Geomorphic Development of the Izumi and Sanuki Ranges and relating Crustal Movement

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Akira SANGAWA

1 Introduction

The central part of the southwest Japan, from Kinki Triangle (Huzita, 1962) to northeast Shikoku, is characterized by the alternative arrangement of small basins and narrow mountains, one or both sides of which are bordered by fault scarp (Fig. 1). Among them, two kinds of direction crossing each other almost at a right angle was recognzied (Huzita, 1968, 1969). The one is E-W direction along the Median Tectonic Line (MTL) such as, the Izumi Range, the Kinokawa River Basin, the Sanuki Range and the Yoshino River Basin; the other is N-S direction represented by the Osaka Basin, the Ikoma Mountains, the Nara Basin and the Suzuka Range.

These characteristic topographic arrangment has been formed mainly by the crustal movement during the Quaternary under the transition of regional stress pattern (Huzita, 1968, 1969; Huzita *et al.* 1973; Huzita and Okuda, 1973; Huzita and Ota, 1977; Okada, 1973), being directly reflected in the geomorphic development of this region.

The writer has investigated the geomorphic development of this attractive region, relating with the crustal movement. He already reported about the middle to eastern part of the Kinokawa river basin (Sangawa, 1977), the southern part of the Izumi Range (Okada and Sangawa, 1978), and preliminarily about the faulting of the northern foot of the Sanuki Range comparing to the southern foot of the Izumi Range (Sangawa, 1978).

In this paper, he refers to the uplift of E-W trending ranges along the northern side of MTL; the Izumi and Sanuki Ranges, comparing the geomorphic development and crustal movement of the southern foot of the Izumi Range and northern foot of the Sanuki Range.

2 The southwestern foot of the Izumi Range

In the central to western part of the Kii Peninsula, the Izumi Range, mainly of Cretaceous Izumi group, is formed along the northern side of MTL. The Range, 50 km in length and 10 km in width, rises from 300 m to 900 m high above sea level, being continuously higher to east (Fig. 1).

To the north of the Izumi Range, there are hills of Plio-Pleistocene Osaka group (deposits in the Osaka sedimentary basin) and terraces whose surfaces are

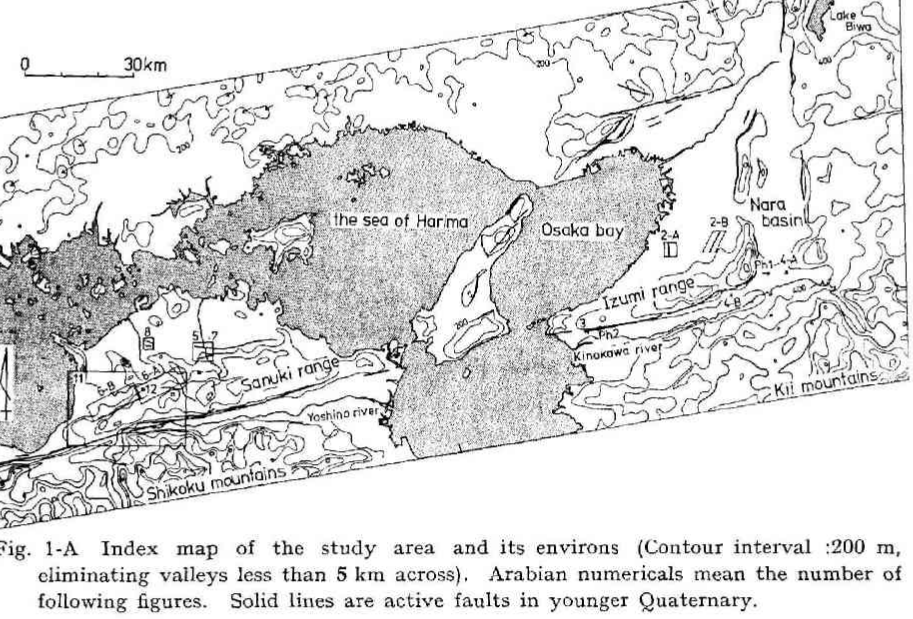

Fig. 1-A Index map of the study area and its environs (Contour interval :200 m, eliminating valleys less than 5 km across). Arabian numericals mean the number of following figures. Solid lines are active faults in younger Quaternary.

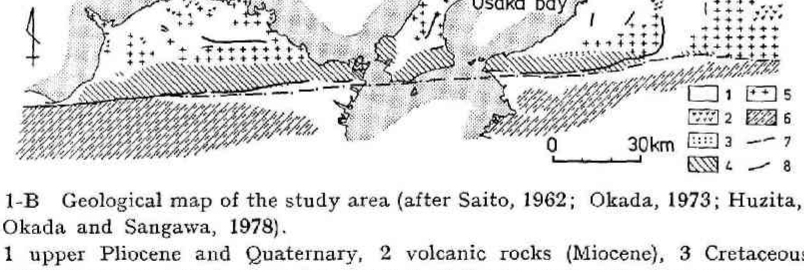

Fig. 1-B Geological map of the study area (after Saito, 1962; Okada, 1973; Huzita, 1974; Okada and Sangawa, 1978).

1 upper Pliocene and Quaternary, 2 volcanic rocks (Miocene), 3 Cretaceous acid volcanic rocks, 4 Cretaceous Izumi group, 5 Ryoke zone, 6 Sanbagawa metamorphic zone, 7 Median Tectonic Line, 8 active fault

partly deformed by faulting.

Along the southern side of MTL, the Kinokawa river basin extends E-W about 70 km in length and 8 km in width. In this basin, several steps of terrace surfaces are distributed, the deposits of which are unconformably overlying the Shobudani formation (mainly deposited in Quaternary). The southern side of the basin are bordered by the Sanbagawa schist zone of Kii mountains.

2.1. Younger Quaternary

2.1.1. Geomorphic development

Continuous river terraces along the Kinokawa river are classified into seven; Gojo, Yamada, Koino, Yamakage, Nohara, Futami and Imai surfaces in descending order (Sangawa, 1977). The highest Gojo surface, which is fairly dissected remaining original flat surface in a few places, is widely distributed in the middle and eastern part of the Kinokawa river basin (Photo. 1). Gojo formation (deposits of Gojo surface about 40～50 m thick) consists of well-rounded boulders transported by Paleo-Kinokawa river. Other surfaces bellow were mostly formed by tributaries, flowing down through the Izumi Range into the Kinokawa river which had been shifted toward the southern border of the basin (Sangawa, 1976, 1977).

As shown in Fig. 2 and Table 1, these terrace surfaces are correlated to the terrace surfaces in the southern part of the Osaka basin (Oka, 1961, 1972; Komyoike research group, 1971, Yoshikawa, 1973; Itihara *et al.*, 1975), based on the landforms of terrace surfaces and weathering of terrace deposits. Higher surface in the Osaka basin is not older than Yamada surface, suggesting that the formation of

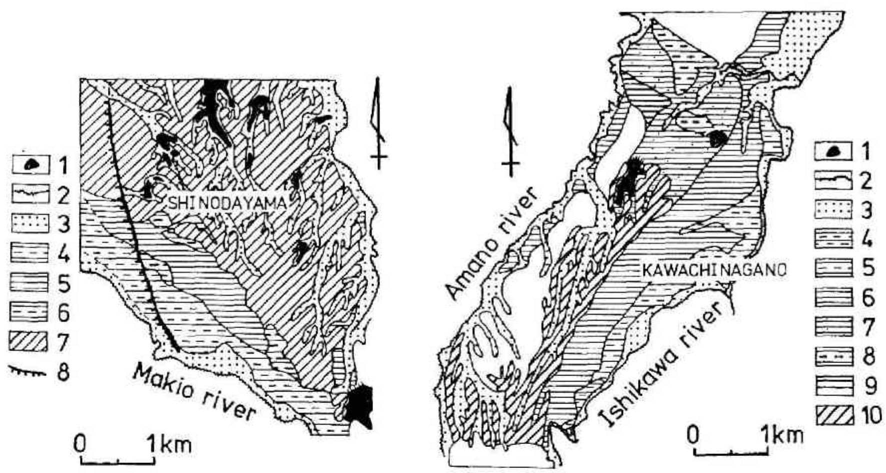

Fig. 2-A Fig. 2-B

Fig. 2-A Distribution of the terrace surfaces along the middle course of the Makio river. 1 pond, 2 river bed, 3 alluvial plain, 4 Sakamoto surface, 5 Kubode surface, 6 Higashi-sakamoto surface, 7 Shinodayama surface, 8 Sakamoto fault (Oka, 1972)

Fig. 2-B Distribution of the terrace surfaces along the middle course of the Ishikawa river. 1 pond, 2 river bed, 3 alluvial plain, 4 Taikohigashi surface, 5 Kawachinagano surface, 6 Chiyoda surface, 7 Kido surface, 8 Takidanihigashi surface, 9 Kusunokimachi surface, 10 Oyamada surface

Table 1 Correlation of terrace surfaces and deposits in the study area

	W of the Kinokawa basin (Okada-Sangawa, 1978)	E of the Kinokawa basin (Sagawa, 1977)	the Makio basin	the Ishikawa basin	the Kōtō basin	the Doki and Saida basin
Lower surface	tl_3 s.	Imai s.		Taikohigashi s.	Iwasaki s.	
	tl_2 s.	Futami s.	Sakamoto s.	Kawachinagano s.	Shimizu s.	Naiden s.
				Chiyoda s.		
	tl_1 s.	Nohara s.	Kubode s.	Kido s.	Oka s.	Zoda s.
Middle surface	tm s.	Yamakage s.	Higashisakamoto s.	Takidanihigashi s.	Kawauchibara s.	Jigenkyo s.
		Koino s.		Kusunokimachi s.	Tenpukujibara s.	Sumidokoro s.
Higher surface	th s.	Yamada s.	Shinodayama s.	Oyamada s.		Yoshino s.
Highest surface	Gojo s.				Yasuhara s.	Yakeotoge s.
	Gojo f.		Upper part of Osaka g.		Yakeotoge grav.	
↑ Younger Quaternary						
↓ Older Quaternary						
	Shobudani f.		Lower part of Osaka g.			
Late Pliocene			Lowest part of Osaka g.		Saida grav.	
					Mitoyo f.	

the Gojo formation belongs to the depositional age of the upper part of the Osaka group.

2.1.2. Crustal movement

The crustal movement is represented by active fault system of MTL, such as, Negoro fault, Gomyodani fault and Kongo fault, running to the north of the geologic boundary between Inner and Outer Zone (Okada, 1973; Huzita and Okuda, 1973; Matsuda, 1973; Okada and Sangawa, 1978).

Negoro fault (Ichikawa *et al.*), locating on the southwestern border of the Izumi Range, continuously displaced terrace surfaces dextrally and vertically (Fig. 3). The mean rate of the displacement along the fault is calculated based on the estimated age of the terrace surfaces, such as 0.8~2.8 $m/10^3$ y dextrally, 0.11~0.40 $m/10^3$ y vertically (Okada and Sangawa, 1976, 1978).

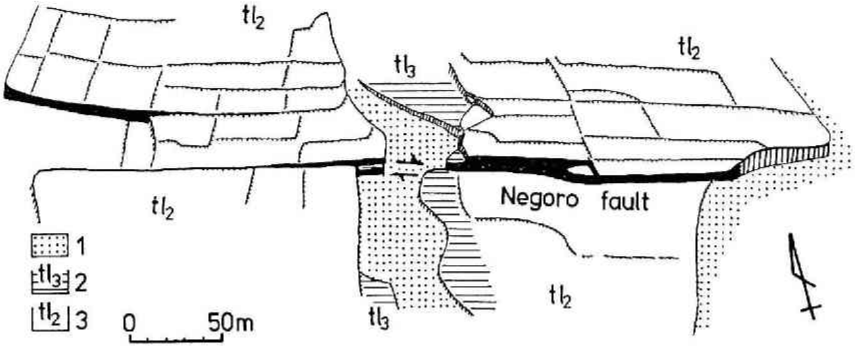

Fig. 3 Fault topography at the western end of the Negoro fault (terrace surfaces and dissected valleys are displaced vertically and dextrally along the fault) (Sangawa and Okada, 1977; Sangawa, 1978).
1 dissected valley, 2 tl_3 surface (Okada and Sangawa, 1978), 3 tl_2 surface (Okada and Sangawa, 1978)

Gomyodani fault (MTL research group of western Kinki, 1977) runs through the southern part of the Izumi Range, displacing numerous ridges and dissected valleys dextrally and vertically (Okada and Sangawa, 1978).

Along these faults, dextral displacement of dissected valleys (D) and the length of the valleys upstream (L) satisfy the relation D=aL (Matsuda, 1976), showing that dextral displacement has proceeded accumlatingly (Okada and Sangawa, 1978). The maximum dextral displacement of the dissected valleys along these faults is 1,200~1,500 m in Uchida-cho (Photo. 2-A), where fault topographies are clearly observed accompanied by shutter ridges. The writer reconstructed the landform reversely in sinistral sense along the Negoro fault about

1200 m (about the maximum displacement of dissected valleys) (Photo. 2-B). In the recovered landform, off-setted valleys and other fault topographies disappeared (Photo. 2-B), and this experiment supports the dextral displacement and its range.

2.2. Older Quaternary

2.2.1. Geomorphic development

Shobudani formation, more than 100 m thick, is distributed widely in the Kinokawa river basin. Its facies are generally as follows: Inner Zone gravels in the north of the basin, containing sand, silt and clay finer toward the basin center, and Outer Zone gravels in the south of the basin (Sangawa, 1977). The deposits of the Shobudani formation were derived from both Inner and Outer Zone, accompanied with the formation of shallow E-W trending basin along the southern part of MTL.

The lowermost part of the Osaka group in the south of the Osaka Plain (Uchihata Group: Oka, 1978) contains a plenty of gravels derived from Outer Zone, showing that some channels had flown across MTL into the Osaka Plain. The age of the uppermost part of the Uchihata Group is estimated about 2.5 m.y. B.P. by Fission Track dating (Ishida, 1970). The deposition of the Shobudani formation *i.e.* the beginning of the Kinokawa River Basin is thought to be later than 2.5 m.y. B.P. (Sangawa *et al.*, 1977b; Oka, 1978).

2.2.2. Crustal movement

Along the northern border of the Kinokawa river basin, many outcrops of reverse faults cutting the Shobudani formation have been reported (Kawata, 1939; Shiida, 1953, 1954; Suzuka, 1961; Ichikawa and Miyata, 1973; Umeda, 1973; Miyata *et al.*, 1974; Ichikawa *et al.*, 1976, 1977; MTL research group of Kinki, 1977, 1978; Sangawa, 1977, 1978; Sangawa *et al.*, 1977a; Sangawa and Okada, 1977; Okada and Sangawa, 1978; Sudo *et al.*, 1978). They are mainly along MTL as a geologic boundary.

These faults are not active in younger Quaternary. They are under Gojo surface especially east of Gojo (Okada, 1973; Sangawa, 1977), and overlaid uncomformably by Gojo formation, as shown in Fig. 4-A (Sangawa and Okada, 1977; Sangawa, 1978). Moreover, they express no fault landforms as shown in Fig. 4-B (Sangawa *et al.*, 1977a; Sangawa, 1978).

In older Quaternary, these faults along MTL were active to form the Kinokawa river basin, and resulted in the deposition of the Shobudani formation. But, in younger Quaternary, they become inactive and the building of the Izumi Range proceeded accompanying the faulting of the active fault system to the north of MTL (Sangawa, 1977; Okada and Sangawa, 1978).

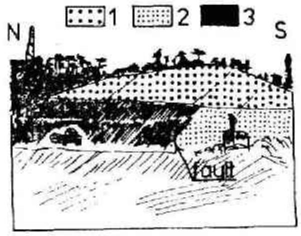

Fig. 4-A

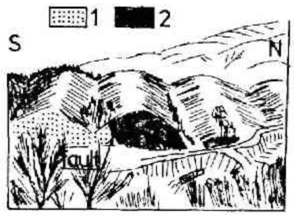

Fig. 4-B

Fig. 4-A Fault outcrop cut the Shobudani formation reversely and overlaid unconformably by Gojo formation (Sangawa, 1978).
1 Gojo formation, 2 Shobudani formation, 3 sheared bed rock (Cretaceous Izumi group)

Fig. 4-B Fault outcrop expressing no fault landform (Sangawa, 1978).
1 Shobudani formation, 2 sheared bed rock (Cretaceous Izumi group)

3 The north foot of the Sanuki Range

In the northeastern part of Shikoku, the Sanuki Range, mainly of Izumi group, exceptionally of Granite in comparatively lower northeastern part, is formed along the northern side of MTL. The Range, 90 km in length and being wide to east, rises up to 1057 m in the central part (Fig. 1).

To the north of the Sanuki Range, there are hills mainly of Plio-Pleistocene Mitoyo group and terraces whose surfaces are displaced in some regions.

Along the southern side of MTL, the Yoshino river basin extends about 80 km in length as a shape of the wedge whose point is in the west. In this region, several steps of terrace surfaces are distributed, being obviously displaced by active faults running parallel to the north of MTL. The southern side of the basin is bordered by Sanbagawa schist zone of Shikoku Mountains.

3.1. Younger Quaternary

3.1.1. Geomorphic development

The rivers, such as the Koto, Aya, Doki and Saida rivers, rising from the Sanuki Range and flowing through the Sanuki Plain into the Inland Sea, have wide terrace surfaces (Figs. 5, 6).

Along the middle course of the Koto river, terrace surfaces are classified into six; Yasuhara, Tenpukujibara, Kawauchibara, Oka, Shimizu and Iwasaki surfaces in descending order (Fig. 5).

The highest Yasuhara surface looks as a dissected fan, with a few original flat surfaces, of the Paleo-Koto and Paleo-Aya rivers joined here. The surface consists mainly of boulders derived from Izumi group, the lowest deposits

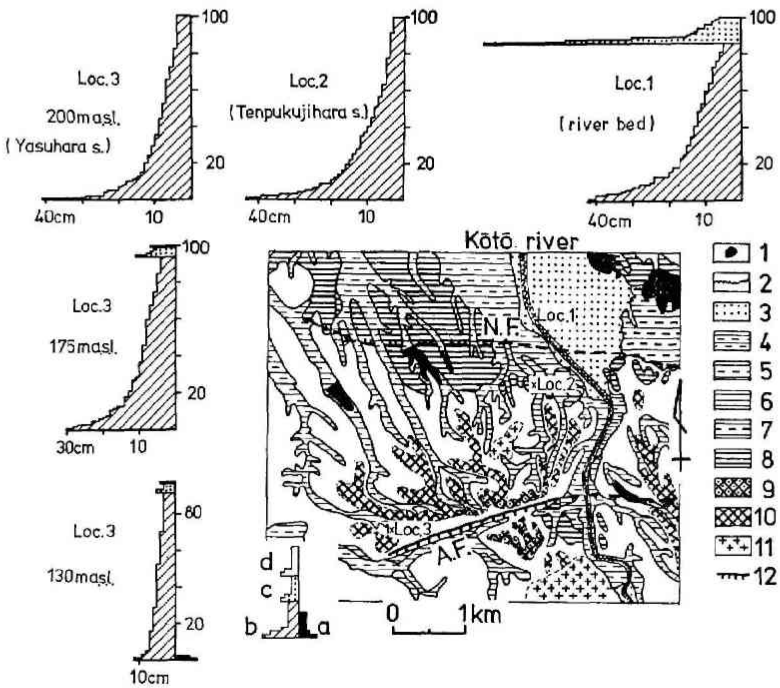

Fig. 5 Distribution of terrace surfaces along the middle course of the Koto river and the size histograms of terrace gravels by origins.
1 pond, 2 river bed, 3 alluvial plain, 4 Iwasaki surface, 5 Shimizu surface, 6 Oka surface, 7 Kawauchibara surface, 8 Tenpukujibara surface, 9 Yasuhara surface, 10 Yasuhara surface (flat summit level), 11 hills (Granite), 12 active fault displacing terrace surface. The maximum size and origin are shown about a hundred gravels measured continuously. a, Sanbagawa schist, b, Cretaceous Izumi group, c, Granite, d, the others

containing Sanbagawa schist in a few percentage (Fig. 5).

Tenpukujibara and Kawahigashi surfaces are also dissected fans, with comparatively wide original surfaces, formed by the Koto river and its tributaries. The deposits mainly consist of weathered boulders derived from Izumi group, which are reddishly weathered within one meter below the original surfaces.

Fig. 6-A, B Distribution of terrace surfaces in the northwestern foot of the Sanuki Range and the size histograms of terrace gravels by origins.
1 pond, 2 river bed, 3 alluvial plain, 4 Naiden surface, 5 Zoda surface, 6 Jigenkyo surface, 7 Sumidokoro surface, 8 Yoshino surface, 9 Yakeotoge surface (flat summit level), 10 hills (Saida gravel), 11 mountain and hills (Cretaceous Izumi group and Granite), 12 fault (active in older Quaternary).
The maximum size and origin are shown about a hundred gravels measured continuously.
a, Sanbagawa schist, b, Cretaceous Izumi group, c, Granite, d, the others

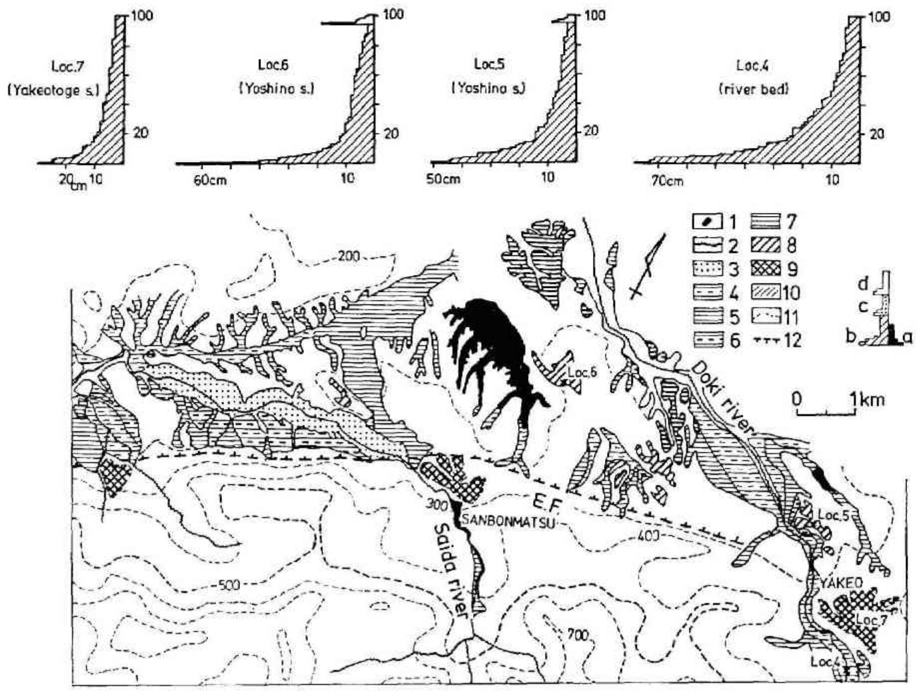
Loc.7
(Yakeotoge s.)
Loc.6
(Yoshino s.)
Loc.5
(Yoshino s.)
Loc.4
(river bed)
100
20
20cm
10
60cm
50cm
70cm
200
300
400
500
700
E.F.
SANBONMATSU
Saida river
Doki river
YAKEO
Loc.6
Loc.5
Loc.7
Loc.4
0 1km
1
2
3
4
5
6
7
8
9
10
11
12
a
b
c
d

Fig. 6-A

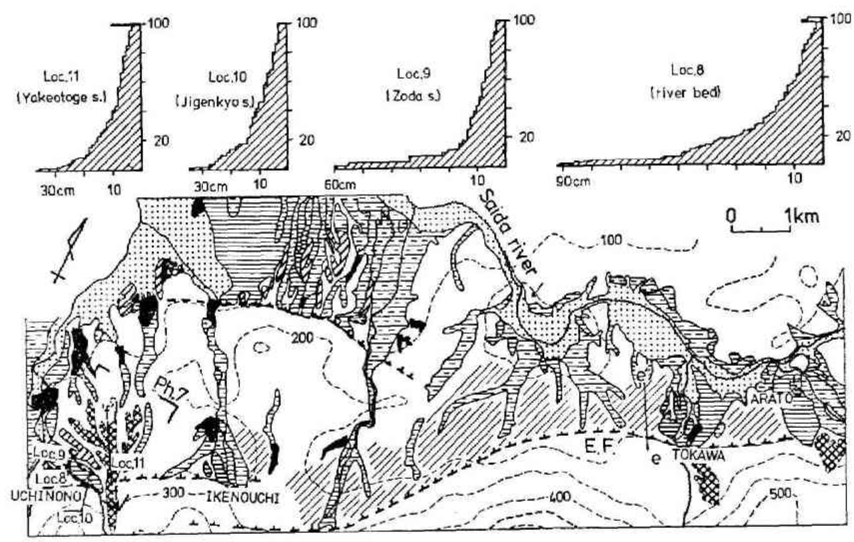
Loc.11
(Yakeotoge s.)
Loc.10
(Jigenkyo s.)
Loc.9
(Zoda s.)
Loc.8
(river bed)
100
20
30cm
10
60cm
90cm
Saida river
0 1km
100
200
300
400
500
Ph.7
E.F.
TOKAWA
ARATO
UCHINONO
IKENOUCHI
Loc.9
Loc.8
Loc.11
Loc.10
e

Fig. 6-B

Oka, Shimizu and Iwasaki surfaces are lower surfaces, scarcely dissected and remaining wide original surfaces. The deposits consist of fresh boulders derived from Izumi group and Granite mass.

In the northwestern foot of the Sanuki Range, terrace surfaces are widely distributed along the Doki and Saida rivers. They are typically developed along the midstream of the Saida river, and classified into six: Yakeotoge, Yoshino, Sumidokoro, Jigenkyo, Zoda and Naiden surfaces in descending order (Fig. 6).

The highest Yakeotoge surface is wide through the study area, for instance, Yakeo (north of Konan-cho), Sanbonmatsu (north of Chunan-cho), Tokawa (southeast of Saida-cho) and Uchinono (southeast of Onohara-cho). It remains few original surfaces, but its flat summit level express the landform of dissected fants (Photo. 7).

Saito (1962) named the thick boulder bed composing higher terrace surfaces "Yakeotoge gravel". The writer distinguished the highest one among higher terraces, and limited the name "Yakeotoge gravel" for the deposits of the highest surfaces. Yakeotoge gravel consists of boulder bed $40 \sim 70$ m in thickness, mainly derived from Izumi group (Saito, 1962).

Yoshino surface is also wide in the study area, especially it develops typically in Manno-cho between the Doki and the upstream of the Saida. It is fairly dissected and remains some original surfaces. Its deposits consit of weathered boulder within 10 m in thickness, mainly derived from the Izumi group.

Sumidokoro and Jigenkyo surfaces are fairly dissected and remains partial original surfaces. Their deposits consists of weathered boulders mainly from the Izumi group, containing reddishly weathered layer within 1 m in thickness below the original surfaces.

Zoda and Naiden surfaces are lower ones. They are scarcely dissected and remain wide original surfaces. The deposits consist of fresh boulders.

Terraces are correlated as shown in Table 1. The highest surface and its thick deposits derived from the Izumi group are important evidences for the uplift of the Sanuki Range.

3.1.2. Crustal movement

Along the southern foot of the Sanuki Range, dominant dextral movement of the active fault system of MTL is obvious on the terrace surfaces, whose mean rate is estimated $5 \sim 10$ m/10^3y (Okada, 1968, 1970, 1973, 1977).

In the northern foot of the Sanuki Range, active faults displacing terrace surfaces have not recognzied except Nagao fault (Saito, 1962) and its extention. The Tenpukujibara surface is cut by Nagao fault (Sangawa, 1973), and the vertical displacement is measured about 9–12.5 m upthrown to S (Figs. 7, 9; Photos, 3, 4).

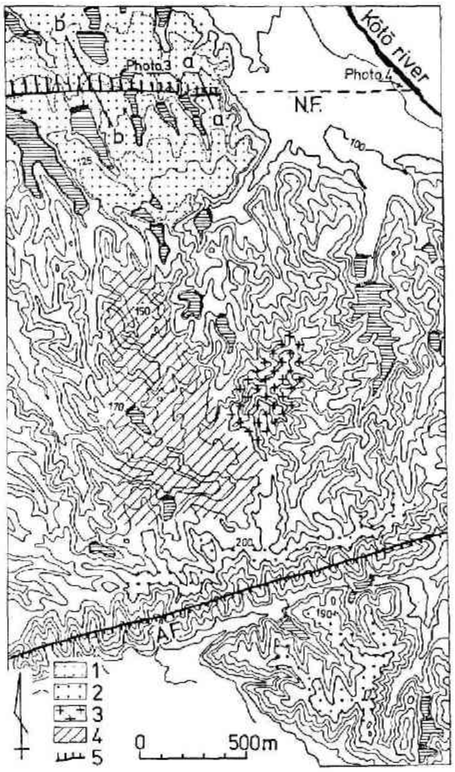

Fig. 7 Fault topography along the Nagao and Ayutaki faults.
1 Yusa surface, 2 Yasuhara surface, 3 hills (Granite), 4 altered landscape by the construction of the country club, 5 active fault displacing terrace surface

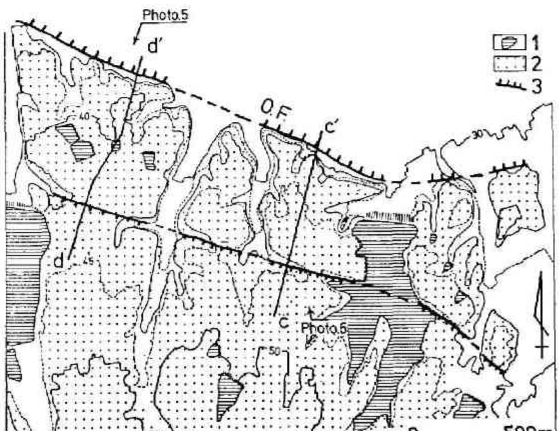

Fig. 8 Fault topography along the Okada and paralleled secondary faults.
1 pond, 2 Shinkai surface, 3 active fault displacing terrace surface

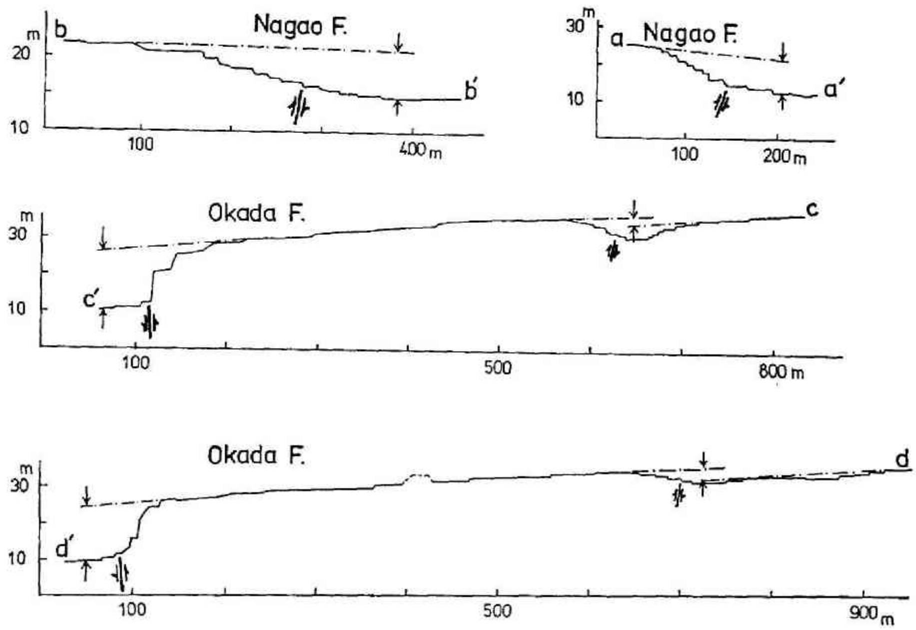

Fig. 9 Cross-profiles along the fault displacing terrace surfaces in the north foot of the Sanuki Range

Table 2 Displacement and mean rate of faulting displacing terrace surfaces in the north of Sanuki Range

Name	Displacement (m) (upthrown side)	Terrace surface	Mean rate $m/10^3y$
Nagao fault	9~12.5 (s)	Tenpukujibara s.	0.07~0.1
Ayutaki fault	10 (N)	Yasuhara s.	0.02±
Okada fault	17.5+ (s)	Shinkai s.	0.2^+
secondary fault of Okada fault	2.5~4.4 (N)	Shinkai s.	0.02~0.04

An outcrop of reverse faulting is observed in the eastern extention of the Nagao fault scarp (Fig. 7; Photo. 4) (Bando *et al.*, 1967). Parallel running Ayutaki fault (Sangawa, 1973) to the south of Nagao fault, displaced the Yasuhara surface about 10 m upthrown to N vertically (Figs. 7, 9).

To the NW extention of the Nagao fault, another fault landform is reported (Hirano, 1973), where the Shinkai terrace surface (correlated to Tenpukujibara or Kawauchibara surface) is displaced more than 17.7 m upthrown to SW. The fault (Okada fault) is also accompanied by a secondary fault to the south, which cut the Shinkai surface upthrown to NE, about 2.5～3.5 m vertically (Figs. 8, 9; Photos. 5, 6).

Tenpukujibara surface is correlated to Koino surface and Yasuhara surface to Gojo surface in the Kinokawa river basin, and their formation ages are estimated 0.13±m.y. B.P. and older than 0.3 m.y. B.P. respectively.

The mean displacement rate of these faults are shown in Table 2. They belong to B～C ranks in Matsuda's classification (1976).

3.2. Older Quaternary

3.2.1. Geomorphic development

Mitoyo formation, composed of clay, silt, sand and gravel, is widely distributed from central to western part of the northern foot of the Sanuki Range (Saito, 1962). It deposited in lacustrine environment during late Pliocene, and it is covered by Yakeotoge gravel (Saito, 1962). As mentioned above, the name of "Yakeotoge gravel" is limited for the deposits forming the highest surface, then the writer gives the name "Saida gravel" for the deposits forming the dissected hills in the region from Saida-cho to Yamamoto-cho. They are thought to be deposited fairly before the formation of the highest surface (Figs. 6, 10).

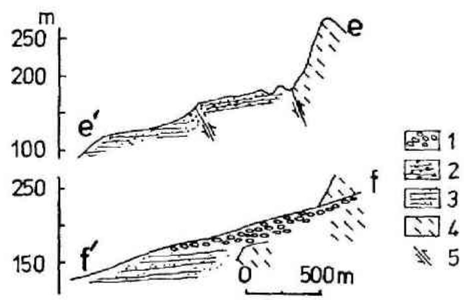

Fig. 10 Cross-profiles of some places in the northwestern foot of the Sanuki Range.
1 Yakeotoge gravel, 2 Saida gravel, 3 Mitoyo formation, 4 Cretaceous Izumi group, 5 fault (active in older Quaternary)

The Mitoyo formation and Saida gravel contain the gravels of Sanbagawa schist from the Outer Zone (Saito, 1962; Okada, 1973; Sangawa, 1978). The content-ratio of gravels from several origins, composing the Mitoyo formation and the Saida gravel, tells that the Outer Zone gravels reach 20～30% in the region from Arato in Saida-cho to Ikenouchi in the south Awai-cho (Fig. 11). As pointed out by Saito (1962), Okada (1973) and Sangawa (1978), some rivers were flowing into the region from the Outer Zone. Paleo-Yoshino river is thought to have brought most of gravels from Sanbagawa schist through the relatively lower pass of the Sanuki Range (Okada, 1973; Sangawa, 1978). Another paleo-streams presumed about 5 km west of the Paleo-Yoshino river. A few Sanbagawa schist gravels are observed widely in other area of Mitoyo group (Fig. 11). Other paleo-

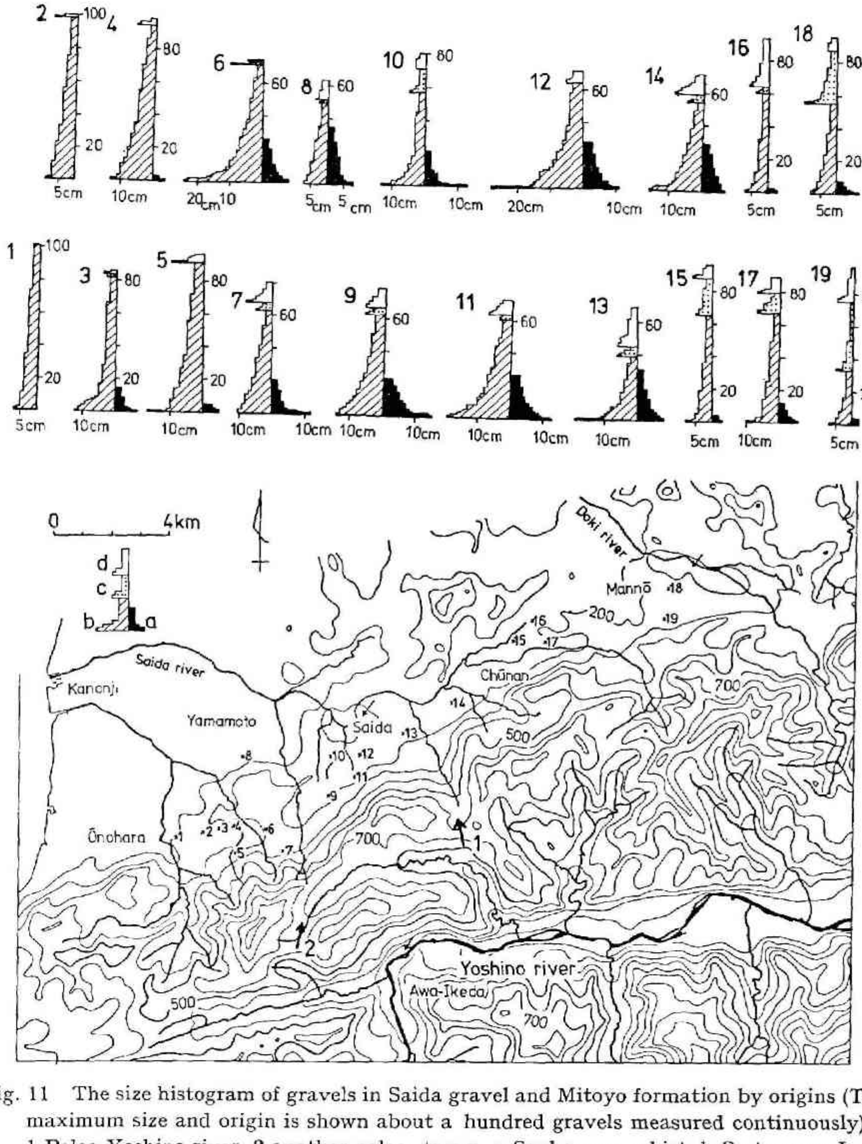

Fig. 11 The size histogram of gravels in Saida gravel and Mitoyo formation by origins (The maximum size and origin is shown about a hundred gravels measured continuously).
1 Paleo-Yoshino river, 2 another paleo-stream, a Sanbagawa schist, b Cretaceous Izumi group, c Granite, d the others

streams into the study area from the Outer Zone are possible. The Paleo-Yoshino river had flowed during the deposition of Mitoyo group and Saida gravel, thereafter the Sanuki Range began to uplift and stopped the Paleo-Yoshino river course and the supply of the Outer Zone gravels.

3.2.2. Crustal movement

Along the northwest border of the Sanuki Range, Ebata reverse fault cuts the Mitoyo group (Saito, 1962) and Saida gravel. The fault outcrops in many locations are mostly covered by Yakeotoge gravel (Saito, 1962). Along the Ebata fault, displaced terrace surfaces (including the highest surface) are scare and other fault landforms are not clear (Fig. 12). Perhaps the fault become inactive in younger Quaternary. Paleo-currents diminished at the uplift of the Sanuki Range accompanied by the action of the Ebata fault.

After the formation of the highest surface, fault activity was removed to the north of the Nagao fault (Saito, 1962; Sangawa, 1978).

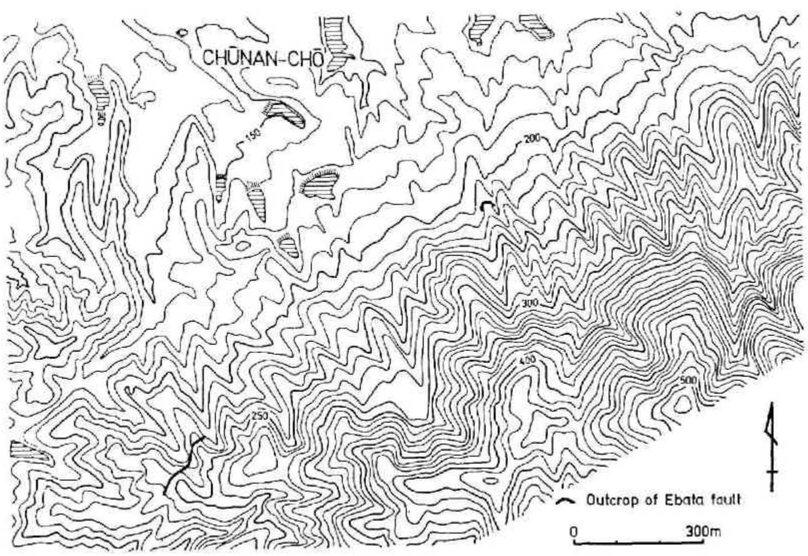

Fig. 12 Landform along the Ebata fault south of Chuan-cho

4 Discussion

4.1. The highest terrace surface and deposit

The terrace surfaces are correlated as shown in Table 1.

The highest Gojo, Yasuhara and Yakeotoge surfaces are thought to have been formed during the depositional age of the upper part of the Osaka group. They are characterized as depositional surfaces of thick boulder beds, overlying the lacustrine deposits. As described before (Sangawa, 1977), Gojo surface was formed through the ages and has wide surface. Its boulders, mainly derived from the mountain behind, have much larger sizes than the lower lacustrine deposits. Boulders of terrace surfaces are increasing the size with the process of time toward recent, as shown in some regions along the north foot of the Sanuki Range (Figs. 5, 6). It supports the opinion (Saito, 1962; Huzita, 1976; Sangawa, 1977; Okada and Sangawa, 1978), that the uplift of Izumi and Sanuki Ranges was accelerated since the beginning of the highest terrace deposition.

4.2. Outer Zone gravel carried into Inner Zone

The Uchihata formation in the south of the Osaka Plain (Oka, 1978), deposited before about 2.5 m.y. B.P., consists of much Outer Zone gravel which was transported by some rivers into Osaka Basin across MTL, when Izumi Range is very low or negligible in relief. Thereafter, with the formation of Izumi Range and Kinokawa river basin these rivers were diminished (Sangawa *et al.*, 1977b; Sangawa, 1977; Oka, 1978; Okada and Sangawa, 1978).

Mitoyo formation and Saida gravel north of Sanuki Range contain much Outer Zone gravel, which was transported by Paleo-Yoshino river and another river westward into Inner Zone across MTL. The deposition of Mitoyo formation and Saida gravel is not exactly aged, but it is older than the highest surface deposits (Yakeotoge gravel), *i.e.* fairly before younger Quaternary.

4.3. Crustal movement (Fig. 13)

4.3.1. Around Izumi Range

The faulting along MTL was inactive because of the existence of through rivers carrying Outer Zone gravel until about 2.5 m.y. B.P.

Since then, Izumi Range began to uplift and the Kinokawa river basin to be formed, accompanied with the faulting along MTL.

During the deposition of Gojo formation (at least within 1 m.y. B.P.), the fault along MTL became inactive again and the faults to the north of MTL have acted with the heavy uplift of Izumi Range. Dextral displacement (1,500 m in maximum) along such faults is thought to be accumulated during the latest 0.5 m.y., assuming the mean rate of 2.8 m/10^3 y. The dextral movement seems to have been most active in this age.

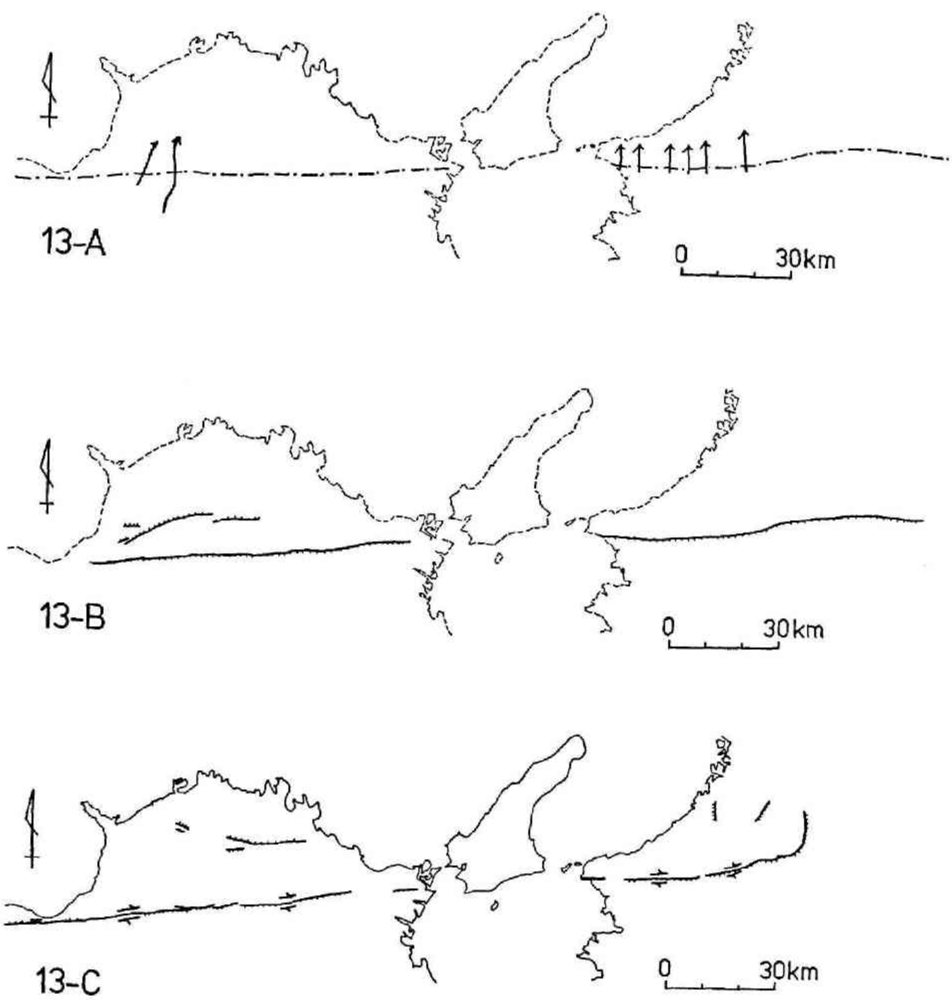

Fig. 13 Faulting in the study area since late Pliocene.
13-A, late Pliocene age (some channels flowed into Inner Zone from Outer Zone; faulting along MTL was inactive),
13-B, older Quaternary age (solid lines are faults),
13-C, younger Quaternary age (solid lines are active faults)

4.3.2. Around Sanuki Range

The fault activity north of Sanuki Range is related to the Range uplift and MTL activity.

It is thought to be not so active during the deposition of the Mitoyo formation and Saida gravel. Thereafter, Ebata fault became active, with the uplift of the Range, when the rivers from Outer Zone disappeared.

Ebata fault cuts the Mitoyo formation and Saida gravels, but it is covered by Yakeotoge gravel and highest surface. In younger Quaternary, Ebata fault stopped the action and Nagao fault to the north began to displace terrace surfaces. The course of Paleo-Yoshino river was displaced dextrally about 4 km along MTL (Okada, 1973; Sangawa, 1978). The displacement is explained as accumulated displacement during the latest $0.5\sim1$ m.y., according to the estimated mean rate of $5\sim10$ m/10^3y (Okada, 1973). The dominant dextral fault activity of MTL seems to be originated in younger Quaternary, accompanied with the heavy uplift of Sanuki Range, simultaneously Nagao fault north of the Range was in action.

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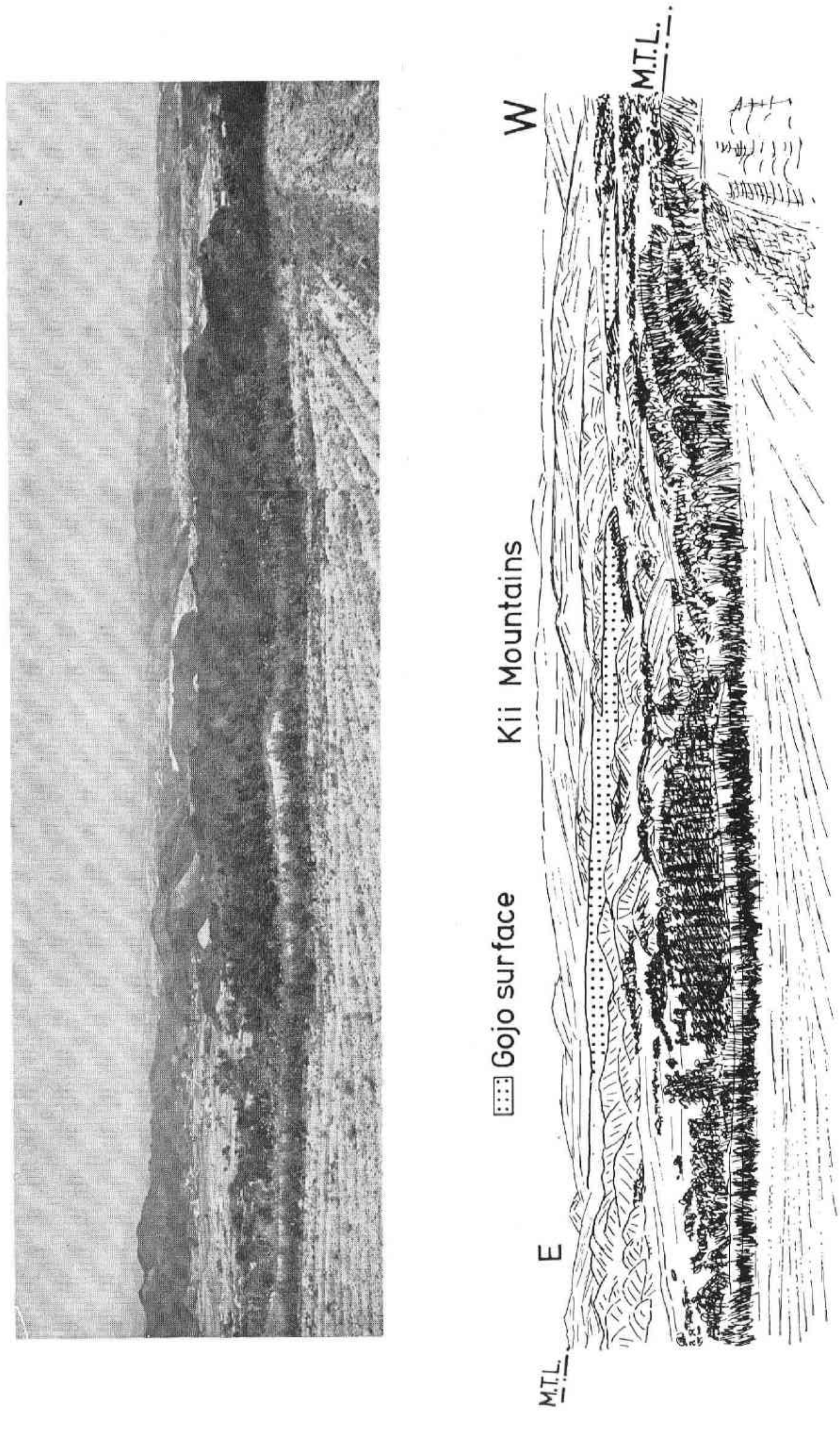

Photo 1. Gojo surface widely distributed in the eastern part of the Kinokawa River Basin.

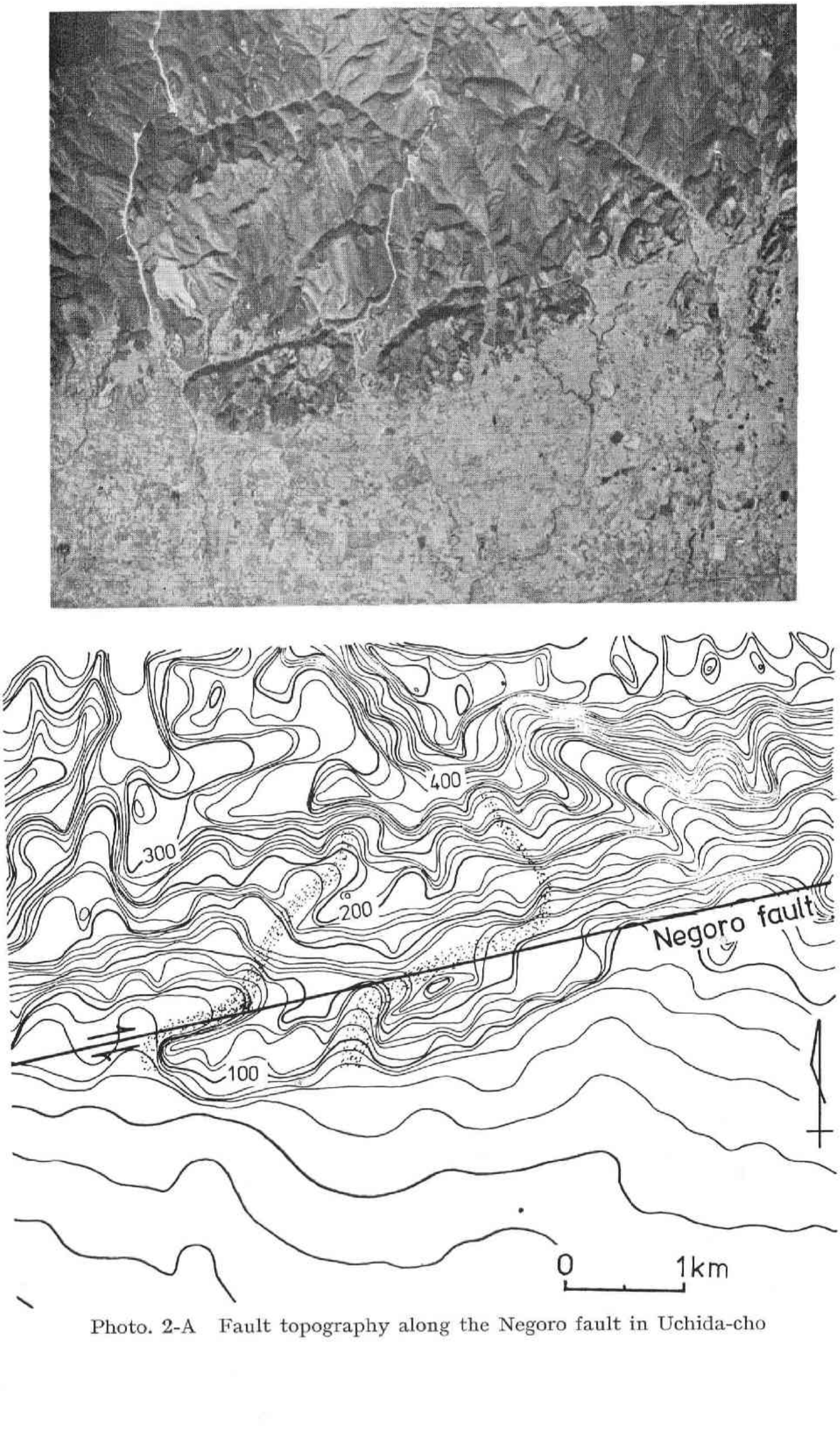

Photo. 2-A Fault topography along the Negoro fault in Uchida-cho

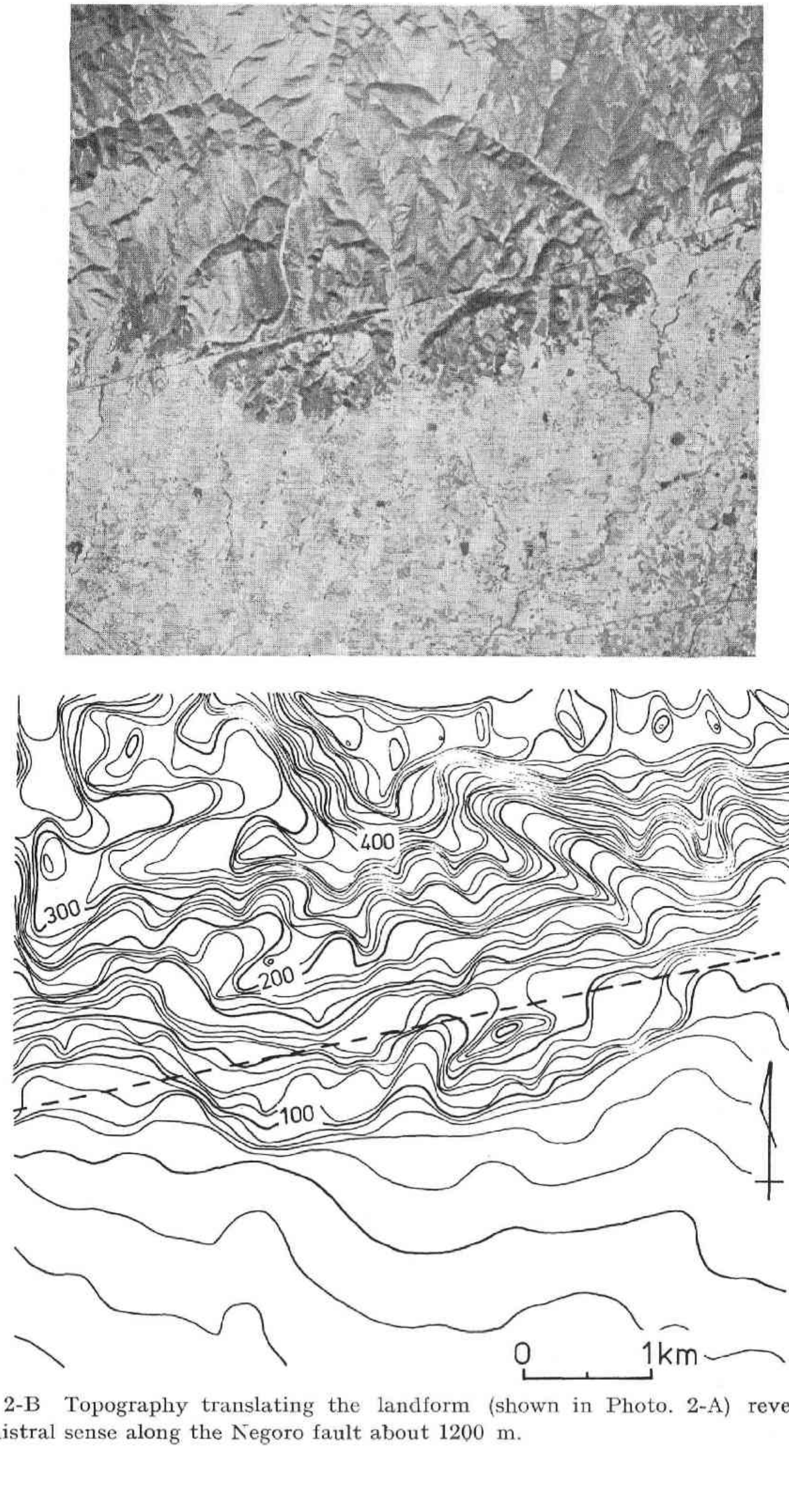

Photo. 2-B Topography translating the landform (shown in Photo. 2-A) reversely in sinistral sense along the Negoro fault about 1200 m.

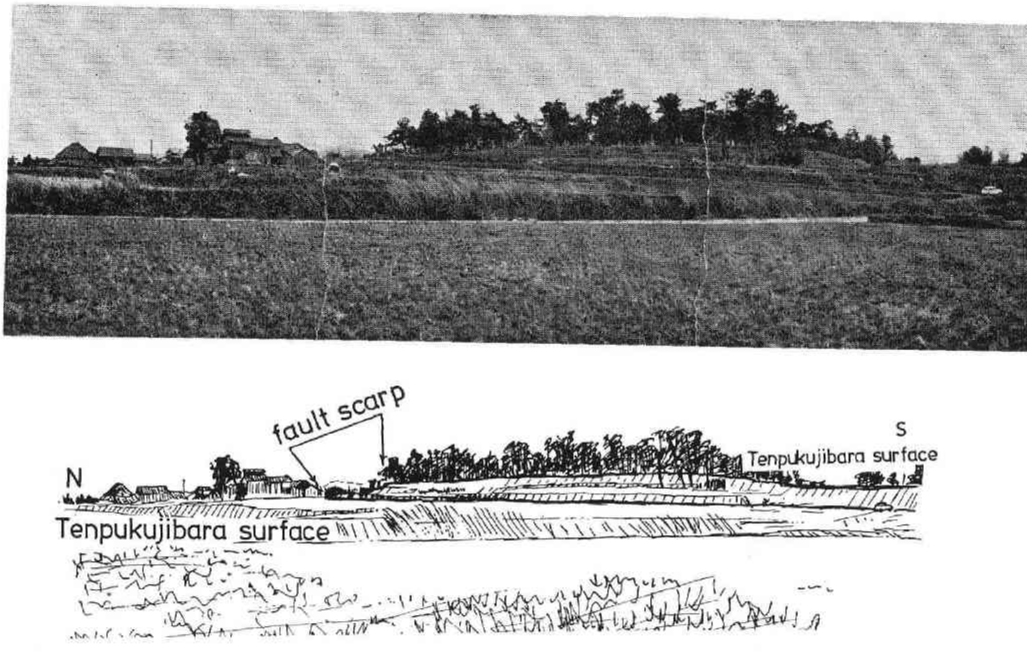

Photo. 3 Fault scarp of Nagao fault displacing Yusa surface

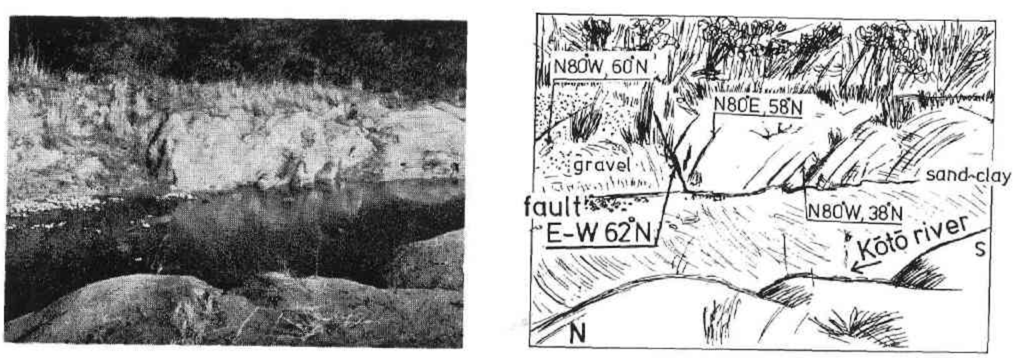

Photo. 4 Fault outcrop of Nagao fault in the Koto river bed

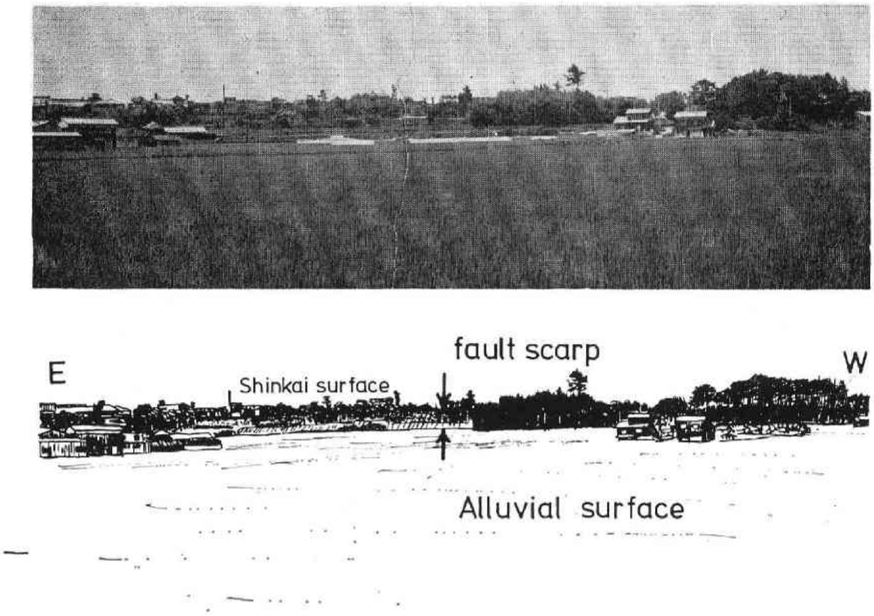

Photo. 5 Fault scarp of Okada fault displacing Shinkai surface

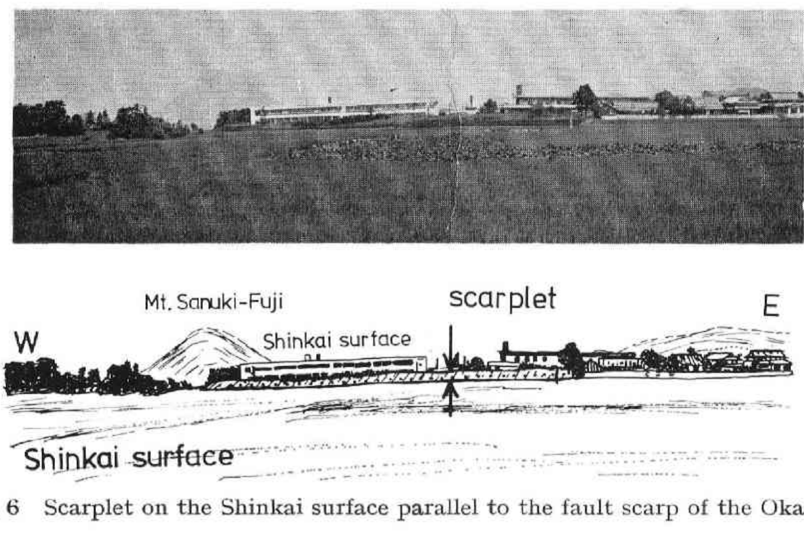

Photo. 6 Scarplet on the Shinkai surface parallel to the fault scarp of the Okada fault

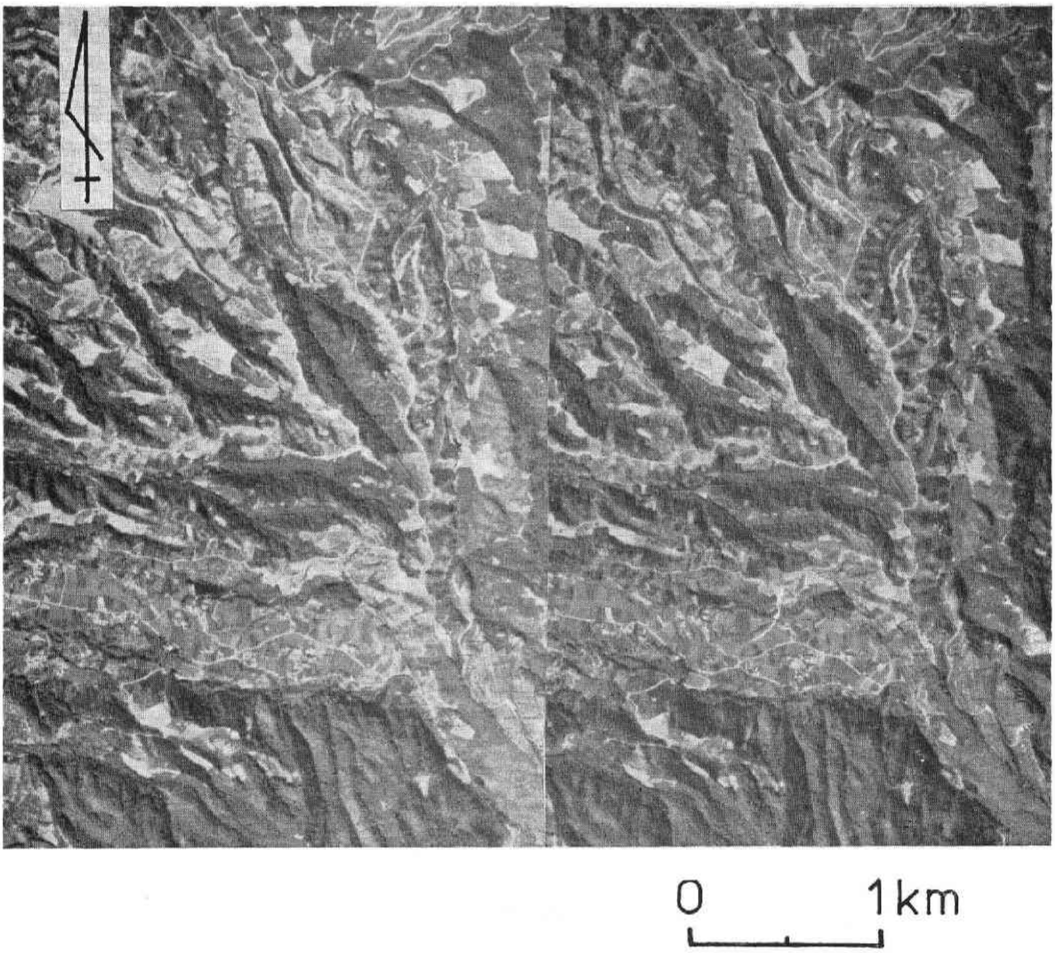

Photo. 7 Stereograph of Yakeotoge surface (flat summit level) about Uchinono in southeast of Onohara-cho