPAN

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概　　要

北海道には46の第四紀火山があり，そのうちの29は火山原面をよく残している。また８火山（渡島大島，恵山，渡島駒ヶ岳，有珠，樽前，十勝，雌阿寒，知床硫黄山）に噴火記録が残っている。記録はないが羊蹄，ニセコ，大雪などの諸火山は最近数100～数1000年間に噴火した形跡がある。地形がよく残る29火山のうち22は円錐（成層）火山で残りは４個の大カルデラ火山，２個の小カルデラ火山，２個の溶岩円頂丘火山である。

分布　千島孤の南端部の火山（知床５火山，屈斜路，阿寒，十勝，大雪）と東北日本孤北端部の火山（渡島駒ヶ岳，洞爺，羊蹄，支笏）に２大別される。前者は雁行配列をなす。

円錐火山と大カルデラ火山の発達　円錐火山は①苦鉄質溶岩・スコリアによる円錐火山体の形成。②安山岩質の厚い溶岩流の積重なりによる急で高い円錐火山体の成長，末期に山頂部の大崩壊が起こることがある。③やゝ珪長質の軽石が噴出，山頂部破壊，火砕丘，山麓に火砕流堆積面を形成する。④デイサイト質溶岩円頂丘の形成，その前に小カルデラが形成されることもある。という発達をする。大カルデラ火山は①デイサイト質軽石の大量噴出で火砕流台地形成。噴出中心付近に大カルデラ形成。②小型の円錐火山がカルデラ内に形成される。その発達は前記の円錐火山の発達と同じ。

第四紀前半の火砕流台地　道央部に総体積2000km³をこえるデイサイト－流紋岩質の大規模火砕流が台地をつくっている。これは300万～70万年前にかけて噴出した数10の火砕流からなる。噴出源その地不明な点が多い。

岩質　すべて玄武岩－案山岩－デイサイト－他紋岩の系列に属し，安山岩，デイサイトはカルクアルカリ岩系で大部分を占める。太平洋側から日本海側に近づくほどアルカリが増え，シリカが減少する。ストロンチウム同位体比は0.7028～0.7039で比較的低く海嶺玄武岩の値に近い。

年代　年代測定値はまだ少い。大雪の層雲峡をつくる溶結凝灰岩は３万年前，火山原面を残す円錐火山の大部分はここ50万年以降のものらしい。その基盤をつくる第三紀末一第四紀前半の火砕流堆積物のうち十勝溶結凝灰岩類の最上位のものは70万年前という値が出されている。

総体積　北海道全体の第四紀火山の総体積は960km³。円錐火山の平均体積は33km³，大カルデラ火山は98km³，小カルデラ火山，溶岩円頂丘火山は２km³以下。

有珠山1977年以後の活動　1977年８月７日から１週間，15～20回の噴火を行ない，0.083km³の軽石を噴出した。山頂部で最大厚３ｍに達した。その後高粘性マグマの上昇に伴う山体の変動が続いた。断層崖，撓曲崖が形成され，山頂カルデラ内部で小さな尾根が200ｍ隆起した。北外輪山は180ｍ北東へ水平移動し，外側へ傾いた。35°であった斜面は60°になり地すべりが発生した。約１年後，地表浅所まで達した高粘性マグマは地下水と接触してマグマ水蒸気爆発を起こす。細粒火山灰が山腹に堆積し土石流を惹き起こし３名が死亡した。土石流災害防止用のダムが山腹の放射谷に200以上つくられている。

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1. GENERAL STATEMENT

In Hokkaido the volcanic activities have been very vigorous throughout the Quaternary to form 46 volcanoes. Of these 29 volcanoes preserve well the initial volcanic surfaces. 8 volcanoes (Oshima-Oshima, Esan, Oshima-Komagatake, Usu, Tarumai, Tokachi, Me-Akan and Shiretoko-Iwo Volcanoes) are active with records of eruptions. In addition to these, some volcanoes (Yotei, Niseko, Taisetsu and so on) may have erupted in comparatively recent times although there are no historical records.

The volcanic activities have done us favors, forming beautiful sceneries such as Lake Toya, Lake Mashu, Sounkyo etc. and hot springs such as Noboribetsu and Kawayu. Ash fall deposits erupted are also beneficial to cultivation, especially in eastern Hokkaido.

On the other hand, the volcanoes have given us disasters, too. In 1926 Tokachi Volcano erupted a small-scale pyroclastic flow. It melted snow on the slopes and changed itself to mud flows which rushed down 30 km distant from the crater along the valleys, killing 144 persons and destroying many houses, roads, bridges and railways and cultivated fields (Tada & Tsuya, 1927).

In 1978, three persons were killed by a cold lahar from Usu Volcano in Toya-spa town (Kadomura et al., 1979).

A large amount of masses having occupied the top of Oshima-Oshima Volcano were destroyed in the 1741 eruption. Voluminous debris slid rapidly into the sea, causing a large-scale tsunami to kill 1475 persons at the coasts of southwestern Hokkaido and Sado Island, 400 km south (Katsui et al., 1977).

In this chapter distribution, type, petrography, and volume of the volcanoes in Hokkaido will be summarized, accompanied with brief descriptions of 6 volcanoes - Kutcharo, Akan, Taisetsu, Tokachi, Shikotsu and Toya Volcanoes.

(1) Distribution

Hokkaido is situated at the junction of the Kurile and Northeast Honshu Arcs. So the volcanoes in Hokkaido are divided into two arcs; i.e., volcanoes on the Kurile and Northeast Honshu Arcs. Kutcharo, Akan, Taisetsu and Tokachi volcanoes stand on the Kurile Arc, while Shikotsu, Toya, Yotei, Oshima-Komagatake and Esan Volcanoes stand on the Northeast Honshu Arc. The volcanoes are distributed only in the Japan Sea side of the volcanic front 250-340 km distant from the Kurile and Japan Trenches, especially densely near the volcanic front. On the contrary no volcano is found in the trench-volcano gap zones such as Tokachi Plain, Hidaka Mountains, Konsen Plain.

The volcanoes in eastern Hokkaido standing on the Kurile Arc form some volcanic chains such as Shiretokodake-Rausu-Shari, Kutcharo- Akan, and Taisetsu-Tokachi, arranging in echelon(Tokuda, 1930). The arrangement may have been brought about by Pacific plate colliding obliquely against the Kurile Arc (Kaizuka, 1975).

(2) Landform Type and Evolution

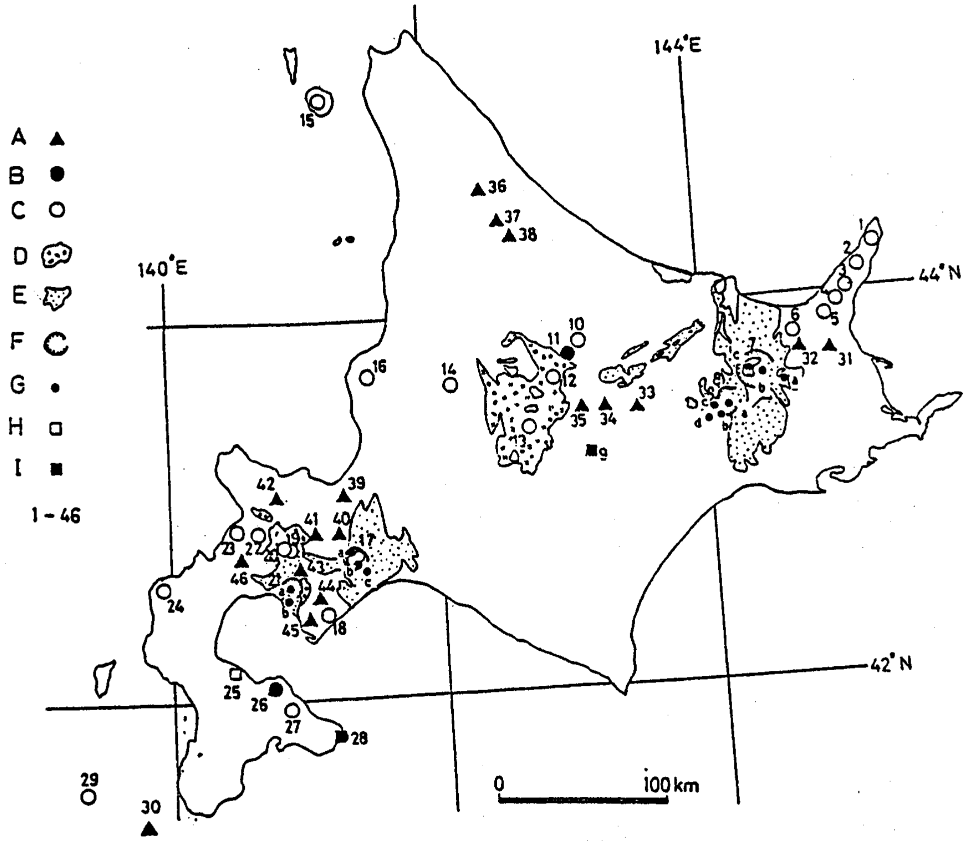
29 volcanoes with comparatively well-preserved initial volcanic landforms are geomorphologically divided into 4 types - 22 cone volcanoes, 4 gigantic Krakatoan caldera volcanoes, 2 small Krakatoan caldera volcanoes and 2 lava dome volcanoes (Fig. 1).

a) Cone Volcano (stratovolcano or composite volcano)

Yotei, Shari, Rausu and Rishiri Volcanoes are typical cone volcanoes in Hokkaido. They have simple landforms and structures composed mainly of alternations of basaltic-andesitic lava flows and pyroclastics. On the other hand, Oshima-Komagatake and Taisetsu volcanoes are cone volcanoes having complicated landforms and structures. These volcanoes had landforms and structures approximately equal to those of Yotei and Shari in the earlier stages, but later they have been deformed by formations of a small caldera, lava domes at the summits and of pumice flows on the lower slopes. The differences of landforms and structures are presumably attributed to the differences in the stages of evolutions.
ences in the stages of evolutions.

The evolutions of the cone volcanoes in Japan are briefly generalized as follows (Fig. 2):

(1st stage) A gently sloping large cone with simple structure is constructed. The cone is composed of mafic thin lava flows and scoria falls (olivine-pyroxene basalt - andesite, SiO_2 56% in average). (2nd stage) Thick lava flows are added on the upper slope of the large cone. Therefore, the



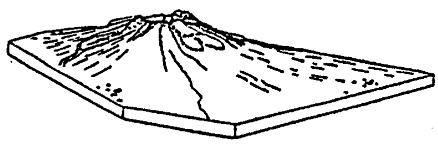
(Fig. 1) Distribution of the Quaternary volcanoes in Hokkaido

A Older large cone volcanoes heavily dissected, without the initial volcanic landforms. B. Younger large cone volcanoes preserving the initial volcanic surfaces. They have developed to the later stages with a small caldera at the summit and small-medium scale pumice flow surfaces in the lower slopes. C. Younger large cone volcanoes remaining the initial volcanic landforms. They have evolved only to the early stages without a small caldera and pumice flow surfaces. D. Large pyroclastic flow deposits erupted in the early Pleistocene. E. Large pyroclastic flow deposits issued out of gigantic Krakatoan caldera volcanoes in the late Pleistocene. F.Gigantic Krakatoan caldera. G. Post-caldera volcanoes H. A small Krakatoan caldera volcano. I. dome volcanoes.

No.1-46: Names of volcanoes.

1 Shiretokodake	13 Tokachi	25 Nigorigawa	37 Numadake	7c nakajima
2 shiretoko-Iwo	14 Irumukeppu	26 Oshima-Komagatake	38 Piyashiri	8a O-Akan
3 Rausu	15 rishiri	27 Yokotsudake	39 Teine	8b Furebetsu
4 Onnebetsu	16 shokanbetsu	28 Esan	40 Sapporo	8c Fuppushi
5 Unabetsu	17 Shikotsu	29 Oshima-Oshima	41 Muine	8d Me-Akan
6 Shari	18 Noboribetsu	30 Oshima-Kojima	42 Akaigawa	17a Eniwa
7 Kutcharo	19 Shiribetsu	31 Musadake	43 Kutchanbetsudake	17b Fuppushi
8 Akan	20 Yotei	32 Shibetsudake	44 Tokushunbetsu	17c Tarumai
9 Shikaribetsu	21 Toya	33 Kitoushi	45 Washibetsudake	21a Nakanoshima
10 Niseikaushuppe	22 Niseko	34 Kumaneshiri	46 Konbudake	21b Usuzan
11 North Taisetsu	23 Raiden	35 Nipesotsu	7a Mashu	
12 South Taisetsu	24 Kariba	36 Hakodake	7b Atosanupuri	

(4)



(1)

(2)

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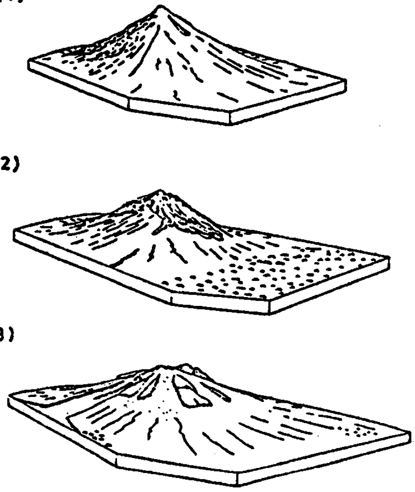


(Fig. 2) Evolution of cone volcano (Moriya, 1979)

(1) Formation of large cone with simple structure mainly composed of mafic thin lava flows and scoria falls(1st stage) (2) Growth of the cone by addition of thick lava flows on the upper slopes. Sometimes large-scale destructions of the upper parts of the cones happen by the trigars of phreatic explosions (2nd stage) (3) Explosive eruptions producing pyroclastic falls and flows, which repeatedly construct and destruct of pyroclastic cones on the summit and extend of the the lower slopes with the accumulations of pyroclastic flow deposits (3rd stage) (4) Formation of lava domes within a small caldera on the summit(4th stage).

surfaces of the cone show stepped slopes. In some volcanoes, the cone is greatly destroyed by the Bandaian eruption just after the maximum growth of it, forming a horseshoe-shaped caldera on the summit. (3rd stage) Explosive eruptions of pyroclastic flows and falls (pumiceous, hornblende-pyroxene andesite - dacite, SiO_2 62% in average) are repeated, causing destruction of the older cone and construction of pyroclastic cones and pyroclastic flow surfaces. (4th stage) A small caldera is formed on the summit of the cone, sometimes accompanied with formation of lava domes within it (Moriya, 1979).

It is deduced from a trend of evolution of cone volcanoes that Oshima-Komagatake Volcano must have had a shape of a typical cone volcano similar to that of Yotei Volcano, while Yotei Volcano would erupt pumice flows to form a small caldera at the summit in future.

b) Large Krakatoan Caldera Volcano

In Hokkaido there are 4 large Krakatoan caldera volcanoes - Kutcharo, Akan, Shikotsu and Toya Volcanoes. They have gigantic calderas at the center, surrounded with extensive flat pyroclastic flow plateaus. Within or around the calderas there rise small cone volcanoes in the post-caldera stage such as Mashu, Atosanupuri, O-Akan, Eniwa, Tarumai, Usu etc..(Fig. 3).

Their activities began with violent eruptions of voluminous pumice without formation of precedent large cone volcanoes. A large amount of pumice flowed to the distance several ten km, in some cases more than 100 km from the calderas. Such activities may have occurred several times in every large Krakatoan caldera volcano within several ten thousand years. The total volume is estimated at more than 100 km^3 for every volcano. As the result, calderas have been formed.

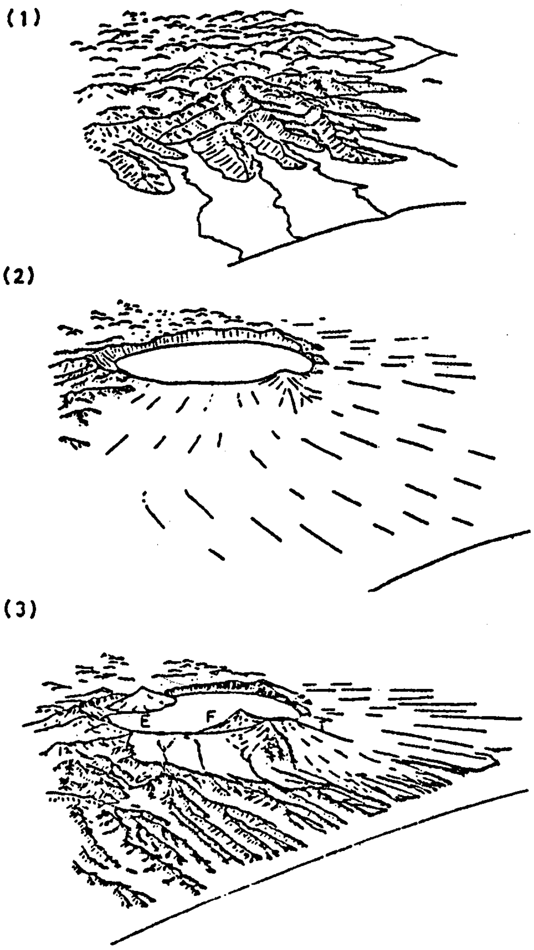
In the post-caldera stage, small cone volcanoes have formed at the center and/or the rim of the calderas. The processes of their evolution are generally similar to those of the large cone volcanoes.

c) Small Krakatoan Caldera Volcano

Nigorigawa Volcano consists of a small caldera, 2 km across and 200 m deep, and pyroclastic flow plateaus composed of hornblende-pyroxene andesite pumice flow deposits issued out about 12,000 years ago.

There is no lava dome within or around the caldera.

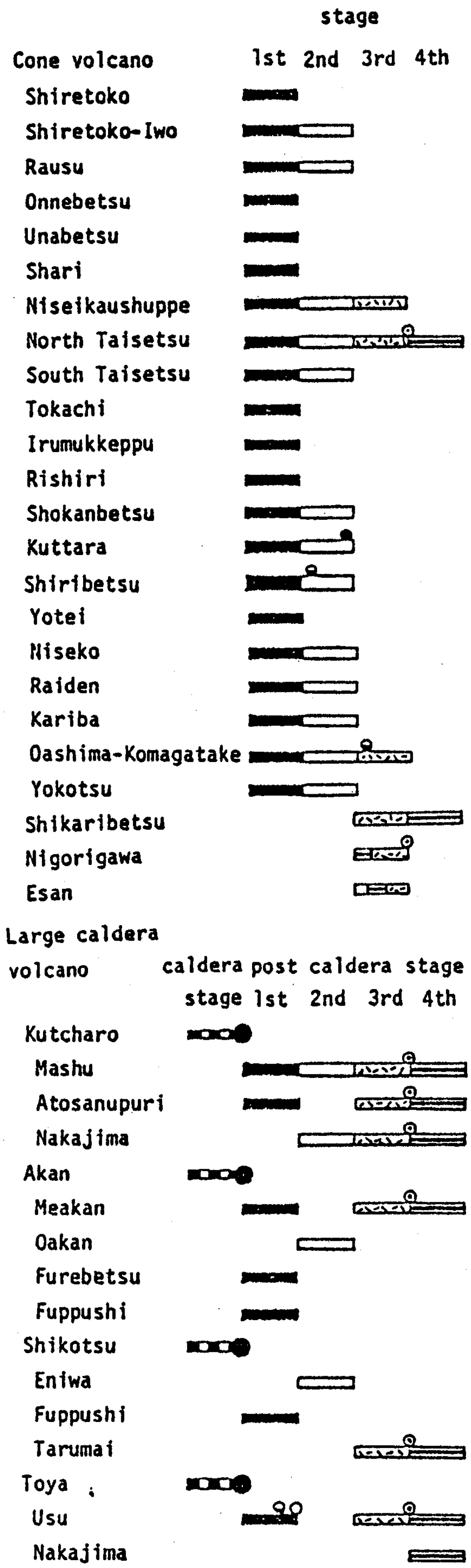
Kuttara Volcano is another caldera volcano which has a circular lake

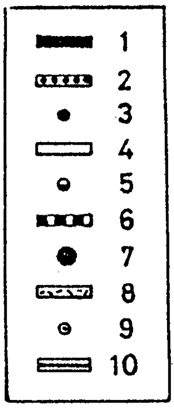


(Fig. 3)

Diagrams showing the developments of Shikotsu Volcano

(1) Nonvolcanic mountains (2) Eruptions of voluminous pumice falls and flows which have formed extensive flat accumulation surfaces resulting in formation of a large caldera 10–12 km in diameter (3) Formations of small composite volcanoes after the formation of the caldera——Eniwa (E), Fuppushi (F) and Tarumai (T) Volcanoes. (Moriya, 1979)





(Fig. 4) Schematic chart of the geomorphological developments of the Quaternary volcanoes in Japan

1. Thin lava flow surface
2. Scoria cone
3. Small caldera without associated with pyroclastic flows
4. Thick lava flow surface
5. Horseshoe-shaped caldera
6. Large-scaled pyroclastic flow surface
7. Large caldera
8. Small-scaled pyroclastic flow surface
9. Small caldera associated with pyroclastic flows
10. Lava dome.

(Moriya, 1979)

about 2 km in diameter on its truncated summit.

Their forms and structures are similar to those of larger Krakatoan caldera volcanoes, but different in their sizes, volume of the eruptive products and chemical composition of pumices.

d) Lava Dome Volcano

Shikaribetsu and Esan Volcanoes consist of some lava domes of andesite 200-500 m in specific height and less than 0.05 km^3 in volume. Before or during formations of the lava domes, some small-scale pyroclastic flows and falls have been erupted (Fig. 4).

e) Pyroclastic Flow Plateaus in the Early Pleistocene

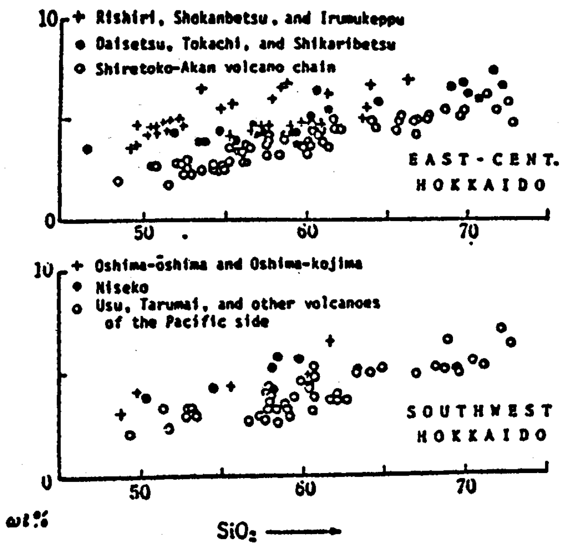
Plateaus, mesas, buttes and hills composed of welded tuffs are found around Taisetsu and Tokachi Volcanoes and in Kitami and Ishikari Mountains. The welded tuffs are products of voluminous rhyolitic or dacitic pumice eruptions in the late Pliocene to the early Pleistocene. They are exposed in Shiranuka and Toyokoro hills, intercalated among silt, sand and gravel layers. More than 15 sheets of the pyroclastic flow deposits have been recognized throughout Hokkaido, and their total volume may be estimated at least 2,000 km^3.

It has been supposed that large -scale eruptions of voluminous pumice had generally brought about formation of large Krakatoan calderas near the eruptive centers, judging from the existence of the welded tuffs. However, distinct caldera landforms have never been found in these cases, probably due to erosion or covering of younger volcanic products. The author presumes that Tokachi-Mitsumata basin and the depression of the upper drainage basin of the Ishikari River may suggest the remnants of such calderas. Existence of a caldera structure has been presumed under Tokachi Volcano(Takahashi, 1965).

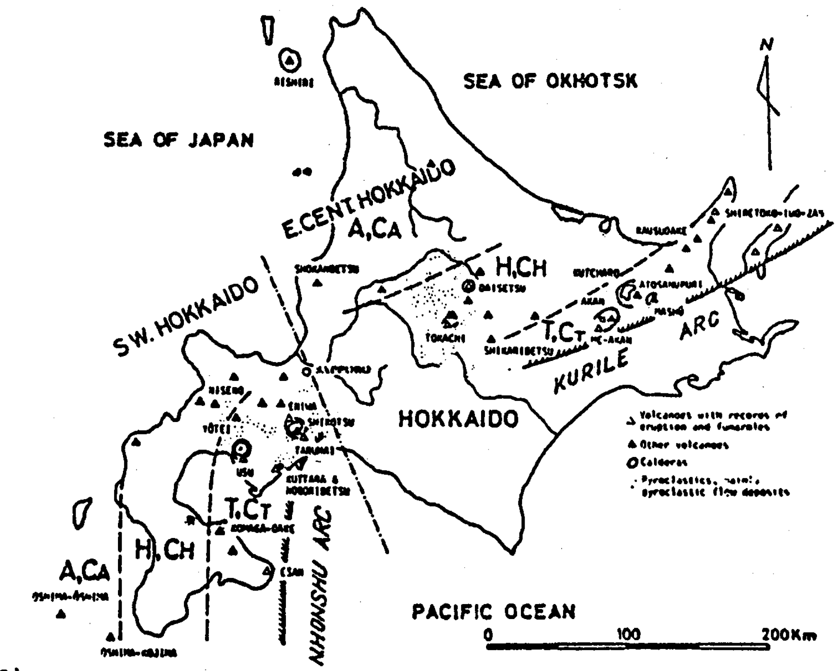
(3) Petrography

Characteristics of mineral and chemical compositions of the rocks of the Quaternary volcanoes in Hokkaido have been summarized by Katsui et al. (1978a) as follows:

All the Quaternary volcanic rocks in Hokkaido are included in a wide range of basalt-andesite-dacite-rhyolite series. Their mineral compositions, rock types, and rock series are shown in Table 1. Of these, andesite and dacite of the calc-alkali series are predominant in most of the volcanic

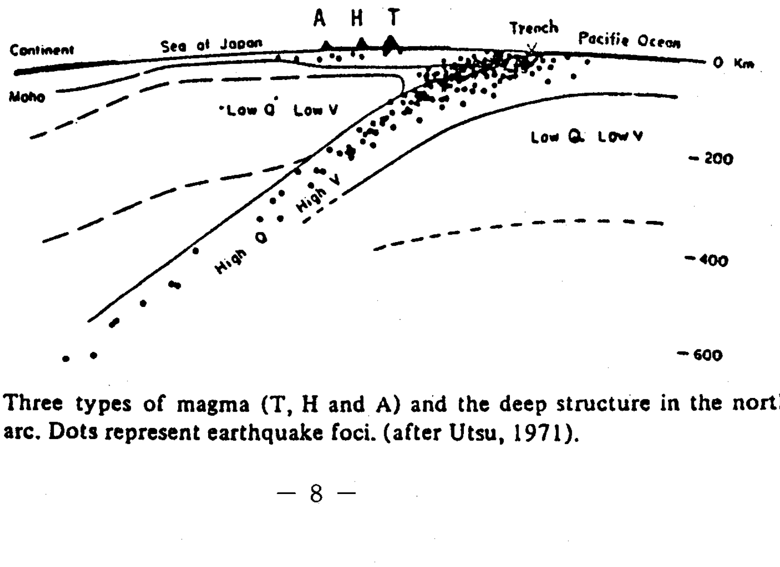


(Fig. 5)
Silika-alkali diagram of volcanoes in Hokkaido (Katsui et al, 1978)



(Fig. 6) Distribution of the Quaternary volcanoes in Hokkaido. Petrographic provinces are shown by the symbols of rock series, T & C_T, H & C_H, and A & C_A (see Table 2).

(Katsui et al., 1978)



(Fig. 7) Three types of magma (T, H and A) and the deep structure in the north Honshu arc. Dots represent earthquake foci. (after Utsu, 1971).

fields in Hokkaido.

Lateral variation of the petrographic feature of the volcanic rocks across the island from the Pacific to marginal sea side is well represented in variation diagrams for total alkali plotted against silica(Fig. 5). The rocks of the Pacific side are generally poor in alkali, whereas toward the marginal sea they become more alkalic(Fig. 6, 7).

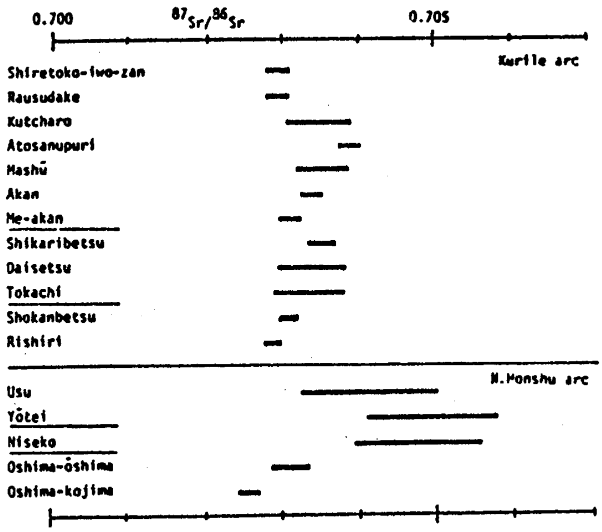
The Sr-isotopic ratios of the Quaternary volcanic rocks of Hokkaido are generally low. Especially those of the Kurile Arc are all within a limited range from 0.7028 to 0.7039, which is almost comparable to the range of ocean ridge basalt. The Sr-isotopic ratios of basalt to dacite (or rhyolite) in a single volcano, Mashu and Tokachi for example, are almost identical and exhibit a small range of variation without any systematic change. The isotopic ratios of a large amount of dacitic or rhyolitic pumice which erupted at caldera formation do not support an origin by anatexis of older continental crust or assimilation(Fig. 8).

(4) Ages of The Activities

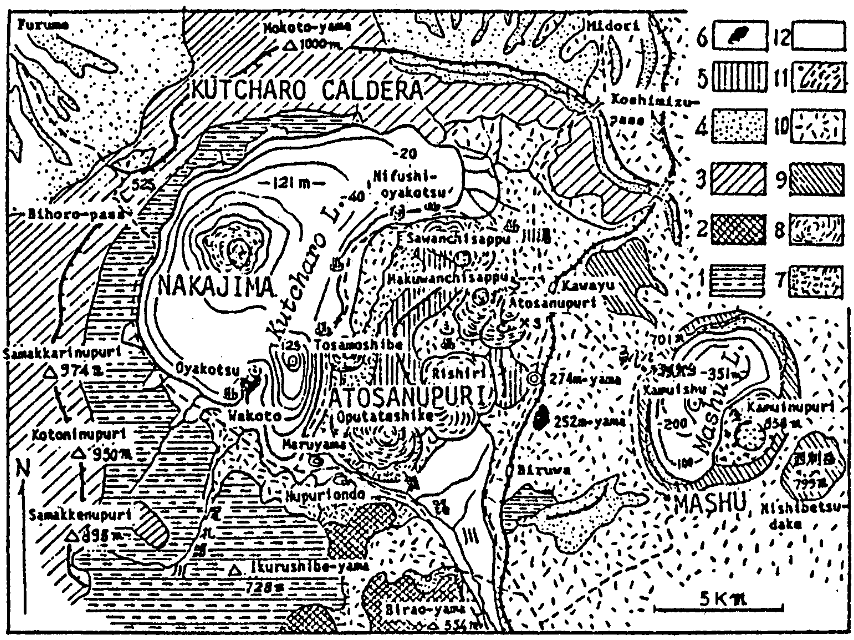
Ages of the volcanoes in Hokkaido are not sufficiently known, due to deficiency of K-Ar and Fission-track dates, although more than 80 C^{14} data are present. In most cases, only the ends of the volcanic histories with the results of C^{14} dates come to be evident. Taisetsu Volcano erupted Sounkyo Welded Tuff about 30,000 years ago (Katsui et al., 1979a) in the late stage of its evolution. Precedent activities in the early stage took presumably several times as long as 30,000 years for construction of the large cone, whereas the uppermost of Tokachi Welded Tuffs where Taisetsu Volcano lies erupted about 700,000 years ago(Shibata et al., 1978). So it is assumed that the cone volcanoes preserving well the initial land-forms started the activities within recent 500,000 years, possibly within the last 200,000 years. The gigantic Krakatoan caldera volcanoes may have been active in the end of Pleistocene.

(5) Volume

The tolal volumes of the Quaternary volcanoes preserving the initial landforms in Hokkaido is estimated at 960 km^3. So the mean volume of every volcano is calculated at 33 km^3. The mean volume of a cone volcano is 38 km^3 and that of a large Krakatoan caldera volcano is 98 km^3. Since most of the eruptive products of the large Krakatoan caldera volcanoes



(Fig. 8) $^{87}Sr/^{86}Sr$ ratios of the rocks of Hokkaido. (Katsui et. al., 1978)



1	Neogene volcanic & sedimentary rocks	7	Atosanupuri pyroclastic deposits
2	Sattomonai volcanic rocks (Neogene ?)	8	Nakajima & Atosanupuri dome lavas
3	Kutcharo somma lava	9	Mashū somma lava
4	Kutcharo pyroclastic flow deposits	10	Mashū pyroclastic deposits
5	Atosanupuri somma lava	11	Kamuishu & Kamuinupuri lavas
6	Oyakotsu & 252m-yama dome lavas	12	Terrace deposits & alluvium

(Fig. 9) Geologic sketch map of the Kutcharo caldera area (after Katsui, 1962).

are porous pumice, the real masses of the eruptive products should be less than 50 km^3. The total volume of small Krakatoan caldera and lava dome volcanoes is estimated at less than 2 km^3. These values are approximately equal to those of other Quaternary volcanoes in Japan.

The total volume of the Plio-Pleistocene welded tuffs such as Tokachi Welded Tuffs may be more than 2,000 km^3. The volume of the older cone volcanoes can not be estimated accurately because considerable parts of the volcanoes have been eroded away. But assuming that the older cone volcanoes were equal to the younger ones in size, the total volume is calculated at about 600 km^3. Therefore, the total volume of the Quaternary volcanoes in Hokkaido is estimated at more than 3,500 km^3. So the production rate of Quaternary volcanoes in Hokkaido is calculated at about 3.2×10^5 m^3/year. 100 km(for every 100 km along the arc), which is roughly equivalent to that of the Quaternary volcanoes in Japan.

(6) Tephra

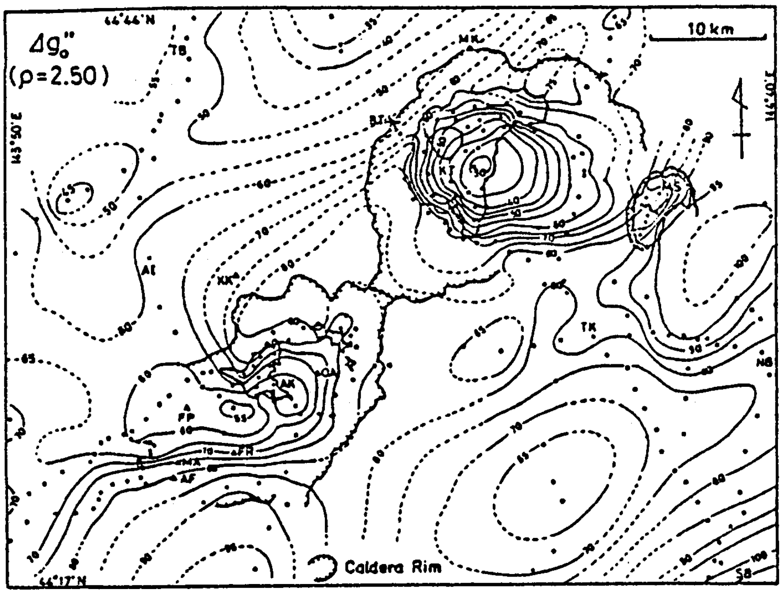
Tephrochronological studies have started as early as 1933 in Hokkaido (Uragami et al., 1933), preceding the study by Thorarinsson (1944). Many investigations on tephras in Hokkaido have been performed in detail, making Hokkaido one of the most well-known regions in tephrochronology in the world. The tephras have been well traced from the original volcanoes to distant plains, in some cases, even beyond high mountains, and detailed studies on stratigraphy, distribution, changes of grain-size and thickness, petrography, age, volume and so on have been completed.

Pumice layers of Shikotsu Volcano have been extensively observed in Ishikari and Tokachi Plains. Tephras derived from Kutcharo and Akan Volcanoes also, are distributed in the Konsen Plain.

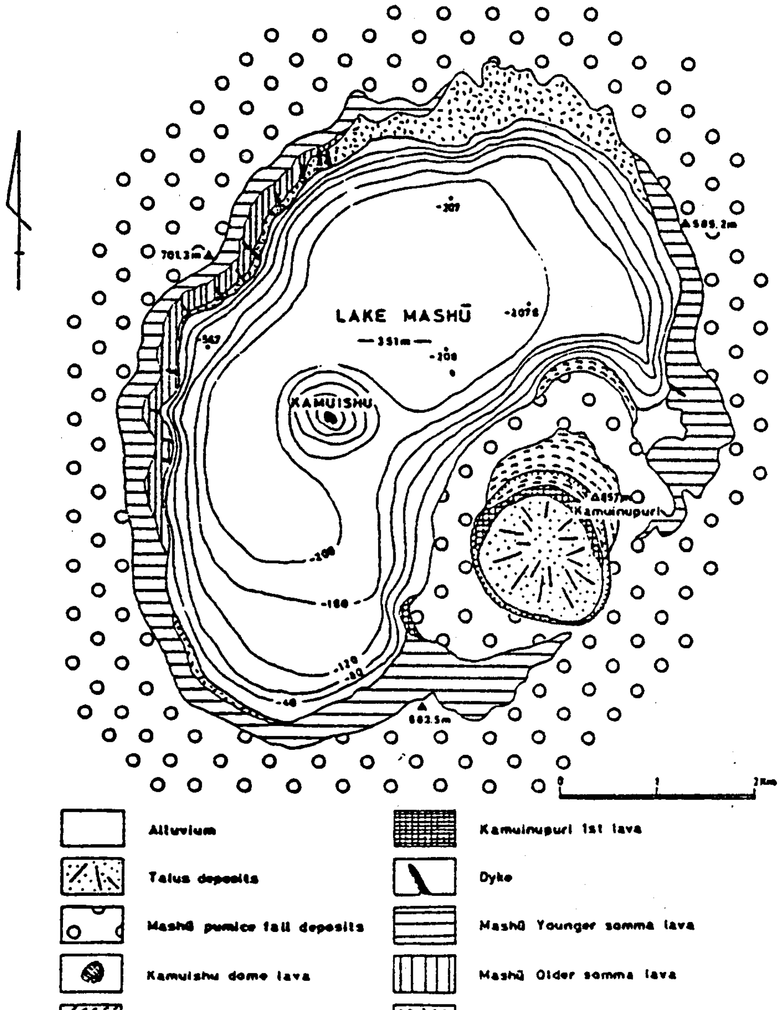
(Table 1) Essential mineral composition of the Quaternary basalt and andesite of Hokkaido.

Rock series	T [C_T]	H [C_H]	A [C_A]
Pheno-cryst	Anorthite* – bytownite Olivine with pyroxene rim Augite, rarely pigeonite in T Hypersthene Magnetite (*sometimes large pheno-cryst > 1 cm in size)	Bytownite – labradorite Olivine Augite Hypersthene Magnetite [Hornblende]	Labradorite – andesine Olivine Augite, Ti-augite in A Magnetite [Hypersthene] [Hornblende] [Biotite]
Ground-mass	Bytownite – labradorite Augite, pigeonite in T Olivine (rare) usually with reaction rim Silica minerals Magnetite [Hypersthene] [Alkali feldspar]	Labradorite – andesine Augite Olivine (rare) with or without reaction rim in H Silica minerals Alkali feldspar Magnetite [Hypersthene]	Andesine – oligoclase Augite Olivine without reaction rim in A Alkali feldspar Magnetite Apatite [Hypersthene] [Silica minerals]

[ ] included only in calc-alkali rocks. (Katsui et al., 1978)



(Fig.10) Distribution of Bouguer gravity anomalies on and around the Kuttyaro Akan volcanic region. Unit is mgal. (Ohkawa & Yokoyama, 1979)



(Fig.11) Geologic map of Mashu volcano, east Hokkaido. (Katsui et al., 1978)

2. DESCRIPTION OF MAIN VOLCANOES IN HOKKAIDO

6 main volcanoes well-known in Hokkaido(Kutcharo, Akan, Taisetsu, Tokachi, Shikotsu and Tóya Volcanoes) will be described in this section.

(1) Kutcharo Volcano

This volcano has a caldera, 23 x 24 km in size, which is the largest caldera in Japan. A large amount of dacitic pumice flow deposits are destributed to form extensive pyroclastic flow plateaus and hills. The caldera may have been formed just after the large-scale pumice eruptions, followed by the formation of 3 post-caldera volcanoes(Mashu, Atosanupuri, Nakajima Volcanoes) (Katsui, 1958, Fig. 9).

a) Basements and Pre-Caldera Volcanic Activities

Before the formation of the caldera, 2 cone volcanoes(Mokotoyama, and Samakkarinupuriyama, both about 20 km^3 in volume) stood on the mountains composed of propylite, green tuff, and sand stone of Miocene. These volcanoes consist of olivine basalt - pyroxene andesite lava flows and pyroclastics exposed on the northern and western walls of Kutcharo caldera. It is not apparent how long was a pause of the activities between the formations of them and Kutcharo volcano.

b) Kutcharo Caldera

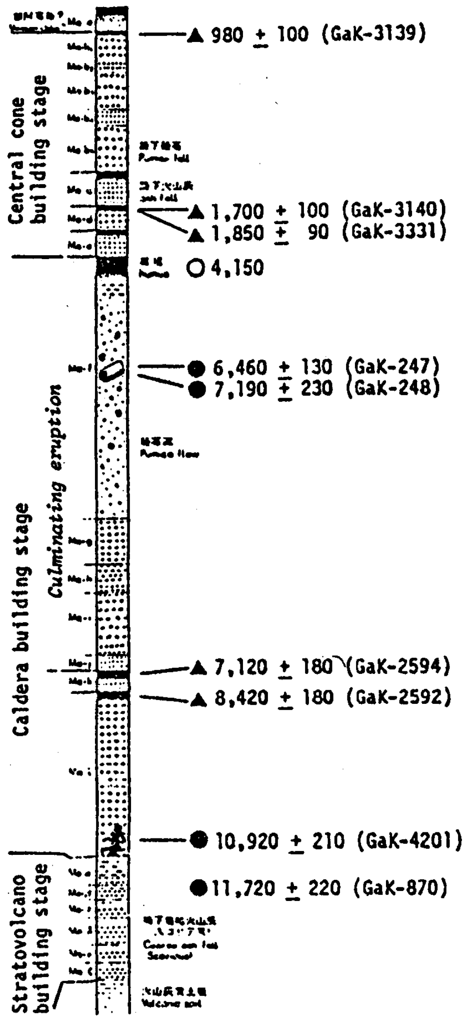
The caldera walls, 300-500 m high, can be comparatively well traced in spite of formation of Mashu Volcano in the eastern rim of the caldera. Probably the walls have retreated 1-3 km from the initial position by erosion. So the initial caldera would be 14-22 km across.

Most of the eastern half of the caldera floor have been occupied by Atosanupuri Volcano and the western half by Lake Kutcharo, 77 km^2 in area. In the southeastern and northern caldera floor, peat lands and fans are distributed. A barranco called the Kushiro River flows out at the southern rim of Lake Kutcharo. On the southern caldera floor, a fault system of left-lateral slip trending NW-SE appeared in the vicinity of Sattekinai, as a result of the 1938 Kutcharo earthquake with a magnitude of 6.1.

Residual low gravity anormalies amounting about 40 mgal has been found on the caldera (Ohkawa & Yokoyama, 1978, Fig. 10).

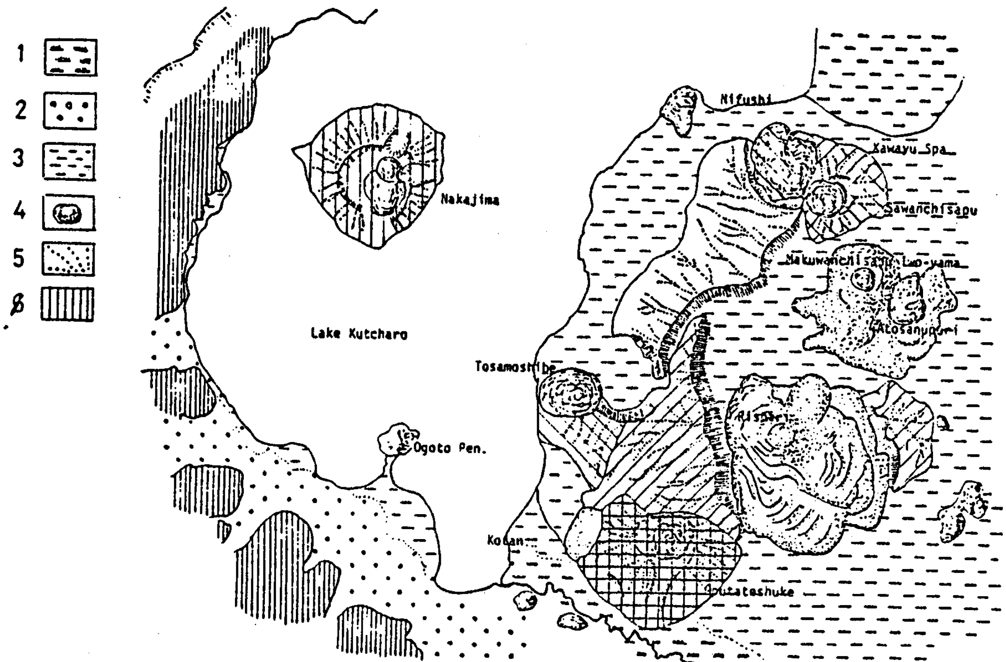
c) Pyroclastic Flow Plateaus

Kutcharo caldera is surrounded by extensive pyroclastic flow plateaus and hills more than 1,000 km^2 in area composed of voluminous pumice flow deposits



(Fig.12)

Standard columnar section and radiocarbon dates of the Mashu pyroclastic deposits. Materials for radiocarbon age determination: solid cricles – charcoal, and solid triangles – humic acid. An obsidian hydration date of stone implements is shown by open circle. Source of data: Katsui, 1963: Katsui and Kondo, 1965: Satoh, 1969; Sasaki et al, 1971; Shoji and Masui, 1974.



(Fig. 13) Geomorphic map of Atosanupuri and Nakajima Volcanoes
1.Peat land 2. Fan 3. Fluvial plain 4. Lava dome and lava cone
5. ridge showing initial surfaces of cone 6. Erosional slope

about 120 km^3 in volume. The pumice flows(pyroxene dacite, 72%) issued repeatedly more than 11 times more than 30,000 years ago(Satoh, 1969).

d) Mashu Volcano

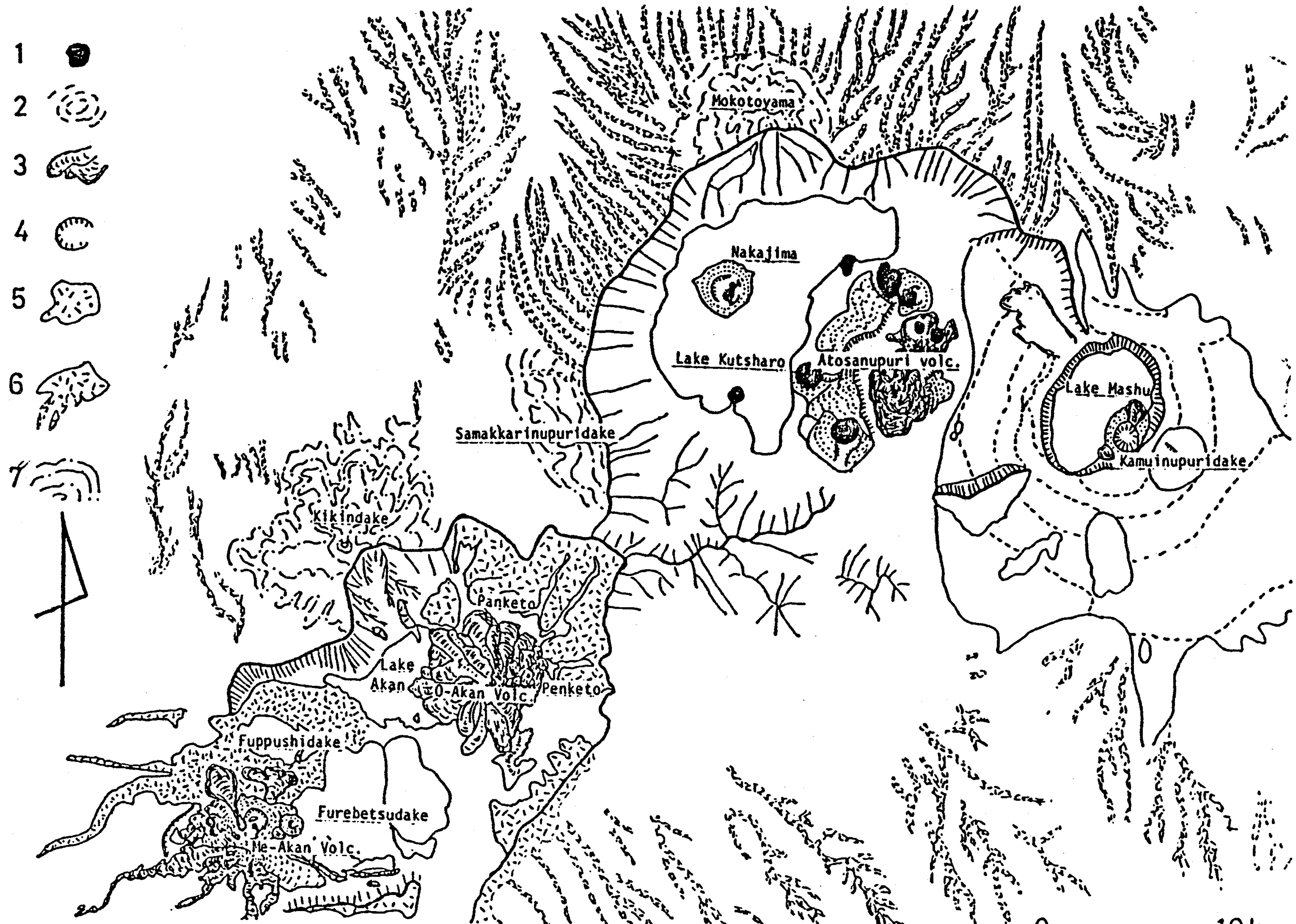
This volcano standing on the eastern rim of Kutcharo caldera is a small cone volcano with a small summit caldera where Lake Mashu is present.

The activities of Mashu Volcano may have begun about 10,000 years ago. At the first stage, thin basalt-andesite lava flows and pyroclastics(SiO_2 57%) were repeatedly erupted, resulting in formation of a typical cone like Fuji Volcano. Scoriaceous air fall deposits which were erupted in this stage are distributed in the eastern area of the volcano - Konsen Plain, called Ma-α~ζ ash layers. At the second stage, a thick lava flow issued out on the northeastern slope, preserving the initial surfaces. About 6,000 years ago, a pumice flow(called Ma-f by Katsui, 1961. 7 km^3 in volume, augite-hypersthene andesite SiO_2 66%) was erupted from the summit, extended thinly on the lower slopes. Just after the eruption, Mashu caldera may have been formed by collapse. The caldera wall 300 m high is well preserved and on the steep cliffs we can find structures of the alternation of the lava flows and pyroclastics of the ancient cone. In the caldera there is Lake Mashu, 212 m deep. The lake water was known as the clearest in the world, but now it is second in transparency, only next to Lake Baikal.

At the center of Lake Mashu, an islet called Kamuishu is protruded. It is a top of a lava dome(pyroxene dacite, SiO_2 72%), 180 m above the bottom of the lake. Kamuinupuri Volcano, a small cone with a large crater, rises to the east of Lake Mashu within Mashu caldera. It is composed of thick lavas of pyroxene dacite, covered by pumice fall deposits, erupted within the last 4,000 years(Fig. 11, 12).

E) Atosanupuri Volcano

This volcanoe situated at the eastern part of Kutcharo caldera is made up of two ridges which are ruins of a small cone with some lava domes or lava cones. At the early stage of the activities, a typical simple cone consisting of basalt-andesite lava flows and pyroclastics(SiO_2 64%) may have been formed. Sequently the cone was destroyed by eruptions of pumice falls and flows(pyroxene dacite, SiO_2 70%), resulting in formation of a small caldera 3.5-5.0 km across called Atosanupuri caldera. At the last stage several lava domes such as Sawanchisapu, Makuwanchisapu and so on, were



(Fig. 14) Geomorphic map of Akan and Kutcharo Volcanoes
1. lava dome and lava cone 2. Composite cone 3. Lava flow 4. Crater or caldera 5. Pumice flow surface of Me-Akan Volcano 6. Akan and Kutcharo pumice flow surfaces 7. Pre-caldera cone

extruded. Iwoyama solfatara field, one of the exiciting sightseeing spots, lies at the northern base of Iwoyama lava dome(pyroxene dacite, SiO_2 73%).

f) Nakajima Volcano

At the center of Lake Kutcharo there is an islet 2.8 km across and 300 m above the bottom of the lake. The islet is the top of Nakajima Volcano. According to Katsui(1958), the volcano may be a double lava dome(hornblended-bearing two pyroxene dacite, SiO_2 68%). At the summit a small caldera, 1.5 km across and 50 m deep, with two small nested lava domes(pyroxene dacite, SiO_2 70%) is present. The formation of the small caldera was accompanied with the eruptions of pumcie(pyroxene dacite, SiO_2 67%, Fig. 13).

(2) Akan Volcano

Akan Volcano is situated nearby to the west of Kutcharo Volcano. It has a large elliptical caldera, 24 km long in the direction of NE-SW and 13 km long in the direction of NW-SE. So it has been called also a volcano-tectonic basin similar to Lake Toba, Indonesia(Williams, 1941).

Akan pyroclastic flows(pyroxene dacite, SiO_2 66%) were erupted more than 30,000 years ago, accompanied with formation of Akan caldera. The deposits have formed pyroclastic flow plateaus and hills in the northwestern and southeastern areas of the caldera. They are estimated at 100 km^3 in the total volume(Ishikawa et al., 1969).

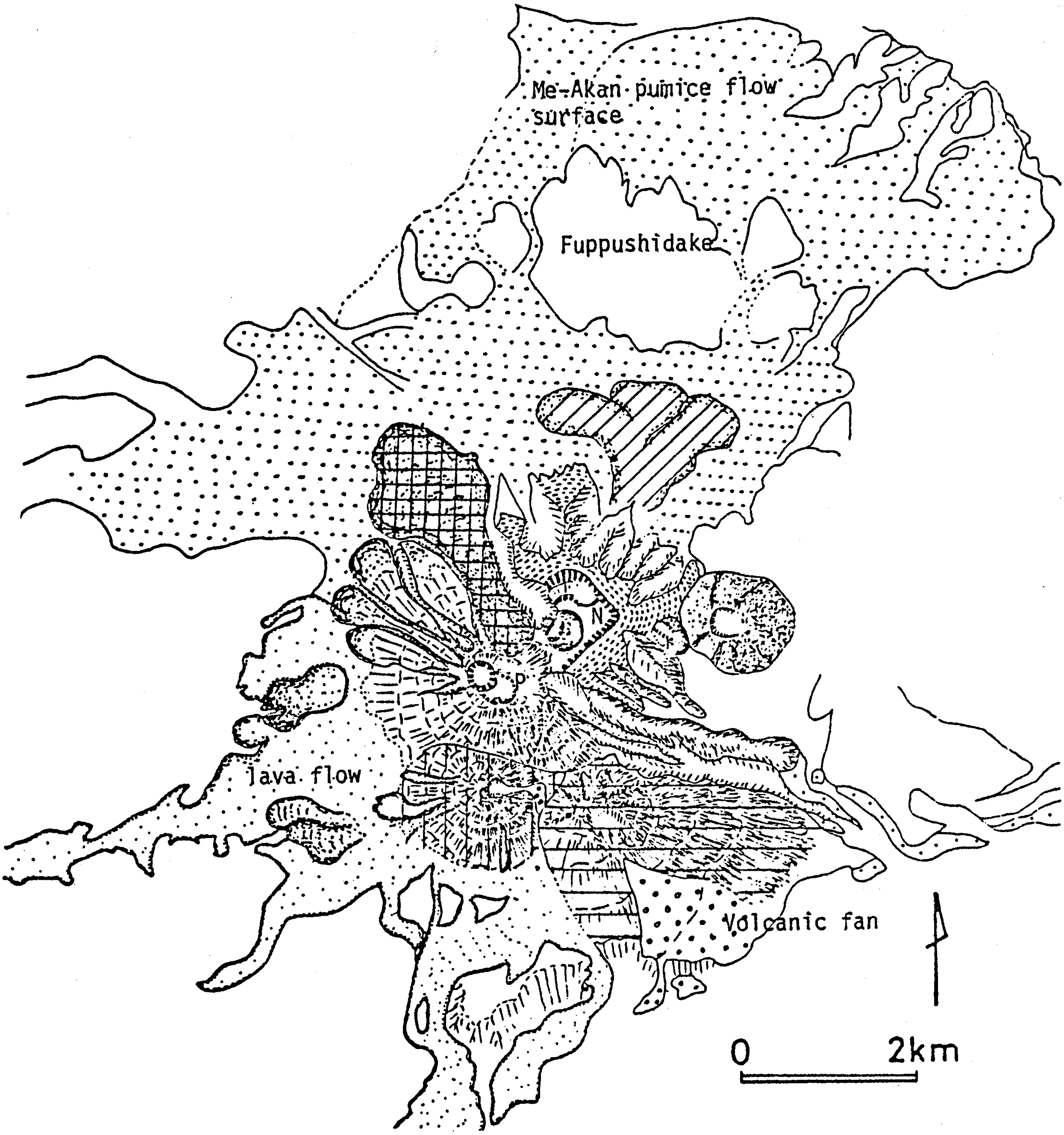
Ohkawa & Yokoyama(1979) have found a residual low gravity anormalies amounting 20 mgal on the caldera(Fig. 10).

Before the eruptions of the pyroclastic flows, low mountains 600-800 m above sea level composed of siltstone, sandstone, tuffs, and propylite of Miocene, occupied this area, and were covered by the products of small-medium sized cone volcanoes of early Quaternary such as Kikindake Volcano just to the north of Akan caldera. The basements are locally exposed on the caldera wall. In the northeastern bottom of the caldera, Kutcharo pumice flows invaded into the caldera beyond the ridge of the caldera rim to form gently sloped pyroclastic flow surfaces.

After the formation of Akan caldera, 4 post-caldera volcanoes(O-Akan, Me-Akan, Furebetsu, Fuppushi Volcanoes) have been formed within the caldera (Fig. 14).

a) O-Akan Volcano

This volcano(1,371 m above sea level) has been formed within Akan caldera.



(Fig.15) Geomorphic map of Me-Akan Volcano.
N: Nakamachineshiri P: Ponmachineshiri F: Akan-Fuji

It is a lava cone formed by piling up of several ten lava tongues(pyroxene andesite, SiO_2 62%) with lava levees and wrinkles. At the early stage the volcano erupted pumice air falls called O-Akan a and b.

b) Me-Akan Volcano

This is a compound volcano with 5 peaks(Nakamachineshiri, Ponmachineshiri, Akan-Fuji, Higashidake and Minamidake).

Nakamachineshiri is a cone with a small caldera(1.1 km across) on the summit. Pumice flow deposits (0.2 km^3 in volume, pyroxene andesite) distributed nearby in the northern lower slopes may have issued out of the small caldere. Later, a small pyroclastic cone and lava dome have been built up within the caldera. The main cone of Nakamachineshiri is composed of alternation of pyroxene andesite lava flows and pyroclastics.

On the western flank of the lava dome, there is a crater where sulfur was mined.

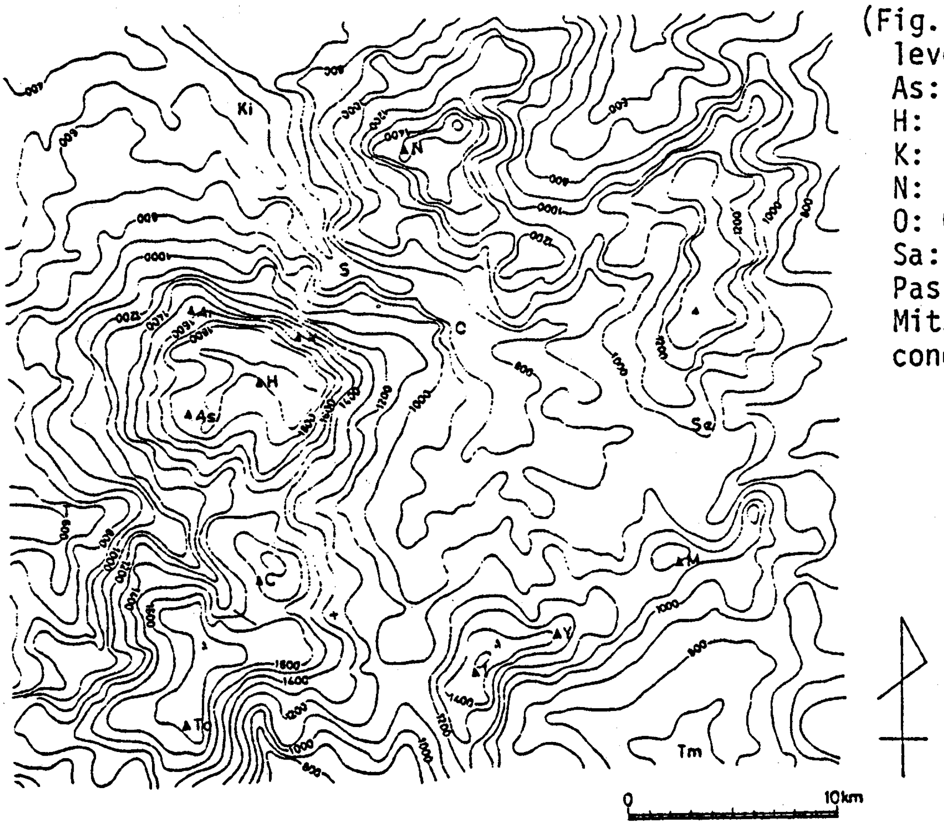
Ponmachineshiri cone with 2 craters on the summit is the highest of 5 peaks and is composed of pyroxene andesite lava flows(SiO_2 58%) and pyroclastics. In 1955-56 it made eruptions in the summit crater, the first historical activity of this volcano.

Akan-Fuji cone(1,476 m) is a beautiful cone-shaped volcano, from which thin fluidal basaltic-andesitic lava flows(pyroxene-olivine andesite, SiO_2 52%) issued out (Fig. 15).

(3) Taisetsu Volcano

This is a compound volcano divided into 2 large cones - North and South Taisetsu Volcanoes(Moriya, 1979, Fig. 16). They have various kinds of volcanic landform features - gently undulated small-scale lava flow plateaus, small composite cones, lava cones, a small caldera, pumice flows and lava flows with lava levees and wrinkles(Fig. 17).

Asahidake(2,290 m above sea level) - a small composite cone - is the highest not only within Taisetsu Volcano, but also in the mountains of Hokkaido. The other cones of Taisetsu Volcano also are nearly 2,200 m high. The lower parts of the eruptive products of Taisetsu Volcano are distributed at height of 600-700 m above sea level, so the specific height of Taisetsu Volcano is calculated at about 1,500 m. But the basements crop out up to 1,800 m above sea level, so the thickness of the volcanic products in average seems to be extremely thin, probably 200-300 m. Thus the total



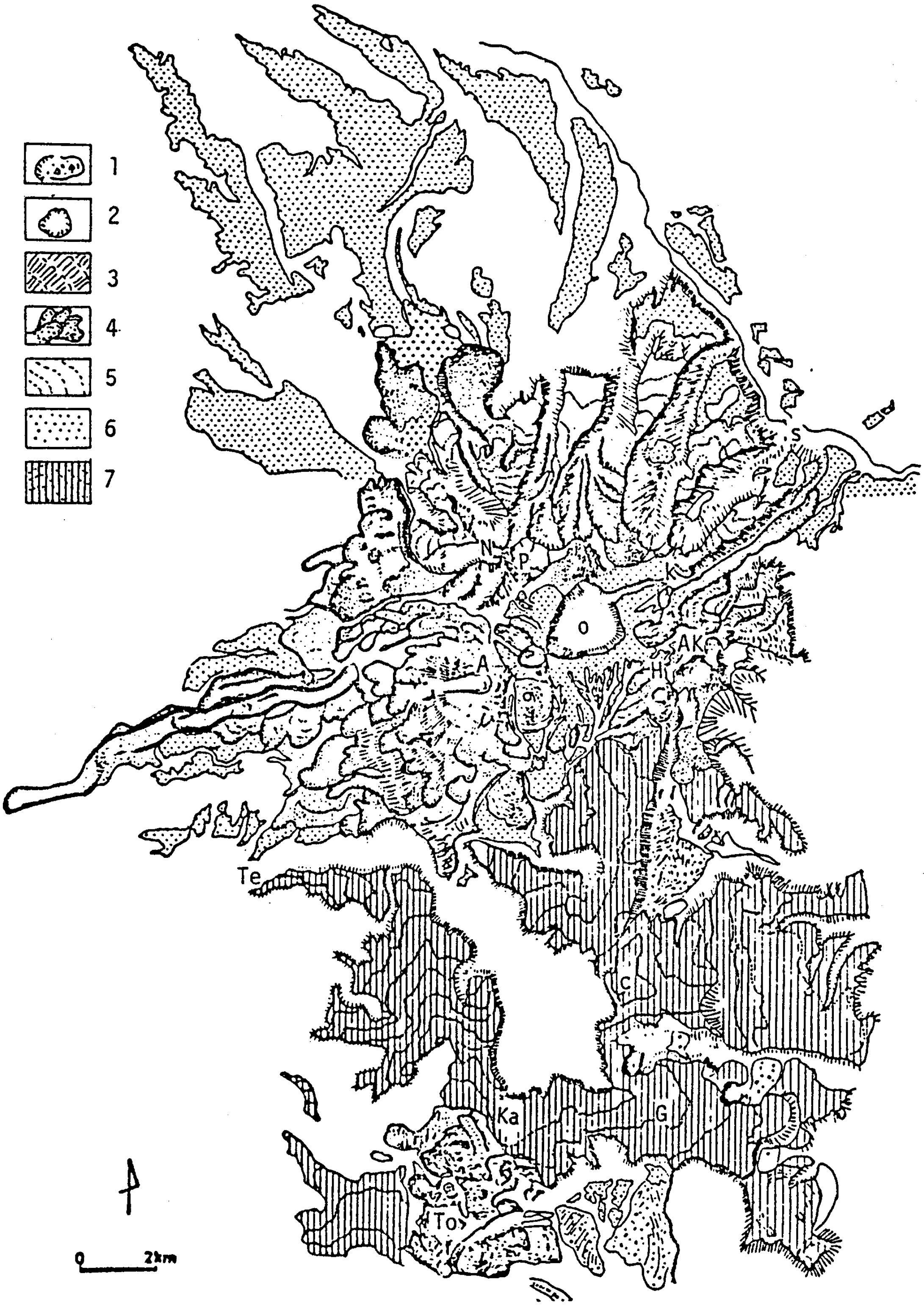
(Fig.16) Map showing the summit level of Taisetsu Volcano
As: Asahidake C: Chubetsudake
H: Hokkaidake I: Ishikaridake
K: Kurodake Ki: Kiyokawa
N: Niseikaushuppe Volcano
O: Obako S: Sounkyo
Sa: Sangokuyama Se: Sekihoku Pass T: Tennikyo Tm: Tokachi Mitsumata To: Tomuraushi laya cone Y: Yuni-Ishikaridake

volume of the volcano is approximately calculated at 100-150 km^3.

Taisetsu Volcano rests on the mountains of basements composed of propylite and green tuffs of the Miocene, basalt - andesite lava flows and pyroclastics in the Pliocene, and Tokachi Welded Tuffs in the Plio-Pleistocene (Konoya et al., 1966, 1968). The basements have formed mountains 1,000-1,600 m high. On Taisetsu Volcano, residual low gravity anormalies amounting to 55 mgal are found (Katsui et al., 1979a, Fig. 18). The fact may suggest that a buried caldera closely associated with the eruptions of Tokachi Welded Tuffs is present under Taisetsu Volcano.

a) North Taisetsu Volcano

At the center of North Taisetsu Volcano there is a small caldera, 2 km across and 200 m deep, called Ohachidaira, surrounded by small-size cones and peaks which may have been built up in various stages. Due to complication of the structures, it is difficult to reconstruct its history completely. Therefore in this guide book, the history will be described mainly according to the author's interpretation on the basis of observation of the landforms with aerial photographs, adding the results of the existing



(Fig.17) Geomorphic map of Taisetsu Volcano

1. Landslide 2. caldera & crater 3. cone of Asahidake 4. Lava flow 5. Surface of older lava flow 6. Pumice flow surface 7. Surface of old cone composed of mainly lava flows. A: Asahidake AK: Akadake C: Chubetsudake G: Goshikigahara H: Hokkaidaira K: Kurodake Ka: Kaundake N: Nagayamadake O:Ohachidaira P: Pippudake S: Sounkyo Te: Tenninkyo T: Tomuraushi

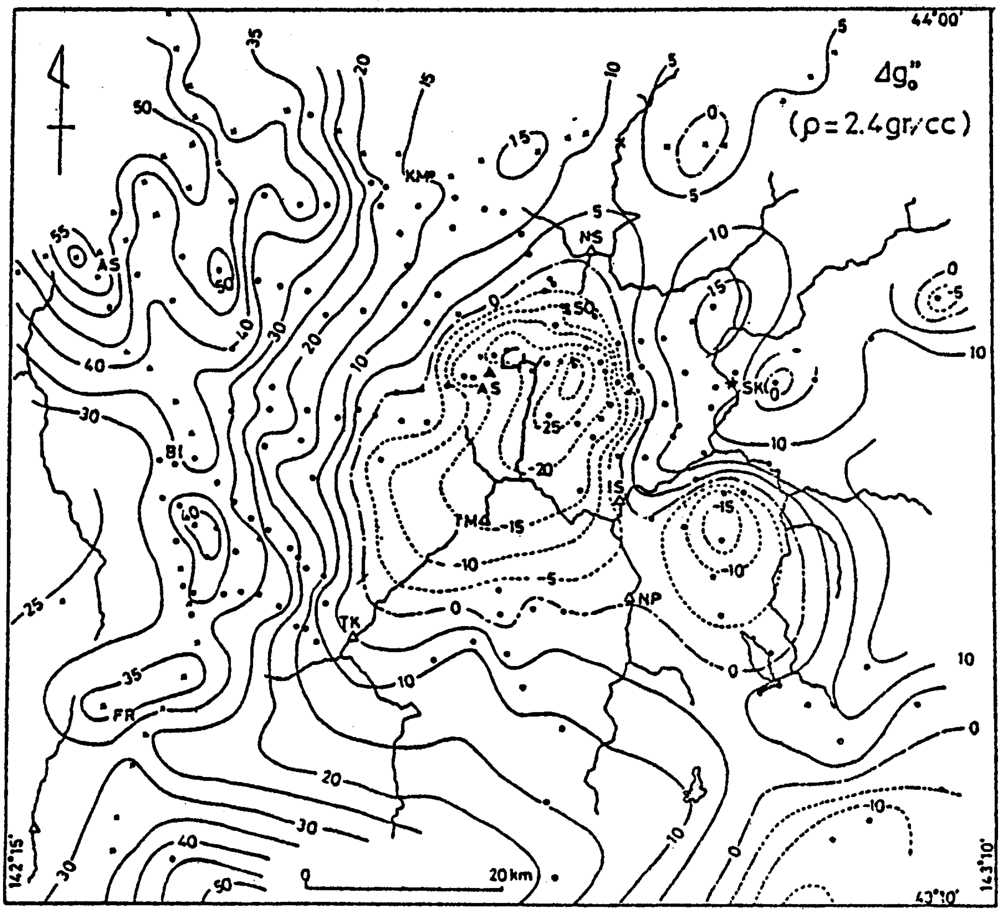
geological investigations (Konoya et al., 1966, 1968; Katsui et al., 1979a).

The history of North Taisetsu Volcano may be divided into 4 stages. In the first stage, a compound volcano(having multiple summits) composed of andesitic lava flows and scoriaceous pyroclastics may have been built. Sequently the cone have been deeply dissected by erosion, forming peaks of Nagayamadake, Pippudake, Aibetsudake and the lava flows on the northern part of Takanegahara.

Ryoundake and Kurodake are lava cones or domes, formed at the end of the first stage.

Lava flows of Eboshidake and Akadake in the second stage have covered the slopes of the cones of the first stage. The lava flows with considerably fresh levees and wrinkles on the surfaces look younger than those of Kurodake and Ryoundake.

In the third stage pumice flows and falls were erupted from the center of the volcano about 30,000 years ago (Katsui and Ito, 1976), resulting in formation of Ohachidaira caldera. The pumice flows named Ohachidaira pumice flows(Katsui and Ito, 1976) or Sounkyo Welded Tuffs, rushed down along the slopes. The pumice flows flowing dowm on the northeastern slopes buried the



(Fig. 18)
Distribution of Bouguer gravity anormalies on and around the Taisetsu-Tokachi volcanic region. Unit is mgal(Katsui et al 1979).

AS: Asahidake
NS: Niseikaushuppe
TM: Tomuraushidake
TK: Tokachidake
IS: Ishikaridake
NP: Nipesotsu
BI: Biei
FR: Furano
KM: Kamikawa
SO: Sounkyo
SK: Sekihoku Pass

valley of the ancient Ishikari River, resulting in formation of the ancient Lake Taisetsu by damming up the river water in the place which nearly coincide with the present Lake Taisetsu, a dammed lake.

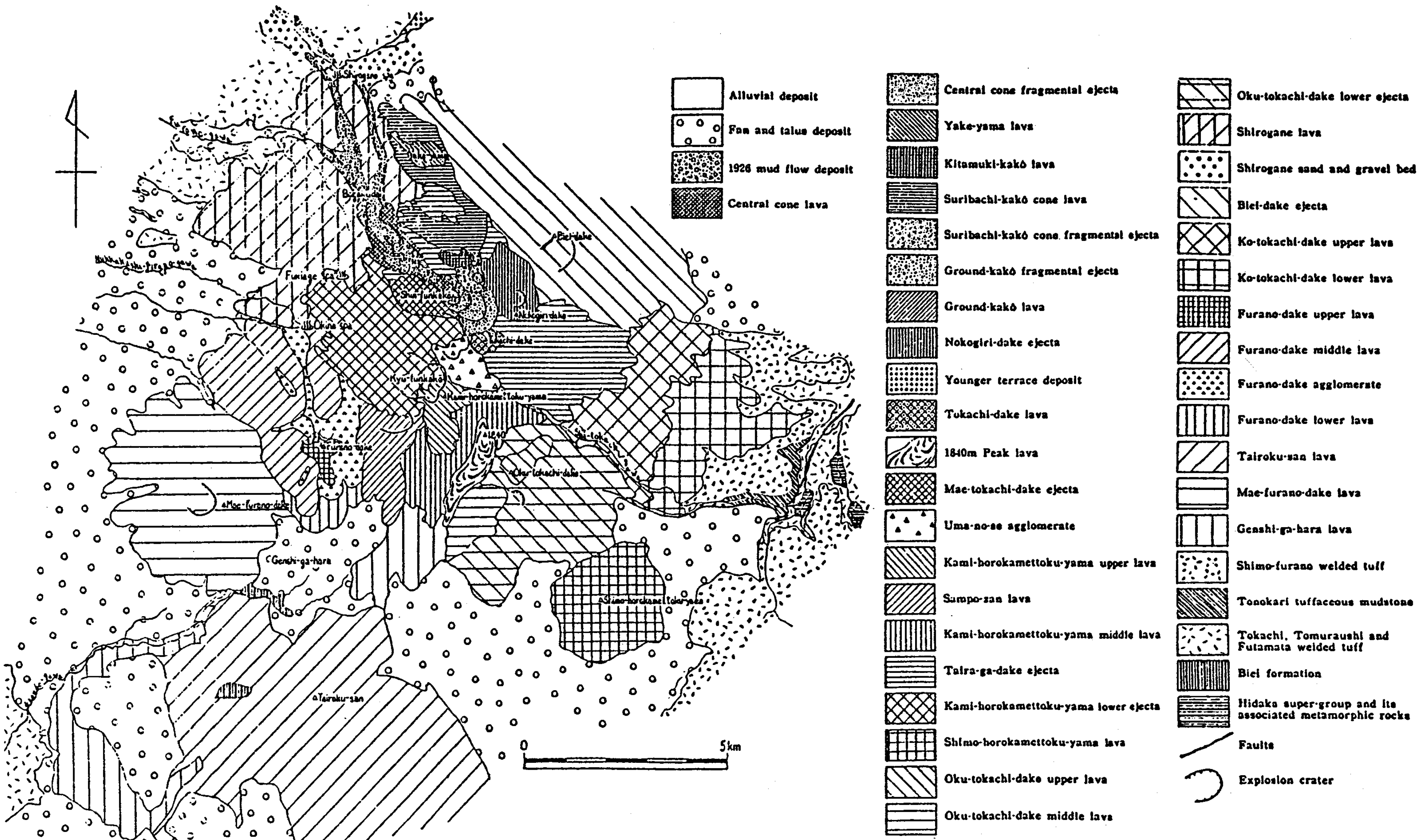
In the uppermost drainage basin of the Ishikari River, terraces composed of lacustrine deposits including pumiceous sand and fragments derived from Ohachidaira pumice flow deposit, are extensively distributed at the height of about 900 m above the sea level, which is approximately equal to the maximum height of the surface of Ohachidaira pumice flow deposit having buried the valley of the Ishikari River. Subsequently the surface of the pumice flow deposit in the valley has been rapidly and deeply dissected by erosion of the Ishikari River to form Sounkyo - a big gorge with vertical walls, 200-350 m high and composed of Sounkyo Welded Tuffs(Ohachidaira pumice flow deposit) with columnar joins.

An excellent exposure of a contact unconformity between the basement and the pumice flow deposit is observed along the road-cut at Kobako gorge. Here the lowermost part of the pumice flow, directly in contact with basement of folded slate formation, is represented by aggregates of loose pumice blocks, which are gradually changed into weakly welded, and finally highly welded tuff with distinct columnar joints with increase of the height from the unconformity(Fig. 37).

In the fourth stage small composite cones or lava cones (Asahidake, Ushiro-Asahidake and Kumagatake) and Mikurazawa lava flows have been formed around Ohachidaira caldera.

Asahidake composite cone are mainly composed of lava flows, showing stepped slopes by piling of thick lava flows where the landforms of lava levees and wrinkles are well preserved. On the upper slope of the cone there is a horseshoe-shaped crater opening westward. The crater has a row of about 20 small explosion pits extending in E-W for a distance of 1.5 km. The pits may have opened 500-600 years ago (Katsui et al., 1979a).

The products in the first stage are composed of olivine-pyroxene, pyroxene, hornblende-pyroxene andesite(SiO_2 55-56%). In the second and third stages the products have changed into fairly acidic (hornblende-pyroxene andesite, SiO_2 60-64%). In the forth stage, content of SiO_2 decreased again to 54-47% and olivine phenocrysts came to be recognized, indicating that the magmas became mafic again.



(Fig.19) Geologic map of Tokachi Volcano (Takahashi, 1965)

On the summit of Taisetsu Volcano patterned grounds are found (Koaze, 1965). Polygons are well-developed on Hokkaidaira, a gently doming peak where a permafrost layer has been found at the depth of 2-14 m (Fukuda & Kinoshita, 1974).

b) South Taisetsu Volcano

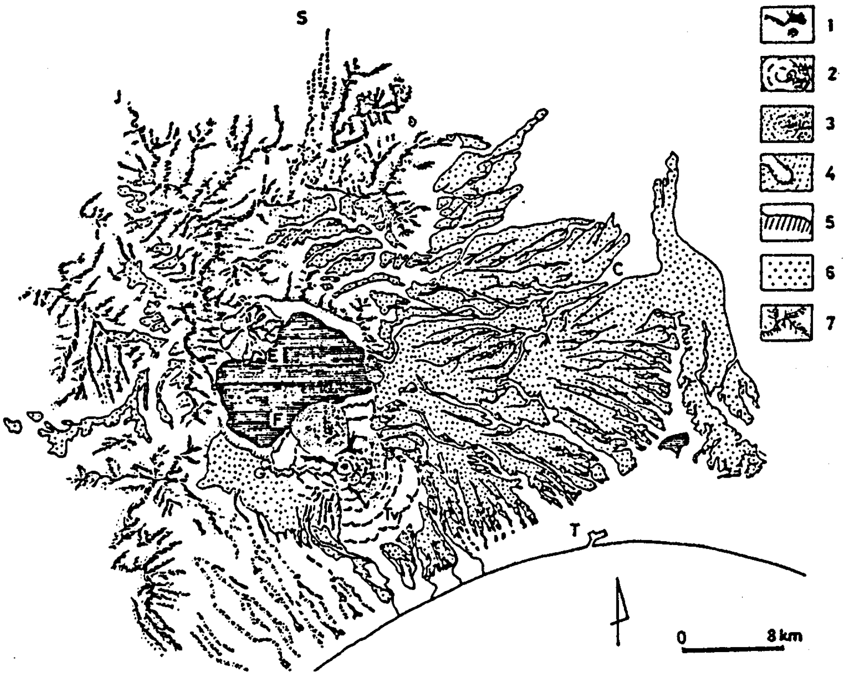
South Taisetsu Volcano are mainly composed of more than 3 sheets of lava flows(olivine-bearing pyroxene andesite). The lava flows may have once formed a large cone volcano. But now the upper part of the cone has been eroded out while the lower slopes survive.

On the southern lower slope of the older large cone, rises a lava cone called Tomuraushidake. It is 300 m in specific height and 2 km^3 in volume and composed of hornblende-pyroxene andesite. Some small fault scarps cut the lava cone. They may have been formed by sliding down of the southeastern half of the lava cone because of having stood just on the head scarp of a landslide.

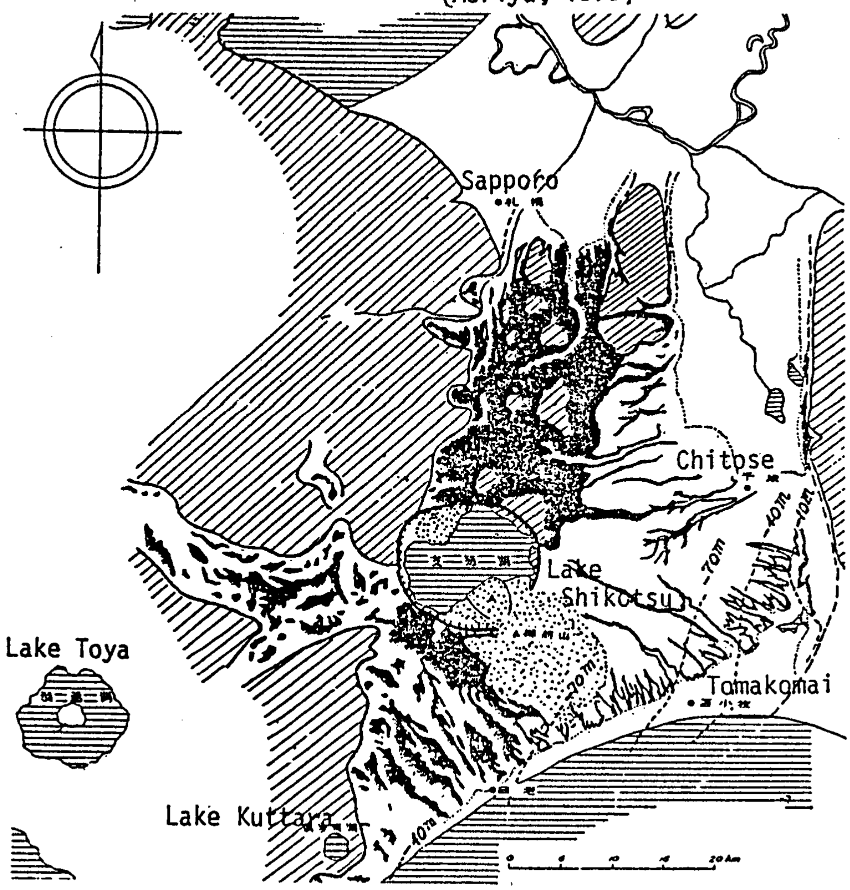
(4) Tokachi Volcano

Tokachi Volcano is a volcanic chain of 11 medium-size cones (Furanodake, Horokamettoku, Tokachidake, Bieidake etc.) arranging about 20 km long in the direction of NE-SW, situated at the region about 35 km southeast from Asahikawa City, central Hokkaido. The tops of the cones are 1,800-2,000 m above sea level and their specific height are about 1,000 m. The cones stand on the extensive plateaus of Tokachi Welded Tuffs. The cones are composed of pyroxene-olivine basalt - andesite lava flows and scoriaceous pyroclastics (Katsui et al., 1963; Takahashi, 1965; Fig. 19). They preserve the initial volcanic landforms. The activities of this volcano may have begun in the late Pleistocene.

The recent activities have occurred on Tokachidake at the center of the volcanic chain. In 1926 a "hot volcanic avalanche" (Tada & Tsuya, 1927) occurred, followed by destruction of a pyroclastic cone on the northwestern slope of Tokachidake, as a result of an explosion. It attacked a mine 2 km northwest from the crater and killed 26 persons within a minute. Then the hot volcanic avalanche changed itself into a cold lahar by melting the snow on the slopes and rushed down through two valleys to strike the towns of Furano and Biei 25 km northwest from the crater. 144 persons were eventually



(Fig. 20) Geomorphological map of Shikotsu Volcano
1. Lava dome and scoria flow surfaces of Tarumai Volcano. 2. Pumice flow surfaces of Tarumai Volcano 3. Fuppushi Volcano 4. Lava flows and pyroclastic flow surfaces of Eniwa Volcano 5. Caldera wall of Shikotsu Volcano 6. Pumice flow surfaces of Shikotsu Volcano 7. Mountain slopes. C: Chitose City E: Eniwa Volcano F: Fuppushi Volcano J: Jozankei Spa S: Sapporo City T: Tomakomai City Tv: Tarumai Volcano. (Moriya, 1979)



(Fig.21) Distribution of Shikotsu pumice flow deposit (Doi, 1959) killed by this eruption.

In 1962 volcanic activities took place again near the 1926 crater. Eruptive columns rose up to about 12,000 m high. Scoria bombs and blocks of older lavas fell down near the crater to kill 5 miners. Fine ashes were thrown high into the atmosphere to be distributed by wind over broad eastern areas of this volcano and did some damage to crops (Katsui et al., 1975).

(5) Shikotsu Volcano

On air planes we can see this volcano in the west side of our flight course near Chitose (Sapporo) air port. The volcano situated about 20 km west from Chitose air port and 27 km south from Sapporo, is composed of Shikotsu caldera, pyroclastic flow plateaus, and 3 post-caldera volcanoes (Eniwa, Fuppushi and Tarumai Volcanoes, Fig. 20).

a) Pyroclastic Flow Plateau

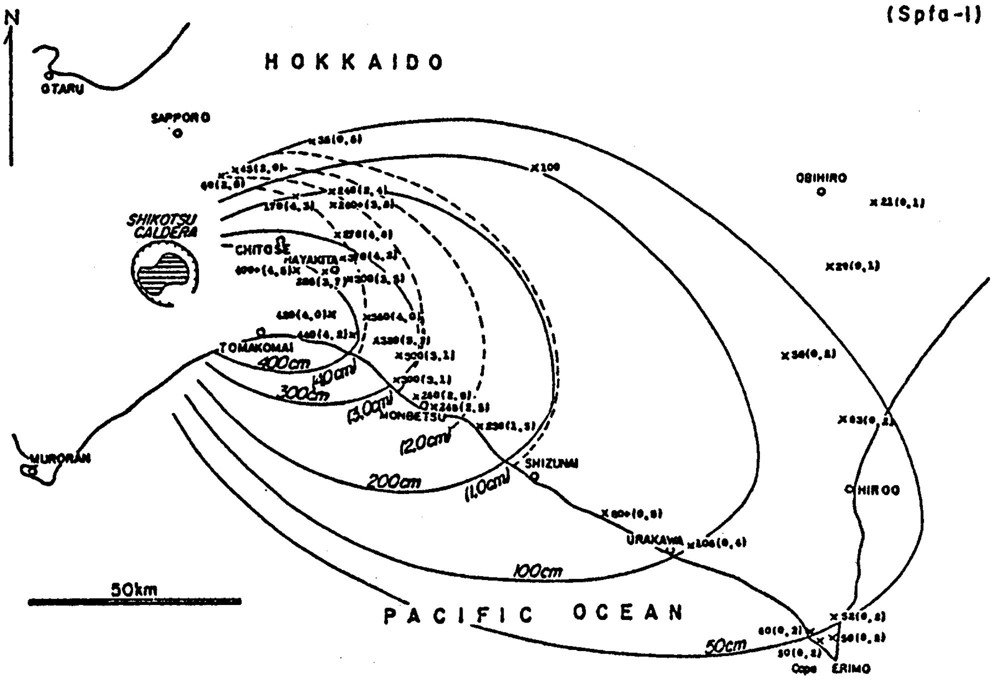
About 30,000 years ago a large quantity of pumice flows (120 km^3 in volume, hornblende-pyroxene dacite, SiO_2 69% in average) were violently issued out, penetrating the mountains composed of shale, tuffs of Miocene, and pyroxene andesite lava flows and tuff breccias of Pliocene (Katsui, 1959). The pumice flows have reached to the areas several ten km distant from the volcanic center(Fig. 21). In the southern part of Sapporo, for example, Makomanai where Olympic games were held in the winter of 1972, the pumice flow deposits have formed pyroclastic flow plateaus and hills.

The flat and extensive plateaus around Chitose air port are composed of the pumice flow deposits, too. Just before the eruptions of the flows, a voluminous pumice air fall deposit covered thickly the eastern areas. At Bibi 7 km south from Chitose air port, completely carbonized standing trunks and horizontally stretching branches of pine trees buried by pumice have been found on the outcrops of the pumice fall layer(Fig. 22,23).

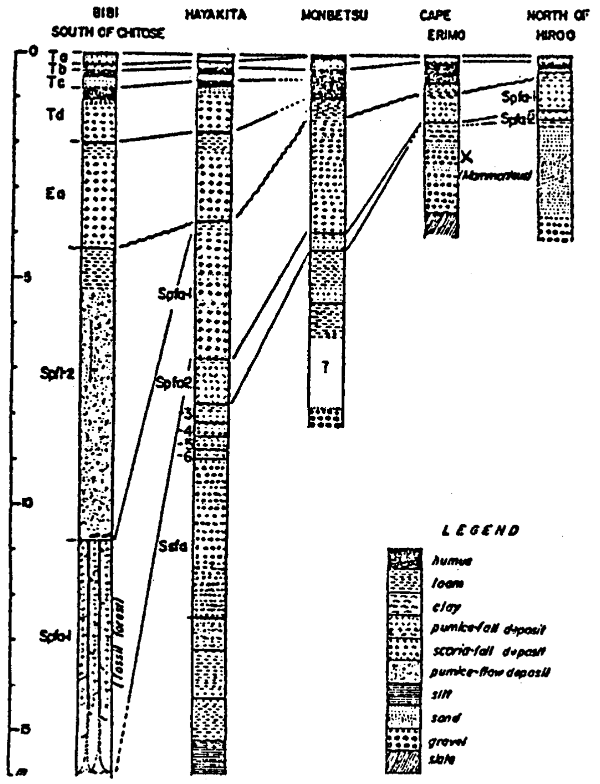
b) Shikotsu Caldera

Shikotsu caldera, 13-15 km across and 300 m deep, may have been formed just after the eruptions of Shikotsu pumice flows. The caldera walls are fairly well preserved, but they have been covered by the eruptive materials of Tarumai Volcano in the southern part.

At the caldera bottom, Lake Shikotsu is present. It is gourd-shaped in plan and 360 m deep. Within and around the caldera, 3 post-caldera volcanoes stand.



(Fig.22) Distribution of Shikotsu pumice fall deposit (Katsui, 1959)



(Fig.23) Columnar sections of the tephras of Shikotsu Volcano (Katsui, 1959)

c) Fuppushi Volcano

This is a small cone volcano(5 km^3 in volume, 850 m above the lake level) composed of pyroxene andesite lava flows and pyroclastics. It is the oldest of 3 post-caldera volcanoes, because many deep valleys have been formed on the sloped by erosion. It is assumed that the volcano may have been active nearly 20,000 years ago.

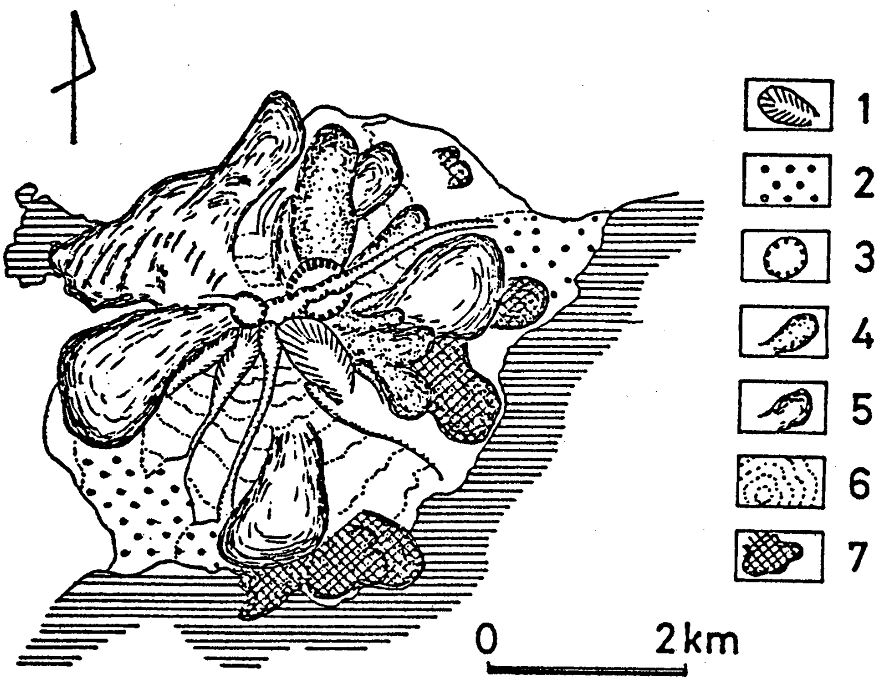
d) Eniwa Volcano

This is a small cone volcano, 1,319 m above sea level, and 5 km^3 in volume. The volcano has been built up by piling of more than 16 thick lava tongues of pyroxene andesite (SiO_2 58-60%, Fig. 24). At the early stage Eniwa pumice fall(En-a) was erupted about 13,000 years ago. The pumice fall deposit(pyroxene andesite, SiO_2 64%) is found in thickness of less than 40 cm in Tokachi Plain.

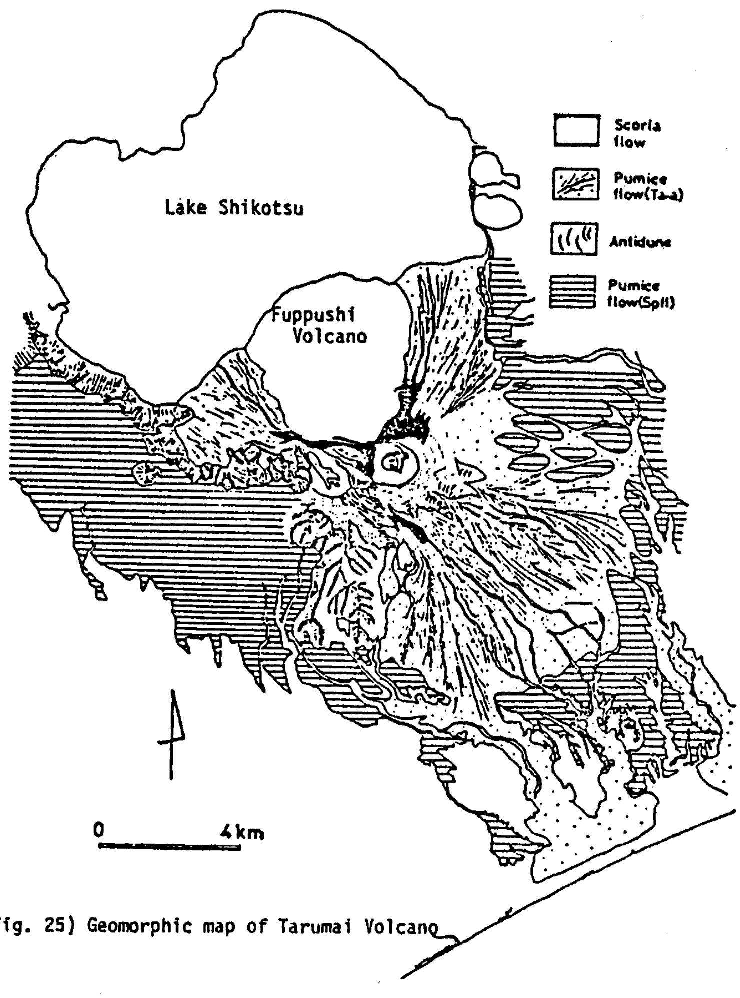
e) Tarumai Volcano

This is a large pumice cone volcano rising on the southern rim of Shikotsu caldera (Soya, 1972). It has grown up by repetition of pumice eruptions of 4 cycles probably 8,900, 1,500-3,000, 300-500 and 200-300 years ago. Of the eruptive materials, pumice flow deposits have mainly made up the cone. The pumice fall deposits have been extensively distributed in the eastern area, and are called Ta-a , b, c and d. The tephra layers are found even in Tokachi Plain, 170 km east from the volcano. The pumice fall and flow deposits are pyroxene andesite (SiO_2 58%). There is a small caldera 1.2 km across on the summit. It may have been formed by the eruption of Ta-a pumice. Most of the slopes of the volcano have been covered by the surfaces of Ta-a pumice flow deposit with minor radial ridges about 10 m high. On the upper slopes, dunes less than 10 m high and several hundred meters long are found around the summit. The dunes may have been formed by base surges(Fig. 25).

A dome has extruded at the center of the small caldera in 1909. The lava swelled horizontally and its summit has become flat. Such a lava dome was also present formerly, but it was later destroyed by the eruption of scoria flows in 1874(Ishikawa et al., 1972). This history may suggest that a similar destructive activity may occur in some recent future. This volcano erupted 26 times between 1917-1955 though on small scale. In 1978-79 small-scale explosions occurred at a fissure on the southern flank of the



(Fig.24) Geomorphic map of Eniwa Volcano.   1. Eroded crater
2. Volcanic fan   3. Crater   4. Lava flow III   5. Lava flow II
6. Surface of small-scale pyroclastic flows   7. Lava flow I



(Fig. 25) Geomorphic map of Tarumai Volcano lava dome (Katsui et al., 1979b).

(6) Toya Volcano

This is a large caldera volcano with a small cone volcano - Usu Volcano which erupted in 1977-1978. It is situated at the area 70 km southwest from Sapporo. Every year about 1,000,000 persons visit the resort with many sightseeing spots - Usu Volcano, Showa - Shinzan, Lake Toya, etc.

The volcano consists of Toya caldera, extensive plateaus of Toya pumice flow deposits and 2 post-caldera volcanoes - Usu and Nakanoshima Volcanoes (Fig. 26).

a) Toya Caldera

This is a roughly round caldera 10 km across formed in the low mountains composed of green tuffs of Miocene, andesite lavas of Pliocene and welded tuffs of Plio-Pleistocene. The caldera walls are well preserved and Lake Toya have been formed within the caldera. At the center of the lake, Nakanoshima - the upper part of Nakanoshima Volcano - is present.

b) Plateaus of Toya Pumice Flow Deposits

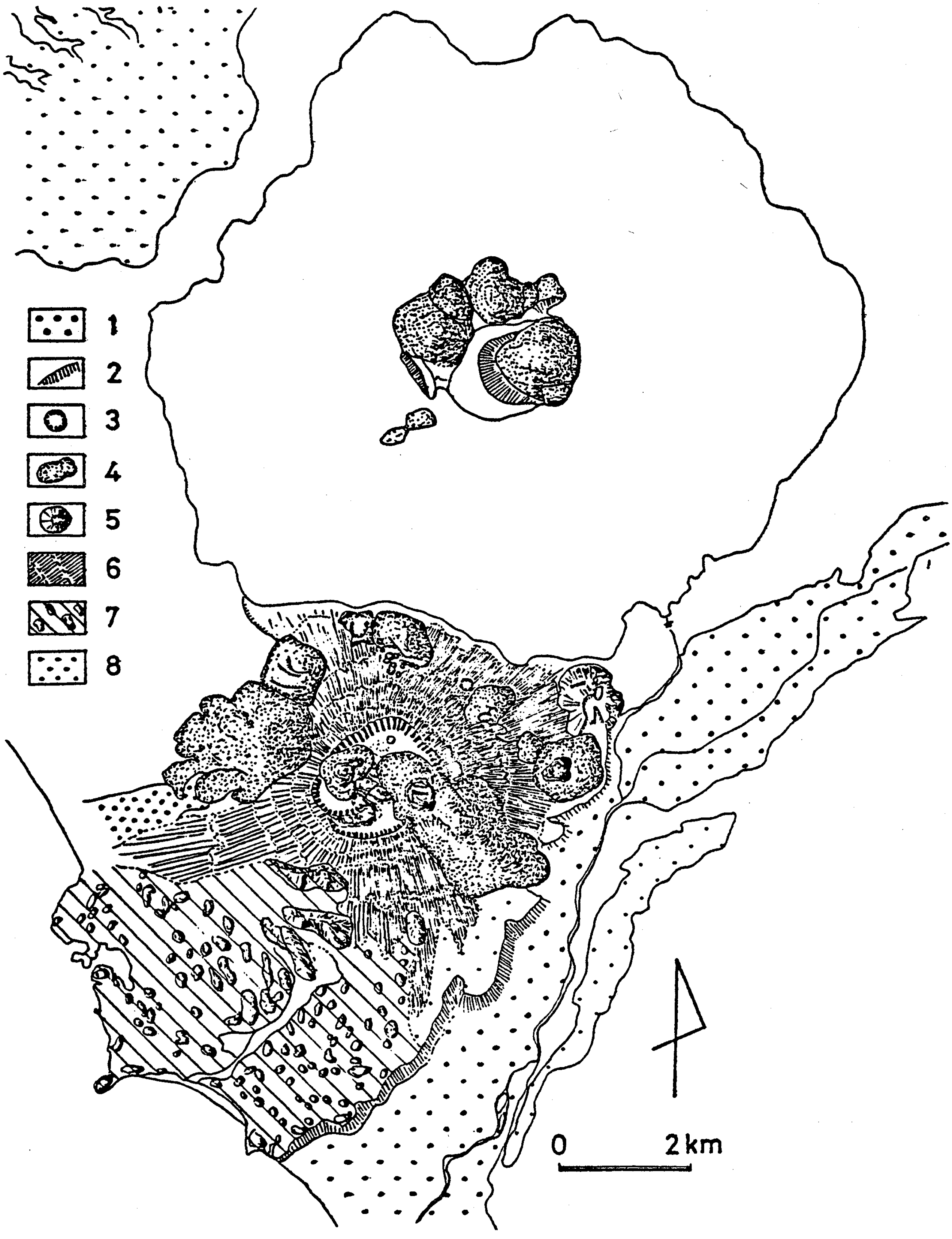
The pumice flow deposits are distributed mainly in the north and northwest of the caldera, forming the plateaus where potatoes and asparagus are cultivated, and some of them are also extended east and west. Most of the deposits southward have probably been immersed in the sea. Some of the eastward extension may have cleared a barrier - Orofure Pass 994 m above sea level to form plateaus near Noboribetsu spa. So the volume of the deposits may reach more than 100 km^3, although the volume has hitherto been estimated only at more than 20 km^3. The pumice flow deposits have 5 flow units and are of pyroxene dacite. The youngest of them may have been erupted 15,000 years ago(Yokoyama et al., 1973).

c) Nakanoshima Volcano

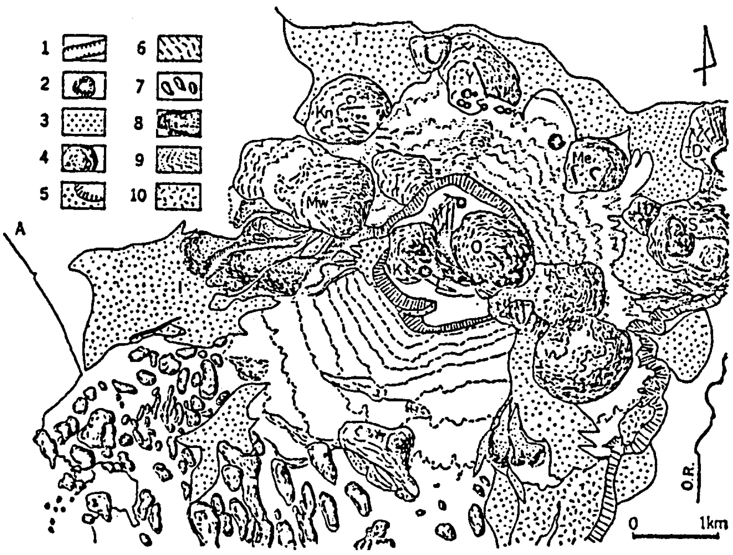
Nakanoshima in the center of Lake Toya is a crowd of 5-6 lava domes(454 m above sea level, hornblende-pyroxene dacite). The ages of the activities are not evident.

d) Usu Volcano

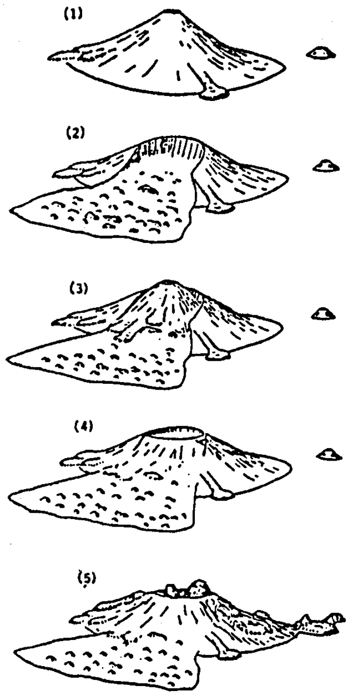
This is a small cone volcano with a small caldera 1.8 km across and 9 lava domes and cryptodomes formed at the southern rim of Toya caldera(Fig. 27). The main cone composed of olivine-pyroxene basalt and andesite lava flows and scoriaceous pyroclastics showed formerly a typical cone-shaped volcano.



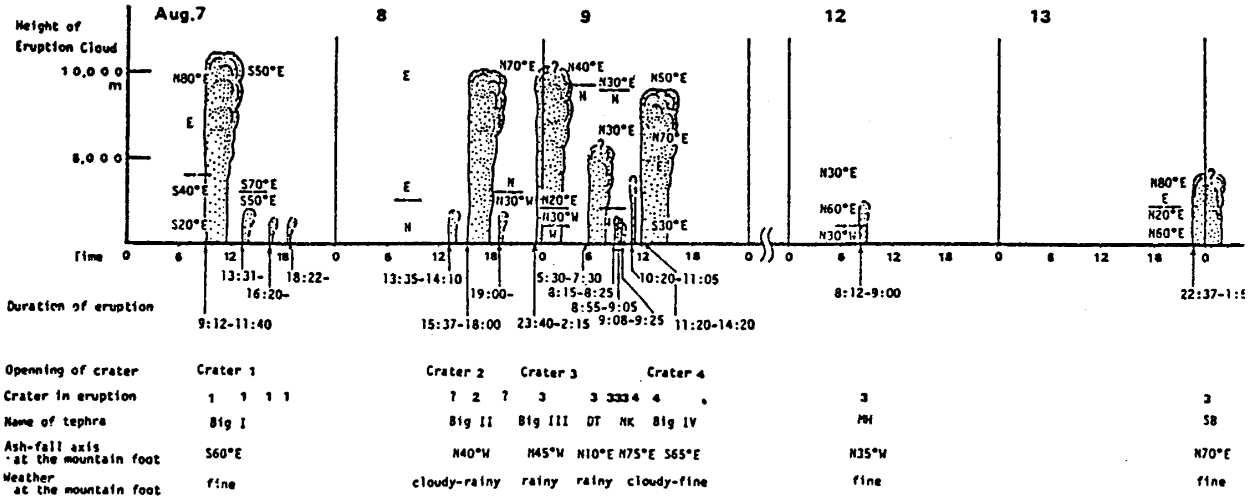
(Fig.26) Geomorphic map of Toya Volcano 1. Fluvial plain 2. Scarp 3. Crater and caldera 4. Lava dome and crypto dome 5. Scoria cone 6. Surface of main cone 7. Surface of dry avalanche deposit with flow mounds 8. Surface of Toya pumice flows



(Fig. 27) Geomorphic map of Usu Volcano
1. Fault 2. Explosion crater 3. Volcanic fan 4. Lava dome or crypto dome 5. Pyroclastic cone 6. Surface II of main cone 7. Surface of debreis flow deposit with flow mounds 8. Surface of somma lava flows 9. Surface I of main cone 10. Surface of Toya pumice flow A: Abuta D: Donkoroyama I: Izumi K: Ko-Usudake Kn: Konpirayama Me: Higashi-Maruyama Mw: Nishi-Maruyama O: O-Usudake OR: Osaru River S: Showa-shinzan T: Toyako-spa Y: Yosomiyama (Moriya, 1978)



(Fig.28) Geomorphological development of Usu Volcano. Oblique view southeastward. (Moriya,1978)



(Fig.29) Sequence of the eruption of Usu Volcano in August, 1977. Direction of wind expressed by leeward at the Sapporo Station of the Japan Meteorological Agency.

(Katsui et al., 1978)

Before several thousand years, the upper part of the cone was suddenly destroyed by Bandaian eruption. The debris rushed down on the southern lower slope into the sea. The deposits of the dry avalanche are found in the southern foot to form numerous flow mounds several ten meters high. The destruction of the upper part of the volcano probably resembles that of St. Helens Volcano in the Cascade of USA at 8;32 May 18, 1980. At that time, a horseshoe-shaped caldera was presumably formed on the summit, but it was buried by the formation of a younger cone. Subsequently a small caldera was formed again in the summit. In 1663 a great eruption of rhyolitic pumice (Us-b, 2.2 km^3 in volume, SiO_2 73%) occurred perhaps to form the small caldera in the summit. After that, great eruptions due to the same magma took place in 1769, 1822, 1853, 1910, 1943-45 and 1977-78. By the eruptions, 9 lava domes and cryptodomes may have been formed sometimes, accompanied with eruption of small-scale nuées ardentes and fine ash falls (Fig. 28).

i) O-Usu Lava Dome

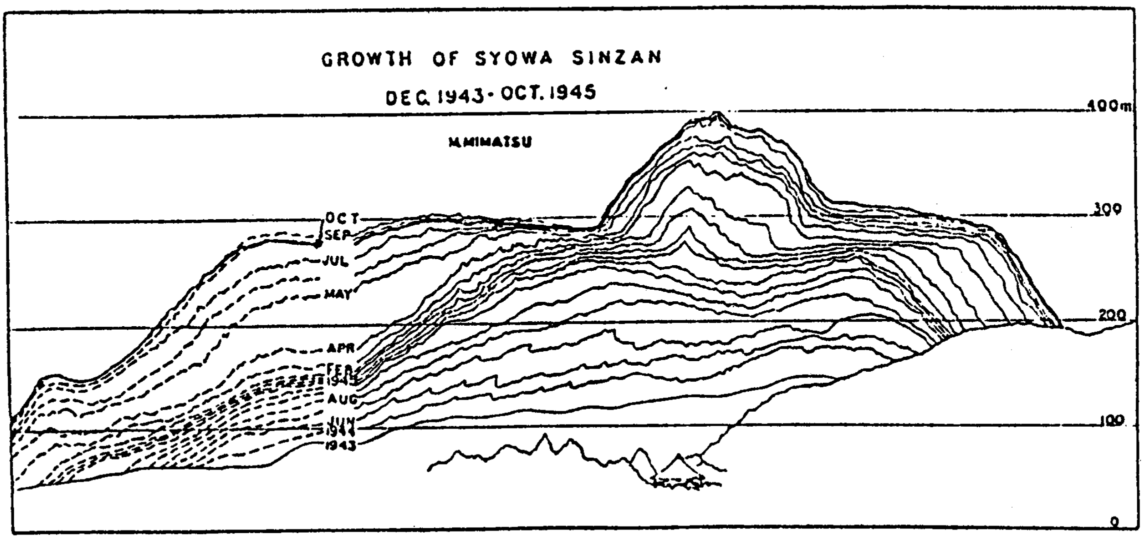
Within the small caldera on the summit O-Usu lava dome extruded probably in 1853. The specific height is about 300 m and the diameter is 700 m. They increased by the dislocation associated with the activities in 1977-78. Before the formation of the lava dome, a nuée ardente may have issued out of the vent where O-Usu dome extruded. A rampart which appears to be a part of a pyroclastic cone is found at the base of O-Usu dome. It may have been formed by explosive eruptions before the dome formation.

ii) Yosomiyama Cryptodome

In 1910 some fissures were formed on the northern foot of Usu Volcano in the direction of E-W. From the fissures volcanic ash and mud flows were erupted to form more than 100 small explosion craters. The ground about 1 km southeast from Toyako-spa town was swelled to form Yosomiyama about 150 m in specific height within 4 months, though a new lava did not appear on the surface.

iii) Showa-Shinzan Lava Dome

The 1943-45 activity of Usu Volcano began with severe earthquakes at the northern foot of the volcano, and ended with formation of Showa-Shinzan, a new parasitic lava dome on the eastern foot(Minakami et al. 1951). It may be conveniently divided into the following three stages(Ishikawa, 1950).



(Fig. 38) Growth of Showa Shinzan

(1) Pre-eruption stage: 28 December 1943 to 22 June 1944.

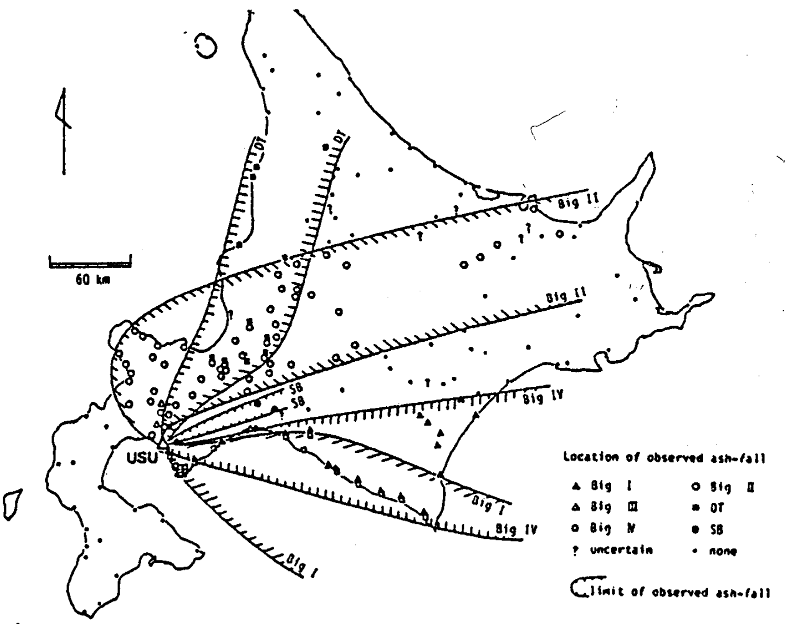
(2) Paroxysmal eruption stage: 23 June to 31 October 1944.

(3) Dome building stage: 1 November 1944 to September 1945.

At the end of the first stage the ground to the east of the volcano was upheaved about 50 m, and on 23 June first eruption occurred on the top of this upheaved part, and this was followed by many violent eruptions, forming plat form-shaped "Roof Mountain". In the third stage protrusion of solid juvenile magma formed a lava dome on the Roof Mountain, more than 300 m higher than the original ground. This lava dome was named Showa-Shinzan. The new lava is a hypersthene dacite, very similar to the lavas of O-Usu and Ko-Usu, representing the activity of the same magma(Yagi, 1953). M. Mimatsu, an old postmaster of nearby village constructed a diagram to illustrate the growth of the dome and Roof Mountain, based on his numerous precise sketches(Fig. 38) (Mimatsu, 1962).

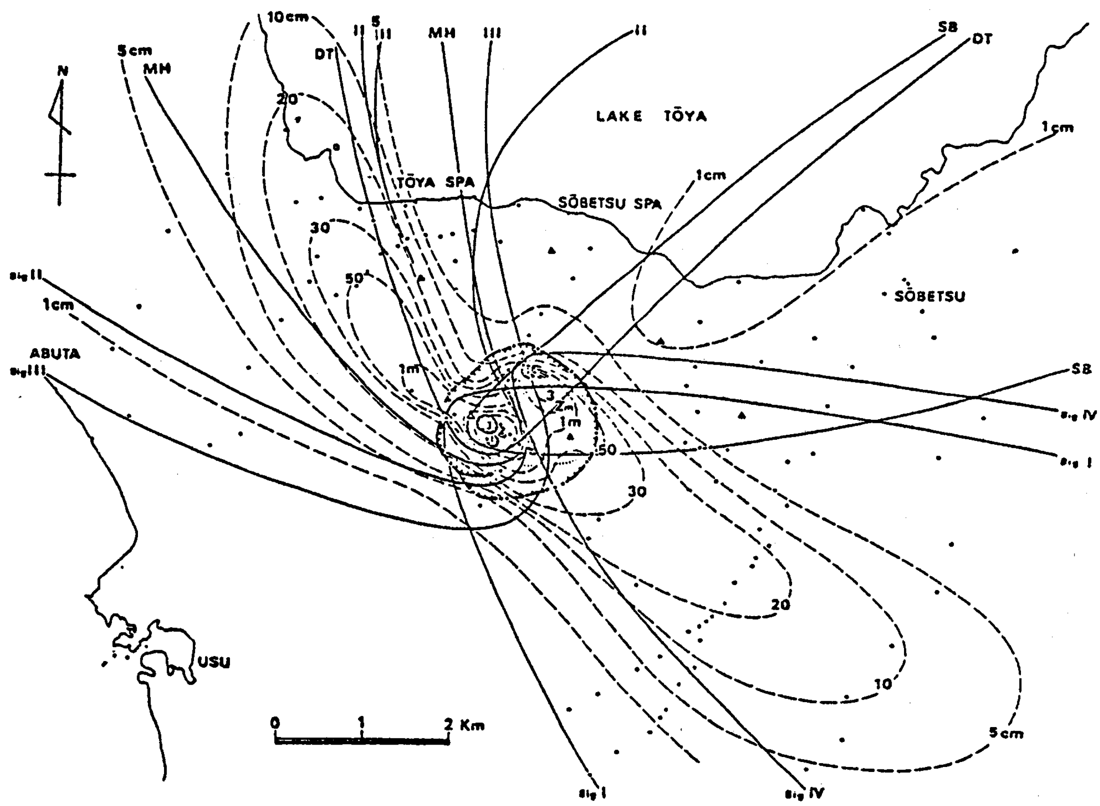
iv) Eruptions in 1977-78

The eruption began at 9;12 August 7, 1977, preceded by micro-earthquakes. The first eruption took place at the southeastern flank of Ko-Usu lava dome within the summit caldera. The eruption column rose vertically up to the height of 12,000 m. Within following week, 3 great pumice eruptions and 15-20 small-scale eruptions took place (Katsui et al., 1978, Fig. 29). As the result, ash and pumice air fall deposits covered extensive areas, giving great damages to crops, vegitation and human lives (Fig. 30). The volume of the ash and pumice has been estimated at 0.083km^3 (Katsui et al., 1978).



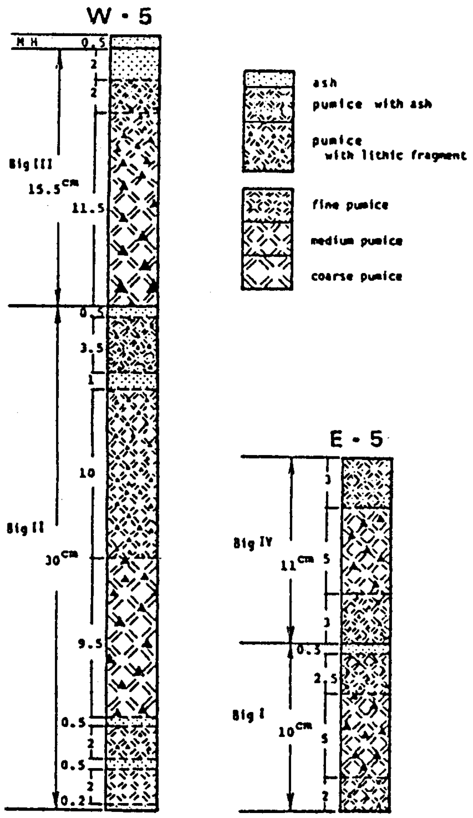
(Fig.30) Map showing the distribution of the ash-fall deposits from the eruption of the Usu Volcano in August, 1977. Data based on the report from town offices and fire-brigade stations in Hokkaido.

(Katsui et al., 1978)



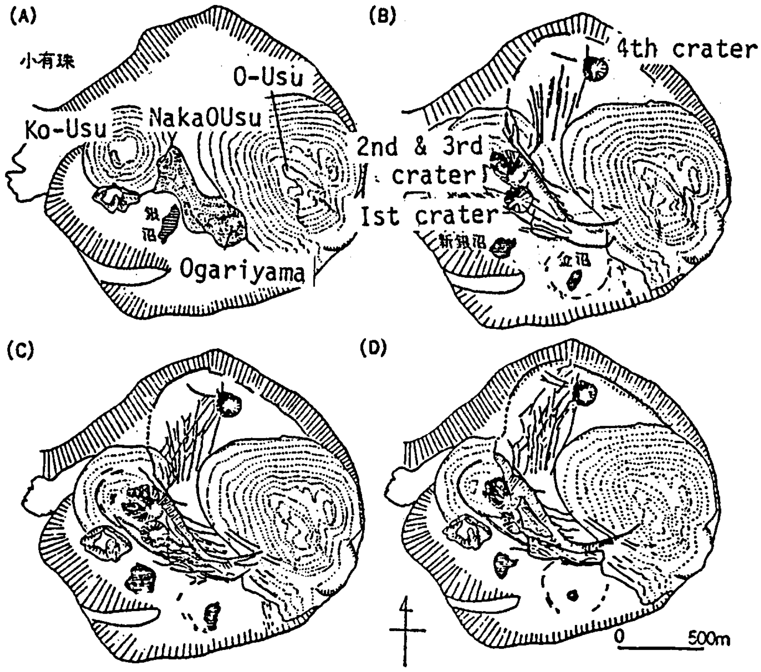
(Fig.31) Map showing the distribution of the 1977 pyroclastic fall deposits around the Usu Volcano. Dot: observed point, solid line: limit of each pyroclastic fall deposit, dashed line: cumulative thickness contour.

(Katsui et al., 1978)

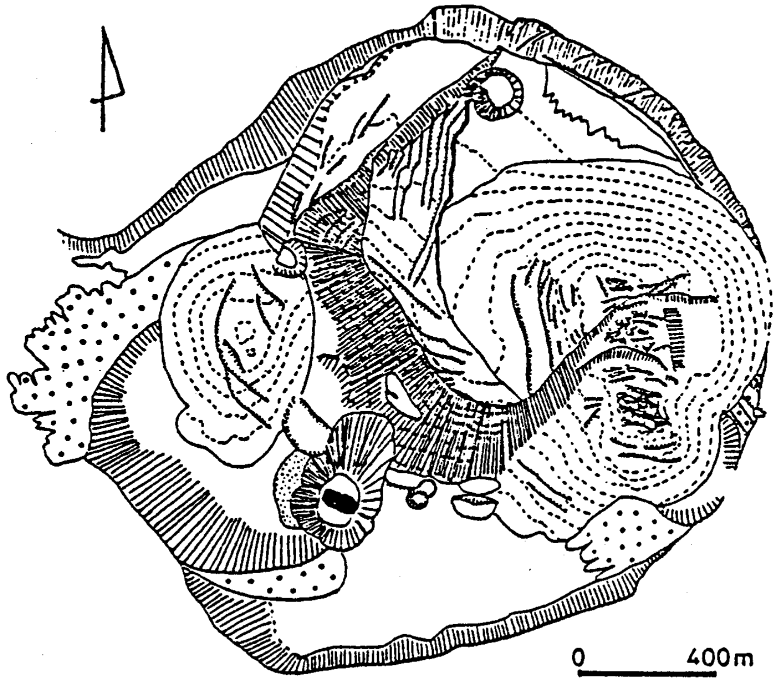


(Fig.32)

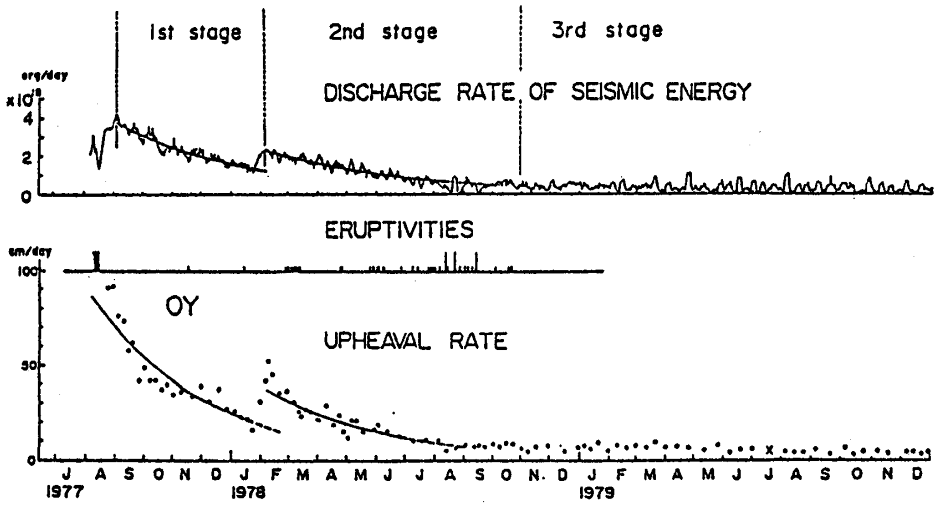
Standard columnar sections of the 1977 pyroclastic fall deposits of the Usu Volcano. Loc. E-5: O-daira, 3.5 km SE of the crater. Loc. W-5: Konomi-danchi, 2.5 km NW of the crater. (Katsui et al., 1978)



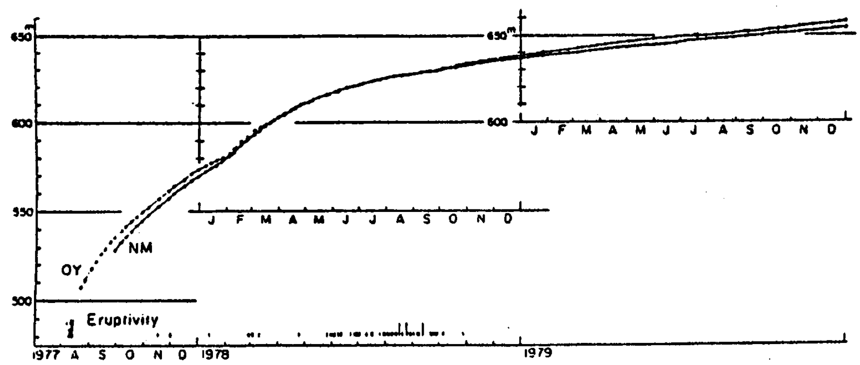
(Fig.33) Geomorphic changes within the summit caldera of Usu Volcano
A: December 1976 B: August 23, 1977 C: September 22-25, 1977
D: October 23, 1977 (Moriya, 1978)



(Fig. 34) Geomorphic map of the summit caldera of Usu Volcano on October 12, 1979.

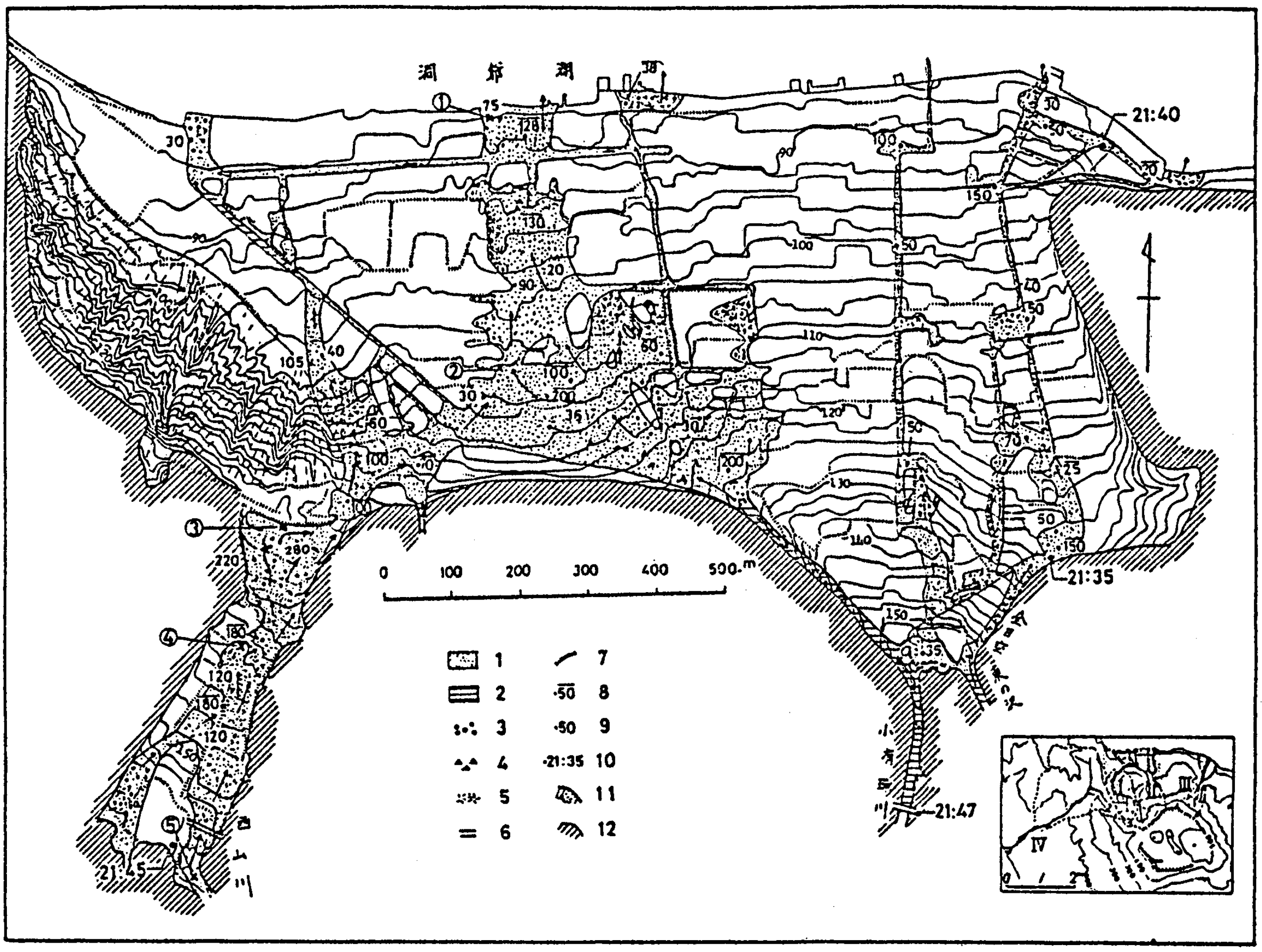


Discharge rate of seismic energy and up heaval rate of Naka-Usu crypto-dome. (after Yokoyama et al, 1981)



(Fig.35) Doming of Naka-Usu shinzan. OY: Ogariyama, a peak at the southeastern end of the ridge of Naka-Usu shinzan NM: New Mountain, a peak at the northwestern end of the ridge of Naka-Usu shinzan. A cross shows a small collapse of the summit. (after Yokoyama et al, 1981)

The thickness reached 3 m at the summit and 50 cm at the eastern foot (Fig. 31, 32). But none was fortunately killed by the eruptions because the eruptions occurred only at the summit and no nuée ardente has been erupted. Paralleled with the eruptions, deformation of the volcanoes on the summit occurred. Due to swelling of magma under the volcano, many fault scarps, grabens and flexture scarps have been formed in the summit caldera (Fig. 33, 34). Especially a ridge between Ko-Usu and O-Usu lava domes has rapidly been upheaved in rate of 90 cm/day at the early stage. Now the ridge has grown up to the specific height of 200 m, called Naka-Usu Shinzan, although the present upheaval rate is decreased to 2 cm/day (Yokoyama et al., 1981, Fig. 35). After the pause for 3 months, a series of phreatic explosions began in November. The activities gradually increased the forces and



(Fig.36) Distribution of the mud flows which attacked Toyako-spa town on October 24, 1978. (Kadomura et al., 1979) finally in June 1978 incandescent lavas appeared on the crater walls. In August and September 1978, some violent magmato-phreatic explosions took place, throwing out fine ash on the slopes and valleys. The explosions may be attributed to the contact of ground water with the upheaved highly viscous magma (Niida et al., 1980). Accumulation of the fine ashes with high content of water led to occurrence of heavy mud flows. On October 26, 1978, three persons were killed by the mud flows in Toyako-spa town (Kadomura et al., 1979, Fig. 36). More than 200 dams have been constructed in the radial valleys of Usu Volcano for prevention of disasters of the mud flows.

The northeastern part of somma has been horizontally displaced 180 m toward northeast, associated with the upheaval of Naka-Usu Shinzan. So the ridge of the somma which was formerly 35 degrees is now inclined 60 degrees toward northeast, resulting in falling and sliding of loose surficial materials composed of tephras. Now under this area 200 m deep earthquakes with a magnitude of less than 4.2 sometimes occur, displacing the somma toward northeast 30-40 cm every time. Therefore the people in the northeastern foot are now exposed to the danger of mud flows as the results of these earthquakes.

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