31. *Deformation of the Earth's Crust along the Pacific Coast, the Japan Sea Coast, and in the Central Zone of Japan.*

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In his recent investigation on the deformation of the earth's crust along the Japan Sea coast, Dr. C. Tsuboi[1] called attention to the existence of undulatory deformations with wave lengths of about 80 km. Prof. T. Terada[2] noted the same thing in connection with the topography of the Tôhoku district. In the present paper, the writer described the modes of deformation of the earth's crust along the Pacific coast and in the central zone of Japan, and discussed the results in relation to the deformation along the Japan Sea coast studied by Dr. Tsuboi.

The level lines along the Pacific coast consist of the sections, i) Hukusima-mati (Kagosima pref.)—Miyazaki—Nobeoka—Sakanoiti, ii) Yahatahama—Uwazima—Nakamura—Kôti—Murotozaki—Tatue, and iii) Wakayama—Kusimoto—Udiyamada—Nagoya—Toyohasi—Siduoka—Okitu—Numadu, while those of the central zone of Japan begin from Okayama to Sirakawa, via Osaka, Kyôto, Gihu (Kanô), Simosuwa, Takasaki, and Utunomiya. The level lines along the Pacific coast, the Japan Sea coast, and in the central zone of Japan are designated by A, B, and C respectively in Fig. 1. These lines are approximately parallel to each other and to the general trend of the Japan arc.

The vertical displacements of bench-marks along level lines A, B, and C are shown in Figs. 2-4, respectively. Since the displacements along the different sections of the lines have been measured at different times and referred to different standard levels, it is necessary to reduce them approximately to a common standard, but we have no satisfactory method of doing it. The reduction method used in the present investigation was therefore either to add a certain constant to or subtract an

1) C. TSUBOI, *Proc. Imp. Acad.*, **10** (1934), 76-79.
2) T. TERADA, *ibid.*, **10** (1934), 65-68.

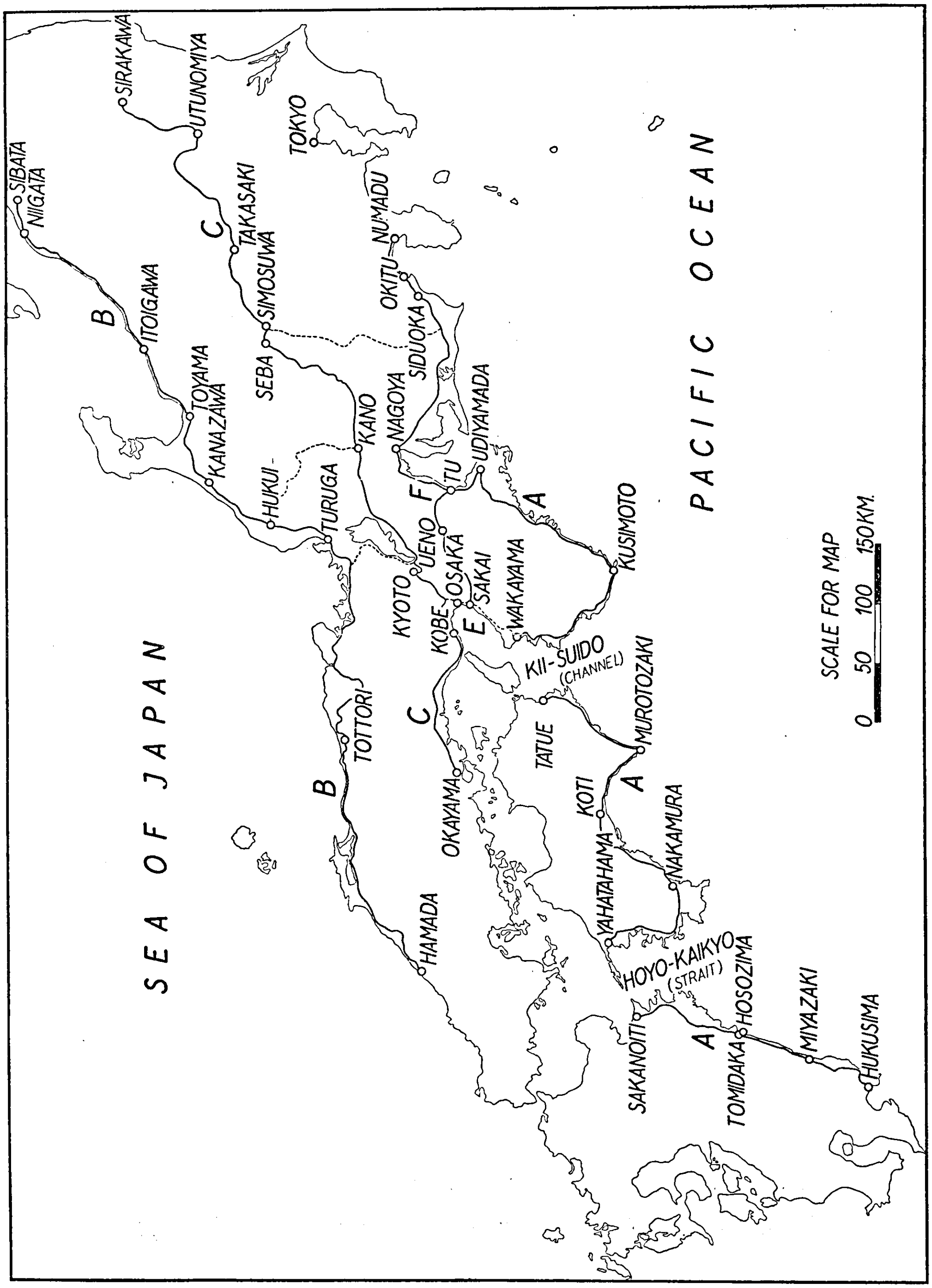

Fig. 1. Geographical distribution of level lines.

another constant from the displacement value. Although these reductions are only rough approximations, they are sufficient for discussing the general modes of deformations with however the following reservations.

In the matter of time, since the first survey was carried out during 1892–1900 and revised during 1927–1934, except for certain regions, the time intervals during which the vertical displacements were measured range theoretically from 44 to 27 years. Actually however the time ranges from 40 to 30 years, an interval several times those of the first and second surveys. If, therefore, the discussion is limited to the general modes of deformations, disregarding all detailed modes and conspicuous acute movements of the earth's crust such as are associated with earthquakes, the differences in the time intervals and epochs may not be so serious as to affect the modes of general crustal deformation.

The vertical displacements of bench-marks in the various sections of the level lines are so adjusted that the curve denoting the vertical earth movements of contiguous sections shall be continuous in order to avoid discontinuities at the junction points.

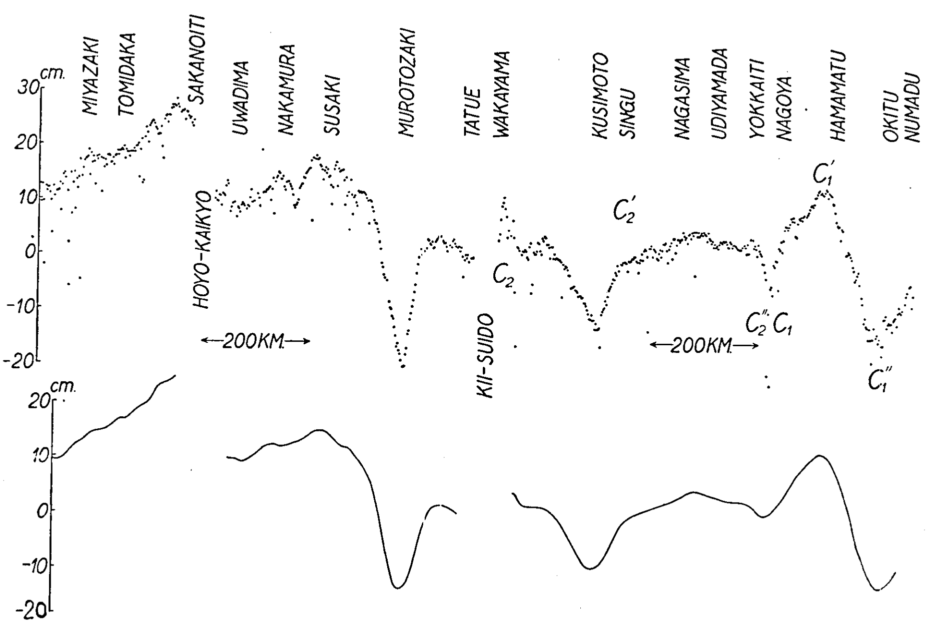

Fig. 2. Vertical displacements of the bench-marks along the Pacific coasts. The lower curves show the smoothed vertical earth movements $\left(\overline{\delta H}=\frac{1}{29}\sum_{n=1}^{29}\delta H_n\right)$.

As we cannot know the actual differences in the heights of the datum levels of the different sections, they may be reduced in the manner just shown.

The correction terms for the vertical displacements of the bench-marks in Kyûsyû were calculated by

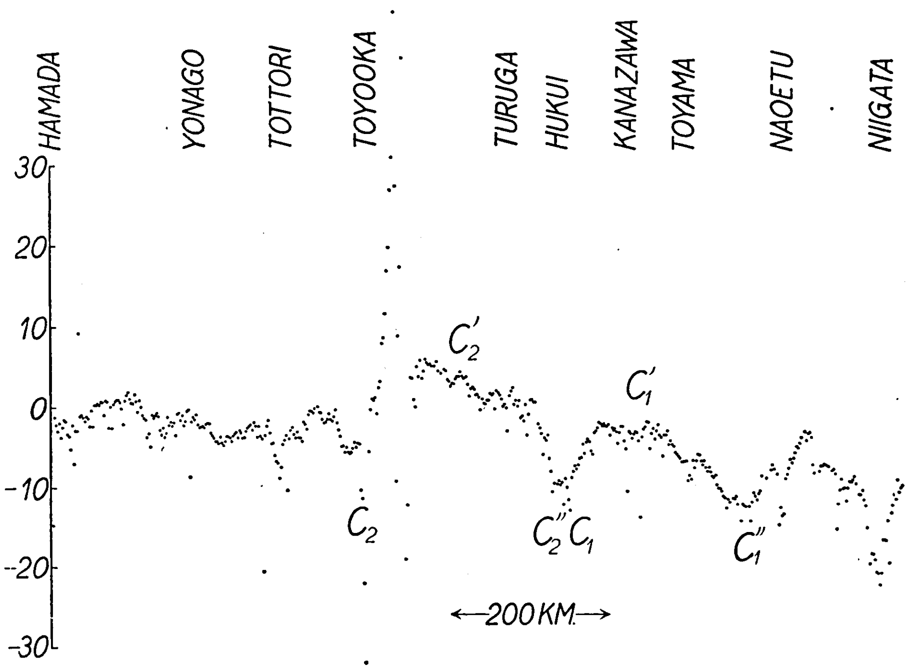

Fig. 3. Vertical displacements of the bench-marks along the Japan Sea coast.

$$\Delta h = \int_{t_1}^{t_2} a\,dt \fallingdotseq a(t_2 - t_1),$$

where a is the rate of secular depression of the sea level at Hosozima,[3] that is, 4·0 mm./year, and t_1, t_2 are the epochs of the first and second precise levellings.

The correction terms added to the values of the vertical displacements of bench-marks along the different sections of the level lines are given in Table I.

3) N. Miyabe, *Bull. Earthq. Res. Inst.*, **12** (1934), 163–173.

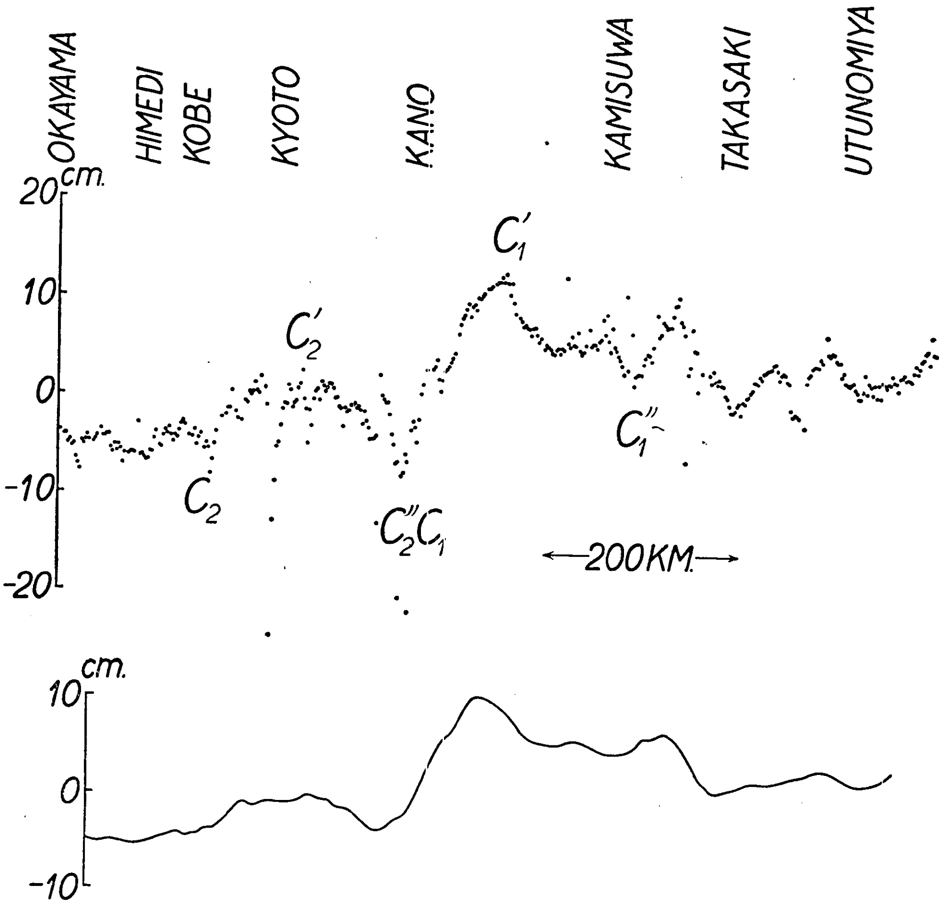

Fig. 4. Vertical displacements of the bench-marks in the central zone of Japan. The lower curve shows $\overline{\delta H} = \frac{1}{29} \sum_{n=1}^{29} \delta H_n$.

The corrections in Table I are calculated so that the vertical displacements on lines A and C shall harmonize with vertical displacements on the line from Kusimoto to Wazima via Wakayama, Osaka, Kyôto, and Kanazawa, which were corrected by taking into account the secular variation of the sea level at Wazima and Kusimoto. Recently relevellings have been carried out not only in a line approximately parallel to the trend of Japan arc, but also across it. These lines connect line A to B or C. The vertical earth movements along these lines are therefore important in discussing crustal movements on the Pacific side in comparison with those on the Japan Sea side or in the central zone.

Table I.

Section.	Time interval.	Correction.	N. B.
Utunomiya—Sirakawa.	1891—1932	− 65·4mm.	
Takasaki—Simosuwa.	1889—1932	− 18·0mm.	
Seba—Hiyosi.	1889—1922	− 82·7mm.	
Hiyosi—Kanô	1889—1916	− 2·4$x$mm.	x : Number of bench-marks from Kanô.
Numadu—Okitu.	1896—1931	− 33·5mm.	
Okitu—Okazaki.	1900—1932	− 31·0mm.	
Okazaki—Issinden.	1895—1932		
Issinden—Owase.	1895 - 1932		
Owase—Kusimoto.	1899—1932		
Susaki—Yahatahama (Sikoku).	1996—1932	+154·3mm.	
Sakanoiti—Tomidaka.	1896—1932	+148·0mm.	correct $= \int_{t_1}^{t_2} a\,dt = a(t_2-t_1)$ $a=4{\cdot}0$ mm./yr. $t_2-t_1=37$ years
Tomidaka—Miyazaki.	1893 -1932	+160·0mm.	correct $= \int_{t_1}^{t_2} a\,dt = a(t_2-t_1)$ $a=4{\cdot}0$ mm./yr. $t_2-t_1=40$ years
Miyazaki—Hukusimamati.	1900—1932	+128·0mm.	" $t_2-t_1=32$ years

One of them is referred to above. There are several other lines on which vertical displacements were measured, such as those from Hukui to Nagoya and from Simosuwa to Kakegawa.[4] Of course, the vertical displacements on the line from Simosuwa to Kakegawa were measured very recently but not yet adjusted to accord with the data already obtained for the points at each end. Relevellings done on the line from Simosuwa to Kakegawa show that the bench-mark at Simosuwa, B. M. J–580, has arisen 120·1 mm. relative to B. M. J–141 at Kakegawa. Since the vertical displacement of B. M. J–141 has been corrected to −34·4 mm., that of B. M. J–580 will be 85·7 mm., as contrasted with 69·9 mm., that was assumed for the same bench-mark from another data, the difference being 15·8 mm. This difference may be due on the one hand to difference in the dates of measurements, and, on the other hand, to accumulation of errors of measurements, although it may be small enough to be disregarded.

In the curves in Fig. 2, we notice wavy forms in the deformation

4) T. Terada and N. Miyabe, *Proc. Imp. Acad.*, **10** (1934), 257–259.

of the earth's crust, their wave lengths being about 200–250 km. (marked by $c_1c_1'c_1''$, $c_2c_2'c_2''$ in A, B, and C). In curve A, we observe conspicuous depressions at Kusimoto and Murotozaki, which show the southward tilts of these peninsulas. The wavy form in this part, designated by $c_2c_2'c_2''$, cannot be observed in the deformation along line A. It is observed however along the line that crosses the peninsula from W to E, shown in Fig. 5, in which the plotted points represent the vertical displacements along line EF (from Sakai to Nagoya).

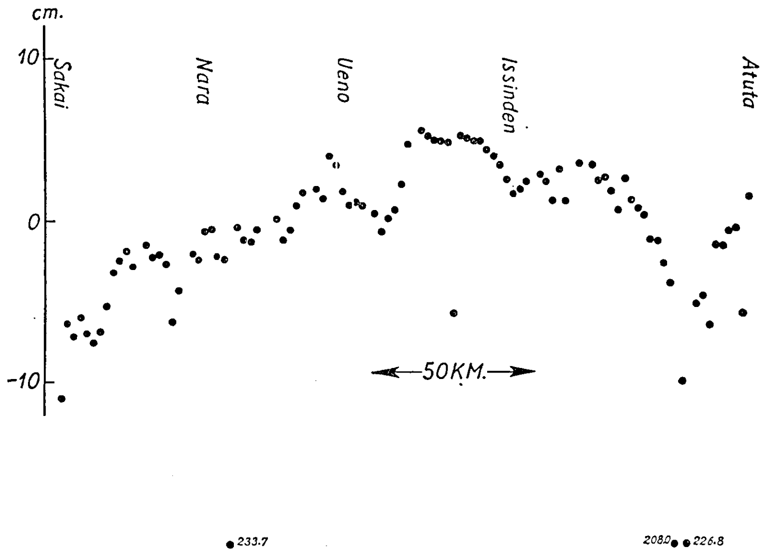

Fig. 5. Vertical displacements along the section of level lines, from Sakai to Atuta via Issinden (Tu).

In comparing curves A, B, and C in Figs. 2–4, it is interesting to find that the line connecting c_1'' in each curve approximately coincides with the "Fossa Magna," or the "Itoigawa-Siduoka Line"[5] while that connecting c_2'' coincides with the zone of "Deep focus earthquakes."[6]

Undulatory deformations of shorter wave lengths are also noticed; that is, those with wave lengths of 100 km., as already pointed out by Tsuboi[7] and also those with wave lengths of about 30 km. The block movements are of course observed as minor fluctuations superposed on curves that represent the crustal deformations.

5) The line of discontinuity is significant in the geologic structures.

6) K. WADATI, *Geophys. Mag.*, 4 (1931), 231-283; etc.

7) C. TSUBOI, *loc. cit.* 1).

To investigate the undulatory mode of deformation in greater detail, the superposing mean values of the vertical displacements of the bench-marks were calculated along the level lines by

$$\overline{\delta H}=\frac{1}{29}\sum_{1}^{29}\delta H_n.$$

The mean vertical displacements thus calculated are plotted as shown by curves A' and C' (Figs. 3, 4) corresponding to level lines A and C, the undulatory forms of deformation with a wave length of 200–250 km. being more or less clearly observable.

The residuals

$$R=\delta H-\overline{\delta H}$$

are also plotted as in Figs. 6 and 7 the undulatory form being again noticable. These curves are again smoothed by calculating the values of the superposing means, $\overline{R}$, for every 11 points.

The vertical displacements of any points may then be written in the form

$$\delta H=\overline{\delta H}+\overline{R}+D,$$

where D is the last re-

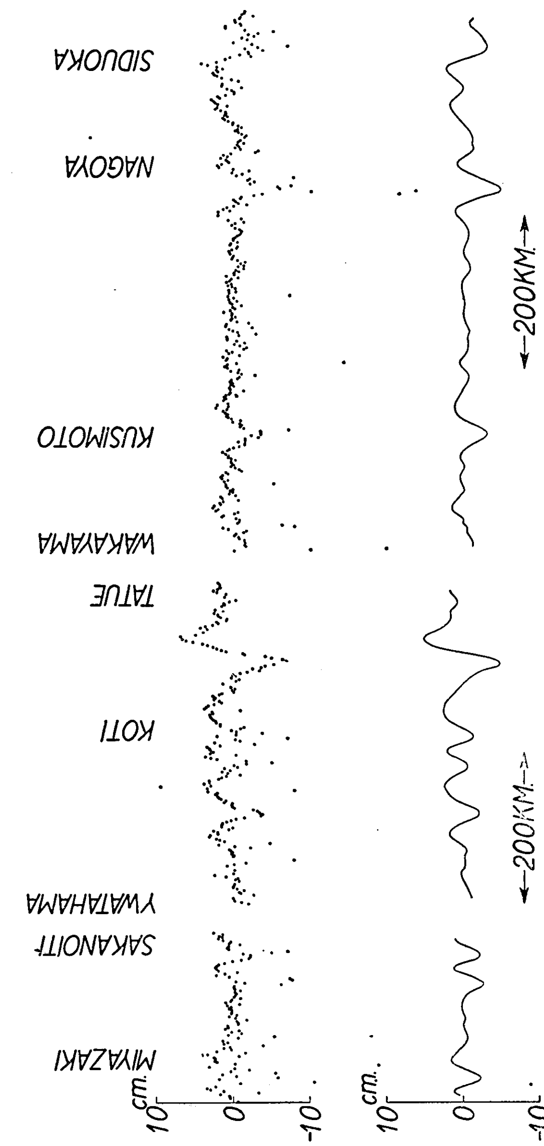

Fig. 6. R and $\overline{R}$ (lower curves) along the Pacific coast.

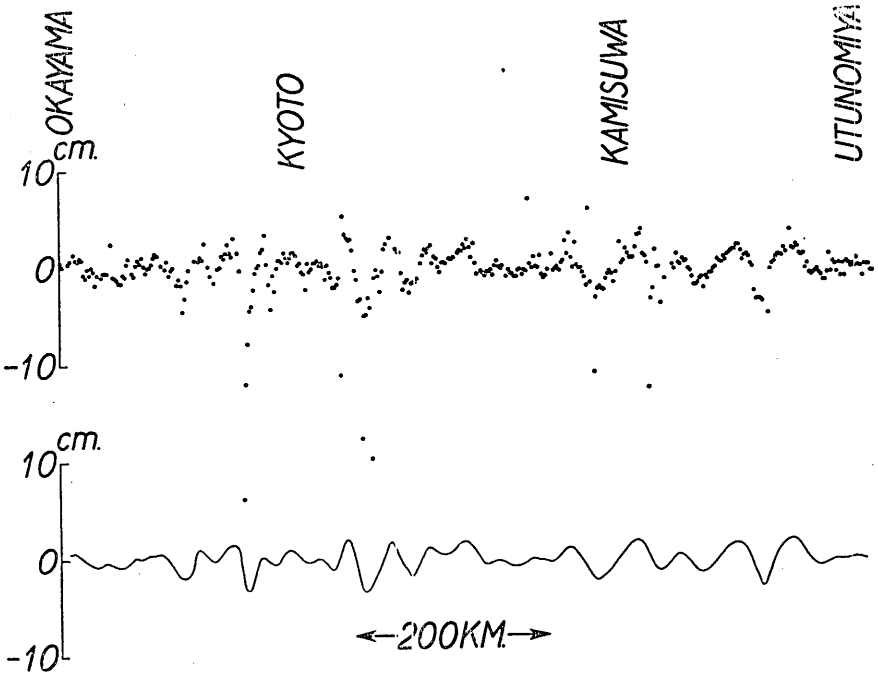

Fig. 7. R and $\overline{R}$ (lower curves) along the central zone.

siduals, fluctuating irregularly, while $\overline{\delta H}$ and $\overline{R}$ vary harmonically with respect to the horizontal distances.

As will be noticed in the curves in Fig. 2, there are several districts where the vertical displacements of the bench-marks fluctuate rather conspicuously. The degree of fluctuation may be expressed in the form

$$\overline{|D|}=\overline{|\delta H-(\overline{\delta H}+\overline{R})|}\,,$$

same as that used in discussing the crustal disturbances in the Kwantô districts.[8] The values of D are averaged for every 20 km., or 10 bench-marks, along the level lines, the results being shown in Fig. 8 and 9.

The distribution of $|\overline{D}|$ thus calculated along line A, that is, along the Pacific coast, takes somewhat the forms of irregularities in the beach lines, and consequently the geological structures, as pointed out by Mr. Y. Otuka.[9]

8) N. MIYABE, *Bull. Earthq. Res. Inst.*, 9 (1932), 1-21.
9) Y. OTUKA, *Tirigaku-Hyôron*, 9 (1933), 819-843. (in Japanese).

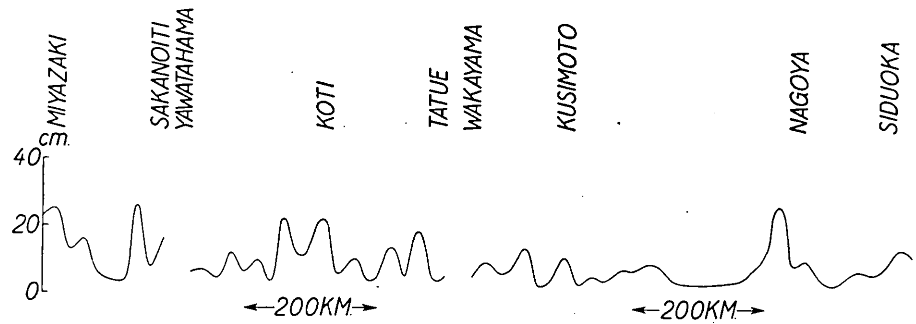

Fig. 8. Fluctuation $|\overline{D}|$ along the Pacific coast.

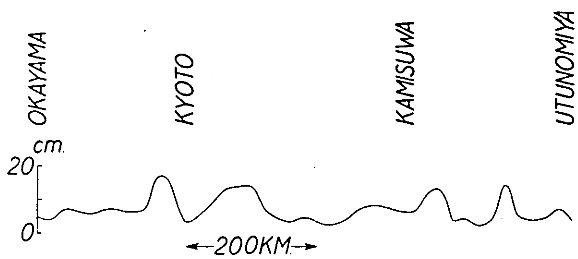

Fig. 9. Fluctuation $|\overline{D}|$ along the Central zone

The fluctuations in the vertical displacements may indeed largely be due to the movements of the blocks that compose the surface layer of the earth's crust. Regarding the chronic crustal movements, however, the block movements may certainly be obscured by the soft character of the upper layer that accumulated in the Aluvium age. In the case of acute crustal deformations, however, the movements of smaller blocks become clearer, as we noticed in the case of crustal deformations associated with the destructive earthquakes of Kwantô, Tango, N. Idu, etc. The irregular forms of the beach lines may thus be related to the deformation of the earth's crust now in progress.

Further investigations are now being conducted in basis of data of vertical displacements recently obtained, the results of which will be published in due course.

In conclusion, the writer wishes to express his sincere thanks to Professor Torahiko Terada for his many kind advices and suggestions.

31. 日本の，日本海岸，太平洋岸並に中央地帯に於ける地殼變動

地震研究所　宮　部　直　巳

最近，坪井助教授は，日本海岸に沿うての地殼の垂直變動が波狀を爲してゐることを指摘せられ，寺田教授は，東北地方の地形に略同樣な波狀地形のあることを注意された．同樣の事實が他の地域に於いても認められる．卽ち，太平洋岸に沿ふての水準再測は九州の南端から，關東地方まで行はれてゐるが，その水準線路に沿ふての垂直變動に於いても，第 2 圖に示す如く，大體 200 乃至 250 km. 位の波長を有する波狀變動が認められ，岡山から大阪，京都，岐阜(加納)，松本，高崎，宇都宮を經て白河に至る水準線路に沿ふ垂直變功についても矢張り同樣の波狀變動が認められる．日本海岸に沿ふて水準點の變動についても，坪井助教授の認められた 80 km. 內外の波長のものゝ外に更に 200-250 km. の波長のものも認められる．この大いなる波の谷にあたる場所を連ねてみるとその 1 つは，"Fossa Magna" として又は "糸魚川一靜岡線" として知られてゐる地質構造上重要な線と略々一致し，他の 1 つは，地形的に低地帯である上，1 つの深層地震の發生する地帯として知られてゐる地帯に一致する．

波狀變形の波長は尙短いもの 60 km. 乃至 30 km. 位のものまでは，認めることが出來る．さうして，かゝる波狀的變形を除いた後の變形の不規則さの程度を

$$\overline{|D|}=\overline{|\delta H-\overline{\delta H}|}$$

で示して，その分布を調べてみると，太平洋岸については，大體大塚氏の調べられた，海岸線の不規則さの分布と相似てゐる．從つて，地殼變動の不規則さは，地殼構造上の不規則さと相似た所があると言へるやうである．