34. *Secular Deformations of the Base Line Rhombus at Mitaka in Relation to Seismic Activities in its Vicinity.*[1]

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(Read Sept. 18, 1941.—Received Sept. 20, 1941.)

In 1916, the Japanese Geodetic Commission laid down a set of five geodetic base lines in the compound of the Tokyo Astronomical Observatory, at Mitaka, which are all very nearly 100 m in length and are so arranged as to form a rhombus consisting of two equal equilateral triangles (Fig. 1). Measurements of length of the base lines which, from 1916 up to 1939, inclusive, have been repeated 25 times with utmost care and precision by experts of the Military Land Survey under the auspices of the Geodetic Commission revealed that the lengths of the base lines do not remain unchanged, but are subject to secular variations.[2]

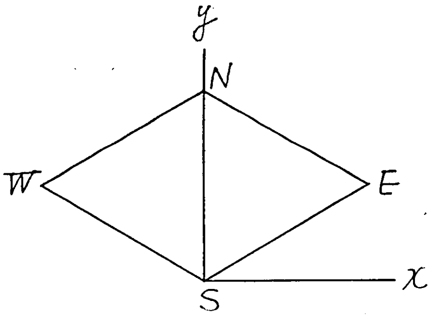

Fig. 1.

Although the variation in length of the base lines between any two successive measurements is usually no more than a few tenths of a millimeter, it occasionally amounts to a millimeter or even more. These large variations in length were observed where strong earthquakes have occurred near Mitaka. For example, at the times mentioned, the lengths of the base line NS were

	m mm
1922 Nov.	100 + 0·82
1923 Sept.	100 + 4·40,

the difference being as much as 3·58 mm. It is between these two times

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[1] A part of this paper was read on March 15, 1939, jointly by Dr. S. Yamaguti and the present writer.

[2] MILITARY LAND SURVEY, Reports of Measurements of the Base Lines at Mitaka.

of measurement that the great Tokyo earthquake of Sept. 1, 1923, with its epicentre approximately 50 km SSW of Mitaka, occurred. Again, for the line WN, the lengths were

	m mm
1930 Feb.	100 + 1·12
1931 Oct.	100 + 1·86,

the difference being 0·74 mm. The Idu destructive earthquake of Nov. 26, 1930, with its epicentre 80 km SW of Mitaka, occurred just between these two measurements.

These outstanding facts call for a careful examination of the secular deformations of the triangles, NES and NSW, both of which are formed by the base lines, particularly in their relations to seismic activities within a reasonable distance from Mitaka, say 150 km.

The present writer, in 1930, calculated from the variations in length of the base lines, the variation in area of the triangles that are formed by the base lines and found a striking relation between the variation in area and the occurrence of strong earthquakes near Mitaka.[3] In 1932, T. Terada further found that the areas of the triangles are likely to vary in parallel rather more closely with the general seismic activity within a reasonable distance from Mitaka, than with the occurrence of any particular individual strong earthquake near that place.[4]

While, in these studies just mentioned, attention was concentrated on the variation in the area of the base line triangles, it recently occurred to the writer that from the variations in length of the base lines, not only are the variations in the area of the triangles calculable, but with a few reasonable assumptions, other strain components, such as shear and principal strains, as well as the relative displacements of the end points of the base lines are also calculable from the same data.

The object of the present paper is to show how these calculations were made, and to see if there is any correlation between deformations of the base line triangles and the general seismic activities near Mitaka.

First, Table I gives the dates and the results of the base line measurements as reported by the Military Land Survey. Since the variations in length between two successive measurements are mostly a few tenths of a millimeter, the relative variation $\Delta l/l$ is of an order not exceeding 10^{-6}. So small are these variations that one may be excused for conclud-

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[3] C. TSUBOI, *Proc. Imp. Acad.*, **6** (1930), 367; **7** (1931), 155. *Bull. Earthq. Res. Inst.*, **8** (1930), 334; **13** (1935), 558. *Erg. d. kos. Phys.*, IV. (1939), Leipzig.

[4] T. TERADA, *Proc. Imp. Acad.*, **8** (1932), 8. *Bull. Earthq. Res. Inst.*, **10** (1932), 402.

Table I. Measured Lengths of the Base Lines and Their Variation. (in mm.)

Date of Measurement	Interval	NE m 100+	ΔNE	ΣΔNE	ES	ΔES	ΣΔES	SW	ΔSW	ΣΔSW	WN	ΔWN	ΣΔWN	NS	ΔNS	ΣΔNS
(1) 1916 VI 4∼11	m d	+0·92			+0·26			+0·72			+0·78			+0·59		
(2) 1917 II 5∼20	8 9	+0·92	0	0	+0·25	−0·01	−0·01	+0·69	−0·03	−0·03	+0·78	0	0	+0·54	−0·05	−0·05
(3) 〃 X 14∼17	7 27	+1·15	+0·23	+0·23	+0·55	+0·30	+0·29	+0·91	+0·22	+0·19	+1·01	+0·23	+0·23	+0·84	+0·30	+0·25
(4) 1918 II 8∼10	3 23	+0·97	−0·18	+0·05	+0·26	−0·29	0	+0·86	−0·05	+0·14	+0·89	−0·12	+0·11	+0·47	−0·37	−0·12
(5) 〃 X 20∼23	8 13	+0·81	−0·16	−0·11	+0·29	+0·03	+0·03	+0·69	−0·17	−0·03	+0·76	−0·13	−0·02	+0·51	+0·04	−0·08
(6) 1919 XII 10∼12	13 19	+1·03	+0·22	+0·11	+0·52	+0·23	+0·26	+0·94	+0·25	+0·22	+0·86	+0·10	+0·08	+0·63	+0·12	+0·04
(7) 1920 XI 20∼24	11 12	+1·26	+0·23	+0·34	+0·55	+0·03	+0·29	+1·07	+0·13	+0·35	+1·02	+0·16	+0·24	+0·85	+0·22	+0·26
(8) 1921 XI 2∼8	11 14	+1·25	−0·01	+0·33	+0·56	+0·01	+0·30	+1·11	+0·04	+0·39	+1·11	+0·09	+0·33	+0·93	+0·08	+0·34
(9) 1922 XI 6∼8	12 0	+1·11	−0·14	+0·19	+0·42	−0·14	+0·16	+1·02	−0·09	+0·30	+1·06	−0·05	+0·28	+0·82	−0·11	+0·23
(10) 1923 IX 4∼6	9 28	+1·73	+0·62	+0·81	+0·53	+0·11	+0·27	+1·84	+0·82	+1·12	+1·12	+0·06	+0·34	+4·40	+3·58	+3·81
(11) 〃 X 19∼24	1 18	+1·64	−0·09	+0·72	+0·33	−0·20	+0·07	+1·47	−0·37	+0·75	+0·95	−0·17	+0·17	+4·00	−0·40	+3·41
(12) 1924 I 27∼29	3 5	+1·91	+0·27	+0·99	+0·07	−0·26	−0·19	+1·39	−0·08	+0·67	+0·72	−0·23	−0·06	+3·76	−0·24	+3·17
(13) 〃 VIII 12∼15	6 16	+1·58	−0·33	+0·66	−0·05	−0·12	−0·31	+1·50	+0·11	+0·78	+0·71	−0·01	−0·07	+3·42	−0·34	+2·83
(14) 1925 XII 15∼17	16 2	+1·84	+0·26	+0·92	+0·25	+0·30	−0·01	+1·44	−0·06	+0·72	+0·82	+0·11	+0·04	+3·69	+0·27	+3·10
(15) 1927 XII 13∼16	23 29	+2·38	+0·54	+1·42	+·080	+0·55	+0·54	+2·16	+0·72	+1·44	+1·38	+0·56	+0·60	+3·91	+0·22	+3·32
(16) 1929 III 17∼20	15 4	+2·21	−0·17	+1·29	+0·72	−0·08	+0·46	+2·02	−0·14	+1·30	+1·44	+0·06	+0·66	+3·78	−0·13	+3·19
(17) 1930 II 8∼14	10 24	+1·97	−0·24	+1·05	+0·53	−0·19	+0·27	+1·73	−0·29	+1·01	+1·12	−0·32	+0·34	+3·59	−0·19	+3·00
(18) 1931 X 1∼6	19 22	+1·77	−0·20	+0·85	+0·57	+0·04	+0·31	+2·24	**+0·51**	+1·52	+1·86	+0·74	**+1·08**	+3·58	−0·01	+2·99
(19) 1934 II 8∼22	28 16	+1·76	−0·01	+0·84	+0·53	−0·04	+0·27	+1·72	**−0·52**	+1·00	+1·33	−0·53	**+0·55**	+3·29	−0·29	+2·70
(20) 1934 XII 1∼24	10 2	+1·59	−0·17	+0·67	+0·15	−0·38	−0·11	+1·63	−0·09	+0·91	+1·06	−0·27	+0·28	+3·12	−0·17	+2·53
(21) 1935 XI29∼XII23	11 29	+1·37	−0·22	+0·45	+0·13	−0·02	−0·13	+1·37	−0·26	+0·65	+0·87	−0·19	+0·09	+2·86	−0·26	+2·27
(22) 1936 XII 1∼22	11 29	+1·58	+0·21	+0·66	+0·13	0	−0·13	+1·44	+0·07	+0·72	+0·92	+0·05	+0·14	+2·89	+0·03	+2·30
(23) 1937 X22∼XI28	11 6	+1·38	−0·20	+0·46	+0·16	+0·03	−0·10	+1·45	+0·01	+0·73	+0·85	−0·07	+0·07	+2·83	−0·06	+2·24
(24) 1938 XI13∼XII9	12 11	+1·38	0·0	+0·46	+0·15	−0·01	−0·11	+1·35	−0·10	+0·63	+1·00	+0·15	+0·22	+2·90	+0·07	+2·31
(25) 1939 XI13∼XII12	12 3	+1·50	+0·12	+0·58	+0·29	+0·14	+0·03	+1·48	+0·13	+0·76	+1·06	+0·06	+0·28	+3·03	+0·13	+2·44

ing that they are due to errors in measurements, with doubts of their real significance, but the following examination of data will show that such is not the case.

Since the base lines NE and SW are parallel, the variations in their length, ⊿NE and ⊿SE, if any, must be equal, provided of course that the strain to which the ground at Mitaka is subjected is uniform. The extent to which the measured values of ⊿NE and ⊿SW are actually equal will therefore serve as basis for judging the accuracy of measurements and the uniformity in strain of the ground. The same test may equally be applied to the other pair of lines, NW and SE. Table II gives the residual values of (⊿NE–⊿SW) and (⊿NW–⊿SE), which ought to vanish if the measurements are accurate and the strain is perfectly uniform.

Since, with the few exceptions that are printed in Gothic type in the table, the residuals are mostly about 0·1 mm, the measured lengths of the base lines may be regarded accurate and the strain of the ground uniform with this accuracy.

Table II. Residuals of (⊿NE–⊿SW) and (⊿ES–⊿WN) (in mm).

	⊿NE-⊿SW	⊿ES-⊿WN		⊿NE-⊿SW	⊿ES-⊿WN
(1)~(2)	0·03	−0·01	(13)~(14)	0·32	0·19
(2)~(3)	0·01	0·07	(14)~(15)	−0·18	−0·01
(3)~(4)	−0·13	−0·17	(15)~(16)	−0·03	−0·14
(4)~(5)	0·01	0·16	(16)~(17)	0·05	0·13
(5)~(6)	−0·03	0·13	(17)~(18)	**−0·71**	**−0·70**
(6)~(7)	0·10	−0·13	(18)~(19)	**0·51**	**0·49**
(7)~(8)	−0·05	−0·08	(19)~(20)	−0·08	−0·11
(8)~(9)	−0·05	−0·09	(20)~(21)	0·04	0·17
(9)~(10)	−0·20	0·05	(21)~(22)	0·14	−0·05
(10)~(11)	0·28	−0·03	(22)~(23)	−0·21	0·10
(11)~(12)	0·35	−0·03	(23)~(24)	0·10	−0·16
(12)~(13)	−0·44	−0·11	(24)~(25)	−0·01	0·08

There is no question of the accuracy of the measured length of each line. As a matter of fact, the lengths were measured with the aid of as many as nearly thirty Jaderin wires, which were carefully calibrated before each measurement, the mean error in each measurement being reported to be as small as a few hundredths of a millimeter. Yet, such large residuals, as for instance, of 0·70 and 0·71 mm, appear both in (⊿NW–⊿SE) and (⊿NE–⊿SW) between the measurements (17) and (18), these exceeding the errors of measurement. This can only indicate that either point E or point W made a real but accidental displacement of this amount unrelated to and quite apart from the general deformation of the ground. There is no theoretical basis on which to decide which of the points E or W made such a large residual displacement. Seeing however from Table I, that ⊿SW and ⊿WN are exceptionally large between measurements (17) and (18), it is very likely that the large residuals of (⊿NW–⊿SE) and (⊿NE–⊿SW) are the results of displacement of point W; and since this displacement of point W, although it may have really occurred, has nothing to do with the general deformation of the ground, so long as the uniformity in strain of the ground is going to be an assumption to be based upon in our subsequent calculations, the rational thing to do is to reject the reported values of ⊿NW and ⊿SW between (17) and (18). For the same reason, ⊿NW and ⊿SW between (18) and (19) will also be rejected.

Now in order to calculate the strain of the ground, we take the co-ordinate axes as shown in Fig. 1. The co-ordinates of point E are the solutions of the simultaneous equations

$$\begin{cases} x^2+y^2=\mathrm{SE}^2 & (1) \\ x^2+(y-\mathrm{NS})^2=\mathrm{NE}^2. & (2) \end{cases}$$

Taking the difference of the two equations, we get the y-co-ordinate of point E,

$$y=\frac{\mathrm{SE}^2-\mathrm{NE}^2+\mathrm{NS}^2}{2\mathrm{NS}}. \tag{3}$$

The northward displacement of point E between any two measurements, which shall be denoted by v_E, is the differential of y, whence

$$\varDelta y=v_{\mathrm{E}}=\frac{1}{2\mathrm{NS}^2}\Big\{2(\mathrm{SE}\cdot\varDelta\mathrm{SE}-\mathrm{NE}\cdot\varDelta\mathrm{NE}+\mathrm{NS}\cdot\varDelta\mathrm{NS})\mathrm{NS} \\ -(\mathrm{SE}^2-\mathrm{NE}^2+\mathrm{NS}^2)\varDelta\mathrm{NS}\Big\}. \tag{4}$$

But since

$$\mathrm{SE}=\mathrm{NE}=\mathrm{NS}=100\,\mathrm{m}=s,$$

v_E reduces to

$$v_E=\frac{1}{2}\Big(2\varDelta\mathrm{SE}-2\varDelta\mathrm{NE}+\varDelta\mathrm{NS}\Big). \tag{5}$$

Taking the differential of the equation (1), we get

$$u_E x+v_E y=\mathrm{SE}\cdot\varDelta\mathrm{SE}, \tag{6}$$

where u_{E} denotes the eastward displacement of point E. Since for point E,

$$x=\frac{\sqrt{3}}{2}s, \quad y=\frac{1}{2}s,$$

and

$$v_E=\frac{2\Delta\mathrm{SE}-2\Delta\mathrm{NE}+\Delta\mathrm{NS}}{2}, \tag{7}$$

u_E is given by

$$u_E=\frac{2\Delta\mathrm{SE}+2\Delta\mathrm{NE}-\Delta\mathrm{NS}}{2\sqrt{3}}. \tag{8}$$

Similarly for point W, we get

$$u_W=-\frac{2\Delta\mathrm{WS}+2\Delta\mathrm{WN}-\Delta\mathrm{NS}}{2\sqrt{3}}, \tag{9}$$

$$v_W=\frac{2\Delta\mathrm{WS}-2\Delta\mathrm{WN}+\Delta\mathrm{NS}}{2}. \tag{10}$$

By assumptions,

$$u_S=v_S=0, \quad u_N=0, \quad v_N=\Delta\mathrm{NS}.$$

By means of these expresssions, the relative displacements of the end points of the base lines were calculated from the variations in their lengths, with results as in Table III.

Table III. Displacements of End Points of the Base-Lines (in mm).

	u_E	$\sum u_E$	v_E	$\sum v_E$	u_W	$\sum u_W$	v_W	$\sum v_W$	v_N	$\sum v_N$
(1)										
(2)	+0·01	+0·01	−0·04	−0·04	0	0	−0·06	−0·06	−0·05	−0·05
(3)	+0·22	+0·23	+0·22	+0·19	−0·17	−0·17	+0·14	+0·09	+0·30	+0·25
(4)	−0·17	+0·06	−0·30	−0·11	−0·01	−0·18	−0·12	−0·03	−0·37	−0·12
(5)	−0·09	−0·02	+0·21	+0·10	+0·19	+0·01	−0·02	−0·05	+0·04	−0·08
(6)	+0·23	+0·20	+0·07	+0·17	−0·17	−0·16	+0·21	+0·16	+0·12	+0·04
(7)	+0·09	+0·29	−0·09	+0·08	−0·10	−0·27	+0·08	+0·24	+0·22	+0·26
(8)	−0·02	+0·27	+0·06	+0·14	−0·05	−0·32	−0·01	+0·23	+0·08	+0·34
(9)	−0·13	+0·14	−0·06	+0·09	+0·05	−0·27	−0·10	+0·14	−0·11	+0·23
(10)	−0·61	−0·48	+1·28	+1·37	+0·53	+0·26	+2·55	+2·69	+3·58	+3·81
(11)	−0·05	−0·53	−0·31	+1·06	+0·20	+0·45	−0·40	+2·29	−0·40	+3·41
(12)	+0·08	−0·45	−0·65	+0·41	+0·11	+0·56	+0·03	+2·32	−0·24	+3·17
(13)	−0·16	−0·62	+0·04	+0·45	−0·16	+0·41	−0·05	+2·27	−0·34	+2·83
(14)	+0·25	−0·37	+0·18	+0·62	+0·05	+0·46	−0·04	+2·23	+0·27	+3·10
(15)	+0·57	+0·20	+0·12	+0·74	−0·68	−0·22	+0·27	+2·50	+0·22	+3·32

(*to be continued.*)

Table III. (*Continued.*)

	u_E	$\sum u_E$	v_E	$\sum v_E$	u_W	$\sum u_W$	v_W	$\sum v_W$	v_N	$\sum v_N$
(15)										
(16)	−0·11	+0·09	+0·03	+0·77	+0·01	−0·21	−0·27	+2·24	−0·13	+3·19
(17)	−0·19	−0·11	−0·05	+0·72	+0·30	+0·09	−0·07	+2·17	−0·19	+3·00
(18)	−0·09	−0·19	+0·24	+0·96	−0·73	+0·64	−0·24	+1·94	−0·01	+2·99
(19)	+0·06	−0·14	−0·18	+0·78	+0·52	−0·12	−0·14	+1·80	−0·29	+2·70
(20)	−0·27	−0·41	−0·30	+0·49	+0·16	+0·04	+0·10	+1·90	−0·17	+2·53
(21)	−0·06	−0·47	+0·07	+0·56	+0·19	+0·23	−0·20	+1·70	−0·26	+2·27
(22)	+0·11	−0·36	−0·20	+0·36	−0·06	+0·17	+0·04	+1·73	+0·03	+2·30
(23)	−0·08	−0·44	+0·20	+0·56	+0·02	+0·18	+0·05	+1·78	−0·06	+2·24
(24)	−0·03	−0·47	+0·03	+0·59	−0·01	+0·18	−0·22	+1·57	+0·07	+2·31
(25)	+0·11	−0·35	+0·09	+0·67	−0·07	+0·10	+0·14	+1·70	+0·13	+2·44

Now, if this part of the ground has been subjected to a uniform strain, then u_E and u_W must be equal and opposite in sign, since in the expressions (8) and (9),

$$\varDelta \mathrm{SE} = \varDelta \mathrm{NW},$$

and

$$\varDelta \mathrm{NE} = \varDelta \mathrm{SW}.$$

The symmetrical relation of u_N and u_W is clearly shown in Fig. 2, in which they are compared as curves. Such symmetrical relation, however, does not exist between v_E and v_W, because the elongation of the ground in NS direction contributes the same amount to both of them, while the shear of the ground along the same direction contributes the displacements, equal in amount but opposite in sign.

Displacement of the ground at any point (xy) near the origin is given in the first approximation by

$$u(xy) = u_0 + \left(\frac{\partial u}{\partial x}\right)_0 x + \left(\frac{\partial u}{\partial y}\right)_0 y, \tag{11}$$

$$v(xy) = v_0 + \left(\frac{\partial v}{\partial x}\right)_0 x + \left(\frac{\partial v}{\partial y}\right)_0 y, \tag{12}$$

but since we have chosen the co-ordinate axes as in Fig. 1, (11) and (12) reduce to

$$u(xy) = \frac{\partial u}{\partial x} x + \frac{\partial u}{\partial y} y, \tag{13}$$

$$v(xy) = \frac{\partial u}{\partial x} x + \frac{\partial v}{\partial y} y. \tag{14}$$

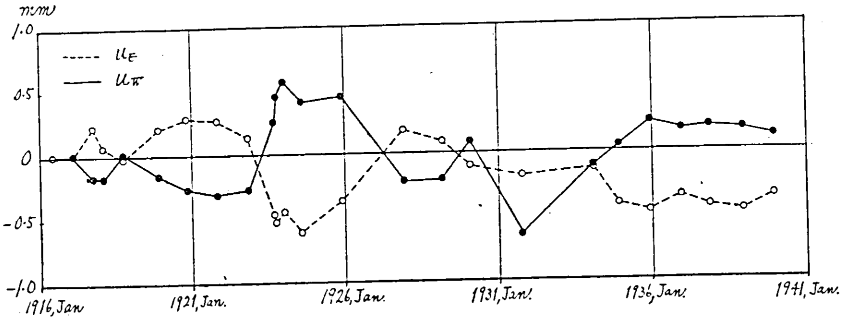

Fig. 2.

At the east and north vertices of triangle NES, we have then

$$u_E=\frac{\partial u}{\partial x}\frac{\sqrt{3}}{2}s+\frac{\partial u}{\partial y}\frac{s}{2}, \tag{15}$$

$$v_E=\frac{\partial v}{\partial x}\frac{\sqrt{3}}{2}s+\frac{\partial v}{\partial y}\frac{s}{2}, \tag{16}$$

$$u_N=\frac{\partial u}{\partial y}s=0, \tag{17}$$

$$v_N=\Delta\mathrm{NS}=\frac{\partial v}{\partial y}s. \tag{18}$$

From these equations, we get

$$\frac{\partial u}{\partial x}=\frac{2}{\sqrt{3}s}u_E,$$

$$\frac{\partial v}{\partial x}=\left(v_E-\frac{v_N}{2}\right)\frac{2}{\sqrt{3}s},$$

$$\frac{\partial u}{\partial y}=0,$$

$$\frac{\partial v}{\partial y}=\frac{v_N}{s}.$$

These expressions enable us to calculate the strains of the ground from the variation in length of the base lines. Similar calculations can be made for the other triangle NSW also. But for the reason already given, it will be rational to take the mean of the strains within the two triangles NES and NSW as representing the general strain of the ground. They are given in Table IV.

Table IV. Simple Strains of the Ground. (in 10^{-5}).

	$\left(\frac{\partial u}{\partial x}\right)_E$	$\left(\frac{\partial u}{\partial x}\right)_W$	$\left(\frac{\partial u}{\partial x}\right)_{\text{mean}}$	$\left(\frac{\partial v}{\partial x}\right)_E$	$\left(\frac{\partial v}{\partial x}\right)_W$	$\left(\frac{\partial v}{\partial x}\right)_{\text{mean}}$	$\left(\frac{\partial v}{\partial y}\right)$	$\Sigma\frac{\partial u}{\partial x}$	$\Sigma\left(\frac{\partial v}{\partial x}\right)$	$\Sigma\left(\frac{\partial v}{\partial y}\right)$
(1)										
(2)	+0·01	0	0	−0·01	+0·04	+0·01	−0·05	0	+0·01	−0·05
(3)	+0·25	+0·20	+0·23	+0·08	+0·01	+0·05	+0·30	+0·23	+0·05	+0·25
(4)	−0·19	+0·01	−0·09	−0·13	−0·08	−0·10	−0·37	+0·14	−0·05	−0·12
(5)	−0·10	−0·21	−0·16	+0·22	+0·05	+0·13	+0·04	−0·02	+0·08	−0·08
(6)	+0·26	+0·19	+0·23	+0·01	−0·17	−0·08	+0·12	+0·21	0	+0·04
(7)	+0·10	+0·12	+0·11	−0·23	+0·04	−0·10	+0·22	+0·32	−0·10	+0·26
(8)	−0·03	+0·06	+0·02	+0·02	+0·06	+0·04	+0·08	+0·33	−0·06	+0·34
(9)	−0·15	−0·06	−0·10	0	+0·05	+0·02	−0·11	+0·23	−0·04	+0·23
(10)	−0·71	−0·61	−0·66	−0·59	−0·88	−0·73	+3·58	−0·43	−0·77	+3·81
(11)	−0·06	−0·23	−0·14	−0·13	+0·23	+0·05	−0·40	−0·57	−0·72	+3·41
(12)	+0·09	−0·13	−0·02	−0·61	−0·17	−0·39	−0·24	−0·59	−1·11	+3·17
(13)	−0·19	+0·18	0	+0·24	−0·14	+0·05	−0·34	−0·59	−1·06	+2·83
(14)	+0·28	−0·06	+0·11	+0·05	+0·20	+0·12	+0·27	−0·48	−0·94	+3·10
(15)	+0·65	+0·78	+0·72	+0·01	−0·19	−0·09	+0·22	+0·24	−1·02	+3·32
(16)	−0·12	−0·01	−0·07	+0·10	+0·23	+0·17	−0·13	+0·17	−0·85	+3·19
(17)	−0·22	−0·34	−0·28	+0·06	−0·04	+0·01	−0·19	−0·11	−0·84	+3·00
(18)	−0·10	**(+0·84)**	−0·10	+0·28	**(+0·27)**	+0·28	−0·01	−0·22	−0·56	+2·99
(19)	+0·06	**(−0·60)**	+0·06	−0·04	**(−0·01)**	−0·04	−0·29	−0·15	−0·60	+2·70
(20)	−0·31	−0·18	−0·25	−0·24	−0·21	−0·23	−0·17	−0·40	−0·83	+2·53
(21)	−0·07	−0·21	−0·14	+0·23	+0·08	+0·16	−0·26	−0·54	−0·67	+2·27
(22)	+0·13	+0·07	+0·10	−0·24	−0·02	−0·13	+0·03	−0·44	−0·80	+2·30
(23)	−0·09	−0·02	−0·06	+0·27	−0·09	+0·09	−0·06	−0·50	−0·71	+2·24
(24)	−0·03	+0·01	−0·01	−0·01	+0·29	+0·14	+0·07	−0·51	−0·58	+2·31
(25)	+0·13	+0·08	+0·11	+0·02	−0·08	−0·03	+0·13	−0·49	−0·61	+2·44

Once these simple strains are known, the other strain components, such as dilatation, maximum shear, magnitude and direction of the principal strains, pure shear and elongation along various directions, etc., are easily calculated by means of the well known formula in connection with the theory of plane strain.

Table V gives the strain between two successive measurements, and Table VI those as compared with the first measurement. Table VII gives the monthly rate of strain during the interval of two successive measurements, while Table VIII shows by plus or minus sign whether the rate during the interval between any two base line measurements has increased or decreased as compared with that during the preceding interval.

Now in order to see if there is any relation between the strain of the ground at Mitaka and the seismic activity within a reasonable dis-

Table V. Various Strains of the Ground. (in 10^{-5}).

	Dil.	Max. shear	γ_1	γ_2	θ	Elongation				Pure shear		
						E—W	E 45° N —S 45° W	N—S	N 45° W —S 45° E	N—S	N 45° W —S 45° E	N 45° E —S 45° W
(1)	−0·05	0·05	+0·01	−0·10	0	0	−0·02	−0·05	−0·03	+0·01	−0·02	+0·03
(2)	+0·53	0·09	+0·61	+0·44	+74°	+0·23	+0·29	+0·30	+0·24	+0·05	+0·06	−0·01
(3)	−0·46	0·30	−0·16	−0·76	−10	−0·09	−0·28	−0·37	−0·18	−0·10	−0·19	+0·09
(4)	−0·12	0·24	+0·12	−0·36	+73	−0·16	+0·01	+0·04	−0·13	+0·13	+0·17	−0·03
(5)	+0·35	0·13	+0·48	+0·21	−18	+0·23	+0·13	+0·12	+0·21	−0·08	−0·09	+0·01
(6)	+0·33	0·15	+0·43	+0·18	−69	+0·11	+0·12	+0·22	+0·21	−0·10	+0·01	−0·10
(7)	+0·10	0·08	+0·17	+0·02	+74	+0·02	+0·07	+0·08	+0·03	+0·04	+0·05	−0·01
(8)	−0·21	0·02	−0·19	−0·24	+37	−0·10	−0·10	−0·11	−0·12	+0·02	+0·01	+0·02
(9)	+2·92	4·30	+7·22	−1·38	−85	−0·66	+1·10	+3·58	+1·83	−0·73	+1·75	−2·49
(10)	−0·54	0·26	−0·28	−0·81	− 6	−0·14	−0·25	−0·40	−0·30	+0·05	−0·10	+0·16
(11)	−0·26	0·45	+0·19	−0·71	−31	−0·02	−0·33	−0·24	+0·07	−0·39	−0·31	−0·09
(12)	−0·34	0·34	0	−0·68	+ 4	0	−0·15	−0·34	−0·20	+0·05	−0·14	+0·20
(13)	+0·38	0·20	+0·58	+0·19	+71	+0·11	+0·25	+0·27	+0·13	+0·12	+0·14	−0·02
(14)	+0·94	0·51	+1·44	+0·43	− 5	+0·72	+0·43	+0·22	+0·51	−0·09	−0·29	+0·21
(15)	−0·20	0·18	−0·02	−0·38	+35	−0·07	−0·02	−0·13	−0·18	+0·17	+0·05	+0·12
(16)	−0·47	0·09	−0·38	−0·57	+86	−0·28	−0·23	−0·19	−0·24	+0·01	+0·05	−0·04
(17)	−0·11	0·29	+0·18	−0·41	+54	−0·10	+0·08	−0·01	−0·18	+0·28	+0·19	+0·10
(18)	−0·23	0·36	+0·13	−0·58	− 3	+0·06	−0·13	−0·29	−0·10	−0·04	−0·20	+0·16
(19)	−0·42	0·24	−0·18	−0·66	−55	−0·25	−0·32	−0·17	−0·10	−0·23	−0·07	−0·15
(20)	−0·40	0·20	−0·21	−0·60	+27	−0·14	−0·12	−0·26	−0·28	+0·16	+0·02	+0·14
(21)	+0·13	0·15	+0·28	−0·02	−31	+0·10	0	+0·03	+0·13	−0·13	−0·10	−0·03
(22)	−0·12	0·09	−0·03	−0·20	+44	−0·06	−0·02	−0·06	−0·10	+0·09	+0·04	+0·05
(23)	+0·06	0·16	+0·22	−0·10	+60	−0·01	+0·10	+0·07	−0·04	+0·14	+0·11	+0·03
(24)	+0·24	0·04	+0·27	+0·20	−65	+0·11	+0·10	+0·13	+0·13	−0·03	0	−0·03
(25)												

Table VI. Various Integrated Strains of the Ground. (in 10^{-5}).

	Dil.	Max. shear.	γ_1	γ_2	θ	Elongation				Pure shear.		
						E—W	E 45° N —S 45° W	N—S	N 45° W —S 45° E	N—S	N 45° W —S 45° E	N 45° E —S 45° W
(1)	−0·05	0·05	+0·01	−0·10	0	0	−0·02	−0·01	−0·03	+0·01	−0·02	+0·03
(2)	+0·48	0·06	+0·54	+0·42	56°	+0·23	+0·27	+0·25	+0·21	+0·05	+0·04	+0·02
(3)	+0·02	0·26	+0·28	−0·25	− 6	+0·14	−0·02	−0·12	+0·04	−0·05	−0·16	+0·10
(4)	−0·10	0·10	0	−0·20	+26	−0·02	−0·01	−0·08	−0·09	+0·08	+0·01	+0·07
(5)	+0·25	0·17	+0·42	+0·08	—	+0·21	+0·12	+0·04	+0·12	0	−0·09	+0·09
(6)	+0·58	0·11	+0·69	+0·46	−30	+0·32	+0·24	+0·26	+0·34	−0·10	−0·08	−0·02
(7)	+0·67	0·06	+0·73	+0·62	−48	+0·33	+0·31	+0·34	+0·37	−0·06	−0·03	−0·03
(8)	+0·46	0·04	+0·50	+0·43	−45	+0·23	+0·21	+0·23	+0·25	−0·04	−0·02	−0·02
(9)	+3·38	4·31	+7·69	−0·92	−85	−0·43	+1·31	+3·81	+2·08	−0·77	−1·73	−2·50
(10)	+2·84	4·04	+6·88	−1·20	−85	−0·57	+1·06	+3·41	+1·78	−0·72	+1·63	−2·35
(11)	+2·58	3·92	+6·50	−1·34	−82	−0·59	+0·74	+3·17	+1·85	−1·11	+1·32	−2·43
(12)	+2·24	3·58	+6·42	−0·74	−82	−0·59	+0·59	+2·83	+1·65	−1·06	+1·18	−2·24
(13)	+2·62	3·70	+6·32	−1·08	−83	−0·48	+0·84	+3·10	+1·78	−0·94	+1·32	−2·26
(14)	+3·56	3·25	+6·81	−0·31	−81	+0·24	+1·27	+3·32	+2·29	−1·02	+1·03	−2·05
(15)	+3·36	3·14	+6·50	+0·22	−82	+0·17	+1·25	+3·19	+2·11	−0·86	+1·08	−1·94
(16)	+2·89	3·22	+6·11	−0·34	−82	−0·11	+1·02	+3·00	+1·87	−0·84	+1·13	−1·98
(17)	+2·77	3·26	+6·03	−0·48	−85	−0·22	+1·10	+2·99	+1·67	−0·57	+1·32	−1·89
(18)	+2·55	2·92	+5·46	−0·37	−84	−0·15	+0·97	+2·70	+1·58	−0·60	+1·13	−1·73
(19)	+2·13	3·04	+5·18	−0·91	−82	−0·40	+0·65	+2·53	+1·48	−0·83	+1·05	−1·88
(20)	+1·73	2·89	+4·62	−1·16	−83	−0·54	+0·53	+2·27	+1·20	−0·67	+1·07	−1·74
(21)	+1·86	2·86	+4·72	−1·00	−81	−0·44	+0·53	+2·30	+1·33	−0·80	+0·97	−1·77
(22)	+1·74	2·83	+4·57	−1·09	−84	−0·50	+0·51	+2·24	+1·23	−0·72	+1·01	−1·73
(23)	+1·80	2·88	+4·68	−1·08	−84	−0·51	+0·61	+2·31	+1·19	−0·58	+1·12	−1·70
(24)	+2·04	2·91	+4·94	−0·87	−84	−0·40	+0·72	+2·44	+1·32	−0·61	+1·12	−1·73
(25)												

Table VII. Monthly Rate of Strain. (in 10^{-5}/Month).

	Dil.	Max. shear.	γ_1	γ_2	Elongation				Pure shear		
					E—W	N 45° E —S 45° W	N—S	N 45° W —S 45° E	N—S	N 45° W —S 45° E	N 45° E —S 45° W
(1)	−0·006	0·006	0·001	−0·012	0	−0·002	−0·006	−0·004	0·001	−0·002	0·004
(2)	0·067	0·011	0·077	0·057	0·029	0·037	0·038	0·030	0·006	0·008	−0·001
(3)	−0·122	0 080	−0·042	−0·202	−0·024	−0·074	−0·098	−0·048	−0·027	−0·050	0·024
(4)	−0·014	0·028	0·014	−0·043	−0·087	0·001	0·005	−0·015	0·015	0·020	−0·004
(5)	0·026	0·010	0·035	0·015	0·017	0·010	0·009	0·015	−0·006	−0·007	0·001
(6)	0·029	0·013	0·042	0·016	0·010	0·011	0·019	0·018	−0·009	0·001	−0·009
(7)	0·009	0·007	0·015	0·002	0·002	0·006	0·007	0·003	0·003	0·004	−0·001
(8)	−0·017	0·002	−0·016	−0·020	−0·008	−0·008	−0·009	−0·010	0·002	0·001	0·002
(9)	0·294	0·433	0·727	−0·139	−0·066	0·111	0·361	0·184	−0·074	0·176	−0·251
(10)	−0·338	0·163	−0·175	−0·506	−0·088	−0·156	−0 250	−0·188	0·031	−0·063	0·100
(11)	−0·082	0·142	0·060	−0·224	−0·006	−0·104	−0·076	0·022	−0·123	−0·098	−0·028
(12)	−0·052	0·052	0	−0·104	0	−0·023	−0·052	−0·031	0·008	−0·021	0·031
(13)	0·024	0·012	0·036	0·012	0·007	0·016	0·017	0·008	0·007	0·009	−0·001
(14)	0·039	0·021	0·060	0 018	0·030	0·018	0·009	0·021	−0·004	−0·012	0·009
(15)	−0·013	0·012	−0·001	−0·025	−0·005	−0·001	−0·009	−0·012	0·011	0·003	0·008
(16)	−0·044	0·008	−0·035	−0·053	−0·026	−0·021	−0·018	−0·022	0·001	0·005	−0·004
(17)	−0·006	0·015	0·009	−0·021	−0·005	0·004	−0·001	−0·009	0·014	0 010	0·005
(18)	−0·008	0·013	0·005	−0·020	0·002	−0·005	−0·010	−0·004	−0·001	−0·007	0·006
(19)	−0·042	0·024	−0·018	−0·066	−0·025	−0·032	−0·017	−0·010	−0·023	−0·007	−0·015
(20)	−0·033	0·017	−0·018	−0·050	−0·012	−0·010	−0·022	−0·023	0·013	0·002	0·012
(21)	0·011	0·013	0·023	−0·002	0·008	0	0·003	0·011	−0·011	−0·008	−0·003
(22)	−0·011	0·008	−0·003	−0·018	−0·005	−0·002	−0·005	−0·009	0·008	0·004	0·004
(23)	0·005	0·013	0·018	−0·008	−0·001	0·008	0·006	−0·003	0·011	0·009	0·002
(24)	0·020	0·003	0·022	0 017	0·009	0·008	0·011	0·011	−0·002	0	−0·002
(25)											

Table VIII. Increase or Decrease in the Rate of Strain and in the Monthly Seismic Activity.

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
Strain		Dilatation			+	−	+	+	+	−	−	+	−	+	+	+	+	−	−	+	−	−	+	+	−	+	+
		Max. shear			+	+	−	−	+	−	−	+	−	−	−	−	+	−	−	+	−	+	−	−	−	+	−
		γ_1			+	−	+	+	+	−	−	+	−	+	−	+	+	−	−	+	−	−	0	+	−	+	+
		γ_2			+	−	+	+	+	−	−	−	−	+	+	+	+	−	−	+	+	−	+	+	−	+	+
	Elonga-tion	E—W			+	−	−	+	−	−	−	−	−	+	+	+	+	−	−	+	+	−	+	+	−	+	+
		E 45° N—S 45° W			+	−	+	+	+	−	−	+	−	+	+	+	+	−	−	+	−	−	+	+	−	+	0
		N—S			+	−	+	+	+	−	−	+	−	+	+	+	−	−	−	+	−	−	−	+	−	+	+
		N 45° W—S 45° E			+	−	+	+	+	−	−	+	−	+	−	+	+	−	−	+	−	−	−	+	−	+	+
	Pure shear	N—S			+	−	+	−	−	+	−	−	+	−	+	−	−	+	−	+	−	−	+	−	+	+	−
		N 45° W—S 45° E			+	−	+	−	+	+	−	+	−	−	+	+	−	+	+	+	−	0	+	−	+	+	−
		N 45° E—S 45° W			−	+	−	+	−	+	+	−	+	−	+	−	+	−	−	+	+	−	+	−	+	−	−
Seismic Activity		N			−	+	−	−	0	0	+	−	+	−	−	+	−	+	−	0	0	0	0	0	0	0	0
		NE			+	−	−	+	−	+	+	−	+	+	−	−	−	+	−	−	+	−	−	+	+	−	−
		E			−	0	+	+	−	0	+	−	+	−	+	−	−	+	−	+	−	−	+	−	+	−	−
		SE			+	+	−	−	+	−	+	−	−	0	0	+	+	−	0	+	−	0	+	−	0	0	0
		S			0	0	0	+	+	−	−	+	−	+	−	+	−	0	0	+	−	−	−	+	+	−	0
		SW			+	−	+	−	0	+	−	0	+	+	−	0	0	0	+	+	−	0	+	−	−	0	0
		W			−	0	+	−	−	+	−	0	+	−	+	−	−	−	0	+	−	0	0	0	+	−	0
		NW			0	0	+	−	+	−	0	0	0	0	+	−	−	+	−	+	−	0	0	0	0	+	−
		Total			+	−	+	−	−	−	+	−	+	−	−	−	−	+	−	+	−	−	+	−	+	−	−
		NW+N+NE			+	−	−	+	−	−	+	−	+	+	−	+	−	+	−	+	−	−	−	+	+	+	−
		EN+E+ES			+	−	−	+	−	−	+	−	+	−	−	−	−	+	−	+	−	−	+	−	+	−	−
		SE+S+SW			+	−	−	−	+	−	+	−	+	+	−	+	+	−	+	+	−	−	+	0	+	−	0
		WN+W+WS			−	−	+	−	+	+	−	0	+	+	−	−	−	+	+	+	−	0	+	−	+	+	−
		N+NE			+	−	−	+	−	+	+	−	+	+	−	+	−	+	−	−	+	−	−	+	+	−	−
		NE+E			+	−	+	+	−	−	+	−	+	−	−	−	−	+	−	−	−	−	+	−	+	−	−
		E+ES			+	+	−	−	−	−	+	−	+	−	+	+	−	+	−	+	−	−	+	−	+	−	−
		SE+S			+	+	−	+	+	−	+	−	−	+	−	+	+	−	0	+	−	−	+	+	+	−	0
		S+SW			+	−	+	−	+	+	−	+	+	+	−	+	−	0	+	+	−	−	+	+	+	−	0
		SW+W			−	−	+	−	0	+	−	0	+	+	−	−	−	−	+	+	−	0	+	−	+	−	0
		W+WN			−	0	+	−	+	−	−	0	+	−	+	−	−	+	−	+	−	0	0	0	+	+	−
		WN+N			−	+	+	−	+	−	+	−	+	−	−	+	−	+	−	+	−	0	0	0	0	+	−

tance from this place, it is necessary to begin by arranging the earthquake data for this purpose. From the earthquake reports published monthly by the Central Meteorological Observatory, we selected 230 earthquakes that occurred within a radius of 150 km from Mitaka from the time of the first base line measurement to that of the last, and which were strong enough to be classed in the reports as "conspicuous" and "rather conspicuous".

In view of the anticipation that the closeness of the relation to be sought, if any at all, might eventually depend on the magnitude of the earthquake as well as on its distance from Mitaka, a suitable weight must be given to each earthquake in order to obtain a measure of the general seismic activity that suits the present purpose. Accordingly, weights 2 and 1 were given to "conspicuous" and "rather conspicuous" earthquakes respectively and weights 3, 2, and 1 were given to each of them according as it occurred within 50, 100, or 150 km from Mitaka. Thus a "conspicuous" earthquake that occurred within 50 km from Mitaka was given a weight 6, while a "rather conspicuous" earthquake that occurred between 100 and 150 km from the same place was given a weight 1. No attention was paid to the depths of the earthquakes. Table IX gives the seismic activities in various directions from Mitaka in terms of the measure just defined, while Table X gives the mean monthly seismic activities during various intervals. In Table VIII, the plus or minus sign indicates whether the mean monthly seismic activity during the interval between any two base line measurements has increased or decreased as compared with that during the one preceding it.

Since the relation between the strain of the ground at Mitaka and the seismic activity near that place, if it exists at all, is expected to be a qualitative one, comparison of the increase or decrease of these two quantities will be sufficient to show the essential feature of the suspected relation, a detailed quantitative study being scarcely necessary for the purpose.

If a certain quantity related to deformation of the ground varies in parallel with the seismic activity in a certain direction from Mitaka, then the plus and minus signs in the two corresponding rows of Table VIII must occur in like sequence. Thus, of the total number of pairs in which the algebraic signs in the rows can be compared, there will be more pairs with same signs than those with opposite signs. In the reverse case in which the two quantities that are compared vary in opposite sense, there are likely to be more pairs with opposite signs than those with same signs. The ratio

Table IX. Seismicity near Mitaka.

	Octant								Total	NW +N +NE	EN +E +ES	SE +S +SW	WN +W +WS	N+ NE	NE +E	E+ SE	SE +S	S+ SW	SW +W	W+ WN	WN +N
	N	NE	E	SE	S	SW	W	NW													
(1)	2	7	1				3		13	9	8	0	3	9	8	1	0	0	3	3	2
(2)		14		8		1			23	14	22	9	1	14	14	8	8	1	1	0	0
(3)	2	2		4					8	4	6	4	0	4	2	4	4	0	0	0	2
(4)	2	3	4	3		3	4	3	22	8	10	6	10	5	7	7	3	3	7	7	5
(5)		13	7	3	2		1		26	13	23	5	1	13	20	10	5	2	1	1	0
(6)		3	1	4	3			4	15	7	8	7	4	3	8	5	7	3	0	4	4
(7)		6			3	2	3		14	6	6	5	5	6	6	0	3	5	5	3	0
(8)	3	18	3	11					35	21	32	11	0	21	21	14	11	0	0	0	3
(9)	1	10	2	3	3				19	11	15	6	0	11	12	5	6	3	0	0	1
(10)	3	3	3			10	4		23	6	6	10	14	6	6	3	0	10	14	4	3
(11)	3	9			2	27	3		34	12	9	29	30	12	9	0	2	29	30	3	3
(12)		14	4				8	3	29	17	18	0	11	14	18	4	0	0	8	11	3
(13)	6	31	9	3	3		6	6	64	43	43	6	12	37	40	12	6	3	6	12	12
(14)		18	1	10			1	3	33	21	29	10	4	18	19	11	10	0	1	4	3
(15)	3	12	7					3	25	18	19	0	3	15	19	7	0	0	0	3	6
(16)		5				6			11	5	5	6	6	5	5	0	0	6	6	0	0
(17)		2	5	3	3	26	4	9	52	11	10	32	39	2	7	8	6	29	30	13	9
(18)		4	1		4				9	4	5	4	0	4	5	1	4	4	0	0	0
(19)		1			1				2	1	1	1	0	1	1	0	1	1	0	0	0
(20)			2	2		2			6	0	4	4	2	0	2	4	2	2	2	0	0
(21)		1			3	1			5	1	1	4	1	1	1	0	3	4	1	0	0
(22)		5	3		4		1		13	5	8	4	1	5	8	3	4	4	1	1	0
(23)		3	1					4	8	7	4	0	4	3	4	1	0	0	0	4	4
(24)									0	0	0	0	0	0	0	0	0	0	0	0	0
(25)																					

Table X. Monthly Rate of Seismic Activity near Mitaka.

	Octant								Total	NW +N +NE	EN +E +ES	SE +E +SW	WN +W +WS	N+ NE	NE +E	E+ SE	SE +S	S+ SW	SW +W	W+ WN	WN +N
	N	NE	E	SE	S	SW	W	NW													
(1)	0·24	0·84	0·12				0·36		1·56	1·08	0·96	0	0·36	1·08	0·96	0·12	0	0	0·36	0·36	0·24
(2)		1·77		1·01		0·12			2·91	1·77	2·78	1·13	0·12	1·77	1·77	1·01	1·01	0·12	0·12	0	0
(3)	0·53	0·53		1·06					2·12	1·06	1·59	1·06	0	1·06	0·53	1·06	1·06	0	0	0	0·53
(4)	0·23	0·35	0·47	0·35		0·35	0·47	0·35	2·61	0·94	1·18	0·71	1·18	0·59	0·83	0·83	0·35	0·35	0·83	0·83	0·59
(5)		0·95	0·51	0·22	0·14		0·07		1·90	0·95	1·68	0·36	0·07	0·95	1·46	0·73	0·36	0·14	0·07	0·07	0
(6)		0·26	0·08	0·35	0·26			0·35	1·31	0·61	0·70	0·61	0·35	0·26	0·70	0·43	0·61	0·26	0	0·35	0·35
(7)		0·52			0·26	0·17	0·26		1·22	0·52	0·52	0·43	0·43	0·52	0·52	0	0·26	0·43	0·43	0·26	0
(8)	0·25	1·50	0·25	0·91					2·91	1·75	2·66	0·91	0	1·75	1·75	1·16	0·91	0	0	0	0·25
(9)	0·10	1·00	0·20	0·30	0·30				1·91	1·10	1·51	0·60	0	1·10	1·20	0·50	0·60	0·30	0	0	0·10
(10)	1·87	1·87	1·87			6·25	2·50		14·37	3·75	3·75	6·25	8·75	3·75	3·75	1·87	0	6·25	8·75	2·50	1·87
(11)	0·94	2·83			0·63	8·51	0·94		10·72	3·78	2·83	9·14	9·46	3·78	2·83	0	0·63	9·14	9·46	0·94	0·94
(12)		2·14	0·61				1·22	0·45	4·44	2·60	2·75	0	1·68	2·14	2·75	0·61	0	0	1·22	1·68	0·45
(13)	0·37	1·92	0·56	0·18	0·18		0·37	0·37	3·98	2·67	2·67	0·37	0·74	2·30	2·48	0·74	0·37	0·18	0·37	0·74	0·74
(14)		0·75	0·04	0·41			0·04	0·12	1·37	0·87	1·21	0·41	0·16	0·75	0·79	0·45	0·41	0	0·04	0·16	0·12
(15)	0·19	0·79	0·46					0·19	1·65	1·19	1·25	0	0·19	0·99	1·25	0·46	0	0	0	0·19	0·39
(16)		0·46				0·55			1·01	0·46	0·46	0·55	0·55	0·46	0·46	0	0	0·55	0·55	0	0
(17)		0·10	0·25	0·15	0·15	1·31	0·20	0·45	2·63	0·55	0·50	1·62	1·97	0·10	0·35	0·40	0·30	1·47	1·52	0·65	0·45
(18)		0·14	0·03		0·14				0·31	0·14	0·17	0·14	0	0·14	0·17	0·03	0·14	0·14	0	0	0
(19)		0·09			0·09				0·19	0·09	0·09	0·09	0	0·09	0·09	0	0·09	0·09	0	0	0
(20)			0·16	0·16		0·16			0·50	0	0·33	0·33	0·16	0	0·16	0·33	0·16	0·16	0·16	0	0
(21)		0·08			0·25	0·08			0·41	0·08	0·08	0·33	0·08	0·08	0·08	0	0·25	0·33	0·08	0	0
(22)		0·44	0·26		0·35		0·08		1·16	0·44	0·71	0·35	0·08	0·44	0·71	0·26	0·35	0·35	0·08	0·08	0
(23)		0·24	0·08					0·32	0·64	0·56	0·32	0	0·32	0·24	0·32	0·08	0	0	0	0·32	0·32
(24)									0	0	0	0	0	0	0	0	0	0	0	0	0
(25)																					

$$r=\frac{\text{the number of pairs with same signs}}{\text{total number of pairs}}$$

may therefore be taken as a measure of the closeness of the suspected relation. If it is 1·0, the relation between the two quantities is closely positive, and if it is 0, then the relation is closely negative.

To illustrate, the increase and decrease in pure shear of the ground at Mitaka along a NS direction and those of seismic activity in the eastern octant are:

Pure Shear + − + − − + − − + − + − − + − + − − + − + + −
Seismic Activity − 0 + + − 0 + − + − + − − + − + − − + − + − −.

There are altogether 21 pairs, of which 17 have same signs, giving the ratio $r=0{\cdot}81$.

Now if the plus and minus signs in any two rows that are compared occur with perfect haphazard, then the probability that out of the total m pairs, n will have same (or opposite) signs is

$$p=\frac{m!}{(m-n)!\ n!}\left(\frac{1}{2}\right)^m,$$

and the probability that more than n pairs will have same (or opposite) signs is

$$P=\sum_{n=0}^{n}\frac{m!}{(m-n)!\ n!}\left(\frac{1}{2}\right)^m.$$

In our present example, the probability that the total 21 pairs will be grouped into 17 and 4 with respect to sign, as is actually the case, is

$$p=0{\cdot}003,$$

while the probability that they will be grouped more unevenly than this is

$$P=0{\cdot}007.$$

Judging from the smallness of this probability, the relation between the simple shear along the NS direction and the seismic activity in the E octant is very likely real.

In Table XI will be found the probabilities P for various pairs of strains of the ground and the seismic activity. Judging from the smallness of the probabilities, the relation between the following pairs of quantities are too striking to be put aside as merely fortuitous:

(1) Pure shear along the NS direction and the seismic activity in directions east and west of Mitaka,

(2) Contraction of the ground along the NS direction and the

Table XI. Probability P. (in 10^{-3}).

		Dil.	Max. shear	γ_1	γ_2	Elongation				Pure shear		
						E—W	E 45° N —S 45° W	N—S	N 45° W —S 45° E	N—S	N 45° W —S 45° E	N 45° E —S 45° W
Octant	N	24	1·000	94	94	268	24	94	94	1·000	582	582
	NE	93	93	286	405	1·000	134	405	405	678	134	405
	E	383	189	115	383	383	503	383	78	7	824	7
	SE	804	77	607	454	454	454	1·000	804	804	804	804
	S	143	1·000	21	629	1·000	143	13	13	332	804	143
	SW	607	1·000	424	1·000	1·000	607	1·000	607	118	118	302
	W	454	804	210	210	210	454	804	210	21	454	210
	NW	582	268	1·000	1·000	582	388	268	1·000	24	94	582
	Total	405	1·000	523	405	405	523	405	405	260	523	405
	NW+N+NE	1·000	678	523	1·000	405	832	210	210	210	832	1·000
	EN+E+ES	405	1·000	523	405	1·000	523	405	405	35	1·000	93
	SE+S+SW	664	1·000	503	664	664	664	1·000	664	1·000	1·000	1·000
	WN+W+WS	664	1·000	824	383	78	824	664	664	27	27	664
	N+NE	210	35	523	678	1·000	286	678	678	1·000	286	678
	NE+E	405	405	523	405	405	523	405	405	35	1·000	405
	E+ES	405	1·000	134	405	1·000	523	405	93	35	523	93
	ES+S	405	1·000	115	189	189	189	664	189	189	503	664
	S+SW	383	383	263	1·000	664	383	383	383	383	41	189
	SW+W	648	648	815	359	167	648	648	648	167	359	1·000
	W+NW	1·000	481	815	815	·238	359	815	815	8	96	1·000
	NW+N	648	648	1·000	648	167	648	1·000	1·000	359	648	1·000

seismic activity in direction north of Mitaka,

(3) Elongation of the ground along the NS direction and the seismic activity in direction south of Mitaka.

These systematic correlations between the deformation of the ground and the seismic activity must at any rate be some indication of the geophysical characteristics of the earth's crust near Mitaka, or even more widely, that of the Kwanto district in which Mitaka is situated—characteristics that may have an important connection with the nature of occurrence of the earthquakes that originate in this district.

On the other hand, the geographical distribution of "push" and "pull" of the first impulsion of an earthquake has been known to serve as an important clue to the mechanism of its occurrence. Moreover, it is generally accepted that the earthquakes originating from one and the same region are mostly due to the same mechanism of occurrence. In fact, T. Fukutomi(5) and F. Kishinouye(6) were able to divide the Kwanto district into a few regions according to the particular ways in which most of the earthquakes originating in them differed the one from the other.

In connection with this problem, M. Ishimoto(7) suggested that the "push" and "pull" of the first impulsion of an earthquake and the permanent deformation of the ground that accompanies that earthquake show the same geographical distribution, the "push" corresponding to to the region of upheaval and the "pull" to that of sudsidence.

If the conclusions reached by these investigators are accepted, the relations that have been pointed out in the present paper to exist between the deformation of the ground and seismic activity seem only very natural consequences, although it does not follow from it that to draw a simple picture of the nature of occurrence of earthquakes in the Kwanto district that would square with all these facts and theories just mentioned will be anything like an easy task.

Leaving these discussions to a later opportunity, this paper is merely an attempt to describe the striking relations that obtain between the deformation of the ground at Mitaka and the general seismic activity near that place.

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(5) T. Fukutomi, *Disin*, **3** (1931), 592. *Bull. Earthq. Res. Inst.*, **9** (1931), 510.

(6) F. Kishinouye, *Disin*, **4** (1932), 18.

(7) M. Ishimoto, *Bull. Earthq. Res. Inst.*, **11** (1933), 254.

34. 三鷹基線菱形の變形と其の附近に於ける地震活動

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三鷹東京天文臺構内に於ける菱形基線の長さは大正5年以來昭和14年迄に25回測定されてゐる．まづ夫等の邊長の變化から此の土地の變形を求めた．

次に同じ期間内に三鷹を中心として150 km 以内の距離に起つた顯著及稍顯著地震を氣象要覽から拾ひ出し，顯著地震には 2，稍顯著地震には 1 といふ重みを，又 50 km 以内に起つた地震には 3，100 km 以内のものには 2，150 km 以内のものには 1 と云ふ重みを附して，三鷹から見た各方向に於ける地震活動を求めた．

かくして求められた土地の變形と，地震活動の消長を較べて，次の如き關係があるを見出した．

(1)　東又は西に地震が多くなると，南北方向に沿つた土地の Shear の速度が大きくなる．

(2)　北に地震が多くなると，南北方向に於ける土地の短縮の速度が大きくなる．

(3)　南に地震が多くなると，南北方向に於ける土地の伸張の速度が大きくなる．