3. *Deformation of the Rhombic Base Lines at Mitaka and Earthquakes in Kwantô.*

(An Abstract.)

By Torahiko TERADA, M.I.A.

Earthquake Research Institute, Tokyo Imperial University.

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A statistical investigation was made regarding the relation between the time-rate of variation of the area of the rhombus formed by a set of geodetic base lines,¹⁾ situated in the compound of the Tokyo Astronomical Observatory at Mitaka, and the frequency of earthquakes in the Kwantô Districts.

For the change of the area, the mean value ΔS was taken of the increments of the areas S of the two adjacent equilateral triangles composing the rhombus and its time rate $ds/dt=\dot{s}$ was estimated by dividing $\Delta S/S=s$ by the number of days contained in the interval between the two consecutive measurements from which the increments were found.

The number n of earthquakes, designated "conspicuous" and "rather conspicuous," were counted for the same time intervals as in the case of s . Those earthquakes were chosen of which the epicentres are located in the eight provinces of Kwantô as well as in Idu, Kai and Iwaki. The counting was made in the following three different ways: (1) The total number. (2) Number of earthquakes originated in the land area (the Tokyo Bay inclusive). (3) The weights 1, 2 and 3 were respectively allotted to the "rather conspicuous," "conspicuous" and "destructive" earthquakes, and then the weighted sum of the numbers was taken. These three kinds of numbers are denoted by n_1 , n_2 and n_3 respectively. Dividing these n 's by the corresponding number of days, are obtained the time rates of the earthquake frequencies, $\dot{n}_1$, $\dot{n}_2$ and $\dot{n}_3$.

For the investigation of the possible relation between $\dot{s}$ and $\dot{n}$'s, the following graphical method was employed. Taking $\dot{n}_i$ ($i=1, 2, 3$) and $\dot{s}$ as the rectangular coordinates, the points $(\dot{n}_i, \dot{s})$ were plotted for the successive intervals and the consecutive points were connected by

1) See Ch. Tsuboi: Proc., **6** (1930), 367; *ibid.*, **7** (1931), 155.

Fig. 1.

Broken lines start from o. • marks the cases in which both $\dot{n}_3$ and $\dot{s}$ increased.

arrow lines showing the timely sequence. If a positive or negative correlation prevailed between $\dot{s}$ and $\dot{n}_i$, these arrows will show a tendency to be inclined to the positive directions of the coordinate axes by acute or obtuse angles respectively. Again, if there existed some systematic time-lag between the two quantities, the successive arrow-vectors will show a tendency to turn either in clockwise or counter-clockwise sense. Such diagrams (Fig. 1 shows an example for $\dot{n}_3$) were constructed respectively for $\dot{n}_1$, $\dot{n}_2$, $\dot{n}_3$ and $\dot{n}_1 - \dot{n}_2$. The numbers of cases with positive and negative correlations, as well as of those with the clockwise and counter-clockwise rotations, were respectively counted. The result is shown in Table (A).

TABLE (A).

	$\dot{n}_1$	$\dot{n}_2$	$\dot{n}_3$	$\dot{n}_1 - \dot{n}_2$
Negative Correlation	10	9	11	9
Positive Correlation	6	7	5	7
Counter-clockwise	10	10	9	8
Clockwise	5	5	5	7

TABLE (B).

	$\dot{n}_1'$	$\dot{n}_2'$	$\dot{n}_3'$	$\dot{n}_1' - \dot{n}_2'$
Negative Correlation	10	11	10	9
Positive Correlation	6	5	6	7
Counter-clockwise	10	6.5	10	10
Clockwise	5	8.5	5	5

TABLE (C).

	$\dot{n}_1''$	$\dot{n}_2''$	$\dot{n}_3''$	$\dot{n}_1'' - \dot{n}_2''$
Negative Correlation	7.5	8	8.5	7
Positive Correlation	8.5	8	7.5	9
Counter-clockwise	10	10	9	8
Clockwise	5	5	6	7

(The case in which the sense of correlation or rotation is indeterminate, is counted as 0.5 for each of the two alternatives.)

It will be seen that the negative correlation is generally prevailing, being most conspicuous in the case of $\dot{n}_3$. The counter-clockwise rotation generally predominates, suggesting a lag of $\dot{s}$ after $\dot{n}$'s. Referring to Fig. 1, there are only two cases in which both the quantities $\dot{s}$ and $\dot{n}_3$ underwent simultaneous increases, as are marked by ● placed upon the respective arrows. It may be noted that the Great Kwantô Earthquake and the recent N. Idu Earthquakes took place respectively in the very intervals marked by these two arrows.

On the other hand, the time intervals for counting the earthquakes were taken respectively one month earlier than those for $\dot{s}$, keeping the length of the intervals constant. Denoting the time rates for these numbers respectively by $\dot{n}_1'$, $\dot{n}_2'$, $\dot{n}_3'$, a similar statistics was carried out and the result is given in Table (B). Again, the epoch for counting the earthquakes was similarly shifted six months earlier than that for $\dot{s}$ and the similar statistics for $\dot{n}''$'s thus obtained was carried out, as shown in Table (C). It will be seen that in (B), the negative correlation is still preserved, and even improved a little for $\dot{n}_2'$, for which the apparent time-lag has completely disappeared. In (C), the negative correlation is quite effaced, while some time-lag effect seems to remain.

From these results, it may be provisionally concluded that (1) $\dot{s}$ generally decreases with the increased $\dot{n}$'s and (2) $\dot{s}$ lags a little after $\dot{n}$'s.

Two alternatives may be suggested for the relations between $\dot{s}$ and $\dot{n}$, which seems probable, and at least not in contradiction with the present results, i.e.

$$(1) \quad \dot{n}_i - f(t) + k\dot{s} = 0 ,$$

$$(2) \quad \frac{d}{dt}\{\dot{n}_i - \phi(t)\} + k'\dot{s} = 0 ,$$

where $f(t)$ and $\phi(t)$ are some slowly varying functions of time and k, k' positive constants. From these, we have

$$(1') \quad k(s - s_0) = \int_0^t f(t) dt - n ,$$

$$(2') \quad k'(s - s_0) = ct + \int_0^t \phi(t) dt - n ,$$

where s_0 and c are constants.

It seems possible to conceive a mechanical model imitating such a behaviour; for example, we may suppose the case of tearing asunder of a sheet of paper by pulling a caoutchouc band attached to a free corner of the paper while another corner is held fixed.

It seems plausible to extend the present investigation taking account of the distance as well as the azimuth of the epicentre of each earthquake. The material at hand seems, however, too scanty for this purpose. It is, moreover, highly desirable that the measurement of the rhombus will be repeated further on, if possible, with more regular and shorter intervals.