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Tectonic Development of the Median Zone (Setouti) of Southwest Japan, since the Miocene

With special Reference to the characteristic Structure of Central Kinki Area*

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(With 6 Tables and 15 Text-figures)

CONTENTS

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Introduction

Many geologists are paying attentions to the zonal arrangement of the geological and geophysical features in Japan. One of the most striking facts is that two recently active belts running along the Mariana Arc and the Ryûkyû Arc traverse the old Honsyû Arc almost meridionally (SUGIMURA, 1960). The area dealt in this paper is situated between these two active belts, and occupies the median zone of Southwest Japan.

Japanese Tertiary geologists usually divide the Japanese Islands into "Southwest Japan" and "Northeast Japan" by a large-scale tectonic line which is called "Itoigawa-Sizuoka Line". This line limits the western border of the "Fossa Magna" traversing the middle part of Honsyû. In comparison with Northeast Japan, Southwest Japan, generally speaking, has rather cratonic characters during the Cenozoic time, so it has been expressed as "quasi-cratonic" by J. MAKIYAMA (1956). Moreover, Southwest Japan is divisible into two zones by the "Median Tectonic Line": "Inner Zone" on the northern side and "Outer Zone" on the southern side.

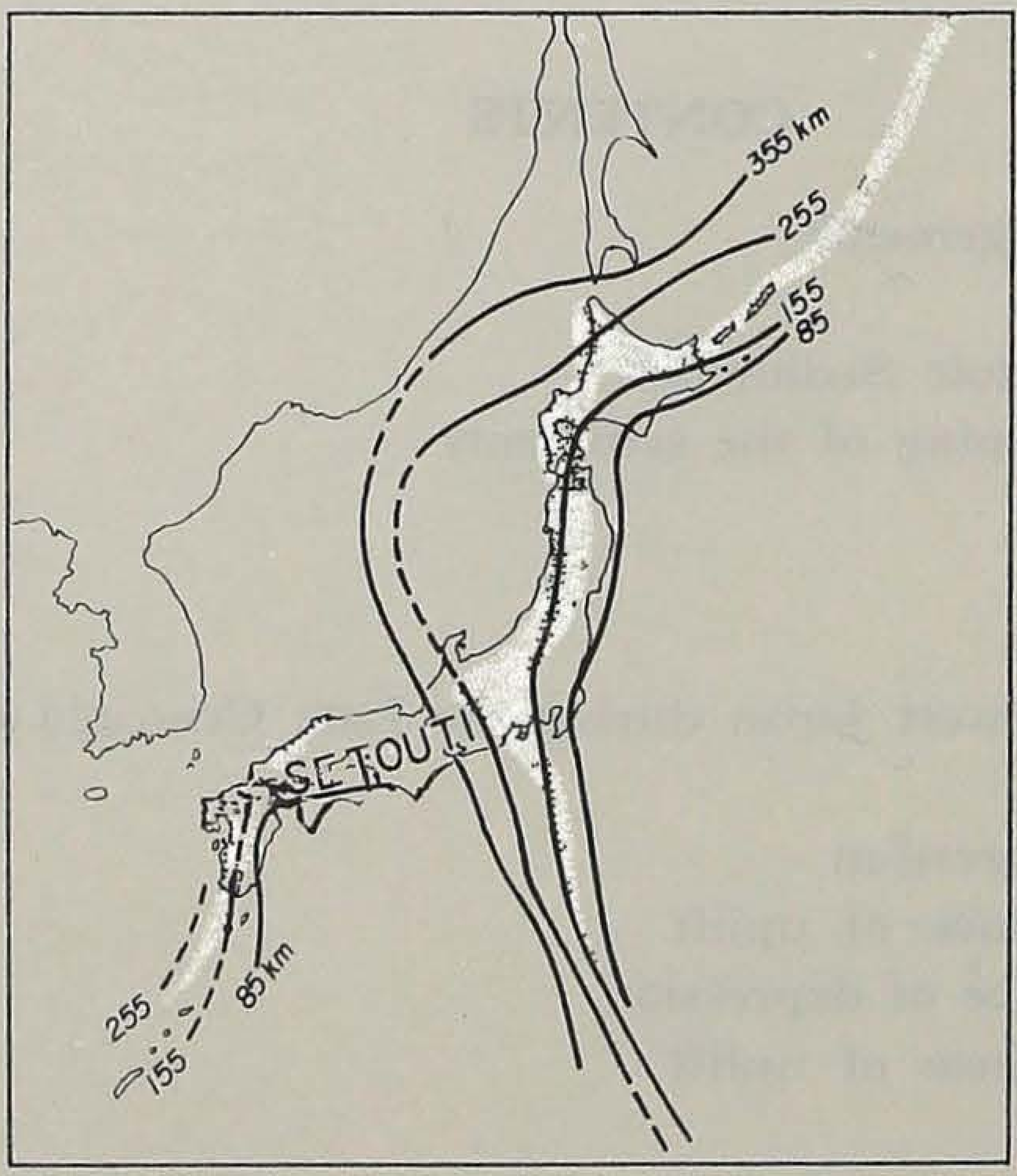

Fig. 1. Index map of the Setouti province (based on A. SUGIMURA 1960). Dotted areas show the volcanic belts; the right is "East Japan Volcanic Belt", the left is "West Japan Volcanic Belt". Thick lines indicate the depth of the intermediate and deep seismic foci.

Southwest Japan is characterized by zonal arrangement of the basement rocks, which are parallel with the Honsyû Arc, although the Inner Zone was disturbed by intrusions or extrusions of vast amount of the Cretaceous acid rocks. The arrangement of the Cenozoic sedimentary and volcanic blankets covering the basement unconformably have also the same tendency as that of the basement rocks. They are distributed in three zones: the inner zone along the Japan Sea, the median zone including the Inland Sea (Seto-Naikai) and the outer zone along the Pacific Ocean. N. IKEBE (1956, 1957) proposed the names as sedimentary provinces for these three zones; the Hokuriku-San'in, the Setouti and the Nankai provinces respectively, among which the Setouti province is mainly treated in the present paper. However, the writer intends to somewhat revise Ikebe's division from the tectonic point of view, and to propose a new division of Southwest Japan.

Before the Second World War, many discussions on the genesis of the Inland Sea were issued, but most of them depended chiefly on the topographic observations. After the War, however, knowledges about the Plio-Pleistocene sediments named Osaka group in the Osaka basin and its surroundings have been quickly accumulated by the members of the "Research Association for the Osaka Group" (1951). Especially M. ITIHARA (1961) has been studying the Osaka group in detail.

On the other hand, the volcanic blankets of the Setouti have been re-examined stratigraphically by the members of the "Research Association of Setouti" (MORIMOTO et al, 1953; SHIIDA et al, 1959). The traditional concepts about the Setouti have been obliged to be revised by these studies.

The writer, as one of the members of these reseach groups, has been engaging in the studies of the stratigraphy of the Cenozoic formations and of the tectonics of this province with many collaboraters in this decade. The results of these investigations were published in 1950, 1955, 1957, and 1960.

The details of individual sedimentary basin which is locally distributed in the Setouti have been revealed out by efforts of many investigators. The survey of the basement complex has also made progress. The writer, herein, intends to compile these numerous data and to summarize the tectonic history of the Setouti province according to his view.

Central Kinki area which is situated in the central part of the Setouti is characterized by many ellipsoidal basins, such as the Osaka, Nara and Oomi basins, bordered by short and narrow mountain ranges running meridionally. Such a topography seems to be a expression of foundation folding accompanied by many thrusts (MAKIYAMA, 1956). The area characterized by such structures forms a triangular shape connecting the Bays of Wakasa, Osaka and Ise. This is the reason why the name of "**Kinki Triangle**" is proposed for this area by the writer (Fig. 11). To discuss on the genesis of this Triangle and on its geologic meaning is also one of the subjects of this paper.

The writer expresses his appreciation to Dr. Taro KASAMA for his collaboration during this study. Special acknowledgements are due to Prof. Nobuo IKEBE, Yukimasa SAITO, Assist. Prof. Kôichirô ICHIKAWA, Dr. Takashi MATSUMOTO, Minoru ITIHARA, Kenichi ISHII of Osaka City University for their valuable suggestions and constant encouragements. Especially, the writer is indebted to Prof. N. IKEBE for the detailed discussions and to Dr. K. ICHIKAWA for the knowledge about the basement geology.

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General Geologic Setting

The Late Cenozoic sediments of the median zone of Southwest Japan* are divisible into two, the Miocene series and the Pliocene-Pleistocene series, distributions of which are shown in Figs. 2 and 3.

Fig. 4 gives the geologic provinces and their subdivisions of Southwest Japan which will be used in the following chapters. The precise definitions of them will be offered in a later chapter. The areas in black color are considered to be the uplifted ones which have not been covered by sediments since the Miocene. A glance of this map will indicate that the fundamental tectonic framework has not changed since the Miocene, although some change of the sedimentary basins occurred.

The structures of the Setouti province during the Late Cenozoic time have been distinctly controlled by those of the basement complex. This fact is proved by comparison between Figs. 4 and 5. Thus, the arrangement of the geologic province is of great importance in considering the geotectonics of Southwest Japan.

The uplifted areas have grown up to the present back-bone ranges of Honsyû. The subsiding areas of the Setouti province have remained as a lower zone including many topographic basins separated by short mountain ranges. The Inland Sea can be regarded as a series of such basins submerged under sea water.

The main topographic features of the Setouti is due to the crustal movement in the Plio-Pleistocene which was named "**Rokkô Movement**"** (IKEBE, 1956). The Miocene series has been cut to pieces by the severe faulting of this movement.

Apparently, in the Setouti Depression, there can be recognized two kinds of different trends of the structures, which are expressed clearly in the present topography. The one is the latitudinal trend shown in the general trend of the Setouti Depression, and the other is the meridional trend typically shown by the short mountain ranges running in central Kinki, such as the Suzuka and the Ikoma ranges: these trends are named "**Setouti trend**" and "**Suzuka trend**" respectively in this paper.

Summary of the Late Cenozoic Sediments

Characteristics and grouping of the sediments

It is convenient for the purpose of this paper to divide the rocks of Southwest Japan into two parts: basement complex and Cenozoic blanket. The former, as the term here used, contains all kinds of the pre-Miocene rocks. The latter is composed of the sedimentary blanket and the volcanic blanket.

Southwest Japan is the area widely exposing the basement rocks of the Japanese Islands. Only small patches of the Cenozoic blanket are scattered in its median zone. In spite of their isolated occurrences, they have some common features.

The Cenozoic sediments of the Setouti province are very thin in vertical extent, compared with those of the San'in-Hokuriku and the Nankai provinces. Owing to shifting of the sinking center of the sedimentary basin, the imbricate arrangement of strata

* In this paper, Kyûsyû is not treated. So, "Southwest Japan" will be used excluding Kyûsyû in the following.

** The Rokkô Movement is designated by N. Ikebe as a sum of the whole displacements that have taken place in the Setouti Depression during the Plio-Pleistocene.

("imbricate sedimentary structure"—FUJITA, 1958) is remarkable. Lateral change of lithofacies occurres frequently and abruptly. Many discordances can be recognized in their sections. Folding is very slight except for the parts disturbed by faulting. The unconformable surface of the basement is so uneven that the strata abut against the basement everywhere in various horizons. Such features are those of the nepton in the quasi-cratonic basin (MAKIYAMA, 1954, 1956).

These scattered sediments can be classified into three series. The "First Setouti Series"* belongs to the Middle Miocene and has marine facies predominantly. The "Setouti Volcanic Series" of the Upper Miocene is chiefly composed of rhyolitic and andesitic lavas and their associated pyroclasts, and also is characterized by Sanukitoid rocks. The last is the "Second Setouti Series" which is the Plio-Pleistocene in age and is almost non-marine.

First Setouti Series

The First Setouti Series is composed of several sedimentary groups, each of which is distributed within one area or subprovince and is not directly connected with others.

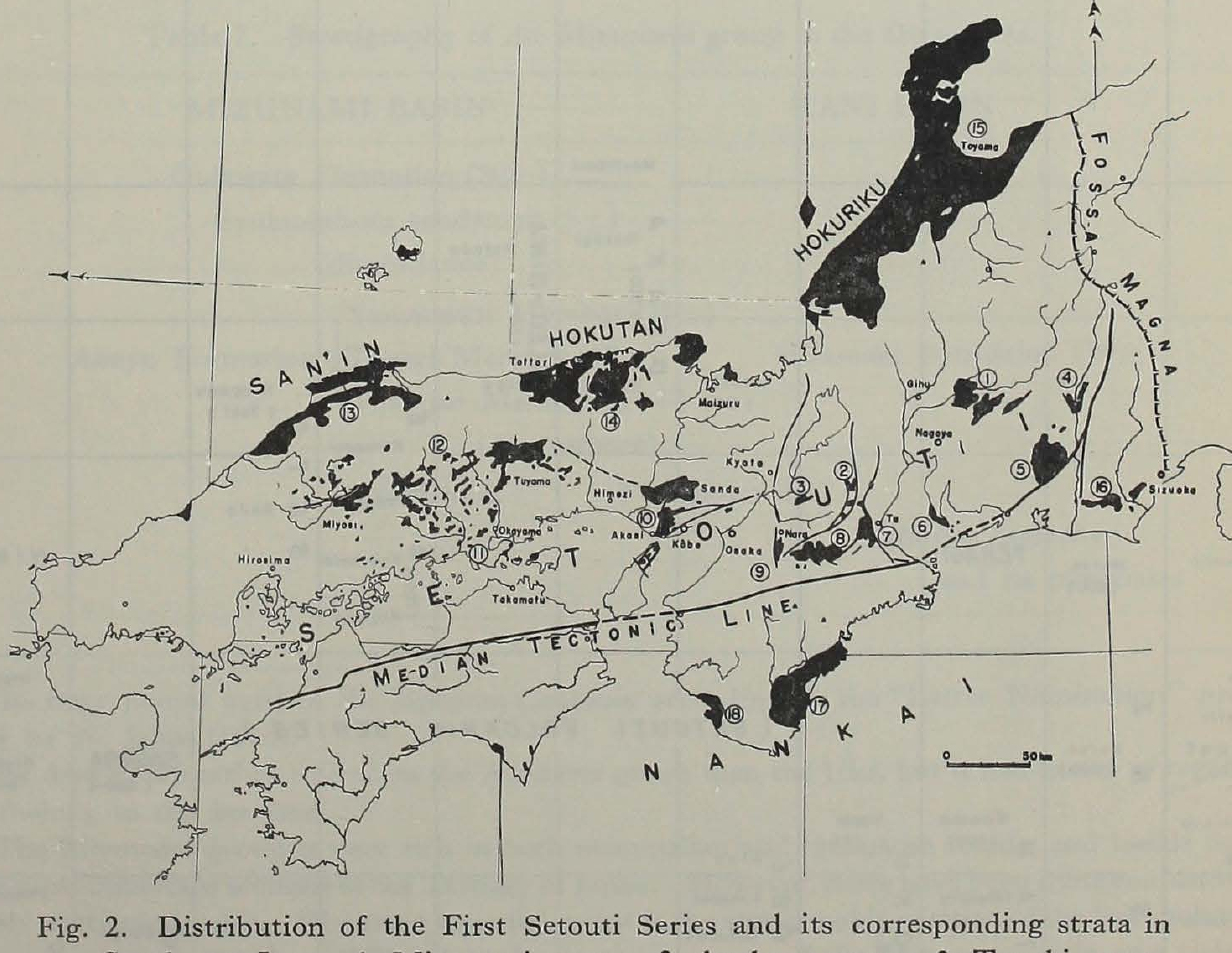

Fig. 2. Distribution of the First Setouti Series and its corresponding strata in Southwest Japan. 1: Mizunami group. 2: Ayukawa group. 3: Tuzuki group. 4: Tomikusa group. 5: Sidara group. 6: Tita group. 7: Itisi group. 8. Yamakasu group. 9: Huziwara group. 10: Kôbe group. 11: Sikai, Obié, Namigata beds. 12: Bihoku group. 13: Sinzi group. 14: Hokutan group. 15: Yatuo group. 16: Kurami and Saigô groups. 17: Kumano group. 18: Tanabe group.

* The "First Setouti Supergroup" designated by the writer (KASAMA and HUZITA, 1957) includes the First Setouti Series and the Setouti Volcanic Series in the present paper. The unit of "supergroup" used in the writer's previous paper is not suitable for such divisions, so is abandoned.

The Mizunami, Itisi and the Kôbe groups are the representatives of them.

There are many difficulties in the correlation among these groups, owing to their peculiarities above mentioned. So many suggestive opinions (MAKIYAMA, 1939; OTUKA, 1939; IKEBE, 1954; HUZITA, 1957 etc.) have been issued, but the detailed correlation of the formations of the whole Setouti province has not yet been established.

However, Y. TAI (1959) set forth the biostratigraphic zonation of these formations by smaller foraminifera. Very recently, M. CHIJI (1961) has also established the Neogene biostratigraphy of the Toyama sedimentary basin in the Hokuriku province. Refering to these zonations, the writer prepared the correlation table as shown in Table 1. The

Table 1. Correlation table of the Late Cenozoic formations in Southwest Japan.

GEOLOGIC AGE	LETTER-NOMINATION	WEST HONSYU (Y. Tai) 1959	SAN'IN - HOKURIKU: SAN'IN	SAN'IN - HOKURIKU: HOKUTAN	SAN'IN - HOKURIKU: BIHOKU	SETOUTI: HARIMA	SETOUTI: OSAKA	SETOUTI: OOMI	SETOUTI: IGA — ISE	SETOUTI: OWARI — MIKAWA	NAN-KAI: SIZUOKA	HOKU-RIKU: TOYAMA	TOYAMA (M. Chiji) 1961
Pleistocene	K												
Pleistocene	J						Mantidani						
Plio-Pleistocene	I_2						OSAKA (500): Ibaragi	PALEO-BIWA (500-): Katada					
Plio-Pleistocene	I_1					Akasi (120)	Senriyama	Iga	AGE (700-): Ooizumi, Kuragari	SETO: Yatagawa (Toki)			
Pliocene	H	*Rotalia beccarii* ZONE	Matue (600)	*TERAGI*					Itinohara, Kusuhara, Koyama	Seto		*HIMI*	*Elphidium* — *Cassidulina* ZONE
Upper Miocene	G	*Uvigerina* — *Epistominella* ZONE; *Cyclamina*- *Martinottiella* ZONE	SINZI: Hurue (1400)	HOKUTAN: Muraoka (500)	BIHOKU (100+): Upper sh	KÔBE (500): Aina	(*SETOUTI*	*VOLCANIC*	*SERIES*)		*SAGARA* (650-)	Otogawa (700); Higasi-bessyo (700)	Radiolaria- R. F. ZONE; *Uvigerina* — *Martinottiella* ZONE
Middle Miocene	F_3	*Lageno-nodosaria* — *Uvigerina* ZONE; *Miogypsina* — *Operculina* ZONE	Koura (800)	(Rhyolitic tuff); Toyooka (250)	Lower s.s.	Sirakawa, Tainoliata, Iwaya			ITISI (650-): Yakuôji, Tyaya	MIZUNAMI (250): Oidawara, Syukunohora s.s.	SAIGO: Saigo m.s. (100), Tozawa s.s. (50)	YATUO: (Rhyolitic tuff); Kurosedani (600)	*Nonion* — *Rotaria* ZONE
Middle Miocene	F_2	*Nonion mizunamiensis* ZONE		Yôka ("Green Tuff")	Siomati				Kaiseki, Hurutaike, Kongôhô	Yamanouti, Togari, Tukiyosi, Nakamura	*KURAMI* (750)	Iwaine ("Green Tuff") (1000)	

boundary of the F_3* and the G* stages was decided by the disappearance of *Miogypsina* and by the faunal change from the Indo-Pacific type to the Arcto-American type.

It is not a chief object of this paper to discuss the problems about the correlation in details. Here, the writer wishes to offer brief notes and new data on the representative groups with discussions only about some important points in this correlation table.

The sediments of the subprovinces of the Setouti province are somewhat different from each other, in spite of their common features (Fig. 4).

1) **Iga-Owari area** This area occupies the inner zone of the Setouti province and is characterized by the Mizunami (HUZITA et OGOSE, 1950, 1951; WATANABE et IWABORI, 1952; ITOIGAWA, 1961), Ayukawa (IKEBE, 1934), AWA**(ARAKI, 1958; ITOIGAWA. 1961) and the Tuzuki (ISHIDA et al, 1954) groups, among which the Mizunami group is the representative.

The sediments of this area are very thin; less than a hundred meters in vertical extent at most places. They are more or less fossiliferous, chiefly consist of coarse arkosic sands strongly cross-laminated, and as a whole exhibit shallow-water condition.

The succesion of the Mizunami group is shown in Table 2.***

Table 2. Stratigraphy of the Mizunami group in the Owari area.

MIZUNAMI BASIN		KANI BASIN
Oidawara Formation (50+)		
Syukuonhora sandstone (5±)		
~~(discordance)~~~		
Akeyo Formation	Yamanouti Member (25±)	
	Togari Member (17±)	Hiramaki Formation (50±)
	Tukiyosi Member (10+)	
~~(discordance)~~~		
Nakamura Formation (100±)		
		Hatiya Andesite and its pyroclasts

* The stage names used in the Japanese Cenozoic according to the "Letter Nomination" proposed by N. IKEBE (1954).

** The Awa group rather resembles the Ayukawa group than the Itisi, but it had better to regard it to belong to the Ise area.

*** The Mizunami group is very rich in both mammalian and molluscan fossils, and builds one of the most important sections in the Tertiary of Japan. However, there have been some confusions on the stratigraphy of it. The most essential point is the stratigraphic position of the Sykunohora sandstone which is locally distributed at the northern corner of the Mizunami basin and yields *Miogypsina-Operculina* assemblage.

Many authors have believed that this sandstone occupies the lowest part of the Akeyo formation, because it rests directly on the Nakamura formation, the lowest of the Mizunami group, although it is overlain by the Oidawara formation conformably. But in other places, the Oidawara formation is underlain by the Akeyo. From the biostratigraphic point of view, Y. TAI (1958) suggested that the horizon of the Syukunohora might be higher than the Akeyo and be the basal part of the Oridarawa fromation. As a result of his own re-survey of this area, the writer agrees with TAI's opinion.

The Mizunami group is distributed in two basins, Mizunami and Kani, which are separated from each other by the narrow barrier of granite. The strata filling up both basins begin with the lignite-bearing Nakamura formation, which is overlain by marine Akeyo and Oidawara formations in the former basin and by non-marine Hiramaki formation in the latter.

From the Tukiyosi member up to the Yamanouti, the molluscan assemblages change their characters from littoral to inner-neritic successively in accordance with the change of lithofacies from coarse sands to silts. The Akeyo formation is characterized by so-called "*Vicarya* fauna", which consists of sub-tropical species such as *Vicarya yokoyamai*, *Vicaryella ishiiana*, *Pseudomurex tukiyosiensis*, *Trapezium modiolaeforme* etc. The Togari fauna is composed of such as *Turritella s-hataii*, *Protorotella togariensis*, *Nipponomarcia nakamurai*, *Felaniella usta*, *Dosinia nagaii* etc. A characteristic Miocene mammalian fossil, *Desmostylus japonicus*, was found in this member. The Yamanouti member is characterized by *Fulgoraria prevostiana*, *Acila submirabilis*, *Nuculana kongiensis*, *Patinopecten kimurai*, *Euspira meisensis*, *Venericardia tokunagai* etc.

The molluscan fauna of the Syukunohora member is not so different from that of the Akeyo. But it is to be noted that this fauna has many common species with that of the upper part of the Kurosedani formation in the Toyama basin, such as *Vicaryella ishiiana*, *Certhium meisense*, *Apollon osawanoensis*, *Babylonia toyamaensis*, *Nassarius kometubus*, *N. simizui*, *Conus tokunagai*, *Acteon ozawai*, *Chlamys yanagawaensis*, *Siratoria siratoriensis*, *Corbula nisataiensis* etc.

It is also noticeable that abundant planktonic foraminifera appear in the muddy part of the Oidawara formation (TAI, 1958). This fact seems to mean that the sea which deposited the Akeyo formation changed its environment from inner bay to inland sea. In other words, the Pacific Ocean was connected with the Japan Sea through the "First Inland Sea" of the Miocene.

Compared with the Tertiary of the Nankai province, the Oidawara formation is probably correlated to the Saigo group in Sizuoka prefecture (MAKIYAMA, 1941, 1950). The Saigo group rests on the Kurami group unconformably and is overlain by the Sagara group with unconformity. The Tozawa sandstone occupying the lower part of the Saigo group contains *Lepidocyclina makiyamai* and *Miogypsina kotoi*, and passes upward into the Saigo mudstone. This is the uppermost horizon of *Miogypsina* in the Tertiary sequence of Sizuoka prefecture.

The Oidawara formation is possibly correlated with the Kurosedani formation, which yields molluscan fauna closely resembling that of the Oidawara and contains *Miogypsina* and *Operculina* in its upper part.

2) **Ise-Mikawa area** This area occupies the outer zone of the Setouti province, and is characterized by the Tomikusa (SHIKAMA, 1954), Sidara (KATO, 1955; YOSHIDA, 1953), Yamakasu (SHIIDA et al, 1960), Itisi (TAKIMOTO, 1935; ARAKI, 1960) and the Huziwara (MAKIYAMA, 1931; SAKAMOTO, 1954) groups, among which the Itisi group is the representative.

In contrast with thin Mizunami group, the groups of this area may reach more than several hundred meters in aggregate thickness, although the detailed surveys of some of them have not yet been completed. Moreover, muddy facies become predominant. Such features are somewhat similar to those of the Tertiary of the Nankai province.

The Itisi group shows two cycles of sedimentation. The lower one begins with conglomerates and ends with shales. It does not contain the molluscan fauna of the littoral Tukiyosi-type, but yields that of the Yamanouti-type which is rather neritic.

This fact is interpreted as that the Mizunami area occupied innermost part of the First Inland Sea, and that the Itisi area, strongly subsided, was connected directly with the open sea.

The upper cycle begins with sandstones which are absent in some places and ends with fine alternations of sandstones and mudstones. Between these two cycles, discordance cannot be recognized. The upper cycle may be correlated to the Oidawara formation.

It is difficult to correlate precisely the strata of these two areas so far as the present knowledge is concerned, but there is little doubt that the strata corresponding to both Akeyo and Oidawara formations develop in this area.*

3) **Harima area** This area is characterized by the Kôbe group** (SHIKAMA, 1938). The Sikai beds in Syôdo Island and the Obié, Namigata beds (OZAKI, 1956) in Okayama prefecture may also belong to this area, judging from their resemblance to the lower part of the Kôbe group.

The Kôbe group is distributed in two basins as in the case of the Mizunami group. The northern, Sanda basin is filled by non-marine sediments. However, the conditions are very complicated in the southern basin around the Straits of Akasi (Fig. 6). In the northern part of Awazi Islands, the marine Iwaya formation rests on the granitic basement directly. The Tainohata formation occupies the northern side of the Straits of Akasi. Marine "Tainohata fossil bed" which has once been regarded as to belong to the Plio-Pleistocene (UEJI, 1937) is intercalated in this formation. The Tainohata formation is faulted by the Kamisamamatu fault (Fig. 6) against the non-marine tuffaceous Sirakawa formation containing rich plant fossils known as the "Sirakawa flora".

Thus, separated by the fault and the strait, these three formations have different properties. Moreover, each of them abuts on the basement directly. So far as the observations of the outcrops are concerned, it is difficult to clarify the mutual relations among them.

The Kôbe group of the Sanda basin consists of four cycles of sedimentation, beginning with coarse clastic sediments and ending with thick pyroclastic strata, by which four formations can be established. Based on the distribution of the tuff beds spreading over the two basins, the following stratigraphy as shown in Table 3 was obtained.

Formerly, the Sirakawa flora was believed to range from the Upper Miocene to the Lower Pliocene (SHIKAMA, 1938). However, it is now clarified that the tuff beds containing the Sirakawa flora constitute only a single member of the Sirakawa formation.

From the lowest horizon of the Iwaya formation, Y. TAI (1959) found the smaller foraminiferal assemblage corresponding to his *Miogypsina-Operculina* zone. From slightly higher horizon than this, the writer collected molluscan fossils, such as *Turritella kiiensis*, *Cymatosyrinx osawanoensis*, *Nassarius* cf. *simizui*, *Fulgoraria* sp., *Siphonaria* sp., *Mactra* sp.

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* There develop coal-bearing thick strata named Suzuka group in the middle part of the Suzuka range which is faulted all around. This group is quite different from other Miocene groups in the Setouti from the structural view-point. It is one of the problems in future.

** The detailed stratigraphy of the Kôbe group, especially that of the Sanda basin has remained unknown up to the present. The writer and his collaborators carried on the survey of this group since 1957. The detailed descriptions will be issued in the near future by M. YAMASHITA, T. KASAMA and the writer.

Table 3. Stratigraphy of the Kôbe group in the Harima area.
(YAMASHITA, KASAMA and HUZITA)

SOUTHERN BASIN	NORTHERN, SANDA BASIN
	Mituta Formation (65±)
Aina Formation	Oogo Formation (110±)
(discordance)	
Sirakawa Formation (90±)	Yokawa Formation (160±)
(faulted)	
Tainohata Formation (90±)	
(separated by strait)	Arino Formation (175±)
Iwaya Formation (80±)	

Such fauna allows the Iwaya formation to be assigned to the Middle Miocene. However, the contents of the Kôbe group are very different from those of other subprovinces of the Setouti in the following points. 1) The Kôbe group misses non-marine sediments containing lignite seams under the marine Iwaya formation, which is usually found at the bottom of the sedimentary basins of any other subprovinces of the Setouti. 2) Near the bottom of the sedimentary basin of the Iwaya formation, there are thick littoral sediments composed of abundant fragments of *Ostrea* and *Balanus* etc. These characteristic sediments are common to the Sikai and the Namigata beds. 3) The molluscan fauna of the Iwaya formation has little common species with those of other subprovinces. 4) The sediments of the Kôbe group do not exhibit the normal cycle of sedimentation as in the case of the Mizunami, Itisi or the Bihoku groups. The marine Iwaya formation is followed by the thick pyroclastic sediments inserted by many rhyolitic tuffs.

The peculialities of the Kôbe group may be interpreted as that the Harima area was invaded by sea water only at the maximum transgression of the Middle Miocene, owing its situation on the extension of the Tamba Uplift. The deposits in this sea were succeeded by the thick pyroclastic sediments quickly accumulated under the influence of violent volcanic activities, the center of which is not yet known (KASAMA, 1961). The volcanism represented by rich pyroclastic material of the Kôbe group may correspond to that of the Sikata rhyolitic tuff inserted between the Toyooka and the Muraoka formations in the Hokutan area, or to that of the Yamadanaka tuff inserted between the Kurosedani and the Higasibessyo formations in the Toyama basin.

4) **Bihoku area** The Bihoku group is scattered at many locations mainly in the Tuyama and the Miyosi basins. The remnants of this group are distributed along the recent valleys in the north, but, to the south and the west, they are scattered on the swell* (Kibi plateau) between the Bihoku and the Harima areas.

The standard section of the Bihoku group shows one cycle of sedimentation. It is composed of the lignite-bearing non-marine strata in the lower; coarse clastic sediments yielding *Miogypsina* and *Operculina* in the middle; muddy strata containing rich pelagic

* The sediments of this part are mainly composed of deeply weathered conglomerates. It is very difficult to discern the Miocene from the younger sediments. There is a possibility that younger sediments are mixed with the Miocene in this part of Fig. 2.

foraminifera in the upper (TAI, 1959). It is noteworthy that the upper part of the Bihoku group belongs to the *Cyclammina-Martinottiella* zone. The sediments belonging to this zone are distributed over whole San'in-Hokuriku province, in spite of their absence in the Setouti proper.

Setouti Volcanic Series

It is one of the characteristics of the Setouti province that the amount of volcanic rocks erupted since the Miocene are very poor in comparison with that of the San'in-Hokuriku province, although pyroclastic material is abundantly contained in the sediments. Only the volcanism represented by the Setouti Volcanic Series flourished this province.

The representative of this series is the Nizyô group (MORIMOTO et al, 1953). It is composed of two series of various kinds of lavas and their associated pyroclastic sediments. Their activities began with effusions of rhyolites or pitchstones, followed by biotite-andesites, and, after short interval, was succeeded by hornblende-andesites and pyroxene-andesites, then finished with extrusions of aphanitic lavas of hypersthene-andesites or dacites known as "Sanukitoid". The eruption-centers of them arrange at regular intervals of about 100 km along the northern side of the Median Line.

The Setouti Volcanic Series develops in isolated localities usually separated not only from those of the First Setouti but also from those of the Second Setouti Series. Therefore, it is difficult to determine the geologic age of this series by the stratigraphic relationship.

The direct relationship between the Setouti Volcanic Series and the First Setouti Series can be observed only in the Sidara basin, where the strata corresponding to the Mizunami group are intruded by pitchstones (KATO, 1955; YOSHIDA, 1953). In the north of Mt. Nizyô, the Nizyô group is overlain by the Osaka group with distinct unconformity. It is evident that the activities of the Setouti Volcanic Series took place in any time during the post-Mizunami and the pre-Osaka time, if the volcanic rocks belonging to this series erupted contemporaneously.

The lithofacies of the Nizyô group is rather similar to that of the First Setouti Series. The result of the pollen analysis of it suggests close relation to that of the Kôbe group (SIMAKURA, 1957)*.

Owing to the above cited reasons, the writer has once correlated the Nizyô group to the Kôbe group (MORIMOTO, HUZITA and KASAMA, 1957). However, on the basis of the study of tuffs of both groups, T. KASAMA (1961) pointed out the differences of the mineral associations between both tuffs and concluded that the pyroclastic material of the Kôbe group cannot be expected from the eruption in the Nizyô area. On the other hand, stratigraphic study of the Kôbe group suggests that the tuffaceous formation containing the Sirakawa flora is considered to rest on the marine Tainohata formation (F_3) conformably. It is most probable that the Nizyô group may belong to G stage.

Second Setouti Series

This series comprises loose sediments made of gravels, sands and clays, and developes

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* Recently plant fossils collected by the writer from the upper part of the Nizyô group (Harakawa formation) identified by N. KOBATAKE. These fossils contain such species as *Equisetum aecticum*, *Salix Lavatieri*, *Zelkova Ungeri*, *Ternstroemia gymnanthera*, *Ligustrum ovalifolium*, *Rhamnus* cf. *japonica*, *Cyclobalanopsis* cf. *Mandraliscae*, *Liquidambar*?, *Betula* sp. This flora has many common species with the Sirakawa flora.

mainly in central Kinki district. Most of the sediments are lucustrine. Only in the Osaka basin and the Bungo area, they are replaced by evident marine strata in their upper part.

The Agé group in the Ise area is divisible into the following formations (TAKEHARA, 1961).

Table 4. Stratigraphy of the Agé group (TAKEHARA, 1961)

	SOUTHERN AREA	NORTHERN AREA
Upper		Komenoo Formation (30-120) Ooizumi Formation (500-150) Kuragari Formation (150-50)
Lower	Kameyama Formation (300) Kusuhara Formation (280) Koyama Formation (250-0)	Itinohara Formation (350-130) Kono Formation (100-25)

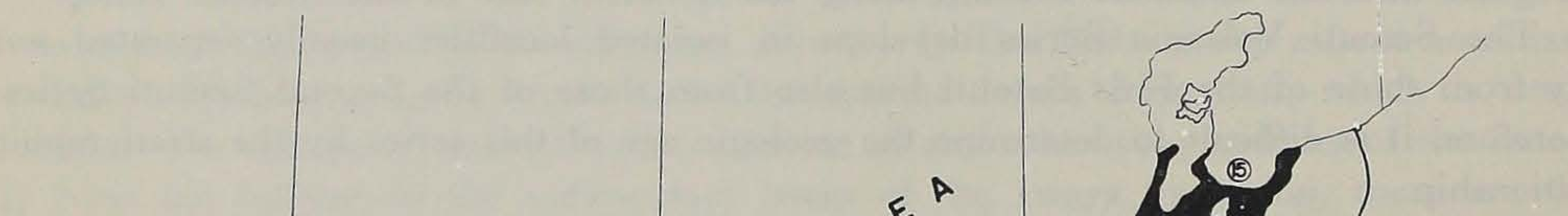

Fig. 3. Distribution of the Second Setouti Series and its corresponding strata in Southwest Japan. 1: Ina group. 2: Seto group. 3: Agé group. 4: Paleo-Biwa group. 5: Soni group (Murô). 6: Osaka group. 7: Ooyodo and Syôbudani formations. 8: Strata along the Yosino River. 9: Mitoyo group. 10: Guntyû formation. 11: Ooita group. 12. Himesima formation. 13: Ningyô-tôge formation. 14. Teragi group. 15: Omma formation.

The Agé group represents two cycles of sedimentation of non-marine strata. The lower cycle begins with the conglomerates of the Koyama formation and is succeeded by the lignite-bearing Kusuhara formation which bears *Stegodon elephantoides*. The upper cycle begins with the conglomerates of the Kuragari formation, which shows the transitional passage upward to the Ooizumi alternations containing *Stegodon akashiensis*. The Agé group converges northward distinctly deducing its thickness. There are many thin tuffs in the Agé group, among which those inserted in the Kameyama formation are most prominent. They are dacitic and are inferred to be attributed to the eruption of the Murô welded tuff, which rests on the conglomerates corresponding to the Koyama formation (Shiida et al, 1960).

The stratigraphy of the Osaka group is shown in Table 5.

Table 5. Stratigraphy of the Osaka group.

	OSAKA BASIN*	HARIMA BASIN
Uppermost	Mantidani Formation (50)	
	(discordance)	
Upper	Ibaragi Formation (70)	
Lower	Senriyama Formation (180+) Simakumayama conglomerate	Akasi Formation (120)**

The lower half is non-marine excepting a marine clay in the upper part of the Senriyama formation. The Ibaragi formation is characterized by regular alternations of the marine clays and sands or gravels. The Akasi formation bearing *Stegodon akashiensis* and *S. insignis sugiyamai* is equivalent to the Senriyama formation (Itihara, 1961).

The sudden change of the flora occurs between the upper and the lower parts of the Osaka group. The former contains archaic *Metasequoia* flora such as *Liquidambar formosana*, *Juglans megacinerea*, *Picea Koribai*, *Metasequoia distica*, *Pseudotsuga japonica*, *Cunninghamia Konishii* etc. On the contrary, the latter yields modern elements of Japonic type (Miki, 1941; Huzita, 1953; Itihara, 1961). There is little doubt about that the upper part of the Agé group containing the *Metasequoia* flora and *Stegodon akashiensis* can be correlated with the Senriyama formation.

There are found three horizons indicating the cool climate of the Ice Age by existence of the remains of boreal plants such as *Pinus koraiensis*, *Larix gmelinii*, *Menyanthes trifoliata* etc. M. Itihara (1961) suggested that the lowest of these horizons might correspond to the boundary between the Pliocene and the Pleistocene, which is drawn in the middle part of the Senriyama formation.

It deserves mention that the Osaka group was deposited under the influences of changes of sea-level due to the Quaternary climatic changes. But, at the same time, it should be noticed that the Osaka group was also affected by the Rokkô Movement.

The Paleo-Biwa group (Ikebe, 1933, 1960) deposited in the Oomi basin is divisible into two; the upper is the Katada formation (200m), and the lower is the Iga formation (400m). The Iga formation characterized by the *Metasequoia* flora seems to be equivalent to the Senriyama formation.

Outside the Kinki Triangle, the Second Setouti Series is very thin. For example,

* A drilling at the central part of the Osaka basin indicates that the thickness of the Osaka group reaches about 500 m.

** According to the drilling at Akasi.

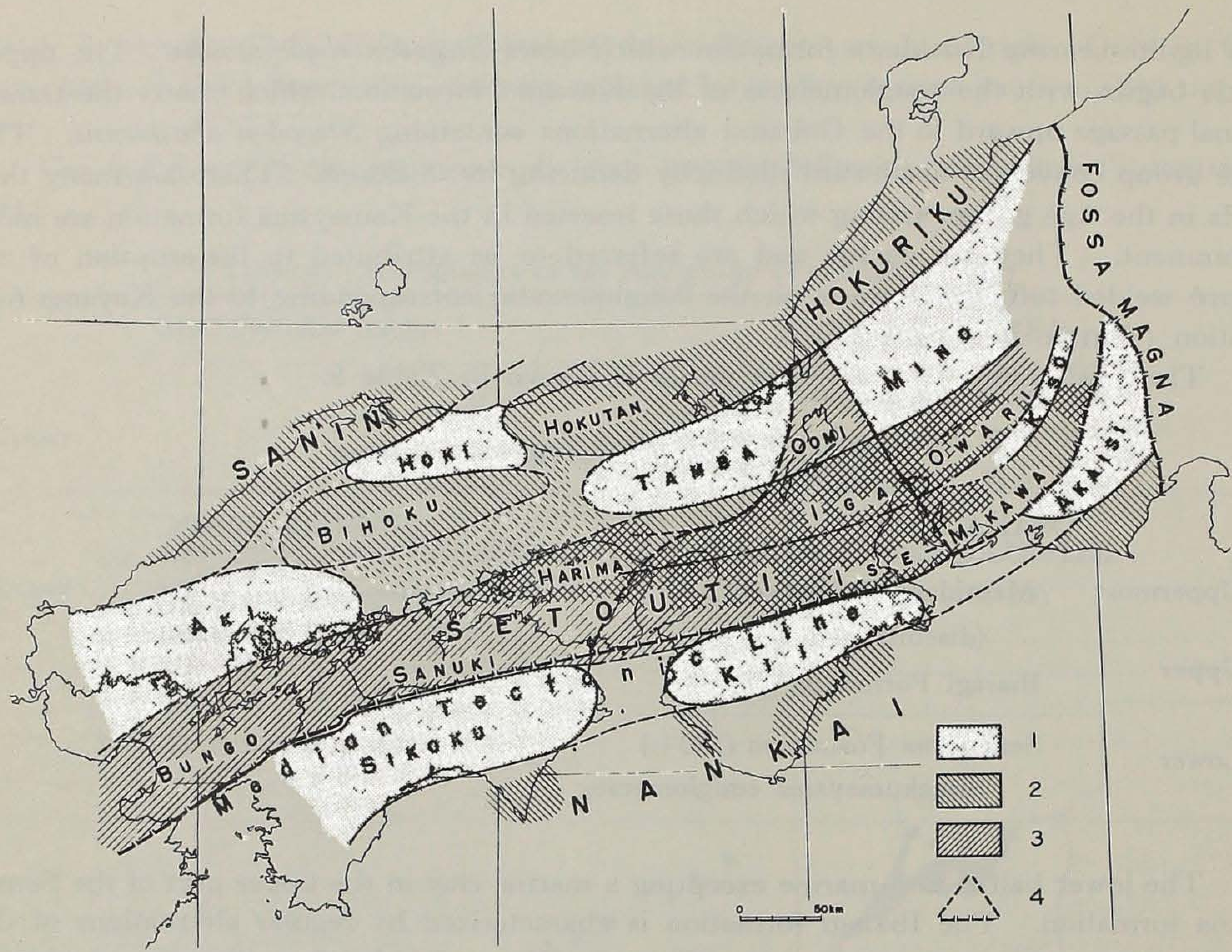

Fig. 4. Division of Southwest Japan into geologic province.
1: province of uplift. 2: depressional area in the Miocene. 3: depressional area in the Pliocene-Pleistocene. 4: Kinki Triangle.

the Seto group developing in the suburbs of Nagoya City (Owari area) mostly corresponds to the Agé group, but its thickness only attains more or less a hundred meters, and the unconformable relation is recognized between the upper, Yatagawa and the lower, Seto formations (MATSUZAWA and KATO, 1960).

In the Harima and the Sanuki areas, the conditions are similar to that of the Owari area. The Akasi formation (ITIHARA, 1960) in the Harima and the Mitoyo formation (SAITO and SAKAMOTO, 1960) in the Sanuki area are equivalent to the lower part of the Osaka group. The strata corresponding to the upper part of the Osaka group are absent in these areas.

In the Bungo area, the subsidence of the sedimentary basin becomes large again. The Oita group (SHUTO, 1953) in Kyûshû and the Guntyû formation (NAGAI, 1958) in Sikoku are the deposits of this basin. The upper part of the Oita group (Turusaki formation) has marine facies, which corresponds to the Himesima formation (KASAMA and HUZITA, 1955) in an isle of the northeast of Kunisaki Peninsula. There, thick marine strata resembling the upper part of the Osaka group are strongly folded with the axes of NNE-SSW direction, and are intruded by biotite-hornblende-andesites.

Geologic Provinces of Southwest Japan during the Late Cenozoic and their Relationship with the Basement Complex

Based upon the foregoing brief descriptions and discussions, the writer intends to define major geologic provinces of Southwest Japan during the Late Cenozoic Era and

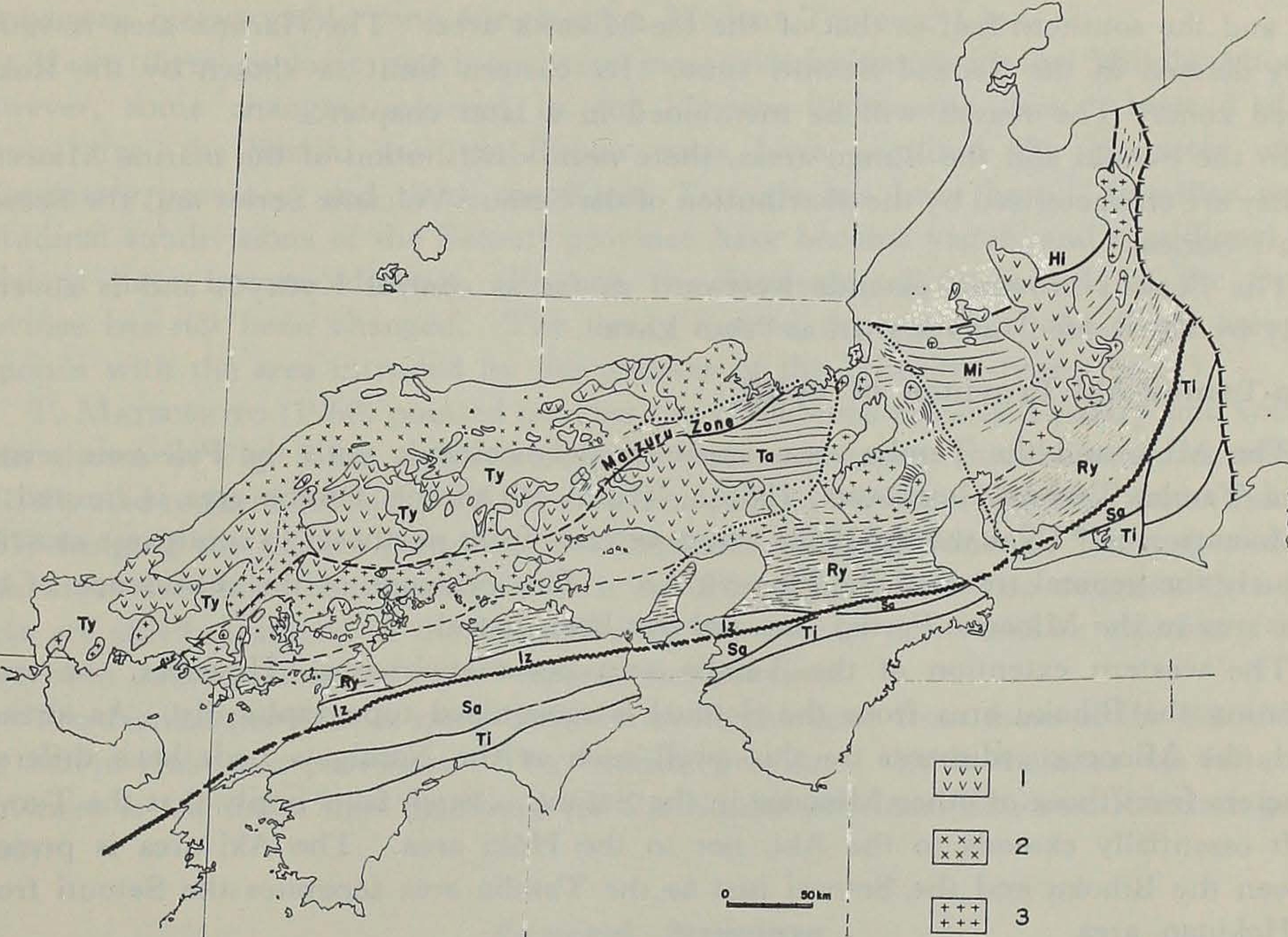

Fig. 5. Division of the basement rocks in Southwest Japan.
1: Cretaceous acid volcanic rocks and their pyroclasts. 2: Cretaceous granites of San'in type. 3: Cretaceous granits of Hirosima-type. Hi: Hida Complex. Ta-Mi: Tamba-Mino Paleozoic Tarrain. Ry: Ryôke Zone. Ty: Tyûgoku zone of Paleozoic. Ti: Titibu zone of Paleozoic. Sa: Sambagawa metamorphic zone. Iz: Cretaceous Izumi group.

subdivisions of these provinces. Figs. 4 and 5 may help the explanation.

Setouti Province of depression

The southern boundary of the Setouti province approximately coincides with the Median Tectonic Line, and the northern boundary mostly corresponds with the northern limits of the Cretaceous granites of Hirosima-type* (KOJIMA, 1953, 1954; H. YOSHIDA, 1961). The northern boundary cannot be drawn by distinct tectonic line or zone, but almost coincides with the boundary between the Paleozoic terrain and the above cited granites.

This province is divisible into two subprovinces, especially in the eastern half; namely Iga-Owari area and Ise-Mikawa area, from the view-point of the features of the First Setouti Series. Sinking of the latter area was more intense than that of the former. The boundary between them may be drawn on the northern limit of the Ryôke metamorphic zone.

The Harima area is characterized by the Kôbe group and the Sikai formation. How-

* The age of the intrusions of these granites is regarded as the close of the Cretaceous or the beginning of the Tertiary.

ever, the northern half zone may be regarded as the western extension of the Iga-Owari area, and the southern half as that of the Ise-Mikawa area. The Harima area is rather clearly defined in the Second Setouti time. Its eastern limit is shown by the Rokkô sheared zone. The reason will be mentioned in a later chapter.

In the Sanuki and the Bungo areas, there is no distribution of the marine Miocene, but they are characterized by the distribution of the Setouti Volcanic Series and the Second Setouti Series.

The Setouti province extends westward as far as central Kyûsyû, and is covered widely by the welded tuffs known as "Aso Lava".

Mino-Tamba-Aki Province of uplift

The Mino and the Tamba areas approximately coincide with the Paleozoic terrain named Tamba Terrain (ICHIKAWA, 1956). The north of the Tamba area is limited by the Maizuru zone* (NAKAZAWA, 1958) which extends from northeast to southwest crossing obliquely the general trend of the Honsyû Arc. The evidence of the subsidence of the Oomi area in the Miocene Period has not yet been found.

The western extention of the Tamba area become obscure. However, the swell separating the Bihoku area from the Setouti is recognized topographically. As already stated, the Miocene sediments on this swell such as the Namigata beds have different characters from those of other Miocene in the Setouti. Such facts imply that the Tamba Uplift essentially extends to the Aki, not to the Hôki area. The Aki area is present between the Bihoku and the Setouti just as the Tamba area separates the Setouti from the Hokutan area.

Hokuriku-San'in Province of depression

The San'in and the Hokuriku areas are separated by a land mass of the Hôki area, which has a possibility to prolong toward northeast and to continue to the Mt. Hôdatu area in the Hokuriku province.

The Bihoku area has usually been considered to occupy a part of the Setouti sedimentary province. It is evident that the First Inland Sea connected the Bihoku area with the Setouti proper through the Harima area, inferred from the distribution of the marine Miocene sediments shown in Fig. 2. However, distribution of sea water is only a phenomenon controlled by relief of land surface. It had better to regard the Bihoku area as an extension of the Hokuriku-Hokutan province from the tectonic point of view.** In the Upper Miocene, this area was separated from the Setouti and took part in the depression of the San'in-Hokuriku province.

Akaisi-Kii-Sikoku Province of uplift

The zonal arrangement of the basement rocks is more distinct in the Outer Zone.

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* The Maizuru zone (MATSUSHITA, 1949) is characterized by zonal arrangement of the Upper Permian, the Triassic and the so-called Yakuno intrusive rocks.

** The reasons why the Bihoku area has been considered to belong to the Setouti are: first, the Bihoku group is very thin and is not so folded same as other Miocene of the Setouti province, and second, the "Green Tuff" characterizing the San'in-Hokuriku province is absent in this area. However, such features are inferred as the phenomena at the western end of the Hokuriku-Hokutan Depression. The existence of the augite-hypersthene-andesite and its pyroclasts which are situated to the south of the Tuyama basin is significant. They are partly colored greenish, but the detail is not yet known.

This province corresponds with the Paleozoic and the Mesozoic zones including the Sambagawa metamorphic zone fringing the Median Tectonic Line.

Above three geologic provinces were most discriminative in the Middle Miocene. However, some changes occurred in the Pliocene-Pleistocene time. Instead of the Bihoku area, the Sanuki and the Bungo areas have acquired the character of the sedimentary province, and then, the Kinki Triangle has been born. In other words, latitudinal subdivisions of the Setouti province have become vague, and meridional subdivisions have become distinct, although the fundamental framework of the Setouti province has not been changed. The newly formed depression of the Oomi area corresponds with the area intruded by the granites of the Hirosima-type (Fig. 5).

T. MATSUMOTO (1960) pointed out that the Cretaceous or early Tertiary acid volcanic rocks shown in Fig. 5 are almost absent in Northeast Japan, but they may correspond with the acid rocks of the Sichota Alin, which belongs to the Outer Volcanic Zone (SHATZKI, 1957) fringing the eastern margin of the northern Asiatic continent. He suggested that such areas are more continental in their nature. The writer also suggests that these rocks are chiefly confined in the Mino-Tamba province of uplift and its extension, which have been rather stable than the depressional province.

The Nankai province is quite different in its character from those of the Setouti and the San'in-Hokuriku provinces. The "Inside province" which includes the latter two provinces is a suitable unit matching for the Nankai province (Cenozoic Research group, 1960).

General Structure

General Statement

T. KOBAYASHI (1941) divided the crustal movements of the Setouti into two phases: "First Setouti Phase" and "Second Setouti Phase". He emphasized the discordance between the Miocene Series and the "Upper Pliocene Series", and considered that the block movement of the former phase occurred during the Pliocene and that the Sanukitoid rocks were the products of this phase. His "Upper Pliocene Series" corresponds to the writer's Setouti Volcanic Series. The Second Setouti Phase was assigned to the Late Pleistocene in age. His opinion should be re-examined based on the recent knowledge.

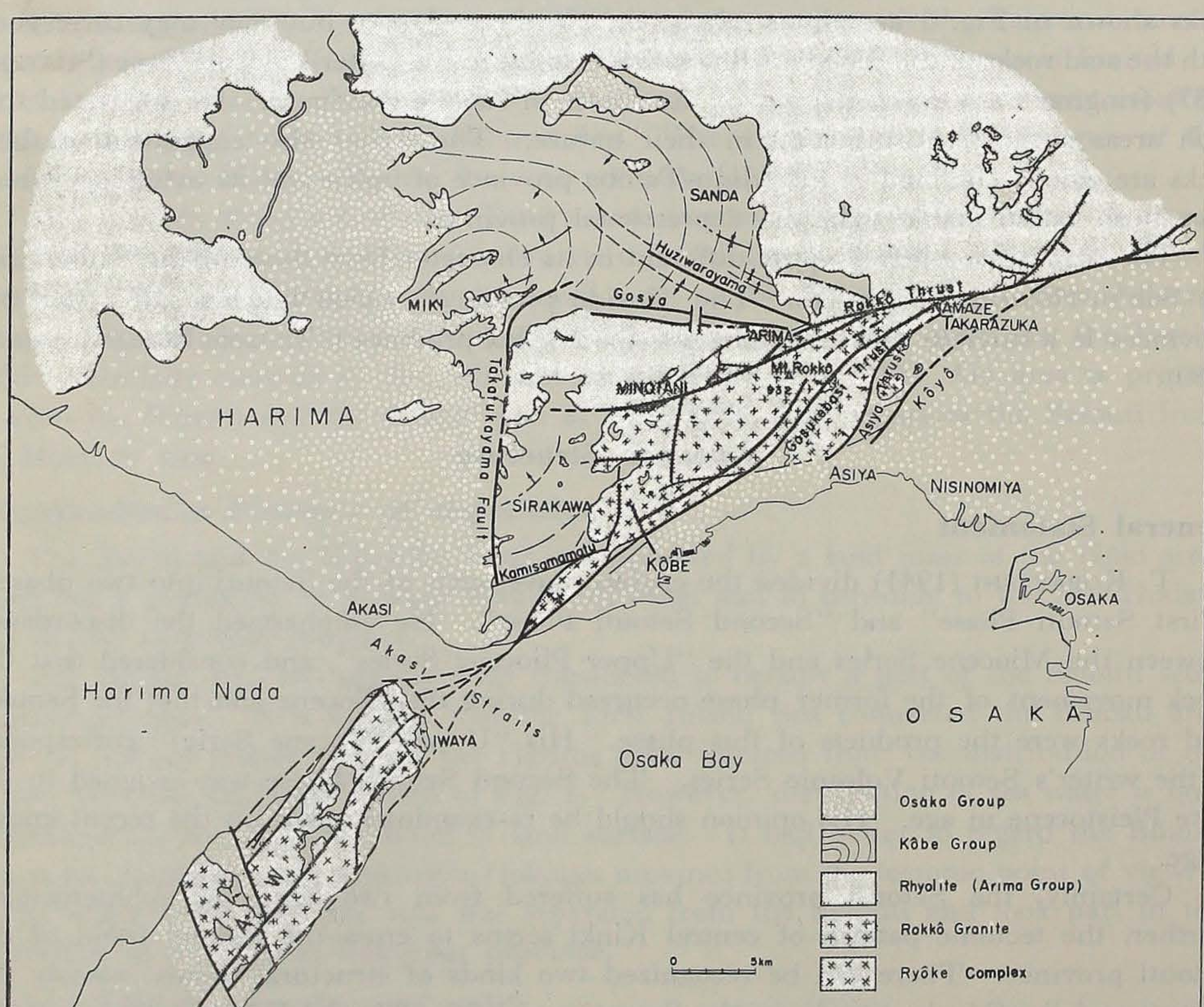
Certainly, the Setouti province has suffered from two times of submergences. Further, the tectonic pattern of central Kinki seems to cross the general trend of the Setouti province. There can be recognized two kinds of structural trends, namely the Setouti and the Suzuka trends, in the Setouti province. The relationship between both trends is clearly shown in the Rokkô range and its surroundings (Fig. 6). For the consideration of the tectonic development of the Setouti province, it is most important matter to clarify the mutual relationships between such geologic events or between these structures of different trends.

This chapter is devoted to the explanation about the structure of the Setouti trend. The structure of the Suzuka trend will be especially discussed in the next chapter.

Structure of the First Setouti Series

Structure of the Kôbe group The Miocene structures are well preserved in the Sanda basin (Fig. 6). Although the Kôbe group of this basin appears to be almost flat in many places, the tracing of tuffs revealed out that its fine structures are more or less complicated, being slightly undulated, cut by faults with E-W direction.

Each formation of the Kôbe group is exposed concentrically in harmony with the shape of the Sanda basin. The lower formations are exposed along the margin of the basin and the upper formations appear southwestward. The uppermost, Mituta formation directly abuts on the basement which is the barrier between the Sanda basin and the Sirakawa area. Moreover, the strata do not gradually dip to the center of the concentric pattern, but are inclined stepwise, alternating nearly horizontal parts and rather steep parts. Such facts mean that the sinking center of the sedimentary basin of the Kôbe group had been shifting southwestward, and that the above cited structures were syngenetic with the deposition of the Kôbe group.



Fig, 6. Structural map of the Rokkô range and its surroundings.
Thick lines indicate the structures of the Pleistocene, and fine dotted lines indicate the structures of the Kôbe group.

The subsidence of the southern basin around the present Akasi Straits commenced keeping in step with that of the Sanda basin. Contrary to the case of the Sanda basin, however, sinking center had been shifting to the northwest. It may be said that the Kôbe group, as a whole, accumulated in two sedimentary basins included in a broad synclinal depression, the axis of which extends in E-W direction, which is the general trend of the Setouti province.

Structural features of the Sedimentary basins The characteristics of the structure of the Kôbe group are more or less common in whole Setouti Depression. As already stated, the Setouti Depression in the Miocene can be divisible into the inner zone and the outer one: Iga-Owari area and Ise-Mikawa area. In the case of the Harima area, these two zones are included in one broad synclinal depression. Such a syncline is inferred to diverge into two parts in the eastern half of the Setouti Depression (Fig. 4). The anticlinal part between them has grown up to the present Kiso mountain land.

In these synclinal zones, there arrange local sedimentary basins such as the Sanda basin, in which comparatively thick sediments deposited. The areas preserving the First Setouti Series at present are presumed to have been such basins. However, the water of the First Inland Sea spread over whole Setouti Depression, in spite of the existence of such local basins.

Structure of the Second Setouti Series

In the Plio-Pleistocene, the Setouti province submerged again under fresh water. However, the above-cited two zones in the Miocene could not be recognized, but the meridional divisions became rather distinct especially in the Kinki Triangle. In the Kinki Triangle, the Second Setouti Series is rather thick and is rather strongly deformed by the Rokkô Movement, while it is almost flat or is only tilted in other areas.

For example, in Fig. 6, the Osaka group distributed along the southern foot of the Rokkô range is strikingly deformed and is displaced by the thrust movement of the Rokkô, while the one in the Harima basin, west of the Rokkô range, is only tilted gently southwestward and is covered by terrace or alluvial deposits.

In the Harima area, the Osaka group is little faulted compared with the Kôbe group. The Kamisamamatu fault, along which the Tainohata formation is juxtaposed against the Sirakawa formation of the Kôbe group, cannot be traced westward in the Osaka group.

Such a relation can be observed also in the Owari area, where the Toki gravel beds belonging to the upper part of the Seto group almost flatly rest on the slightly inclined Mizunami group. The fault cutting the latter are covered by the former. All of these faults are gravity-faults with the Setouti trend. It is no doubt that the faulting took place in the pre-Agé time.

The large difference between the location of the sedimentary basins of the First and those of the Second Setouti Series suggests a high degree of discordance between them. However, the Second Setouti Series, in most places, rests almost flatly on the First Setouti Series which is slightly undulated.

Summary of the Tectonics of the Setouti Depression

The arrangement of the geologic provinces of Southwest Japan is greatly in accordance with that of the structure of the basement. In some cases, the tectonic lines or zones can be recognized between each division, although it is not always so. The younger faults are apt to be superimposed on the older ones. The old faults, in some cases, suffer so much movement as to mask the evidence of their earlier existence. It is not easy to clarify the significance of these tectonic lines for the development of the Setouti Depression.

The southern limit of the Setouti Depression coincides with the Median Line approximately, but there is no positive evidence to prove that this old tectonic line moved again to creat the Setouti Depression in the Miocene Period, because it has moved at the culmination of the Rokkô Movement. However, it is probable that the fault movements took place along the Median Line in the Ise-Mikawa area where the sinking was most prominent in the Miocene.

The boundary between the Iga-Owari area and the Ise-Mikawa area almost coincids with the boundary between the Ryôke zone and the Cretaceous granites. Although this boundary was very obscure, the existence of tectonic line between them has recently been confirmed in the Suzuka range (OGATA, 1959) or in the Owari area (KATADA, 1961). These tectonic lines approximately coincide with the faults limiting the southern margin of the First Setouti Series of the Iga-Owari area. The Miocene of this area is considered to be deposited in the synclinal depression down thrown along these faults. Then, these faults moved on during and after the deposition of the First Setouti Series.

No prominent tectonic line can be confirmed between the Tamba-Mino Uplift and the Setouti Depression. The distribution of the Bihoku group is limited in the western margin by the Yamazaki tectonic line, which is newly described by K. NAKAZAWA and K. SHIMIZU (Geologic map of Hyôgo prefecture, 1961). It may be inferred that the connection between Harima and the Bihoku areas by the First Inland Sea was controlled by this tectonic line.

The origin of the Setouti Depression, as a whole, may be regarded as the down-warping due to the differential movement of the zonal rock bodies of the basement. Such a movement not only occurred in the Miocene, but also reappeared in the Pliocene-Pleistocene. The previously mentioned relationship between the First and the Second Setouti Series suggestes that the repetition of down-warping rather gently occurred accompanied by a small number of faults.

These faults are considered to take place owing to the gravitational fall of the median zone of geanticlinal upheaval of Southwest Japan. But most of them superimposed on the faults which created the sedimentary basins of the First Setouti Series.

Tectonic Significance of the Kinki Triangle

General Statement

The structures in the Second Setouti Epoch are characterized by a large number of thrusts same as those of the Rokkô range. They are concentrated in the Kinki Triangle as ahown in Fig. 13.

The effects of these faults are strongly reflected to the basin-and-range topography of central Kinki. Formerly, such topography was simply attributed to a series of horsts and grabens, chiefly based on reading of the topographic maps. As the tracing of faults were carried on, however, the different considerations have been born (NAKAMURA, 1934; MAKIYAMA, 1926). Recently J. MAKIYAMA (1956) has introduced the concept of the foundation folding, and has discussed the tectonic process of the growth of the cylindrical thrust by means of the example of the Ikoma range.

The writer, in this chapter, intends to discuss about the structures of the Kinki Triangle on the basis of the survey of the Rokkô range.

Thrust System of the Rokkô Range

The faults occured along the Rokkô range diverge westward from the eastern end of the range, and then converge to the Straits of Akasi* (Fig. 6). They are all thrust faults.

* The faults of the submerged part of the Straits of Akasi are interpreted from the results of the sonic survey (IZAKI, 1960).

The Rokkô thrust running along the northern flank of the range is most important in distinguishing the Kinki Triangle from the Tamba massif. It stretches straight and forms the steep fault-scarp along the nothern side of the Rokkô range. The thrust plane dips to the south. From the Rokkô thrust diverge many segments. They die out quickly in the Tamba massif.

Contrary to the Rokkô thrust, all faults running along the southern side of the Rokkô

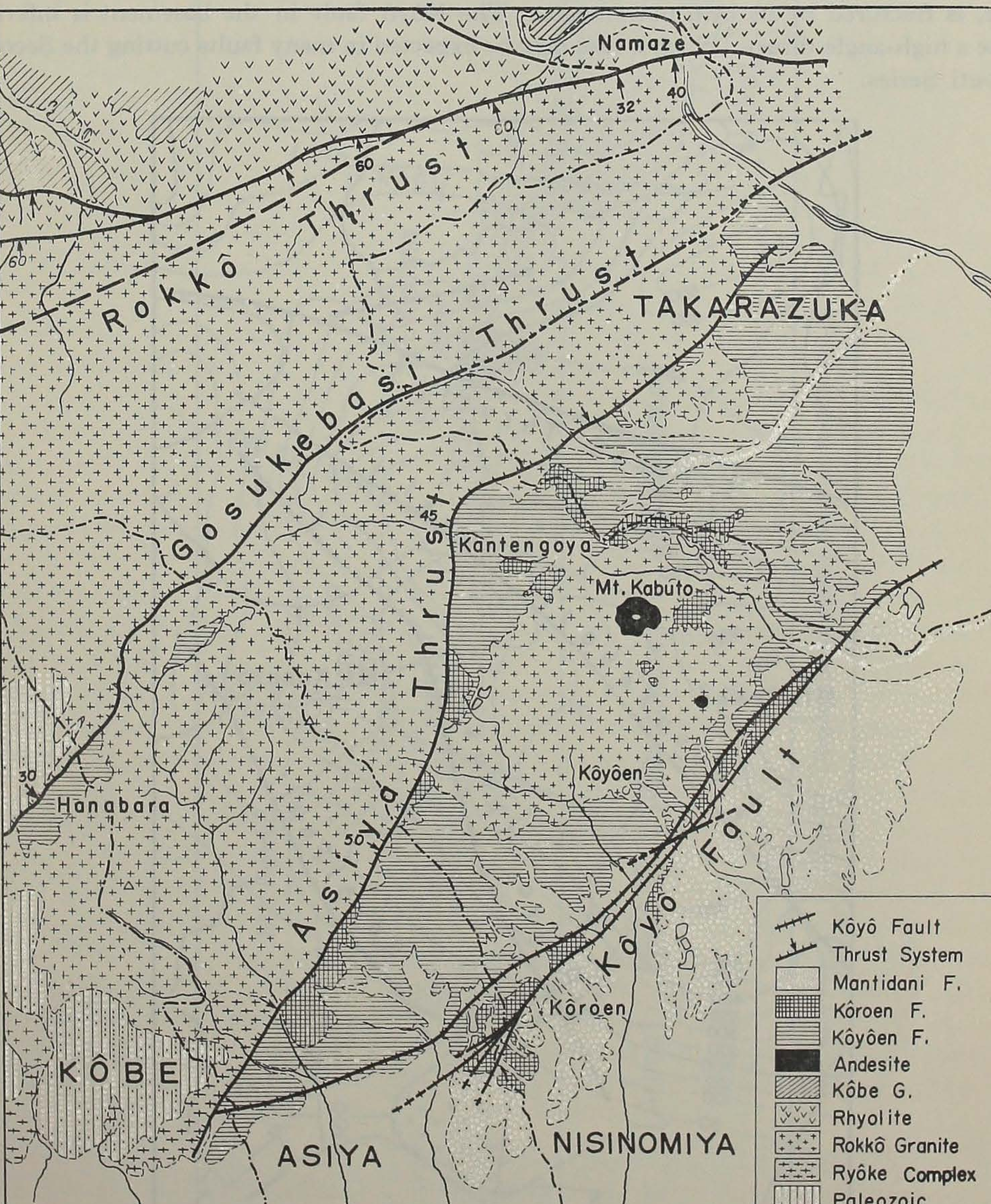


Fig. 7. Geologic map of the eastern par: of the Rokkô range. (about 1/50.000) Terrace deposits are excluded. The Kôroen formation is equivalent to the Ibaraki formation adding together the uppermost part of the Senriyama formation

range dip to the north or to the northwest. Namely, all thrust planes dip to the inner side of the range in opposite directions on both side of the range (Fig. 9).

The fault plane of the Kôyô fault running in the Osaka group is not simple. It is nearly vertical in most places, but appears reverse-type or normal-type locally. At least, however, small fractures of reverse-type indicating the effect of compressive stress are seen along the main fault. Deformations of the soft rocks resting on the rigid basement are complicated; the former is influenced by the movements of the latter, but at the same time, is fractured by its own movements. The Kôyô fault in the basement is inferred to be a high-angle thrust. Such a case may be expected in many faults cutting the Second Setouti Series.

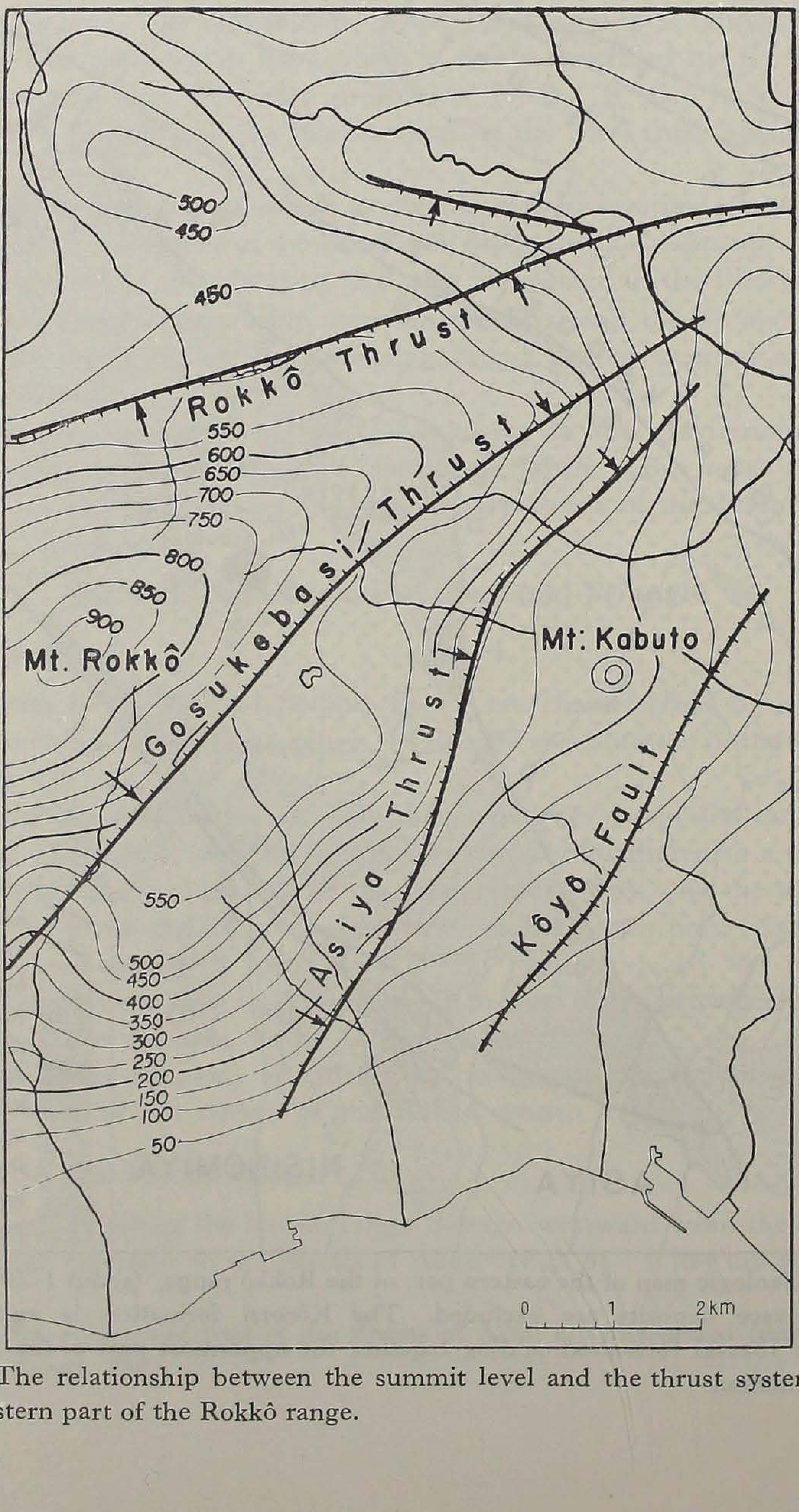


Fig. 8. The relationship between the summit level and the thrust system in the eastern part of the Rokkô range.

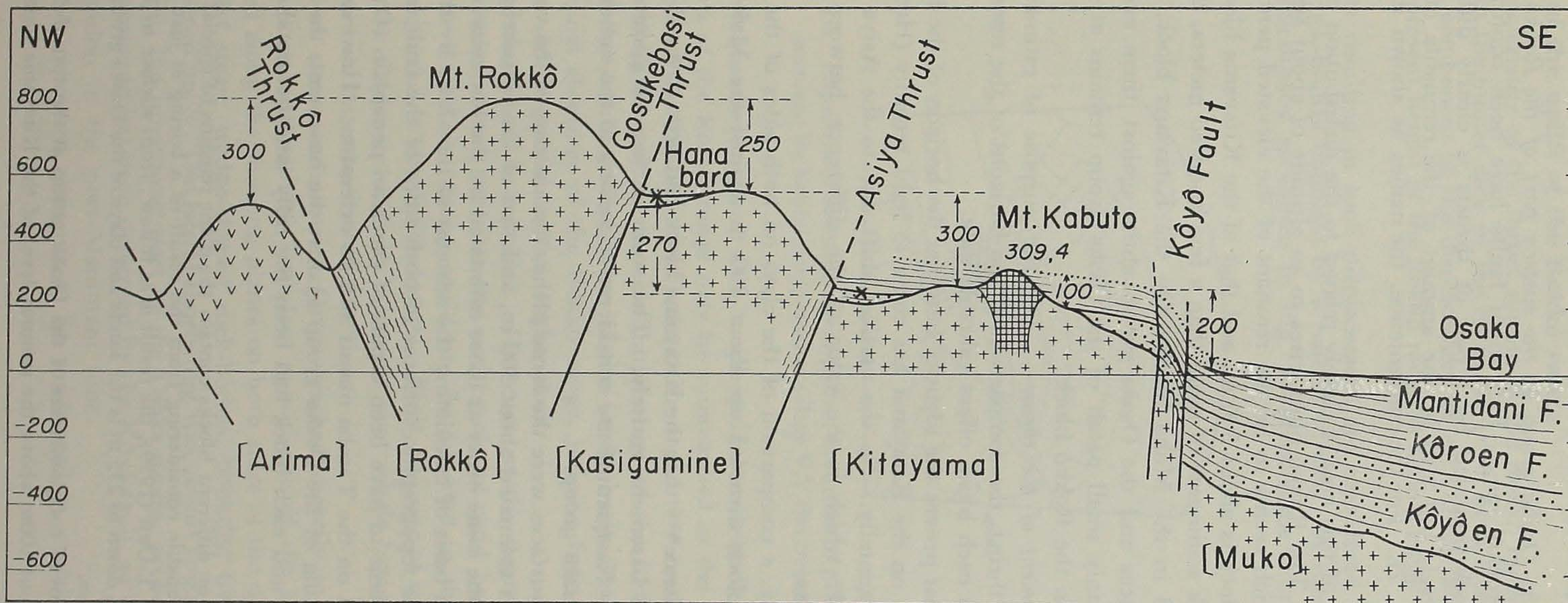


Fig. 9. Diagammatic profile of the Rokkô range.

Amount of the displacement along the thrust

Distribution of the Osaka group in the eastern part of the Rokkô range In the eastern part of the Rokkô range, four main faults have been confirmed. It is noteworthy that each block bounded by a pair of thrusts is clearly different not only in altitude above sea-level, but also in the amount of the remnants of the Osaka group distributed on it (Fig. 7). For the convenience, the names as shown in Fig. 9 are given to these blocks.

The topography of this area is closely related to the distribution of this fault system as shown in Fig. 8. The Rokkô block rises to an altitude of about 800 m and preserves the worn surface which seems to be the remnant of the elevated peneplain. The hight of the Kasigaminé block is about 500 m, and that of the Kitayama block is about 200 m.

Covered by thick sediments of more than a few hundred meters, the granite of basement is not exposed in the Muko block. On the Kitayama block, basement granites exposed in some places and the Osaka group abuts against them everywhere. In the Kasigaminé block, only small patch of the Osaka group remains at Hanabara. There is no Osaka group on the Rokkô block.

Vertical displacement of the thrust For the purpose of estimating the total displacement along the thrust, the comparison of the horizons of the remnants of the Osaka group distributed on each block offers valuable data.

An evidence* that proves the identity between the horizon of the bed on the Kasigaminé block and that on the Kitayama has come to light recently (HUZITA, 1961). Both beds lie almost horizontally. So the vertical shift due to the Asiya thrust is assumed to be about 270 m** which is the value of the difference between the hights above sea-level of both beds.

In the same way, a comparison of the clays on both sides of the Kôyô fault shows that the Kitayama block thrusted up about 200 m against the Muko block in vertical component.

There is an evidence*** that the Kitayama block had been covered by the Osaka group so as to conceal the basement entirely. The worn surface of granite of the Kitayama block and that of the Kasigaminé are considered to belong to the same peneplain stripped by erosion of the Osaka group.

Provided these surfaces were the same plane, the amount of the vertical displacement of the Asiya thrust is estimated about 300 m, and that of the Gosukebasi is about 250 m. These values are in the same order as those estimated by the horizons of the Osaka group. This fact may give a basis of calculating the amount of the shifts by the difference of the altitudes between the topographic surfaces of both sides of the fault in this area.

Such a plain seems to have been a part of the Kibi peneplain (OTUKA, 1937), which is widely distributed on the Tamba massif and its extension. However, considered from the prominent abutting of the Osaka group against the basement, the peneplanation had not been completed and each block had been the hilly land before the deposition of the

* Both beds resting on different blocks contain the plant remains of special type (HUZITA, 1961).

** This value is reasonable considering from the result of a boring at just northern side of the thrust. According to T. UEJI (1959), the result is as follow; from surface to 35 m is granite, then, through crushed zone, down to 235 m is the sands and clays of the Osaka group, and further downward granite reappears.

*** There is a remnant of conglomerates of the Osaka group at the top of Mt. Kabuto, a dome of andesite, rising about 100m above the summit level of the Kitayama block.

Osaka group.

Tectonic process of the uplift of the Rokkô range

The chief characteristics of the thrust system of the Rokkô range; first, the opposite thrusts which dip to the innner side of the range occur on both sides of the range, and second, the vertical component of the displacement of each thrust attains more than 200 meters, that is, the present height of the Rokkô range is almost equal to the result of these thrust movements.

The movements resulting in such displacement are considered to be the uplifts of the wedge-shaped rock-bodies bounded by a pair of thrusts. A model experiment performed by V. V. Beloussov as shown in Fig. 10 gives some hint as to the possible

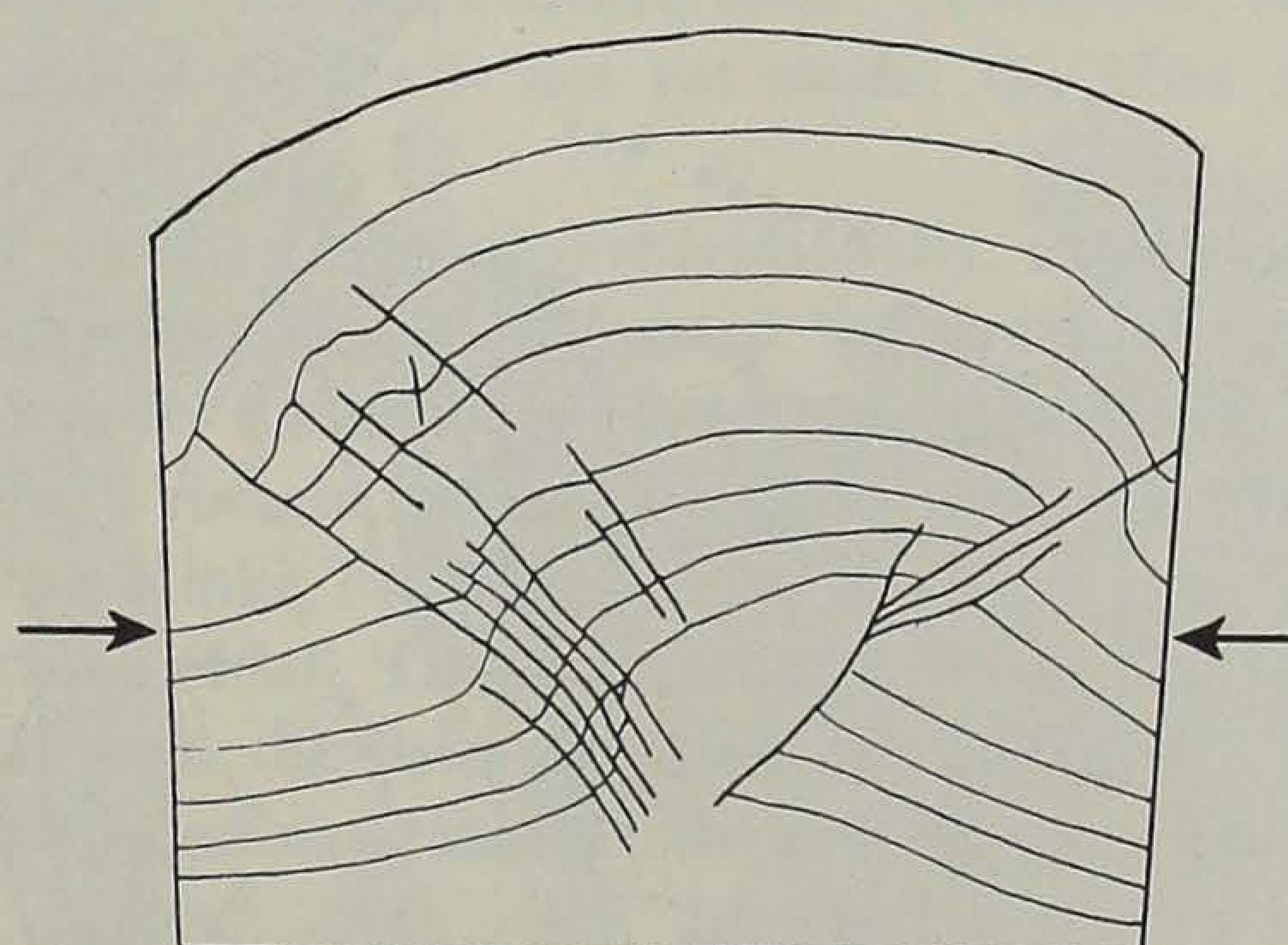


Fig. 10. Experiment showing shear planes occurred in plastic material by lateral compression (after V.V.Beloussov).

mechanism of the "squeezing up" of such a sphenoidal rock-body. The hypothetical course of the genesis of the Rokkô range may be summarized in the following.

1) At the close of the Pliocene, the Osaka basin began to subside and to accumulate the lower part of the Osaka group. In this initial stage of the foundation folding, the absolute amount of the synclinal depression of the Osaka basin was larger than that of the attendant anticlinal elevation of the Rokkô range, judging from the preservation of the remnants of the old peneplain on the Rokkô block.

2) The basin continued to subside . However, as the depression increased, the stronger the compressive elastic stress at the surface of the rigid basement of the basin became. Hence, the lateral shortening could not be adjusted in the depressional part, but could only be adjusted in the uplifted part. Then, the rate of subsidence decreased. The upper part of the Osaka group, which spreads over whole basin with uniformity, is inferred to be formed in this transitional stage.

3) In the next stage, compressive forces reached directly to the anticlinal part, elevation of which increased without attendant subsidence of the basin. At this time movements occurred along the shearing planes on both sides of the uplift.

4) In the last stage, wedge-shaped rock-bodies, bounded by a pair of shearing planes, were "squeezed up." The lateral shortening was almost complete. The gravelly Mantidani formation, the uppermost part of the Osaka group, probably accumulated in this stage. This formation has been deformed by the Kôyô fault, so the thrust movement reached its culmination in the post-Manitdani time.

There are three important elements to be condisered in explaining the fan-shaped distribution of the thrusts: 1) the principal axis of regional stress, 2) initial swell of basement, and 3) old tectonic lines or boundaries of rock-bodies within the basement.

The thrust system of the Rokkô range can be understood by these elements. The Rokkô, Kasigaminé and the Kitayama blocks had been the initial hills of the basement. The Rokkô thrust has been broken out along the boundary between the granite and the

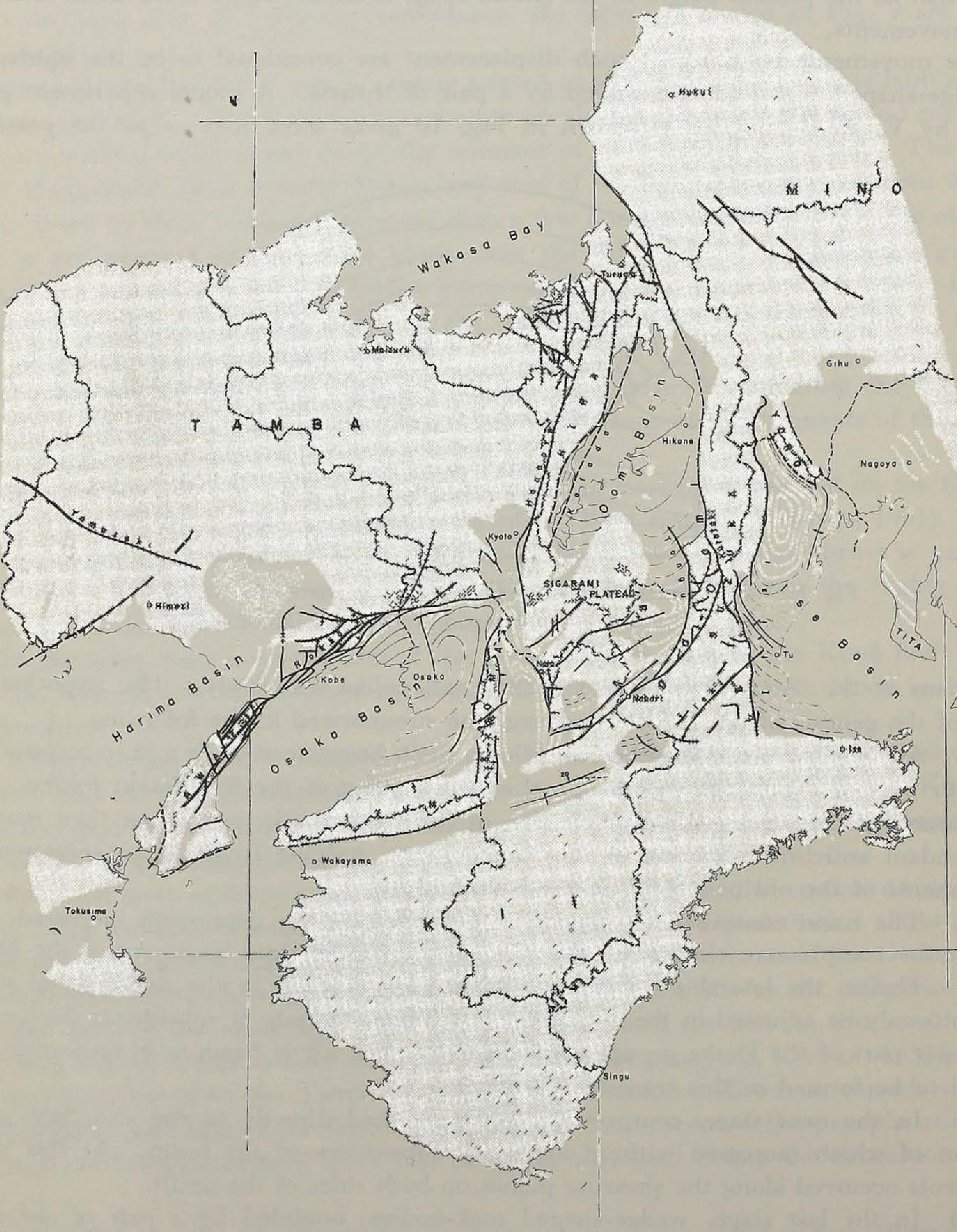


Fig. 11. Tectonic map of the Kinki Triangle. (about 1/1,250,000)
Thick lines show fault-system related to the Rokkô movement. Fine lines indicate roughly the strike lines of the Second Setouti Series. Broken line: lower part of the Agé group (H). Dotted line: upper part of the Agé group and the lower part of the Osaka and Paleo-Biwa groups (I_1). Contineous line: upper part of the Osaka and Paleo-Biwa groups (I_2).

rhyolite bodies. Moreover, it should be noted that the Rokkô range runs along the fringe of the Tamba massif. Strong local stress was concentrated at such position. This may be a reason why Rokkô range runs obliquely to the general trend of the ranges of central Kinki such as Ikoma and Suzuka.

Fault system of the Kinki Triangle

Fig. 11 indicates the distribution of the faults took place by the Rokkô Movement. It is clear that most of the mountain ranges in the Kinki Triangle have essentially the same characters as the Rokkô.

The mountain land between Wakasa Bay and Lake Biwa, the apex of the Triangle, is severely faulted, so is called "Wakasa crushed zone" (TSUKANO, 1955, ISOMI and KURODA, 1958). Although the detailed survey is not yet made, the Hira range is probably same as the Rokkô in its construction.

In the central part of the Triangle, meridionally extending mountain ranges are remarkable such as Suzuka and Ikoma. Toward the south, the faults running along the foots of these ranges curve to the eastern or western directions. That is, they become parallel to the base of the Triangle, which coincides with the Median Line.

Crowded faults in the Kinki Triangle can be analyzed into four systems. The first is perpendicular to the base (Itisi, Tongu, Kurotaki, Roppyaku and Ikoma etc.). Other three systems are parallel with the three sides of the Trianlge. The folding axes of the Agé group, which is distributed near the eastern side of the Triangle, are also not exceptional.

Geologic situation of the Kinki Triangle

Fig. 13 may help to understand the geologic situation of the Kinki Triangle. This map suggests that the Kinki Triangle is caught among three stable massifs in thin black color, which have been less fractured than the Triangle by the Rokkô Movement. The influences of the Rokkô Movement were strongest in the Triangle.

The contrast between the fault-folded Triangle and the surrounding stable massif can be seen typically in Fig. 6. Some segments of the Rokkô thrust diverge into the Tamba massif, but die out quickly. The Osaka Group of the Harima area (Akasi formation) is merely tilted westward gently, although that of the Osaka side is strongly disturbed by many thrusts.

It is very difficult to find out younger fault in the Tamba massif which is composed of the Permo-Carboniferous rocks. However, this massif well preserves the old peneplain, so is inferred to be too rigid to be fractured by the Rokkô Movement. The Hira and the Rokkô ranges are regarded as the sheared zone between the Tamba-Harima massif and the Kinki blocks.

Where the boundary between the Mino-Owari and the Kinki blocks should be drawn is an important problem awaiting to be solved. The Seto group, composing the hilly land of the environs of Nagoya City, is gently tilted to the southwest and is covered by the alluvial deposits. On the contrary, the Agé group which is distributed between the Suzuka and the Yôrô ranges is strongly affected by the Rokko Movement. It is probable that the boundary should be drawn in any place overlain by Alluvium along the eastern side of the Yôrô range. The faults of NW-SE direction which are parallel to the eastern side of the Kinki Triangle must be noted. The recent earthquake faults are apt to occur in this direction, such as Neodani (KOTO, 1893) and Hukui fault (NASU, 1947). The recent re-survey of the triangulation points shows that the Mino-Owari massif is moving northwestward and the Kinki blocks to opposite direction (Geographical Survey Institute, 1957).

The southern side of the Triangle approximately coincides with the Median Tectonic Line, along which wide valleys develop; the Yosino River in Sikoku, and the Kino-kawa in Kii. Along the northern sides of these river plain, the Izumi massif composed of the Cretaceous Izumi group thrusts up on the Syôbudani and the Ooyodo formations which are equivalent to the lower part of the Osaka group (KAWATA, 1939; IMAMURA, 1950; SHIIDA, 1953). These thrust planes coincide with the Median Line.

Thus, the Kinki Triangle is limited by the sheared mountain ranges along the western side, by recently active zone along the eastern side. and by the Median Line along the southern side.

Development of the Kinki Triangle

Main sedimentary basins of the Kinki Triangle are the Osaka, Oomi and the Ise basins, which are filled by the Osaka, Paleo-Biwa and the Agé groups respectively. The equivalent of the lowermost part of the Agé group does not exist in any other basins as far as known. The upper part of the Agé group corresponds to the lower part of the Osaka group and of the Paleo-Biwa group (Fig. 11).

In the Ise basin, the lower part of the Agé group is widely exposed in the southern half of the basin, and it becomes thinner northward missing the lowest part in the northern half, whereas, the upper part spreads over the northern half of the basin increasing its thickness (TAKEHARA, 1961).

In the Oomi-Iga area, the Iga formation, the lower part of the Paleo-Biwa group, is confined in the Iga basin, and the overlying Katada formation is chiefly distributed in the Oomi basin. The same tendency is recognized in the Osaka basin.

The following process of the development of the Kinki Triangle is inferred from above cited facts.

1) At first, sinking of the sedimentary basin of the Second Setouti Series began in the Ise area. The center of sinking shifted toward the eastern side of the Triangle, as interpreted from the relationship between the lower and the upper parts of the Agé group.

2) The depression of the Oomi and the Osaka sedimentary basins began in the stage of the deposition of the upper part of the Agé group, and continued to later stage. The shifting of the centers of the basins was toward the western side of the Triangle.

3) The Suzuka range bounded by the Itisi fault and the Iga-Oomi Great Fault is the most important uplift, which have accelerated the differentiation of the sedimentary basins. The Sigaraki Plateau is the second-class uplift dividing the Oomi and the Oosaka basins.

The regional stress of the Rokkô Movement in Kinki is compressional and the principal axis of it may be latitudinal, considered from the characters of the thrust system and the above mentioned tectonic process.

The fact that the Oomi area was newly subsided by the Rokkô Movement may support above consideration. The Mino and the Tamba massifs are the old rigid terrains composed of Paleozoic rocks which underwent the main folding in the pre-Cenozoic time. The general trends of their structures are strongly disturbed in the Oomi area, which also coincides with the area intruded by the granites traversing the Mino-Tamba terrain (Fig. 5). These facts imply that the Oomi area had been a weak zone tectonically from the pre-Cenozoic time. Owing to such original structures, this area has yielded to deforming stress of the latitudinal trend rather easily than that of the meridional trend.

In contrast with the Inner Zone, the Kii massif belonging to the Outer Zone has resisted to such a stress, owing to its distinctly zonal arrangement of the rock-bodies with the latitudinal trend. This may be one of the reasons why most of faults running meridionally in the middle part of the Triangle curve to the latitudinal direction, as they approach to the base of the Triangle.

The culmination of the Rokkô Movement which was represented by the violent thrust movements occurred after the deposition of the Mantidani formation, and ceased before the deposition of gravels of the Higher Terrace. Although the time of thrusting determined around the Rokkô range is not necessarily adapted to the other thrusts strictly, it is evident that all thrusts of the Kinki Triangle moved in the post-Agé time at least. The uplift of the mountain areas may have been continuing after the culmination of the Rokkô movement. There are found a few outcrops which may show the thrust planes cutting the gravel beds of the Higher Terrace at the northern side of Mt. Rokkô. The altitude of the terrace has a tendency to reach rather higher level around the mountain ranges.

The culmination of the Rokkô Movement may roughly correspond to the "Pasadenian Orogeny" of R. REED (REED and HOLLISTER, 1936) or the "Pasadenian Phase" of H. STILLE (1955) in California.

Rokkô Movenemt in Southwest Japan

Rokkô Movement in Southwest Japan

The Rokkô Movement has given its influences not only to the Kinki Triangle, but also to other massifs in various types of deformation. To the west of the Triangle, the Rokkô Movement is expressed as the weak foundation folding with faulting, the axes of which are parallel with the Rokkô range. Harima, Hiuti and Iyo Nadas* correspond to the synclinal parts, and the areas crowded by samll isles between two of these Nadas may be the anticlinal parts of the foundation folding, the wave length of which is about 80 km.

Especially in Himesima, the marine strata corresponding to the upper part of the Osaka group are strongly folded with axes of NNE-SSW trend. The Quaternary volcanoes belonging to the West Volcanic Belt (SUGIMURA, 1959, 1960) erupted through these strata at their anticlinal parts (KASAMA and HUZITA, 1955). The West Volcanic Belt extends northeastward. Along the southern margin of this volcanic belt in Hoki area, thrust movements took place (KAWAI, 1957, IMAMURA, 1953). As a matter of interest, it must be pointed out that the trend of the axes of this foundation folding coincides with that of the Ryûkyû Arc.

To the east of the Triangle, faults can be classified into two systems. The system of NE-SW direction is predominant in the Owari-Mikawa province, while that of NW-SE direction is seen in the Mino massif. The formar is parallel with the Setouti trend, but it must be noted that the trend of the Setouti itself curves to the northeast in this area. Some of the faults of this system are high-angle thrusts (MATSUZAWA and KATO, 1961). The Ina basin, a typical intermount basin along the Median Line, has same characters of the structure as those of the basins in the Kinki Triangle. The massifs of the Kiso and the Ina ranges thrust up toward the basin from both sides (ARII, 1956).

* Nada means a "rough sea" in Japanese.

The nature of the faults belonging to the latter system is not yet clear. The Adera fault running through the middle part of the Mino area is confirmed to disturb the higher terrace deposits. The displacement along this fault may reach more than 800 m (KAWATA, 1961). As already stated, there are also some evidences that the recently active belt may exist between the Mino and the Oomi massifs in this direction.

Bounded by the so-called "Itoigawa-Sizuoka Line" in the east, Southwest Japan is against the Fossa Magna. Along the boundary between these two large geologic units of Japan, there develops distinct tectonic zone which is characterized by violent thrust movements. The thick strata of the Miocene series develop along the eastern side of the Akaisi range, which is the highest (3192 m at the highest point) in the Japanese Islands except for the Quaternary volcano. They are strongly folded and are cut by many clean-cut thrusts (MATSUDA, 1961). All of these thrust planes dip to the west. The Akaisi massif thrusts up against such Tertiary terrain along the Kobutizawa-Sizuoka thrust, which extends for more than 100 km in the northwest direction. The youngest of this folded Tertiary belongs to the Upper Miocene in age, so it can be inferred that Kobutizawa-Sizuoka thrust moved actively corresponding to the Rokkô Movement, although its origin may be older.

Additional discussions on the Rokkô Movement

There is no doubt that the essential difference exists between the movement of the Miocene and that of the Pleistocene. The former is represented by the structures of the Setouti trend, and the latter is by those of the Suzuka trend.

How was the process of this change? A series of the paleogeographic maps in the Pliocene-Pleistocene may give an answer for this question (Fig. 15). The distribution area of the Pliocene sediments (lower part of the Agé group) elongates in the Setouti trend. But the fact that the sediments deposited between the Suzuka and the Yôrô ranges are the thickest, indicates the appearance of the structure of the Suzuka trend. Then, the Plio-Pleistocene sediments corresponding to the lower part of the Osaka group spread over whole Setouti province. That is, the structures of the Setouti trend were superior to those of the Suzuka trend. In the Pleistocene, the condition was quitely reverse. The sediments corresponding to the upper part of the Osaka group were confined only to two series of basins, namely the Osaka-Oomi and the Iyo-Bungo basins.*

The depression of the Setouti trend reappeared in the H age and reached the maximum stage in the I_1 age, and then declined in the I_2 age. On the contrary, the structures of the Suzuka trend have become prominent in the last mentioned age, although their embryo can be recognized in the H age (Pliocene).** In the post-Mantidani*** time, the foundation folding of the Suzuka trend reached to the maximum stage, which corresponds to the culmination of the Rokkô Movement. It is noteworthy that the change of these movements has occurred in the Plio-Pleistocene, but that it is not represented as the unconformity within the Second Setouti Series.

* It can be expected that the marine strata corresponding to the upper part of the Osaka group develop in the submerged areas such as Harima or Hiuti Nadas.

** It is noteworthy that the eruption of the Mikasayama andesite, which is situated at the eastern margin of the Nara basin, took place in the I_1 age in accordance with the tectonic line of the Suzuka trend (KOKAWA, 1954).

*** As already stated, the ages of all of the thrust movements in Southwest Japan do not necessarily coincide strictly with this time which is determined in the Rokkô range.

The Rokkô Movement has performed the groundwork of the main topography of Southwest Japan. Southwest Japan can be divided into three topographic provinces especially in the Inner Zone; Tyûbu region between the Fossa Magna and the Kinki Triangle, Kinki region coinciding with the Kinki Triangle, and Tyûgoku region occupying the west of the Triangle.

The dotted lines in Fig. 13 indicate the limits of distribution of altitude of the land-relief. These lines run parallel to the "Itoigawa-Sizuoka Line" of the Suzuka trend in Tyûbu region, whereas they run parallel to the Setouti trend in Tyûgoku and Sikoku regions.

As already discussed, the Rokkô Movement can be regarded as the combination of two types of movements. In Tyûbu region, uplift of the Suzuka trend is superior to that of the Setouti trend especially in the eastern front against the Fossa Magna. In the case of Tyûgoku, however, the condition is reverse. The culmination of the Rokkô Movement, which has completed the structures of the Suzuka trend, has been expressed only by the weak foundation folding with a number of faults.

A. SUGIMURA (1959, 1960) distinguished two volcanic belts matching to the island arcs: "East Japan Volcanic Belt" and "West Japan Volcanic Belt". He also pointed out that the distribution of the intermediate and deep seismic foci has the same trend of the elongation as that of the above mentioned two volcanic belts (Fig. 1).

It may be safely assumed that Tyûbu region, as the frontal massif against Fossa Magna, is influenced by the movement forming the Mariana Arc, and that the structures of Tyûgoku region are related with the activities along the Ryûkyû Arc. The Kinki Triangle can be understood as the junction of these movements.

Von BUBNOFF (1954) pointed out the importance of Diktyogenese as one of the types of crustal movements. He insisted on separating it from Epirogenese and Tektogenese. The crustal movements of the Setouti province have many common features with his Diktyogenese on the mobile shelf in the following points.

1) The basement is not the homogeneous gneissose complex, but the secondary basement composed of various kinds of the Paleozoic and the Mesozoic rock-bodies, strongly folded and intruded by plutonic rocks.

2) The falt-folded structures are predominant, as typically shown in the Kinki Triangle.

3) Deformations of the same type occur repeatedly in the same area.

4) The younger structures are distinctly controlled by the older structures of the basement.

5) The structures are clearly reflected in the main relief of the present land-surface.

However, the structures of the Suzuka trend cross those of the basement in many places, although they are locally controlled by the structure of the basement as shown in the Oomi area. Apparently, the crustal movement forming these structures is very drastic and is considered to be essentially different from the foregoing movements. In Southwest Japan, such movement has become distinct in the Pleistocene, but in the Fossa Magna, the movement of the same trend is said to have started in the Miocene or even in earlier time (MATSUDA, 1960; OOMORI, 1960). The nature of the Pleistocene diastrophism is one of the most important problems to be clarified in future.

Tectonic History and Paleogeography

Summarizing the descriptions and the discussions in the previous chapters, the tectonic history of the Setouti province is compiled in Table 6.

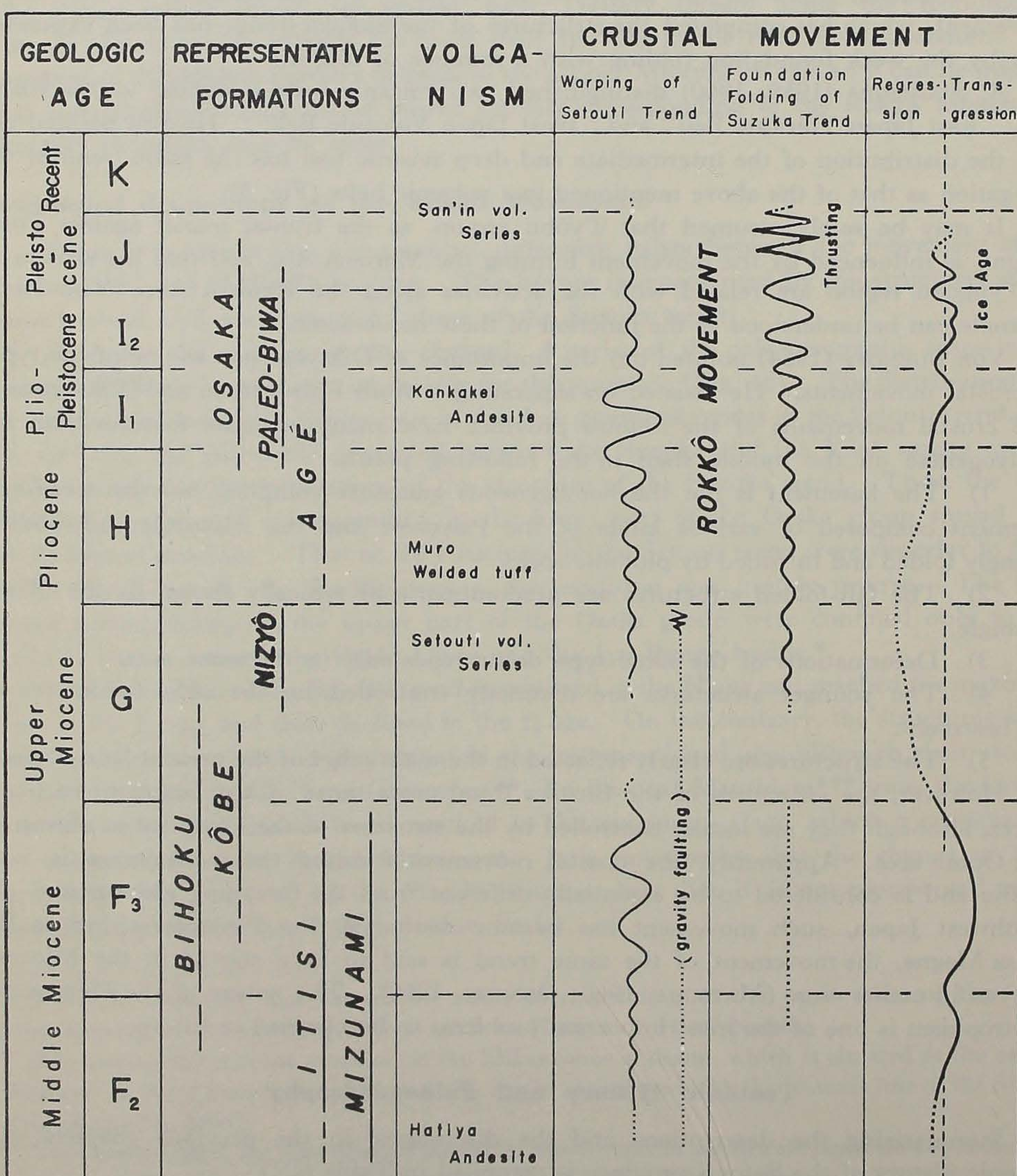
Pre-Setouti Period

1) After the intrusions of the granitic rocks at the close of the Cretaceous or at the beginning of the Paleogene, the geologic conditions of Japan were greatly changed. Southwest Japan underwent denudation extending over a long time. Then, granitic rocks widely exposed before the deposition of the Miocene series.

Birth of the Setouti Depression —Middle Miocene (F_2-F_3)—

2) At the beginning of the F_2 age, the Setouti province commenced to subside corresponding with the subsidence of the Hokuriku-San'in province. The latter is characterized by the violent volcanism represented by the so-called "Green Tuff", which is mainly composed of various kinds of andesite lavas and their pyroclasts. In the Setouti, the

Table 6. Synopsis of the tectonic history of the Setouti province.



volcanic rocks of this time are very poor. Only the Hatiya andesite (two-pyroxene andesite) in the Kani basin can be cited. This fact is in accordance with the fact that the sinking of the Setouti was very slight compared with those of other provinces.

3) Gentle sinking bagan in the Ise-Mikawa and the Iga-Owari areas. At first, small lakes appeared, and then sea water invaded. The Akeyo formation was accumulated in the innermost part of this bay (Fig. 14-a).

4) After the small-scale regression represented by the discordance between the Akeyo and the Oidawara formations of the Mizunami group, the First Inland Sea spread rapidly and connected the Nankai province with the Hokuriku-San'in province (F_3). This sea did not extend to the western part of the Setouti province, but to the Bihoku area. Reflecting the differential movement of each unit of the zonal rock-bodies of the basement, sinking of the Ise-Mikawa area was greatest, and the Iga-Owari area was under the shallow sea. The Median Line and the tectonic line between the Ryôke zone and the Cretaceous granites might be responsible for this differential movement. The Harima area on the extension of the Tamba Uplift accumulated the coarse sediments of special type.

5) The Middle Miocene was the greatest transgressive age in the Japanese Islands through the Cenozoic Era. The Setouti was not exceptional. The coarse sediments, which contain the abundant *Miogypsina-Operculina* assemblage at the beginning of the invasion of the First Inland Sea, passed upward quickly into the muddy sediments as well as in the Hokuriku-San'in province (Fig. 14-b).

Geanticlinal Upheaval and the Activities of the Setouti Volcanic Series

—Upper Miocene (G)—

6) In the Upper Miocene, the First Inland Sea regressed. Then, the Setouti Volcanic Series characterized by the Sanukitoid rocks erupted along the southern margin of the Setouti province from Mikawa to Kyûsyû at interval of about 100 km.

This volcanism is significant in the following respects: firstly, this series is prolonged as far as to Kyûsyû beyond the western limit of the First Setouti Depression, and its elongation suggests the area of the next subdsience of the Second Setouti Series; secondly, each center of eruption is situated approximately on the axis of anticline of the foundation folding of the Rokkô Movement. This volcanic activities seem to have been the forerunner of the crustal movement of the Pliocene and the Pleistocene (Fig. 14-c).

7) Although subsidence continued from the Middle Miocene to the Upper Miocene in the Hokuriku-San'in province, the Setouti province entered into the upheaval stage earlier. Namely, the Setouti has occupied the geanticlinal part between the Hokuriku-San'in and the Nankai provinces.

8) This upheaval occurred accompanied by a samll number of gravity-faults of the Setouti trend. Peneplanation made progress through this stage, but it was not completed.

Reappearance of the Setouti Depression —Pliocene (H)—

9) The Setouti province bagan to subside again in the Pliocene. However, it is noteworthy that the newer movement, i.e. the compressional effect of latitudianl direction, was added. Owing to this movement, the subsidence firstly appeared in the Ise-Mikawa area, and the eruption of the sub-alkalic Murô welded tuff took place on the Suzuka uplifted area (Fig. 15-a). Then, the Second Setouti Depression spread over whole Setouti province in the Plio-Pleistocene (I_1, Fig. 15-b).

Appearance of the Kinki Triangle —Plio-Pleistocene to Lower Pleistocene (I_1-I_2)—

10) The foundation folding of the Suzuka trend became distinct gently in the I_1 age, although it had started at the beginning of the Pliocene. The sedimentary basin of

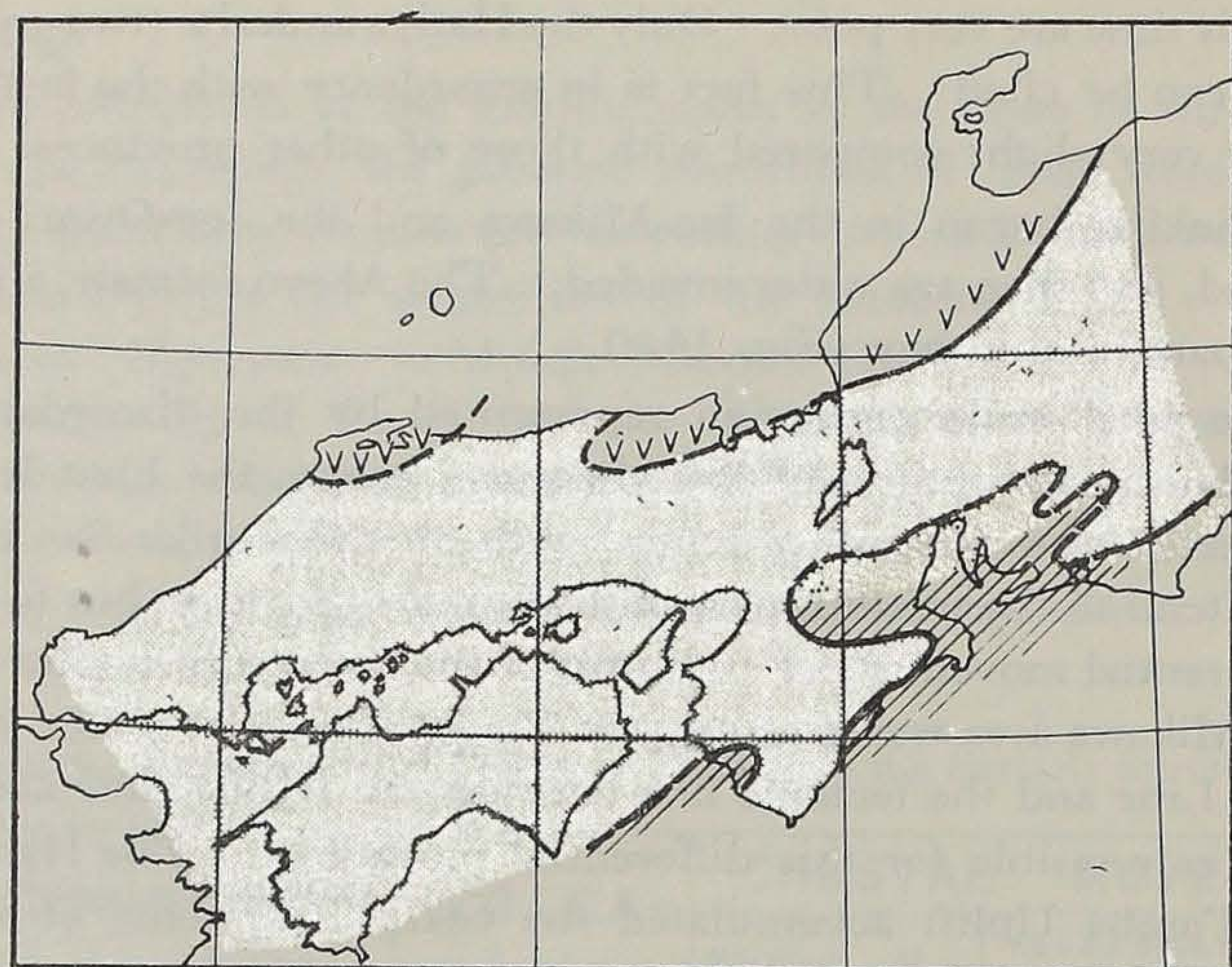


Fig. 14-a. Paleogeographic map of F_2 age (Middle Miocene).

Fig. 14-b. Paleogeographic map of F_3 age (Middle Miocene).

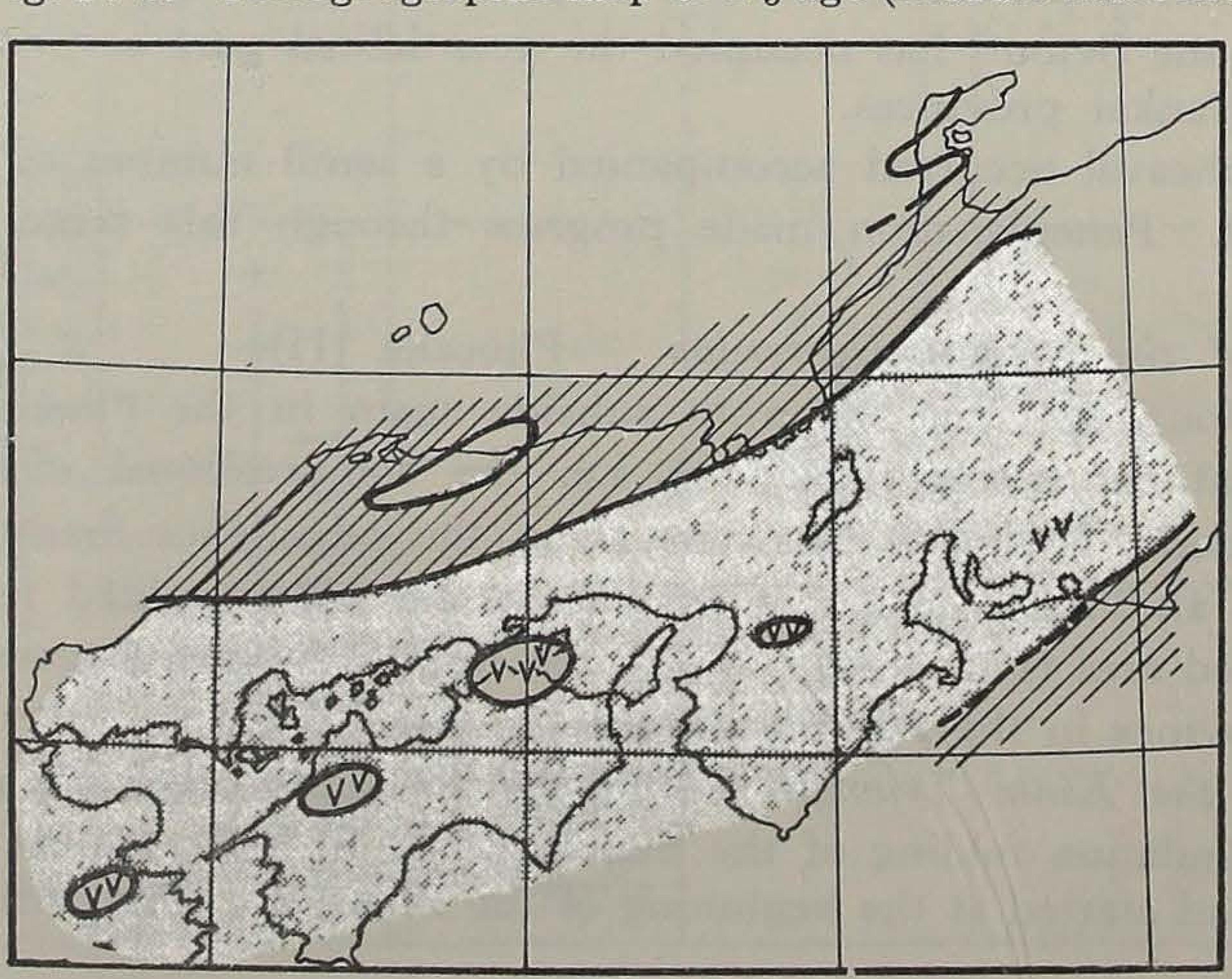


Fig. 14-c. Paleogeographic map of G age (Upper Miocene).

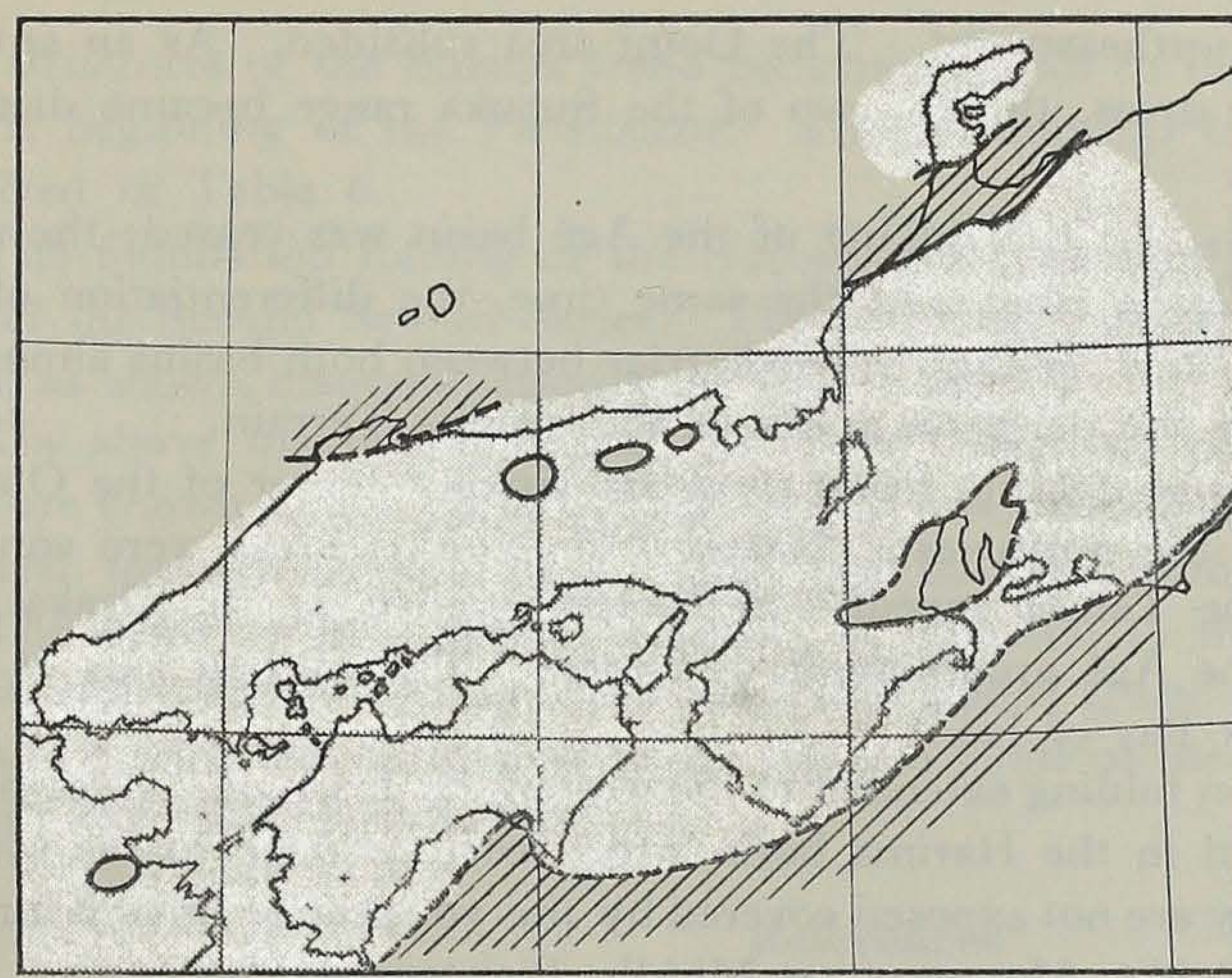


Fig. 15-a. Paleogeographic map of H age (Pliocene).

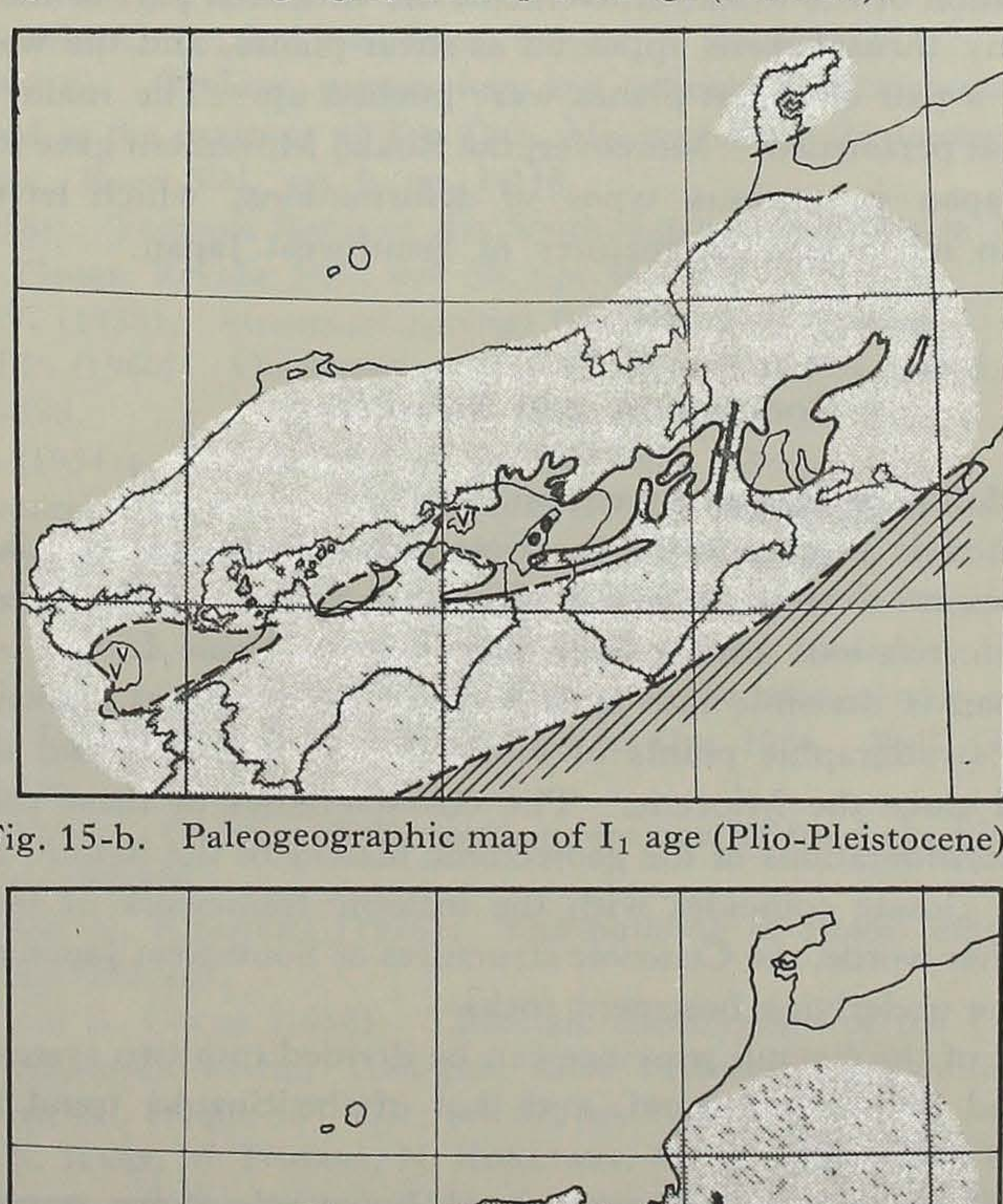


Fig. 15-b. Paleogeographic map of I_1 age (Plio-Pleistocene).

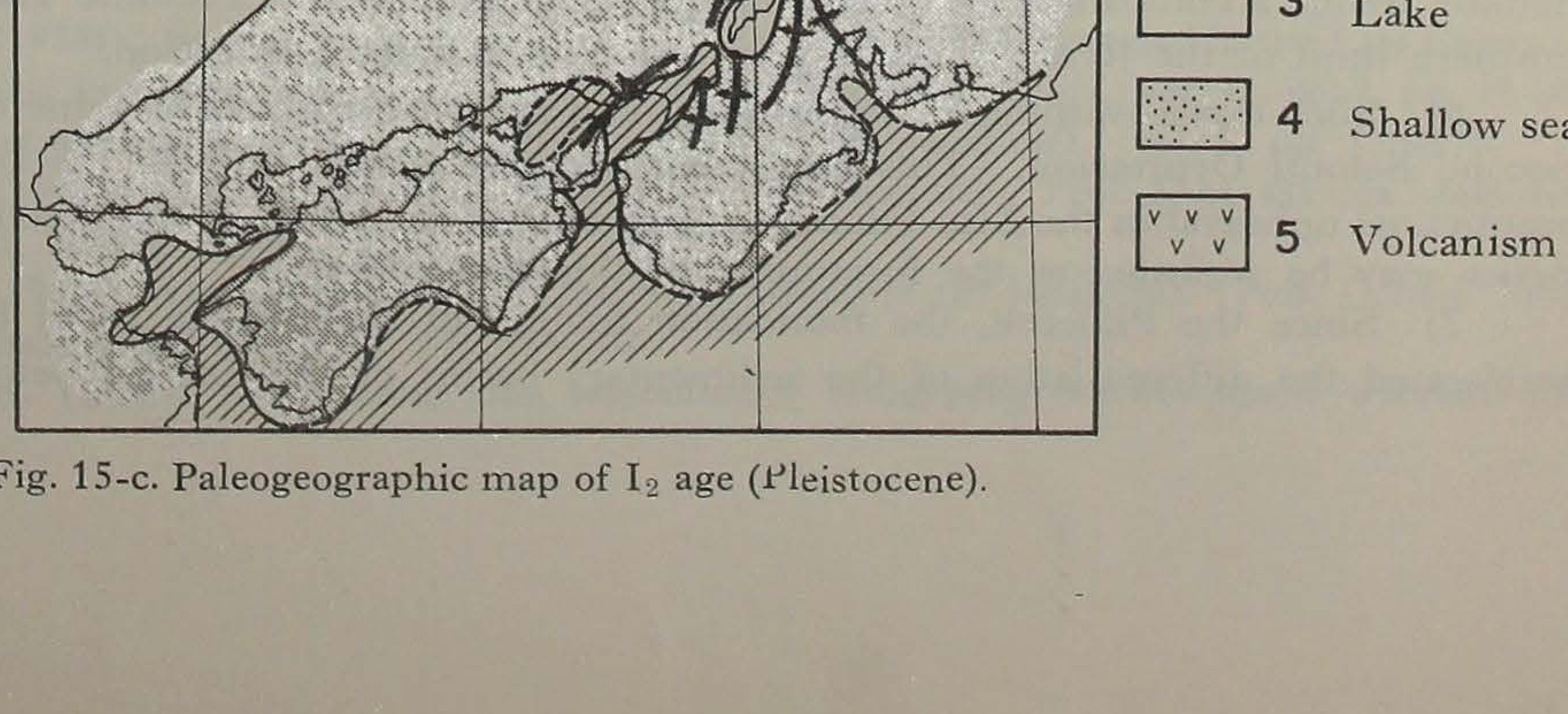


Fig. 15-c. Paleogeographic map of I_2 age (Pleistocene).

the Agé group shifted northeastward. The Oomi area subsided. As an anticlinal part separating these sinking areas, the embryo of the Suzuka range became distinguishable (Fig. 15-b).

11) Then in the I_2 age, the sinking of the Agé basin was ceased; the sinking was localized in the Oomi-Osaka zone. At the same time, the differentiation of the Oomi and the Osaka basins became distinct. The barrier between both basins almost coincides with the prolongation of the paleozoic rocks of the Tamba Terrain.

12) As the foundation folding made progress, sinking center of the Oomi and the Osaka basins shifted to the northwest. Namely, the sinking areas were confined along the outer margin of the Tamba massif. Sea water invaded in the Osaka basin (Fig. 15-c). In this stage, the Agé group might be folded. The folding axis is parallel to the shape of the present Bay of Ise.

13) The foundation folding extended to the west of the Triangle. The marine strata might have been formed in the Harima basin which corresponded to the synclinal part of the folding. But they are not exposed covered by the younger sediments or sea water.

Culmination of the Rokkô Movement —Middle Pleistocene (J)—

14) At the culmination of the Rokkô Movement, the anticlinal part of the foundation folding fractured. Many thrusts were appeared as shear planes, and the wedge-shaped rock-bodies bounded by a pair of thrust planes were pushed up. The main topography of the Kinki Triangle was performed. Moreover, the Rokkô Movement gave its influences for whole Southwest Japan in various types of deformations, which have made the groundwork of the main morphological features of Southwest Japan.

Conclusion and Summary

In conclusion, the following deserve mention.

1) The Late Cenozoic sediments of the Setouti province can be classified into three series: the First Setouti Series, the Setouti Volcanic Series and the Second Setouti Series. The stratigraphic relations among them are given in Table 1.

2) Southwest Japan is divisible into such geologic provinces as shown in Fig. 4, from both tectonic and stratigraphic points of view. These divisions and subdivisions took form and persisted since the Miocene. The characteristics of these provinces are very significant for the considerations of the geotectonic history of the Setouti Depression.

3) Each province closely coincides with the tectonic framework of the basement complex (Fig. 5). In other words, the Cenozoic structures of Southwest Japan are strongly controlled by those of the underlying basement rocks.

4) The structures of the Setouti province can be divided into two systems, namely, that of the Setouti trend (latitudinal trend) and that of the Suzuka trend (meridional trend).

5) The Miocene structures are characterized by gentle down-warping of the Setouti trend, accompanied by gravity-faults along the Median Tectonic Line and the northern limit of the Ryôke zone, to form the First Setouti Depression.

6) Such down-warping of the Setouti trend reappeared in the Pliocene to form the Second Setouti Depression. This movement occurred gently through the stage of the geanticlinal upheaval in the Mio-Pliocene. The volcanic activities of the Setouti Volcanic Series may be regarded as the forerunner of this movement.

7) Since the Pliocene, the foundation folding of the Suzuka trend began, and accelerated the differentiation of the sedimentary basins of the Second Setouti Series.

Then, the structures of the Suzuka trend became superior to the warping of the Setouti trend at the beginning of the Pleistocene. The relationship between both movements is summarized in Table 6.

8) The foundation folding of the Suzuka trend reached its culmination after the deposition of the Second Setouti Series. The anticlinal parts were pushed up by thrust movements, as shown diagrammatically in Figs. 9 and 12.

9) The above mentioned crustal movements that took place during the Pliocene-Pleistocene are known as the "Rokkô Movement", by which the groundwork of the general morphological features of Southwest Japan has been performed.

10) The name of the "Kinki Triangle" is proposed to the triangular area which has been strongly fold-faulted by the Rokkô Movement (Figs. 11 and 13). The Kinki Triangle can be regarded as the junction of the two kinds of the movements forming the Mariana Arc and the Ryûkyû Arc.

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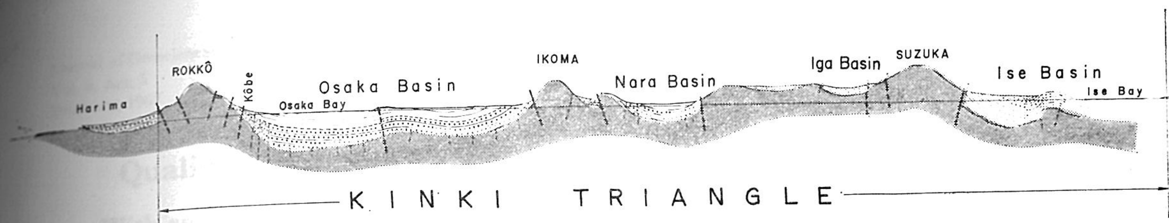

Fig. 12. Diagrammatic section of the Kinki Triangle.

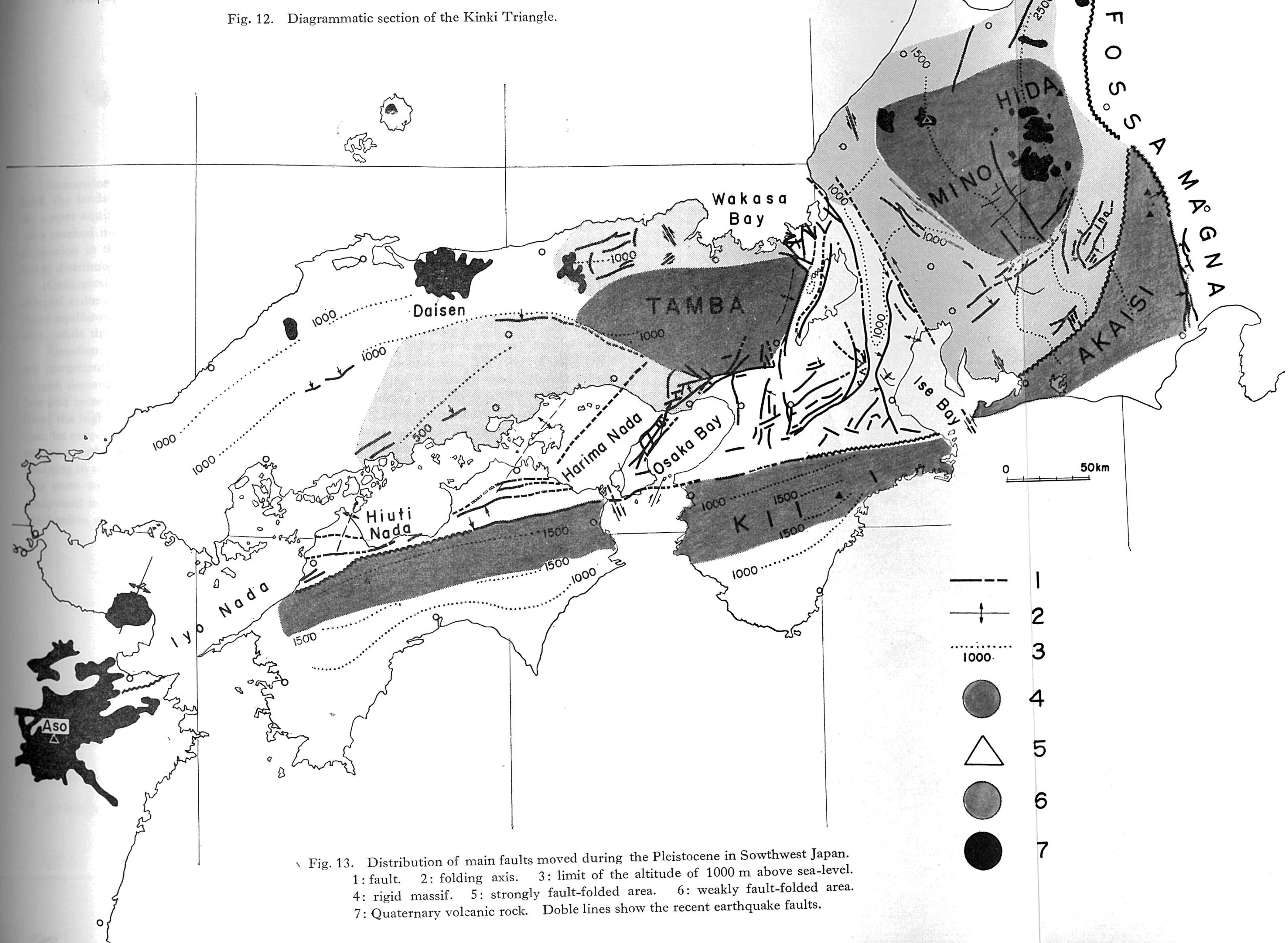

Fig. 13. Distribution of main faults moved during the Pleistocene in Sowthwest Japan. 1: fault. 2: folding axis. 3: limit of the altitude of 1000 m above sea-level. 4: rigid massif. 5: strongly fault-folded area. 6: weakly fault-folded area. 7: Quaternary volcanic rock. Doble lines show the recent earthquake faults.