5. *Block Movement along the Seismic Fault (1).* (*Fukui Fault and Others*)

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A noteworthy fact in the topographical changes at the time of the Fukui earthquake of 1948 was the occurrence of an invisible, or intrinsic fault which could be detected only by means of the precise surveys[1]. As this fault occurred across the lowland, the Fukui Plain, the boundary of the land-blocks which moved at the time of the earthquake could not be traced clearly as in the cases of the seismic faults which appeared in the past earthquakes. With the naked eye no direct evidence of the relative movement of the land-blocks was observed on the ground, but the movement was remarkable as was revealed by the surveys. So far as determined on the land, the fault, with its northern extension terminating near the coast-line of the Japan Sea, extended over a distance of 25 km., taking a direction N. 20°W.–S. 20°E. in its northern part and N. 7°W.–S. 7°E. in the southern. There were uplift and subsidence of the ground. In general, the former was on the eastern side of the fault and the latter was on the western side of it. As the direct measurement of the horizontal shift of this fault was impossible, the shift was estimated in the manner as will be described in the following paragraph.

Estimation of the horizontal displacement. The horizontal displacement of the land-blocks along the fault has been made clear by means of the triangulation survey carried out by the Geographical Survey Bureau after the present earthquake (Fig. 1). However, the shifts of the points as determined by this survey are only relative, since the survey had not yet been carried outside the seismic region to establish the absolute movement. As to the horizontal displacements, the data have been already made public (Table I).

It will be seen that excepting Funayose, the directions of the shifts

1) T. NAGATA and A. OKADA; N. NASU, S. KAWASHIMA; Geographical Survey Bureau; K. MUTO, T. OKUDA; *Advanced Report Fukui Earthq., March 1949.*

of the triangulation points are nearly parallel with the trend of the faults. Strictly speaking, the deviations of the direction from this trend range

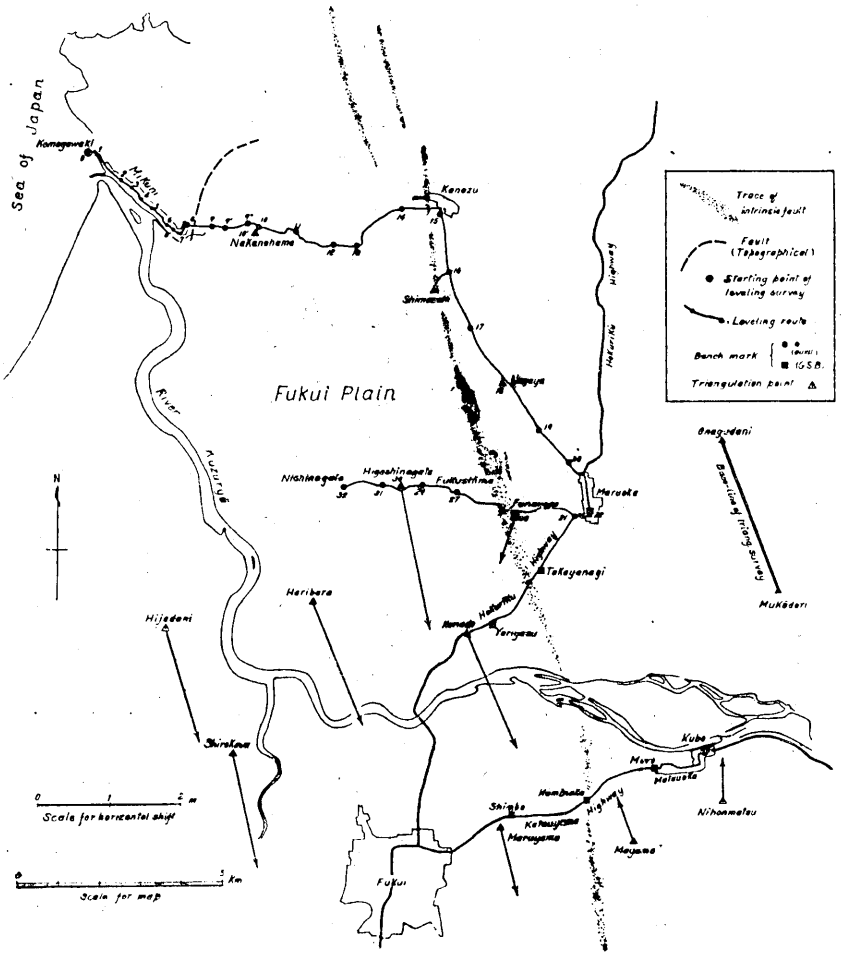

Fig. 1. Resurveyed route of leveling and the horizontal displacement of the triangulation point.

between 3° and 7° in the area lying north of the Katsuyama Highway and between 7° and 15° in the area south of the same highway. The deviation at Funayose showed a maximum of 39°. This might be resulted from the complicated movement of the ground lying in a zone of sliding between land-blocks.

Taking five points, Higashinagata and others, which lie on the western side of the fault and to the north of the Katsuyama Highway just men-

tioned, the components of the displacement parallel to the fault were calculated and plotted against the distance of the point measured from the fault (Fig. 2). Let y be the component displacement (in cm.) and x the distance (in km.). Then, the relation between these quantities may be expressed by

$$y=203e^{-0.0250x},$$

Hence, on the fault line where $x=0$, the horizontal displacement of the western side becomes as 203 cm. in a southerly direction. As there is no triangulation points of which displacement was determined by the survey, the movement of the eastern side of the faults is uncertain, but this much is true that the eastern side of the same fault has slipped in a direction opposite to that of the western side. If so, the land which lay between the base-line of survey[2] and the fault must have moved relatively to this base-line. Further, if the rate of

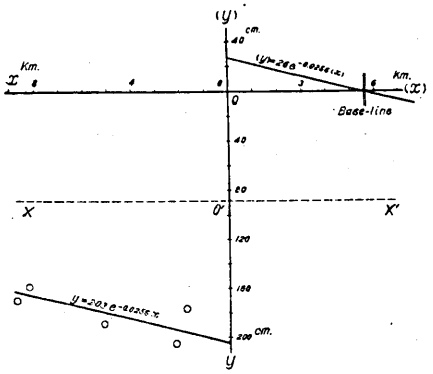

Fig. 2. Horizonal shift of of the northern part of the Fukui fault.

Table I. Horizontal displacement of the triangulation point.

Triangulation point (order)	Horizontal displacement			
	N. S.—comp.	E. W.—comp.	Resultant	Direction
	cm.	cm.		
Mukōdori (II)	0	0	End points of base-line of survey.	
Onagadani (III)	0	0		
			cm.	
Higashinagata (III)	−200	+47	205	166° 47′
Hijadani (III)	−160	+50	168	162 39
Kanado (Yoriyasu) (III)	−163	+70	177	156 46
Shirokawa (III)	−154	+35	158	167 12
Haribara (III)	−173	+73	188	157 7
Funayose (IV)	−65	−22	76	198 42
Nihonmatsu (IV)	+62	0	62	0 0
Mayama (IV)	+62	−25	67	338 2
Maruyama (IV)	+92	+25	95	164 48

N. S.—component: (+) towards N., (−) towards S.
E. W.—component: (+) towards E., (−) towards W.
Angle is measured from the north in clockwise direction.

2) The line is nearly parallel to the fault, the distance between them is 5.7 km.

decrease of the displacement with increasing distance from the fault was the same as that on the western side, the displacement of the eastern side relative to the base-line was as much as 26 cm. Thus, a horizontal shift of about 230 cm. would have been observed, if the ground had been cut clearly by the fault as in the case of an ordinary fault. By the way, the shift estimated here is smaller by 40 cm. than that actually measured at Mineyama where the dislocation was most remarkable along the Gōmura fault which appeared as an accompaniment of the Tango earthquake of 1927[3].

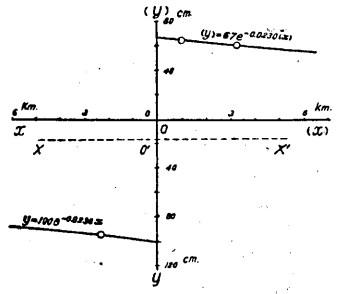

Fig. 3. Horizontal shift of the southern part of the Fukui fault.

For the three points lying south of the Katsuyama Highway, similar estimations have been made (Fig. 3). From the two points situated to the east of the fault we have

$$(y)=67e^{-0.0235(x)},$$

where (y) and (x) denots the northward displacement and the distance from the fault measured eastwards. For the point lying on the western side of the same fault we have

$$y=100e^{-0.0235x}.$$

Hence, the horizontal shift becomes as 167 cm. in the southern part of the fault. If both sides of the fault had slipped to an equal extent in the opposite directions as actually revealed to be the absolute displacement in the Tango district[4], the movement of the fault may be illustrated by the same curves, but refering to new axes XOX′ in Figs. 2 and 3. The estimations given above are helpful in determining the amount of the relative movement of the fault, especially when the direct measurement is impossible as in the case of the Fukui fault.

Resurvey of the land-level. By means of the leveling survey made along the route as shown in Fig. 1, the changes in land-level undergone by the seismic area during about one year following the last survey were studied. The resurvey was completed in 12 days from July 22 to August 2, 1949. In the area north and east of the River Kuzuryū, the survey started from Komegawaki (bench mark of the Hydrographic Bureau) of which elevation was assumed to be unchanged as was in the last year, while in the area

3) A. IMAMURA, *Theoretical and Applied Seismology*, p. 212, 1937.
4) A. IMAMURA, *loc. cit.*

south of the Katsuyama Highway, the bench mark at Kubo in Matsuoka (No. 5254, GSB) was assumed to be steady. The instrument and the accuracy of the survey[5] were the same as those in the last survey. The changes as determined by the present survey are shown in Fig. 4.

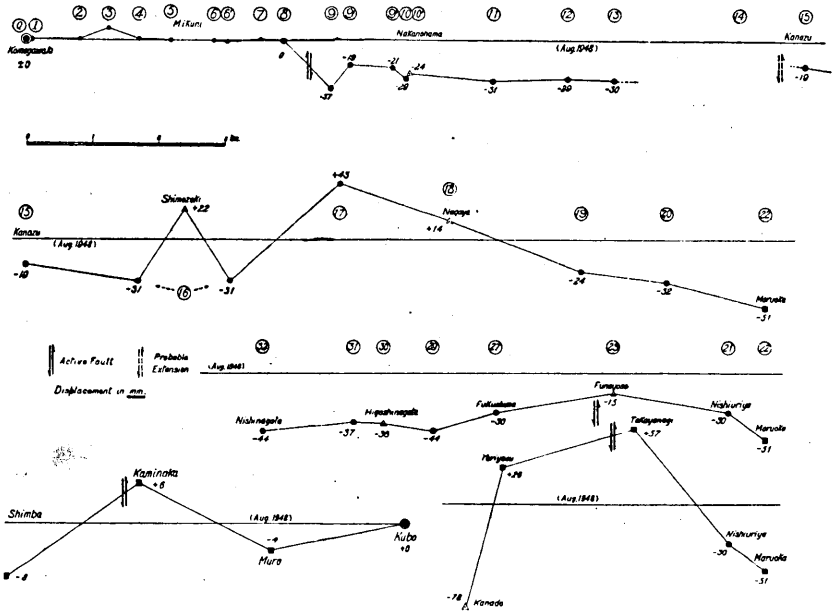

Fig. 4. Resurvey of the land-level in July 1949.

It will be seen that along the route between Komegawaki and bench mark No. 8, there can be seen practically no change. Although in this figure, a change of 10 mm. is seen at bench mark No. 3, the change is insignificant, because it was merely due to some artificial causes. However, a remarkable change has been revealed between bench marks Nos. 8 and 9 such that a general depression can be seen along the route between the latter bench mark and that No. 16. The change is in the same downward sense, similar to that experienced at the time of the main shock. The geologic map shows that this subsided area is of the alluvial formation. From the topographical point of view, a fault is drawn along the boundary of this alluvium and the diluvium on the side of Mikuni. By the survey, a vertical but relative movement of the land-blocks along this fault was proved to be still continued up to present. Hence, this fault is evidently active.

5) N. Nasu, S. Kawashima, loc. cit.

As bench mark No. 14 was unfortunately missed, the post-seismic movement of the northern part of the intrinsic fault is uncertain. However, a gap seems to exist in the amounts of changes undergone by bench marks Nos. 13 and 15; the depression at the latter point is rather smaller.

An upheaval of 22 mm. is seen at the triangulation point at Shimozeki which lies on the intrinsic fault. Bench mark No. 17 uplifted 43 mm., while in the area south of this point and up to the bench mark in Maruoka (No. 897, GSB), the change is a southward tilt, which roughly corresponds to a tilting of 3 seconds of angle. It is notable that a subsidence of 51 mm. occurred at Maruoka where an upheaval of 194 mm. was once revealed by the first survey made immediately after the earthquake of the last year.

Along the route which run westward from Maruoka to Nishinagata, the subsidence was in general, but at Funayose where the fault passed, an upward movement of the eastern side of this fault occurred relatively to the western such as the vertical dislocation at this point growing still larger.

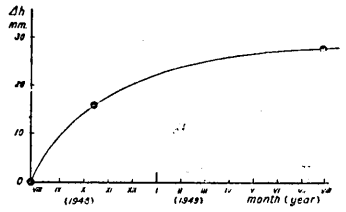

Fig. 5. Subsequent vertical displacement of the Fukui fault.

On the Hokuriku Highway, a remarkable uplift of 57 mm. is seen at Takayanagi (No. 898, GSB), while at Yoriyasu (No. 899, GSB) an upheaval of 28 mm., the former place lies on the eastern (uplifted) side of the fault and the latter on the western (subsided) side. It must be remembered that the fault was most pronounced near Takayanagi, the relative vertical displacement which occurred between bench marks at these two places was determined to be 755 mm. by the first post-seismic survey[6]. Since then this vertical dislocation was increased by 28 mm. This vertical displacement, however, gradually decelerated with time as shown in Fig. 5. A similar fact has been already pointed out by C. Tsuboi for the seismic faults in the Tango and Izu districts.

An increase of the vertical displacement of the same kind which occurred subsequently can be seen also in the southern part of the fault traversing the leveling route between Kaminaka (No. 5256) and Shimbo (No. 5257). There is an increase of 14 mm. of the relative height of the bench marks at these places during these ten months.

Subsequent displacement along the fault. From the experience gained in the past and the recent earthquakes, the following fact has been found as to the vertical displacement of the seismic fault. In general, most of the

6) N. NASU and also T. NAGATA, A. OKADA, see 1).

7) C. TSUBOI, *Japanese Journ. Astro. Geophy.*, **10** (1932—33).

vertical displacement occurred at the time of the main earthquakes, while the remaining displacement occurred subsequently during several months or years. So far as known at present, the subsequent displacement was in the same sense as that at the time of the earthquake. For the Gōmura (appeared in 1927), Yamada (1927), Tanna (1930) and Fukui (1948) faults, the rates of the subsequent displacement to the initial displacement at the time of catastrophe are listed as below.

Fault	Vertical displacement		Subsequent / Initial	Period of subsequent displacement
	Initial	Subsequent		
	cm.	cm.	%	month
Gōmura	75	1.7	2.3	39
Yamada	114	3.0	2.6	39
Tanna	7	1.9	37.0	8
Fukui	75	2.8	3.7	12

It is noteworthy that in the Tanna fault, the subsequent vertical movement was far larger than those of the other faults. The movement of this fault at the time of the earthquake was mostly in a horizontal direction and it seems that the vertical motion was relatively active during the subsequent period.

It should be added that although in the present Fukui fault, the fault-line itself was intercepted to the naked eye, the crustal deformations undergone by both sides of the fault showed no particularly different characters when they were compared with the case of the clearly traceable seismic fault. We have experienced that there exists a new kind of the seismic fault which is called the intrinsic seismic fault as mentioned in this paper.

After the dissolution of the Special Investigation Committee of the Fukui Earthquake in March, 1949, the study of the post-seismic topographical changes was made personally by the writer with the Fund for Scientific Research of the Ministry of Education. To establish the general character of the seismic fault, the study will be extended further to the faults which made their appearances at the past great earthquakes.