16. The Crust Deformations in the District between Okitu and Kusimoto, along the Pacific Coast of the Main Island of Japan.

By Naomi MIYABE,

Earthquake Research Institute.

(Read Jan. 17, 1933.—Received March 20, 1933.)

Introduction.

The recent revision of precise levelling along the route from Okitu to Kusimoto revealed a considerable crust deformations. Thus, as the result[1] of this recent revision the vertical displacements of the bench-marks on the said route along the Pacific coast were measured which are regarded to have occurred since the previous survey. No destructive earthquake was experienced during this time interval in the most part of the district in question. The dates of the previous levelling surveys for the different sections of this route are not the same. They are given in Table I.

Table I. Dates of earlier surveys in different sections of the levelling route.

Section	Earlier Survey
From Okitu to Okazaki.	June—October, 1900.
〃 Okazaki to Nagoya.*	January—May, 1895.
〃 Nagoya to Issinden.**	February—May, 1895.
〃 Issinden to Sana.	April—August, 1889.
〃 Sana to Owase.	November, 1895—March, 1896.
〃 Owase to Kusimoto.	May—November, 1899.

* B.M. 174·2 (Junction point) is situated at Atuta, Nagoya.

** Issinden is close to Tu.

As for the levelling route from Atuta to Matuzaka via Issinden, a revision of precise levelling was carried out also in August-November, 1929.

1) A preliminary report of the result of this recent revision of the precise levelling is published in Proceedings of the Imperial Academy. T. Terada, *Proc. Imp. Acad.*, 8 (1932), 411.

The results of the recent revisions, i.e., the vertical displacements of the bench-marks on the route from Okitu to Kusimoto, are discussed in the following pages, with regard to the deformations of the earth's crust in the district thus revealed, in connection with allied geological and geographical evidences.

The earth's crust in the district under consideration had not been much disturbed by a destructive earthquake, as noted above, but for a part of the route near Nagoya, where it was presumably much disturbed by an acute crust movements associated with the Nôbi Earthquake of 1891. Hence, the crust deformations in the most parts of the district examined may be regarded as due mainly to the chronic movements, but for the district near Nagoya, where the after effect of local disturbances due to the destructive earthquake is still evident in the crust deformation due to the later time intervals from which the Nôbi earthquake is excluded. These specific effects of the destructive earthquake of 1891 may be better discussed by using the results of several post-seismic revisions of the precise levellings carried out in the district where the earth's crust is considered to have been disturbed conspicuously by this earthquake. The general mode of the crust deformations in the entire district under consideration, however, may not be much affected by these local disturbances.

The Results of the Recent Revision of the Precise Levelling.

The vertical displacements of the bench-marks on the levelling route from Okitu to Kusimoto obtained as the result of 1931 revision are shown in Fig. 1,[2] for which the horizontal scale was contracted considerably in order that the general mode of the crust deformation may easily be seen[3]. The map of the district under consideration with the location of the levelling route is shown in Fig. 2.

The vertical displacements, shown in Fig. 1, may be regarded as indicating those which had occurred during the time interval of some 30 years or more, though the previous surveys of precise levellings have not been carried out at the same time in different sections of the route.

---

2) The vertical displacements of the bench-marks are reproduced from the Report in *Bull. Earthq. Res. Inst.*, 10 (1932), 490.

3) As for the general mode of the crust deformation in the district, discussions are given by Mr. C. Tsuboi. *Jap. Journ. Astr. Geophys.*, 10 (1933), 93.

According to difference in the modes of crust deformations due to these 30 years, the district along the levelling route under consideration may conveniently be divided into four different parts. The first part is

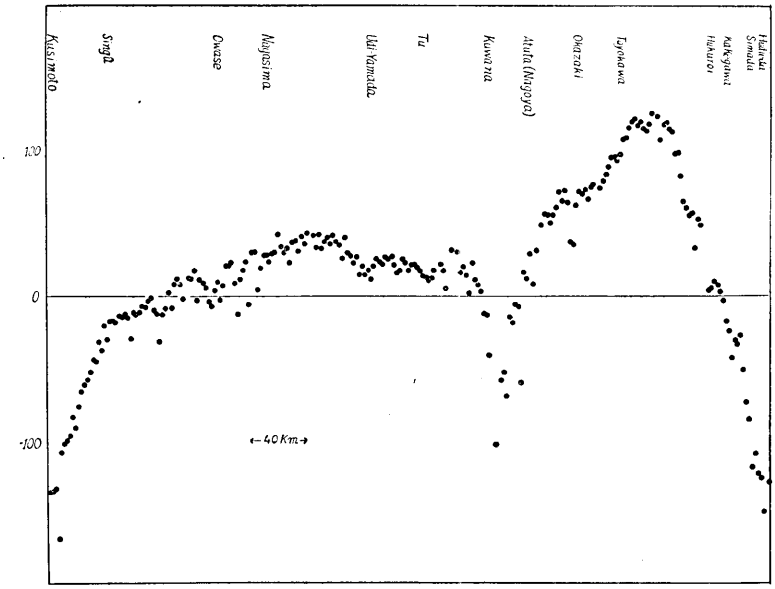

Fig. 1. The vertical displacements of the bench-marks on the route from Hudieda, near Siduoka, to Kusimoto.

the district corresponding to the section of the levelling route from Okitu to Toyokawa, in which the deformation of the earth's crust seems, at a glance on Fig. 1, to consist of a simple tilting towards the east. The horizontal dimensions of this part of the district is some 100 km. and the difference in vertical displacements between the bench-marks of the both ends amounts to about 27 cm. Hence, the tilting of the earth's crust in this part, along the levelling route, is $2{\cdot}7\times10^{-6}$, or $0{\cdot}5''$.

The second part is the district around Ise-wan (the Bay of Ise), in which the general mode of crust deformation is downwarping, having the synclinal axis extended from N to S approximately coincident with the axis of the trough of Ise-wan.

The third part is the district from Udiyamada to Singû. The southern part of the levelling route in this district is situated along the coast of Kumano-nada. As to the general mode of the crust deformation in this district, we notice, as the curve of Fig. 1 shows, a south-

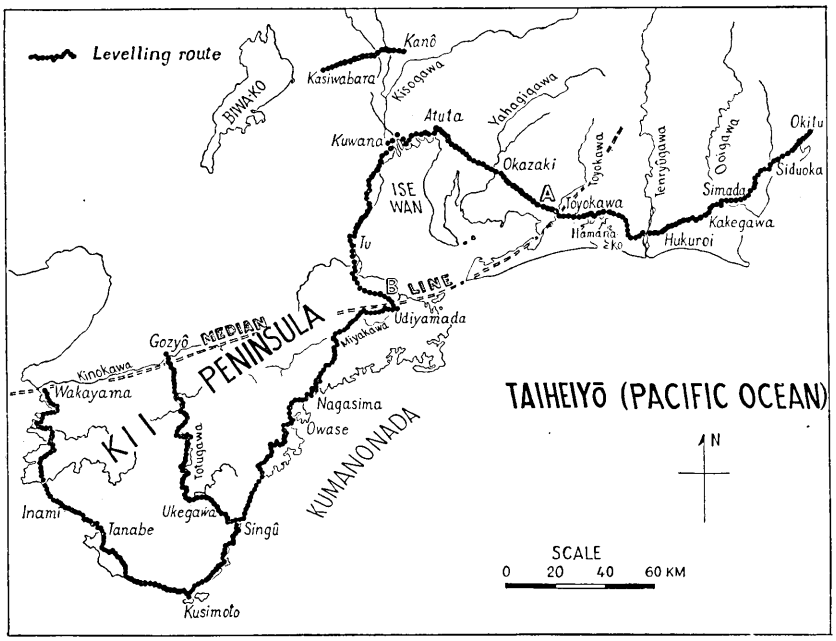

Fig. 2. The location of the levelling Routes.

or southwest-ward tilting with the amount of some $0{\cdot}4\times10^{-6}$ in radians accompanied by fluctuations.

In the district between Singû and Kusimoto, i.e., the fourth part, the general trend of the levelling route may be regarded as a straight continuation of the third part, whereas the amount of tilting of the earth's crust is discontinuously changed in comparison with the third part, i.e., tilting in this district, along the trend of the levelling route, amounts to $2{\cdot}5\times10^{-6}$ in radians, or six times the tilting in the district of the third part, both of the amounts of tiltings being due to the time interval of these 30 years.

The details of the present investigation on the crust deformations are described below under three separate chapters, i.e., the districts between Okitu and Toyokawa, the first part, between Toyokawa and Udiyamada via Atuta and Kuwana, the second part, and between Udiyamada and Kusimoto, the third and fourth part.

The Crust Deformation in the District Between Okitu and Toyokawa.

According to the results of investigations by geologists, there is a remarkable structural zone extending from N to S over the prefectures of Niigata, Nagano and Siduoka usually known as "Fossa Magna." The district to the west of the tectonic line connecting Itóigawa, in Niigata prefecture, and Siduoka, in Siduoka prefecture, i.e., the west boundary of "Fossa Magna", is known as Southwest Japan. The land of Southwest Japan is divided by a median line into two zones, northern and southern, which are called the Inner Zone and the Outer Zone respectively. The crust deformations, with which we are going to deal in the present chapter and the chapter next but one, are those occurred in the districts belonging to the Outer Zone of Southwest Japan. The median line is extended southwest-ward, passing along the valley of the river Toyokawa and crossing the mouth of Ise-wan. The trend of the median line is then curved and extended to the west along the valley of the river Kinokawa in Kii Peninsula and the river Yosinogawa in Sikoku. The trend of the median line intersects, as shown in Fig. 2, the levelling route under consideration at Point A, very near Toyokawa, to the north of Toyohasi, and at Point B, near Udiyamada. At these points, the signs of the general gradients of the vertical displacements are changed. The district to the east of Point A corresponds to Part I, for which the general mode of the vertical crust deformation is an eastward tilting along the route with an amount of some 0.5″, as already referred to in the preceding chapter.

The first precise levelling was carried out in 1885 along the route from Okitu to Okazaki, and the survey was revised in 1900. The vertical displacements of the bench-marks on this route, which are shown in Fig. 1, are those measured recently due to the time interval 1900–1931. The vertical displacements due to the time interval 1885–1900 are shown in Fig. 3. The data were kindly placed at our disposal by Messrs. K. Mutô and Y. Kawabata of the Military Land Survey[4], to whom the present writer's cordial thanks are due.

As may be seen in Fig. 3, the vertical crust deformation during 1885–1900, in the district between Okitu and Simada, the district to

4) The data are published in this volume of the Bulletin. K. MUTÔ and Y. KAWABATA, *Bull. Earthq. Res. Inst.*, **11** (1933), 315.

the east of the river Ooigawa is approximately in positive correlation with that of the same district due to the time interval of 1900–1931. The negative correlation of the vertical displacements due to the different time intervals in the district between the river Ooigawa and Toyokawa is shown by the diagram of Fig. 4.

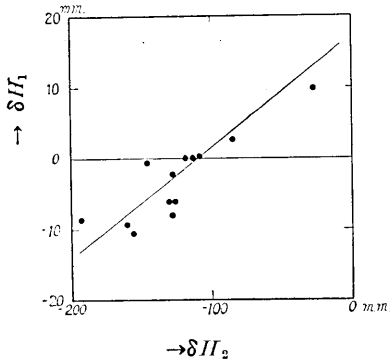

Fig. 3. The Relation between δH_1 and δH_2 of the bench-marks on the route from Siduoka to Simada.

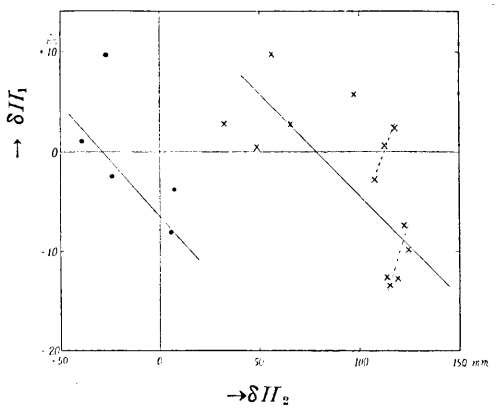

Fig. 4. The relation between δH_1 and δH_2, of the bench-marks on the rout from Kanaya to Hukuroi (•) and these from Hukuroi to Toyokawa (×).

The relation between δH_1, the vertical displacements during 1885–1900, and δH_2, those during 1900–1931, in the district between Siduoka and Simada, may be expressed approximately by

$$\delta H_2^{(\text{mm.})} = -110{\cdot}0^{(\text{mm.})} + (90/14)\delta H_1^{(\text{mm.})}.$$

It may be remarked that the coefficient to δH_1 in the above expression $90/14 = 6{\cdot}4$ is much different from $31/16 = 1{\cdot}9$, the ratio of the time intervals to which the vertical displacements, δH_1 and δH_2, are respectively due. The district has not experienced any destructive earthquakes which was accompanied by a conspicuous deformation of the earth's crust, as remarked above. Hence, the fact, that the coefficient in the above expression is much greater than the ratio of the time intervals to which the vertical displacements δH_1, and δH_2, are due, may lead us to a conclusion that the rate of deformation of the earth's crust during 1900–1931 is three times as great as those during 1885–1900, i.e., the rate has been sensibly accelerated in the recent epoch.

In the district adjoining to the west of that mentioned above, i.e., the district between Kanaya and Hukuroi, the correlation between δH_1

and δH_2 seems to be negative, as shown in the diagram of Fig. 4. It may also be noticed, in Fig. 4, that the rates of the vertical displacements due to the different time intervals are, in this district, much different from that which may be expected from the time intervals, besides the difference in senses of the gradients of the vertical displacements.

As for the vertical displacements δH_1 and δH_2 of the bench-marks in the district between Hukuroi and Toyokawa, we cannot notice a definite relation in its details. It may, however, be noticed, though not quite remarkable, that there is also a general tendency of negative correlation between δH_1 and δH_2 along this part of the route.

The apparently irregular fluctuations in the curve showing the vertical displacements of the bench-marks in this district are found, in several cases, significant in connection with the local features of the district from geological, geographical and geophysical points of view. For a detailed investigation of the features of the crust deformations in different parts of this district, the vertical displacements of the bench-marks are reproduced in Fig. 5.

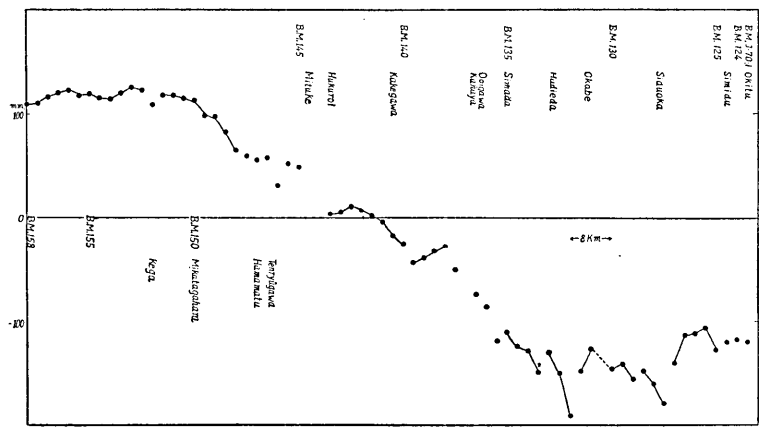

Fig. 5. Vertical displacements of the bench-marks along the route from Okitu to Toyokawa.

The details of the features of the crust deformations are described as follows:

a) There are five bench-marks, B.M.'s 125, 125·1, 126, 126·1 and 127, situated on the route passing through the region to the north of

Kunô-san (Mt. Kuno). The geographical distribution of these bench-marks is shown in Fig. 6, and their heights are shown in Fig. 7. As shown in Fig. 5, the vertical displacements of these bench-marks may

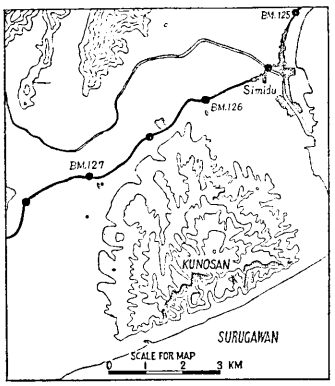

Fig. 6. Bench marks and topographical features in the neighbourhood of Kunôsan.

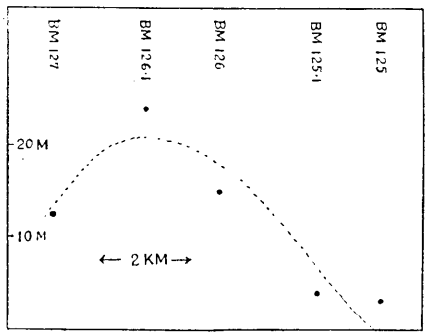

Fig. 7. Profile of the earth's surface along the route situated to the north of Kunôsan.

suggest us that the earth's crust in this region has been subjected to an upwarping crust movement. Moreover, the curve of the vertical displacements of the bench-marks, representing the upwarping crust movement in this region is, in some measure, similar to the curve showing the profile of the region along the route represented by the heights of the same bench-marks. The fact may suggest that the present crust deformation in this region is a continuation of the past one which had produced the present feature in topography of this region.

On the other hand, however, a slightly curved trend of the levelling route in this region may result in an apparent warping deformation, when the earth's crust including Kunô-san was tilted to N or NW. The actual crust deformation may include a resultant effect of these two factors.

b) In the region between Siduoka and Simada, the bench-marks may be classified into several groups with respect to their vertical displacements. These groups of the bench-marks are given in the following Table (Table II), and topographical features in the regions, in which the bench-marks under consideration are distributed, are shown in Fig. 8.

As may be seen in Fig. 8 and Table II, we notice different features in topography corresponding to each group of the bench-marks. B.M.'s 127.1, 128 and 128.1, belonging to Group A_2 are distributed in an alluvial plain in which the city of Siduoka is situated.

Table II. Groups, vertical displacements and heights of the bench-marks situated on the route from Siduoka to Simada.

Group	Locality	B.M.	δH	$\overline{\delta H}$	H.
			mm.	mm.	m.
A_2	Siduoka	127·1	−179·4	−163·1	17·05
		128	−160·8		21·49
		128·1	−149·0		17·77
A_3	Utunoya-tôge (Pass.)	129	−156·3	−143·9	12·74
		129·1	−141·4		26·09
		130	−145·9		45·76
		130·1	——		——
		131	−127·5		35·64
	Okabe	131·1	−148·6		18·08
A_4	Hudieda	132	−191·9	−157·3	11·22
		132·1	−150·4		15·12
		133	−129·7		24·66
A_5		133·1	−149·5	−127·9	22·78
		134	−127·9		30·76
		134·1	−124·0		39·00
		135	−110·0		48·34
	Simada	135·1	−118·8		58·40

N.B. The vertical displacements of the bench-marks are due to the time interval 1900–1931.

B.M.'s 129, 129·1, 130, 130·1, 131 and 131·1, the bench-marks belonging to Group A_3, are distributed on the route crossing a mountain range through the pass of Utunoya-tôge. The crust movement in this region is similar to that of the region to the north of Kunô-san. The earth's crust in this region is upwarped, approximately parallel to the topographical feature along the levelling route, which is represented by the heights of the bench-marks under consideration. The route is, on the other hand, arcuated convex to NW, which may produce an apparent mode of crust deformation as above described, when the earth's crust in this region was as a whole tilted to SE.

Between the mountain range of this region, extending southeast-

ward to the coast of Suruga-wan (the Bay of Suruga), and the river Ooigawa, there is an alluvial plain of considerable extent. The bench-marks belonging to Group A_4 and A_5, B.M.'s 132, 132.1, 133 and 133.1, 134, 134.1, 135, are distributed on the levelling route passing the NW margin of this alluvial plain. Corresponding to the regions occupied by the bench-marks belonging to Groups A_4 and A_5 respectively, we may notice two distinct blocks in the topographical features of the mountain mass close to NW margin of this alluvial plain. The present slope of the earth's surface, represented by the curve giving the heights of the bench-marks is parallel to the curve showing the gradients of the vertical displacements of the bench-marks measured.

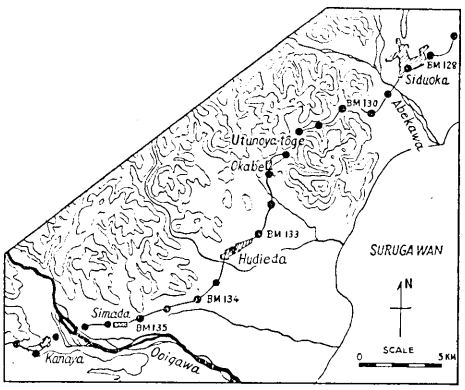

Fig. 8. The topographical features along the route from Siduoka to Simada (to the east of the river Ooigawa).

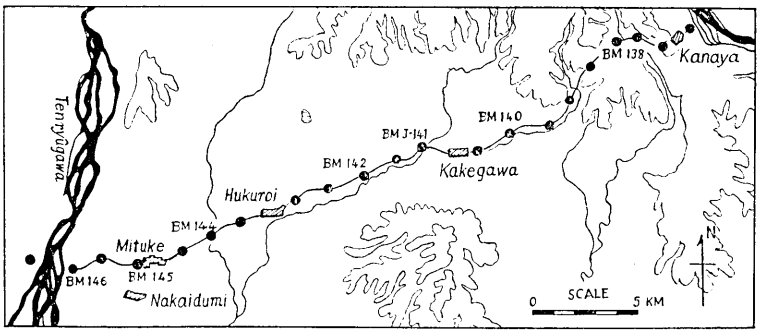

Fig. 9. The topographical features along the route between the river Tenryûgawa and the river Ooigawa.

c) In the region between the river Ooigawa and the river Tenryûgawa, we notice two groups of the bench-marks. The vertical displacements measured and the present heights of these bench-marks are given in Table III. The topographical map of the regions is shown in Fig. 9.

Table III. Groups, vertical displacements and heights of the bench-marks situated on the route from B.M. 138 to B.M. 143·1 (from Kanaya to Hukuroi).

Group	Locality	B.M.	δH	$\overline{\delta H}$	H
			mm.	mm.	m.
A_6	(Kanaya)	138	−27·2	−35·3	157·51
		138·1	−31·5		72·16
		139	−39·2		50·72
		139·1	−43·3		40·66
A_7		140	−24·2	− 2·0	34·29
	Kakegawa	140·1	−16·9		27·07
		141	− 3·4		22·02
		141·1	2·3		19·02
		142	7·2		16·70
		142·1	9·5		12·78
		143	5·4		10·26
	Hukuroi	143·1	4·0		7·94

N.B. The vertical displacements of the bench-marks are due to the time interval 1900–1931.

The bench-marks belonging to Group A_6 are distributed on the route of which the trend is nearly straight being extended from SW to NE. The mode of deformation of the earth's crust in this region along the levelling route is a southwestward tilting parallel to the present slope of the earth's surface in this region represented by the heights of the bench-marks.

The bench-marks belonging to Group A_7 are also distributed on the levelling route of an approximately straight trend directed E-W. The deformation of the earth's crust in this region is an upwarping, which is not parallel to the profile of the surface of the earth represented by the present heights of the bench-marks, contrary to several other cases already referred to. As the trend of the route is straight, the configuration of the levelling route cannot explain the present mode of distribution of vertical displacements. On the other hand, however, as the results of investigations by geologists[5], it was concluded that the earth's crust in this region was subjected to an upwarping movement in the

5) Z. MAKIYAMA, *Tikyû*, 9 (1928), 23-35, 100-118, (in Japanese).

later period of the Tertiary Formation. This crust movement in the Tertiary period is approximately coincident with the crust deformation in recent epoch, discovered by means of the present geodetic method.

The crust deformation in the neighbourhood of the Ooi-gawa seems to be complicated. The vertical displacements of the bench-marks, i.e., of B.M.'s 135.1, 136.1, 137 and 137.1, appear to show that the earth's crust in this region was displaced as a single block, if the data of the vertical displacement of B.M. 137, which is wanting, were also in accord with the tilting of the earth's crust represented by the vertical displacements of the other bench-marks. The topographical features in this region, however, is not in good accord with the mode of the crust deformation described above. Moreover, in the west part of the region near Kanaya, the phenomena of creeping or sliding of land mass occurred for several times[6], producing cracks in the wall of the railway tunnel of Kanaya. These facts may appear rather unfavourable for regarding the region under consideration as a single crust block.

A similar case is met with in the region in the neighbourhood of the river Tenryûgawa. The conspicuous depression of B.M. 146, situated on the east embankment of the river Tenryûgawa relative to the adjoining bench-marks, the wanting data of the vertical displacements for B.M.'s 144 and 144·1, and complicated topographical features in this region render it difficult to determine a definite mode of the crust deformation. The irregularities in the crust deformations in this region may partly be due to the fact that the bench-marks are situated in the alluvial plain, except for B.M.'s 144.1 and 145, which are situated on a part of the levelling route crossing the mountain range to the east of Mituke.

Lastly, it may be remarked that the general mode of the crust deformation in the district to the east of the Tenryûgawa, i.e., the district between the Tenryûgawa and Siduoka, may be regarded as a simple tilting. The amount and the direction of the tilting of the land may be determined by the amounts of general tilting in two branches of the levelling route and their directions. The two branches are a part of the route from the Tenryûgawa to Hudieda and that from Hudieda to Siduoka. The trends of the routes in these two parts are nearly straight. The amounts of general tiltings may be estimated

6) K. Jimbo, *Sinsai-Yobô-Tyôsakwai Hôkoku* (*Bull. Imp. Earthq. Invest. Comm.*), No. 38.

from the data of δH's for each of the groups of the bench-marks, given in Table II and III. The estimated amounts of general tiltings and the directions of these two parts of the levelling route are shown in Table IV.

Table IV. Directions and amounts of tilting of the earth's crust in two different sections of the route.

Section	Amount	Direction
The Tenryûgawa-Hudieda	$5{\cdot}5\times10^{-6}$	N 68° E
Hudieda-Siduoka	0·0	N 37° E

The amount of the general tilting of the earth's crust in the region, thus determined, is $6{\cdot}5\times10^{-6}$ in the direction of E 37° S.

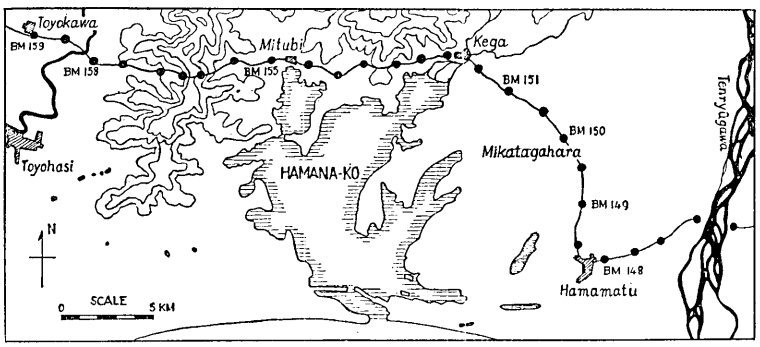

Fig. 10. The topographical features in the neighbourhood of Hamana-ko (Lake).

d) In the region to the west of the Tenryûgawa, the trend of the levelling route is directed N-S in the region from Hamamatu to Kega, crossing the high land of Mikatagahara. The trend of the levelling route is again directed E-W, in the region to the west of Kega, along the northern coast of Hamana-ko (lake). The topographical features in this district are shown in Fig. 10. In this district, the vertical displacements of the bench-marks are approximately proportional to the heights of the bench-marks, as shown in Table V.

Table V. Groups, vertical displacements and heights of the bench-marks situated on the route from Hamamatu to Toyokawa.

Group.	Locality	B. M.	δH	H
			mm	m
	Hamamatu	148	65·8	4·00
		148·1	82·9	30·43
		149	97·5	38·05
A_8		149·1	98·9	43·96
		150	113·0	51·18
		150·1	115·2	52·76
		151	118·0	50·72
		151·1	117·7	12·09
	Kega	152	108·9	7·25
		152·1	122·5	32·79
		153	124·9	78·82
A_9		153·1	119·4	38·85
		154	114·3	6·65
	Mikahi	154·1	115·3	12·37
		155	119·0	13·67
		155·1	117·1	21·64
		156	122·6	131·66
		156·1	120·5	193·58
		157	115·8	61·97
A_{10}		157·1	109·8	36·20
		158	108·5	13·20
		158·1	97·8	6·33
	Toyokawa	159	93·4	12·72

N. B. The vertical displacements of the bench-marks are due to the time interval 1900–1931.

Among these different parts of the route, the earth's crust of the region from Hamamatu to Kega may be regarded to have been tilted south-or southwestward, while, that of the region to the west of Kega has been deformed into a form similar to that which is represented by the present profile of the route. The boundary of these two regions are coincident with a valley extending SW-NE, which was pointed out by

Mr. T. Okayama,[7] as the boundary of Blocks A_2 and B_5, in his investigation on land blocks from topographical or geomorphological point of view.

Between B. M.'s 156 and 156·1, there is a fault traced by Mr. K. Ishii.[8] This may form a boundary between the regions in which the bench-marks belonging to Groups A_9 and A_{10} are distributed respectively. If, however, this fault were disregarded, the regions occupied by the bench-marks belonging to Groups A_9 and A_{10} may be bound up together and regarded as one block. The crust deformation in the this region is then regarded as an upwarping which is similar in form with the profile of the topographical features along the levelling route. If, on the contrary, the geological fault was active and significant as a boundary of the crust blocks, the regions occupied by the bench-marks belonging to Groups A_9 and A_{10} respectively may be separated as different crust blocks and the latter regions may be regarded as tilted westward parallel to the profile of the route.

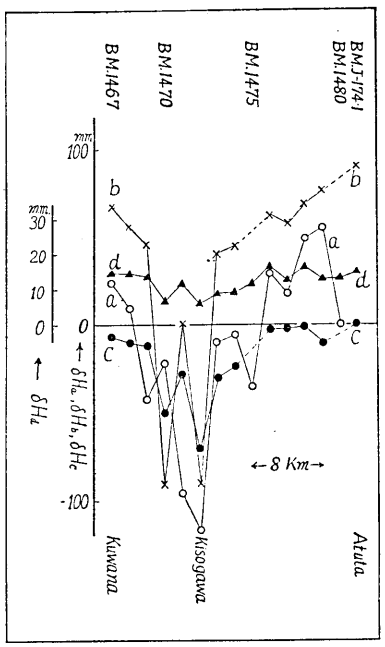

Fig. 11. The vertical displacements of the bench-marks, between Atuta and Kuwana, due to different time intervals.

The crust Deformation in the District around Ise-Wan.

To investigate the general mode of the crust deformation in the district around Ise-wan (the Bay of Ise), it is convenient first to investigate the local crust deformation in the region between Atuta and Kuwana. In this region, the levelling surveys were revised several times after the Nôbi Earthquake of 1891. The vertical displacements of the bench-marks distributed in this region due to the time intervals 1885–1895,[9] 1895–1918, 1918–1929 and 1929–1931 are shown respectively by the curves a, b, c and d in Fig. 11. In these curves, we notice the remarkable depression of the

7) T. OKAYAMA, *Tirigaku-Hyôron*, 6 (1930), 479.

8) K. ISHII, Geological Map, "Toyohashi" Sheet, Scale 1/75000.

9) The data of the vertical displacements due to the earlier epochs are kindly placed by Mr. K. Mutô, of the Military Land Survey.

bench-marks situated near the mouth of the river Kisogawa, except for the curve corresponding to the time interval 1929–1931. It may be remarked that, in each of these series of the data of the vertical displacements, the reference bench-mark is not the same of which the vertical displacement during the corresponding time interval is assumed to be zero. Hence, the absolute amounts of the vertical displacements may want a later correction, but the relative dispalcements which are only significant as due to the local crust deformations are here correctly represented.

In comparing the curves *a*, *b* and *c* in Fig. 11, we notice that the bench-marks situated near the mouth of the river Kisogawa, B. M. 1470 and B. M. 1472, were depressed remarkably during the time interval including the destructive Nôbi earthquake and the post-seismic period of a certain duration. A closer inspection of the curve *d*, we also notice that the form of this curve is similar to that of *a*, *b* or *c*. This may show that the earth's crust in the neighbourhood of B. M.'s 1470 and 1472 has been deformed in the same sense in these some fourty years, including the disturbance due to the acute crust deformation associated with the destructive Nôbi earthquake of 1891.

On the other hand, the vertical displacements of the bench-marks on the route from Kanô to Kasiwabara were also measured for several times since the year 1885. The trend of this levelling route is parallel to that of the route from Atuta to Kuwana and located several tens of kilometers to the north of it, as shown in Fig. 2. In Fig. 12 the vertical displacements of the bench-marks situated between Kanô and Kasiwabara due to the time intervals 1885-1896, 1896-1899, 1899-1917 and 1917-1928, are shown by

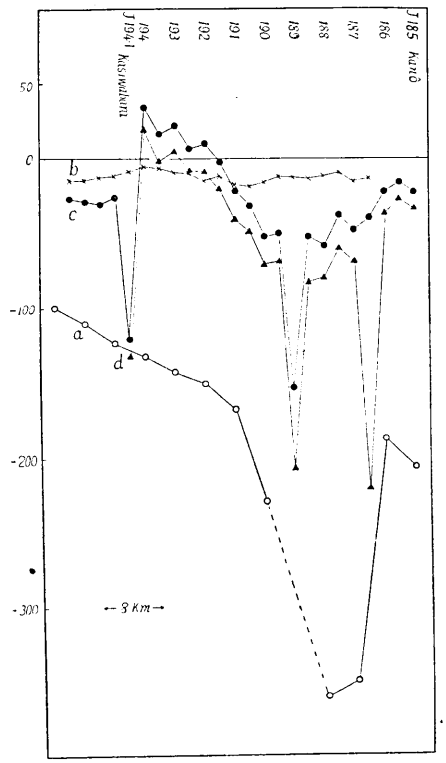

Fig. 12. The vertical displacements of the bench-marks, between Kanô and Kasiwabara, due to different time intervals.

the curves a, b, c, and d.[10] It may be noticed that the curves are similar in form, though the scales for each of the curves are different, except for the curve b, representing the vertical displacements due to the time interval 1896-1899. B. M. 189 shows the maximum depression in each epoch and the region to the west of this bench-mark is tilted to the east whereas to the east of the bench-mark has a tendency of westward tilting throughout the whole period of times. B. M. 1941, situated very near Kasiwabara was remarkably depressed during 1899-1917 and 1917-1928. B. M. 1861 was depressed conspicuously during 1917-1928. B. M. 189, the bench-mark of the maximum depression in all period of times, is situated to the north of the region of depression in the neighbourhood of B. M. 1470 on the southern levelling route.

A zone of depression, including B. M.'s 1470 and 1472 in the south and B. M. 189 in the north, if it really existed may be approximately coincident with the central zone of the area disturbed most severely at the time of the destructive Nôbi earthquake of 1891.

On considering the existence of this zone of depression extending from N to S, in Ise-Wan, the general mode of the crust deformation may be explained.

The district under consideration belongs to the Inner Zone of Southwest Japan. The geological structures in the district may be considered much different from those of the district belonging to the Outer Zone, as it was shown by the gelogists. Hence, it may be allowed to consider that the present crust deformation in this district is more or less different from those of the district belonging to Outer Zone, i. e., the district between Okitu and Toyokawa and the district between Udiyamada and Kusimoto.

The general trends of the levelling route in this district are i) directed SE-NW in the section from Point A, Toyokawa, to Atuta, ii) E-W in the section from Atuta to Kuwana, and iii) N-S in the section from Kuwana to Udiyamada. Such a configuration of the levelling route may produce a mode of the crust deformation shown in Fig. 1, if there existed a zone of depression as mentioned above, and the earth's crust on both sides of the zone are tilted as a whole towards the central line of this zone of depression. The trend of the levelling route on the east side of the zone of depression, or Ise-wan obliquely intersects the axial

10) The data of the vertical displacements of these bench-marks are reproduced from Prof. Imamura's paper. A. IMAMURA, *Publication of Imp. Earthq. Invest. Comm.*, No. 25 (1930).

line of the zone of depression, while the levelling route on the west side of the bay is approximately parallel to the trend of the axial line of depression. Hence, the amount of tilting of the earth's crust along the former levelling route is considerable, while that of the earth's crust along the latter levelling route is approximately zero, as far as the minor fluctuations are disregarded.

It may also be pointed out as a noteworthy fact that the bench-marks situated very near the river Yahagigawa are depressed remarkably in comparison with the adjoining bench-marks. The depression of B. M. 166, situated close to the Yahagigawa is noticed in the result of the revision of the survey of precise levelling carried out in 1899, which is shown in Fig. 13.

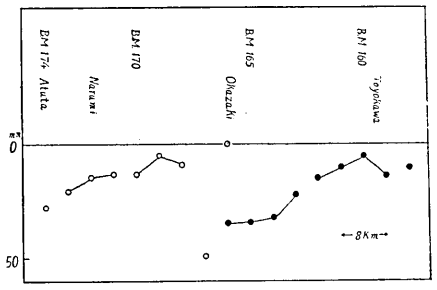

Fig. 13. The vertical displacements of the bench-marks along the route Toyokawa-Okazaki-Atuta, due to the earlier epoch.

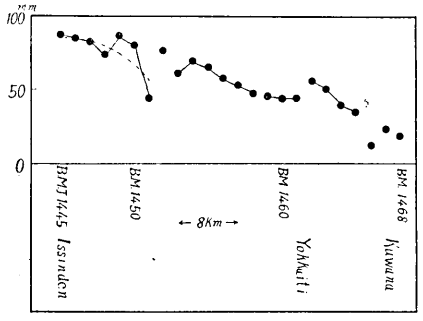

Fig. 14. The vertical displacements of the bench-marks on the route from Kuwana to Issinden, due to the earlier epoch.

As already referred to in the preceding chapter, we have the data of vertical displacements for earlier epochs of the bench-marks situated in the district under consideration. The sections of the levelling route and the time intervals to which the vertical displacements of the earlier epochs are due, are:

1. Toyokawa-Okazaki 1885–1900 displacements shown in Fig. 13
2. Okazaki-Atuta 1885–1895 „ „ „ „ 13
3. Kuwana-Tu (Issinden) 1888–1895 „ „ „ „ 14

As for the sections 1 and 2 the correlations between δH_1 and δH_2 are positive as shown in Fig. 15, in which δH_1 denotes the vertical displacements of the bench-marks due to the time interval of 1885–

11) As for the vertical displacements of the bench-marks on the route from Atuta to Kuwana due to various time intervals, we have already referred to them in the above.

1900 for the district 1 and those due to the time interval of 1885–1895 for the district 2, while δH_2 denote the vertical displacements of the same bench-marks due to the time interval of 1900–1931 for the district 1 and those due to the time interval of 1895–1931 for the district 2.

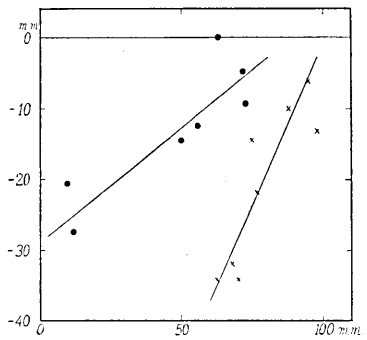

Fig. 15. The relation between δH_1 and δH_2 of the bench-marks, situated in the districts Toyokawa —Okazaki (×) and Okazaki—Atuta (•).

It may be remarked that the rates of variations of the gradients of the vertical displacement of the bench-marks are approximately the same in different time intervals or a little less in the recent epochs than in the earlier in the district between Toyokawa and Atuta, as may be understood by comparing the inclinations of straight lines representing the relations between δH_1 and δH_2 with the ratios of the time intervals to which δH_1 and δH_2 are due. The inclinations of these straight lines, representing approximate linear relations between δH_1 and δH_2 in Fig. 15, are $40/34=1{\cdot}2$ for the district between Toyokawa and Okazaki and $90/32=2{\cdot}8$ for the district between Okazaki and Atuta, while the ratios of the time intervals, to which δH_1 and δH_2 are due, are $31/16=62/32=1{\cdot}9$ for the former district and $36/10=108/10=3{\cdot}6$ for the latter district.

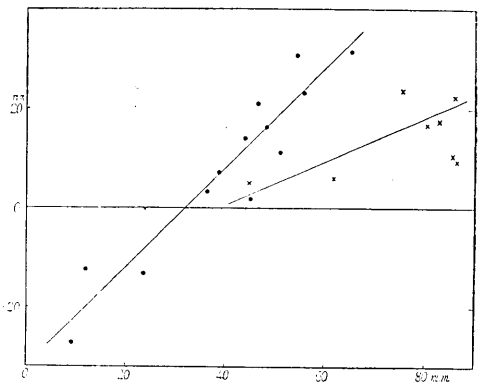

Fig. 16. The relation between δH_1 and δH_2 of the bench-marks situated in the district Kuwana-Issinden.

As for the vertical displacements of the bench-marks on the route from Kuwana to Tu, a correlation diagram is given in Fig. 16, taking δH_2, the vertical displacements due to the time interval of 1895–1931, in abscissae, and δH_1, the vertical displacements due to the time interval of 1888–1895, in ordinates. The diagram shows that the correlation is approximately

positive for the group of the bench-marks, B. M.'s 1468–1455. As for the other bench-marks, the correlation is also positive, but the slope of the straight line representing an approximate linear relation between δH_1 and δH_2 is a little gentler than that referred to above.

It may be remarked that the line representing the approximate linear relation between δH_1 rnd δH_2 of the bench-marks, B. M.'s 1468–1455, is inclined by some 45° to the horizontal line, the scale for δH_1 and δH_2 being the same. As the time interval to which δH_1 are due is about one fifth of that for δH_2, the rates of gradients of the vertical displacements is greater in the earlier epoch than in the recent epoch. The mode of the variation in rates of the gradients is reversed in comparison with those of the earth's crust in the district between Okitu and Hukuroi. The straight line representing the approximate linear relation between δH_1 and δH_2 of the bench-marks, B. M.'s 1455-1445 is gentler than 45°, which shows that the variation in the rates of gradients of the vertical displacements is, in this region, much more greater in earlier epoch than in recent epoch, in comparison with the case in the northern region, which was referred to above.

The detail of the crust deformation in the district between Toyokawa and Udiyamada are described as follows, the crust deformations in the districts on the east and west sides of Ise-Wan being treated separately:

a) The vertical displacements of the bench-marks on the route from Toyokawa to Atuta are plotted again in Fig. 17, and the topographical feature of the district between Toyokawa and Atuta is shown in Fig. 18. The route may be divided into several parts, as before, according to the modes of the crust deformation. These parts of the levelling route, or the groups of the bench-marks, are given in Table VI.

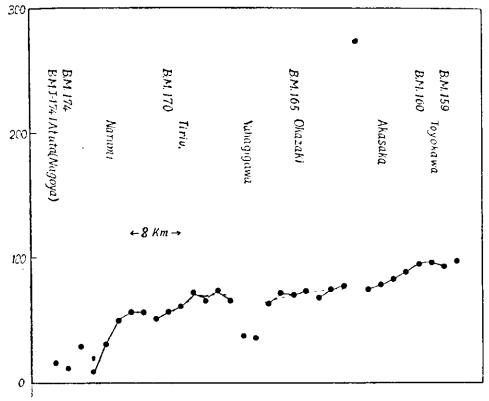

Fig. 17. The vertical displacements of the bench marks, between Toyokawa—Atuta, due to the time interval 1900–1931.

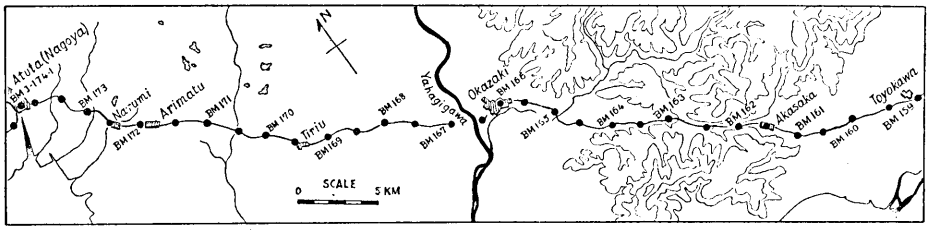

Fig. 18. The topographical features along the route from Toyokawa to Atuta.

Table VI. Groups, vertical displacements and heights of the bench-marks situated on the route from Toyokawa to Atuta.

Group	Locality	B. M.	δH	H
			mm	m
	Toyokawa	159	93·4	12·72
		159·1	95 8	14·66
		160	95·0	12·74
B_1		160·1	88·7	23·96
		161	83·3	29·05
	Akasaka	161·1	79·1	46·35
		162	75·0	67·83
		162·1	274·2 *	105·31
		163	77·0	94·22
		163·1	74·6	78 39
		164	68·1	56·50
B_2		164·1	73·5	43·85
		165	70·3	29·32
		165·1	71·7	25·73
	Okazaki	166	62·9	24.50
	The Yahagigawa (river)	166·1	35·9	17 47
		167	37·5	14·52
		167·1	65·8	20·90
		168	73·4	21.49
		168·1	66·5	17·05

(to be continued.)

Table VI. (continued.)

Group	Locality	B. M.	δH	H
			mm	m
B_3	Tiriu	169	72·0	16·22
		169·1	61·5	11·74
		170	56·4	4·92
		170·1	50·6	5·86
		171	56·3	20·56
		171·1	56·9	26·34
B_4	Arimatu	172	49·7	8·97
	Narumi	172·1	30·7	3·60
		173	* 8·8	3·62
		173·1	29·1	13·57
		174	11·9	1·15
	Atuta	J-174·1	16·1	5·71

N. B. The vertical displacements of the bench-marks from B. M. 159 to B. M. 166 are due to the time interval 1900–1931, and those from B. M. 166–J-174·1 are due to the time interval 1895–1931. The vertical displacement marked by asterisks may be due to the local disturbance at the point where the bench-mark in question is situated.

One of the characteristics in the modes of the crust deformations in this district is regional upwarpings superposed on a general northwestward tilting. A typical example of the crust deformation of this sort is that of the region between Toyokawa and Akasaka, i. e., between B. M.'s 159 and 162. A similar mode of the crust deformation is shown in this region between B. M.'s 169–172, where the vertical displacements of the bench-marks are nearly proportional to their topographical heights.

B. M. 162·1 was upheaved abnormally, but nothing particular, either artificial or natural, is recorded which might have caused this abnormal upheaval.

The region in which the bench-marks belonging to Group B_2 are distributed may be subdivided into two regions as Groups B_2' and B_2''. This division, however, has no counterpart in the topographical features along this section of the levelling route. There is indeed a fault line, which may divided up the regions, but the trend of this fault line is nearly parallel to that of the levelling route. Hence, within the limit of accuracy in determining the trend of the fault line in the map, we

cannot find a point where the trend of the fault line intersects that of the levelling route which might be the boundary of the two regions mentioned above.

b) The vertical displacements of the bench-marks situated on the west side of Ise-wan are reproduced in Fig. 19. The trend of the

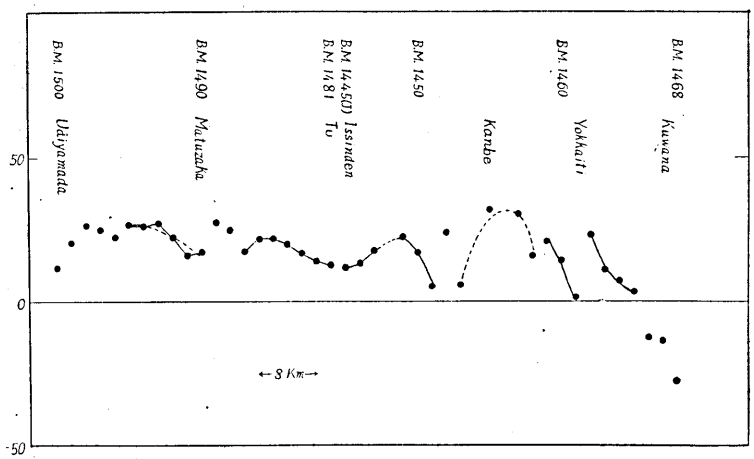

Fig. 19. The vertical displacements of the bench-marks along the route from Kuwana to Udiyamada; the result of 1931 revision.

levelling route in this district is directed approximately N-S, being not much deviated from a straight line, as shown in the map of Fig. 20.

From the curve of Fig. 19, we notice several crust blocks either tilted to the north or upwarped. Among them, the crust deformation in the region occupied by the groups of B. M.'s 1465–1462, and 1461–1459 are in a negative and that of B. M.'s 1451–1445 is approximately in positive correlation with the topographical features represented by the heights of the bench-marks. As for the region between B. M.'s 1458 and 1454, the mode of the crust deformation cannot be determined, for the lack of the data of the vertical displacements of B. M.'s 1456 and 1454. If, however, the vertical displacements were approximately proportional to the heights of the bench-marks, as we have noticed in several other cases, the crust deformation is an upwarping in this region.

The correlation between the vertical displacements and heights of the bench-marks may be seen in the numerical figures given in Table VII.

As may be seen in the table above, the correlations between the

vertical displace ments and the heights of the bench-marks belonging to Groups B_5 and B_6 are negative and that of Group B_7 are positive. But no correlation, neither positive nor negative, existed for the relation between the heights and the vertical displacements of the bench-marks, belonging to Groups B_8, B_9 and B_{10}, which are distributed in the alluvial plain. In this alluvial plain, the crust deformations, shown by the vertical displacements of the bench-marks, seem to be a general upwarping. Among them, the crust deformation in the regions occupied by the bench-marks belonging to Groups B_9 and B_{10} are similar with that which we have noticed in the crust deformation in the region belonging to Group B_1.

The Crust Deformation in Kii Peninsula.

In Kii peninsula, the precise levelling has been already revised in 1927 along the route from Kusimoto to Osaka via Tanabe, Yuasa and Wakayama and then in 1931 along the route from Singû to Gozyô via Ukegawa, the route passing through the central part of the peninsula, from S to N. By using these data, Prof.

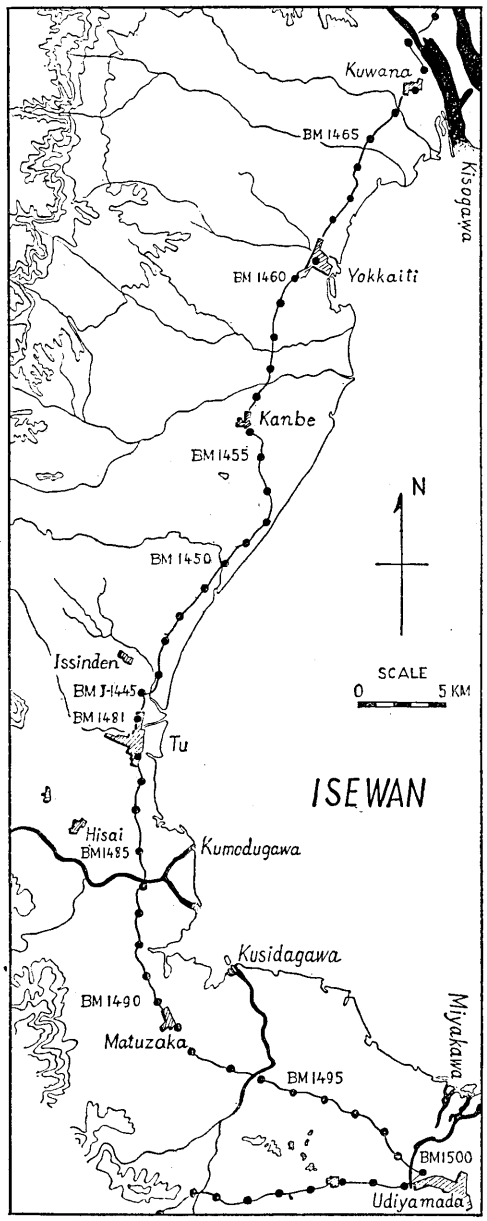

Fig. 20. The topographical features alo ng the route from Kuwana to Udiyamada.

Table VII, Groups, vertical displacements and heights of the bench-marks situated on the route from Kuwana to Udiyamada.

Group	Locality	B. M.	δH	H
			mm.	m.
	Kuwana	1469	−40·1	6·03
		1468	−27·4	2·66
		1467	−13·3	1·66
		1466	−12·3	6·90
B_5		1465	2·3	6·76
		1464	7·3	4·73
		1463	11·1	1·51
		1462	23·2	3·44
B_6	Yokkaiti	1461	1·7	4.48
		1460	14·1	2·90
		1459	21·0	2·73
B_7	Kanbe	1458	16·3	6·42
		1457	30·7	8·93
		1456	—	10·27
		1455	31·5	9·52
		1454	—	7·74
		1453	5·9	11·64
		1452	23·8	3·06
B_8	Issinden	1451	5·1	1·83
		1450	17·0	1·66
		1449	22·4	2·53
		1448	—	3·53
		1447	17·7	2·67
		1446	12·9	2·35
		J-1445	11·6	1·29
B_9	Tu	1481	12·9	3·88
		1482	13·9	2·28
		1483	17·2	2·67

(to be continued.)

Table VII. (continued.)

Group.	Locality	B. M.	δH	H
			mm.	m.
B_9		1484	20·0	2·02
		1485	21·7	2·99
		1486	21·6	7·34
		1487	17·4	3·01
		1488	24·9	2·52
		1489	27.6	3·43
	Matuzaka	1490	17·0	8·33
		1491	16·2	7·87
		1492	22·2	5·33
B_{10}		1493	26·8	11·15
		1494	26·2	11·11
		1495	26·5	14·27
		1496	22·6	8·92
		1497	25·0	10·30
		1498	26·2	10·15
		1499	20·6	10·46
	Udiyamada	1500	11·9	5·13

N. B. The vertical displacements of the bench-marks from 1469 to J-1445 are due to he time interval 1895-1931, and those from J-1445 to 1500 are due to the time interval 1889-1931.

Imamura[12] discussed the crust deformations, particularly the movements of the crust blocks in this district in association with the occurrenec of the earthquakes.

Disregarding the irregular minor fluctuations in the vertical displacements, shown in Fig. 1 of the present paper and also in the figures in Prof. Imamura's paper, and considering the general aspect of displacement which may be considered as due to the movements of the crust blocks, the crust deformation in Kii Peninsula may be regarded to consist of two different modes. One of them is a southward tilting near the southern end of the peninsula, which we have pointed out in

12) A. Imamura, *Jap. Journ. Astr. Geophys.*, 1 (1929), 31.
Disin, 1 (1924), 321; 4 (1932), 474, (in Japanese).

the preceding paper.[13] The tilting of the earth's crust in this part of the peninsula was determined by smoothing the displacement curve along the routes from Inami to Kusimoto and from Kusimoto to Singû. It may be added that the general tilting of the earth's crust along the route from Singû to Ukegawa, a part of the levelling route from Singû to Gozyô, also well agree with the tilting near the end of the peninsula.

In the map showing the distribution of the coastal terraces and the topography of the sea bottom in the neighbourhood of the promontary of Kii Peninsula, which is given in Prof. T. Tsujimura and Mr. S. Kawada's paper,[14] it may be noticed that the earth's crust near the southern end of the peninsula may be regarded as a single or an united crust block which seems to have been tilted to SW in geological past.

Another mode of the crust deformation is an upwarping movement of the earth's crust in the district adjoining to the north of the above mentioned part of the peninsula forming its southern end.

The upwarping movement of the earth's crust in this district may be shown by combining the results of the levellings carried out recently. The dates of the revisions of the precise levellings are not the same for different sections of the levelling route in the peninsula. Hence, the time intervals to which the vertical displacements measured of the bench-marks on different sections of the routes are due, are not exactly but approximately coincident. Therefore, the vertical displacements on different routes are compared on the assumption that the vertical displacement of the bench-mark situated at Kusimoto, B. M. 3, is the same for the two slightly different periods of time, i. e., 1889–1929 and 1889–1931. In Fig. 21, Curves I and II show the vertical displacements of the bench-marks on the route from Kusimoto Wakayama and those on the route from Singû to Gozyô, reproduced from Prof. Imamura's paper. Curve III shows the vertical displacements on the route from Udiyamada to Kusimoto. It may be noticed, in Fig. 22, that the earth's crust in the region along the route corresponding to Curve II, i. e., the central part of the peninsula, has been upheaved more conspicuously that those in the regions corresponding to Curves I and III, i. e., the eastern and western sides of the peninsula, as we have referred to above.

The upwarping movement of the earth's crust in this district which had occurred in the recent epoch, may be, in some measure, coincident with the crust movement in the recent geological period which was

13) T. TERADA and N. MIYABE, *Proc. Imp. Acad.*, 8 (1932), 288.

14) T. TSUJIMURA and S. KAWADA, *Tirigaku-Hyôron*, 6 (1930), 1754, (in Japanese).

shown by the geologists.[15]

Regarding the detail of the vertical crust deformation in this dis-

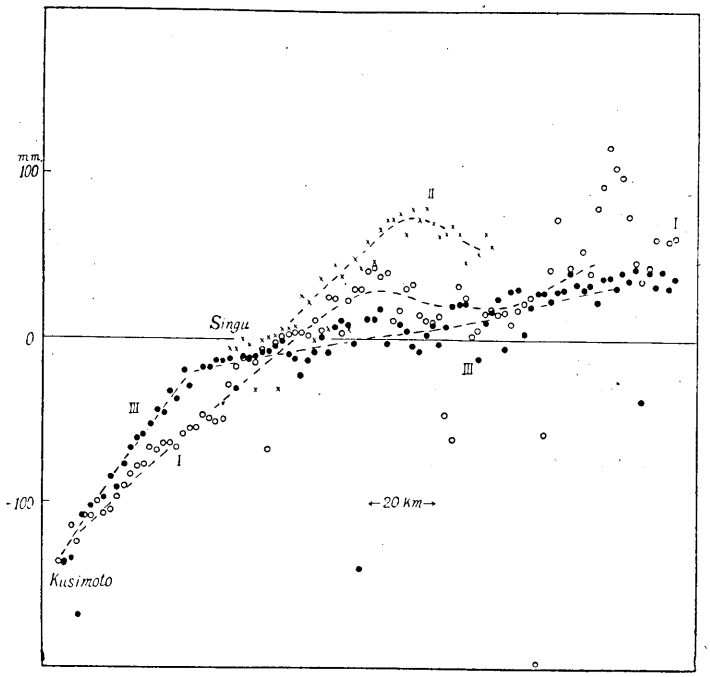

Fig. 21. The vertical displacements of the bench-marks situated in Kii Peninsula due to these 30 years.

I: along the route, Kusimoto—Wakayama.
II: „ Singû—Gozyô.
III: „ Kusimoto—Udiyamada.

trict, it may be noticed that the curve representing the vertical displacements on the route Udiyamada to Kusimoto, is superposed by irregular fluctuations. The amplitudes of the fluctuations in several place exceed several tens of milimetres. On the other hand, the form of the levelling route is also irregular and fluctuating from the general straight trend directed NE-SW. Hence, the fluctuations in the vertical displacements may be considered as partly due to the fluctuations in the form of the levelling route. For the purpose of a rough estimation, take the extreme case in which the general trend of the route is perpendicular to the direction of general tilting of the crust. If two successive bench-marks be situated on opposite sides of the straight line representing the trend

15) Y. Ôtuka, *Bull. Earthq. Res. Inst.*, 9 (1931), 240.

of the route and the sum of the distances of these two points from the straight line be Δs, we have, for the difference of the vertical displacements of these two points,

$$\Delta\delta H = a \times \Delta s,$$

where a corresponds to the amount of general tilting of the earth's crust in the district under consideration. In the present case, it may be probable to be assumed that $a=10^{-6}$ and $\Delta s=1$ km. in order of magnitude. Then, we have $\Delta\delta H=1$ mm., which is less than the order of magnitude of the actual fluctuations.

The fluctuations in the vertical displacements may, therefore, be largely due to the movements of the local crust blocks. An attempt is, therefore, made to determine the local crust blocks and their modes of tiltings by using the data of the vertical displacements of the bench-marks. As a criterion for determining the crust blocks, the already established relation[16] between the gradients of the vertical displacements and the azimuth of successive bench-marks, was employed. Several

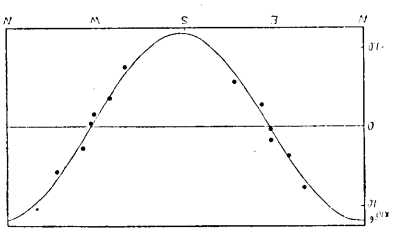

Fig. 22. a. The sine curve used for determining the tilting of Block V.

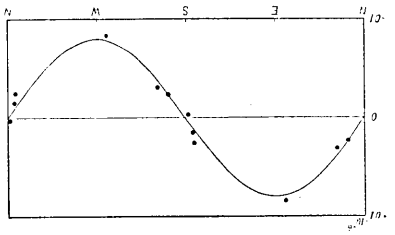

Fig. 22 b. The sine curve used for determining tilting of Block VII.

curves, used for determining the crust blocks are shown in Figs. 22 a and b. Thus, the crust blocks and their modes of tilting are determined and they are given in Table VIII.

The crust blocks thus determined seem to be significant also with respect to the local features of the topography.

Even in several regions, where the levelling route is straight and therefore the crust blocks cannot be completely determined by the usual geometrical method, it may be noticed that approximately corresponding to some discontinuity in the vertical displacements, there are also discontinuities in the local features of the topography. If we were allowed

16) N. MIYABE, *Proc. Imp. Acad.*, 7 (1931), 150.
Bull. Earthq. Res. Inst., 9 (1931), 257.

Table VIII. Crust Blocks in Kii Peninsula, determined by using the data of the vertical displacements of bench-marks on the route from Udiyamada to Kusimoto.

Block	Bench-marks situated	Magnitude of Tilting	Azimuth
I	BM's 1503-1506	$4{\cdot}8\times10^{-6}$	E-75°-S
II	„ 4749-4752	$1{\cdot}4_4$ „	E-49°-S
III	„ 4753-4756	$2{\cdot}9$ „	E-2°-S
IV	„ 4759-4762	$0{\cdot}8_8$ „	E-46°-S
V	„ 4771-4774	$2{\cdot}0_4$ „	E-7°-S
VI	„ 4784-4787	$2{\cdot}3_6$ „	E-85°-N
VII	„ 4795-4798	$2{\cdot}3$ „	W-84°-S
VIII	„ 4809-4810 4966-4967	$0{\cdot}1_6$ „	E-1°-S
IX	„ 4979-4982	$1{\cdot}9_6$ „	E-68°-S.

to regard these discontinuities as the boundaries of crust blocks, several of these blocks are upwarped while others are tilted. These divisions of the earth's crust or the crust blocks are shown in Table IX.

Table IX. Groups, vertical displacements and heights of bench-marks situated on the route from Udiyamada to Kusimoto.

Group.	Locality	B. M.	δH	H
			mm.	m.
	Udiyamada	1500	11·9	5·13
		1501	17·5	8·10
		1502	14·8	15·34
		1503	21·6	19·67
		1504	15·0	22·64
Block I		1505	26·6	41·47
		1506	22·7	42·30
		1507	28·5	48·51
C_1		1508	30·3	38·83
		1509	40·4	53·30
		J-1510	26·2	34·40

(to be continued.)

Table IX. (continued.)

Group.	Locality	B. M.	δH	H
			mm.	m.
		4736	35·3	44·38
C_2		4737	37·8	75·57
		4738	41·8	56·74
		4739	35·6	68·33
		4740	40·3	71·91
C_3		4741	36·7	93·60
		4742	33·4	82·82
		4743	42·0	77·72
		4744	33·6	97·95
		4745	42·3	101·32
		4746	* −37·1	106·36
		4747	43.1	115·81
		4748	36·2	127·17
		4749	41·1	124·73
Block II		4750	31·2	138·50
		4751	38·2	145·18
		4752	36·8	157·38
		4753	22·4	169·40
Block III		4754	33·2	182·14
		4755	29·6	202·92
		4756	34·3	242·35
		4757	44·6	147·96
		4758	30·0	22·42
		4759	29·1	1·98
Block IV	Nagasima	4760	24·3	3·21
		4761	28·4	2·44
		4762	28·4	49·72
		4763	19·3	47·23
		4764	3·5 *	64·66

(to be continued.)

Table IX. (continued.)

Group.	Locality	B. M.	δH	H
			mm.	m.
		4765	30·1	36·83
		4766	29·8	22·50
		4767	* − 5·7	148·22
C_4		4768	24·1	37·63
		4769	17·7	11·04
		4770	11·1	8·93
Block V		4771	−13·1	5·89
		4772	8·0	2·44
		4773	22·5	45·28
		4774	20·5	86·96
C_5	Owase	4775	20·3	43·19
		4776	7·8	34·19
		4777	−2·6	3·20
C_6		4778	9·9	6·41
		4779	2·6	37·13
		4780	− 7·3	81·45
C_7		4781	− 4·7	203·55
		4782	5·3	390·65
		4783	8·5	560·02
Block VI		4784	10·8	676·53
		4785	− 8·5	807·82
		4786	17·8	703·32
		4787	12·0	601·09
		4788	12·2	497·10
		4789	* 140·4	405·38
C_8		4790	− 2·5	364·58
		4791	8·1	340·20
		4792	11·5	320·45
		4793	7·0	301·90

(to be continued.)

Table IX. (continued.)

Group.	Locality	B. M.	δH	H
		4794	mm. − 8·7	m. 331·94
Block VII	Kinomoto	4795	1·6	388·12
		4796	− 8·1	310·33
		4797	−13·4	156·03
		4798	−32·0	7·34
		4799	−12·2	11·40
		4800	−10·3	12·04
C_9		4801	− 1·5	12·77
		4802	− 3·3	11·17
		4803	− 7·6	7·10
C_{10}		4804	− 6·9	17·93
		4805	−10·9	4·00
		4806	−12·2	11·57
		4807	−11·2	7·62
		4808	−30·0	6·17
Block VIII	Singû	4809	−15·1	6·91
		J 4810	−12·6	9·82
		4966	−13·6	5·42
		4967	−13·5	33·58
	Miwasaki	4968	−17·1	8·10
		4969	−16·9	9·57
		4970	—	7·22
		4971	−29·6	40·53
		4992	−19·6	14·58
		4973	−36·9	3·82
C_{11}		4974	−31·7	69·76
		4975	−45·1	1·64
		4976	−44·1	10·92
		4977	−52·0	3·19

(to be continued.)

Table IX. (continued.)

Group.	Locality	B. M.	δH	H
		4978	mm. −58·2	m. 3·26
Block IX		4979	−61·5	2·90
		4980	−65·6	5·60
		4981	−75·9	12·04
		4982	−91·2	2·35
C_{12}	Koza	4983	−84·6	5·78
		4984	−97·2	7·25
		4985	−100·4	5·69
		4986	−102·4	7·51
	Kusimoto	4987	−108·8	5·58
		4988	* −169·4	2·79
		4989	−133·9	3·16
		9221	−136·2	2·73
		3	−136·1	3·33

N. B. The vertical displacements of the bench-marks from 1500 to J-1510 are due to the time interval 1889-1931, those from J-1510 to 4775 are due to the time interval 1895-1931, and those from 4775 to 3 are due to the time interval 1899-1931. The vertical displacements marked by asterisks may be due to the local disturbances at the points where the bench-marks in question are situated.

The locations of the crust blocks, including the divisions of the earth's crust mentioned above, are shown in Fig. 23. In this figure, the crust blocks determined by the usual geometrical method are shown with arrows indicating the directions and magnitudes of their tiltings.

As for the crust deformations in this district, it may be remarked that the amounts of tilting of local crust blocks are of the same order of magnitudes while they are tilted in various directions. The order of magnitude of tilting of these local crust blocks is $1\text{–}5 \times 10^{-6}$, those situated near the southern end of the peninsula and the district to the north of it being included. On the other hand, the general tilting of the earth's near the southern end of the peninsula and that of the district adjoining to the north of the former are evidently different, as already referred to. Moreover, the general tilting in the northern district is smaller in order of magnitude than those of smaller crust

blocks situated there. It may, therefore, be pointed out that the tilting of the local crust blocks does not always represent the general tilting of the earth's crust in the district including these crust blocks. The case is similar with that which has already been shown in the crust deformation in Bôsô Peninsula.[17]

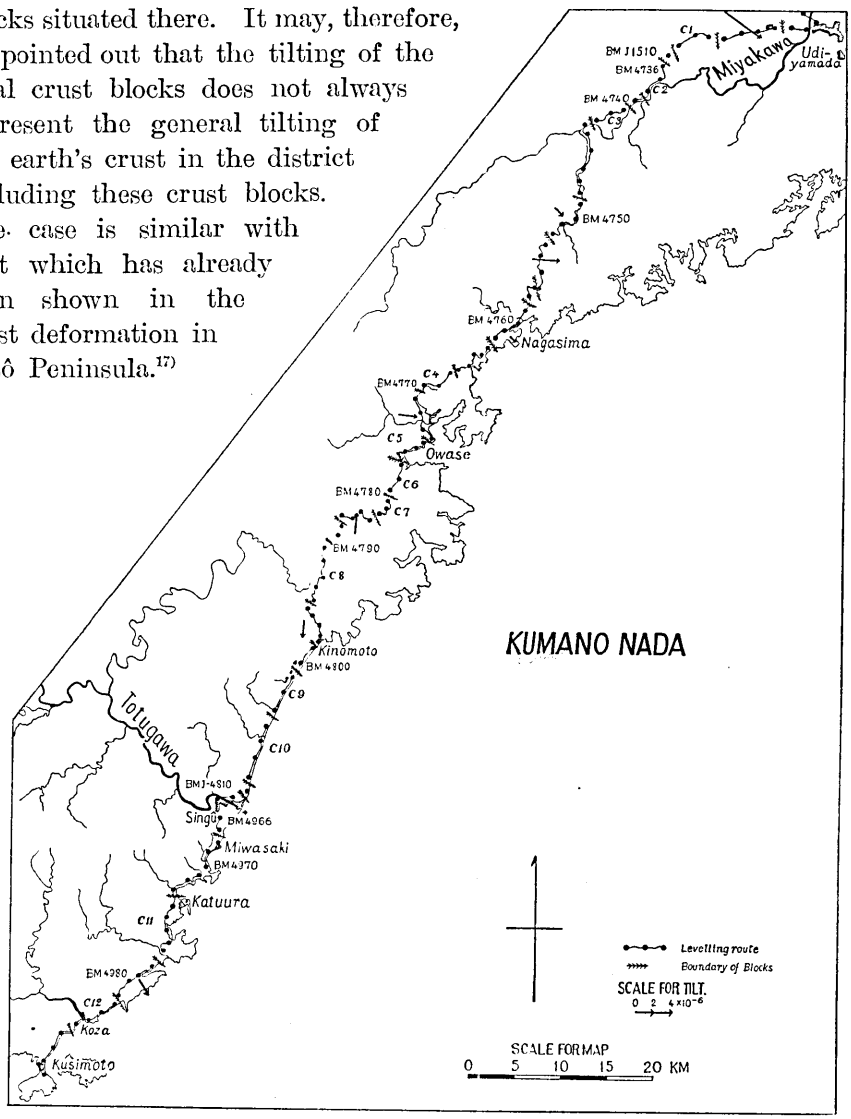

Fig. 23. Levelling-route and blocks in the eastern coast of Kii Peninsula.

17) N. MIYABE, *Bull. Earthq. Res. Inst.*, **9** (1931), 407.

Summary.

The results of the present investigation may be summarized as follows:

1) The district between Okitu and Kusimoto, along the Pacific coast, may be divided into three or four districts with regard to the difference in the modes of crust deformations. The first, third and fourth parts of the district belong to the Outer Zone and the second part belongs to the Inner Zone of Southwest Japan, according to the division which has been established by the geologists on the basis of the geological evidences.

2) Taking these parts separately, general modes of the crust deformations and also the local ones, such as due to the movements of the local crust blocks are investigated. The results in detail are described in respective chapters. It may be remarked that the general mode of the crust deformation in Kii Peninsula is in accord with the results of geological and geomorphological investigations and that in most cases, the discontinuities in local crust deformation or the boundaries of the crust blocks are also significant with regard to topographical features and geological evidences.

3) In the districts between Okitu and Okazaki, Okazaki and Atuta and Atuta and Tu, the vertical displacements of the bench-marks recently measured are compared with those of the earlier epoch. The correlatians between the vertical displacements of recent and earlier data are generally positive, disregarding the negative correlations in smaller regions.

It may be remarked however, that, in the district between Okitu to Simada, the rate of variation of the gradient of the vertical displacement was several times as great in the recent epoch, compared with the rate in the early epoch.

4) As for the crust deformation in Kii Peninsula, it was pointed out that the modes of local crust deformation are not always coincident with the mode of the general crust deformation.

Before concluding, it must be stated with acknowledgements and gratitude that the entire cost of the recent revision of the precise levelling, along the route under consideration, was defrayed by the grant from Harada Sekizenkwai.

In conclusion, the present writer wishes to express his sincere thanks

to Professor Torahiko Terada for his kind advices and guidance. Cordial thanks are also due to Mr. K. Mutô of the Miltary Land Survey for his kindness in placing valuable data at the writer's disposal.

---

16. 興津串本間に於ける地殻の變動.

地震研究所 宮 部 直 巳

昭和 6 年 (1931 年) に靜岡縣下の興津から紀伊半島の南端串本に至る水準線の改測が行はれ, この間にある水準點の 30-40 年間の垂直變動量が知られた. 本文はその結果に基いて, この地域の地殻の變動を調べたものである.

水準點の垂直變動の示す所を見るに, 豐川以東に於ける地殻は大體東に傾斜し, 宇治山田以西に於いては南又は西南に傾斜してゐる模樣であつて, この兩區域は地質學上の西南日本外帶に屬してゐる. 又, 豐川から宇治山田に至る伊勢灣周圍の地域は, 東側では西に傾斜し西側では殆ど傾斜してゐない樣に見える. 是等の三つの區域について二三の著明な事實を指摘すれば, 次のやうなものがある.

i) 興津—豐川.

a) 天龍川以東の地域は大體東 37 度南へ約 1·3″ 傾斜してゐる.

b) 1885-1900 の間の垂直變動と 1900-1931 の間のそれとを比較すると後の期間の方が變動の割合が大になつてゐる.

ii) 豐川—宇治山田.

a) 熱田—桑名の間には濃美地震後數回の測量が行はれてゐて, その各期間に起つた垂直變動を示す曲線は何れもその形が似てゐる.

殊に木曾川河口にある水準點の沈下が何れも著明である. そこで, もし, この點を通つて南北に亙る沈降地帶がありとすれば, 伊勢灣の兩岸の地域はこの地帶の沈降運動に伴つて夫々東岸は西に西岸は東に傾いたものの如くに思はれる.

b) 豐川—熱田間, 桑名—一身田間の變動を, 以前の變動に較べれば, 大體に於いて, 同一の向きに變動を繼續しつゝあるかの如き樣子を示しその變動の割合はあまり變らないか或は寧ろ小さくなつてゐる.

iii) 宇治山田—串本.

a) 宇治山田—新宮と新宮—串本とは垂直變動を示す曲線の上でかなり明瞭な區別が認められるが, その中, 宇治山田—新宮間の變動は, 緩なる西南又は南への傾斜を示し, 先に今村博士の發表された, 紀伊半島西岸並に中部に於ける水準測量の結果と併せて, 紀伊半島の中部以北では, 全體として, 地殻が南北線を背斜軸とする warping をなしつゝあるかの如く見える.

b) 新宮以南の地域は, 曾ても指摘されたやうに大體南へ傾斜してゐる.

以上の外, 各地域を通じて, 地塊を認めることが出來る. 是等の地塊は必ずしも單一な傾斜を示さず曲隆的な變形を示してゐるものもある樣に思はれる. 又地形や地質の上から認めらる地塊と, 測量によつて見出された上記の地塊とが略〻一致してゐるやうな場所も尠なからず存在する.

尙, 上述の水準測量は, 原田積善會から提供された資金により, 陸地測量部に委囑して遂行されたものであつて, 同會に對して筆者も亦玆く御禮を申上げたいと思ふ.