ON THE ARRANGEMENTS OF VOLCANOES IN THE YATSUGATAKE VOLCANIC CHAIN WITH SPECIAL REFERENCE TO THE BASEMENT

by

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(with 4 Tables and 5 Text-figures)

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Introduction

Distinct en echeron arrangements of volcanoes in the Yatsugatake volcanic chain (Fig. 1), Central Japan, has already been pointed out by the present author (1961), and also by KAWACHI, et al. (1967). In the former paper, many volcanoes locating in the Yatsugatake area, are divided into three parallel zones, convex to the northeast, and the general characteristic of the rocks and the mode of eruptions in each zone were described. After the formation order of these lava cones had been established (KAWACHI, et al. 1967), the authors pointed out that there are minor alignments of the lava cones in the northwest ~ southeast direction. Nowadays, en echeron arrangements of volcanoes observed in the Yatsugatake volcanic chain is known as one of the most remarkable ones in Japanese Islands. In the present article, the characteristics of the volcano-alignments in the Yatsugatake volcanic chain will be summarized based on the field data, and the nature of supposed basement of the volcanic chain will be estimated from the study of xenoliths found in the volcanic rocks.

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1. Geologic setting and the scale of the Yatsugatake volcanic chain.

The Yatsugatake volcanic chain is situated nearly in the centre of Japanese Islands, and is located at the crest of syntaxis structure of the basement rocks. Since younger volcanic materials cover this area, the relationships of many

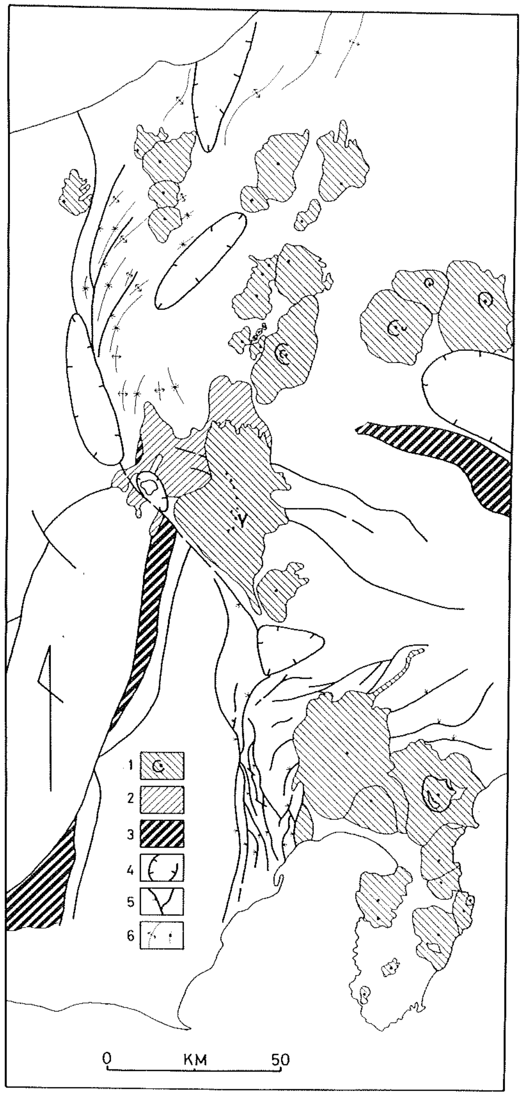

Fig. 1
Locality of the Yatsugatake volcanic chain.
1: Quaternary volcanic rocks, volcanic craters, and effusive centres.
2: Pliocene volcanic rocks of the Kirigamine-Yashigamine area.
3: Sanbagawa-type metamorphic rocks, mainly various crystalline schists.
4: Tectonic basins of Quaternary period.
5: Faults. (→; reverse faults).
6: Fold axis.
Y: Yatsugatake.

important tectonic lines of the basement, such as the Median Tectonic Line, the Fossa Magna Zone, and others, are not fully understood yet. The correlation of the geologic units of basement in both east and west side of the Yatsugatake volcanic chain is presented in Table 1.

Table 1. Correlation of basement geologic units.

Outerzone, SW Japan (typically from Shikoku Island)	Akaishi mountains	Kanto mountains
Ryoke metamorphic zone	Ryoke metamorphic zone	
(Median tectonic line)	(Median tectonic line)	
Sanbagawa metamorphic zone	Sanbagawa metamorphic zone	Sanbagawa metamorphic zone
(Mikabu tectonic zone)	(Mikabu tectonic zone)	(Mikabu tectonic zone)
Chichibu super group: Northern zone (Cretaceous sedimentary basins)	(lack)	Chichibu super group: Northern zone (Sanchu graben)
(Kurosegawa tectonic zone)		
Middle zone (partially lack)		Middle zone (?)
Southern zone	Chichibu s.g.: Todai zone, Koshibu zone	Southern zone
(Butsuzo-Itokawa tectonic zone)	(Kagarazawa tectonic line)	(Takaiwa- Shiroiwayama- Gozenyama tectonic line)
Shimanto super group	Shimanto super group: Akaishi zone, Shirane zone	Shimanto super group: Ogochi zone
	(Sawarajima tectonic line)	(Itsukaichi- Kawakami tectonic line)
	Oigawa zone, Mikura zone, Setogawa zone	Kobotoke zone
	Fossa Magna zone	Fossa Magna zone

The crest zone of the syntaxis is cut by the great traverse graben of Fossa Magna. The closest outcrops of the basement rocks are separated 7 km. by the Fossa Magna in the south of Mt. Yatsugatake. A left lateral offset by the Fossa Magna is estimated from the occurrences of Sanbagawa – type metamorphics in the northern end of Akaishi crystalline shist zone in the south and those in the north of Suwa – Lake (Figs. 1 and 2).

It is more likely that the basement of the Yatsugatake volcanoes is composed of the rocks of the Shimanto Zone, the Chichibu Zone, and the Fossa Magna Zone. Thus, the northern part of the Yatsugatake volcanic chain is laid on both Honshu unit and Shimanto unit.

The Yatsugatake volcanoes belong to the northern subzone of Fuji Volcanic Zone (Kuno, 1952). Since the Nasu and Chokai Volcanic Zones cross each other around the Yatsugatake volcanoes, many Quaternary volcanoes which belong to these three zones occur closely. Many of these Recent volcanoes in Central

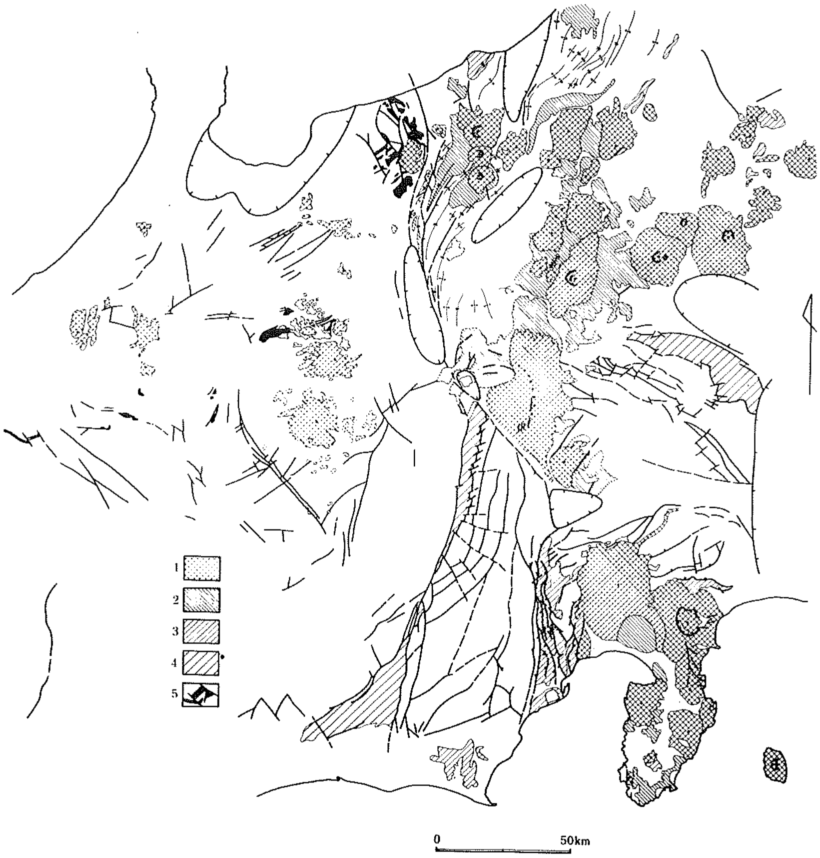

Fig. 2
Geotectonic map of Central Japan
1: Quarternary volcanic rocks.
2: Pliocene volcanic rocks.
3: Non-volcanic sediments of the Pliocene period.
4: Sanbagawa metamorphic rocks.
5: Ultrabasic rocks along the Hida Marginal Zone.
Other symbols are the same as those in Fig. 1. The position of Mt. Yatsugatake is known with reference to Fig. 1.

Japan accompany the volcanic rocks of Pliocene age in the basal part. These basal volcanics develop widely in the northwest extension of the Yatsugatake volcanic chain, forming a wide plateau of 1,500 – 2,000 m. a.s.l., such as the Kirigamine – Yashigamine volcanic areas.

The Yatsugatake volcanic chain consists of more than 20 cones with eruption centre in various size. These cones are arranged on a smooth arc, convexing toward the northeast, of 21 km. in length from Tateshinayama (2,530 m.) in the north to Amigasayama (2,524 m.) at the southern end. The highest cone is Akadake, 2,899 m. a.s.l. The exploded materials, except for the ash falls blown away, cover very wide area, i.e., about 1,900 km^2, 60 km. in north – south and 35 km. east – west direction. These materials distribute on the slopes of 2,500 m. attitude difference in the area mentioned above.

The oldest record of volcanic activity in the Yatsugatake volcanic chain is found in the earliest Pleistocene succession and is laterally grading into the Uriusaka group, the upper most group of the Komoro formation which includes the boundary between Pliocene and Pleistocene (IIJIMA, et al., 1956). Although no activity has been reported in the historical period, it is certain that the youngest eruption took place in the Recent period, judging from the vividly preserved surface grooves of the lava flows, the contrast of vegetation, and the hot spring of 52°C.

2. Outline of the history of formation and the arrangement of volcanoes.

The outline of the history of formation of the Yatsugatake volcanoes is illustrated in Table 2. Whole successive activities are divided into two periods; the Older period and the Younger period, separated by a distinct erosional gap. On the other hand, the area of Yatsugatake volcanic chain can be divided into two areas; the Southern area is composed of stratovolcanoes, consisting of mafic to intermediate andesites, while the Northern area is composed of stratovolcanoes and lava cones consisting of basalts, intermediate to salic andesites, obsidians, and rhyolites. The boundary between these two areas is located at the Natsuzawa pass around the middle of the volcanic chain.

Fig. 3 shows the distribution of erupted materials of the Older and Younger period respectively. The erupted materials from Older volcanoes develop widely from the northeast to south of the volcanic chain, while those of the Younger volcanoes occupy a wide area from the middle to north of the chain.

It is worthy to note that all these volcanoes are arranged in en echeron pattern, as shown in Fig. 4, making two main alignments; the Eastern and the Western alignment. The volcanoes of the Younger period make the third alignment overlapping on both ones.

The outline of history of formation of volcanoes in the whole area is described as follows, refering to Table 2.

I The Older period

I - 1). Formation of the stratovolcanoes along the Eastern alignment of the Northern area.

A large flat mass of stratovolcanoes of 1,000 m. high from the basement, 2,100 m. a.s.l., were formed by large scale Strombolian eruptions mainly of basalts and basaltic andesites.

I - 2). Formation of stratovolcanoes along the Eastern alignment of the Southern area.

The mode of eruption was Vulcanian, accompanied by some Strombolian activities of mafic to intermediate andesites. The Nirasaki - type pyroclastic flow was accompanied.* This is a special type of pyroclastic flow and was suggested to be intermediate type between lava flow and pyroclastic flow by the KOFU BASIN QUARTERNARY RESERCH GROUP (1969). A group of stratovolcanoes of 1,000 m high from the basement, with 2,400 m. high a.s.l., was formed by these activities.

II The Younger period

II - 1). Stratovolcanoes along the Eastern alignment of the Southern area.

These volcanoes are composed of some tens of rather thin lava flows of mafic to intermediate andesites by Vulcanian explosion. Strombolian eruptions are accompanied in the later stage. Welded tuffs are also produced.

Linear arrangement of volcanoes became distinct, and the centres of activity migrated toward the north gradationally. The highest peak Akadake was formed in this stage.

* ; The difinition and classification of pyroclastic flows are after ARAMAKI (1956).

Table 2. Outline of the formation history of the Yatsugatake volcanic chain.

		Western alignment	Eastern alignment
II Younger period	Northern area	II-6). Lava cones. Intermediate andesites. V(d $\rightarrow$ c). VI(d).	Southern area
		II-4). Lava cone with pyroclastic flows. Intermediate - mafic andesites. V(d). VI(d).	II-5). Stratovolcano. Intermediate andesite lavas, welded tuffs, mud-flows. V.
	Southern area	II-3). Two lava cones. Mafic andesites. V(d $\rightarrow$ c). Vd.	
	Northern area	II-2). Eruption of pyroclastic flows and thick lava flows with some lava cones. Intermediate - salic andesites, obsidians, rhyolites, various pyroclastic flows partially welded, mud-flows. V(d). VI(d). VI. XVI(d). XVI. X.	
	Southern area	II-1). Stratovolcanoes. Mafic - intermediate andesite lavas, scorias, agglutinates, agglomerates, welded tuffs. Va $\rightarrow$ c. Va $\rightarrow$ d. V(d). V.	
I Older period	Southern area	I-2). Stratovolcanoes. Intermediate - mafic andesite lavas, agglomerates, scorias, "Nirasaki-type pyroclastic flow". IVd $\rightarrow$ c. Va $\rightarrow$ c. Vd.	
	Northern area	I-1). Stratovolcanoes. Basalt - mafic andesite lavas, agglutinates, scorias. b. IIIb $\rightarrow$ c. IVb $\rightarrow$ c. IIIc. IVc. IVd $\rightarrow$ c. Vb $\rightarrow$ c. IId. IIId. IVd.	

The symboles of rock types are after Kuno (1950).

Fig. 3

Geologic outline around Yatsugatake

1: Alluvium.
2: Loam formations and gravel beds.
3: Talus deposits.
4: Effusive materials from the Younger Yatsugatake period.
5: Effusive materials from the Older Yatsugatake period.
6: Pliocene volcanic rocks.
7: Granitic rocks.
8: Diabases.
9: Rocks of the green tuff groups.
10: So-called Paleozoic and Mesozoic formations.
11: Sanbagawa metamorphic rocks.
12: Faults.
13: Volcanic craters and eruption centres.
14: Fixed points for the triangulation.

Alphabet symbols are the place names;

W: Wada-pass	K: Kurumayama	D: Daimon-pass
S: Suzuran-pass	T: Tateshinayama	O: Ohgawara-pass
M: Mugikusa-pass	N: Natsuzawa-pass	A: Akadake

II - 2). Eruptions of thick lava flows and various types of pyroclastic flows along the Western alignment of the Northern area.

The eruptions occurred along the middle of the Eastern and Western alignment. Most of these lava flows and pyroclastics, partially welded tuffs, are intermediate to salic andesites, obsidians, and rhyolites. Many mud flows were accompanied. The volcanism in this stage was very strong. Some lava cones of this stage were formed under the lava cones which construct the main ridge of the present volcanic chain. The centres of activity began to migrate toward the west.

II - 3). Formations of two lava cones in the Western alignment of the Southern area.

Main rocks are block lavas of mafic andesites.

II - 4). Lava cones in the Western alignment of the Northern area.

Intense volcanism with various types of pyroclastic flows and intermediate to mafic andesite lavas took place and the main ridge of the present day was constructed. En echeron shaped double alignments completed in this stage. The minor alignments (mentioned later) represented by the pair-arrangements of lava cones in the northwest – southeast direction were formed in this stage.

II - 5). Stratovolcanoes in the Eastern alignment of the Southern area.

Several andesite lavas and welded tuffs covered the rocks of II - 1) stage. A mud flow was accompanied. A hot spring with 52°C comes out from the crator bottom opening toward the northeast, even in the present days.

II - 6). Formation of lava cones in the Western alignment in the northern part of the Northern area.

Block lavas of viscous intermediate andesites erupted from 7 craters. The surface grooves of these lava flows have been preserved very well and one of them shows distinct contrast of vegetation from the others. The minor-alignments of lava cones, mentioned later, were eventually achieved in this stage.

Thus generally speaking, the volcanism began from the Eastern alignment of the Northern area in the Older period and formed large scale strato-volcanoes, then the centre of activity successively migrated to the Southern area and constructed again some stratovolcanoes there. After an erosion interval, the Younger period started in the formation of stratovolcanoes of the Eastern alignment in the Southern area and many lava cones were formed along the Western alignment of the Northern area. Two lava cones were formed in the Southern area along the Western alignment. Thus, the volcanoes of the Younger period occur both on the Eastern and Western alignment, presenting overlapped another alignment; the alignment of the Younger period.

From the view points of lithologic characteristics, basalts and intermediate andesites (pyroxene andesites) explored along the Eastern (frontal) alignment during the Older and the Younger period. On the other hand, rhyolites, obsidians, salic andesites (dacites and hornblende andesites), and basic andesites extruded along the Western (inner) alignment in the Younger period. Distinct double echelon arrangements of cones and volcanic rocks of different characteristics achieved in the Younger period. This type of arrangement (KAWACHI, 1961) is common in the scale of one volcanic zone (KUNO, 1952) and also in the scale of whole Japanese Islands (ISHIKAWA and KASTUI, 1959).

The Yatsugatake volcanic chain has various types of activity as mentioned above. The erupted materials from these volcanoes intercalate many non-volcanic sediments, such as gravel, sand, mud, and peat beds, around the foothill of the chain (KAWACHI, et al., 1969). Some plant fossils have been found from them. Thus, the Yatsugatake is one of the most important volcanoes in the Japanese Islands, because it has very complicated history of development including all problems of Quarternary geology.

The natures of arc shaped volcano-alignments in the Yatsugatake volcanic chain are summarized in Table 3. The Eastern alignment has the largest radius of curveture and the length of arc and the smallest angle at the arc. Those of the Western alignment are just opposite to the Eastern one. The volcano alignment of the Younger Yatsugatake period, mentioned above, has intermediate nature between the Eastern and the Western one.

Table 3. Natures of volcanic alignments

	Center of the arc*	Radius of curveture (km)	Angle at the arc	Length of the arc (km)	Width of the arc (km)
Eastern align.	6	20.0	55°	19.5	North: 6.0 Middle: 2.5 South: 1.5
Western align.	7	12.5	65°	14.3	
Align. of Younger period	8	17.8	62°	19.0	————

*See Fig. 4.
6: 2km north of Chino, Chino city. (This is roughly the same as the centre of volcano alignment of the Older period).
7: 1 km east of Kamibazawa, Chino city.
8: Funakubo, Chino city.
(The centre of gravity for these three points locates at Miyahara, Chino city).

Another important point on the distribution of volcanoes in this volcanic chain is "the minor alignments" of lava cones found in the Northern area in the Younger period (Fig. 4). The minor alignments are illustrated as joint lines connecting a pair of volcanoes in the N 60° ~ 70° W direction.

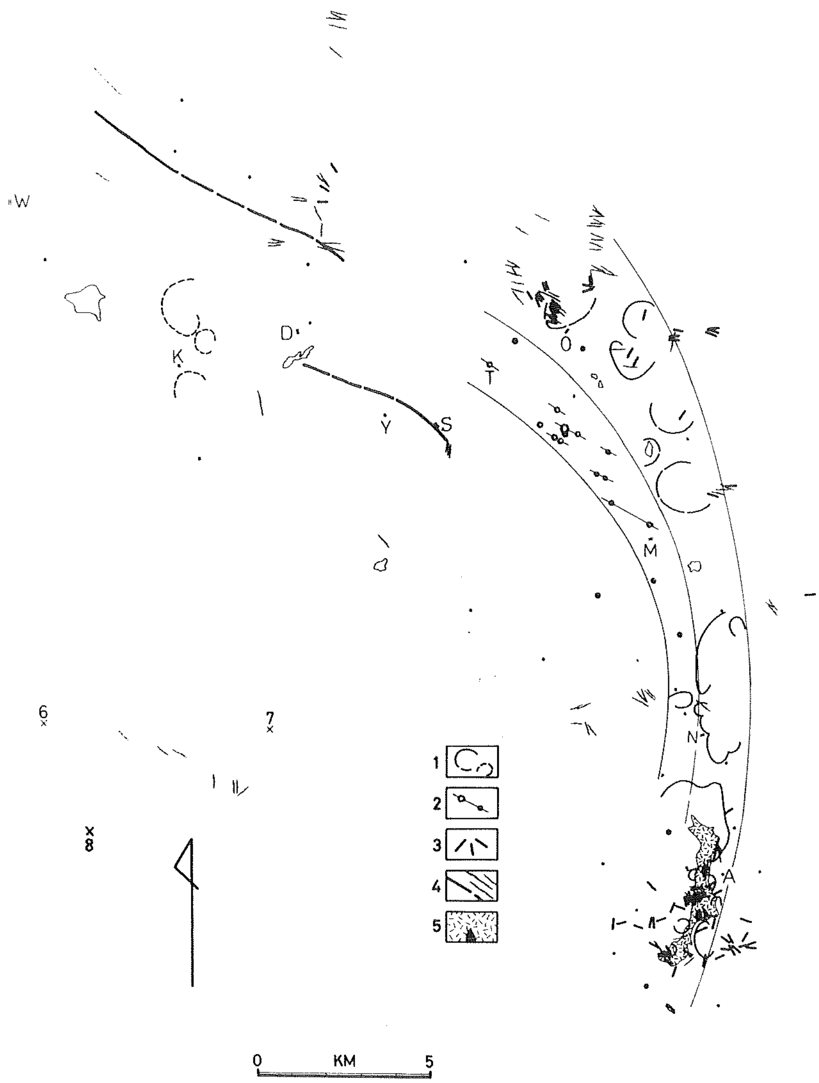

Fig. 4
Alignments of volcanoes.
1: Volcanic craters.
2: Correlation of individual volcanoes, estimated from the distribution of lava cone eruption centres, sheared zones and others (Minor alignment of lava cones).
3: Dykes.
4: Thick lines: Faults, thin lines: Small faults and sheared zones.
5: The specific massif of the andesite-hornfelses and pyroxene porphyrites (black).
6: Centre of arc of the Eastern alignment.
7: Centre of arc of the Western alignment.
8: Centre of arc of the Younger Yatsugatake period alignment.
Other patterns and alphabet symbols are the same as those in Fig. 2.

These minor alignments are characterized by;
1) twin lava cones, arranging in a definite direction,
2) most of dykes extend in the same direction,
3) numerous small faults and shear zones, mostly cutting the erupted materials of the Older volcanoes. Direction of shear zones is in the N 50° ~ 80° W strike, average N 60° ~ 70° W, and nearly vertical dip with a few meters (0 ~ several meters) offset. Their widths range from 5 cm. to 200 cm.
4) The Oiwake volcanic graben, mentioned later, in the Kirigamine – Yashigamine area runs in the same direction.

It is important that these minor scale echeron arrangements of volcanoes were formed simultaneously with the formation of double arc alignments of whole Yatsugatake volcanic chain. This en echeron arrangement is in harmony with the large scale structure of the Kirigamine – Yashigamine area in the west, as shown in Fig. 4.

Andesites recrystallized into hornfelses and holocrystalline rocks widely distribute in the central part of the Eastern alignment of the Southern area with the north ~ south trend. These are also illustrated in Fig. 4. These rocks construct some peaks, such as Nakadake, Tsurune and Giboshidake. They are conformable to the rocks of the Older period, while they are in contact with those of the Younger period by fault. The size of this specific massif is 4 km. in length, 600 m. in maximum width, and the visible thickness is 400 m. (+), although the base is hidden. No pyroclastic intercalation has been observed in this succession. Numerous joints, small faults and fracture zones develop in the north-south trend and pyrite impregnates along these surfaces.

This specific massif has following lithologic facies;
1). holocrystalline, hypersthene – augite porphyrite in the central part around Naka-dake, Tsurune and others.
2). hypersthene-augite andesite with recrystallized groundmass.
3) evidently recrystallized andesite under the microscope, but apparently fine grained, compact black rock as slate.

Lithologic heterogeneity is distinct in this massif. These evidences indicate that these specific rocks make up an unit massif and represent "*the root of volcanoes*". This "*root*" had been utilized as eruption channel of repeated activities, and the rocks around it had been thermally metamorphosed and recrystallized into hornfelses.

3. Geology of the Kirigamine volcano

The geologic outlines of the Kirigamine area in the north western extension of the Yatsugatake volcanic chain is illustrated in Fig. 5. Detailed geology of this area will be reported in near future.

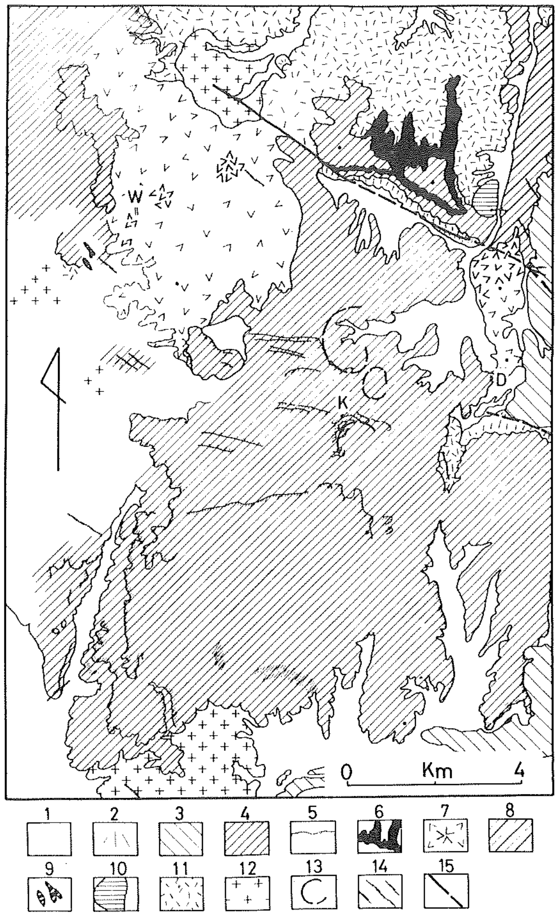

Fig. 5

Geologic outline of the Kirigamine region.

1: Alluvium.
2: Talus deposits.
3: Effusive materials from the Yatsugatake volcanoes.
4: Volcanic rocks of the Kirigamine-Yashigamine area.
5: Andesites of the flat lava-type in the Kirigamine-Yashigamine area.
6: Pitchstone.
7: Obsidians and rhyolites.
8: Tuff-breccias.
9: Basalts.
10: Dolerites.
11: Rocks of the green tuff groups.
12: Granites.
13: Eruption centres.
14: Sheared zones.
15: Faults.

Other patterns and alphabet symbols are the same as those in Fig. 2.
The rocks of 4 and 5 are the Kirigamine-Yashigamine volcanics in the strict sense, and those from 4 to 9 are of broad sense.

Distribution of obsidians and rhyolites in this area is directly contineous to that of the Yatsugatake volcanic chain (KAWACHI, 1961). The age of Kirigamine volcanics has already been decided by some authors; early Quarternary period by SAWAMURA & OWA (1953). Pliocene by MOMOSE et al. (1959), 4 m.y. by KAWANO & UEDA (1964) by means of K-A method from the obsidians, 13 m.y. for Kirigamine obsidians and 0.85 m. y. for the Wada-pass obsidians by KANEOKA & SUZUKI (1970) by Fission Track method. These data indicate that the ages of the Kirigamine volcanics are older than the same type of rocks from the Yatsugatake volcanic chain. Accordingly, certain definite types of rocks; such as the obsidians, rhyolites and hornblende-andesites, erupted along the same zone, although their ages of activity are different.

The most distinct structural lines in the Kirigamine area are two faults arranged in en echeron with the northwest – southeast trend in the northern half of the area (Figs. 4 and 5). The area besieged by these faults is depressed as a graben. The Oiwake volcanic graben is proposed for this graben. This graben is distinguished by ;

1). the existence of talus deposits and other topographic characteristics.

2). the lava flows incline outwards from these faults, and are discontinuous in both side of the graben.

3). many small subordinate fractures develop around the faults in the Suzuran-pass and the Daiman-pass area.

This graben has 3 km. in width, 13 km. long, and the vertical offset is apparently more than 200 m. Although the significance of the Oiwake volcanic graben has not been clarified yet, it is noteworthy that the direction of this graben is concordant to the general structural trend of the Kanto Mountains far in the east (Fig. 2).

This suggests that the structural trend of the basement is contineous from the Kanto Mountains to the Oiwake volcanic graben. Although the Sanbagawa-type metamorphics in the north of the lake Suwa are located in the western extension of the trend mentioned above, this massif has the north ~ south internal structural trend which is concordant to the structures of the Akaishi Mountains. Thus, this crystalline schist massif is an offset block from the Akaishi Mountains (KAWACHI, et al, 1966). Therefore, some structural discontinuities may be estimated from the basement of the Kirigamine volcanic area. Thus, the solution of the tectonic relationship between the graben and the basement structures becomes more complicated than apparent simplicity. En echeron arrangement of the faults suggests apparently left lateral offset. It is also a large problem whether this en echeron offset is accidental, or relates to the Sanbagawa metamorphics cut by the Itoigawa – Shizuoka Tectonic Line, or relates to the left lateral en echeron offset of lava cone minor alignments in the Yatsugatake volcanic chain. After all, all these tectonic features in the Kirigamine and Yatsugatake volcanic chain and neighbouring basements suggest that the comprehensive consideration is required for whole these areas in the time scale including later Neogene Tertiary to Recent.

Present data suggest that such comprehensive studies are possible.

4. The xenoliths

The Yatsugatake volcanic chain, as already mentioned, is situated at the focus of geologic structures of Japanese Islands and extends across the general trend of the basement geologic units. Therefore, the study of xenoliths included in the volcanic rocks is very important to estimate the hidden basement of this area.

Table 4 represents the xenoliths for 4 subareas from the north (Nn) to south (Ss), based on the identification by nacked eyes. The N and S means the Northern and the Southern area respectively. The total number of xenoliths

Table 4. The xenoliths

Area	Subarea	Locality	Number of xenoliths obtained	Number of xenoliths identified	Granites	Gabbros	Porphyrites	Diabases	Volcanics	Tuffs	Aplites	Holnblendites	Quartz rocks	Cherts	Limestones	Sandstones	Ores	Epidotes	Spinel bg. rocks	Green rocks	Slates	Hornfelses	Schists
Northern area	Nn	Hacchyojigawa	7	7	5									1	1								
		Karasawa	17	16	8	1							4		3								
		Kakumagawa	29	20	7	1							6		4	1						1	
		Hosokojigawa	11	6	3										1	2							
		Otakegawa	166	89	19	7	1		2	2			33	2	7	5					2	9	
		Oishigawa	240	132	29	16			2				27	3	24	10	1				2	18	
		Total of Nn	470	270	71	25	1		4	2			70	6	40	18	1				4	28	
	Ns	Honmagawa	69	49	21	15		5	2				2		1	1					2		
		Otsukigawa	4	3								1				1						1	
		Yukawa	28	14	3								9			1						1	
		Naruiwagawa	4	4	1								1		1	1							
		Total of Ns	105	70	25	15		5	2			1	12		2	4					2	2	
Southern area	Sn	Takaishigawa	136	53	3	8						1	10	1	14	6					2	8	
		Somazoegawa	215	80	6	9							18	3	24	4	1	1	1	1	6	6	
		Nishikawa	85	24	1								3		12	2					4	2	
		Daimongawa	149	58	10	9							5	3	19	8			1			3	
		Itabashigawa	52	21		1									13							7	
		Yanagawa	40	37	6	1			1				11	2	7	5						4	
		Total of Sn	677	273	26	28			1			1	47	9	89	25	1	1	2	1	12	30	
	Ss	Kawamatagawa	215	88	12	10		1	1			4	7	6	28	2				1	4	12	
		Kabutogawa	18	14	1	3					1		6		1	1					1		
		Karasawa	7	5	1	2									1	1							
		Takagawa	10	9		3							4			1					1		
		Furusomagawa	84	57		5							16	1	31	1						3	
		Tatsubagawa	208	120	10	29			3	1			13	3	31	7					1	19	3
		Hirokawarazawa	74	37	7	3							1	3	21	1						1	
		Total of Ss	616	330	31	55		1	4	1	1	4	47	13	113	14				1	7	35	3
Northern area			575	340	96	40	1	5	6	2		1	82	6	42	22	1				6	30	
(Nn + Ns)			%	59	28	12		1	2				24	2	12	6					2	9	
Southern area			1293	603	57	83		1	5	1	1	5	94	22	202	39	1	1	2	2	19	65	3
(Sn + Ss)			%	47	9	14			1			1	16	4	33	6					3	11	
Total			1868	943	153	123	1	6	11	3	1	6	176	28	244	61	2	1	2	2	25	95	3
(N + S)			%	50	16	13			1				19	3	26	6					3	10	

obtained is about 2,000, and about a half of them are possible to be identify by nacked eyes. 19 types of rocks are distinguished among them, including various granitic rocks and crystalline schists. Although the number of hornfelses certainly increase by advanced studies under microscope, general characteristics of the basement rocks of the Yatsugatake volcanic chain are given in Table 4.

Brief descriptions of the xenoliths in Table 4 are as follows;

1). Nn area; Granites are relatively abundant. Gabbros, cherts, quartz rocks, sandstones, limestones, and hornfelses are often observed.

Ns area; Granites are abundant. Gabbros, quartz rocks, and diabases are predominant. Less sandstones, limestones and hornfelses.

Sn area; Quartz rocks and limestones are predominant. Granites, gabbros, cherts, sandstones, hornfeleses and slates are often observed.

Ss area; Gabbros, quartz rocks, limestones, hornblendites, and crystalline schists are predominant. Granites, cherts, sandstones and hornfelses are also abundant.

2). Whole Northern area (Nn + Ns); Granites > Quartz rocks > Gabbros = Limestones > Hornfelses > Sandstones > Cherts = Slates = various volcanics > Diabases.

98% of all xenoliths from these subareas were examined.

Whole Southern area (Sn + Ss); Limestones > Quartz rocks > Gabbros > Hornfelses > Granites > Sandstones > Cherts > Slates > Hornblendites = various volcanics.

The total of them reaches 98% of all xenoliths from these subareas.

3). In the whole area (N + S); Limestones > Quartz rocks > Granites > Gabbros > Hornfelses > Sandstones > Cherts = various volcanics.

Limestone xenoliths are abundant and crystalline schists are characteristic in the Southern area, whereas in the Northern area granites and quartz rocks are abundant and poor in limestone. No crystalline schist has been found in the Northern area.

Sillimanite, kyanite, spinel, cordierite, diopside, garnet, and biotite are found in these hornfelses by preliminary microscopic observations which will be reported in detail eleswhere.

Comparison of these xenoliths to the major rock types of the neighbouring basement supports the idea that the basement of the Yatsugatake volcanic chain is composed of the rocks of the Outer Zone of Japanese Islands. The study of xenoliths contributes to the basement problems of the Southwest and the Northeast Japan. The migrations of activity centres from time to time with different types of volcanic rocks may closely related to the difference of the basement. The study of xenoliths will give a clue to solve the problems how basement behaves as a reflection of the formation of volcanic chain.

Summary

1). The alignments of volcanoes, the history of formation of the arrangements, and the possible nature of the basement estimated from the xenoliths are described in the Yatsugatake volcanic chain.

2). The history of the Yatsugatake volcanism is divided into two periods; the Older and the Younger, separated by a distinct erosion interval. This chain is spacially divided into the Northern and Southern areas based on mode of activities and lithology. Two alignments of volcanoes, the Eastern and the Western one, are recognized with large arc shape convexing to the northeast (Tables 2 & 3, Fig. 3 & 4).

3). The arrangements of volcanoes in the Yatsugatake volcanic chain is closely related to those of Pliocene volcanoes and the major geologic structures of the Kirigamine – Yashigamine area (Fig. 5) in the northwestern extension of the former. Comprehensive considerations for these two volcanic areas are required in the future.

4). On the basis of the studies of xenoliths obtained from the Yatsugatake volcanics (Table 4), the nature of basement of this volcanic chain was estimated. The importance of the study of the xenoliths was pointed out from the view points of the basement tectonics and of the mechanism of volcano-alignment formation.

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