26. *Later Crustal Deformations in the Tango District.*

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It is well known that in the case of the great Tango earthquake of March 7, 1927, there occurred very characteristic crustal deformations, the most outstanding of which was the appearance of the Gōmura and Yamada faults. According to Dr. N. Nasu, the deformations are likely to have consisted largely of tilt-like movements of a crustal block, triangular prism in shape, with the Gōmura and the so-called γ fault planes as its bases, and the Yamada fault plane as one of its lateral faces, while the area enclosed by the Gōmura, Yamada, the γ faults, and another, which last is assumed to extend off the adjacent coast parallel to the Yamada fault, constitutes another side face (Fig. 1). The consideration is based on the results of a stereometric study of after-shocks, together with those of geodetic triangulation and precise levelling, repeatedly carried out in the district.

The line of precise levels, about 108 km long, linking Maiduru with Yōka, which passes through the seismic area, intersects the Yamada, Gōmura, and the γ faults, so that from the revisions of levels carried out there the land deformations associated with the earthquake and those that occurred during the ensuing periods can be easily deduced.

This line, which was first laid down during the period from 1887 to 1888, was re-levelled since the great 1927 earthquake in the following periods:—

- I. April 19—May 30, 1927.
- II. June 1—July 31, 1927.
- III. March 3—April 20, 1928.
- IV. August 7—September 19, 1929.
- V. June 17—September 21, 1930.

I have elsewhere discussed some of the results deduced from these revisions¹⁾, while Dr. C. Tsuboi has also investigated these deformations, taking into consideration at the same time the results of geodetic triangulations carried out repeatedly in the district.²⁾

The line of levels traverses the Yamada fault from south to north, almost at right angles, while the Gōmura and γ faults do so from east to west, so that a diagrammatic view of the changes in height of the successive bench-marks serves as a profile of the movements of the said land block as referred to the adjacent blocks. Fig. 2 illustrates the movements, curve *A* indicating those that occurred with the earthquake, while curve *B* indicates those that took place during the 3.2 years from April 1927 to July 1930.

1) A. Imamura: Publ. Earthq. Inv. Comm. **25** (1928), 112-121.

2) C. Tsuboi: Bull. Earthq. Res. Inst.; **6** (1928), 71; **8** (1930), 153, 338; **9** (1931), 423.

Fig. 1.

Fig. 2.

It will be seen at a glance that the outstanding feature is the Yamada and Gōmura faults. As to the former fault, its connexion

with the 1927 earthquake is shown by a relative vertical throw of as much as 114 cm between B. M. No. 1235 and 1236. The block, as well as the one contiguous to it on the south, thus shows on the whole a typical *N*-shaped fault. After the earthquake, however, the deformation was changed into one, apparently, of flexure type with a throw of 3.8 cm, B. M. No. 1236, which previously had undergone maximum subsidence as a result of the earthquake, now remaining midway between B. M. No. 1235 and 1237, each of which is consecutive to No. 1236, the former on the north and the latter on the south, all of which suggest that the blocks on either side of the fault underwent movement in a manner similar, although on a greatly reduced scale, to those that occurred with the earthquake, while the shearing along the fault face became much smaller, as if the *wound* that had been made in the two blocks at their boundary had almost *healed*.

A similar feature will also be seen in the Gōmura fault, the presence of which, as the result of the 1927 earthquake, is shown by a relative vertical throw of as much as 75 cm between B. M. No. 1228 and 1229, and by one of 3.3 cm for the post-seismic period of 3.2 years, although it is probable that in the present case, the *healing* after the earthquake proceeded, as Dr. C. Tsuboi says, at a more rapid rate than did the Yamada fault.

As to the γ fault, it is recognisable only at a point between B. M. No. 1220 and 1221, these marks having undergone vertical displacements relatively to each other of not more than 10.4 and 0.9 cm respectively with the earthquake and during the 3.2 post-seismic years. It is also noteworthy that another much larger, *V*-shaped dislocation of as much as 61 and 4.5 cm occurred respectively during the periods 1887–1927 and 1927–1930 in B. M. Nos. 1208–1214, a secular topographic variation possibly connected in some way with the formation of the River Maruyama-gawa.

Seeing that it is almost 9 years since the last levels had been run, in order to study the crustal deformation that ought to have been going on there since, it was naturally desired to re-run the precise levels, with the result that it was undertaken with the aid of a grant made to me by the Imperial Academy and with the courtesy of the Military Land Survey, for both of which favours I wish to take this opportunity of expressing my sincere thanks.

The revision was carried out during October—November 1939, along the line linking Yōka with Maiduru, as also along three short lines, two of which branch from Yōka and the other from Yamada, over a distance totalling about 122 km. The changes in height made by each B. M. during the period of 9.3 years from 1930 to 1939 are given in Table I, the change being based on the assumption, as in the previous cases, that B. M. No. 1232, at Kutōno, remained unaffected during the period concerned. Fig. 2, curve C, illustrates the corresponding land deformations thus worked out.

TABLE I.

Changes (in mm) in height of bench-marks with No. 1232
assumed stationary.

Main line.

B. M. Change		B. M. Change		B. M. Change		B. M. Change	
Yōka		1216	0.3	1230	— 9.2	1241	— 9.1
		1217	— 0.5	1231	— 0.8	1376	— 2.8
1164	13.6*	Kumihama		Kutiōno		1375	— 0.7
1202	12.5*					1374	—82.6
1203	10.1*					1373	1.4
1204	5.4*	1218	— 3.4	1232	0.0	Yura	
1205	1.4	1219	— 5.8	1233	2.4		
1206	1.4	1220	—14.5	1234	7.1		
1207	2.1	1221	2.0	Yamada		11	1.1
1208	— 6.5	1222	— 3.3			1372	— 4.8
1209	—10.5	1223	— 7.6			1371	— 8.9
1210	—21.4	1224	— 9.0			1370	— 2.4
Toyooka		1225	— 7.8	1235	2.7	1369	— 3.2
		1226	— 5.6	1236	—13.1	1368	— 6.4
		1227	— 2.4	1237	—11.4	1367	— 5.0
		1228	— 3.1	1238	— 2.3	1366	— 5.9
				1239	— 1.3		
		Mineyama		Miyadu		Maiduru	
1211	—64.4					1365	—16.4
1212	—69.4					1364	— 8.1
1213	— 0.8						
1214	6.1						
1215	5.2	1229	— 3.4	1240	— 4.0		

Branch lines.

B. M.	Change	B. M.	Change	B. M.	Change
(1) Yōka		(2) Yōka		(3) Yamada	
1164	13.6*	1164	13.6*	1235	2.7
1163	9.2*	1165	8.9*	10461	-12.8
12	16.4*	1166	12.2*	10460	-19.1
1162	13.2*			Kaya	

Data for B. M. 1364-1376 (No. 11 inclusive) indicate changes
for the period 1928-1939; * for the period 1927-1939.

Upon comparing the land deformations thus shown with those suffered in the two preceding periods, it will be seen that their general aspects do not greatly differ, although they do so in the details somewhat as follows.

1) Land deformation connected with the Yamada fault. The movements of the two contiguous blocks that are bounded by the present fault are quite similar to those experienced during the 3.2 years' period soon after the earthquake, the only difference being that the amount in the present case is much smaller than that shown in the preceding period. Or, to be more precise, the deformation suffered per annum on the average during the recent 9.3 years was no more than about one-sixth of that for the preceding 3.2 years. It is likely that the *healing* above noted had almost reached its last stage. (See also Fig. 3.)

Fig. 3. Mean daily change in land-level for the successive periods.
(IV indicates 1939.)

2) Land deformation connected with the Gōmura fault. What is notable about the Yamada fault applies equally to the present case. Quantitatively, the deformation suffered per annum on the average for the recent 9.3 years is about one-sixteenth of that for the preceding period. (See also Fig. 3.)

3) Land deformation connected with the γ fault. While the land deformations connected with the two above-mentioned faults became much smaller in recent years, those connected with the γ fault advanced with a uniform rate, exhibiting an *N*-shaped dislocation of a relative vertical throw of as much as 2.3 cm at B. M. No. 1220 and 1221, so much so that if *healing* had taken place here also, the deformation ought to have been nearly equal, but opposite in sense, to that exhibited along the Gōmura fault. It may be said that the block, the tilting of which was responsible, as Dr. Nasu pointed out, to the great Tango earthquake of 1927, now underwent an upheaval, so far as the east-west component movement is concerned, almost parallel to itself. On considering moreover that the movement along the Yamada fault was similar and nearly equal to that along the Gōmura fault, the parallelism applies even to the north-south component, so that it may be said that the upheaval of this block occurred with hardly any tilt.

4) Land deformation connected with the Maruyama-gawa fault. The deformations connected with the present fault that occurred in the three successive periods in question are almost similar (vertical disloca-

tion for the last period = 6.9 cm), suggesting that the secular topographic variation was going on approximately at a uniform rate.

As regards the *healing* of both the Yamada or the Gōmura fault, the process, as shown in diagrammatic view (Fig. 3), is apparently in reverse order in time to that which ordinarily takes place when the equilibrium of a strained block suddenly breaks with the formation of a seismic fault. As instances of the latter case, we may take the land deformations that occurred both before and with the Anegawa earthquake of 1909¹⁾, and the Tokyo earthquake of May 21, 1928.²⁾ Our experience of such a phenomenon, however, being very limited, this matter is reserved for future study.

1) A. Imamura: Jap. Jour. Astr. and Geop., **6** (1928), 77-80.

2) Loc. cit., **8** (1931), Figs. 5 and 6, 181.