Journal of Geosciences, Osaka City University
Vol. 12, Art. 5
March, 1969

Tectonic Development of Southwest Japan in the Quaternary Period*

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(With 16 Figures and 2 Plates)

Introduction and Geologic Setting

This is a preliminary report on the neotectonics of Southwest Japan. A working hypothesis is presented concerning the significance of its intersecting structural patterns which are remarkable from both geological and geomorphological points of view. Detailed descriptions and discussions will be given in the succeeding papers.

As shown in Fig. 1, the Japan island arcs are divisible into two parts neotectonically, Northeast Japan and Southwest Japan, by Itoigawa-Sizuoka Line, along which the recently active belt, Izu-Mariana Arc, cuts the Honsyu Arc almost at a right angle. The Ryukyu Arc is another active belt extending to the south subparallel to the Mariana Arc. These two belts are thought to be the late Cenozoic orogenic belts by MATSUDA *et al.* (1967).

Southwest Japan lies between them and has behaved rather cratonically during Cenozoic times unlike Northeast Japan. It consists of Inner and Outer Zones divided by the Median Tectonic Line. The latter is characterized by distinct zonal arrangement of formations ranging from Paleozoic to Paleogene with a trend parallel to that of the Honsyu Arc. Its northern marginal part is occupied by the Sambagawa metamorphic zone.

The Inner Zone of Southwest Japan is chiefly composed of the Paleozoic rocks, which was invaded by vast amounts of acid intrusives (granites and granodiorites) and effusives (rhyolites and pyroclastics) mainly of the Cretaceous age. Along the southern margine of this zone the Ryôke gneiss is exposed. By such intensive invasions of granitic rocks, the basement complex of Southwest Japan has acquired a rather cratonic character, so it is described as "quasi-cratonic" by MAKIYAMA (1956).

As the author has pointed out in the previous paper (HUZITA, 1962), the neotectonics of the Inner Zone has many common features with BUBNOFF's (1954) Diktiogenese on the mobile shelf in the following points: i) The basement is not the homogeneous gneissose complex, but the secondary basement composed of various kinds of the Paleozoic and Mesozoic rock-bodies strongly folded and intruded by plutonic rocks. ii) The fault- folding structures are predominant as typically shown in the central part

* Contribution from the Department of Geosciences, No. 208.

of the Kinki district. iii) Deformations of the same type occur repeatedly in the same area. iv) The younger structures are distinctly controlled by the older structures of the basement. v) The structures are clearly reflected in the main relief of the present land surface.

The southern part of the Inner Zone is a depressional zone occupied by the Seto Inland Sea (Setouti) in its western part. The Plio-Pleistocene sediments named Second Setouti Series are scattered in this depression undergone by the tectonic movements of fault-folding type.

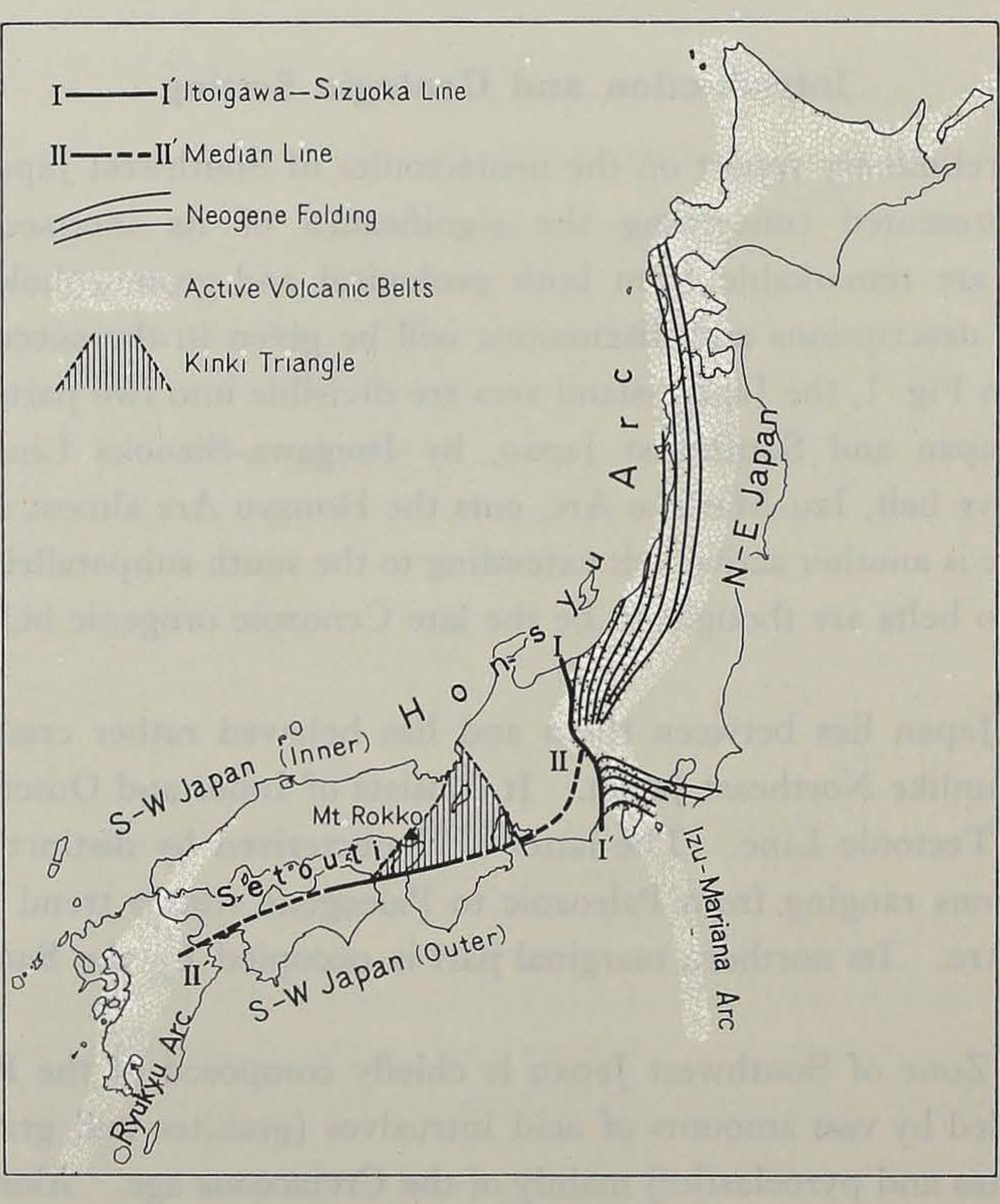


Fig. 1 Index map showing the neotectonic elements of the Japanese Islands (based on MATSUDA, 1964).

The neotectonic elements of the Inner Zone are intensively expressed in the area of triangular-shape occupying the central part of the Kinki district, which was named **Kinki Triangle** by the author (HUZITA, 1962) (Fig. 1). From a geomorphological view-point, the Kinki Triangle is characterized by the alternative arrangement of small basins, such as Osaka, Nara and Oomi basins, and of short mountain ranges, such as Suzuka, Ikoma and Hira, which run almost perpendicular to the general trend of the Setouti depression or to the Honsyu Arc. However, only the Izumi range extending along the base of the Triangle is parallel to the general trend (Fig. 13).

The writer summarized the tectonic development of the Kinki Triangle in 1962 and concluded that the structures of N–S trend developed in a later stage than those of E–W trend. The later movements are so typically demonstrated in the Rokko mountain range rising just behind the port city of Kobe, that the term of **Rokko Movements** was proposed to denote the later crustal movements by IKEBE and the author (1966).

The Rokko Movements is considered to have appeared in the Pleistocene and to continue up to recent times. It surely has close relation with the recent seismicity. The purpose of this paper is to take a step forward to approach to the nature of the Rokko Movements.

Change of the Stress Conditions in Southwest Japan during the Pleistocene Epoch

Since the Pliocene, the Setouti depression was filled with the **Second Setouti Series**, which consists of loose sediments made of gravels, sands and clays (HUZITA, 1962). It is considered to range from the middle Pliocene to the early Pleistocene (IKEBE, 1969).

The **Osaka group** deposited in the Osaka sedimentary basin is a representative of this series (ITIHARA, 1961). Detailed stratigraphic researches by tephrochronological method have been carried on recently by the "Research Group for the Osaka group" (ISHIDA *et al.* 1969). A standard succession of the Plio-Pleistocene stratigraphy of Japan will be established soon. The maximum thickness of the Osaka group is estimated as about 600 m by deep drilling in the central part of the Osaka basin. It is divisible into two parts, Upper and Lower, by a characteristic tuff bed widely spread over the whole Osaka basin. The lowest part of the group is a freshwater facies, but the upper are cyclic alternations of freshwater and marine facies.

The depressional zones filled up with the Lower part of the Osaka group and its equivalents are shown in Fig. 2. Fig. 4 shows those of the Upper part of it. The former zones are almost parallel with the Honsyu Arc, while the latter are almost perpendicular to it. These two figures suggest that a distinct change of the crustal movement has taken place during the Pleistocene, but it is noteworthy that no remarkable angular unconformity can be recognized in the full sequence of the Osaka group in the Osaka sedimentary basin.

MAKIYAMA (1956) introduced a concept of **foundation folding** to explain the genesis of the neptons of the Osaka group. It means the up-and-down buckling deformation of the quasi-cratonic basement. The dotted lines in Figs, 3, 5 show stress trajectories which are drawn perpendicular to the anticlinal axes of foundation folding. They suggest that the direction of the principal stress axis has changed horizontally almost 90 degrees in the Kinki area during the Pleistocene. The author intends to give the name of Rokko Movements strictly to the movements which have formed the structures shown in Fig. 5.

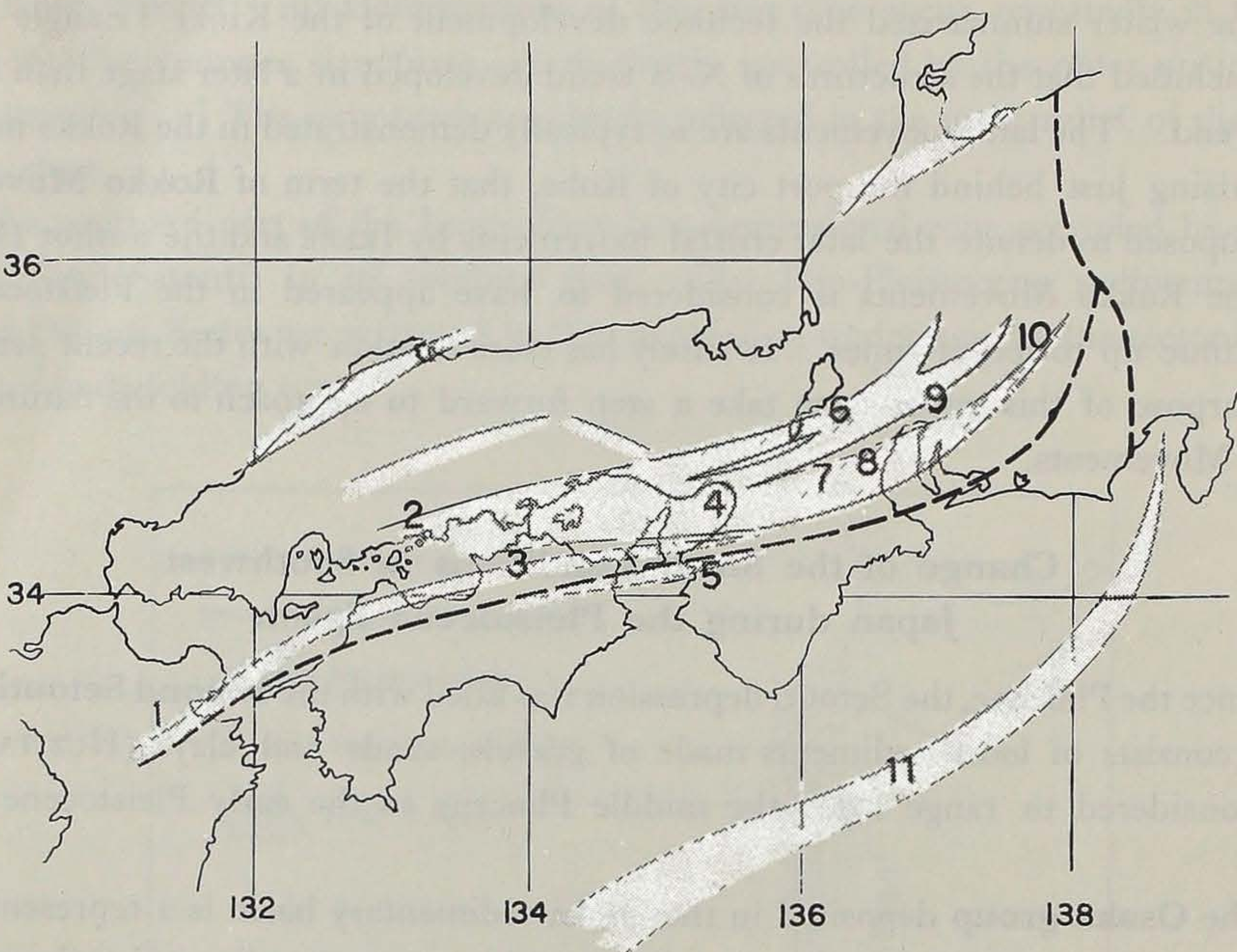


Fig. 2 Depressional zones in the age of the lower part of the Second Setouti Series (Middle Pliocene to Earliest Pleistocene). 1: Ooita group. 2: Onomiti formation. 3: Mitoyo group. 4: Osaka group. 5: Syôbudani formation. 6, 7: Paleo-Biwa group. 8: Agé group. 9: Seto group. 10: Ina group. 11: Nankai Trough.

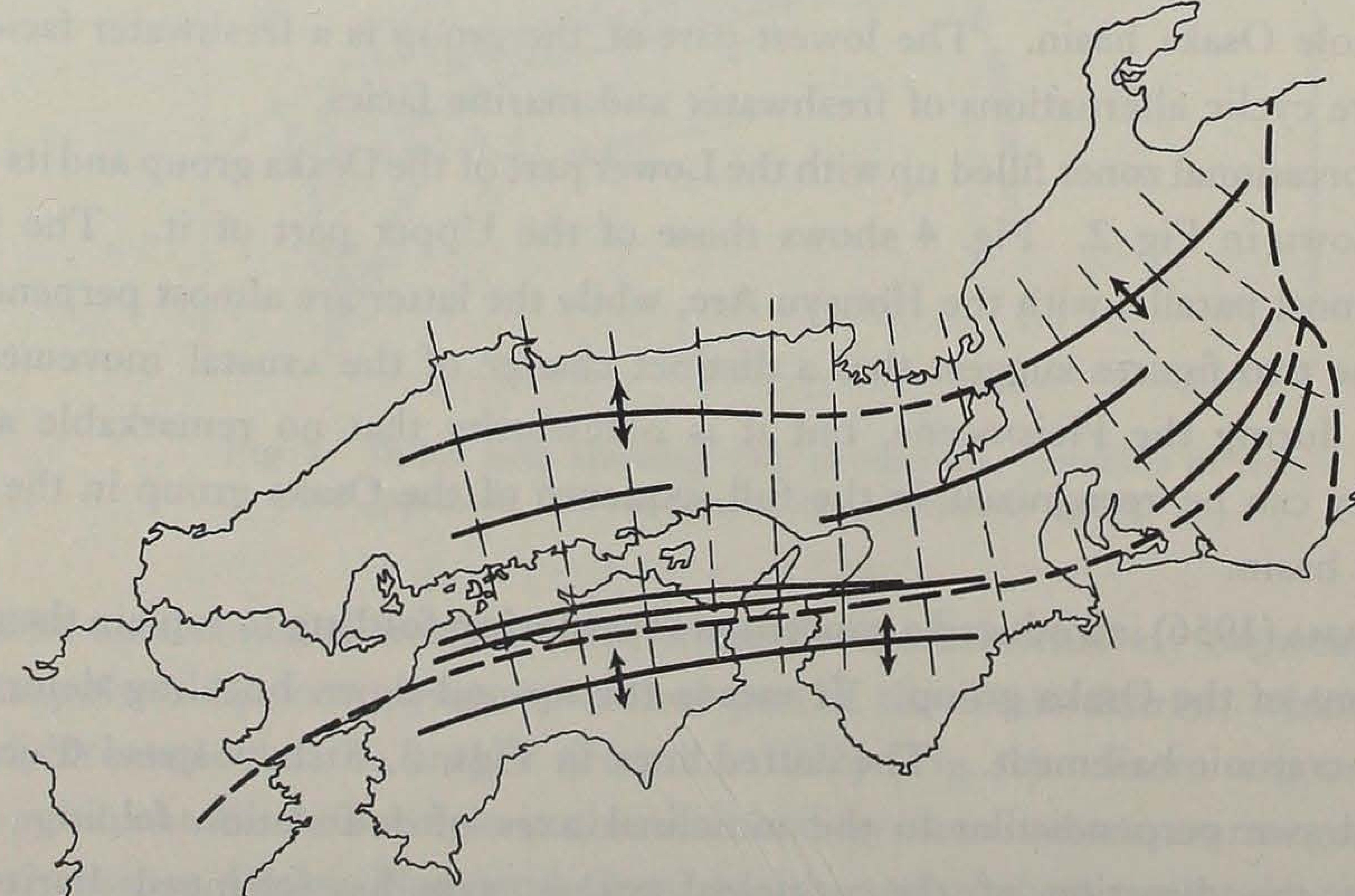


Fig. 3 Trajectories (broken lines) of maximum principal stress axis (compressive) drawn perpendicular to the anticlinal uplifts (solid lines) corresponding to Fig. 2.

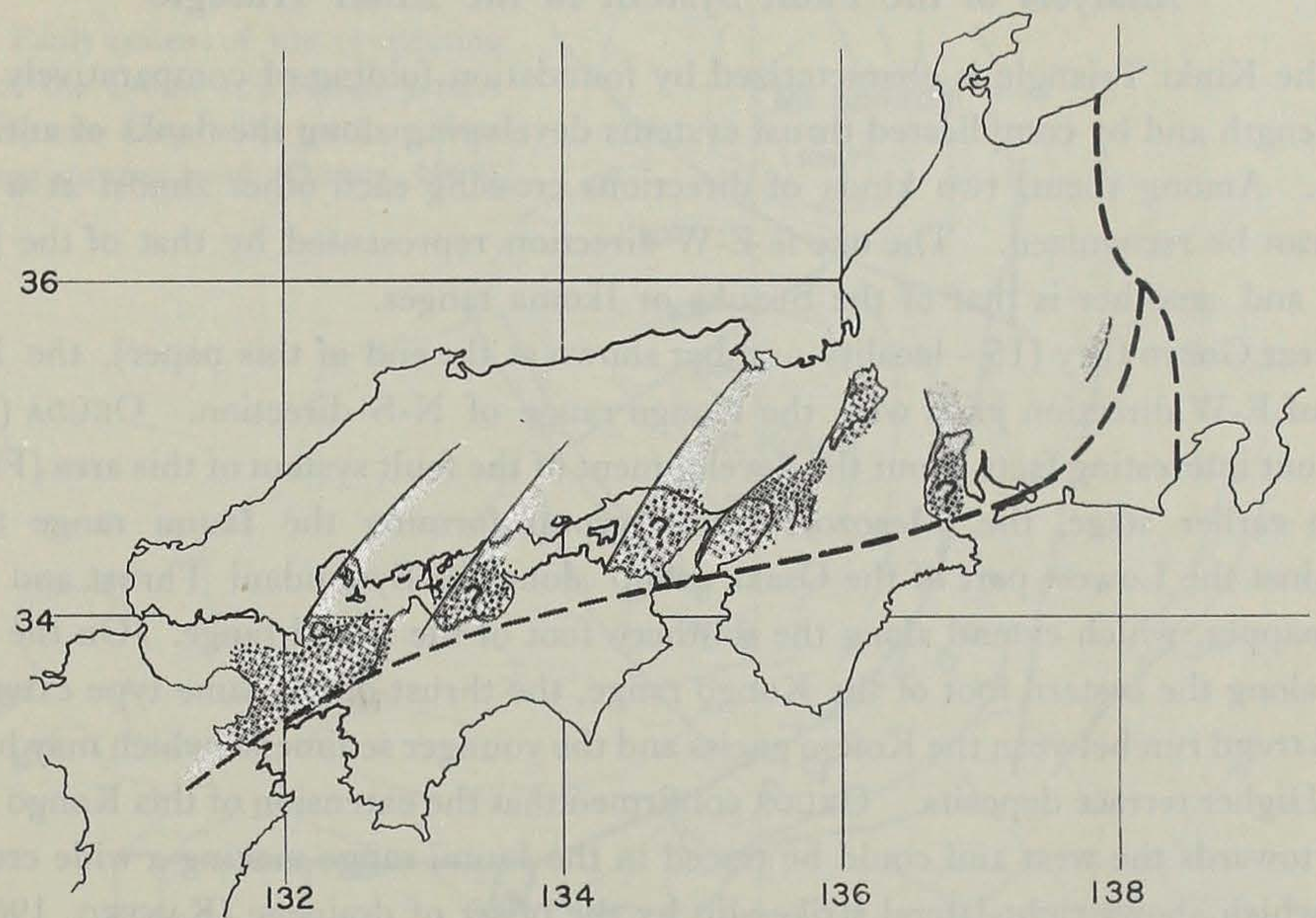


Fig. 4 Depressional zones in the age of the upper parts of the Second Setouti Series (Early to Middle Pleistocene) deposited in the dotted areas.

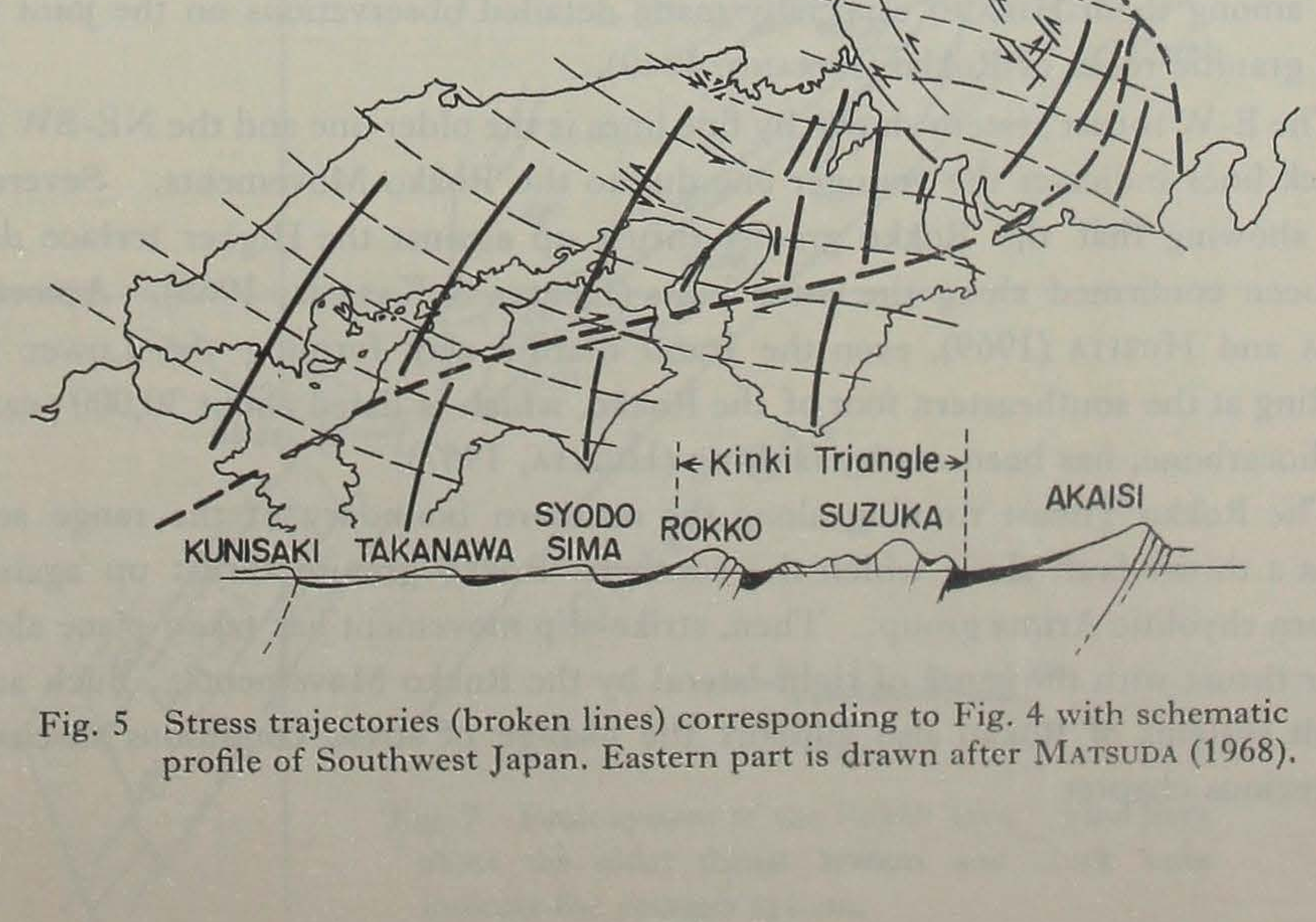


Fig. 5 Stress trajectories (broken lines) corresponding to Fig. 4 with schematic profile of Southwest Japan. Eastern part is drawn after MATSUDA (1968).

Analysis of the Fault System in the Kinki Triangle

The Kinki Triangle is characterized by foundation folding of comparatively short wave-length and by complicated thrust systems developing along the flanks of anticlinal uplifts. Among them, two kinds of directions crossing each other almost at a right angle can be recognized. The one is E-W direction represented by that of the Izumi range, and another is that of the Suzuka or Ikoma ranges.

Near Gozyo City (15 – locality number shown at the end of this paper), the Izumi range of E-W direction joins with the Kongo range of N-S direction. OKUDA (1969) found out interesting facts about the development of the fault system of this area (Fig. 6).

In earlier stage, the Mesozoic Izumi group forming the Izumi range thrust up against the Lowest part of the Osaka group along the Syobudani Thrust and made small nappes, which extend along the southern foot of the Izumi range. On the other hand, along the eastern foot of the Kongo range, the thrust of the same type extending in N-S trend run between the Kongo gneiss and the younger sediments which may belong to the Higher terrace deposits. OKUDA confirmed that the extension of this Kongo Fault bends towards the west and could be traced in the Izumi range making a wide crushed zone, which shows right-lateral strike-slip by the offset of drainage (KANEKO, 1965) or by the horizontal striations on the fault planes.

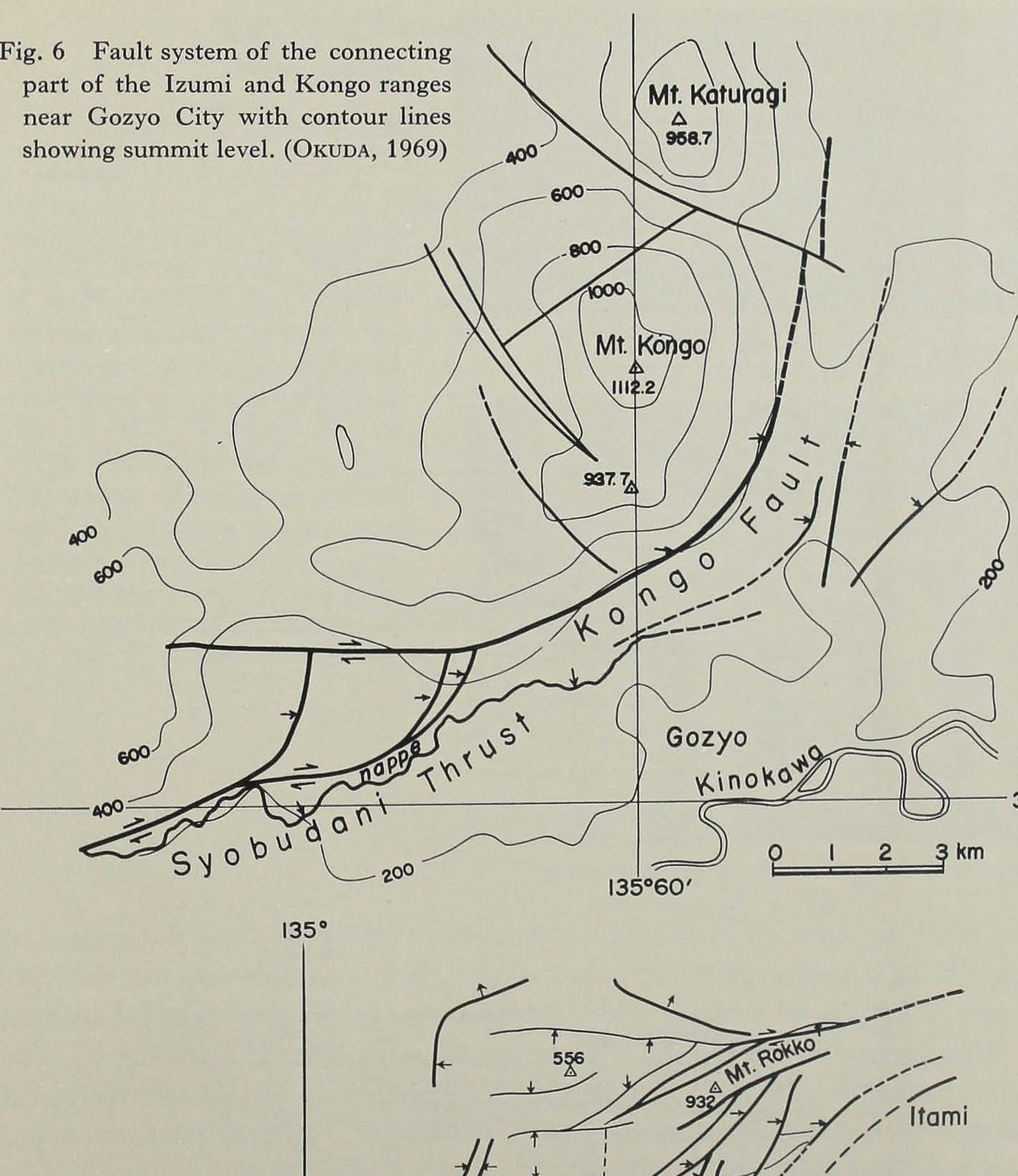
Such a thrust system is thought to be similar in origin with that of the "oroflex" described by ALBERS (1967). The right-lateral strike-slip can also be recognized just behind the Syobudani Nappe along the old thrust plane as shown in Fig. 6. These facts indicate that the structures of N-S trend occurred later than those of E-W trend, that is, by the Rokko Movements.

The study of the Rokko area, the type area of the Rokko Movements, is another way of examining the relation between the two systems of fault (Fig. 7). This area has been surveyed in detail by his collaborators, KASAMA, HIRANO *et al.* (HUZITA *et al.*, 1964), among them HIRANO especially made detailed observations on the joint system of the granitic rocks of Rokko (HIRANO, 1969).

The E-W thrust system shown by fine lines is the older one and the NE-SW system by thick lines indicates the younger one due to the Rokko Movements. Several outcrops showing that the Rokko granite thrust up against the Higher terrace deposits have been confirmed along the latter faults (HUZITA & KASAMA, 1968). According to MAEDA and HUZITA (1969), even the Itami marine clay forming the Lower terrace spreading at the southeastern foot of the Rokko, which is dated about 30,000 years B.P. by radiocarbone, has been cut by faulting (HUZITA, 1967).

The Rokko Thrust running along the northern boundary of the range acted at first as a thrust fault along which the southern Rokko granite thrust up against the northern rhyolitic Arima group. Then, strike-slip movement has taken place along the former thrust with the sense of right-lateral by the Rokko Movements. Such analyses of fault systems of Rokko also support the change of stress conditions discussed in the previous chapter.

Fig. 6 Fault system of the connecting part of the Izumi and Kongo ranges near Gozyo City with contour lines showing summit level. (OKUDA, 1969)



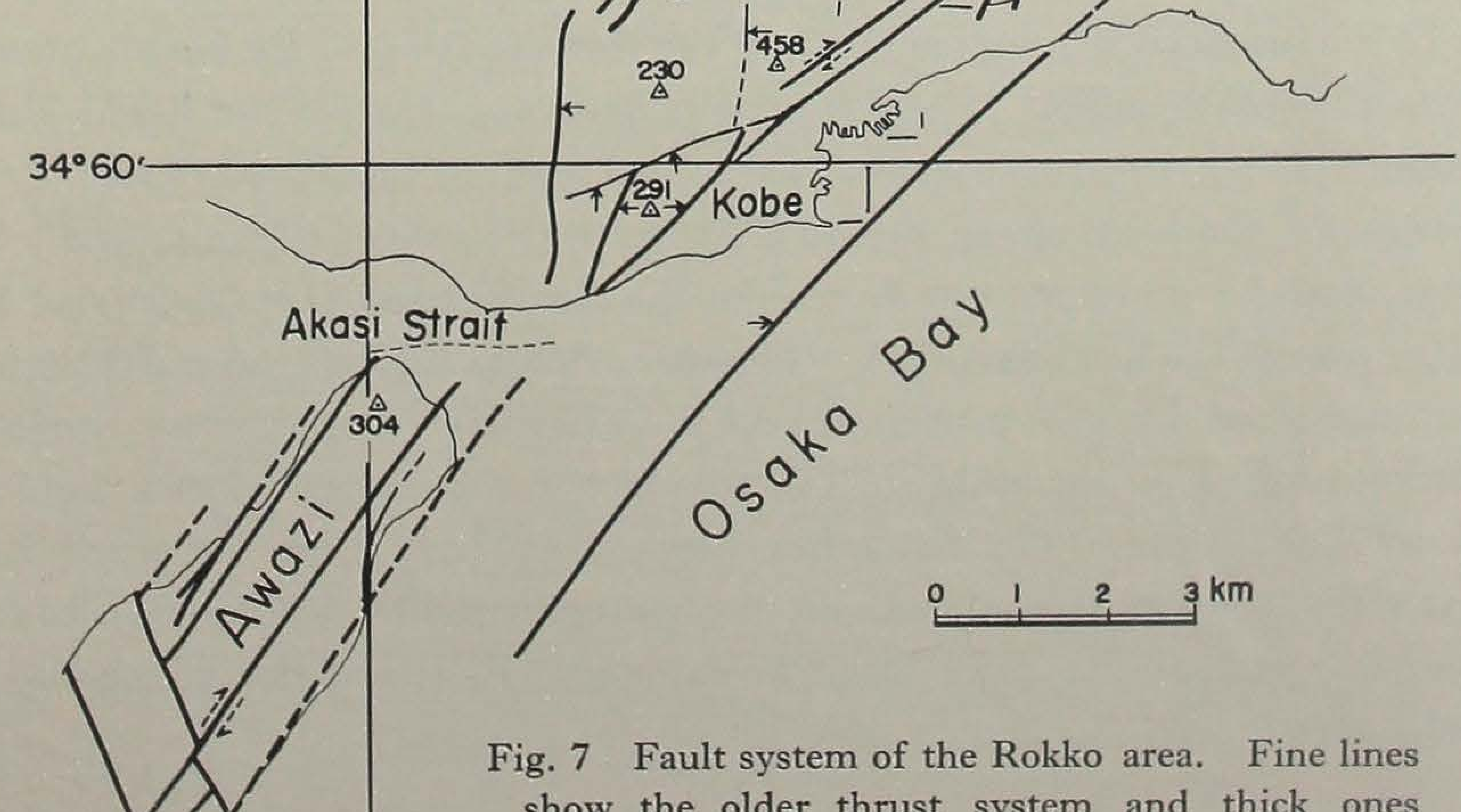


Fig. 7 Fault system of the Rokko area. Fine lines show the older thrust system and thick ones indicate the younger system.

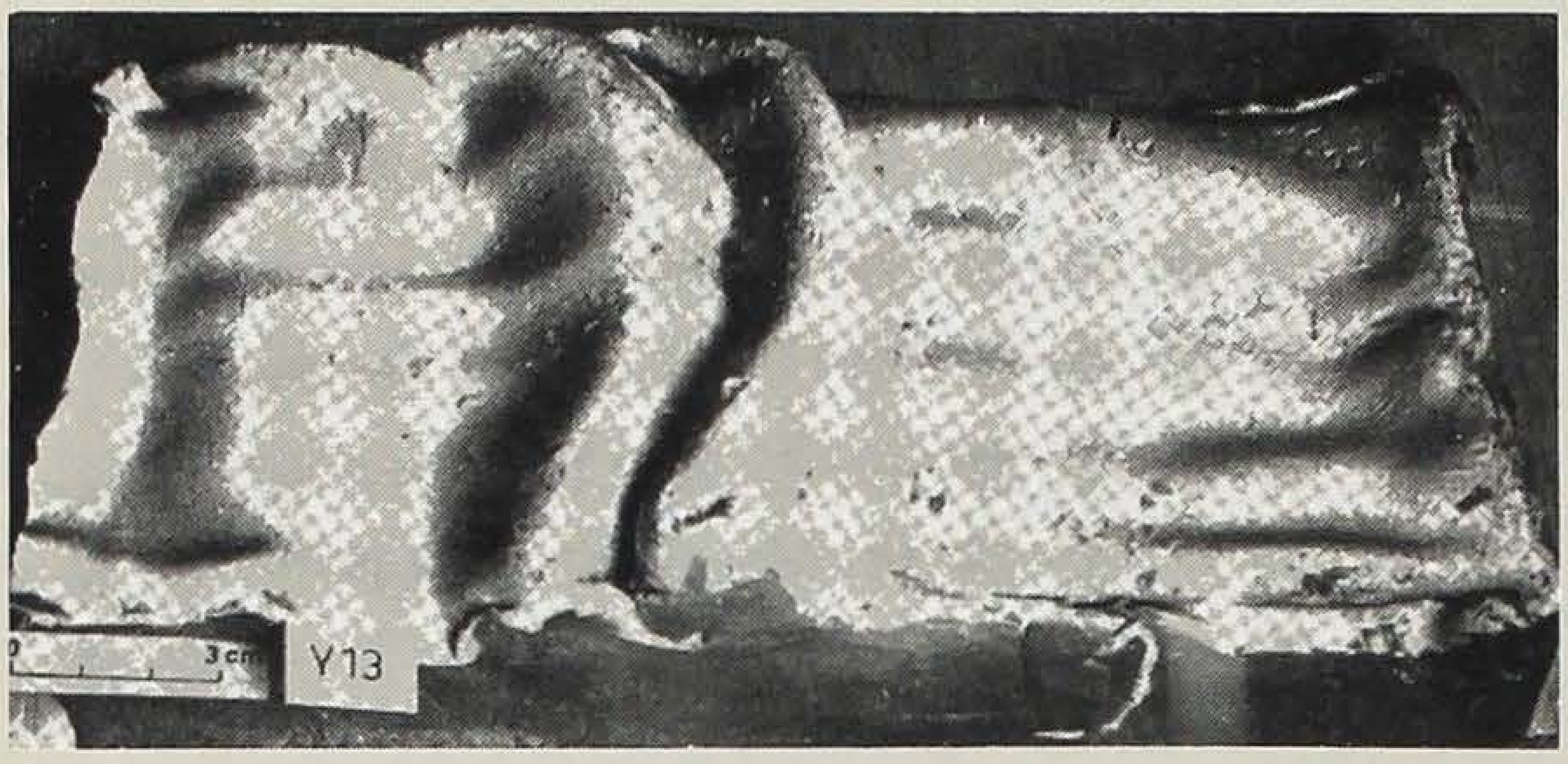


Fig. 8 Superposed folds of the first type.

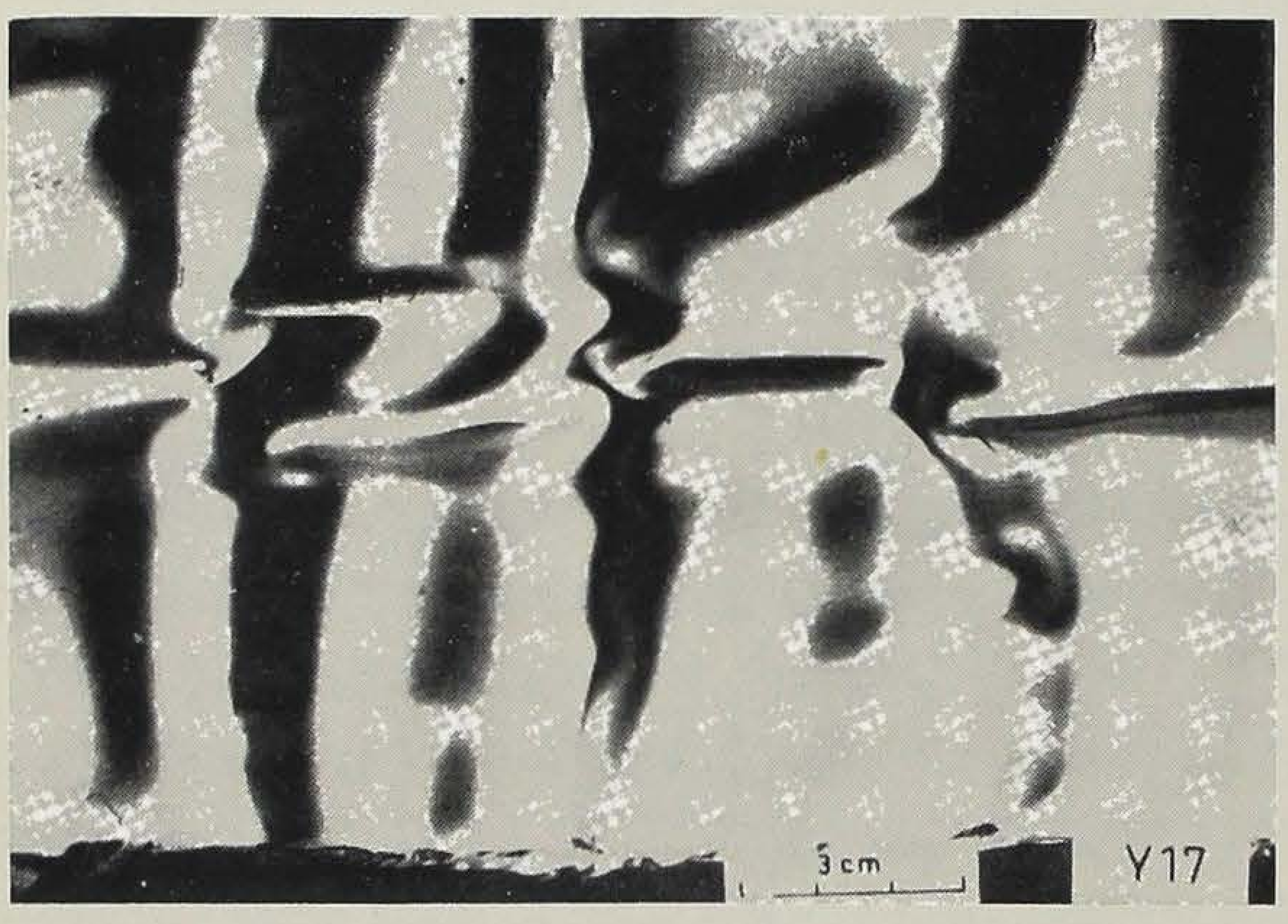


Fig. 9 Superposed folds of the second type.

Figs. 8, 9 are the model experiments showing the intersecting buckle-folds formed in two periods of deformation. The folds running from front to back are first-generation folds occurred by compression in one direction. The second-generation folds running from left to right are formed by compression perpendicular to the former direction. Note that the second-generation fold are not larger than the first-generation folds. (after GHOSH & RAMBERG, 1968)

The model experiments of GHOSH and RAMBERG (1968) offer many suggestions on such intersecting structural patterns. They made deformation tests with soft materials on mercury. A series of tests of buckle-folding formed in two periods of deformation by the compressions of two directions perpendicular each other is especially valuable to explain the structures of the Kinki Triangle. The folds produced in the second period of deformation were superposed on those of the first period. In these cases, two types of second-generation folds can be recognized as shown in Figs. 8, 9.

Fig. 13 is a idealized illustration showing the tectonic relief of the basement surface of the Second Setouti Series. The foundation folds appeared in the Kinki Triangle can be understood by the combination of above two types of superposed folds.

For example, the bend of the Kongo (IV)-Izumi (X) ranges (OKUDA, 1969) is the second type, and the first type can be seen in the Sanda basin (10) (SHINODA, 1969), the northern part of the Rokko area (I). The older uplifts can be traced although they have been disturbed by the younger folding. They are recognized as barriers for sedimentation in the younger basin such as seen in the middle part of the Oomi basin occupied by Lake Biwa. On the other hand, they have been remained as the prominent elevations like monadnocks on the younger uplifts. They are situated at the intersecting part of the older anticline extending E-W and the younger one of N-S trend.

Strike-Slip Faults and Large-Scale Fracture System —The Recent Shear Patterns in the Kinki Area—

Recently, clear strike-slip faults were discovered in the Kinki area. At first, KANEKO (1965) pointed out the right-lateral strike-slip movement along the Median Tectonic Line, and OKADA (1968) made a detailed survey of that of the Sikoku area. The largest offset of drainage may reach 1.5 km.

In summer of 1968, IKEBE, MATSUDA, OKADA and the writer (1969) recognized topographically doubtless left-lateral strike-slip movement along the Yamazaki Fault (Fig. 16–A). Much attention has been paid to this fault because of remarkable coincidence with the linear distribution of the epicenters of microearthquakes as shown in Fig. 10 (KISHIMOTO *et al.*, 1966). The writer surveyed another area of the same tendency and could find out a left-lateral strike-slip fault of the same direction as that of the Yamazaki Fault. It is named Mitoke Fault (Fig. 16–B).

Now, the complicated fault system of the Rokko area is being reexamined from such a view-point. The right-lateral movement may be expected along some of them as shown in Fig. 7. These may be regarded to make conjugate sets with the Yamazaki or Mitoke

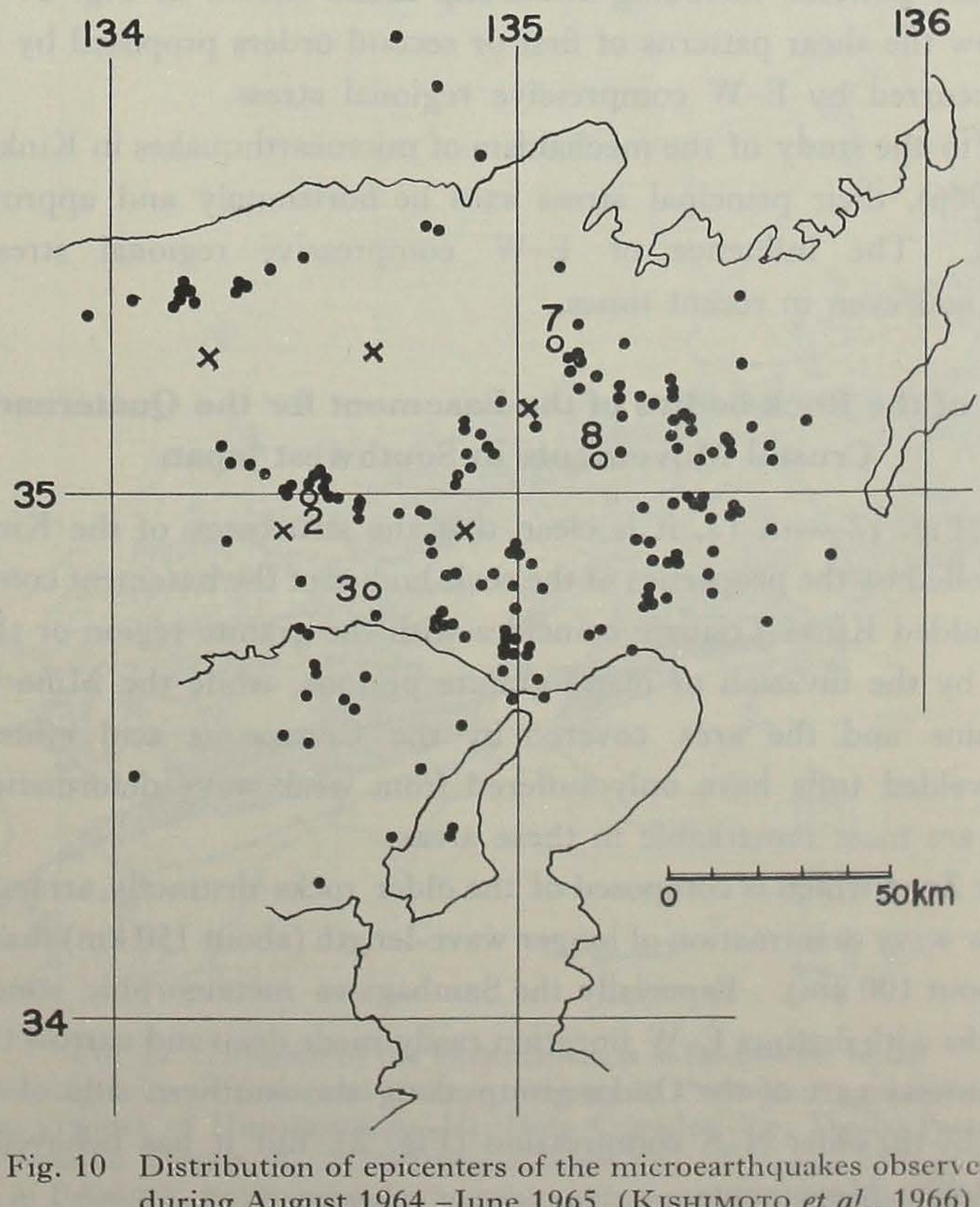


Fig. 10 Distribution of epicenters of the microearthquakes observed during August 1964 –June 1965. (KISHIMOTO *et al.*, 1966)

Faults in the same regional stress field, the maximum principal axis of which may be almost horizontal and has E–W direction.

Another new interesting event is the discovery of the large-scale fracture system especially developing in the rigid but brittle basement rocks. They can be clearly traced on aerial photos as long as many ten kilometers as shown by fine lines in Fig. 14. These fractures are contributing to make narrow or younger tributaries along the clear lineamants which traverse the older wide rivers associated with terraces. have wide crushed zones, but no distinct vertical displacement can be recognized. Slight lateral slip is expected along them.

They seem to disappear in the Cenozoic sedimentary covers, but Shinoda (1969) revealed in a detailed survey of the Sanda (10) basin occupying the northern part of the Rokko that they controll the microstructures of the Miocene beds as well as the drainage patterns in the basin (Plate, 2).

The above mentioned facts indicate that they may have appeared related with the movement of the strike-slip faults of Yamazaki or Mitoke. Especially at the junction of the Suzuka (VI) and Nunobiki (VII) ranges or that of the Ikoma (III) and Kongo (IV), such fractures cut the fault system of N–S trend.

Such fracture patterns including strike-slip faults shown in Fig. 14 are thought probable to show the shear patterns of first or second orders proposed by Moody and Hill (1956) occurred by E–W compressive regional stress.

According to the study of the mechanism of microearthquakes in Kinki by Hashizume *et al.* (1966), their principal stress axes lie horizontaly and approximately in E–W direction. The influence of E–W compressive regional stress may be prevailing in Kinki even in recent times.

Role of the Rock-bodies of the Basement for the Quaternary Crustal Movements in Southwest Japan

Compared Fig. 12 with 13, it is clear that the structures of the Kinki area are distinctly controlled by the properties of the rock-bodies of the basement complex. The strongly fault-folded Kinki Triangle coincides with the granite region or the Paleozoic area disturved by the invasion of many granite plutons, while the Mino and Tamba Paleozoic terrains and the area covered by the Cretaceous acid effusives chiefly composed of welded tuffs have only suffered from weak wavy deformation although large fractures are most remarkable in these areas.

The Outer Zone which is composed of the older rocks distinctly arranged in E–W trend only show wavy deformation of longer wave-length (about 150 km) than that of the Inner Zone (about 100 km). Especially the Sambagawa metamorphic zone comprised of schistose rocks with distinct E–W lineation easily made deep and narrow trough filled up with the Lowest part of the Osaka group along the southern side of the Median Tectonic Line by the older N–S compression (Fig. 2), but it has behaved very rigid mass for the Rokko Movements.

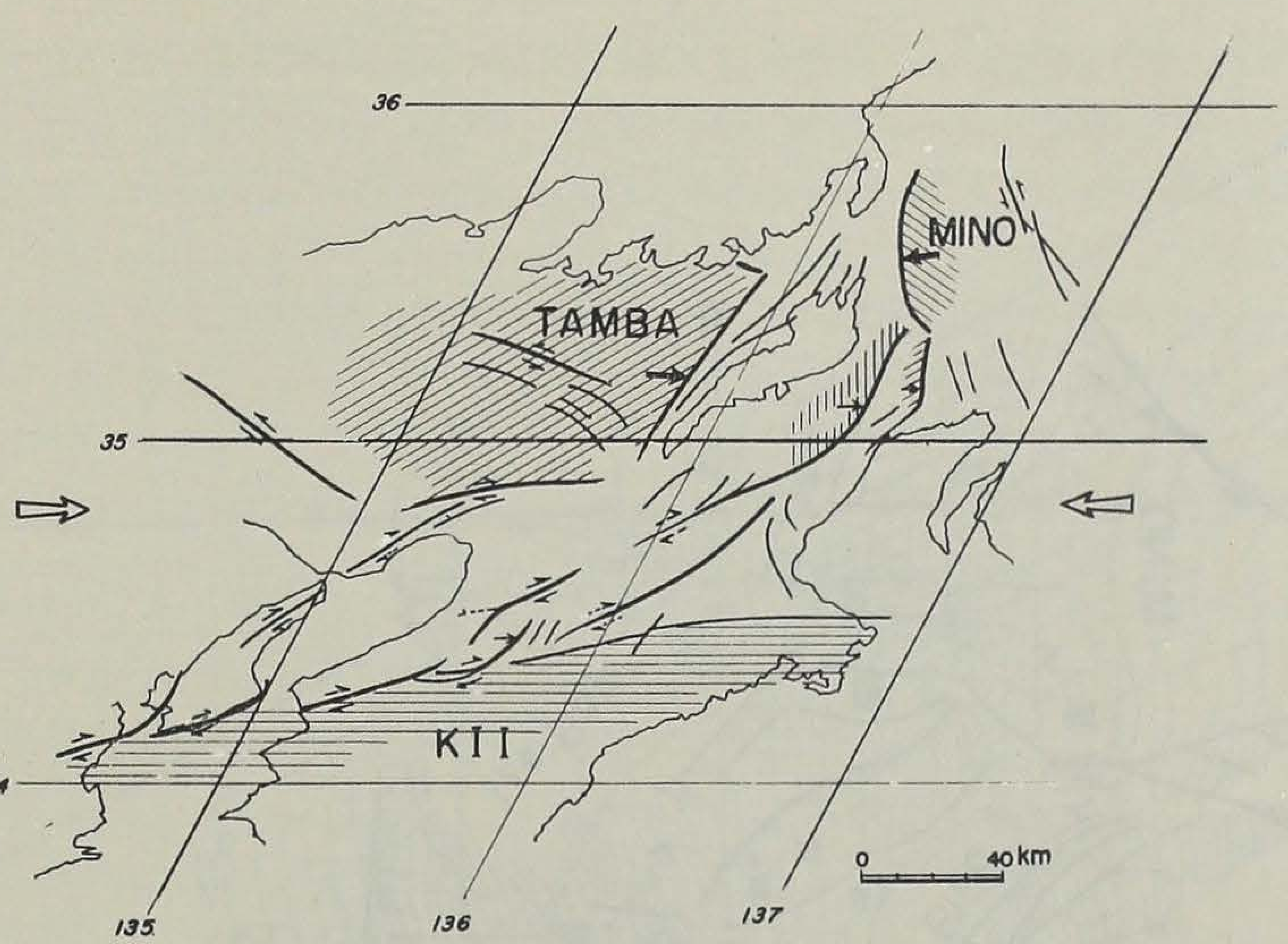


Fig. 11 Map showing the fault displacements in the Kinki Triangle due to the differential movements of the rock masses of basement under the regional compression of E-W trend.

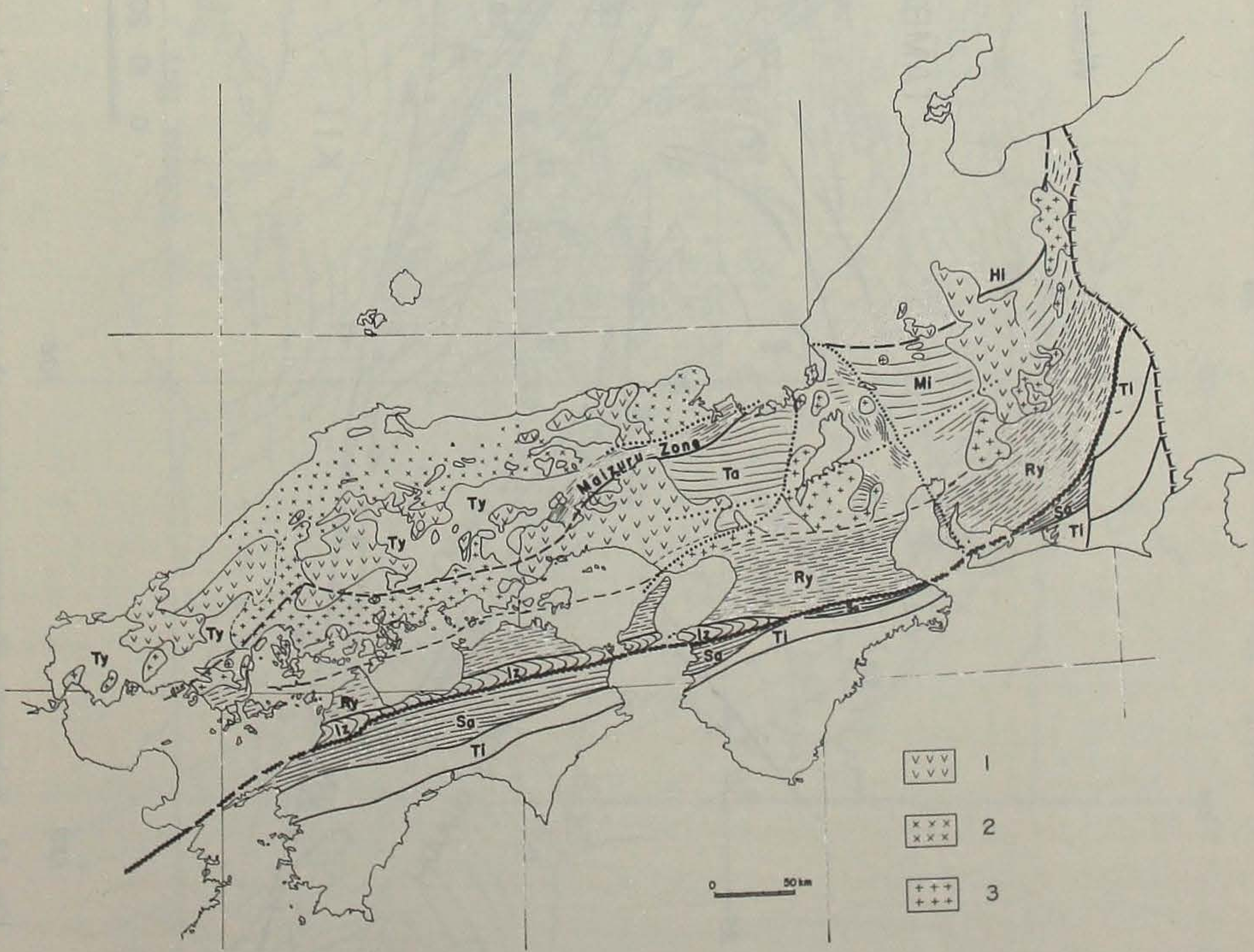


Fig. 12 Division of the basementrocks in Southwest Japan.
1; Cretaceous acid volcanic rocks and their pyroclasts. 2; Cretaceous granites of San' in-type. 3; Cretaceous granites of Hirosima-type. Hi; Hida Complex. Ta; Tamba Paleozoic Tarrain. Mi; Mino Paleozoic Terrain. Ry; Ryôke Gneiss zone. Ty; Tyugoku zone of Paleozoic. Ti; Titibu zone of Paleozoic. Sa; Sambagawa metamorphic zone. Iz; Cretaceous Izumi group.

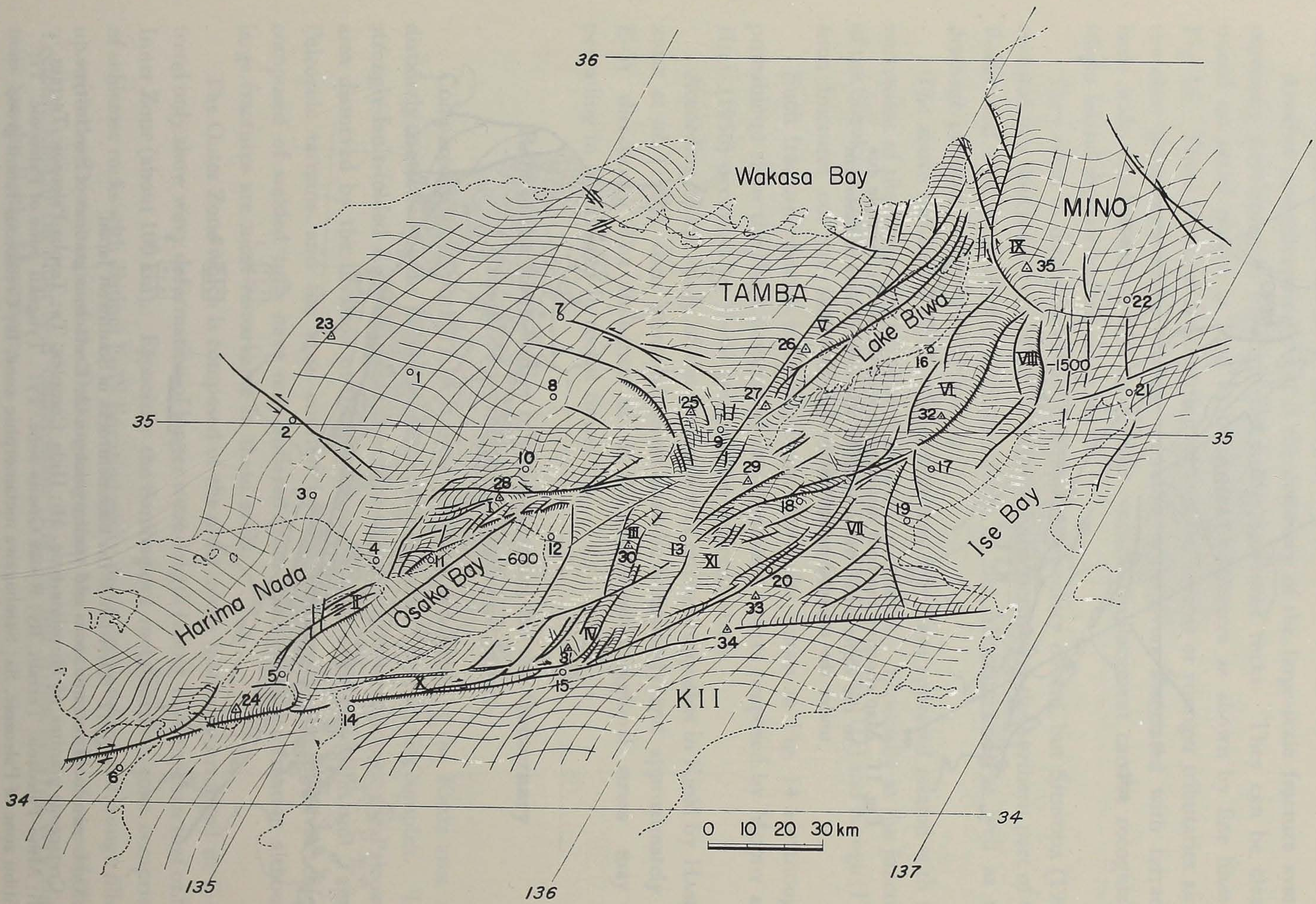


Fig. 13 Schematic illustration showing the tectonic relief of the basement surface of the Second Setouti Series (Plio-Pleistocene). The index of locality numbers are given at the end of this paper.

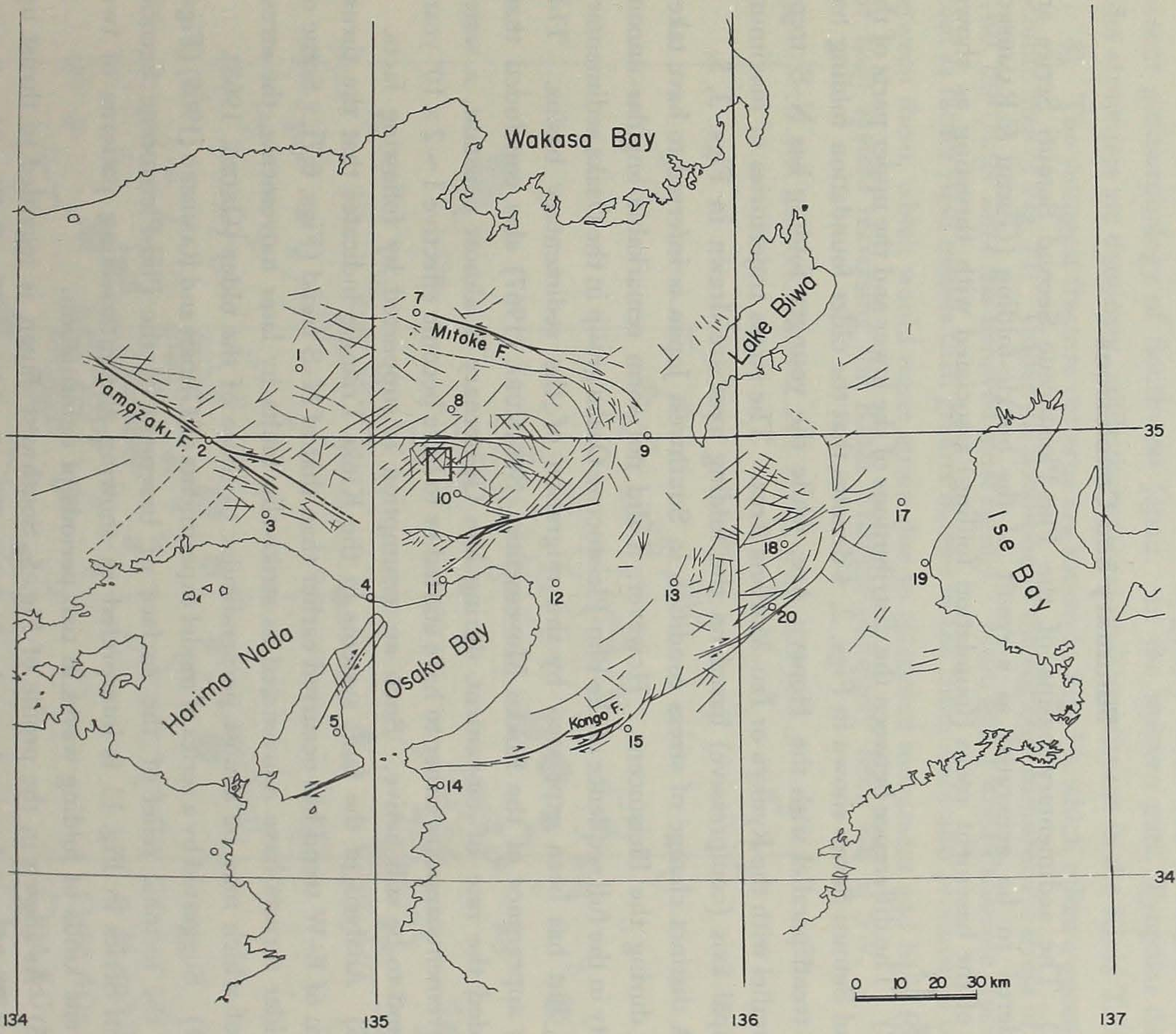


Fig. 14 Map showing the youngest fractures along which no distinct vertical displacement can be recognized (see Pl. 2).

Concerning the plastic deformation of granitic rocks, KUMAGAI and ITO (1968) tried a interesting experiment of secular bending of big granite beams made of the Cretaceous granite of Setouti extending for 10 years. They concluded that granite makes a viscous flow or a plastic one having a very small yield stress. The viscosity of granite is calculated to be 10^{20}–10^{21} poises by them. These facts contribute to the understanding of the structures of the Kinki Triangle.

Summary and Conclusions

1) The sedimentary basins of the Plio-Pleistocene Second Setouti Series are considered to be generated as a result of the buckle-folding (GHOSH & RAMBERG, 1968) of the basement rocks (foundation folding) associated with thrusting as shown in Fig. 13.

2) The difference between the distributions of the lower and the upper parts of the Second Setouti Series shown in Figs. 2, 4 denotes that the older foundation folding has E–W trend parallel with the Honsyu Arc, while the younger folding has N–S trend subparallel with the Ryukyu or Izu-Mariana Arcs. The stress trajectories of maximum principal axis (compressive) based on the folding axes are drawn in Figs. 3, 5.

A distinct change of stress condition in Southwest Japan is inferred to have taken place during the Pleistocene. However, it did not form remarkable angular unconformity in the full sequence of the Plio-Pleistocene Osaka group in the Osaka sedimentary basin, but has been expressed by the migration of the sedimentary basins. This is the appearance of the Rokko Movements. SUGIMURA (1967) also concluded that, provided the rate of movement during late Quaternary is almost constant, a series of movements appears either to have started or to have become effective $1\sim2\times10^6$ years ago, and to be still active. Such an assumption is supported by following facts.

3) Analysis of the fault systems in the Kinki Triangle indicates that the thrust system of E–W trend has occurred earlier than that of N–S trend (Figs. 6,7). Some of the older thrusts have rejuvenated as strike-slip faults by later movements, the stress axes of which may be almost perpendicular to those of the older (OKUSA, 1968).

4) Suggested by a series of model experiments of GHOSH and RAMBERG (1968) (Figs. 8,9), the tectonic relief of the surface of basement of the Plio-Pleistocene Second Setouti Series in Fig. 13 is interpreted as showing the intersecting patterns of two different kinds of folding waves in two periods of deformation.

5) As shown in the profile of Fig. 5, Southwest Japan is regarded to thrust up against Northeast Japan along the Itoigawa-Sizuoka Line. The E–W regional compressive stress of the Rokko Movements would relate to this movements.

6) The Rokko Movements has formed various types of structures in the basement rock-bodies depending on the different behavior of each body for the same regional stress. For example, weak wavy deformation has occurred in the Tamba Paleozoic mass, but intense fault-folding has affected the granitic regions of the Kinki Triangle.

In contrast to the Inner Zone occupied by vast amounts of granitic rocks, the

Outer Zone has older rocks showing distinct linear features aligned almost perpendicular to the trend of the younger structures. Separating these two zones, rejuvenation of the Median Tectonic Line due to the Rokko Movements has caused strike-slip movement as shown in Fig. 6.

7) The structures due to the Rokko Movements have been superposed on the older structures parallel to the Honsyu Arc. Both of these structures strongly control the present geomorphology of Southwest Japan. In the western part, Tyugoku district, older structures are dominant, while the younger ones are distinct in the Kinki Triangle.

8) The youngest fracture patterns are shown in Fig. 14, which offers a speculative tectonic map of Fig. 11. Under the condition of the regional compressive stress of E–W trend, the Outer Zone has behaved most rigidly. Mino and Tamba Paleozoic areas have acted as rather rigid masses than granite masses in the Inner Zone and produced a couple between them, which would cause strain due to rotational movement and have formed the fault system traversing the Kinki Triangle obliquely from NE to SW.

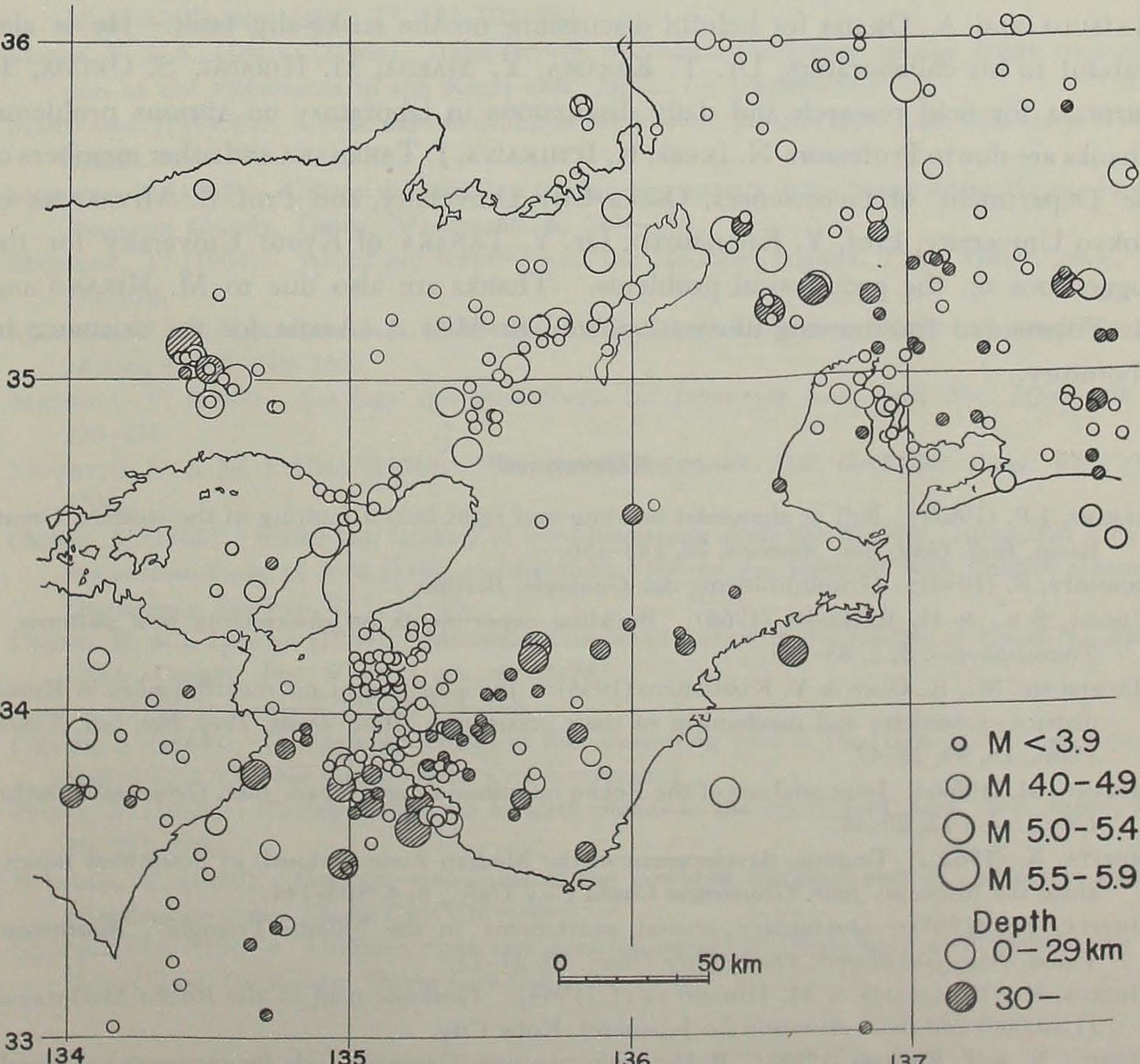


Fig 15 Distribution of epicenters of the earthquakes observed during 1961–1967. (Compiled by Wakayama Earthquake Observatory)

In the rigid masses themselves, conjugate sets of strike-slip faults or large fractures have developed as shown in Fig. 14. They have a close relation with the seismicity of the microearthquake as shown in Fig. 10. Fig. 15 shows the distribution of earthquakes during 1961–1967. These maps indicate that the earthquake foci have a tendency to concentrate along the marginal zones of rather rigid masses among the basement rock-bodies and along the strike-slip faults.

9) The author intends to present a working hypothesis on the significance of the Rokko Movements. The appearance of the Rokko Movements means that the maximum principal axis of the regional stress has rotated anticlockwise horizontally from N–S direction to E–W in the Kinki area during the Pleistocene. the cause of which may be assumed to be the change of the currents in the upper mantle.

Acknowledgments

The author expresses his sincere thanks to Drs, A. SUGIMURA, S. KANEKO, T. MATSUDA and A. OKADA for helpful discussions on the strike-slip fault. He is also grateful to his collaboraters, Dr. T. KASAMA, Y. MAEDA, M. HIRANO, S. OKUDA, T. SHINODA for field research and daily discussions in laboratory on various problems. Thanks are due to Professors N. IKEBE, K, ICHIKAWA, J. TAKENAKA and other members of the Department of Geosciences, Osaka City University, and Prof. S. MIYAMURA of Tokyo University, Prof. Y. KISHIMOTO, Dr. Y. TANAKA of Kyoto University for the suggestions on the geophysical problems. Thanks are also due to M. HIRANO and M. YOSHIMOTO for drawing illustrations and to Miss A. ASADA for the asistance in laboratory.

References

ALBERS, J.P. (1967): Belt of sigmoidal bending and right-lateral faulting in the western Great Basin. *Bull. Geol. Soc. America*, **78**, 143–156.

BUBNOFF, S. (1954): Grundprobleme der Geologie. Berline.

GHOSH, S.K. & H. RAMBERG (1968): Buckling experiments on intersecting fold patterns. *Tectonophysics*, **5**, 2, 85–105.

HASHIZUME, M., K. OIKE & Y. KISHIMOTO (1966): Investigation of microearthquakes in Kinki district—seismicity and mechanism of their occurrence. *Bull. Disas. Prev. Res. Inst. Kyoto Univ.*, **15**, 99, 35–47.

HIRANO, M. (1969): Joint analysis of the Rokko mountain range, Japan. *Jour. Geosciences Osaka City Univ.*, **12**, 25–44.

HUZITA, K. (1962): Tectonic development of the Median Zone (Setouti) of Southwest Japan, since the Miocene. *Jour. Geosciences Osaka City Univ.*, **6**, 4, 103–144.

HUZITA, K. (1967): Quaternary crustal movements in the "Kinki Triangle", Southwest Japan. *Jour. Geosciences, Osaka City Univ.*, **10**, 21–23.

HUZITA, K., T. KASAMA & M. HIRANO et al. (1964): Geologic map of the Rokko Mountains (1/50,000) and its explanation (in Japanese). Kobe City.

HUZITA, K. & T. KASAMA (1968): Rokko mountain area (Geologic guide for excursion to several areas in the Kinki district, central Japan, edited by N. IKEBE et al.) *Jour. Geoscienses, Osaka City Univ.* **11**, 4, 85–93.

HUZITA, K. (1968): Rokko Movements, and its appearanc. (in Japanese with English abstract). Quaternary Resarch. **7**. 248–260.

IKEBE, N. & K. HUZITA (1966): The Rokko movements, the Plio-Pleistocene crustal movements in Japan. *Quaternaria*, **VIII**, 277–287.

IKEBE, N. (1969): A synoptical table on the Quaternary stratigraphy of Japan. *Jour. Geosciences, Osaka City Univ.*, **12**. 45–51.

IKEBE, N., K. HUZITA, T. MATSUDA & A. OKADA (1969): A strike-slip active fault in western Kinki, Japan (Yamazaki Fault). (in preparation)

ISHIDA, S., K. MAENAKA & T. YOKOYAMA (1969): Paleomagnetic chronology of volcanic ash of the Plio-Pleistocene series in Kinki district, Japan. *Jour. Geol. Soc. Japan*. **75**. (in press).

ITIHARA, M. (1961): Some problems of the Quaternary sedimentaries in the Osaka and Akasi areas. *Jour. Osaka City Univ. Inst. Polytech.*, **5**, 13–30.

KANEKO, S. (1965): Transcurrent displacement along the Median Line, Southwestern Japan. *New Zealand Jour. Geol. Geogr.*, **6**, 45–59.

KISHIMOTO, Y. & M. HASHIZUME (1966): On the mechanism of earthquake swarm at Hamasaka. *Bull. Disas. Prev. Res. Inst. Kyoto Univ.*, **16**, 107, 41–55.

KUMAGAI, N. & H. ITO (1966): Results of experiments of secular bending of large granite beams extending for 10 years and their analysis. (in Japanese with English abstract) *Jour. Soc. Materials Science, Japan*, **17**, 181, 925–932.

MAEDA, Y. & K. HUZITA (1969): Itami terrace, with special reference to the latest transgression of the Pleistocene in the Kinki area, Japan. (in preparation)

MAKIYAMA, J. (1956): Cyclic nepton group of Kinki area, Japan. *Mem. Coll. Sci. Univ. Kyoto*, **XXIII**, 169–177.

MATSUDA, T. (1962): Crustal deformation and igneons activity in the South Fossa Magna, Japan. *American Geophy. Union. Monograph.* **6**, 140∼150.

MATSUDA, T. (1964): Island arc features and the Japanese Islands. *Tokyo Geogr. Jour.*, **73**, 271–278.

MATSUDA, T., K. NAKAMURA & A. SUGIMURA (1967): Late Cenozoic orogeny in Japan. *Tectonophysics*, **4**, 4–6, 349–366.

MATSUDA, T. (1967): Geology and seismology. (in Japanese) *Jour. Seis. Soc. Japan*, **20**, 4, 230–235.

MOODY, J, D. & M. J. HILL (1956): Wrench-fault tectonics. *Bull. Geol. Soc. Amer.*, **67**, 1207–1246.

OKADA, A. (1968): Strike-slip faulting of late Quaternary along the Median Dislocation Line in the surroundings of Awa-Ikeda, northeastern Shikoku. (in Japanese with English abstract) *Quaternary Research*, **7**, 1, 15–26.

OKANO, K. & I. HIRANO (1964): Microearthquakes occurring in the vicinity of Kyoto (1). *Spec. Contr. Geophy. Inst. Kyoto Univ.*, **4**, 63–74.

——— (1965): ——— (2). **5**, 151–168.

OKUDA, S. (1969): Geologic structures of the connecting part of the Izumi and Kongo mountain ranges. (Master thesis, Osaka City University)

OKUSA, S. (1968): Sliding conditions in weak planes in the crust. *Jour. Geol. Soc. Japan*, **74**, 10, 511–520.

SHINODA, T. (1969): Geologic structures of the northern marginal part of the Sanda basin. (Graduation thesis, Osaka City University)

SUGIMURA, A. (1967): Uniform rates and duration period of Quaternary earth movements in Japan. *Jour. Geosciences, Osaka City Univ.*, **10**, 25–35.

Index of Locality Names

1: Ikuno(生野)
2: Yamazaki(山崎)
3: Himezi(姫路)
4: Akasi(明石)
5: Sumoto(洲本)
6: Tokusima(徳島)
7: Hukutiyama(福知山)
8: Sasayama(篠山)
9: Kyoto(京都)
10: Sanda(三田)
11: Kobe(神戸)
12: Osaka(大阪)
13: Nara(奈良)
14: Wakayama(和歌山)
15: Gozyo(五条)
16: Hikone(彦根)
17: Kameyama(亀山)
18: Ueno(上野)
19: Tu(津)
20: Nabari(名張)
21: Nagoya(名古屋)
22: Gihu(岐阜)
23: Mt. Hyônosen(氷ノ山, 1510)
24: Mt. Yuzuruha(諭鶴羽山, 609)
25: Mt. Atago(愛宕山, 942)
26: Mt. Hira(比良山, 1174)
27: Mt. Hiei(比叡山, 848)
28: Mt. Rokko(六甲山, 932)
29: Mt. Zyubusen(鷲峯山, 658)
30: Mt. Ikoma(生駒山, 642)
31: Mt. Kongo(金剛山, 1125)
32: Mt. Gozaisyo(御在所山, 1210)
33: Mt. Kuroso(倶留尊山, 1037)
34: Mt. Takami(高見山, 1243)
35: Mt. Ibuki(伊吹山, 1377)
I: Rokko(六甲) range
II: Awazi(淡路) range
III: Ikoma(生駒) range
IV: Kongo(金剛) range
V: Hira(比良) range
VI: Suzuka(鈴鹿) range
VII: Nunobiki(布引) range
VIII: Yôrô(養老) range
IX: Ibuki(伊吹) range
X: Izumi(和泉) range
XI: Gôwa(江和) plateau

Plate I Bird's-eye view from a hight of about 8,000 m above the Rokko mountain range towards the east. (Mainichi Press)

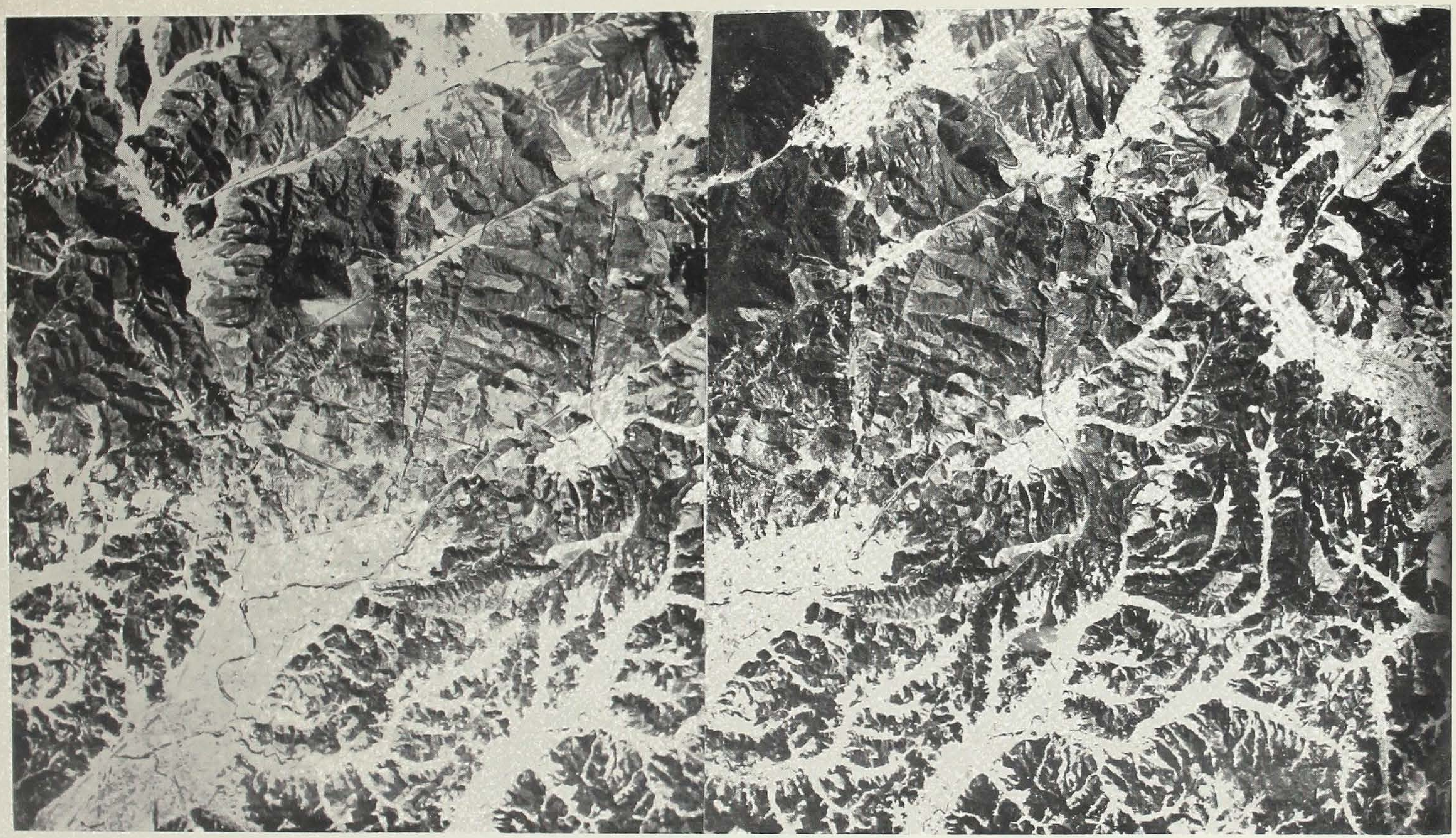


Plate II Stereographic aerial view of the northern part of the Sanda basin. Fractures occurred in the Cretaceous pyroclastic sediments can be seen clearly in the northern mountain area. They stretch to the southern basin covered by the Miocene blanket and control its drainage patterns (Shinoda, 1969). The location is indicated by a rectangle in Fig. 14. (Geographical Survey Institute)

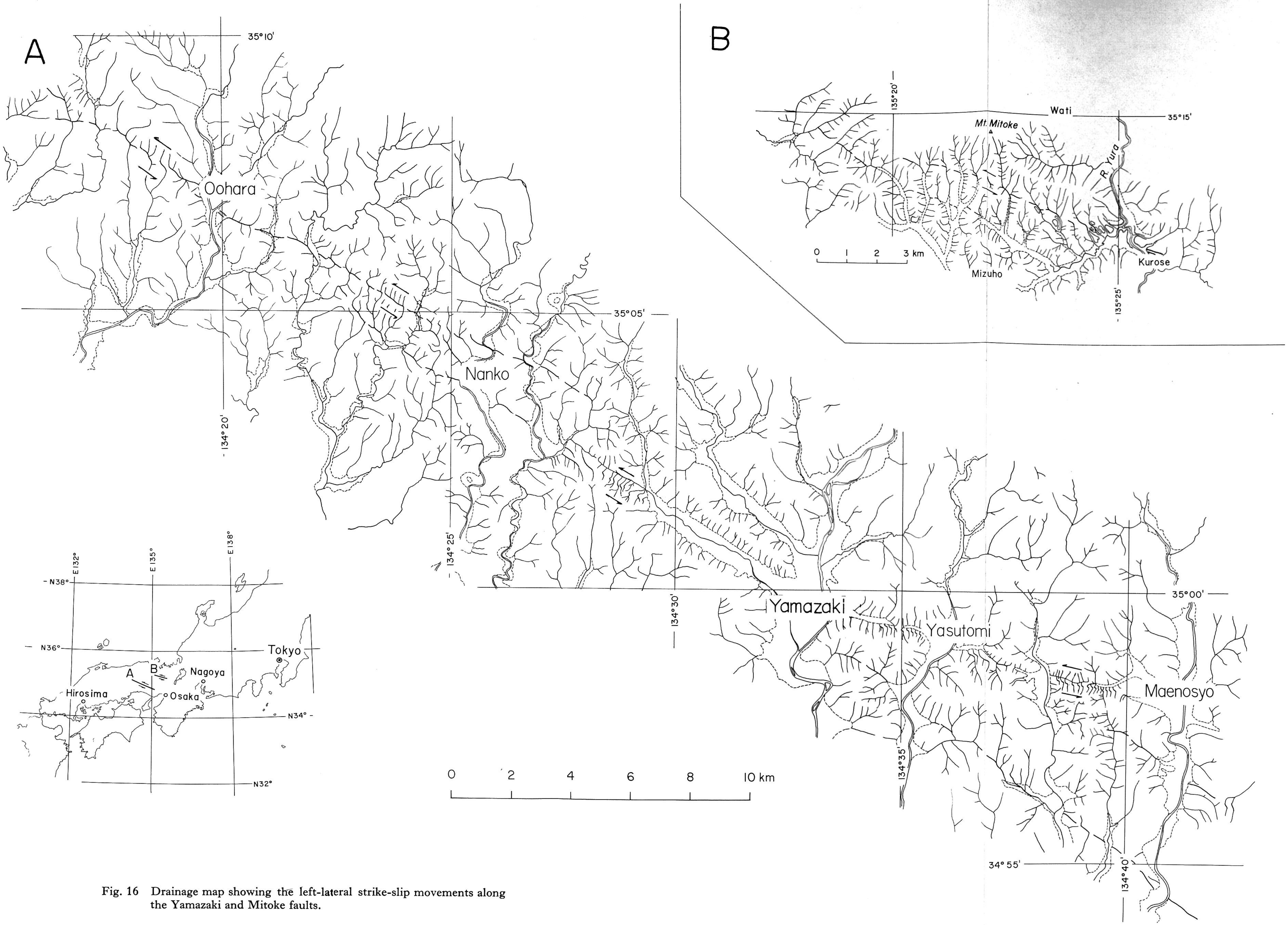


Fig. 16 Drainage map showing the left-lateral strike-slip movements along the Yamazaki and Mitoke faults.