15. Deformation of the Earth Crust in Kwansai Districts and its Relation to the Orographic Feature.

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After the recent destructive earthquake in the Tango district, an extensive revision of the trigonometrical survey was executed by the Military Land Survey Department, not only over the very region severely disturbed by the earthquake but also over a much wider area including those districts which may probably be assumed to have been intact from the disturbance of the earthquake. A part of the results of the survey has already been published and the present authors[1] inferred from it a rather remarkable relation between the "divergence" of the surface displacement and the post-seismic vertical displacement. The rest of the results of the survey works comprising the entire area revised was published later in Vol. VII of this Bulletin. This latter provides us with an invaluable material not only for visualizing the actual mode of deformation in the district in question, but also for subjecting the different theoretical considerations regarding various geotectonic problems in general to a crucial test, based on the direct measurements of the strain of the crust. The deformation of the crust deduced from the results of the present survey is probably composed of the two parts, i.e. one due to the cumulative effect of the secular or chronic deformation[2] and the other due to the immediate effect of the earthquake. The relative magnitudes of the two effects are at present difficult to determine. For the problem with which we are going to deal in the following, this point may, however, be put aside as immaterial for the present.

In the present communication, we will confine our attention to the general essential features of the deformations prevailing over the entire area covered by the recent triangulations, referring exclusively to the data for the primary trigonometrical points. The minor details, which may be revealed

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1) T. TERADA and N. MIYABE, *Proc. Imp. Acad.*, 4 (1928), 211, 215, 218.

2) The existence of sensible chronic deformations of the crust was confirmed by N. YAMASAKI, *Proc. Imp. Acad.*, 4 (1928), 60 and also by A. IMAMURA, *ibid.*, 4 (1928), 58; 5 (1929), 161.

from the analysis of the data for the secondary points will be reserved for a future study.

The data published by the Land Survey Department give the horizontal component of displacement for each of 25 primary and supplementary trigonometrical points. From these data we can calculate the horizontal strain components for each of the triangles, on the assumption that the strain is uniform within each triangle and thence deduce the magnitudes and directions of the principal strains and also the divergence, rotation and shear respectively, if desired.

Let u, v be the component displacements of a trigonometrical point with respect to an arbitrary system of coordinates x, y and

$$2\frac{\partial u}{\partial x}=\gamma_{xx}, \qquad 2\frac{\partial v}{\partial y}=\gamma_{yy}, \qquad \frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}=\gamma_{xy}.$$

The values of the principal strains will be given by the roots of the equation,

$$\begin{vmatrix} \gamma_{xx}-\gamma & \gamma_{xy} \\ \gamma_{xy} & \gamma_{yy}-\gamma \end{vmatrix}=0,$$

and the angle θ, which is made by the axes of the principal strains with x axis, by

$$\operatorname{tg}\theta=-\frac{\gamma_{xx}-\gamma}{\gamma_{xy}}.$$

Assuming the displacement components to be linear functions of x, y within each triangle formed by three stations P', P'', P''' of which the coordinates are

$$x'\ y' \qquad x''\ y'' \qquad x'''\ y''',$$

and the displacements

$$u'\ v' \qquad u''\ v'' \qquad u'''\ v'''.$$

We can substitute these values into

$$u=a_1x+b_1y+c_1,$$
$$v=a_2x+b_2y+c_2,$$

and determine the six constants a's, b's and c's respectively. Then

$$\gamma_{xx}=2a_1, \qquad \gamma_{yy}=2b_2, \qquad \gamma_{xy}=a_2+b_1$$

and

$$\gamma_{\frac{1}{2}}=a_1+b_2\pm\sqrt{a_1^2+a_2^2+b_1^2+b_2^2+2(a_2b_1-a_1b_2)},$$

$$\operatorname{tg} \theta_{\substack{1\\2}} = \frac{\gamma_{\substack{1\\2}} - 2a_1}{a_2 + b_1} = \frac{a_2 + b_1}{\gamma_{\substack{1\\2}} - 2b_2},$$

whence

$$\begin{aligned} &\text{Divergence} \quad \Delta = a_1 + b_2, \\ &\text{Rotation} \quad = \tfrac{1}{2}(a_2 - b_1), \\ &\text{Shear} \quad = \tfrac{1}{2}(a_2 + b_1). \end{aligned}$$

For the actual calculations, one of P's may conveniently be taken for the origin.

The calculation was carried out only roughly, mainly by means of a graphical method, for the present preliminary investigation.[3] The results are shown by Figs. 1–4.

Fig. 1 shows the distribution of the triangular nets taken into account. The value of the divergence for each triangle is inscribed at the centre of the triangle. Contour lines, corresponding to the supposed lines of equal divergence, are drawn tentatively to visualize the general feature of the deformation. It needs not be remarked that these lines may be modified in details, if we take account of the data for the secondary triangular points.

Fig. 2 shows the magnitudes and directions of the principal axes of the strain ellipse for each of the triangles taken.

Figs. 3 and 4 show respectively the geographical distributions of the rotation and shear.

Examining these figures, we may remark the following:

(1) The largest strains are not confined to the region disturbed by the recent Tango Earthquake, but extended further towards E, i.e. from Oku-Tango Peninsula to the Lake Biwa and probably further eastwards. It is interesting to observe that this zone of the maximum deformation, if prolonged, seems to pass through the epicentres of Nôbi Earthquake of 1891, Anegawa Earthquake of 1909 and Ooigawa Earthquake of 1917, and still further to point to the epicentre of the Great Kwantô Earthquake of 1923, —a conspicuous zone already pointed out by the authors in a previous paper[4] on the secular fluctuation in position of the macroseismic zone of the earth.

(2) The strain is generally small in magnitude and mainly similar in type on the southern side of a line connecting the points A and B in Fig. 1. The small magnitude may partly be due to the fact that the two stations

3) Mr. CH. TSUBOI made numerical calculations for the divergence, the result of which he kindly placed at our disposal for the verification.

4) T. TERADA and N. MIYABE, *Proc. Imp. Acad.*, **3** (1927), 275; *Bull. E.R.I.*, **6** (1929), 333.

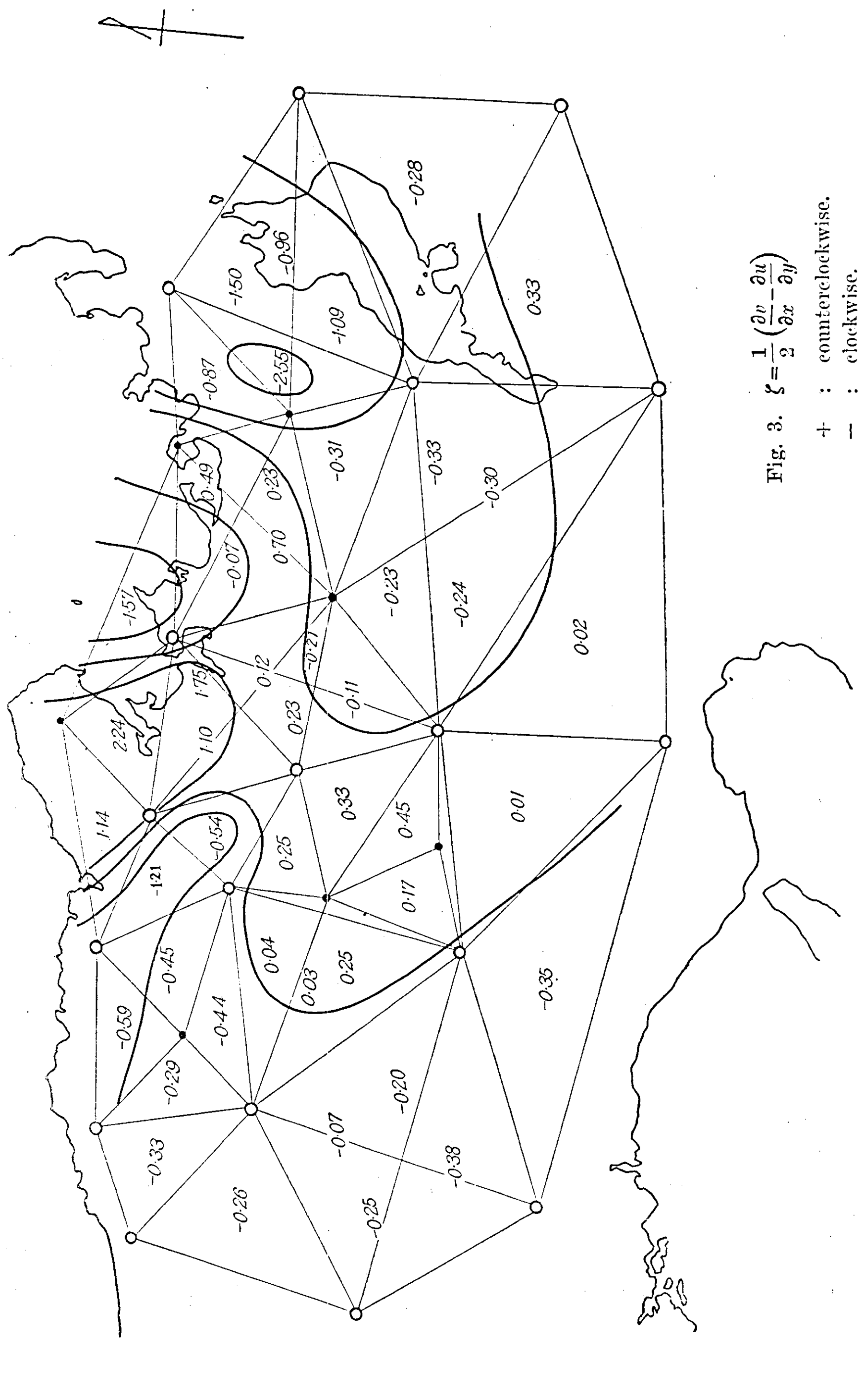

Fig. 3. $\zeta = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$

+ : counterclockwise.

− : clockwise.

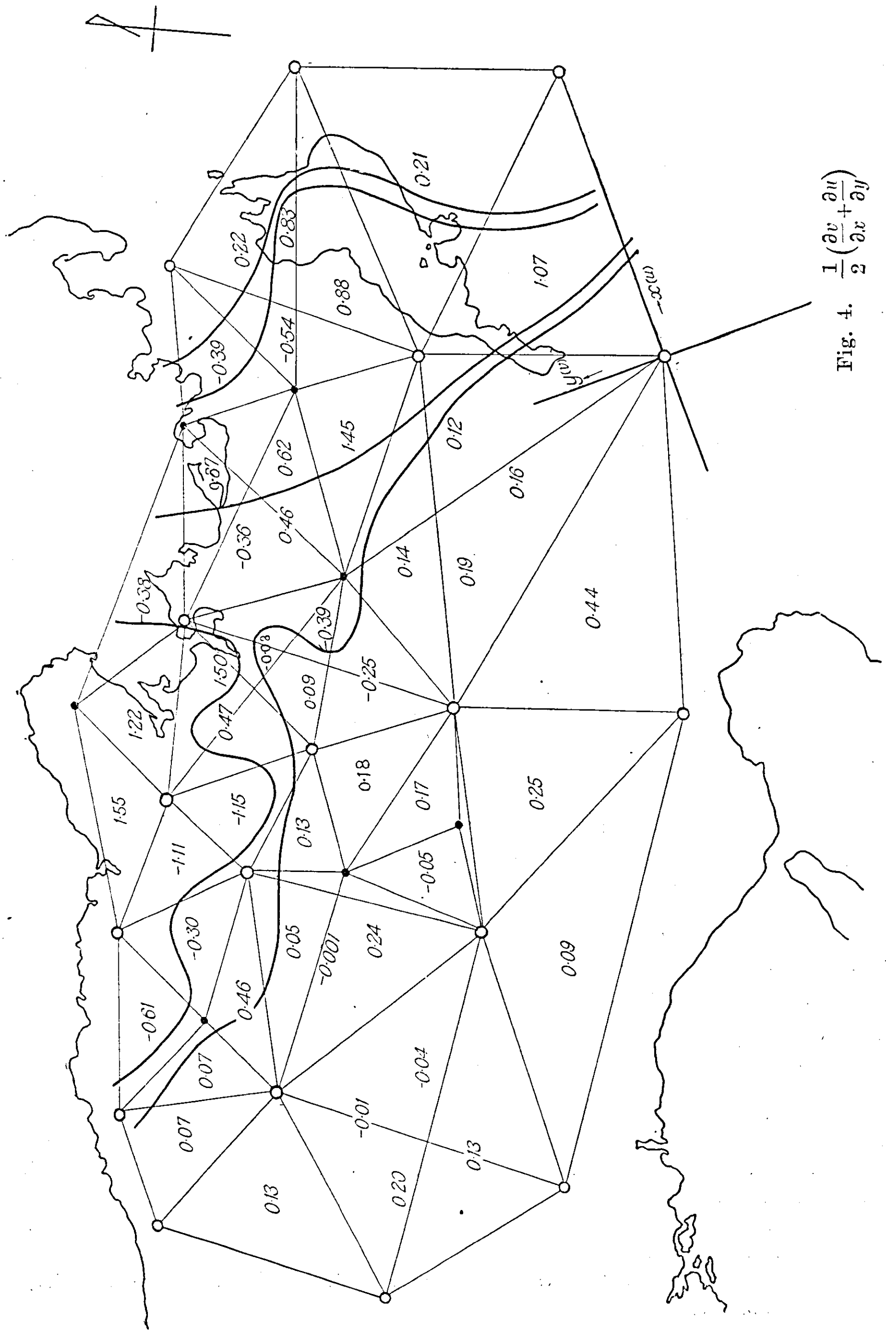

Fig. 4. $\frac{1}{2}\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)$

assumed immovable are situated within this area. Still, the uniformity of the size and shape of the strain ellipse in this region may be taken as an evidence of the fact that this region has been comparatively free from any conspicuous crustal deformation.[5)]

(3) The magnitude and type of the strain show generally a zonal distribution parallel to a line connecting the points A and B in Fig. 1, which seems to be interrupted along a line connecting C and D. It may be pointed out that the line CD corresponds to a conspicuous zone on the geological map of the region, which is marked by the exposure of the parallel bands of diorite.

(4) In Fig. 2, we may divide the area of the map into a number of regions according to the type of the strain ellipse; thus, provisionally as follows:

I*a*: Elongation in N-S direction,
I*b*: " " all " ,
I*c*: The same as I*a*.

In short, we may regard I*a*, I*b* and I*c* as a zone with conspicuous N-S elongations

II*a*: Contraction in N-S direction.
II*b*: The same in less amount,
III: Strain generally small and mainly elongation in N-S direction.
IV: Large contraction in all directions.

It must be remarked that the striking contrast between the two regions I*a* and II*a*, or between I*c* and IV may be brought about by some anomalously large displacements of a few number of the trigonometrical stations lying between the two regions. It will be, however, interesting to regard the strain as continuous as in the case of an ordinary elastic body and compare the type of the strain with some well known cases of elastic deformations. For example, we may point out that the relation between the two regions I and II show some qualitative similarity with the case of flexural stretching of a curved rod.[6)]

(5) Examining Fig. 3, we may notice that in the above mentioned

5) It may be expected from the theory of fluctuation that the greater the average strain of a district, the greater the spatial fluctuation of the strain. On the other hand, it seems difficult to reduce the distribution of strains on the northern side of AB into such a state as it is on the southern side, by any choice of the base stations assumed fixed. The assumption made seems, therefore, approximately correct, though we must admit some margin of error in the values of the specific displacements, divergence, etc.

6) For example, see TH. WYSS, Die Kraftfelder in festen elastischen Körpern, Tafel 13, Abb. 166.

zone of maximum disturbance, i.e. on the northern side of the line AB (Fig. 1), the sense of rotation is alternatively clockwise and counterclockwise when we proceed along the E-W direction. Such an alternation of the sense of rotation in the neighbouring regions was also found by Prof. Fujiwhara[7] in the case of the Kwantô District. On the other hand, it is interesting to note that the Oku-Tango Peninsula shows apparently a large counterclockwise rotation with regard to the main land, as the general trend of the coast line of this peninsula suggests that it might have been formed by a counterclockwise rotation of the whole peninsula from an initial position, in which the present NW coast of the block might have formed a prolongation of the general coast line to the west of it. Assuming a continuous rotation of 10^{-5} radians per 40 years, which is the observed rate, it will take about two million years to produce a total rotation of 30 degrees, a quite short interval of time on the geological point of view.[8]

(6) Drawing, in Fig. 4, the contour lines with the equal magnitudes

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7) S. FUJIWHARA and T. TAKAYAMA, *Bull. E.R.I.*, **6** (1929), 149, Pl. 7. The present case may probably be regarded as an example of the "chain of vortices" in Fujiwhara's sense.

8) According to the estimation from He-contents of minerals, the age of the Pliocene is given as 1.5 million years which is considered an under-estimation. An estimation from Pb-contents gives 35 million years for the late Oligocene in U.S.A. See A. HOLMES, "The Age of the Earth," 1927, O. HAHN, "Was lehrt uns die Radioaktivität über die Geschichte der Erde," etc. The presence of fossil remains of some kinds of elephants and rhinoceros in this country shows that the interruption of the land connection between the continent and Japan took place in comparatively recent ages. Lately, Prof. H. Yabe inferred from his investigation on the reliefs of the sea-beds in different parts of this country, that very late in the geological history the connection between Formosa and the continent was broken by a considerable submergence of the connecting bridge, (Records of Oceanographic Works in Japan, **1**, 1929, 97 and *Proc. Imp. Acad.* **5**, 1929, 179). A similar submergence was also observed in other parts of Japan. It seems possible that such a remarkable submergence might have been connected with a considerable horizontal straining of the crust and therefore that a local differential movement might have caused a rotation of some marginal land block by a sensible angle. In the present authors' opinion, the fact of the submergence is easily reconcilable with the theory of horizontal drift of the Japanese Arc, if we may assume that the submergence was caused here by the decrease of the thickness of the crust by stretching rather than due to the change of density which cannot account for a level change of such an order as is here concerned, unless we resort to some physico-chemical change of crust materials. With regard to this point, see p. 235 of the text. It may depend upon the type of the strain whether the crust is merely decreased in its thickness, or is decreased in density associated with volcanic activity. On the other hand, if the angular velocity be fluctuating at random, its probable amount will be proportional to the square root of time. The above estimation of time must therefore be regarded as a kind of lowest limit.

of shear,[9] we may notice again an interruption of the zone of maximum shear at its middle part. It is rather remarkable that the mountainous district to the north of Kyôto, on the western side of the Lake Biwa, reveals

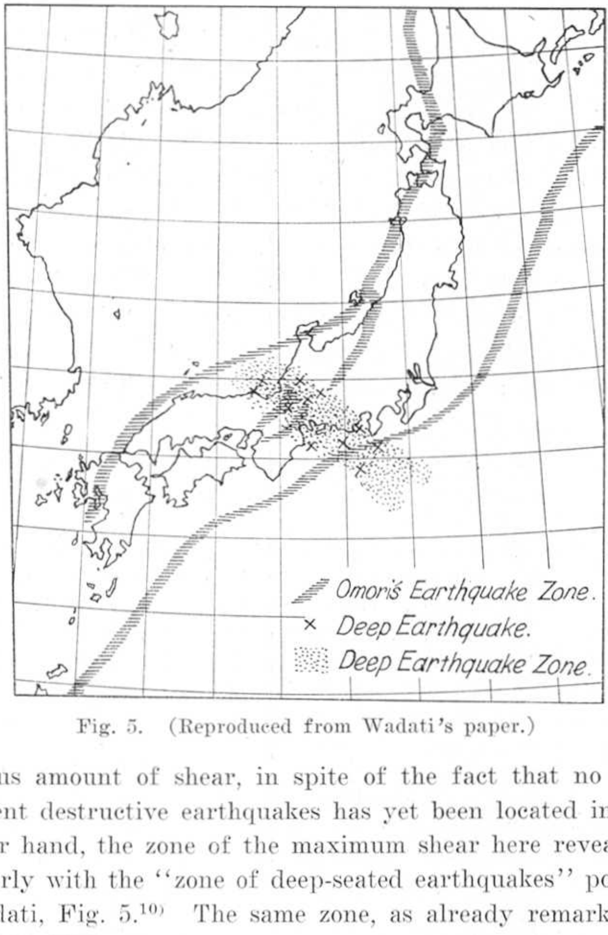

Fig. 5. (Reproduced from Wadati's paper.)

a conspicuous amount of shear, in spite of the fact that no epicentre of sensible recent destructive earthquakes has yet been located in this region. On the other hand, the zone of the maximum shear here revealed seems to coincide nearly with the "zone of deep-seated earthquakes" pointed out by Mr. K. Wadati, Fig. 5.[10] The same zone, as already remarked, coincides

9) The algebraic sign of the shear depends on the choice of the axes of reference, which is shown in Fig. 4. The direction of shear may roughly be estimated from the form of the strain ellipses in Fig. 2. The fact that the direction of the shear is rather irregularly distributed among the zone of the maximum shear is rather immaterial for the present discussions, since on account of the "chain of vortices" above mentioned, the local distribution may be subjected to an irregular fluctuation, as may be illustrated by the sand grains on the slip plane of a disturbed sand mass. At present, we refrain from drawing any conclusion on the average sense of the shear in the zone in question.

10) K. WADATI, *Journ. Met. Soc. Jap.*, [ii], 5 (1927), 119; *Geophys. Mag.*, **1**, No. 4 (1928), 162.

nearly, or with a little inclination, with the line connecting the epicentres of some recent destructive earthquakes with rather shallow origins. It seems, therefore, that this very zone forms, as it were, the trace of a slip plane of the plastic deformation of the crust going on at the present half century. Our previous investigation[11] on the fluctuation of the position of the macroseismic zone suggests that this very zone of the maximum shear may gradually shift its position in the course of two or three centuries.

Our experimental studies[12] on the formation of slip planes in sand mass decidedly speaks in favour of such a conjecture.

(7) A comparison of Fig. 1 with the topographical map of the area investigated suggests a remarkable relation between the divergence Δ of the displacement above obtained and the height of the land above sea level. To demonstrate this relation, the following procedure was taken. The two lines EF and GH were drawn (not shown in Fig. 1) such that they run across the alternate zones with positive and negative Δ. The values of Δ along these lines are shown in Fig. 6 by the échelon curves, as the value of Δ is assumed constant within each triangle. The step-like curve is smoothed by a hypothetical curve to visualize the general feature of the distribution. On the other hand, the mean profile curve of the three vertical sections EF, E′F′, E″F″ was constructed from a rough topographical map and compared with the Δ-curve. The similar profile curve was also obtained for the section GH. A glance at this figure will show an infallible resemblance in the general features of the two curves compared.

Fig. 7 is given to show the above relation between the distribution of Δ and the gross topographical feature over the entire area in question.

The above result seems to shed a considerable light on the geophysical significance of the superficial topography of the earth crust. In our previous papers, the horizontal divergence in the vicinity of Oku-Tango Peninsula, obtained from the pre-and post-seismic triangulations, was compared with the *post-seismic* vertical movement of the same region. From the result of this comparison, it was made probable that the vertical movement is due to the process of the isostatic compensation caused by the change in density of the crust connected with the horizontal deformation observed. In the present case, the integral horizontal strain which has been effected during the recent forty years is compared with the existing topographical feature of the land, which must have been produced as the result of a complicated

11) *loc. cit.*

12) T. Terada and N. Miyabe, *Bull. E.R.I.*, 4 (1928), 33; 6 (1929), 109; 7 (1929), 65.

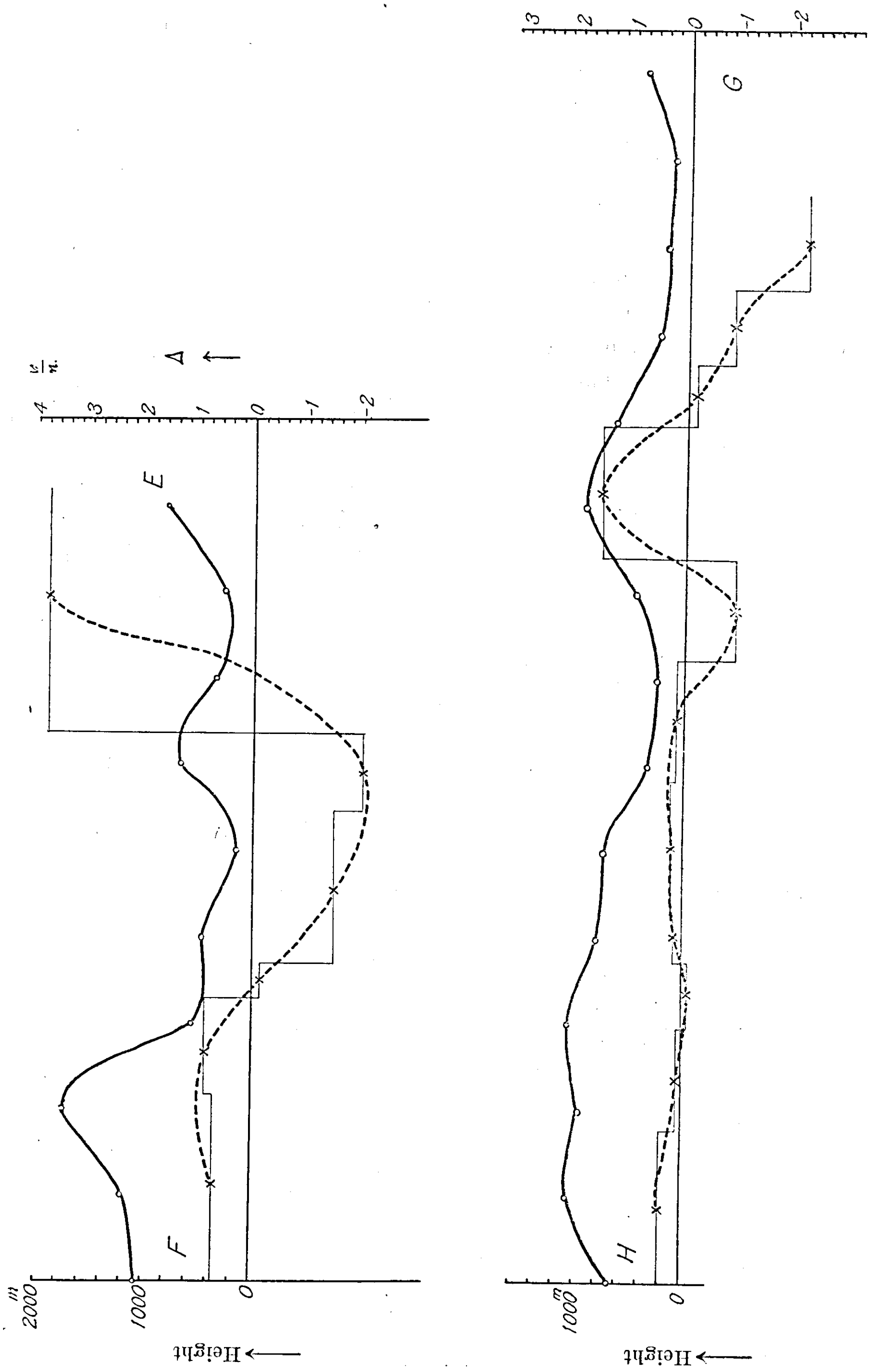

Fig. 6. ×: divergence; ○: height.

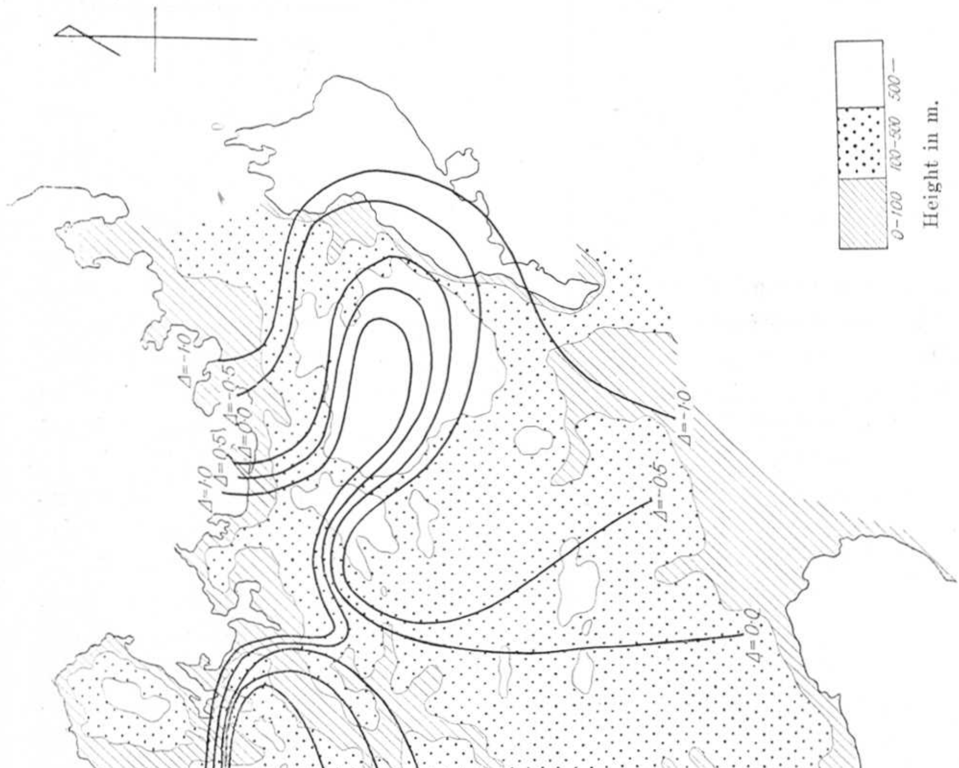

Fig. 7.

geological process continued since the remotest past. It appears, therefore, that the present topography was built up in the main by the process of the isostatic compensation determined by the type of deformation of the crust, and also that the type of the deformation which gave rise to the present feature of the land is continued even in the recent half century. It must be admitted that the process of deformation must have been subjected to a sensible fluctuation not only in the magnitude but even in the sense of motion. Still, it is interesting to observe that (i) the integral effect since a certain geological age, (ii) the effect during the recent forty years and (iii) the post-seismic effect revealed within a few years are directed largely in the same sense. Whether the same would hold also in other districts, or not, is of course another question which may only be answered after the similar thorough revision of the trigonometrical survey has been extended to a much wider area.

Returning to Fig. 7, we may notice that the agreement between the Δ-contours and the topographic feature may become more remarkable, if the height of Oku-Tango Peninsula be raised by a few hundred metres. Hence, assuming the correctness of our hypothesis, we may suppose that the horizontal dilatation and the consequent upheaval of the peninsula have been in progress since a relatively recent past, compared with the other regions, and the motion of upheaval is still lagging after the increase of the divergence. According to Mr. F. Tada[13] of our Institute, the results of his investigations of the coastal terraces as well as of the river beds afford us with the strong evidence of the fact that this region has been rising up remarkably in the recent geological age, though probably with some occasional fluctuations.

Again, it will not be superfluous to point out that the remarkable depression of the crust corresponding to the Lake Biwa appears in Fig. 1 associated with the region of a remarkable areal compression. This zone of compression is probably extended into the heart of the Bay of Wakasa which was presumably depressed in a recent age. A map[14] showing the geographical distribution of the prehistoric remains in the Province of Wakasa gives two zones corresponding to two kinds of remains. One of these zones, on the sea side, running parallel to the other which is on the land side, is abruptly interrupted on the coast of the Bay. It may, therefore, be suggested that the depression of the bay might have been completed even in the time of our remotest ancestors.

13) F. TADA, *Bull. E.R.I.*, 5 (1928), 111.

14) 若越小誌 (A Provincial History of Wakasa and Etizen.)

On the other hand, Prof. Fujiwhara and Mr. Takayama[15] calculated the "convergence" or the negative divergence of the Kwantô District from the similar data for this district. Glancing at the diagram given in Pl. VII of their paper, it is interesting to observe that the contour line corresponding to the relative number 20 of the convergence coincides very nearly with the general coast line surrounding the Bay of Sagami. The area with the larger convergence lies on the sea, whereas the area with the less convergence or negative convergence corresponds to the land area. It must be remarked that the sense at least of the correlation between the divergence and the topographical feature is just the same as in the case of the region here investigated.

In the above we have simply assumed that the divergence of the horizontal displacement corresponds to the variation of the density of the crust. It is, however, necessary to discuss this point in more details. In order to explain the present topography as the result of the density variation of the crust, we must indeed assume a considerable change of the density. For example, assuming a crust of 100 km. thickness, the vertical movement of 1 km. will require a density change of 1/1000, even if the Poisson ratio be zero. Moreover, the deformation is probably not elastic but mainly plastic. Beyond a certain amount of compression or dilatation, the effect of the divergence will be counteracted by the effect of the lateral elongation or contraction. This is evident, if we consider that, when the density change is zero, the change of thickness of the crust will vary with $-\Delta$. Therefore, in order to account for the required change of density, we must resort to some other effect than to the purely mechanical one. We may quote here as a probable factor the change of specific volume accompanying some allotropic transformation of the crustal substances as brought about by the change of prevailing pressure, which we may assume as a definite function of Δ.

A glance at a geological map of Japan will reveal a very conspicuous fact that the patches of area coloured brown, marking "volcanic ash and mud lava," appear always upon the region coloured yellow denoted as "Tertiary." This simple broad fact may signify that the Tertiary and post-Tertiary upheaval of the land was concomitant with an extensive display of volcanic activity. It seems[16] that, in the beginning of the Tertiary, the Northern Arc of Japan which had been largely submerged in the preceding age, was subjected to an upward motion, meanwhile the

15) S. Fujiwhara and T. Takayama, *loc. cit.*

16) 日本帝國地質圖說明書 (明治二十三年)

volcanic activity broke out with an unusual intensity which was continued up to the beginning of the Quaternary. It seems, therefore, that during the Tertiary Age the Northern Arc was subjected to a considerable divergence.

Similarly, the Palæozoic area richly spotted with the plutonic rocks, granite, porphyry, etc. seems to be a facsimile of the relation quite similar to the above, but referring to a much remoter past.

According to Mr. Tsuya[17] of our Institute, who carried out a thorough geological investigation of Oku-Tango Peninsula in question, a submarine eruption of andesite took place in the early Tertiary; then after an episode with a submergence of several hundred metres, the land was upheaved by a considerable amount to the present height. The upheaval was followed by conspicuous faulting movements accompanied with volcanic activities.

These considerations may suggest an interesting future problem of studying the relation between the activity fluctuation of some volcano, such as Sakurazima or Usu, and the divergence of the surrounding district, which may be obtained by repeated triangulations of a wide area including the district in question.

Thus far, we have tacitly assumed that the horizontal displacement of a trigonometrical point deduced from the results of the repeated triangulations is actually produced by a purely horizontal translation of the point. It is, however, necessary to consider the effect of the tilting of the land mass upon which the point stand, especially because the point is usually situated upon some mountain peak.

Let h be the height of the point above the crustal surface, which is tilted by a small angle θ. Then, the horizontal displacement will be $h\theta$. Assume $h=1$ km. in round number. As for the greatest possible amount of tilting for the present case we may consult the result of the precision levelling published in Vol. III of this Bulletin. Taking the section of the levelling route between B.M. 1229 and 1235, we find a level difference of about 1.2 m. per 8 km. distance. This makes $\theta=15\times10^{-4}$ in radian and $h\theta=0.15$ m. which is by no means small. On the other hand, the relative horizontal displacements among the neighbouring trigonometrical points, as obtained from the result of the trigonometrical survey, are generally of the order of several cm. at most. It follows that at least a sensible part of the observed displacement may be due to the effect of tilting. This may seem to vitiate our present results utterly. The difficulty is, however, apparent, as will be seen, if we consider the mechanism by which the tilting of the crustal surface is made possible.

17) H. TSUYA, *Bull. E.R.I.*, 4 (1928), 139.

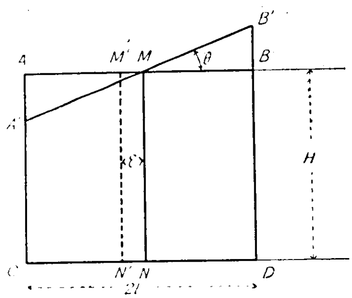

Fig. 8.

Referring to Fig. 8, suppose ABCD as a vertical section of a strip of block extending indefinitely in the direction perpendicular to to the plane of the figure. Suppose that the surface AB is tilted by θ and takes a new position A′B′, while the other boundaries of the block are fixed. Such a deformation is only possible by a compression of the part AMNC and an expansion of MBDN. The average compression or expansion is $l\theta/2H$. On the other hand, if there is no tilting, but a horizontal displacement of MN by MM′$=\varepsilon$ towards the left, the amount of compression and expansion will be ε/l.

Equating, for a trial, the two values of the specific volume change with each other, we have

$$\frac{\varepsilon}{l}=\frac{l\theta}{2H} \quad \text{or} \quad \theta=\frac{2\varepsilon H}{l^2}.$$

In the case of the ordinary block tilting, the depth to which the sensible change of density is thereby brought about, is quite unknown, but it may be plausible to assume that H will be of the same order of magnitude as l. This may be expected from the theories and experiments regarding the plastic deformation of materials, especially those regarding the hardness test. Putting $2H=\alpha l$, where $\alpha\approx 1$, we have $\theta=\alpha\varepsilon/l$. Thus, the tilting by an amount θ is *equivalent* to a purely horizontal displacement of $\alpha\varepsilon/l$, as far as the compression and expansion of the crust is concerned.

Unfortunately, it is not feasible for the present to analyse the effect of tilting from that of the pure horizontal displacement, as it is necessary for this purpose to be able to avail of the ample data of the precise levellings repeated along a sufficiently dense network of the levelling routes, such that the complete mozaics of the block structure are covered by the net. The ambguity, however, is immaterial as far as the essential points of the result of the present investigation is concerned, i.e., our inference regarding the relations between Δ and topography.

If, however, the effect of tilting be predominating, the meaning of the strain ellipse, rotation, shear, etc. obtained in the above manner may be interpreted in a manner more or less different from usual. For the present, it will be plausible to take the *virtual* horizontal strain as something real, follow up the inferences to be drawn therefrom and seek after the crucial evidences from the other sides.

It may be remarked in passing that the assumption above made on the tilting of mountain may be an over-estimation. When the plane surface AB (Fig. 8) is tilted to such a position as A′B′, the tilted surface can probably no more remain as a plane, but may be deformed into an échelon form, as may be abundantly illustrated by similar examples observed in the case of land-slides or in our model experiments with sand mass.[18] This effect will reduce the apparent horizontal displacement due to the tilting by more or less amount, depending on the mode of the échelon formation. For a further inquiry after this problem, however, we must wait until more abundant data has been accumulated.[19]

From what we have seen in the above discussions, it seems that the study of the actual mode of strain going on in the earth crust, based on the results of repeated triangulation is the most *direct* way of obtaining, if possible at all, the clue for the so-called earthquake forewarning, though the present authors are at a loss to realize the exact meaning of this words.

Finally, we must express our most sincere feelings of gratitude for the invaluable contributions to the science of earthquakes made by the Authorities of the Land Survey Department, in providing seismologists and geophysicists with such precious data that we are now able on account of them to study the actual modes of deformation of the earth crust with nearly equal ease as we are dealing with a handy test piece of metal in the laboratory. As a Chino-Japanese adage says, "Procuring Rô Land, we long for Syoku." Nothing is more desirable on behalf of the Science of Earthquake than a further extension of the similar survey work by the hands of the same Authorities.

SUMMARY.

(1) From the result of the revision of the primary trigonometrical survey in the Kwansai Districts, the apparent horizontal strain components were calculated, for each mesh of the primary triangulation network, whence the divergence, rotation and shear as well as the magnitudes and directions of the principal axes of the strain were deduced for each triangle and the geographical distributions of these quantities were investigated.

(2) A remarkable correlation is found which exists between the divergence of the horizontal displacements effected during the past forty

18) *Loc. cit.*

19) Prof. NAGAOKA remarked, after this paper was read, that a deformation of the mountain body itself due to the shock, may also contribute to the observed horizontal displacement.

years and the present topographical relief of the districts, the positive divergence corresponding to the mountainous region. This result taken together with that of a previous investigation of the authors seems to throw a new light on the geophysical significance of the topographical feature of the surface crust at large.

(3) The zone of maximum strains revealed by the present analysis coincides, on one hand, nearly with a zone of macroseismic activity for the recent half century and, on the other hand, with a remarkable zone of deep-seated earthquakes, recently pointed out by K. Wadati.

(4) The effect is discussed of the tilting of a land block on the apparent horizontal displacement of the trigonometrical station which is situated on a mountain peak lying on the block, and it is shown that the tilting and a horizontal tilting may be regarded as equivalent when the compression and dilatation of the crust is in question.

(5) Some suggestions are given under the light of the present result, regarding the genetical factors which might have been essential in determining the present topographical and geological structures of Japan.

In conclusion, the present authors wish to express their best thanks to Prof. S. Tsuboi, Dr. F. Tada and Dr. H. Tsuya for many valuable informations and also to Assist. Prof. Ch. Tsuboi for his kindness in checking our calculation.

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15. 關西地方の地殼變形並に現在地形との關係

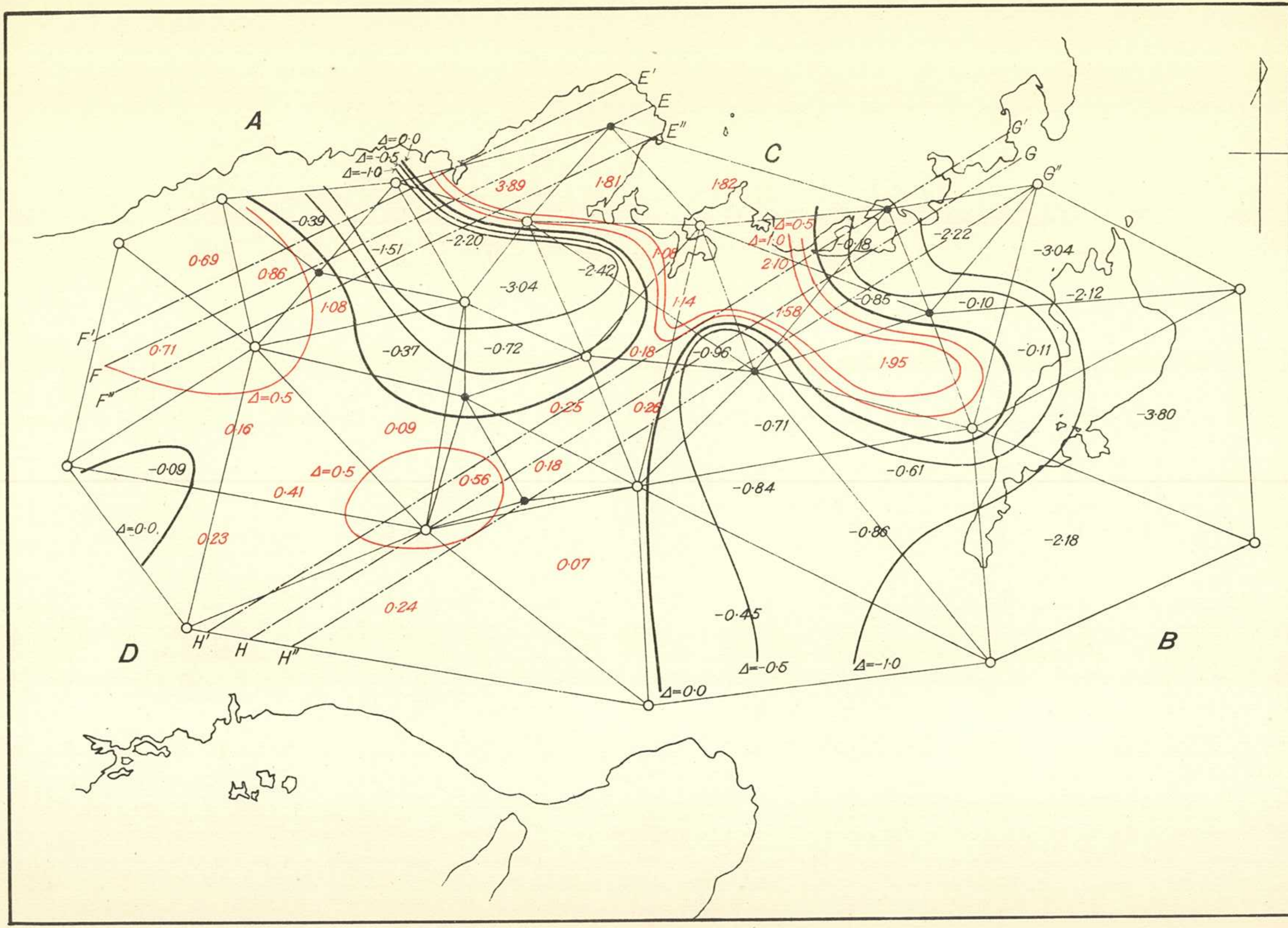
寺 田 寅 彦
宮 部 直 巳

陸地測量部によつて行はれた關西地方復舊一等三角測量の結果から、各點水平移動の divergence, rotation, shear 及 strain ellipse の主軸の大さと方向を算出し其の地理的分布を調べた結果として次のやうなことが云はれる。

(1) 過去四十年間の水平移動のダイヴァーヂェンスと現在の陸地の高さとは正の相關がある。此事は地形といふものゝ地球物理學的の意義の解釋上參考になる。

(2) 變形の量の最大な地域を連れる一つの地帶は和達淸夫氏の深層地震帶と略一致し、又最近數十年間に於ける大地震の或ものを連れる線とも近接する。

(3) 以上の結果から考へて、日本陸地の生成の機巧に關する想像説を述べておいた。



(震研彙報第七號、圖版、寺田、宮部)

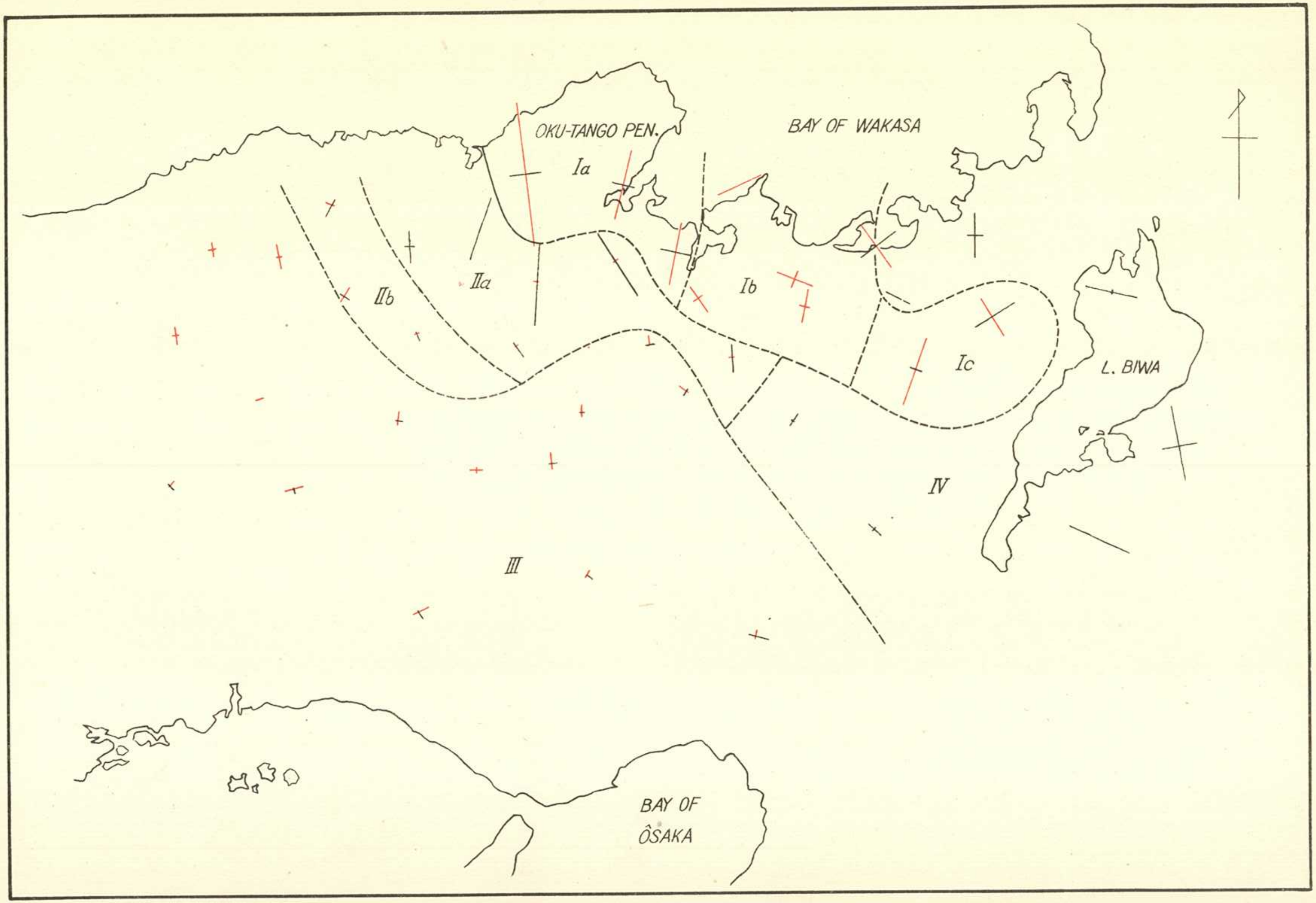


Fig. 2.

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