30. *Investigation on the Deformation of the Earth's Crust in the Tango District Connected with the Tango Earthquake of 1927.*[1] (*Part III*)

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In his previous papers,[2] the writer discussed the deformation of the earth's crust that was produced in the Tango District of northern Central Japan connected with the Tango destructive earthquake of 1927. The discussions expressed in these papers were based on the results then available of the repeated precise levellings and triangulations executed by the experts of the Land Survey Department over the Tango District by means of which the horizontal and vertical displacements of geodetic points in the district had been obtained. Since then two series of new additional data have been obtained by the same authorities. The one of them is the result of the extensive survey over the third order triangulation points in the district whose displacements were calculated by the comparison of the results of the survey with those of the older one that was made over the same triangulation points some 30 years before. The other is the result of the precise levelling that was carried out along the levelling routes in the district for the fifth time after the earthquake. The purpose of the present paper is to discuss the results of the latter survey, discussions for those of the triangulation survey being preserved for future publication.

The present levelling survey was made by a grant generously given jointly to Drs. M. Ishimoto, F. Tada, and the writer by the Imperial Academy to which the writer expresses his sincere thanks. We could

1) Preliminary report was published in *Proc. Imp. Acad.*, 7 (1931), 234.

2) C. TSUBOI, *Proc. Imp. Acad.*, 4 (1928), 529; 6 (1930), 56: *Bull. Earthq. Res. Inst.*, 6 (1928), 71; 8 (1930), 153; 338.

thus entrust the execution of the levelling survey to the Land Survey Department of the Imperial Army which carried out the work from June 17 to Sept. 21, 1930. In Fig. 1 is shown the levelling route covered by the present survey with ordinal numbers of the bench-marks on it. The results that were obtained by the new survey were compared with those of the fourth post-seismic levelling obtained in 1929 and the following changes were found to have taken place in the heights of the bench-marks on the measured route.

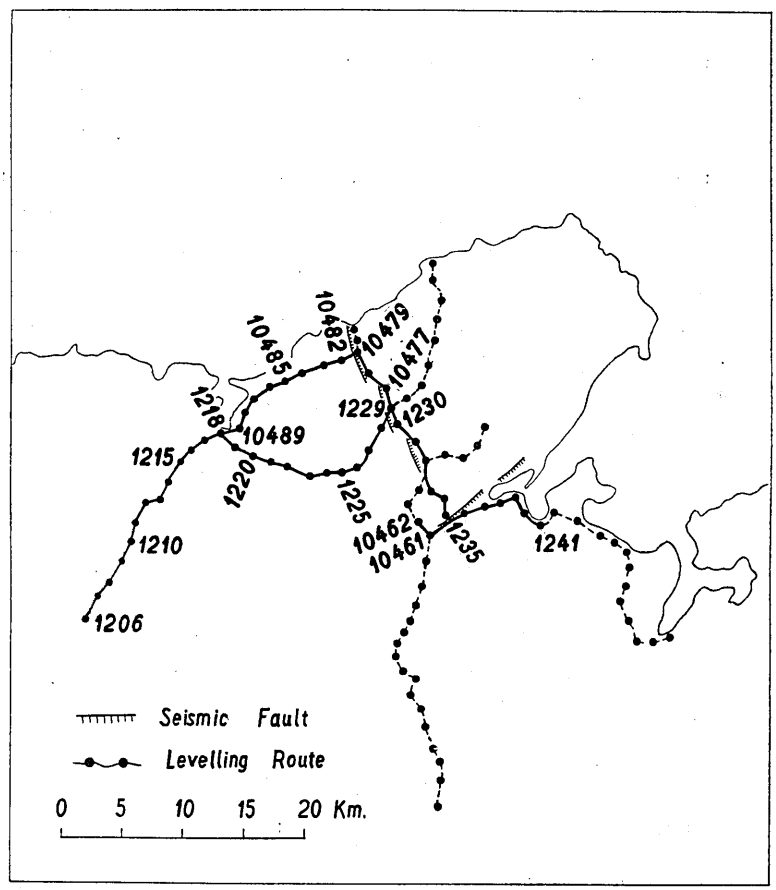

Fig. 1.
Levelling Routes Covered by the Fifth Precise Levelling.

Table I.

Change of Heights of Bench-Marks in the Tango District Between the Fourth & Fifth Precise-Levellings after the Earthquake of 1927.

Bench-Mark	(Height in 1930) −(Height in 1929)	Date of Measurement
1206	+15·3 mm	Sept. 7, 1930.
1207	+16·0	" 8, "
1208	+12·7	" 9, 10, "
1209	+ 9·8	" 10, 11, "
1210	+ 7·2	" 11, "
1211	− 0·6	" 1, 2, "
1212	− 0·6	Aug. 31, Sept. 1, "
1213	+10·2	Sept. 5, 6, "
1214	+ 8·1	" 3, 6, "
1215	+11·0	Aug. 24, 25, "
1216	+ 2·9	" 26, "
1217	+ 1·4	" 22, "
1218	− 2·1	" 21, 22, "
1219	− 0·5	" 23, "
1220	− 4·2	" 17, "
1221	− 1·4	" 18, "
1222	− 2·0	" 15, 19, "
1223	− 2·4	" 14, 16, "
1224	+ 1·6	" 14, 15, "
1225	+ 3·7	" 5, "
1226	+ 0·6	" 6, "
1227	+ 4·1	" 6, 11, "
1228	+ 2·6	" 7, 8, "
1229	+ 1·3	" 3, 4, "
1230	− 0·2	" 2, 3, "
1231	+ 0·6	" 2, "
1232	taken to be stationary	July 25, "
1233	+ 2·4	" 25, 26, "
1234	+ 3·6	" 27, "
1235	+ 1·2	" 24, 30, "
1236	− 2·4	" 23, 24, "
1237	− 3·0	" 18, "
1238	− 2·5	" 18, 19, "
1239	− 4·6	" 19, 20, "
1240	− 3·4	" 20, 21, "
1241	− 4·6	

(*to be continued.*)

Table I. (*continued.*)

Bench-Mark	(Height in 1930) −(Height in 1929)	Date of Measurement
1218	− 2·1 mm	
		Aug. 29, "
10489	− 1·6	
		" 28, "
10488	− 4·0	
		" 27, 28, "
10487	+ 9·7	
		Sept. 19, 20, "
10486	+ 4·9	
		" 20, 21, "
10485	+ 4·2	
		" 18, 19, "
10484	− 1·9	
		" 16, 17, "
10483	− 1·3	
		" 15, 16, "
10482	+ 1·6	
		" 14, 15, "
10479	+ 2·1	
		" 10, "
10478	+ 3·2	
		" 10, "
10477	+ 3·5	
		Aug. 4, 8, 11, "
1229	+ 1·3	
10462	+ 1·3	
		July 28, 29, "
10461	− 3·1	
		" 29, "
1235	+ 1·2	

Generally speaking, the variations of the heights of the bench-marks in this district may be said to have become ultimately more or less dormant, though not quite stationary, after the lapse of three years since the earthquake of 1927. For comparing the present variations with those for former intervals, the following table is constructed in which are shown the calculated mean daily variations in the heights of the bench-marks on the route from B.M. 1206 to B.M. 1241 during different intervals of the levelling surveys after the earthquake.

Table II.

Mean Daily Variation of Heights of Bench-Marks in the Tango District.

Bench-Mark	(II–I)	(III–II)	(IV–III)	(V–IV)
	mm	mm	mm	mm
1206	+0·033	−0·080	−0·066	+0·039
1207	+0·002	−0·082	−0·067	+0·041
1208	−0·004	−0·076	−0·078	+0·032
1209	−0·040	−0·064	−0·077	+0·025
1210	−0·027	−0·061	−0·097	+0·018
1211	−0·056	−0·080	−0·112	−0·002
1212	−0·072	−0·084	−0·116	−0·002
1213	+0·009	−0·026	−0·086	+0·027
1214	−0·028	−0·001	−0·089	+0·021
1215	−0·083	+0·009	−0·095	+0·030
1216	−0·088	+0·009	−0·083	+0·108
1217	−0·173	+0·007	−0·077	+0·004
1218	−0·202	+0·001	−0·077	−0·006
1219	−0·121	−0·008	−0·071	−0·001
1220	−0·143	−0·014	−0·072	−0·012
1221	−0·190	+0·015	−0·072	−0·004
1222	−0·133	+0·009	−0·065	−0·006
1223	−0·061	+0·002	−0·057	−0·007
1224	−0·163	+0·004	−0·048	+0·005
1225	−0·214	+0·010	−0·050	+0·011
1226	−0·186	+0·016	−0·039	+0·002
1227	−0·059	+0·018	−0·038	+0·012
1228	+0·059	+0·027	−0·029	+0·008
1229	−0·074	−0·009	−0·029	+0·004
1230	−0·124	−0·023	−0·032	−0·001
1231	−0·135	−0·008	−0·009	+0·002
1232	taken to be stationary	—	—	—
1233	−0·032	−0·005	+0·003	+0·008
1234	−0·060	+0·010	+0·009	+0·012
1235	−0·025	+0·004	+0·013	+0·004
1236	−0·065	−0·039	−0·007	−0·008
1237	−0·080	−0·055	−0·012	−0·010
1238	−0·050	−0·036	−0·009	−0·008
1239	−0·029	−0·032	−0·006	−0·014
1240	−0·076	−0·032	−0·008	−0·011
1241	−0·083	−0·038	−0·005	−0·014

The values given in Table 2 are shown by the curves in Fig. 2, in which the gradual decrease with time in the rate of variation of the height change is evidently apparent.

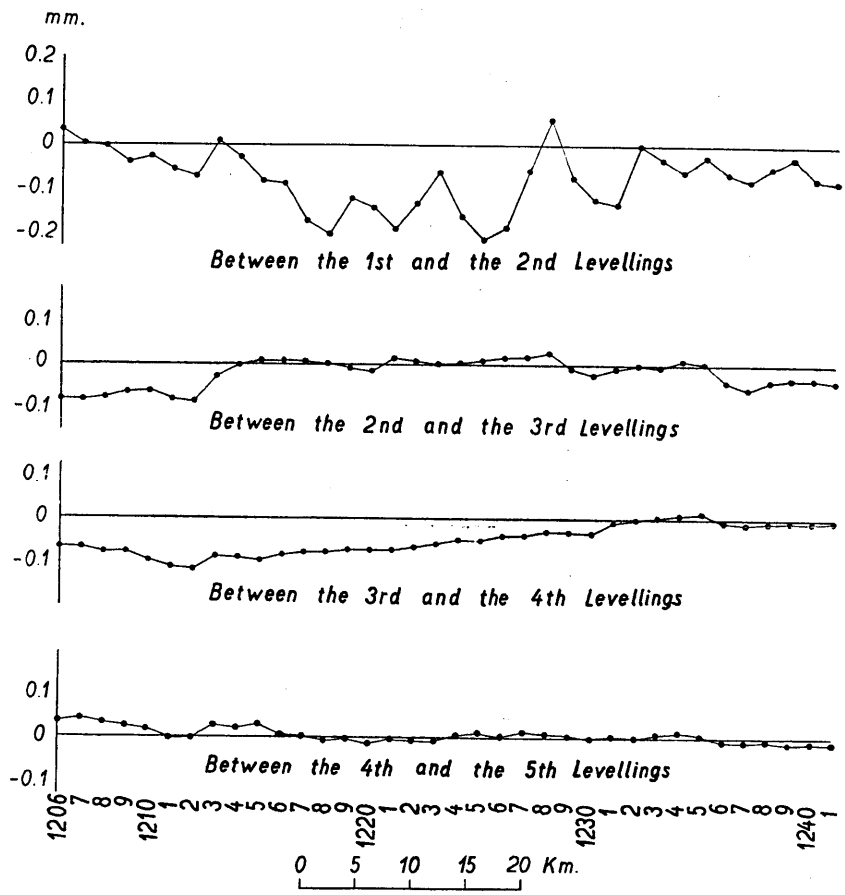

Fig. 2.
Mean Daily Variation of the Heights of Bench-Marks.

The total change of heights of the bench-marks that occurred after the earthquake along the same levelling route are given in Table 3 in which it will be compared with what was produced at the time of the earthquake of 1927.

Table III.
Comparison of the Changes of Heights of Bench-Marks that were Produced at the Time of and After the Earthquake of 1927.

Bench-Mark	Change of Height at the Time of the Earthquake	Total Change of Height After the Earthquake
1206	−197·0 mm	−37·7 mm
1207	−196·0	−39·1
1208	−254·2	−46·1
1209	−266·3	−47·2
1210	−375·3	−58·3
1211	−467·7	−79·6
1212	−832·3	−84·9
1213	−221·9	−39·7
1214	−174·3	−37·9
1215	−162·2	−37·0
1216	−162·9	−40·1
1217	−156·3	−42·7
1218	−173·8	−49·7
1219	−141·5	−44·3
1220	−194·9	−51·7
1221	− 90·6	−42·6
1222	− 84·3	−39·5
1223	− 54·6	−34·8
1224	+ 2·2	−29·9
1225	+ 31·7	−29·6
1226	+100·3	−24·2
1227	+135·4	−14·1
1228	+308·1	− 3·1
1229	−441·0	−20·2
1230	−252·8	−29·9
1231	− 76·4	−12·2
1232	taken to be stationary	—
1233	+263·4	+ 1·4
1234	+468·2	+ 8·5
1235	+784·8	+ 9·6
1236	−353·0	−20·3
1237	−277·7	−28·6
1238	−210·7	−19·9
1239	−128·6	−17·8
1240	−127·3	−18·9
1241	−151·8	−21·7

The values in Table 3 are graphically shown in Fig. 3. When the scale for the lower curve is taken ten-times reduced as that for the upper

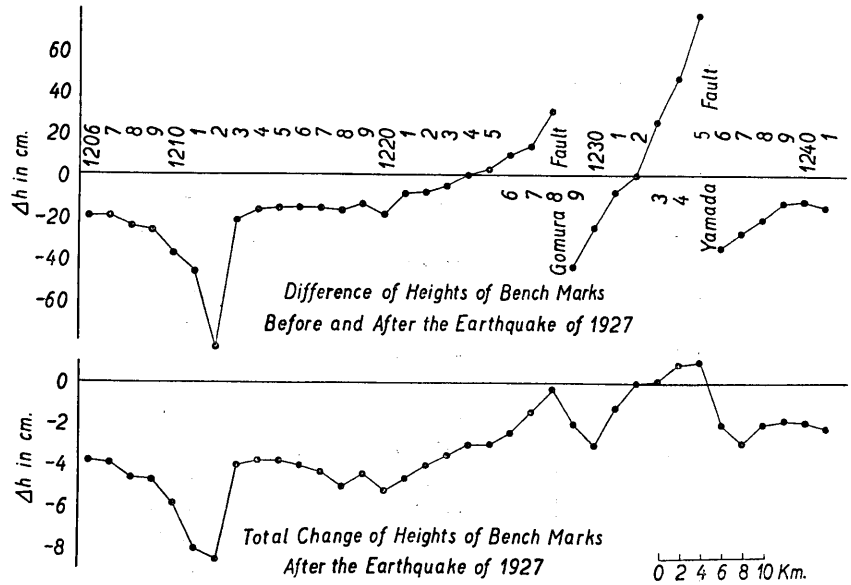

Fig. 3.

one, as is the case in Fig. 3, the two curves are seen very much similar in their forms. This implies that the vertical deformation after the earthquake has been of the same sense and proprotion with what was produced at the time of the earthquake. In the neighbourhood of the Gômura and Yamada seismic faults both of which were produced at the time of the earthquake, the vertical deformtion of the ground is sensibly different for the two curves. B.M. 1229 and B.M. 1236 in the immediate neighbourhood of the faults have been sensibly drag up from the positions which they would have respectively occupied otherwise. This would seem to indicate that the two land blocks on the opposite side of the faults have been healed up with each other and the relative vertical movements along these seismic fault planes have become somewhat ill-difined. The difference of heights of the bench-marks that lay on the opposite side of and nearest to the Gômura fault increased rapidly after the earthquake but soon approached to an asymptotic value. The case for the Yamada fault

is somewhat different, the decrease in the velocity of the change of the difference of the heights of the bench-marks on its opposite sides being small with a little sign of tending to its asymptotic value. These circumstances may be seen in Table 4 and Fig. 4.

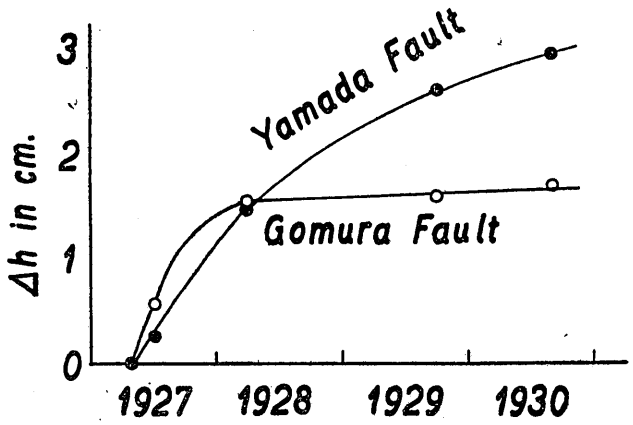

Fig. 4. Relative Vertical Movements along the Gomura and Yamada Seismic Faults.

Table IV.

Gômura Fault (B. M. 1228—1229)

	mm
April 24, 1927	0
June 5, 1927	5·6
March 9, 1928	15·6
Sept. 2, 1929	15·8
Aug. 8, 1930	17·1

Yamada Fault (B. M. 1235—1236)

	mm
April 23, 1927	0
June 5, 1927	2·7
March 13, 1928	15·0
Sept. 11, 1929	26·3
July 30, 1930	29·9

The witer pointed out in previous papers that the evidence of block movements is pronounced in the results of the repated precise levellings in the Tango District. By the results of the fifth precise levellings, we find that the block movement is still predominant in this district, with the boundaries of the land blocks remaining at the same positions as before As a remarkable illustration for this, we may mention the change of heights along the levelling route from B.M. 1206 to B.M. 1218.

Table V.

Bench-Marks	II-I	III-II	IV-III	V-IV
	mm	mm	mm	mm
1206	+ 1·4	−22·4	−32·0	+15·3
1207	+ 0·1	−22·7	−32·5	+16·0
1208	− 0·2	−20·9	−37·6	+12·7
1209	− 1·8	−17·7	−37·5	+ 9·8
1210	− 1·2	−16·9	−47·4	+ 7·2
1211	− 2·4	−22·2	−54·4	− 0·6
1212	− 3·0	−23·5	−57·8	− 0·6
1213	+ 0·4	− 7·3	−43·0	+10·2
1214	− 1·1	− 0·4	−44·5	+ 8·1
1215	− 3·5	+ 2·4	−47·7	+11·0
1216	− 3·6	+ 2·6	−42·0	+ 2·9
1217	− 7·1	+ 1·9	−38·9	+ 1·4
1218	− 8·5	+ 0·2	−39·3	− 2·1

The values given in this table are graphically shown in Fig. 5, in which the points were connected by broken straight lines, each of them corresponding to land blocks. The boundaries of these land blocks agree in position with minor tectonic lines in the district which were traced by means of geological surveys. What a characterictic structure the earth's crust was found to have which has mostly been assumed to be homogeneous and isotropic in geophysical especially in seismometrical research only for the sake of simplicity for the application of mathematics. It seems hardly necessary to say that most of the conceipts in seismology, such as epicentre, uniform propagation of elastic waves through the homogeneous earth's crust without hysterisie, etc., must be rewritten under the new light as to the structure of the earth's crust which revealed itself as a natural *fact* by means of geodetic surveys.

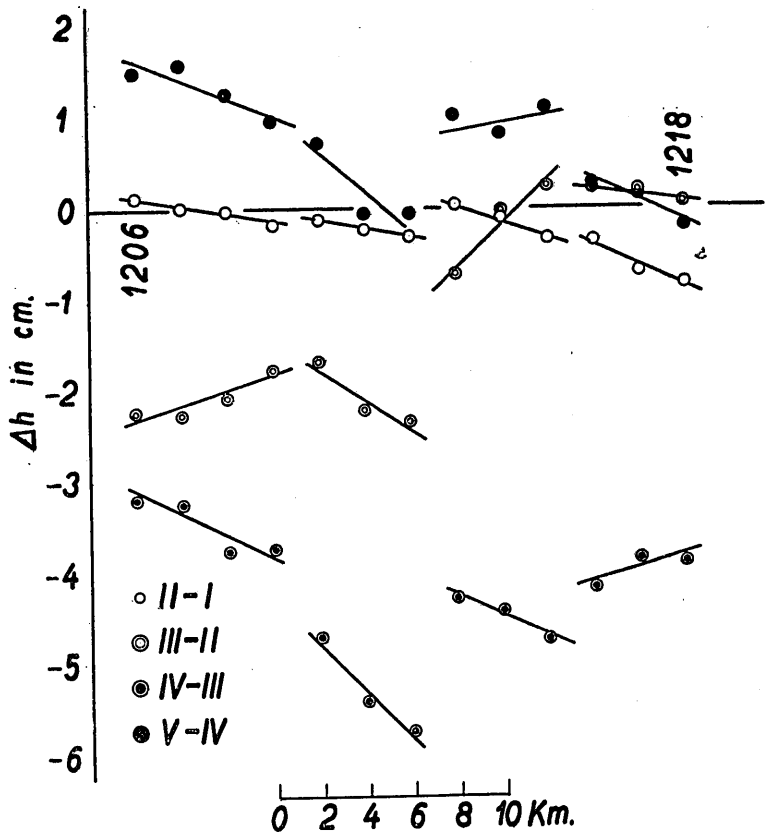

Fig. 5.

Block Movements as Revealed by Means of Precise Levellings.

In conclusion the writer expresses his sincere thanks to the Imperial Academy for the grant which enabled the writer to make this investigation. Thanks are also due to Professors K. Suyehiro and T. Terada for their interests in this work and also for their kindness in recommending us to the Academy for the grant. Last, but not least, thanks must be expressed to the Land Survey Department for the execution of the laborious work of the levelling surveys at our request.

30. 昭和二年丹後地震に關聯せる丹後地方の地殻變動に關する研究（第三報）

地震研究所　坪井忠二

丹後地方に於いて地震後第五回目の精密水準測量を行ふに就いて幸にも帝國學士院から補助を仰ぐ事が出來たので夫によつて陸地測量部に委託して貴重な結果を得る事が出來た。本論文は其の結果を前に得られた結果と對照して若干の考案を加へたものであつて、同地方の變動が次第に納まりつゝある事、地震の時の變動と地震後の變動とが大きさこそ違へ殆んど同形である事、地塊運動の證據が未だに明かである事等を示した。