39. *Comparison of the Modes of the Vertical Deformations of the Earth's Crust in the Same District during Different Time Intervals.*

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If a levelling route in a certain district is covered by precise levelling more than thrice in a certain interval of time, we can, by the results of these surveys, compare the modes of the vertical deformations of the earth's crust in the district for at least two different time intervals and in this way we can get informations regarding whether the deformation of the earth's crust in the district is ever going on in one same direction, or goes forward or backward alternately, or gradually changes in its mode, etc. In the present paper, the writer is going to give a few examples of such comparisons, basing solely on the results of measurements obtained recently in our country.

The Case of Positive Correlation.

The case to be mentioned first is that in which the crust deformations in defferent intervals are in a positive correlation. The deformation of the earth's crust found in the Tango district is a typical example of this. Connected with the Tango destructive earthquake of 1927, precise levelling has been repeated five times after the earthquake over the Tango district by

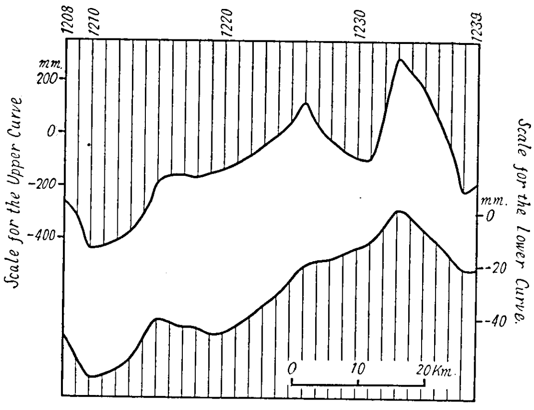

Fig. 1. Overrupping Means of the Change of Height of the Bench Marks in the Tango District at the Time of (Upper Curve) and After (Lower Curve) the Tango Earthquake of 1927.

the experts of the Military Land Survey at the request of the director of our Institute. The results of these surveys were given and discussed in detail in the writer's previous papers[1]. The vertical displacements of the beuch marks in the district that were produced at the time of and after the earthquake are given in Table I, together with their overrupping means. They are in a very close positive correlation as the curves in Fig. 1 show. This is made still clearer by the correlation diagram for the observed values which is given in Fig. 2. The correlation becomes still closer if the overrupping mean values are taken as in Fig. 3. This positive correlation would seem to indicate that the crust deformation at the time of the earthquake did not just match the agency by which it was caused and was somewhat insufficient in its amount.

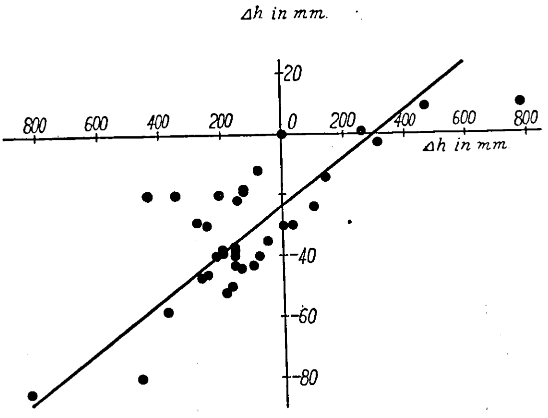

Fig. 2. Correlation Diagram for the Measured Change of Height of the Bench Marks in the Tango District at the Time of (Abscissa) and After (Ordinate) the Tango Earthqake of 1927.

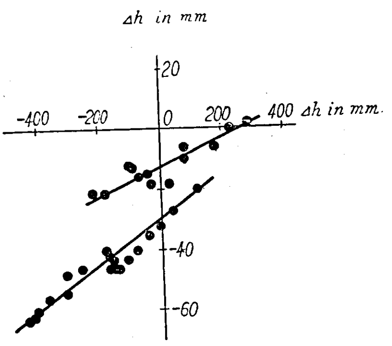

Fig. 3. Correlation Diagram for the Overrupping Means of the Change of Height of the Bench Marks in the Tango District at the Time of (Abscissa) and After (Ordinate) the Tango Earthquake of 1927.

Another example of positive correlation is given by the vertical deformation of the earth's crust along the levelling route from Okitu

1) C. Tsuboi, *Bull. Earthq. Res. Inst.*, 6 (1929), 71 ; 8 (1930), 153 ; 9 (1931), 423.

Table I. Change of Height of the Bench Marks in the Tango District at the Time of and After the Tango Distructive Earthquake of 1927.

B.M.	The Change of Height at the Time of the Earthquake.	Overrupping Mean	Total Change of Height after the Earthquake	Overrupping Mean.
	mm			
1206	−197·0		−37·7	
1307	−196·0		−39·1	
1208	−254·2	−257·8	−46·1	−45·7
1209	−266·3	−311·9	−47·2	−54·1
1210	−375·3	−439·2	−58·3	−63·2
1211	−467·7	−432·7	−79·6	−61·9
1212	−832·3	−414·3	−84·9	−60·1
1213	−221·9	−371·7	−39·7	−55·8
1214	−174·3	−310·7	−37·9	−47·9
1215	−162·2	−175·5	−37·0	−39·5
1216	−162·9	−165·9	−40·1	−41·5
1217	−156·3	−159·3	−42·7	−42·8
1218	−173·8	−165·9	−49·7	−42·7
1219	−141·5	−151·4	−44·3	−46·2
1220	−194 9	−137·0	−51·7	−45·6
1221	− 90·6	−113·2	−42·6	−42·6
1222	− 84·3	− 84·4	−39·5	−39·7
1223	− 54·6	− 39·1	−34·8	−35·3
1224	+ 2·2	− 0·9	−29·9	−31·6
1225	+ 31·7	+ 43·0	−29·6	−26·5
1226	+100·3	+115·5	−24·2	−20·2
1227	+135·4	+ 26·9	−14·1	−18·2
1228	+308·1	− 30·0	− 3·1	−18·3
1229	−441·0	− 65·3	−20·2	−15·9
1230	−252·8	− 92·4	−29·9	−13·1
1231	− 76·4	−101·4	−12·2	−12·2
1232	0	+ 80·5	0	− 6·4
1233	+263·4	+238·0	+ 1·4	+ 1·5
1234	+468·2	+232·6	+ 8·5	− 0·2
1235	+784·8	+177·1	+ 9·6	− 5 9
1236	−353·0	+ 82·3	−20·3	−10·1
1237	−277·7	− 37·0	−28·6	−15·4
1238	−210 7	−219·5	−19·9	−21·0
1239	−128·6	−179·2	−17·8	−21.4
1240	−127·3		−18·9	
1241	−151·8		−21.7	

to Kôhu which is shown in Fig. 4. The change of height of the bench marks[2] on the route for different time intervals is given in Table II and graphically in Fig. 5.

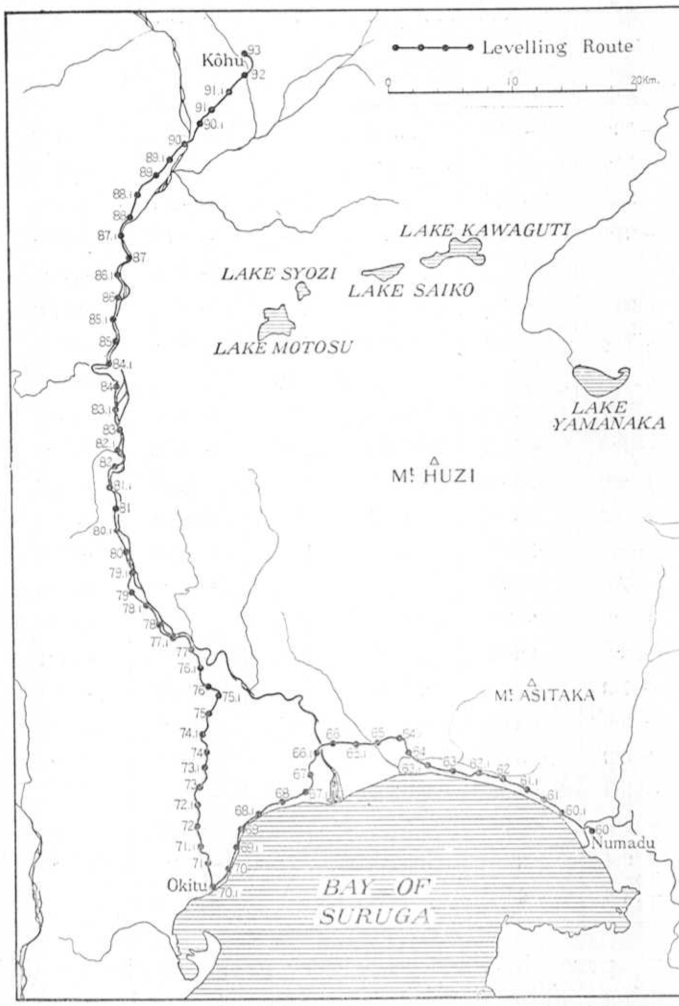

Fig. 4. Levelling Route from Okitu to Kôhu.

2) THE IMPERIAL JAPANESE MILITARY LAND SURVEY, *Bull. Imp. Earthq. Inv. Comm.*, **11** (1930); "*Change of Heights of the Bench Marks in the Meizoseismal Area of the Kwanto Great Earthquake of 1923,*" (1930).

Table II. Change of Height of the Bench Marks on the Levelling Route from Okitu to Kôhu, during Different Time Intervals.

A............(1925–1895)
B............(1931–1925)
C............$\{A+2{\cdot}34\,n+12{\cdot}2\}$

B.M.	A	B	C	B.M.	A	B	C
93	mm −32·9	−14·8	−20·7	81	—	+26·2	—
92	−31·4	—	−16·9	80·1	− 18·3	+25·0	+50·1
91·1	−33·7	− 2·1	−16·8	80	− 48·3	+23·6	+22·4
91	−21·9	+ 2·8	− 2·7	79·1	− 67·3	+18·3	+ 5·7
90·1	—	—	—	79	− 58·5	+18·8	+16·9
90	−29·3	+ 1·5	− 5·4	78·1	− 63·8	+13·8	+13·9
89·1	−50·8	+10·8	−24·6	78	− 80 4	+ 8·6	− 0·3
89	—	—	—	77·1	—	+ 9·9	—
88·1	− 6·7	+14·0	+24·2	77	− 90·9	+ 5·9	− 6·2
88	+ 3·3	+17·2	+36·6	76·1	− 97·2	+ 4·9	−10·1
87·1	+ 9·0	+18·0	+44·6	76	−101·4	− 0·7	−12·0
87	+ 9·8	+23·6	+47·7	75·1	−102·3	+ 5·5	−10·5
86·1	—	+30·7	—	75	− 90·8	+10·8	+ 3·3
86	− 7·6	+22·4	+35·0	74·1	− 93·9	+ 8·8	+ 2·5
85·1	+ 6·9	+27·0	+51·9	74	− 89·8	+ 8·0	+ 9·0
85	+ 2·0	+28·1	+49·3	73·1	− 91·4	+ 6·1	+ 9·7
84·1	+ 7·2	+28·6	+56·8	73	− 95·1	− 2·9	+ 8·4
84	+ 3·0	+29·5	+55·0	72·1	−106·5	− 3·3	− 0·7
83·1	+ 0·2	+33·4	+54·5	72	−110 0	+ 3·6	− 1·9
83	− 8·9	+32·9	+47·8	71·1	−119·2	− 8·3	− 8·7
82·1	− 7·1	+26·6	+51·9	71	−114·5	− 4·3	− 1·7
82	−10·4	+25·6	+50·9	70·1	−111·8	− 6·3	+ 3·4
81·1	−12·8	+29·4	+50·9				

The two curves in Fig. 5 are very much similar in their forms with each other; more precisely, the curve A may be regarded as one which is obtained by the superposition of a linear southward tilting of the earth's crust and the variation that is similar to the curve B. Thus the curve A can be expressed by the equation,

$$A=an+b+kB,$$

where n is the ordinal number of the bench mark counted from the

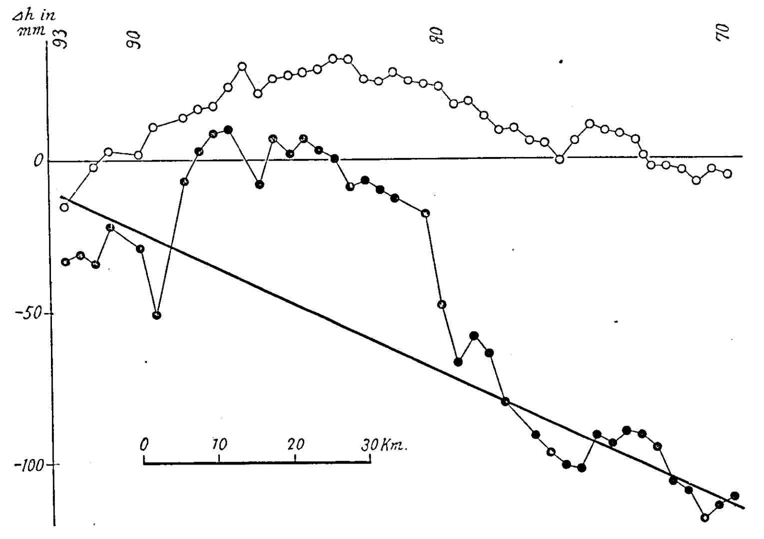

Fig. 5. Change of Height of the Bench Marks on the Route from Okitu to Kôhu.

A ●...............(1925)-(1895)

B ○...............(1931)-(1925)

north end of the route and a, b and k are numerical constants to be determined by the method of least square. The result of the calculation gave

$$a = -\ 2{\cdot}34,$$
$$b = -12{\cdot}2,$$
$$k = \ 1{\cdot}41,$$

thus we have,

$$A = -2{\cdot}34\,n - 12{\cdot}2 + 1{\cdot}41\,B.$$

We can thus expect a close positive correlation between $\{A + 2{\cdot}34\,n + 12{\cdot}2\}$ and B, the values of which being already given in Table II. This is actually the case as the correlation diagram in Fig. 6 indicates.

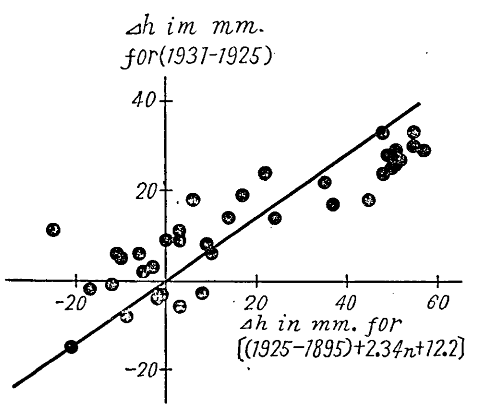

Fig. 6. Correlation Diagram for C [(1925–1895) + 2·34 n + 12·2] and B (1931–1925).

The Case of Negative Correlation.

As the complementary phenomena of what was described in the preceding paragraph, there have been found cases in which the crust deformations during different intervals are negatively correlated with each other. Good examples of this are given by the crust deformation produced at the time of and after the Kwanto destructive earthquake of 1923 in its meizoseismal area. The negative correlation is especially clear for the deformation along the levelling routes along the Sagami Bay coast and around Boso Peninsula. The change of height of the bench marks[3] on the route shown in Fig. 7 along the Sagami Bay coast is given in Table III and graphically in

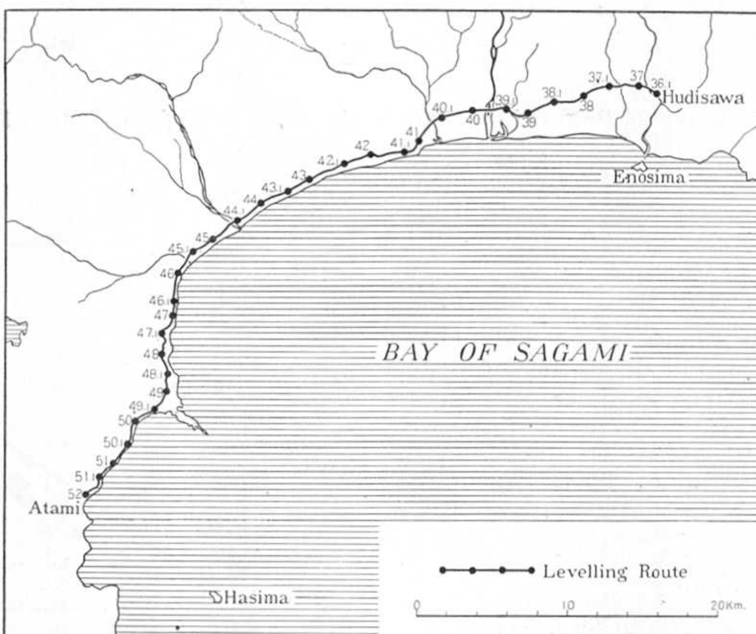

Fig. 7. Levelling Route from Hudisawa to Atami along the Sagami Bay Coast.

3) The Imperial Japanese Military Land Survey, *Bull. Imp. Earthq. Inv. Comm.*, 11 (1930); "*The Results of Precise Levellings executed in the Interval from Feb. 1930 to March 1931*," (1931).

Table III. Change of Height of the Bench Marks on the Route from Hudisawa to Atami at the time of and after the Kwanto Destructive Earthquake of 1928.

B.M.	Change of Height at the Time of the Earthquake.	Overrupping Means.	Total Change of Height After the Earthquake.	Overrupping Means.
52	+ 43·5		+72·1	
51·1	+ 41·5		+94·5	
51	—	+ 87·8	—	+83·9
50·1	—	+ 263·1	—	+63·9
50	+ 178·3	+ 472·5	+65·0	+45·7
49·1	+ 569·5	+ 539·1	+62·3	+44·7
49	+ 669·8	+ 539·1	+39·9	+44·7
48·1	+ 738·9	+ 659·4	+41·4	+37·9
48	—	+ 867·6	—	+40·3
47·1	—	+ 966·5	—	+40·7
47	+1194·1	+1098 3	+40·1	+26·9
46·1	—	+1113·3	—	+26·9
46	+1002·6	+1207·8	+13·8	+ 1·0
45·1	+1143·2	+1344·1	—	−28·2
45	+1491·5	+1438·5	−51·0	−37·5
44·1	+1739·2	+1620·3	−47·5	−54·0
44	+1815·9	+1780·7	−65·4	−54·6
43·1	+1911·5	+1862·3	−52·3	−59·5
43	+1945·3	+1878·4	−56·8	−61·2
42·1	+1899·6	+1865·4	−75·5	−56·7
42	+1819·5	+1807·5	−55·8	−54·6
41·1	+1751·2	+1688·6	−42·9	−53·0
41	+1622 1	+1546·6	−42·2	−46·1
40·1	+1350·6	+1355·8	−48·4	−49·5
40	+1189·7	+1202·6	−41·1	−51·1
39·1	+ 865·5	+1046·2	−72·7	−48·5
39	+ 985·0	+ 927·0	—	−42·8
38·1	+ 840·2	+ 832·3	−31·9	−36·6
38	+ 754·6	+ 824·0	−25·5	−24·6
37·1	+ 716·3	+ 734·3	−16·5	−23·4
37	—		—	
36·1	+ 626·1		−19·7	

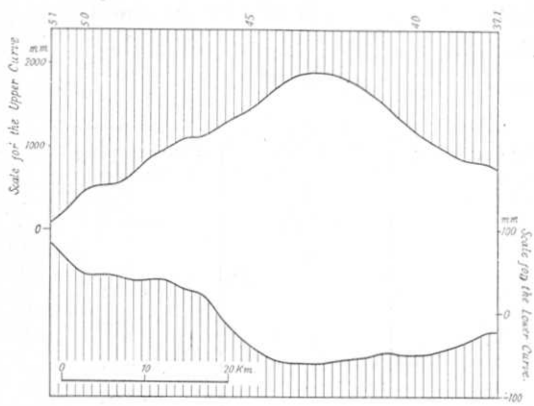

Fig. 8. Overrupping Means of the Change of Height of the Bench Marks on the Route from Hudisawa to Atami at the Time of (Upper Curve) and After (Lower Curve) the Kwantô Earthquake of 1923.

Fig. 8. In Fig. 9 is shown the correlation diagram for the overrupping mean values. As these figures clearly indicate, the correlation between the crust deformations in this district during different time intervals is closely negative. This indicates that the crust deformation after the earthquake of 1923 has been such that to recover what was produced at the time of the earthquake, this being in a remarkable contrast with the case of the Tango earthquake.

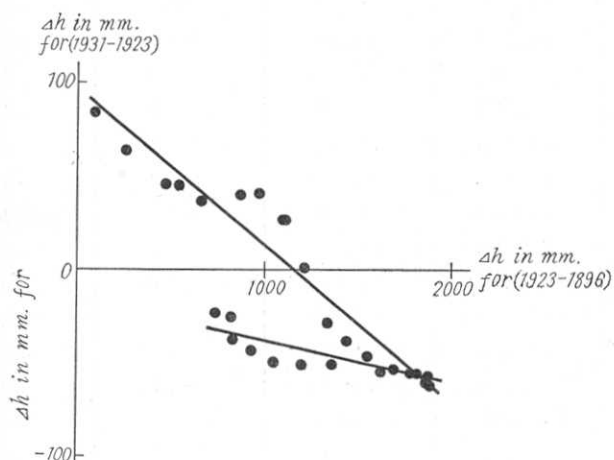

Fig. 9. Correlation Diagram for the Overrupping Means of the Change of Height of the Bench Marks on the Route from Hudisawa to Atami at the Time of (Abscissa) and After (Ordinate) the Kwantô Earthquake of 1923.

The crust deformations in Boso Peninsula at the time of and after the earthquake of 1923 are also in a close negative correlation, as the curves in Fig. 10 show. This has already been pointed out by N. Miyabe.[4] The correlation diagram in Fig. 11 for the overrupping means of the

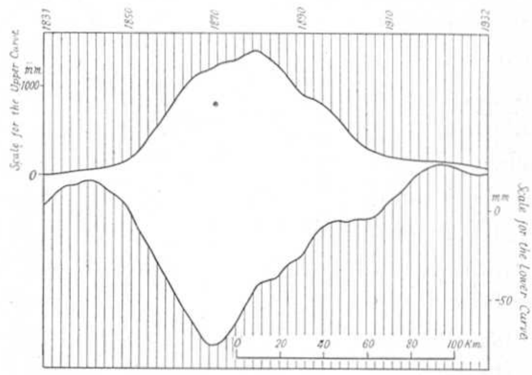

Fig. 10. Overrupping Means of the Change of Height of the Bench Marks on the Route around Boso Peninsula at the Time of (Upper Curve) and After (Lower Curve) the Kwantô Earthquake of 1923.

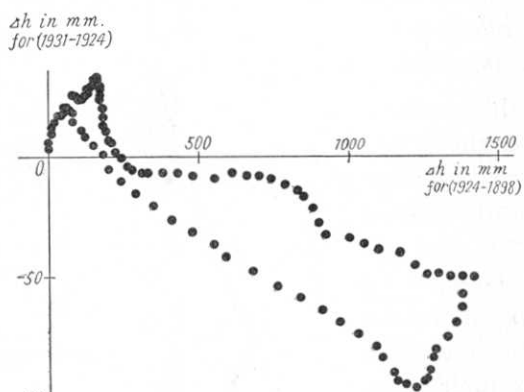

Fig. 11. Correlation Diagram for the Overrupping Means of the Change of Height of the Bench Marks on the Route around Boso Peninsula at the Time of (Abscissa) and After (Ordinate) the Kwantô Earthquake of 1923.

4) N. Miyabe, *Bull. Earthq. Res. Inst.*, 1 (1931), 407.

change of height of the bench marks in the peninsula, however, suggests that in some parts of the peninsula they are positively correlated while in other parts negatively. The points in the figure are arranged on a number of segments of straight line which incline either right hand high or left hand high corresponding respectively to positive and negative correlations. The boundaries of the regions of positive and negative correlations seem to be closely connected with the geological structure of the peninsula.

The Region of Positive and Negative Correlations Situated Side by Side.

The remarkable example of this is seen in the deformation of the earth's crust in Noto Peninsula which projects into the Sea of Japan.[5] The change of height of the bench marks on the route shown in Fig. 12 together with their overrupping means are given in Table IV and graphically in Fig. 13.

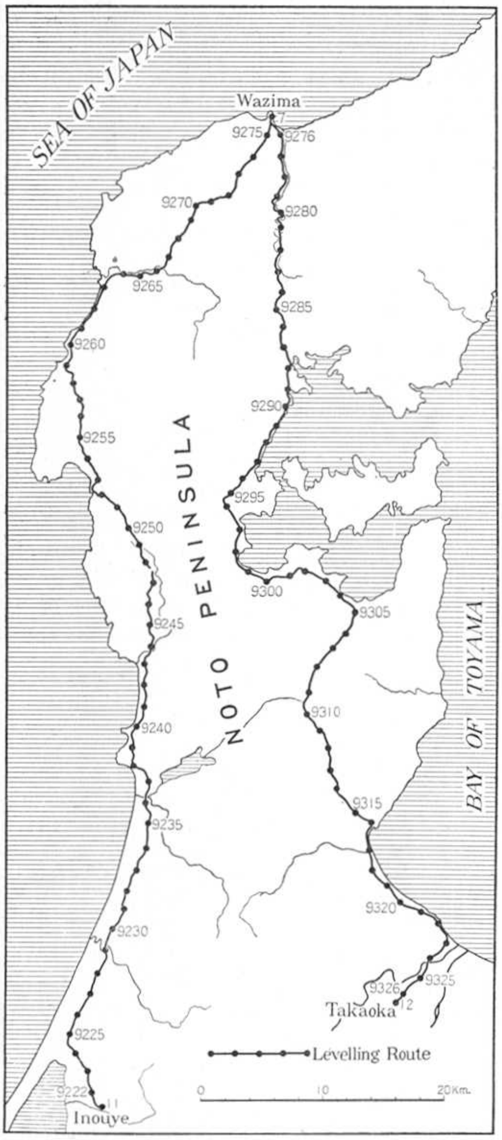

Fig. 12. Levelling Route around Noto Peninsula.

5) A. IMAMURA, *Pub. Earthq. Inv. Comm.*, 25 (1930).
THE IMPERIAL JAPANESE MILITARY LAND SURVEY, "*Change of Height of the Bench Marks in the Meizoseismal Area of the Tango Earthquake of 1927,*" (1929).

Table IV. Change of Height of the Bench Marks in Noto Peninsula.

B.M.	1919 -1917	O.M.	1928 -1917	O.M.	B.M.	1917 -1900	O.M.	1928 -1917	O.M.
	mm								
11	+ 8·4		-40·0		9249	+ 3·3		-27·4	
							- 1·8		-24·0
9222	+ 4·8		-39·4		9250	+ 8·4		-22·8	
							- 3·0		-21·9
9223	+ 3·4		-39·0		9251	- 6·4		-24·5	
							- 4·8		-20·5
9224	+ 0·9		-46·0		9252	-13·6		-14·9	
							- 6·0		-18·9
9225	—		—		9253	-11·5		-14·4	
		+4·6		-39·4			- 6·4		-17·0
9226	+11·1		-46·4		9254	-11·0		-16·8	
		+2·2		-38·8			- 7·5		-15·8
9227	(-56·0)		—		9255	- 9·2		-13·1	
		+2·6		-38·4			-11·1		-15·2
9228	+ 8·3		-33·9		9256	- 6·9		-14·3	
		+3·0		-37·5			-11·8		-14·1
9229	+10·9		-31·2		9257	- 7·1		-11·6	
		+3·4		-36·0			-11·6		-14·2
9230	- 1·0		—		9258	- 9·8		- 9·9	
		+2·6		-35·6			-12·4		-14·3
9231	-10·4		-36·0		9259	- 7·6		-15·6	
		+2·7		-33·7			-13·0		-14·5
9232	+ 7·4		-36·3		9260	-27·8		-16·5	
		+2·5		-33·4			-13·8		-14·7
9233	+ 7·5		-32·8		9261	-13·8		—	
		+2·4		-32·5			-15·6		-15·6
9234	+ 3·1		-35·4		9262	-11·3		-16·0	
		+2·0		-31·8			-15·9		-16·0
9235	- 3·9		-33·2		9263	-19·9		-15·2	
		+2·8		-31·5			-16·2		-16·4
9236	+ 2·7		-31·1		9264	-16·4		-18·4	
		+3·6		-31·2			-17·5		-15·9
9237	+ 0·8		-31·0		9265	-17·0		-15·1	
		+3·5		-30·7			-16·4		-17·2
9238	+ 6·5		-25·3		9266	-24·9		-21·8	
		+3·8		-30·7			-16·3		-16·9
9239	+ 7·7		-24·9		9267	-10·9		-15·7	
		+3·8		-30·2			-16·2		-16·6
9240	+ 6·9		-29·2		9268	-12·8		-13·4	
		+4·4		-30·3			-14·8		-16·5
9241	- 2·8		-33·2		9269	-20·3		-11·5	
		+5·3		-29·9			-14·0		-16·8
9242	+ 6·8		-30·5		9270	-16·8		-27·4	
		+5·7		-29·6			-14·7		-15·0
9243	+10·6		-33·6		9271	-13·1		-14·0	
		+4·4		-30·0			-12·7		-14·2
9244	+ 2·5		(+0·4)		9272	-10·2		-13·1	
		+4·0		-30·3			-12·0		-13·9
9245	+ 2·3		-33·8		9273	- 6·0		-14·1	
		+4·1		-29·6			-11·7		-14·1
9246	+11·5		-27·9		9274	- 6·9		-21·5	
		+3·8		-28·6			- 9·2		-14·8
9247	+ 4·6		-27·9		9275	-25·5		+ 2·2	
		+1·7		-26·9			- 7·8		-12·5
9248	- 5·8		-29·3		7	- 4·0		-13·0	
		-0·5		-24·8			- 7·1		-12·3

(to be continued.)

Table IV. (*continued.*)

	1921 −1900	O.M.	1928 −1921	O.M.		1921 −1900	O.M.	1928 −1921	O.M.
9276	− 4·1	−5·8	—	−11·5	9302	+13·7	+ 8·2	−27·7	−22·7
9277	− 9·8	−5·9	−14·2	−10·5	9303	+11·1	+ 7·9	−20·8	−21·8
9278	+ 4·8	−5·5	−18·5	− 9·4	9304	+ 8·7	+ 7·5	−23·5	−21·4
9279	− 2·7	−2·3	− 6·6	−10·9	9305	+ 2·7	+ 7·8	−22·3	−21·3
9280	− 6·7	−1·2	−10·9	−10·7	9306	+ 8·1	+ 4·9	−20·2	−21·4
9281	+ 2·8	+0·1	− 6·9	−10·4	9307	+ 5·1	+ 4·3	−20·2	−20·6
9282	− 7·1	+1·2	− 5·4	−10·0	9308	+ 7·0	+ 4·1	−16·1	−20·6
9283	− 2·9	+1·8	−11·5	− 9·0	9309	− 0·2	+ 3·8	−19·8	−18·1
9284	+ 7·1	+0·4	−10·9	−10·1	9310	—	+ 3·9	—	−15·8
9285	+ 6·3	+1·6	−11·2	−10·3	9311	−12·3	+ 3·4	−22·5	−14·4
9286	+ 8·6	+2·1	− 7·8	−10·8	9312	+ 8·9	+ 2·5	—	−13·7
9287	+ 2·2	+3·3	—	−11·4	9313	+ 8·7	+ 2·4	—	−12·9
9288	+10·5	+3·6	− 9·9	−11·6	9314	+ 6·2	+ 0·2	− 5·6	−11·8
9289	−17·3	+3·6	−16·1	−12·4	9315	+ 3·3	0	− 6·7	−12·5
9290	+ 5·6	+4·3	−13·4	−13·5	9316	+ 4·0	− 0·9	−10·1	−11·2
9291	+ 7·8	+3·0	−10·9	−15·6	9317	− 3·1	− 1·9	−15·2	−11·8
9292	+ 5·1	+3·9	−10·5	−16·2	9318	+ 6·2	− 4·5	−10·9	−12·5
9293	+ 0·3	+3·8	−14·0	−17·7	9319	−20·3	− 9·3	—	−13·3
9294	+ 6·8	+5·9	−17·5	−18·5	9320	− 2·0	−12·2	−16·6	−14·2
9295	+13·0	+5·8	−21·0	−19·4	9321	− 2·8	−14·6	−13·2	−14·7
6296	− 4·3	+6·6	−27·1	−20·4	9322	−19·2	−16·5	−16·3	−14·5
9297	+11·0	+7·3	−21·2	−22·1	9323	−19·2		−17·5	
9298	+ 9·6	+8·4	−25·4	−22·8	9324	−39·9		−13·6	
9299	+ 4·0	+8·6	−24·0	−23·4	9325	−25·5		—	
9300	+ 4·6	+7·6	−22·5	−23·6	9326	−19·8		—	
9301	+14·4	+8·8	−21·0	−22·9	12	−22·2		−13·2	

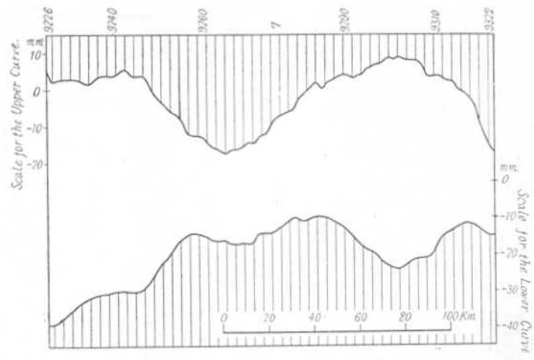

Fig. 13. Overrupping Means of the Change of Height of the Bench Marks on the Route around Noto Peninsula during 1917–1900 (Upper Curve) and 1928–1917 (Lower Curve).

The correlation diagrams of the measured values and their overrupping means are shown in Figs. 14 and 15 respectively. It is an interesting fact that the correlation diagram for the former does not show any clear sign of positive or negative correlation while that for the latter clearly indicates that there are four separate regions in each of which the correlation is negative and positive alternately. The transision from the region of positive correlation to that of negative one is quite distinct.

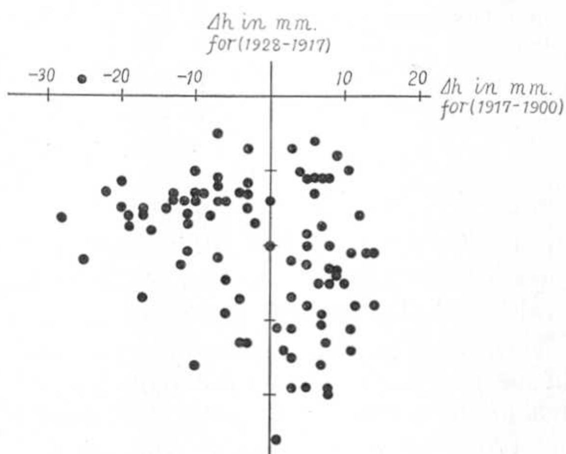

Fig. 14. Correlation Diagram for the Measured Change of Height of the Bench Marks on the Route around Noto Peninsula during 1917–1920 (Abscissa) and 1928–1917 (Ordinate).

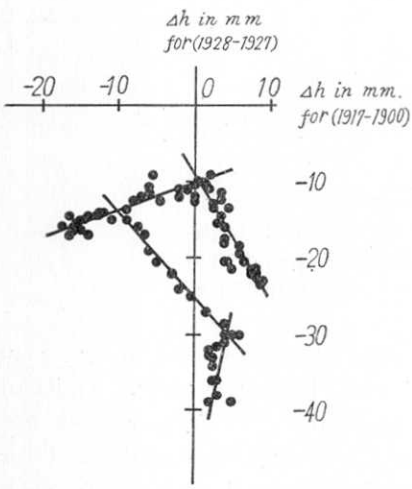

Fig. 15. Correlation Diagram for the Overrupping Means of the Change of Height of the Bench Marks on the Route around Noto Peninsula during 1917–1900 (Abscissa) and 1928–1917 (Ordinate).

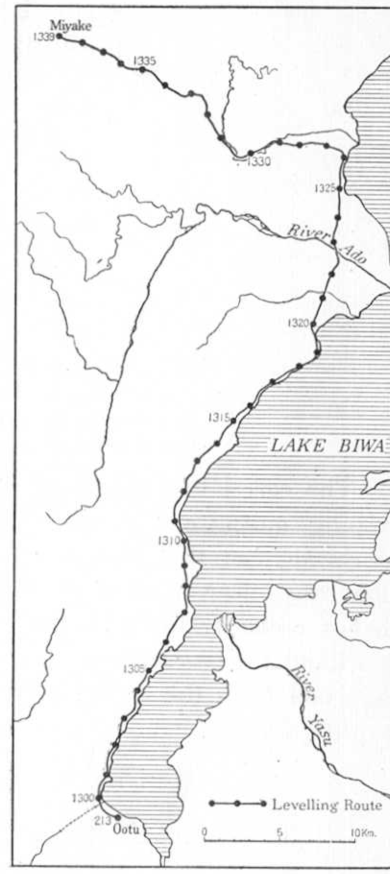

Fig. 16. Levelling Route from Ootu to Miyake.

The vertical deformation of the earth's crust[6] along the route from Ootu to Miyake which is shown in Fig. 16 also belongs to this category. The values of the measurements are given in Table V and graphically shown in Fig. 17. While the crust deformation in the southern half of the route during different interval are negatively correlated, that in the northern half positively. As the curves in Fig. 17 shows, the tilting of land blocks in this district are in opposite

6) A. Imamura, *loc. cit.*
The Imperial Japanese Military Land Survey, "*Change of Height of the Bench Marks in the Meizoseismal Area of the Tango Earthquake of 1927*," (1929).

Table V. Change of Height of the Bench Marks on the Route from Ootu to Miyake.

B.M.	1918 -1888	O.M.	1927 -1818	O.M.	B.M.	1918 -1888	O.M.	1927 -1918	O.M.
213	mm +13·6		−28·7		1320	−6·7	−3·4	−22·6	−23·5
1300	+9·3		−29·7		1321	−10.6	−6·0	−24·1	−23·2
1301	+6·7	+9·4	−23·9	−27·7	1322	−9·0	−7·2	−20·4	−21·1
1302	+5·7	+9·0	−26·4	−26·7	1323	−2·6	−7·4	−17·2	−21·1
1303	+11·7	+8·7	−29·7	−25·6	1324	—	−6·4	—	−20·4
1304	+11·7	+7·9	−23·9	−23·7	1325	−7·4	−3·4	−22·6	−19·7
1305	+7·5	+6·9	−24·3	−23·7	1326	−6·4	−2·0	−21·2	−19·7
1306	+2·9	+6·6	−14·0	−22·4	1327	+3·0	−2·0	−17·6	−19·7
1307	+0·5	+5·0	−26·5	−22·1	1328	+2·9	+3·3	−17·4	−19·6
1308	+10·0	+4·4	−23·4	−21·5	1329	—	+10·5	—	−15·1
1309	+3·8	+4·5	−22·2	−24·0	1330	+13·6	+15·8	−14·0	−13·4
1310	—	+4·6	—	−22·1	1331	+22·6	+21·3	−11·5	−11·9
1311	+3·3	+0·8	−23·8	−20·4	1332	+23·9	+21·3	−10·5	−11·9
1312	+0·9	−1·1	−18·9	−19·6	1333	+25·2	+23·9	−11·4	−11·1
1313	−4·9	−1·4	−16·7	−19·0	1334	—	+25·5	—	−11·1
1314	−3·7	−2·6	−18·8	−17·7	1335	—	+27·5	—	−11·2
1315	−2·4	−3·5	−16·9	−17·4	1336	+27·5	+27·9	−11·5	−11·2
1316	−3·1	−1·9	−17·0	−17·9	1337	+29·7	+28·9	−10·8	−11·0
1317	—	−1·2	—	−21·1	1338	+26·4		−11·4	
1318	+1·8	−2·3	−18·7	−22·5	1339	+32·0		−10·3	
1319	−1·2	−4·2	−31·8	−24·3					

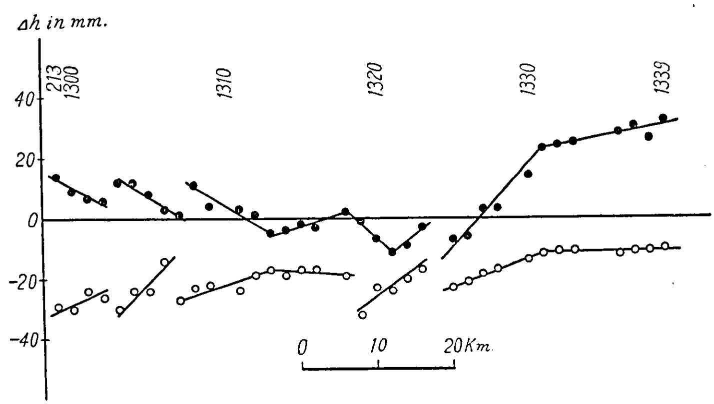

Fig. 17. Change of Height of the Bench Marks on the Route from Ootu to Miyake.
●........(1918-1888) ○........(1927-1918)

sense in the southern half of the route while they are in the same sense in the northern half. This is more clearly indicated by the curves for the overrupping means in Fig. 19. When the correlation diagram for the overrupping means is constructed, we have the diagram shown in Fig. 19. The points in the figure are evidently arranged on two segments of straight line with opposite inclination. The boundary of the two regions of positive and negative correlations lies in the neighbourhood of B. M. 1313.

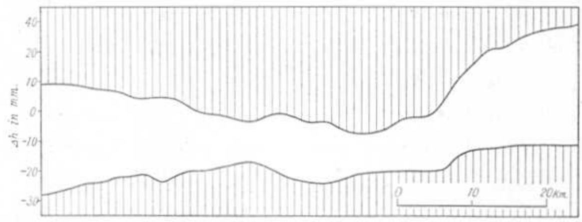

Fig. 18. Overrupping Means of the Change of Height of the Bench Marks on the Route from Ootu to Miyake during 1918-1888 (Upper Curve) and 1927-1918 (Lower Curve).

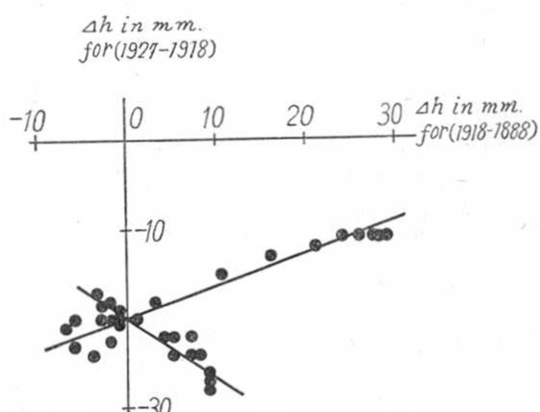

Fig. 19. Correlation Diagram for the Overrupping Means of the Change of Height of the Bench Marks on the Route from Ootu to Miyake during 1918-1888 (Abscissa) and 1927-1918 (Ordinate).

Alternate Sequence of Positive and Negative Correlations.

There have also been found cases in which the deformations of the earth's crust in the same region during different intervals are alternately positively and negatively correlated. This is the case for the deformation of the earth's crust in the Sakurazima volcanic district caused by the eruption of the Sakurazima volcano in 1914. After the eruption, the precise levellings were made in 1914, 1915 and 1918, along the route shown in Fig. 20 in the neighbourhood of the volcano, each survey being referred to as I, II and III hereafter. The results of these measurements are given in the papers of F. Omori and. A. Imamura.[7] We will refer the results of the levelling made in 1892 before the eruption as P. Then (I–P) and (II–I) are positively correlated while (III–II) are negatively correlated to both of them as the curves in Fig. 21 show. This means that soon after the eruption, the deformation of the earth's crust in the district went in the same direction with what was produced at the time of the eruption while some years afterwards the crust deformation was such that to restore the deformation produced before. This is clearly indicated by the correlation diagrams in Figs. 22, 23 and 24.

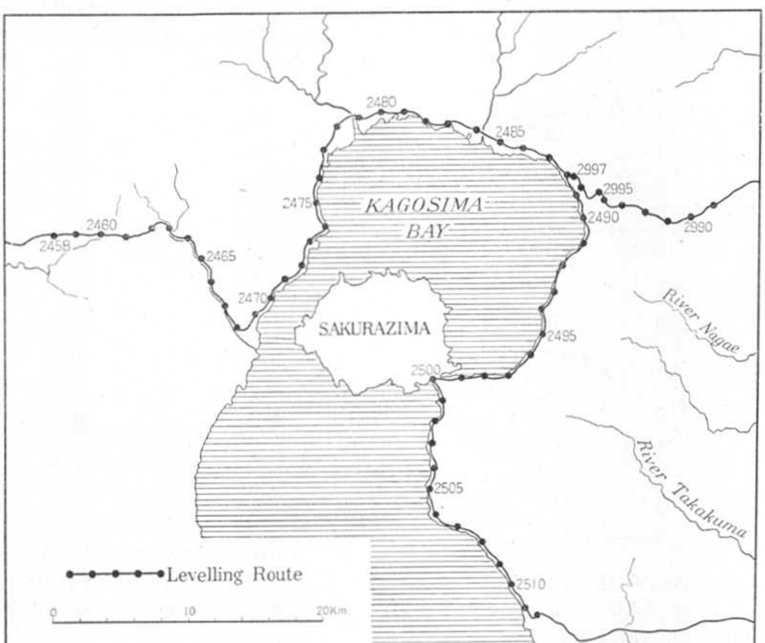

Fig. 20. Levelling Route in the Sakurazima District.

7) F. Omori, *Bull. Imp. Earthq. Inv. Comm.*, 8 (1914–1922).
A. Imamura, *loc. cit.*

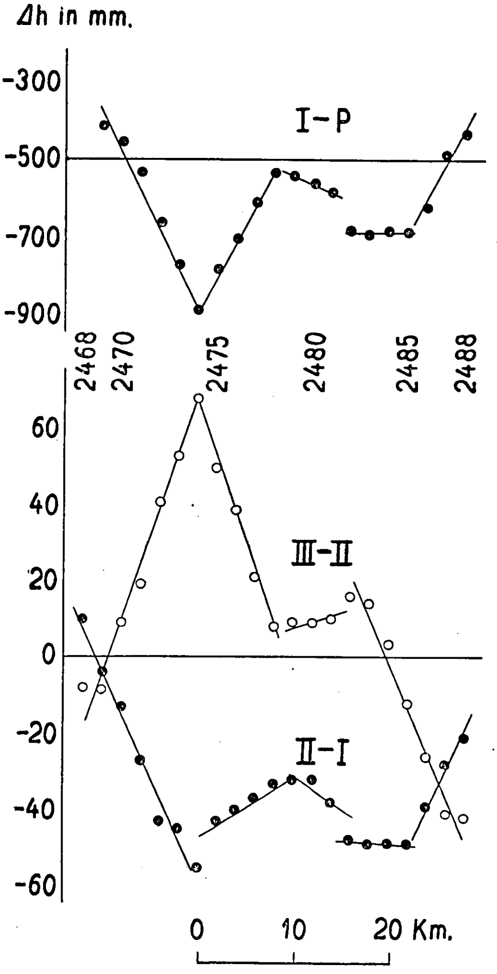

Fig. 21. Change of Height of the Bench Marks in the Sakurazima District Before and After the Eruption of 1914.

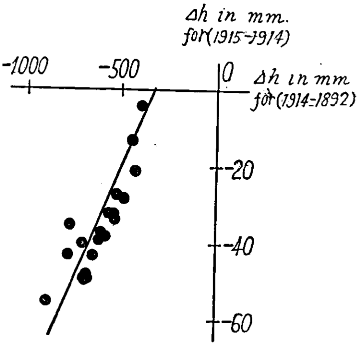

Fig. 22. Correlation Diagram for the Change of Height of the Bench Marks in the Sakurazima District during 1914-1892 (Abscissa) and 1915-1914 (Ordinate).

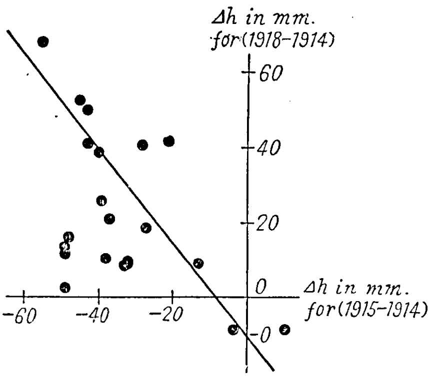

Fig. 23. Correlation Diagram for the Change of Height of the Bench Marks in the Sakurazima District during 1915-1914 (Abscissa) and 1918-1914 (Ordinate).

For the purpose of making clearer the variation with time in the mode of the vertical deformation of the earth's crust in this district, the three measured heights of the bench marks after the eruption were connected by means of curves of second order. This was made by determining three numerical constants in the equation,

$$h = at^2 + bt + c,$$

where h is the height of a bench mark at time t and a, b and c are numerical constants. t is measured from June 1914, one by one for each month. The results of the calculation are given in Table VI.

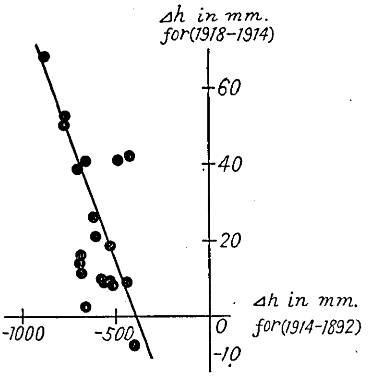

Fig. 24. Correlation Diagram for the Change of Height of the Bench Marks in the Sakurazima District during 1914-1892 (Abscissa) and 1918-1914 (Ordinate).

Table VI.

B.M.	a	b	c	B.M.	a	b	c
2468	−0·031	+1·499	0	2479	+0·103	−5·499	+ 5·396
2469	+0·007	−0·506	0	2480	+0·103	−5·499	+ 5·396
2470	+0·039	−1·944	0	2481	+0·122	−6·491	+ 6·369
2471	+0·083	−4·039	0	2482	+0·156	−8·258	+ 8·102
2472	+0·137	−5·468	0	2483	+0·158	−8·421	+ 8·263
2473	+0·161	−7·882	+7·721	2484	+0·179	−9·955	+19·194
2474	+0·199	−9·646	+9·447	2485	+0·173	−9·892	+19·092
2475	+0·154	−7·527	+7·373	2486	+0·130	−7·804	+15·088
2476	+0·140	−6·976	+6·836	2487	+0·084	−5·510	+10·684
2477	+0·124	−6·397	+6·273	2488	+0·059	−4·085	+ 7·934
2478	+0·106	−5·666	+5·560				

From these values, the monthly vertical velocities of the bench marks in different epochs were calculated according to the relation,

$$\frac{dh}{dt} = 2at + b.$$

These values are arranged in the scheme as shown in Fig. 25 in which contour lines were drawn for equal velocities. In this way it is made clear that the depression gradually changed into upheaval with the lapse of time. As the writer pointed out elsewhere,[8)] the district in the neighbourhood of Sakurazima is made up of a number of what we call land blocks and the vertical crust deformation should be expressed in the terms of the inclination of such land blocks. The tiltings of the

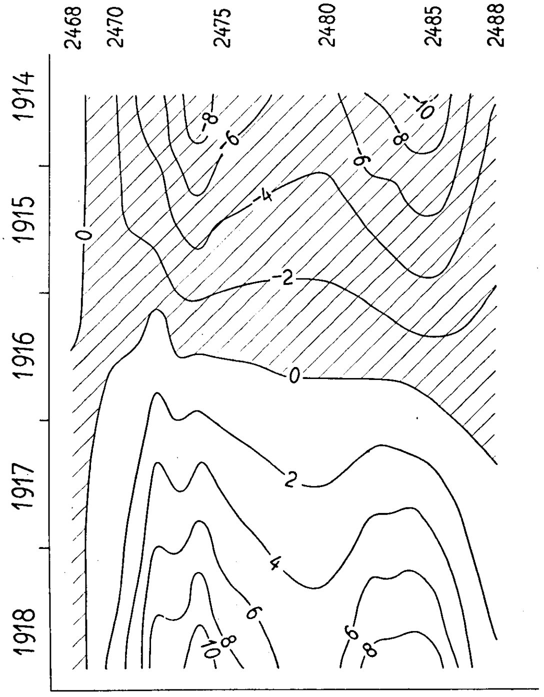

Fig. 25. Monthly Vertical Velocities of Different Bench Marks in the Sakurazima District in mm/month.

land block on which lie the bench marks 2474–2482 during different intervals, for example, were obtained by the Miyabe's method.[9)] The tiltings of the land block during (I–P) and (II–I) are naturally of the same sense while that during (III–II) of the opposite sense to both. This is clearly indicated by three sine curves in Fig. 26 and 27 which are constructed by the values in Table VII. The zero gradient of tilting occurs at the azimuth of N 65°E for all three of them but the phase of the curve (I–P) is just opposite to that of (III–II).

8) C. TSUBOI, *Bull. Earthq. Res. Inst.*, 7 (1929), 103.
9) N. MIYABE, *Bull. Earthq. Res. Inst.*, 9 (1931), 256.

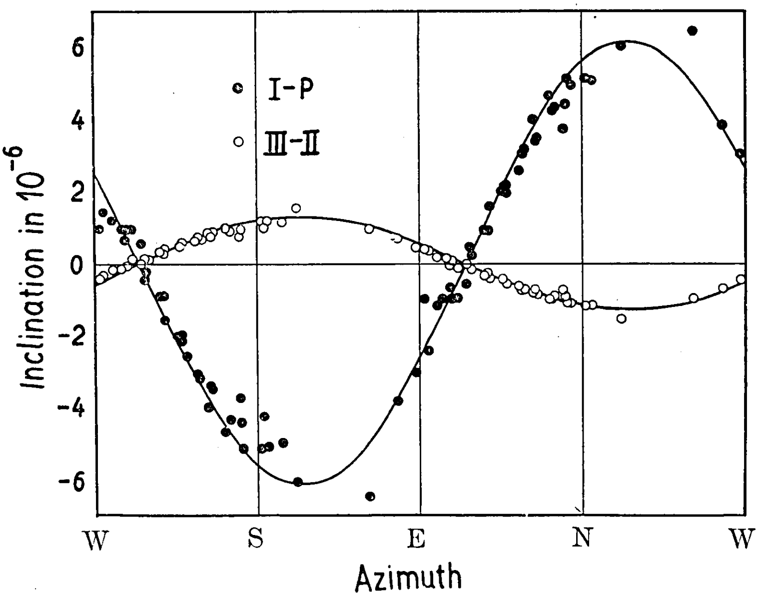

Fig. 26. Sine-Curves Indicating the Tilting of a Land Block in the Sakurazima District.

●........(1914-1892) ○........(1918-1915)

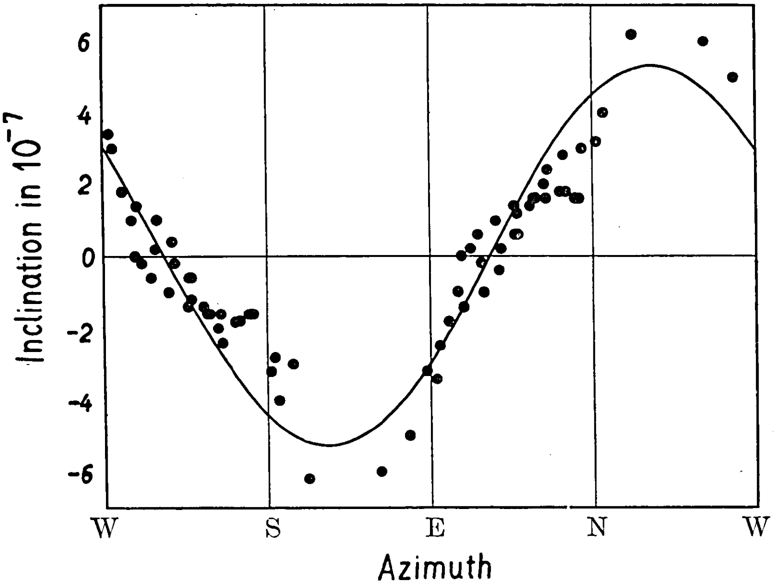

Fig. 27. Sine-Curve indicating the Tilting of a Land Block in the Sakurazima District during (1915-1914).

Table VII.

Azimuth in Degree Measured Counter-clockwise from E.

From \ To	2474	2475	2476	2477	2478	2479	2480	2481	2482
2474	—	+112	+ 96	+ 92	+ 84	+ 74	+ 65	+ 57	+ 48
2475	− 68	—	+ 80	+ 81	+ 75	+ 64	+ 55	+ 47	+ 38
2476	− 84	−100	—	+ 82	+ 72	+ 58	+ 48	+ 39	+ 29
2477	− 88	− 99	− 98	—	+ 63	+ 46	+ 36	+ 28	+ 18
2478	− 76	−105	−108	−117	—	+ 26	+ 21	+ 15	+ 5
2479	− 86	−116	−122	−134	−154	—	+ 17	+ 10	− 2
2480	−115	−125	−132	−144	−159	−163	—	+ 3	− 12
2481	−123	−133	−141	−152	−165	−170	−177	—	− 28
2482	−132	−142	−151	−162	−175	+178	+168	+152	—

Distance in km.

From \ To	2474	2475	2476	2477	2478	2479	2480	2481	2482
2474	—	1·95	3·75	5·55	7·40	8·45	9·55	10·45	10·75
2475	1·95	—	1·95	3·80	5·75	7·05	8·35	9·50	10·10
2476	3·75	1·95	—	1·85	3·80	5·25	6·65	8·00	8·75
2477	5·55	3·80	1·85	—	2·05	3·60	5·25	6·75	7·80
2478	7·40	5·75	3·80	2·05	—	1·75	3·50	5·20	6·50
2479	8·45	7·05	52·5	3·60	1·75	—	1·80	3·50	4·90
2480	9·55	8·35	6·65	5·25	3·50	1·80	—	1·75	3·25
2481	10·45	9·50	8·00	6·75	5·20	3·50	1·75	—	1·65
2482	10·75	10·10	8·75	7·80	6·50	4·90	3·25	1·65	—

Gradient for (I–P) in 10^{-6}.

From \ To	2474	2475	2476	2477	2478	2479	2480	2481	2482
2474	—	+6·06	+5·10	+5·16	+5·98	+4·24	+3·50	+3·04	+1·96
2475	−6.06	—	+3·74	+4·42	+4·34	+3·40	+2·58	+2·10	+0·92
2476	−5·10	−3·74	—	+5·14	+4·66	+3·18	+2·16	+1·58	+0·22
2477	−5·16	−4·42	−5·14	—	+4·00	+2·00	+0·92	+0·46	−0·98
2478	−5·98	−4·34	−4·66	−4·00	—	−0·58	−0·98	−0·98	−2·44
2479	−4·24	−3·40	−3·18	−2·00	+0·58	—	−0·68	−1·18	−3·02
2480	−3·50	−2·58	−2·16	−0·92	+0·98	+0·68	—	−0·98	−3·82
2481	−3·04	−2·10	−1·58	−0·46	+0·98	+1·18	+0·98	—	−6·48
2482	−1·96	−0·92	−0·22	−0·98	+2·44	+3·02	+3·82	−6·48	—

Gradient for (II–I) in 10^{-6}.

From \ To	2474	2475	2476	2477	2478	2479	2480	2481	2482
2474	—	+0·62	−0·40	+0·32	+0·30	+0·28	+0·24	+0·16	+0·06
2475	−0·62	—	−0·16	+0·16	+0·18	+0·16	+0·14	+0·06	−0·04
2476	−0·40	−0·16	—	+0·16	+0·18	+0·16	+0·12	+0·02	−0·10
2477	−0·32	−0·16	−0·16	—	+0·20	+0·14	+0·10	−0·02	−0·14
2478	−0·30	−0·18	−0·18	−0·20	—	+0·06	+0·02	−0·10	−0·30
2479	−0·28	−0·16	−0·16	−0·14	−0·06	—	0	−0·18	−0·32
2480	−0·24	−0.14	−0·12	−0·10	−0·02	0	—	−0·34	−0·50
2481	−0·16	−0·06	−0·02	+0·02	+0·10	+0·18	+0·34	—	−0·60
2482	−0·06	+0·04	+0·10	+0·14	+0·30	+0·32	+0·50	+0·60	—

Gradient for (III–II) in 10^{-6}.

To / From	2474	2475	2476	2477	2478	2479	2480	2481	2482
2474	—	−1·54	−1·18	−1·18	−1·12	−0·98	−0.86	−0·72	−0·56
2475	+1·54	—	−0·74	−0·92	−0·90	−0·74	−0·62	−0·50	−0·28
2476	+1·18	+0·74	—	−1·12	−0·98	−0·72	−0·56	−0·38	−0·16
2477	+1·18	+0·92	+1·12	—	−0·82	−0·46	−0·32	−0·16	+0·08
2478	+1·12	+0·90	+0·98	+0·82	—	0	−0·14	+0·06	+0·34
2479	+0·98	+0·74	+0·72	+0·46	0	—	−0·02	+0·18	+0·46
2480	+0·86	+0·62	+0·56	+0·32	+0·14	+0·02	—	+0·40	+0·70
2481	+0·72	+0·50	+0·38	+0·16	−0·06	−0·18	−0·40	—	+0·98
2482	+0·56	+0·28	+0·16	−0·08	−0·34	−0·46	−0·70	−0·98	—

Gradual Variation in the Mode of the Crust Deformation.

In all of the above examples, each district seems to have its inherent mode of deformation. In the case of the crust deformation in Ito district along the route shown in Fig. 28 on the eastern coast of Idu Peninsula which is connected with the unusual seismic activity in 1930 in it, the deformation of the crust gradually changed in its mode. This fact was already pointed out in the writer's previous papers[10] in which the results of the surveys were given also. For the purpose of making this circumstance clearer, the successive mean daily velocities of each bench mark was calculated just in the same manner as in the case of Sakurazima. The results of the calculation are graphically shown in Fig. 29. As this diagram clearly indicates, the point at which the vertical velocity is maximum has been migrating northward slowly. It was found on the other hand seismometrically[11] that the epicentre of the earthquakes also migrated northward gradually with time. Thus it seems that the maximum upheaval is, at least for this district, intimately connected with the distribution of the origin of the earthquakes. The maximum vertical velocity itself was also variable,

10) C. TSUBOI, *Proc. Imp. Acad.*, 7 (1931), 153; *Bull. Earthq. Res. Inst.*, 9 (1931), 151.
11) N. NASU, F. KISHINOUYE and T. KODAIRA, *Bull. Earthq. Res. Inst.*, 9 (1931), 22.

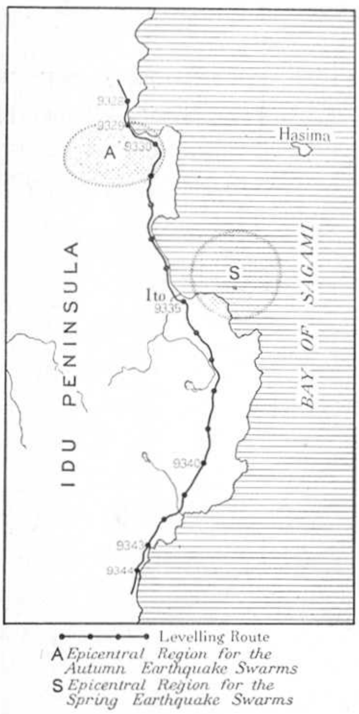

Fig. 28. Levelling Route in the Ito District.

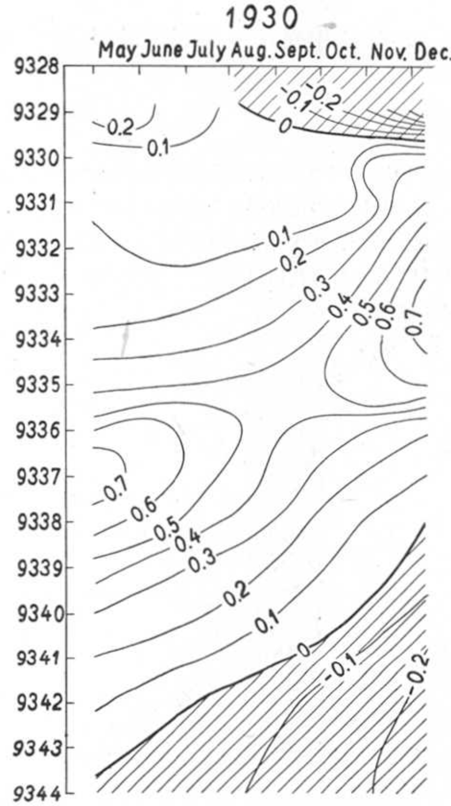

Fig. 29. Daily Vertical Velocities of Different Bench Marks in the Ito District in mm.

being small in summer season of 1930. This is again in good accord with the smallness of the earthquake numbers in the same season.

In conclusion, the writer expresses his sincere thanks to Professor Torahiko TERADA for his interest in this study.

39. 相異なる期間に於ける同一地域の地殼の垂直變動の比較

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同一の地域内で三回以上水準測量が行はれた場合には、我々は少くとも二つの相異なる期間に於ける其の地域内の垂直變動を比較する事が出來る。此の報告では若干の例を擧げて、夫等が正の相關に在る場合、負の相關に在る場合、正相關の地域と負相關の地域とが相隣れる場合、時によつて正相關になつたり負相關になつたりする場合、及び變動の形式が次第に變化して行く場合等がある事を示した。