25. *A Study of Displacements of Triangulation Points.*

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Soon after the great Kwantô and Tango earthquakes the Land Survey executed revisional triangulations with a view to detecting earth movements that had taken place since the previous observations were made a number of years before.[1)]

In computing these displacements in the Kwantô region the position of the primary point, Teruisi-yama, and the azimuth of the line from Teruisi-yama to Tukuba-san (the primary point); and in Tango the positions of the primary points, Kasagata-yama and Hyôno-yama, were all assumed not to have changed their positions since the previous triangulation observations were made there.

The reason for not making the same assumption for the two triangulations is that whereas in Kwantô the Sagamino base line was measured and the length of each side of the triangles determined, in Tango no base line was measured so that a side of a triangle had to be used as the base for the new triangulation.

In both Kwantô and Tango the survey was carried into regions where none of the usual earthquake effects were noticed, and the position and azimuth of points in regions where the ground could hardly have been displaced were selected as points for reference. Unless the changes as shown by differences in the position and azimuth as compared with the previous triangulation were absolutely beyond question, no displacement however apparent was recognized.

But since in both triangulations no examinations were made to check possible systematic errors in length, which, needless to say, is of paramount importance, in triangulation, the following investigation, which forms the subject of this paper, was made in order to detect possible displacements of reference points and also errors in length of sides of triangles.

1. When a point in the triangulation net is displaced in a certain

1) THE MILITARY LAND SURVEY, *Bull. Earthq. Res. Inst.*, 4 (1927); 7 (1929), 187.

direction, the change v in the direction angle of this point with reference to another point is given by the following expression in both direct and opposite directions.

$$v=\frac{e}{s}\rho''\sin(360^\circ-\varphi+\psi),$$

where

- e displaced length,
- s distance between the occupied station and the sighted point,
- φ direction angle of displacement measured clockwise from a specified initial direction,
- ψ direction angle of the sighted point measured clockwise from the same initial direction as that of φ.

When all the distances from a point to several other points are equal then the v of all the directions from that point distribute themselves on the same sine curve, but when the distances differ, v deviate from the sine curve according to the magnitudes of the difference.

2. Fig. 1 shows the changes in the angles at the primary points, Tôkyô and Tanzawa-yama, together with those of the primary points, Tukuba-san, Teruisi-yama, Dôhira-yama, Kokusi-dake, and Kenasi-yama,

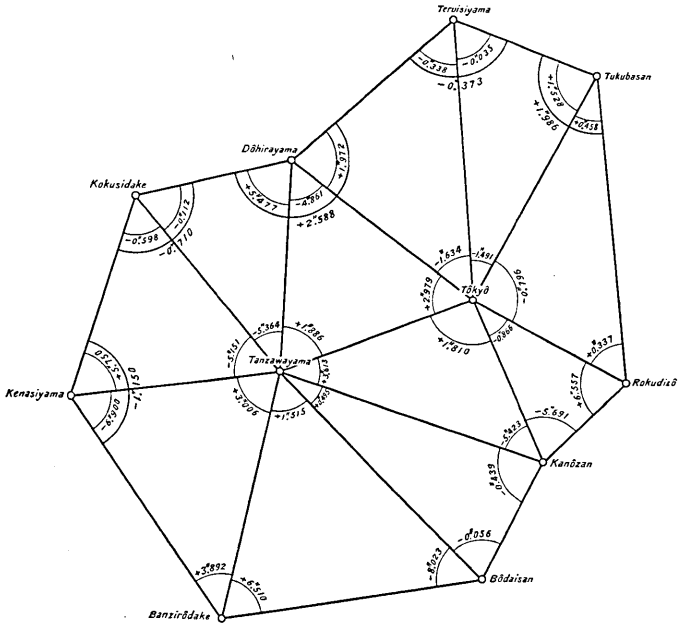

Fig. 1. Changes in the angles.

the last five of which are situated outside of the area devastated by the earthquake. It seems that the changes in the angles at these triangulation points were caused by the displacements of Tôkyô and Tanzawa-yama. Indeed as shown below the change in the angles of Teruisi-yama, Dôhira-yama, etc., are so small that it is evident that these points have practically not changed their positions:

Teruisi-yama	{ Tukuba-san Dôhira-yama	$-0''\cdot 373$
Dôhira-yama	{ Teruisi-yama Kokusi-dake	$+2''\cdot 588$
Kokusi-dake	{ Dôhira-yama Kenasi-yama	$-0''\cdot 710$
Kenasi-yama	{ Kokusi-dake Banzirô-dake	$-1''\cdot 150$

3. As factors of the displacements ascertained by comparing the old and new triangulations, we may consider

1. The displacement of the point itself,
2. The displacement of the reference point,
3. The effect of the change in the reference azimuth,
4. The effect of systematic errors in length.

Let the west-east and south- north lines passing through the reference point, X axis (increases toward east) and Y axis (increases toward north) respectively, and resolve the apparent displacement of each point into two components, x and y, then

$$x=a+a_0+x'+x'',$$
$$y=b+b_0+y'+y'',$$

where a, b are the displacements of the points themselves.

a_0, b_0 are the displacements of the reference points,

x', y' the magnitude of the change in the reference azimuth,

x'', y'' the magnitude of the systematic errors in the length of the side.

Now let X and Y be the coordinates of each point, then between x'' and y'', and between x' and y' the following relation holds:

$$\frac{x''}{X}=\frac{y''}{Y} \quad \text{and} \quad \frac{x'}{Y}=-\frac{y'}{X}.$$

By selecting several points, of which a and b are assumed to be small, i. e., practically undisplaced, and by plotting (x, y) against (X, Y) as well as against (Y, X), then since a_0 and b_0 are constant for all

points, we can determine the relation between (x'', y'') and (X, Y) and also between (y', x') and (X, Y); because if in the first two terms (x'', y'') and (X, Y) we can treat (x', y') as an accidental error, and in the two second terms (y', x') and (X, Y) treat (x'', y'') as an accidental error, then the systematic error in length, the changes in the azimuth of reference, as well as the magnitudes of a_0 and b_0, can be determined.

4. Figs. 2 and 3 show the relation between (X, x) and (Y, y), that is (X, x'') and (Y, y''), of the triangulation in the Kwantô district, the origin of the coordinate axes being Teruisi-yama. In the figures the thick lines show the mean position of the plotted points. In both figures the mean lines pass through the origin of the coordinate axes and their inclinations are almost the same. This fact shows not that the reference point Teruisi-yama had been displaced during the interval between the old and new triangulations, but that there are systematic errors in the length of the sides of the triangles.

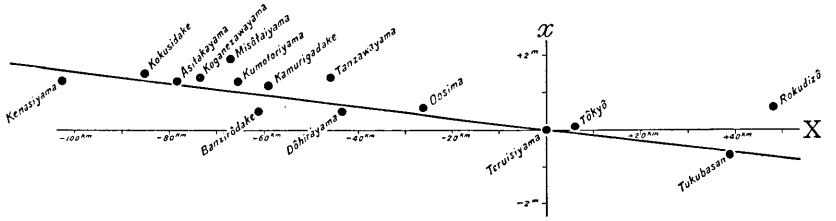

Fig. 2.

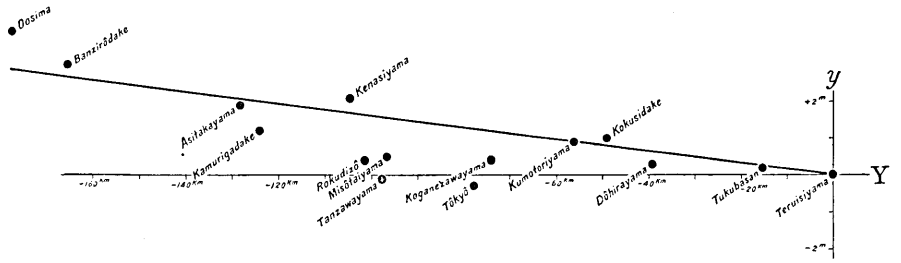

Fig. 3.

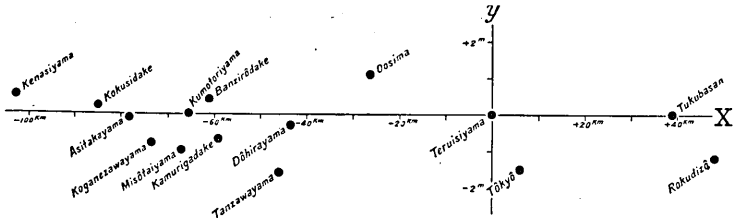

Fig. 4.

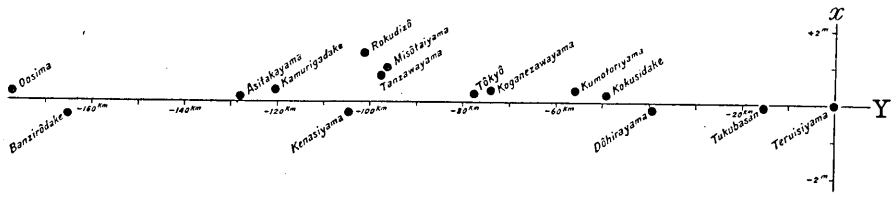

Fig. 5.

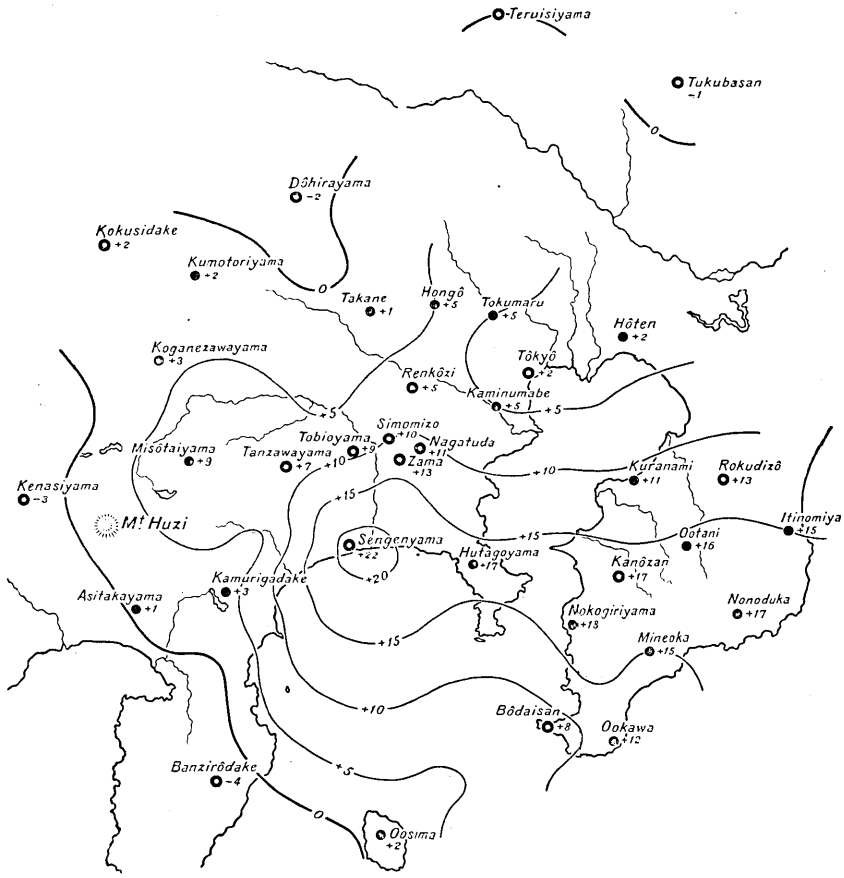

Fig. 7. Contours indicating lines of equal displacement of the x component of the triangulation points.

Figs. 4 and 5 represent the true relation of (x', Y) and (y', X); for in these figures I have used the values of x and y, from which x'', y'', the systematic error in length, had been eliminated. Since the mean lines of the plotted points coincide with the horizontal axis in these figures 4 and 5, the reference azimuth has not changed.

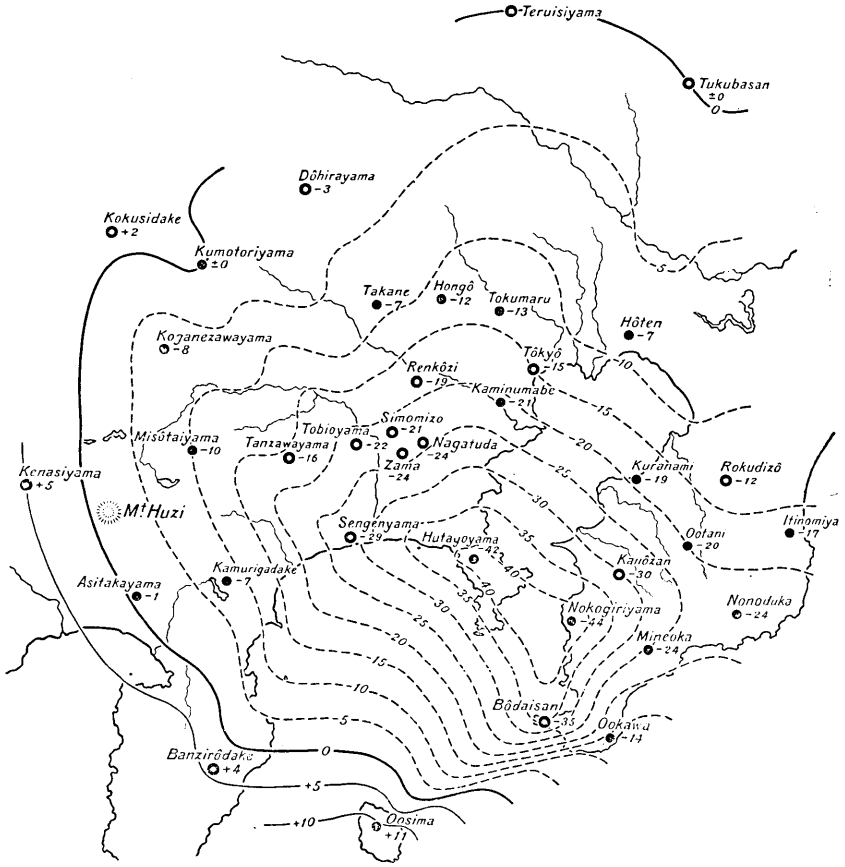

Fig. 8. Contours indicating lines of equal displacement of the y component of the triangulation points.

In Fig. 6 the arrows drawn with full lines represent the corrected displacements. These corrected values, which are corrections for the systematic errors of length, were obtained from Figs. 2 and 3, and are additions of 1·5 cm. per kilometre to the apparent displacements shown by the dotted arrows. Figs. 7 and 8 are the displacement lines based on the corrected values from which I computed roughly the expansion and contraction of the area. The result is seen in Fig. 6, the full thick lines being contraction and the dotted thick lines the expantion. The result is almost the same as that obtained by Mr. N. Miyabe of the Earthquake Research Institute.[2] The numerals on the contours indi-

2) N. Miyabe, *Bull. Earthq. Res. Inst*, 9 (1931), 12.

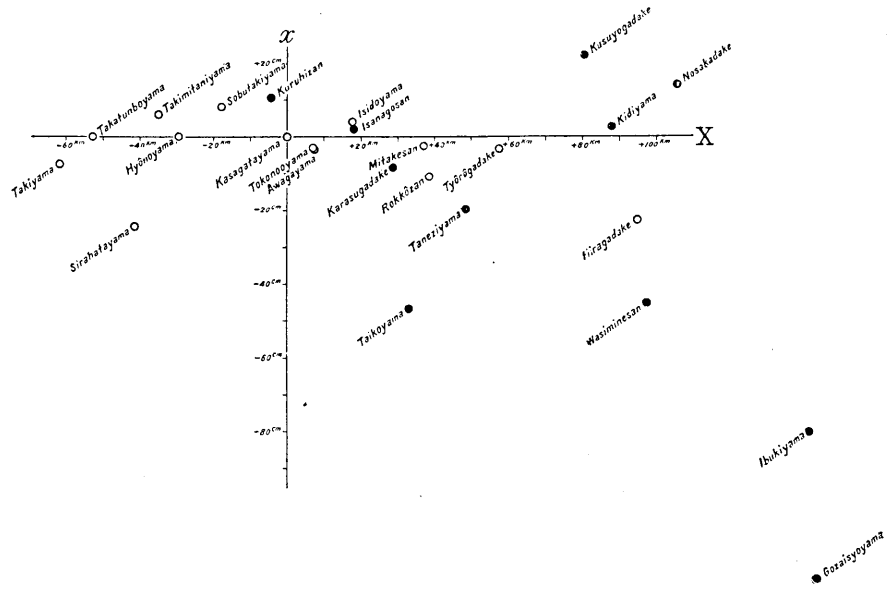

Fig. 9.

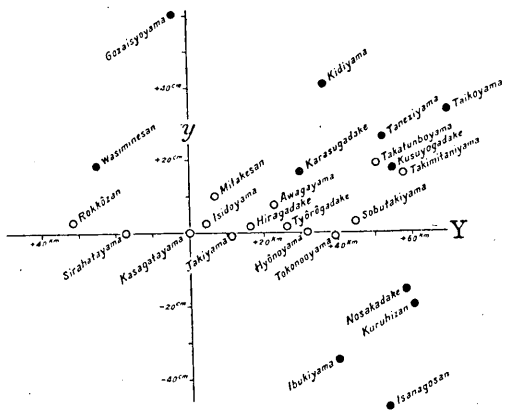

Fig. 10.

cating the lines of equal displacements of x and y components and on the contours indicating expansion and contraction are not true values but only values proportional to them.

5. I applied the same method as that used for the Kwantô to the result of the Tango triangulation, the origin of coordinate axes being the primary point, Kasagata-yama.

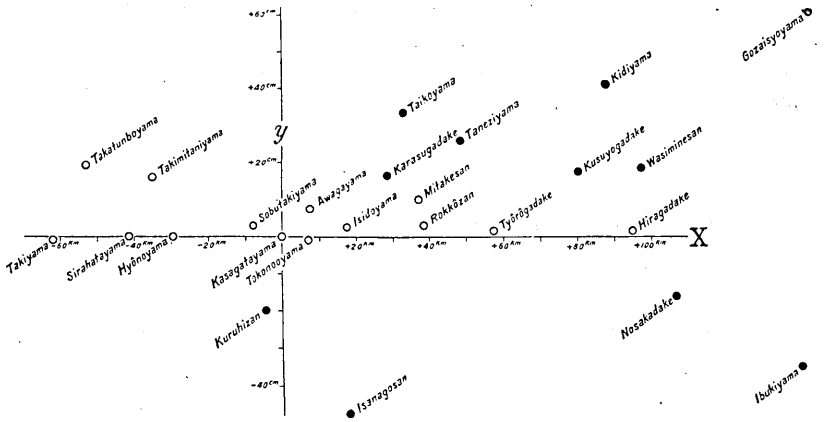

Fig. 11.

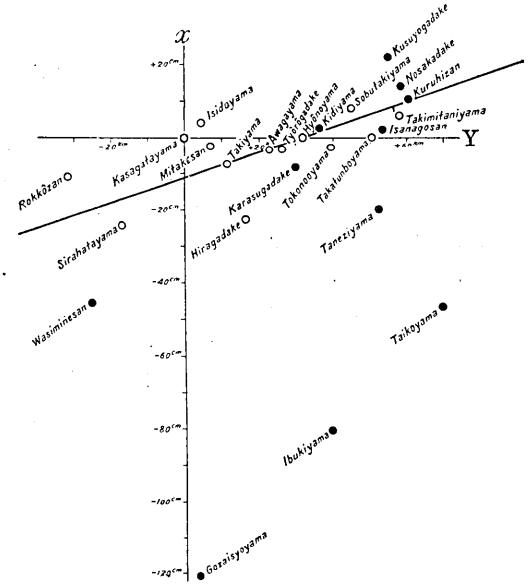

Fig. 12.

Figs. 9, 10, 11, and 12 represent the relations of (x, X) and (y, Y), (x, Y) and (y, X) respectively. The circles in the figures are points situated in regions where changes in the angles was comparatively small. In Figs. 9 and 10 these points are distributed on the X axis. This shows that the side length is free from systematic error.

In Fig. 11 the points are distributed along the X axis, and in Fig. 12 along the inclined line, but they are not evidence of changes in the reference azimuth of the line from Kasagata-yama to Hyôno-ayma, for neither figure satisfies the relation

$$\frac{x}{Y}=-\frac{y}{X}.$$

The displacement of every point can now be accepted as true. From Fig. 12, however, the Tango district seems to have been sheared toward the west in the north part and toward east in the south part of the east-west line passing through the neighbourhood of Hyôno-yama.

In conclusion I wish to thank Colonel M. Suzuki, Chief of the Section of Geodesy in this Department, for facilities given in carrying out this investigation and for his continued interest during its progress.

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25. 測量結果より得たる三角點變位の吟味

武　藤　勝　彦

陸地測量部が發表した關東、丹後兩震災地に於ける三角點の變位は不動と假定した三角點に關する相對變位である。

此の論文に於ては各三角點の實際の變位を求むる爲め不動と假定した點の運動及び三角形の邊長に存するかも知れない定誤差を調べて見た。

其の結果關東地方に就ては不動點の變位は認むる事は出來なかつたが邊長に定誤差が含まれてゐる事が知れ Fig. 6 に示した様な三角點の變位を求むる事が出來た。

然しながら丹後地方に就ては不動點の變位並に邊長定誤差共認むる事は出來なかつた。

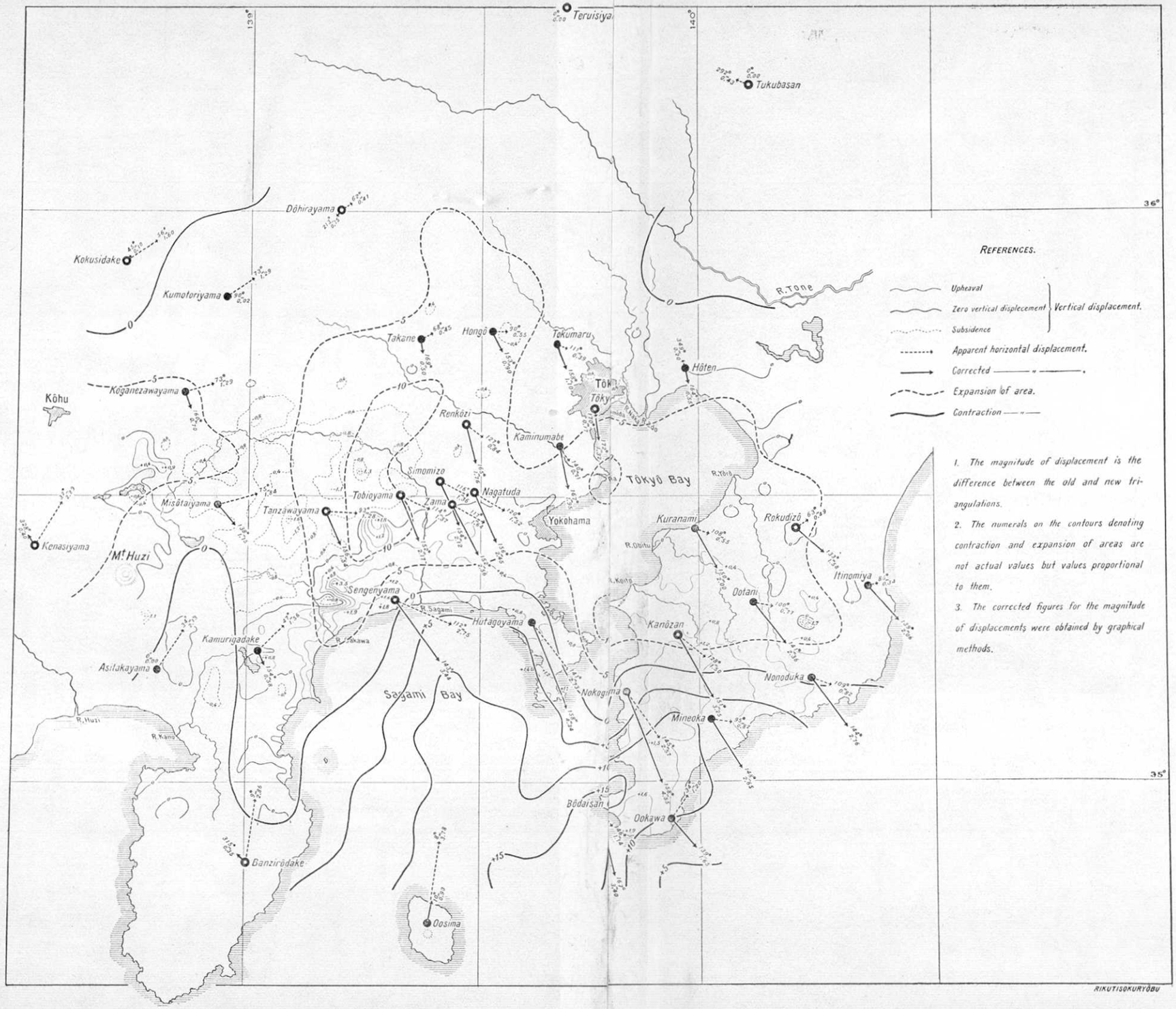

Fig. 6. Relative Horizontal Displacements of Triangulation Points.

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