47. *Post Pliocene Crustal Movements in the Outer Zone of Southwest Japan and in the "Fossa Magna."*

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Introduction.

In a previous paper[1] the writer compared the geologic structure of the lower Pliocene strata in the Outer zone of Southwest Japan with that in the Fossa Magna, and arrived at the following conclusions:

The lower Pliocene or Pliocene strata are usually monoclinal at low angles either to the southwest or to the southeast, with the exception of a few small displacements in other directions, while the contemporaneous deposits in the Fossa Magna form a complex anticlinorium, each pericline having a trend parallel to that of the Fossa Magna. There are many thrust- and normal-faults associated with these folds. Volcanism was frequently active. The structural lines of the lower Pliocene deposits conform neither to the general trend of the Honsyû arc nor to the main structural lines of the Outer zone of Southwest Japan, but with the trend of contour lines of a summit-level in the Outer zone of Southwest Japan. Moreover, the inclination of the bedding plane of the Pliocene strata is steeper than that of the surface of the summit-level, which dips in the same direction. The writer inferred from these facts that an extensive crustal movement in the form of broad swells took place in the Outer zone of Southwest Japan along a line parallel to the Ryûkyû arc rather than to the Honsyû arc.

The land surface that is represented in outline by the summit-level was denuded during post lower Pliocene, seeing that the lower Pliocene strata are cut by the surface of the summit-level. After that came crustal deformation in the form of broad swells by which the denuded surface was upwarped to the same height as the surface of the summit-level, and this may have continued into the post-Pliocene.

It is a question whether the structural movements in this geologic

1) Y. ÔTUKA, "Early Pliocene Crustal Movement in the Outer Zone of Southwest Japan and in Naumann's Fossa Magna," *Bull. Earthq. Res. Inst.*, 9 (1931), 340-352.

region in the form of broad swells as stated above have continued since the Pliocene to recent times. In this first half of the paper (the second to follow at a later date) will be discussed the geologic structures and the geomorphologic characters that point to crustal deformation during post-Pliocene. Since the Pliocene, the Outer zone of Southwest Japan has been deformed by a marked type of crustal deformations, and the old upwarped land surfaces have worn away through atmospheric denudation, while the old downwarped sea bottoms are covered by fresh deposits. In profile, the old imaginary surfaces that existed as dry land as well as under the sea are seen to have increased their amplitudes, just like stationary waves (Fig. 1).

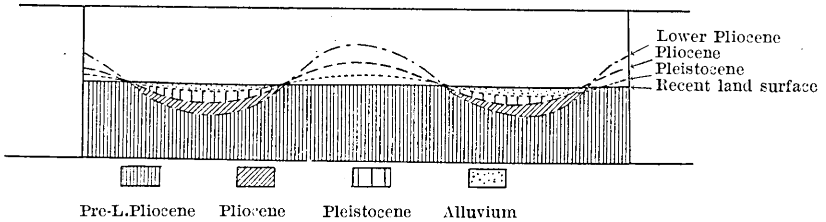

Fig. 1. Ideal section of the areas being deformed in the form of broad swells.

In view of the fact that crustal deformations, such as described in the previous paper, have been found in lower Pliocene strata in the Outer zone of Southwest Japan, the writer considers it reasonable to expect to find similar deformations in the geological structure of post-Pliocene deposits, in the very same part of Japan as well as in the Fossa Magna. These deformations in the crust of the two regions just mentioned will be treated in the latter half of this paper (to follows at a later date), when the crustal disturbances will be considered with reference to the result of precise levels that were run in the two regions.

The Stratigraphic Correlation of the Post Pliocene Strata in the Outer Zone of Southwest Japan with that in the Fossa Magna.

Before discussing the crustal deformations of these region, their general stratigraphy will be outlined. The stratigraphic correlation of the Neogene formations in these regions, which were listed in the writer's previous paper (Table I), needs some corrections in the light of new facts that have come to our knowledge since last year. In Table II are ten stratigraphic columns for these region, which were compiled from different sources, and is the new scheme of stratigraphic correlation of the Neogene strata in these regions. The post-Pliocene stratigraphy being fully discussed in the "Dai Si Ki" (The Quaternary) of Iwanami Kôza,[2] it will not be repeated here, although certain features of it will be explained in later sections.

For convenience, the Outer zone of Southwest Japan, i.e., the Southern part of the median dislocation line of Southwest Japan, will be divided into five regions as follows:—(a) Tôtômi,[3] (b) Kii,[4] (c) southeastern Sikoku,[5] (d) southwestern Sikoku, (e) Hyûga[6] coastal plain; and the Fossa Magna into three, (f) Suruga,[7] (g) Idu[8] and Sagami[9] and (h) Sinano.[10] In six of these regions,—a, c, e, f, g, h, the Pliocene strata are exposed as already mentioned, while with the exception of southwestern Sikoku, the post-Pliocene strata are exposed in all of them. (Fig. 2.)

Table I. (1931, 9. Y. Ôtuka.)

Locality / Geologic Age	(1) Miyazaki	(2) Kôti	(3) Kakegawa	(4) Asigara	(5) Nagano
Upper Diluvium	Gravel beds	Gravel beds	Gravel beds	Volcanic lava and ash	
Lower Diluvium	Freshwater deposits		Ogasa conglomerate	Gravel beds	
Upper Pliocene			Soga beds	(Ninomiya beds) Nisikoiso beds	
Lower Pliocene	Takanabe group { Heki beds, Kôonzi beds, Sadowara beds	Suzuki's Pliocene	Kakegawa series	Asigara beds	Sigarami beds
		Umbonium mysticum Zone	Horinouti series		Ogawa beds
Miocene	Tuma group		Sagara beds	Misaka beds	

Post Pliocene Crustal Deformation in the Outer Zone of Southwest Japan.

In order clearly to understand the post-Pliocene crustal deformation in the Outer zone of Southwest Japan, the geologic and geomorphologic features of the respective regions will first be discussed, after which the

2) Y. Ôtuka, "Daisiki" (The Quaternary), *Iwanami Kôza*, (1931), (in Japanese).

3) 遠江. 4) 紀伊. 5) 四國. 6) 日向. 7) 駿河. 8) 伊豆. 9) 相模. 10) 信濃.

Table II. New scheme of stratigraphic correlation of the Neogene strata in the Outer zone of Southwest Japan and in the Fossa Magna. (1932, 6. Y. Ôtuka.)

Province / geologic age	a Tôtômi I. Makinoga-hara.	a II Mikataga-hara.	a III Ogasa hill	a IV. Atumi peninsula	b Kii	c SE Sikoku	e Hyûga	f Suruga	g Idu Sagami	h Sinano
Du.	Makinoga-hara upheaved fluviatile plain	Mikataga-hara upheaved dalta plain		Atumi penin. raised coastal plain	Coastal terraces	Coastal terraces	Coastal terraces	Base of Hudi volc.		
du_I.	Makinoga-hara gravel beds	Mikataga-hara gravel beds		Upper division of Atumi beds					Hakone volcanic ashes	Gravels of River terraces
dl_{II}.	Huruya shell beds	Sahamma shell beds		Lower division of Atumi beds	Sakisima beds		Tôriyama-hama beds		Hirai pumiceous beds	Siokawa beds
dl_I.	Ogasa con-glomerate	Ogasa con-glomerate	Ogasa con-glomerate					Kunôsan & Kanbara conglome-rate	Suruga & Kuroiwa conglome-rate	
pd.		Soga beds	Soga beds						Zyô beds	Kabutoiwa plant beds
pu.								Kunôsan beds	Kasiwa-tôge beds	
p.	Horinouti series	Kakegawa Series				Tôno-hama group	Takanabe group	Asigara beds		Sigarami & Ogawa beds
m.	Tamari beds						Tuma group			

Du=topographic surfaces of upper Pleistocene; duI=lower half of upper Pleistocene; dlII=upper half of lower Pleistocene; dlI=lower half of lower Pleistocene; pd=transitional formations between lower Pleistocene and upper Pliocene; pu=upper Pliocene (Lower Carabrian); p=Pliocene (middle and lower); m=Miocene (upper).

marked features of the crustal deformation of the post-Pliocene in these regions will be readily grasped.

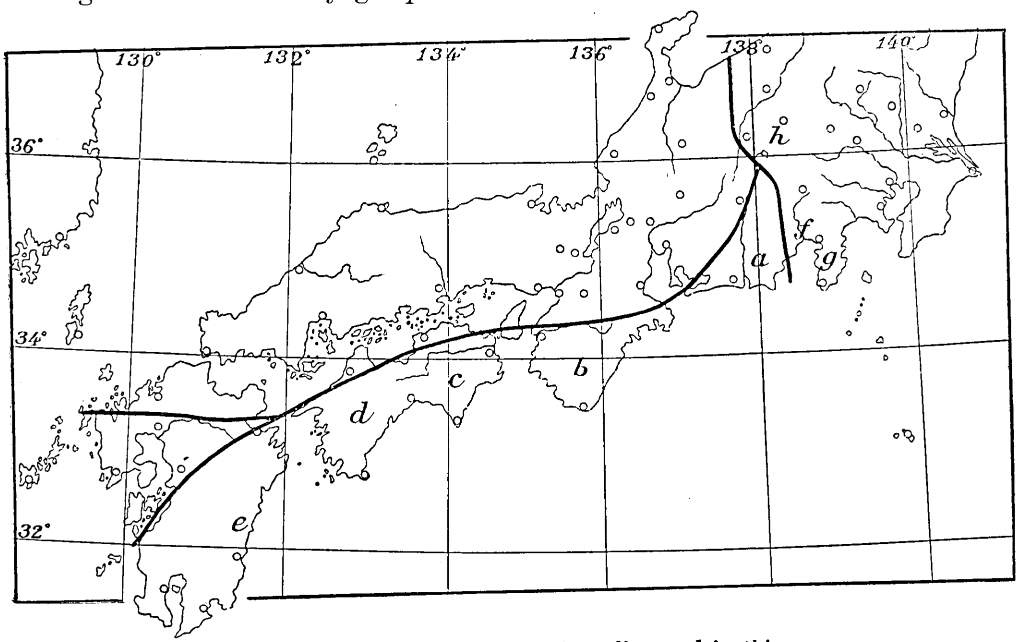

Fig. 2. Index map showing the regions discussed in this paper.

a = Tôtômi, b = Kii, c = Southeastern Sikoku, d = Southwestern Sikoku, e = Hyûga
Outer Zone of Southwest Japan.

f = Suruga, g = Idu, h = Sinano
Fossa Magna.

(*a*). *"Tôtomi" region.* The stratigraphy of the Tôtômi districts, as shown in the list (Table II), was surveyed by the late S. Miura,[11] the late K. Nakajima,[12] and later studied by Ishii,[13] Chitani[14] and Makiyama.[15] It is from the writing of the three last-named that the writer has arranged the succession of strata for this region in Table II, column a I, II, III, IV. (Fig. 3).

11) S. Miura, Expl. Text Geol. Map Japan. "Toyohashi" sheet, 1:200.000, (1889), (in Japanese).

12) K. Nakajima, Expl. Text Geol. Map Japan, "Shidzuoka" sheet, 1:200.000, (1886), (in Japanese).

13) K. Ishii, Expl. Text Geol. Map Japan, "Irakozaki" sheet, 1:75.000, (1927).

14) Y. Chitani, Expl. Text Geol. Map Japan, "Sagara" sheet, 1:75.000, (1927); Expl. Text Geol. Map Japan, "Shidzuoka" sheet, 1:75.000, (1932).

15) J. Makiyama, "Stratigraphy of the Kakegawa Pliocene in Tôtômi," *Mem. Col. Sci., Kyôtô Imp. Univ.*, Ser. B, 7, 1 (1931).

This region is divided for convenience into four sub-regions:— I. Makinogahara[16] (eastern portion of the Ôigawa[17] dissected delta), II. Mikatagahara[18] (the Tenryûgawa[19] dissected delta), III. the Ogasa[20] hill (between I and II.), IV. the Atumi[21] peninsula (southwestern part of Mikawa[22]).

I. *The Makinogahara subregion,* lying between the industrial city of Hamamatu and the city of Siduoka (noted for its tea), is the upheaved dissected fluviatile plain of the ancient Ôigawa. Its height ranges from 280 m. in the north, where the dissected fluviatile plain is bounded by the mountainland of pre-Tertiary formations, to 60 m. in the southeast, near the Pacific side. The surface of this upheaved fluviatile plain, which is very flattened, is built up of horizontal gravel beds, the gravels of which have been derived from the northern pre-Tertiary mountainland. The gravel beds are horizontal and composed of a mixture of brown fine sand and gravel, either crossbedded or in lens or pocket structure, or in well stratified beddings. Below these gravel beds, here and there, greyish sandy mud-beds are exposed on the cliffs of dissected valleys in the upheaved fluviatile plain. The Huruya[23] beds, whose name comes from the small village of Huruya, and where the muddy beds are exposed in a typical manner, contain some fossil shells, such as *Ostrea gigas* Thunberg and *Anadara granosa* Linné. These are common species in the Sahamma beds, to which reference will be made later. These beds are underlain unconformably by either the highly dipping Kakegawa[24] series, the Horinouti[25] series, or the Ôigawa series. Near Takaoyama,[26] the older conglomerate beds project like an isolated hill from underneath the surface of the Makinogahara dissected fluviatile plain. This dissected plain, which is bounded on the west by the Ogasa hill, is therefore not considered a typical dissected delta spreading from north to south without any barriers. On the east side of the Ôigawa, the Makinogahara dissected plain disappears. From the distribution of the dissected plains, Watanabe[27] has explained this disappearance by a flexuose deformation of an ancient delta plain, as a result of which the east side of the Ôigawa is flexured downward. But this explanation is based on the assumption that the Makinogahara

16) 牧野原. 17) 大井川, gawa=river. 18) 三方ケ原. 19) 天龍川. 20) 小笠. 21) 渥美.
22) 三河. 23) 古谷.
24) 掛川. 25) 堀之内. 26) 高尾山.
27) A. WATANABE, "Some considerations concerning the Japanese raised deltas," *Geogr. Rev.*, Japan, 5, 1 (1929), (in Japanese).

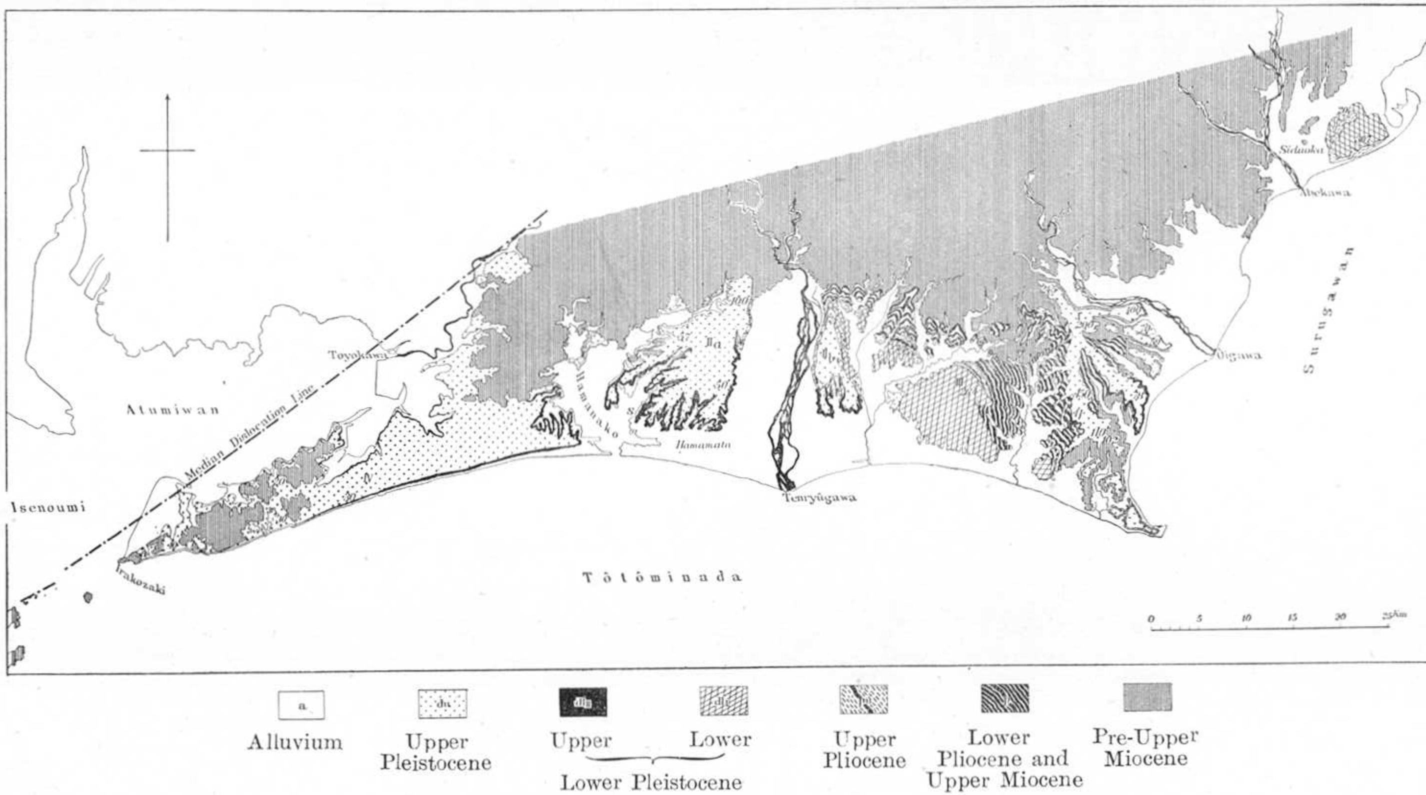

Fig. 3. Geologic map of "Tôtômi" region.

1. Makinogahara, II. Mikatagahara, III. Ogasa hill IV. Atumi peninsula.

Numbers in roman type indicate the height of upheaved plain.

(After Chitani, Makiyama and Ishii.)

was a typical delta, which however seems to contradict the above flexuous deformation theory, but this problem is likely to be solved by Murata's later studies[28] on fluvial fans. There is really no dislocation or flexuose deformation in this region; the eastern extension of the fluviatile plain should be traceable in the east side of the river Ôi(gawa), at least, in the valleys there in the form of river terraces of the same level as that of Makinogahara. But we cannot find any traces of this upheaved plain or of terraces in a topographic map of these areas (scale 1/25.000). So the writer accepts Watanabe's opinions in the absence of anything better.

II. *Mikatagahara subregion.* On each side of the river mouth of the Tenryû, which, like the Ôigawa, originates from lake Suwa,[29] the broad upheaved dissected delta plain is about 100 m. or 200 m. in height. Of these dissected terraces, the Iwatagahara[30] is on the east side of the river and Mikatagahara on the west. As the surface of the latter is well preserved, we call this the "Mikatagahara" region. The height of the terrace increases northwards, as shown in Fig. 3*, and is somewhat lower than that of the Iwatagahara, which is situated to the east of it. Near Sahamma,[31] a small village along lake Hamana,[32] there are some exposures that show the structure of the Mikatagahara dissected delta. According to J. Makiyama,[33] who has made observations and collected fossils there, the upper half of the exposure consists of thick fluviatile deposits, consisting of boulders, gravels, pebbles, and small intercalating pockets of sand and clay, while the lower half consists of estuarine clay, sand, and pebbles. The two divisions are distinctly separated by crossbedded yellowish sand of about a meter or less in width. Makiyama has collected from the lower division 45 species of fossil shells, besides the remains of a mammal, *Elephas (Palaeoloxodonta) naumanni* Makiyama,[34] an important fossil of the Japanese lower Pleistocene. The upper division, the sand and gravel beds, which the writer has called the Mikatagahara beds, forms the surface of the dissecting delta plain.

28) T. MURATA, *Geogr. Rev.*, Japan, **7**, 7 and 8 (1931), (in Japanese).

29) 諏訪. 30) 磐田ケ原.

* Numbers in roman type in fig. 3 indicate the height of terraces above mean sea-level.

31) 佐濱. 32) 濱名.

33) J. MAKIYAMA, "Notes on a Fossil Elephant from Sahamma, Tôtômi," *Mem. Col. Sci., Kyôto Imp. Univ.*, Ser. B, **1**, 2 (1924).

34) Formerly "*Loxodonta namadicus naumanni* Makiyama," J. MAKIYAMA, *Chikyû*, **12**, 5 (1929), (in Japanese.)

The shell bearing lower division, which for convenience is called the Sahamma beds, are observed in the southwestern part of the Mikatagahara, but not in the eastern part of the Iwatagahara district. As common species of the lower division, are collected *Ostrea gigas* Thunberg, *Anadara granosa* Linné from the Huruya beds also. Therefore the Sahamma shell beds of the lower Pleistocene may be contemporaneous with the Huruya beds, whence the upper division, the Mikatagahara beds may, together with the Makinogahara gravel beds, be Pleistocene in age. Consequently the surface of the Mikatagahara dissected delta and the surface of the Makinogahara dissected fluviatile plain may both be of the same age. Hence these two regions have a similar geologic history. But considering the distribution of the heights of the upheaved surfaces and the distribution of the shell beds, their crustal deformations

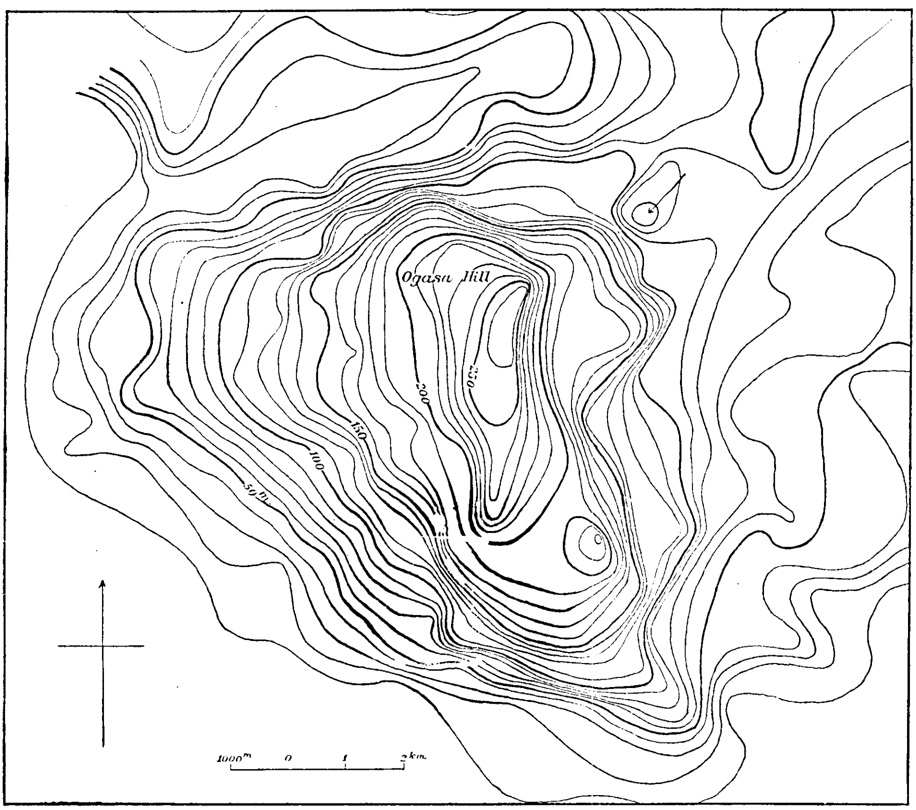

Fig. 4. Summit-level of Ogasa Hill. (Contour line is referred to the highest points in the 1250 m. nets.)

must have taken place in different directions, namely the Makinogahara flexing toward the southeast and the Mikatagahara and the Iwatagahara southwest.

III. *The Ogasa hill.* The Ogasa hill being higher than the two dissected plains just mentioned, occupies a mid-position as regards height between the Mikatagahara and the Makinogahara. The hill surface inclines slightly toward the southwest and the highest ridges of the northeastern limit of the hill borders is bounded by steep escarpments. Fig. 4 is the summit-level of the hill surface contour line showing a broad tilted deltaic surface and steep escarpments. The hill is mainly built up of conglomerate beds, called by our geologists the Ogasa conglomerate beds. These beds generally dip less than 10° southwest, while in places the amount of dip is steeper than the inclination of the hill surface. The gravels that form the conglomerates are rocks of the Mikura series, porphyrite, granite, and Palaeozoic rocks derived from the northern mountainland. Under the conglomerates are the Soga[35] beds, shallow sea deposits with alternations of sand and mud, with basal conglomerates at its western base. The Ogasa conglomerates overlap the Soga beds in the southeast areas and conceal it from the ground surface, but in the southwest area the latter is extensively exposed below the Ogasa conglomerate beds and above the next older Kakegawa series. The writer takes this occasion to rectify an error in his previous paper on the stratigraphic relationship between the Kakegawa and the Horinouti series. It has been corrected in correlation Table II. Instead of the Kakegawa series being underlain by the Horinouti series, the upper part of the latter is contemporaneous with the former.[36] The distribution of the Kakegawa series and the younger formation in these regions is shown in Fig. 3, drawn after the geologic maps of Chitani,[37] Ishii[38] and Makiyama.[36] According to this map, the dips of these strata incline in the same direction, and are steepest in the oldest formation, the Horinouti series, but become less so as the younger formations are reached. But their strikes are almost parallel to all the formations now under discussion. From these considerations it would seem that since the lower Horinouti period, the earthcrust has been gradually flexed in the same direction, i.e., southward and

35) 曾我.
36) J. Makiyama, *op. cit.*, (1931).
37) Y. Chitani, *op. cit.*, (1927), and (1932).
38) K. Ishii, *op. cit.*, (1927).

westward.

From the present position of the reliefs, by which the Ogasa hill is higher than the Makinogahara and the Mikatagahara, some believe that an upwarping of the earth's crust took place with its axis situated on Ogasa hill. But in the writer's opinion, Makinogahara is the fluviatile plain that was formed in the "vale[39] of the cuesta" like topography of Ogasa hill, and believes there is an earth-flexure near the mouth of the Ôigawa, because the asymmetrical structure of the post-lower Pliocene strata does not reconcile with the views above mentioned.

IV. *The Atumi Peninsula.* The Mikatagahara dissected plain extends southwestward and forms a raised coastal plain of the Atumi peninsula, a long and narrow land with a straight contraposed shoreline along the Pacific side of Japan.

The Peninsula is bounded on its north side by the median dislocation line. The height of the raised coastal plain at the headland, Irakozaki,[40] is only 6 m., but as one goes eastward, its height gradually increases to about 60 m. or more. Fig. 3 shows the distribution of their heights. The structure of the raised coastal plain may be observed on sea cliffs along the Pacific coast. The brown sand and fine gravel beds may be seen in the upper half of the exposures, with alternations of fossil bearing fine sand and mud exposed in the lower half, both of which rest unconformably on Palaeozoic rocks. Prof. Yokoyama[41] has described 48 species of fossil shells from the lower division, which is continuous with the Sahamma shell beds. Though Prof. Yokoyama concluded by the Lyellian method, that the age of the lower division is upper Pliocene, it is continuous with the Sahama beds which yielded *Elephas* (*Paleoloxodonta*) *naumanni* Makiyama, a lower Pleistocene fossil. Owing to the ancient surface inequalities in the Palaeozoic rock, the Pleistocene gravel beds could not have completely covered the surface of the lower member. The Palaeozoic land projected above the surface of the Pleistocene gravel beds like tops of islands. But these Palaeozoic lands are gradually drowned in the sea at the mouth of the Ise-no-umi.

From the geologic structure and the distribution of heights of relief in the above four districts, the writer believes that gradual crustal deformation in the form of broad swells was actively in progress since

39) C. A. Cotton, "Geomorphology of New Zealand," (1926).
40) 伊良湖岬.
41) M. Yokoyama, *Jour. Fac. Sci., Imp. Univ.*, Tokyo, Sec. II, 1, 9 (1926), 369-375.

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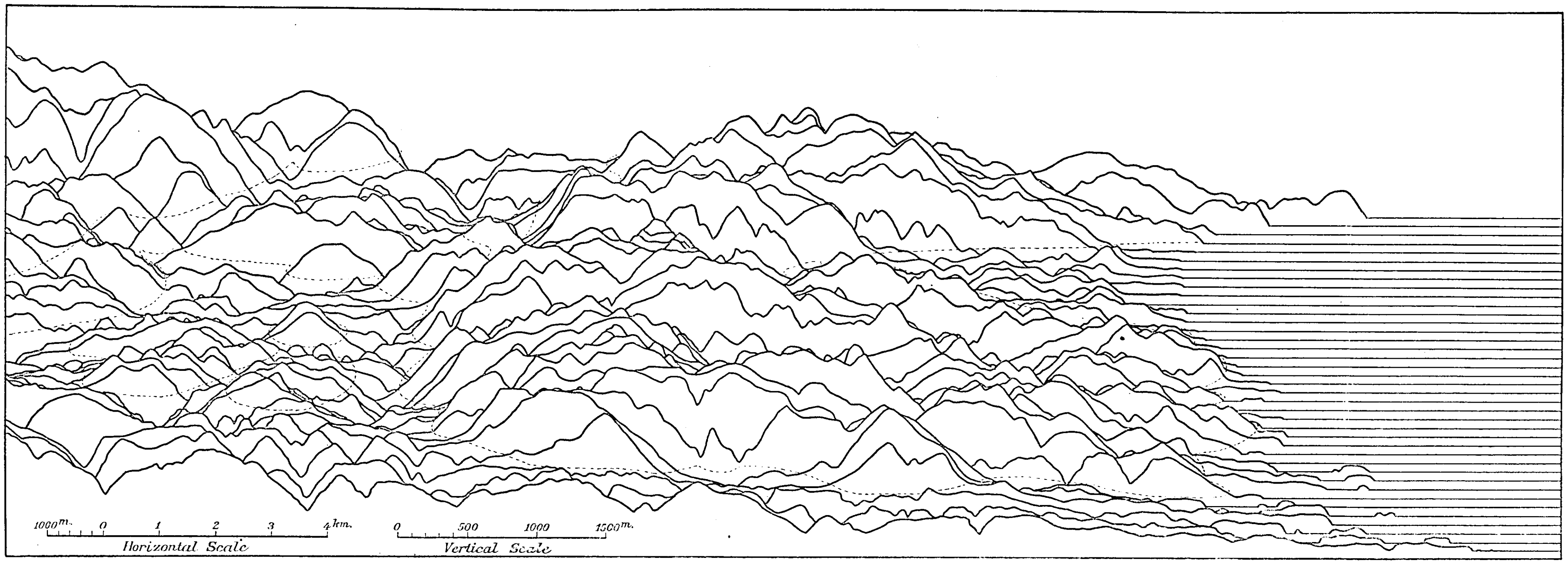

Fig. 5. Projected profiles of the southeastern Kii (near Singû) arranged in equal intervals. Ridge tops are projected upon 39 parallel vertical planes which are put at about right angles to the general trend of the shoreline at intervals of 1000 m. "............" lines are the approximate boundary lines of the erosion surfaces which are suggested by the arranged projected profiles.

early Pliocene. In other words, the northeast part of these regions gradually upwarped while the southwest part gradually downwarped.

(*b*) ***Kii Peninsula.*** In the Kii Peninsula, which is a part of Richthofen's "Kuma Kii mountainland," there are no Pliocene deposits, so we have only the topographic features to aid us in deducing the upwarping movement of the Kii Peninsula. According to W. Penck,[42] broad upwarping of the earthcrust and intermittent changes of erosion base are favourable for the formation of his "Piedmonttreppe." Recently Miyasaki[43] has studied the distribution of mountain heights in these districts and concluded as follows:

1. The Kii-mountainland steeply faces the sea.
2. There are flexuose deformations on the margin of the Kii mountainland.
3. There are five stepped topographic plains in the Kii mountainland. These plains are not considered to be the result of the solitary erosion cycle.

Miyasaki's third conclusion suggests the existence of Penck's "Piedmonttreppe" topography, while his second conclusion practically admits upwarping deformation in the Kii peninsula.

Fig. 5 is a "Piedmonttreppe" topography near Singû[44] in Kii, which was first pointed out by Sawatari,* according to whom there are more than two stepped topographic plains in this region, the lower one surrounding the higher at a height of about 400–200 m, while the boundary line of the lower plain has the same form as the base of the flow of granite porphyry that has extruded over the older erosion surface. The lower plain may then be a stripped fossil plain—a re-exposed old erosion surface. The higher plain is also an erosion surface because the surface is not the same character as the surface of the flow of granite-porphyry, but on the surface of it is exposed a facies of high crystalinity, suggesting it to be the inner facies of the flow mass. The surface of this higher plain is represented by the surface of the summit-level, as shown in the writer's previous paper. The inclination of the old erosion surface is steeper than that of the surface of the summit-level. In other words, the old erosion surface has been flexed

42) W. Penck, "Die morphologische Analyse," (1924).
43) K. Miyasaki, *Geogr. Rev.*, Japan, **6**, 9 (1930).
44) 新宮.
* He studied the geology of the granite porphyry cropping out near Kinomoto (木本). This granite porphyry is coloured as liparite in other geologic maps.

seaward. To determine the crustal deformation from the terrace distribution along the margin of the Kii mountainland is not easy; for if the configuration of the shoreline has been affected by crustal movements, it might be the combined result of two types of possible earth flexures, the one in a N-S direction and the other E-W. That is, the shoreline may be a nodal line of two orthotomic flexuose crustal movements.

(*c*) *Southeastern Sikoku.* The relations between the Pliocene formations and the summit-level in these regions were discussed in the previous paper. A. Watanabe,[45] who recently discussed this region in detail in this bulletin from the geomorphologic point of view, also believes that an upwarp occurred here.

(*d*) *Southwestern Sikoku.* Southwestern Sikoku also is a region where the same type of crustal deformation as just described is expected to have occurred, but here, as in the Kii-mountainland, no younger formations are exposed, so that crustal deformations if any, can only be deduced from geomorphologic evidence.

The writer[46] in 1925 noticed the peculiar digitate way in which the tributaries of the Simanto[47] river were distributed, and tried to explain the peculiarity by regarding it as an upwarped surface dissected in old age. As his report is in Japanese, a few extracts will here be made from it.

> The inclosed meander and the various forms of valleys have been studied in detail by Winslow, Gilbert, Davis, Rich, Tarr, and Vacher. Recently, Moore,[48] after summarising the views of other writers, classified the inclosed meander into incised or ingrown meander, ingrown-intrenched meander, and intrenched meander, and referred to the Colorado river for the peculiar distribution of various types of inclosed meanders.
>
> From the writings of the above-mentioned authors, the writer has extracted the following relationships holding between the form of valley, the volume of water, the gradient of river-floor, the load, the hardness of the rocks, etc., as in Table III. According to these relations, when the dissected area, as shown in section in Fig. 6,

45) A. WATANABE, *Bull. Earthq. Res. Inst.*, **10**, 1 (1932).

46) Y. ÔTUKA, *Geogr. Rev.*, Japan, **3**, 5 (1927), (in Japanese).

47) 四萬十川.

48) R, C. MOORE, *Jour. Geol.*, **34**, 1 and 2 (1926).

Table III.

	Volume of water		Gradient		Load		Hardness of rock	
	large	small	increase	decrease	excess	defect	soft	hard
Velocity of erosion	quick	slow	quick	slow	quick	slow	quick	slow
Lateral erosion	increase	decrease	down-ward increase	increase	increase	decrease	increase	decrease
Vertical erosion	increase	decrease	increase	decrease	increase	increase	increase	increase
Types of inclosed meanders	ingrown or ingrown-intrench-ed meander	shrink	decrease the swings	ingrown or ingrown-intrench-ed meander	ingrown or ingrown-intrench-ed meander	intrench-ed meander	ingrown or ingrown-intrench-ed meander	intrench-ed meander

is upwarped gradually as in Fig. 7, it follows that the erosion bases of the valleys (b in Fig. 6 and 7) near the axis of the upwarp is lowered more rapidly than that of the other two valleys (a and c in Fig. 6 and 7) distant from the axis; for the base levels of the

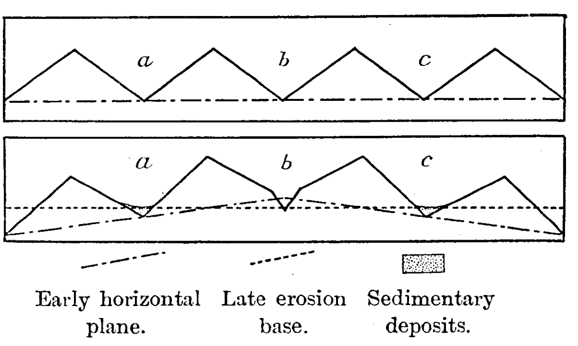

Fig. 6.

Fig. 7.

former valley is upheaved relatively to that of the latter two, so that in the former valley, W. Penck's "aufsteigende Entwicklungsform" may be seen and in the latter the "absteigende Entwicklungsform." If these three valleys belong to one river system, the contrast in the valley forms as mentioned above is heightened because the local erosion bases of a river system do not remain in the same condition for long.

Fig. 8 shows a relief dissected in old stage, on which a meandering river flows with three courses parallel and one course perpendicular to the three.

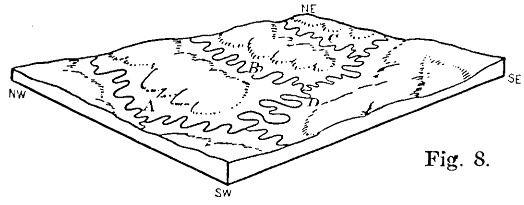

Fig. 8.

If an upwarping erosion deformation occurs on the relief in such a manner that the axis of the upwarping is parallel to the trend of the three parallel valleys, and such that the axis lies in the middle of them, the middle river course (B in Fig. 8) is rejuvenated and is represented by the "aufsteigende Entwicklungsform", while in the other two valleys on each side of the middle one (A and C in Fig. 8), the erosion bases of which are lowered relatively to that of the middle one, still retain the old stage topography, and is represented by "absteigende Entwicklungsform." In the former valley, therefore, the current velocity, the downward lateral erosion and the vertical erosion, the load, the transportation of the load, and the gradient of the river-floor are increased, and smooth meandering valleys in the middle course changed into those of sharp zigzag form; whereas in the latter valley, the current velocity, the vertical erosion, the load, the transportation of the load, and the gradient of the river floor are decreased, while the lateral erosion and the aggradation are increased. Then the meander courses of these two rivers broaden their swings and cut off the meander spurs and overspil the necks of the meander spurs.

Valleys at right angles to the axis of the upwarping (D in Fig. 8) that is cutting through the upwarped area, change the valley form continuously in "absteigendes Entwicklungsform" in the upper course and in the "aufsteigendes Entwicklungsform" in the middle, and in "absteigendes" in the lower courses. But the middle region of the "aufsteigendes Entwicklungsform" does not increase in gradient of valley floor and does not transport the waste,

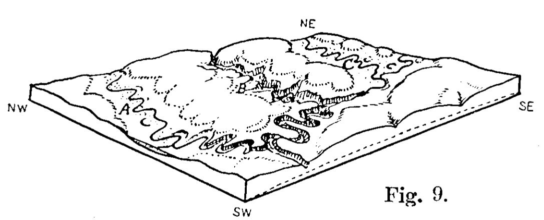

Fig. 9.

most of which is unloaded in the upper course, the "absteigendes Entwicklungsform" region, so that the the lateral erosion is small. For these conditions the formation of the intrenched meander is most suitable. Fig. 9 shows the results of topographic developments of the upwarped relief shown in Fig. 8.

The topographic features of the drainage of Simanto-river, is exactly like that shown in Fig. 9. The Yusuhara-gawa,[49] where it confluxes with the Simanto at Tanono,[50] shows a very sharp zigzag course, and cut-off spurs are observed at heights of about 200 m. above the recent valley floor. The tendency of the increasing amplitude of the meander swing is not observable in this valley. Near Nisituno-mura[51] an ingrown intrenched meander is seen to be scarped. The valley was deepened by vertical and downward lateral erosion. These characteristics are represented in valley B shown in Fig. 9.

The Matubaragawa,[52] which is the upper course of the Simanto river that originates from Mt. Kakusyonomori,[53] and which runs through the Kubokawa[54] basin, is where the broad alluvial plain spreads out. The rivers flow freely on the broad alluvial plain, being restricted only by the low valley wall. Near the town of Kubokawa, the secondary inclosed meanders are developeing into a "valley in valley" topography, a topography that becomes quite distinct toward the east. Examining the isolated hills or spurs projecting from this alluvial plain, all these hills or spurs have their slip-off slopes on the side of the lower course, and the steep attacked-surface slope on the upper course.

From these topographic characters then the valleys must be considered as having similar characters to valley C in Fig. 9.

Similar topographic features are observed in the Yosinogawa,[55] the western tributary of the Simanto. There is a broad basin along the Yosino as in the case of the Kubokawa basin, and cut off spurs and over-spil spurs have developed in the basin floor.

Near Hirose,[56] where the Simanto flows in an East-West course as in valley D in Fig. 9, the river runs through an ingrown meander. The flood-plains on both sides of the river floor gradually decrease from Kubokawa to Hirose, and in the lower course or near Hirose, it is seen only on the inner side of the loop where the

49) 檮原川. 50) 田野々. 51) 西都野村. 52) 松原川.
53) 鶴松森. 54) 窪川. 55) 吉野川. 56) 弘瀬.

current flows slowly. All the spurs have distinct slip-off slopes on the side of the lower course. In the lower course of Ôno,[57] the Simanto runs in a typical intrenched meander valley. Each side of the vally wall whose heights reach 320 m, 435 m, and 320 m respectively are steep and symmetrical. The course of the Simanto between Hirose and Naro[58] then corresponds to valley C in Fig. 9. If these analogies of the four valleys of the Simanto to the valleys in Fig. 9 are true, southwestern Sikoku must be deformed by an upwarping in shown in Fig. 10.

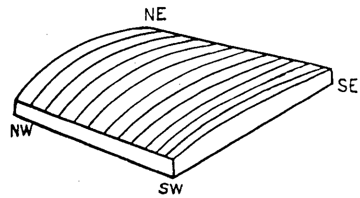

Fig. 10.

Judging from the above extracts from the writer's previous paper, and from the submerged topography of the coast around Southwestern Sikoku, the existence of signs of upwarping movements in this region may be regarded as established.

(*e*) ***The Hyûga coastal plain.*** From the foregoing results the upwarping crustal deformations taking place in the above four districts have been established. The writer now desires to know whether or not similar types of crustal deformations exist in the most western region of Southwest Japan, and also in the Ryûkyû[59] arc. Explanations of the stratigraphy and the structure of the Hyûga coastal plain were given briefly in the writer's previous paper.[60] The rock facies of these groups are as follows (Table II) :—

Lower Pleistocene	The Tôriyamahama[61] beds.	Muddy sand and mud beds with basal conglomeratic gravel beds at its base, and in places containing estuary shells.
	unconformity	
Neogene	The Takanabe[62] group.	The Heki[63] beds ; sandy mud beds with marine fossils.
		The Koonzi[64] beds ; thin alternations of mud and sand.
		The Sadowara[65] beds ; alternations of sand and mud, and fine conglomeratic sand at its base (Flysch type).
	uncomformity	
	The Tuma[66] group.	Black muddy beds with pelagic fauna.

57) 大野. 58) 奈路 59) 琉球.
60) Y. ÔTUKA, *op. cit.*, (1931).
61) 通山濱. 62) 高鍋. 63) 日置. 64) 光音寺. 65) 佐土原. 66) 妻.

Late Miocene and middle and lower Pliocene strata are arranged in such order that the younger formations lie in the east and the older in the west, generally parallel to the boundary line between the Osuzu[67] mountainland and the Hyûga coastal plain, the boundary line almost coinciding with the line of unconformity running NNE-SSW. The Takanabe group may be contemporaneous with the Kakegawa series and the Horinouti series of Makiyama; the Heki beds of the group may be more or less younger than the Dainiti[68] horizon of the lower Kakegawa series.

The general strikes of the Takanabe and Tuma groups are arranged in directions varying from NNE to SSE and dipping E. But the dips are steep in the base and low in the upper horizon. In other words, the older the strata the steeper is the inclination toward the east. Between the Tuma group and the Takanabe group, two cycles of sedimentation are seen to have occurred during the middle Neogene, judging from the great change of rock facies between the base of the Takanabe group and the upper limit of the Tuma group. This boundary may have been caused by the same level change or by the epeirogenic earth movements that led to the abrupt change of facies between the base of the Kakegawa series of the Horinouti series and the upper limits of the Sagara beds or the Tamari beds, in the Tôtômi districts.

The eastern slope of mount Zyômegi is the same plain continued from the basal plain of the Tama group.

As the inclination of the eastern slope of mount Zyômegi,[69] which amounts to 10° in its eastern part accords with the dips of the basal plain of the Tuma group, the eastern slope may be Cotton's " stripped fossil plain," or the surface that is re-exposed from the basal surface on the Tuma group by differential erosion due to the solid Mesozoic rocks and the loose young Tertiary strata. From the foregoing considerations, the crustal deformation of the Hyûga coastal plain took place in the form of gradual tilting of the crust toward the east, during which two cycles of sedimentation were repeated.

On these two Neogene formations, the horizontal Tôriyamahama beds are scattered in patches. Hitherto the writer was of the opinion that these beds were fresh water deposits, judging from its rock facies, but according to Takeyama, who recently visited these regions, estuary fossils have been collected from the same beds near Tonogôri[70]. The

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67) 尾鈴. 68) 大日. 69) 上面木. 70) 都於郡.

age of the crustal movement, when the Tertiary beds tilted 10° is uncertain, but it is probably the same age as that of the pre-Tôriyamahama beds.

To our geologists and geomorphologists, the practical uniformity in the heights of the summits recalls remnants of a subdued form of peneplain which was uplifted and dissected at full maturity. Then the question arises, when was the low relief surface formed? The Tôriyamahama strata, as mentioned in the previous paper, are sediments in the valleys which are dissected in the denuded surface of the Tertiary beds. The age of Tôriyamahama beds is younger than that of the denuded surface of the Tertiary which may be contemporaneous with or later than the age of the so-called peneplain surface. The age of the so-called peneplain is consequently older than that of the Tôriyamahama beds, that is, it may be late Pliocene or early Pleistocene, and the deformation of the Tertiary deposits antedates the so-called peneplain. And if the so-called peneplain did suffer such crustal deformations, Penck's "piedmonttreppe" should form in these regions.

Of the "Piedmonttreppe" in these regions, the writer awaits with no small interest the result from Miyasaki's study of the geomorphology of these regions.

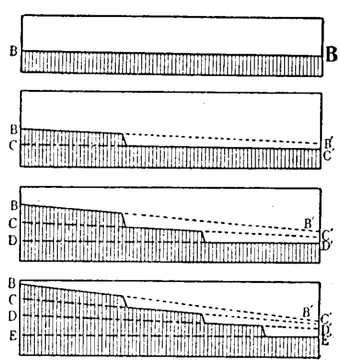

Fig. 11. Developement of terrace surfaces.

We shall now study the coastal terraces bordering the Hyûga coast line, in order to find the same type of crust deformation as above discussed, that took place during the post-Tertiary. If there is tilting and uplifting of the crust, as shown in Fig. 11, the first terrace BB′ would be tilted and upheaved with formation of the lower surface of the second terrace CC′, but in the next interval, the first and second terrace BB′ and CC′ are tilted and upheaved by the same crustal movement, and the third new terrace surface DD′ relatively to the new erosion base level formed, when the first, second, and third terraces are deformed with formation of the fourth EE′ and so on. The inclination of the oldest terrace therefore assumed the largest angle, while of the youngest terraces, the recent fluviatile plain may assume the lowest.

With these facts in mind, the writer measured the grades of these coastal terraces spreading over the regions concerned. He[71] had already classified these coastal terraces into the following: Pre-Tyausubaru,[72] Tyausubaru, Sanzaibaru,[73] Nyutabaru,[74] and the recent Fluviatile plain of the Omaru[75] and the Hitotuse.[76] (Fig. 12.)

The grades of these terraces were compared in the following manner:

1. Interfluviatile areas between the Omaru and the Hitotuse are selected and jotted down on paper and an XY vertical plane is drawn almost parallel to these two river courses, namely at right angles to the shoreline.

2. Then the vertical planes 1, 2, 3, ...*n* are drawn at right angles to the vertical plane XY at intervals of 500 m.

3. The mean height of the respective terrace surfaces intersecting the vertical planes 1, 2, 3, 4, ...*n*, is projected on the vertical plane XY. (Fig. 12).

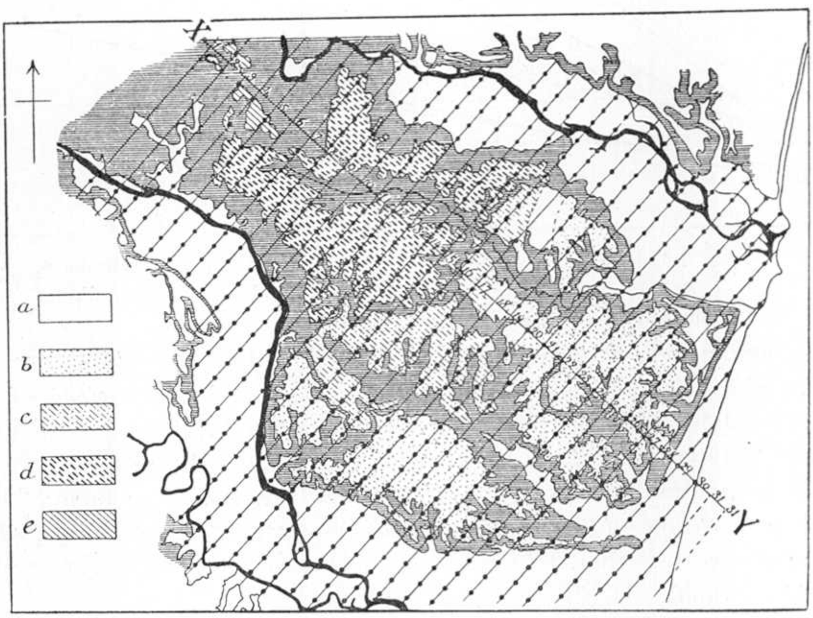

Fig. 12. Coastal terraces bordering the Hyûga coast line.

a. Alluvial plain. d. Tyausubaru.
b. Niitabaru. e Pre-Tyausubaru.
c. Sanzaibaru.

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71) Y. ÔTUKA, "Some Geologic Problems in the Southwestern Coast of Kyûsyû," *Geoq. Rev.*, Japan, **6**, 7 (193), (0in Japanese).

72) 茶臼原. 73) 三財原. 74) 新田原. 75) 小丸. 76) 一ツ瀬.

If the surfaces of the respective terraces were ideal planes, the projected points of the mean height of the respective terraces at the XY plane may be arranged in a straight line. Now the slope of the respective terraces can be compared with the inclination of these straight lines on the XY plane. Fig. 13, shows these line. From Fig. 13, it is seen that the oldest terrace, the pre-Tyausubaru, is the most steeply inclined, while the younger ones become less so in order of age.

The recent fluviatile plain of the Hitotusegawa is a solitary exception, but this is due in the writer's opinion to the fact that the surfaces of the terraces are ideal planes, without any flexuose deformation. But in reality this assumption of the flatness of the terraced surfaces or of the fluviatile plain is open to criticism. The untenability

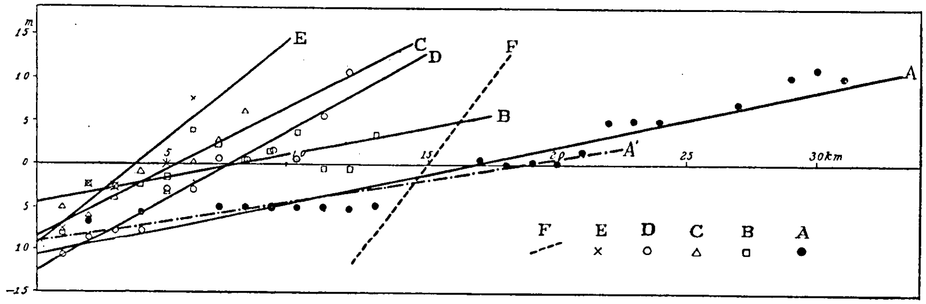

Fig. 13. Inclination of coastal terraces. a. Alluvial plain, b. Niitabaru, c. Sanzaibaru, d. Tyausubaru, e, Pre-Tyausubaru, f. mean dip of Tôriyamahama beds.

of this assumption is clearly shown at least in the case of the fluviatile plain. Since the positions of the mean heights of the surface of the fluviatile plain are concave, in considering only the points of the mean heights of typical fluviatile plain near Tuma-mati, the slope shows the lowest inclination (A in Fig. 13), so that the same problem should apply to the slope of the older terraces, but these terraces selected by the writer are distributed in the same way as the typical fluviatile plain near Tuma-mati.

From the foregoing, the writer believes that since early Pliocene, gradual deformation took place, the change being confined to that part between the two nodes as shown in Fig. 1, as a dominant type of crustal deformation in the Outer zone of Southwest Japan. And recent land areas, such as the Tôtômi region, the Kii mountainland, southeastern and southwestern Sikoku, and the Hyûga coastal region are upwarped and recent embayments, while the mouth of the Ise-no-umi, the embayment between Kii and Sikoku, Tosa bay, and Hyûganada, and Pacific coast have downwarped since the Pliocene. This type of crustal deformation is not observed in the eastern part of the river Ôi near where the western limits of the Fossa Magna or where the Itoigawa Siduoka geotectonic line is situated.

Quite recently, Prof. T. Terada[77] has reported a change in the bottom of Tosa bay during the last about 40 years, as deduced from soundings made by the Naval Hydrographic Department. According to him, the sea bottom of Tosa bay has deepened about 6 m. about its deepest part, while on the other hand the sea shore has shallowed.

Results of repeated precise levellings also show the upwarped characters of the land in the Outer zone of Southwest Japan. It is also worthy of notice that the epicentres of earthquakes are packed together in some of the downwarped areas, e.g., the Hyûganada, the embayment between the Sikoku and Kii mountainland, and the mouth of Ise-no-umi.

(*To be Continued.*)

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47. 西南日本外帶とフオツサ・マグナとに於ける鮮新世以後の地殼運動 (其一)

地震研究所　大塚彌之助

筆者の前論文(1931)に於て知り得た材料から西南日本外帶と フオツサ マグナ とに於ける鮮新世以後の地殼運動の性質に就いて述べてある。この論文はその西南日本外帶に關するものに就いて述べてあるものであつて、前論文で知り得た西南日本外帶のウネリの樣な波狀の地殼運動は鮮新世の地殼運動と解するよりも鮮新世以後も繼續してゐる地殼運動と解する方がよいやうなこととなつた。便宜上取扱ふ地域を a. 遠江、b. 紀伊、c. 東南四國、d. 西南四國、e. 日向海岸段丘の五區域に分けた。遠江地域に於ては堀之內統・掛川統・曾我層・小笠山礫岩層・佐濱貝層或は古谷貝層或は渥美半島下部・及び牧野ヶ原礫層或は三方原礫層或は渥美半島上部層の地質構造に就いて述べ、最古の地質系統から順に傾斜の度の緩くなることと傾斜の方向が一致してゐることから古い地層の堆積時代から順に南及び西へ傾き下つてゐることを知つた。更にこの地方に發達する海岸段丘に就いて、その高度分布を調べて、同樣なことを知り得た。そして略ぼ大井川を境として東部が東南へ撓曲してゐると言ふことは渡邊氏の意見に贊成する。

紀伊では若い地層の發達がないので、宮崎氏の論文と最近佐渡氏によりて注意された新宮附近の山麓階に就いての地形學的研究を試みて、大體宮崎氏の意見に贊成することができた。

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77) T. Terada, "Change of Depth in the Bay of Tosa." *Proc. Imp. Acad.*, 8, 5 (1932).

四國東南部は渡邊氏の論文によることとした。

四國西南部は筆者の四萬十川の流路に關する古い論文によりて大體を知ることができた。

日向の海岸平野に就いては段丘及び地質構造に依つたが之等は地理學評論第八卷第二號に述べたことを再錄した迄の事である。

最後に最近寺田博士によりて紹介された土佐灣海底變化及び水準測量の結果が簡單に紹介されてある。

そして之等の事から現在西南日本外帶では鮮新世初期から陸地になつてゐる部分は次第に曲隆し、海になつてゐる部分は次第に曲窪してゐて、同時に太平洋の方へ即ち南方へ撓曲し下つて行く様な地殼運動が見られることがわかつた。曲隆された古い地表面は次第に浸蝕し去られて、air saddle の様に空中に曲隆した表面として想像されるだけである。