46. *Landslide at Tôge, Katagami-mura, Osaka-Hu.*[1]

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1. Towards the end of November 1931, a phenomenon of a most alarming nature was discovered at Tôge, a village in Osaka prefecture. An area of nearly 74 acres, containing the village of Tôge, was found to be sliding slowly downwards in a southerly direction towards the Yamatogawa[2] (river). Many cracks had formed on the boundary zones of the moving and stationary regions as well as in the middle of the sliding ground itself, and these seemed to grow in size and number every day. Not long after the discovery, the inside wall of the Kamenose[3] railway tunnel that passes underneath the sliding region, caved in and temporarily interrupted traffic. This paper is a report of studies of the landslide made by the writer on the spot.

2. The map, Fig. 1, shows the location of the village of Tôge and the topographical features of its environs. It will be seen from the figure that the slope on which the village is situated is gentler than the opposite slope across the Yamatogawa (river). The topographical feature of this gentle slope, together with the curious trend of the river-course, suggests frequent landslides here in recent geological time.

The area not slipping is bounded by a zone of major cracks, while in the area itself minor cracks have developed here and there. The distribution of these cracks are shown in Fig. 2, and parts of them also in Figs. 5, 6, and 7 (Pl. LXXXVII & LXXXVIII).

On tracing the trend of the zone of major cracks, its continuity is interrupted by a sudden change in direction at the point marked E in the Fig. 2. In observing these cracks, Mr. Nasu[4] noticed that the cracks at a place westward of point E differed in rate of growth from those at a place eastward of it. For case of reference, therefore, the cracks have been divided into two groups, the Eastern and Western, in accordance with their location and mode of growth.

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1) 大阪府堅上村峠.
2) 大和川.
3) 龜ノ瀬.
4) N. NASU, *Bull. Earthq. Res Inst.*, this vol.

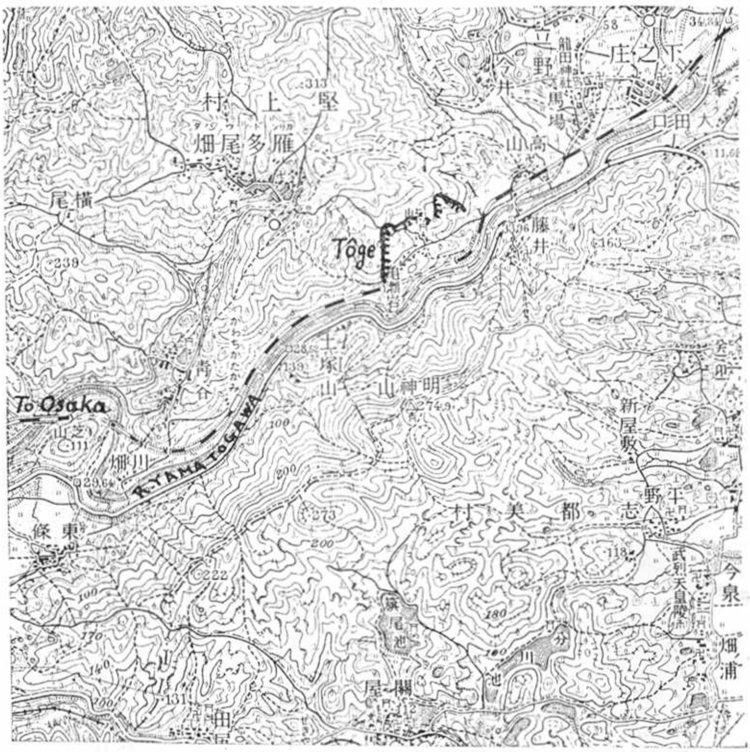

Fig. 1. Topographical Feature in the Vicinity of the Village of Tôge.

In the Western group, the cracks at A (Fig. 2) consist of several parallel fissures *en échelon*, which might have been produced by a shear movement. These cracks are traceable southward down to R, where the uplifted bed (probably a result of the landslide) of the Yamatogawa river is exposed. At the place marked M, popularly called "Owankake" and "Ubagakake", considerable quantities of sand and gravel drop from time to time into the river below.

The cracks B and C which were the first to be discovered, have grown since then and become the largest of them all. The movement of the area that is sliding is recognized at these places by the opening of cracks and formation of steps, and has been found to be in the direction approximately perpendicular to the trend of the cracks at these places. It is here also that the horizontal and vertical movements of the sliding earth mass have been most marked. Shear type cracks are observed in the region lying between C and D.

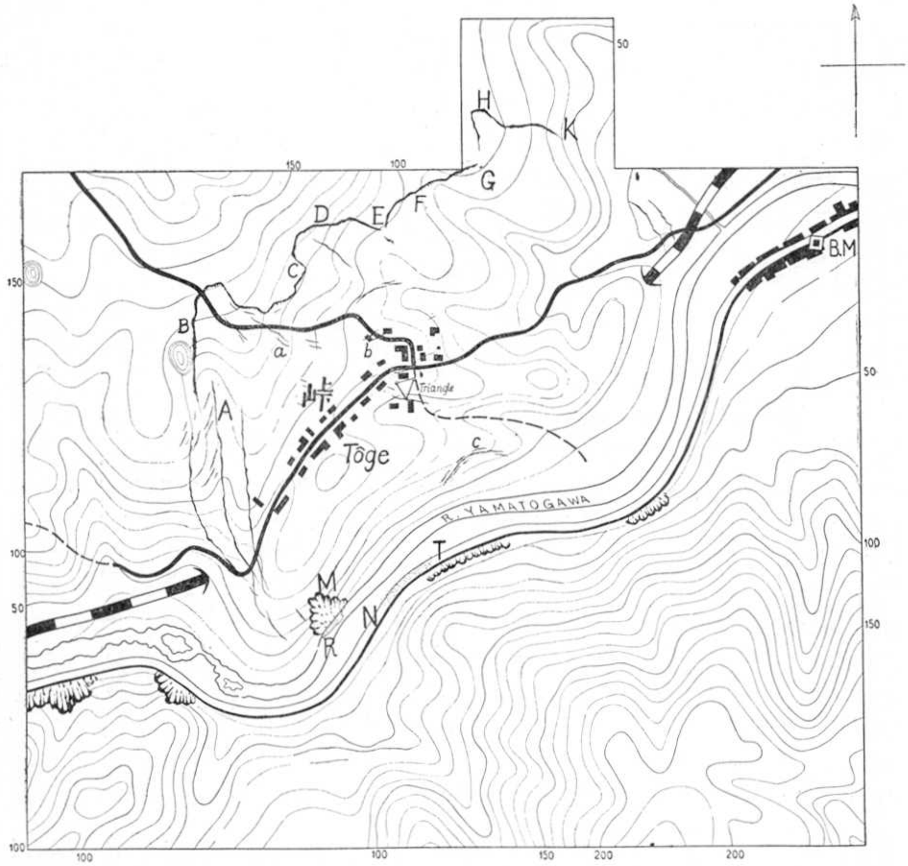

Fig. 2. Distribution of Cracks in the Vicinity of the Village of Tôge, Osaka-Hu.

The existence of these shear cracks between C and D and the cracks *en échelon* between A and B, is consistent with the presence of tension cracks between B and C, and consequently with the implication that the movement of the sliding earth mass is being directed perpendicular to the trend of the cracks at B and C, that is, from N to S.

As already mentioned, the trend of the cracks of the Eastern group, i.e., the cracks EFGHK (Fig. 2), are traceable over the rice fields and the railway track from K to the eastern portal of the Kamenose railway tunnel.

On the southern side of the Yamatogawa (river) a continuation of a sliding earth is observed at an upheaval of several metres of a part of a highway, the prefectural road joining Osaka and Nara, and denoted by NT in Fig. 2 (cf. photo Fig. 8, Pl. LXXXVIII). This fact seems to strengthen the conclusion that the movement of the earth mass is in such a manner that it as a whole slides over some curved surface down to the south as shown schematically in Fig. 3.

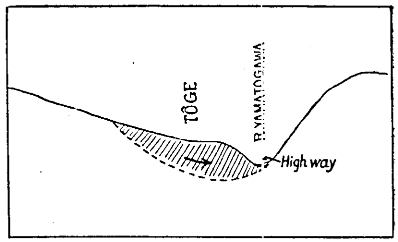

Fig. 3.

As has been already mentioned, in addition to the cracks in the boundary zones, many cracks or groups of cracks are observed in the sliding area itself, the outstanding ones being those marked *a* and *b* and some others near *c*.

3. Since the landslide is slowly proceeding, houses in the village of Tôge, in the sliding area, have been more or less damaged, probably because of deformation of the sliding earth mass.

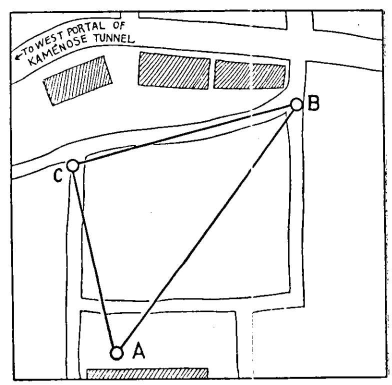

Fig. 4.

The writer has measured the lengths and angles of a triangle framed in Tôge (Fig. 4) for the purpose of investigating the variations in the deformation of the earth's surface with respect to time. These measurements were carried out three times since the 1st of February this year, with results as shown in Table I.

Table I. The Result of the Triangulation.

Date of Measurement	Lengths and Changes in Length of Lateral Sides						Heights referred to *A*	
	$\overline{AB}$	$\delta(\overline{AB})$	$\overline{BC}$	$\delta(\overline{BC})$	$\overline{CA}$	$\delta(\overline{CA})$	*B*	*C*
	m	cm	m	cm	m	cm	m	m
Feb. 1. p.m.	38·718		31·107		18·947		1·331	1·220
		+4·6		−2·9		+ 2·5		
Feb. 3. p m.	38·764		31·078		18·972		1·325	1·182
		+9·8		+1·7		+10·3		
Feb. 13. p m.	38·862		31·095		19·075		1·429	0·988

From these results, elongations and contractions of the lateral sides of the triangle for different time intervals were obtained by means of a simple calculation, whence the horizontal deformation of the triangular area its computed by the formula

$$\frac{dS}{S}=\frac{1}{2}\left\{\frac{ds}{s}+\frac{ds-d\alpha}{s-\alpha}+\frac{ds-d\beta}{s-\beta}+\frac{ds-d\gamma}{s-\gamma}\right\},$$

where α, β, γ are lengths of the lateral sides of the triangle, s is half the periphery, and ds, $d\alpha$, $d\beta$, $d\gamma$, are their changes. The calculated values of dS/S for different time intervals are shown in Table II. Notwithstanding the lack of accuracy incident to instrumental errors

Table II. dS/S calculated from the data in Table I.

Time interval	dS/S
Feb. 1—Feb. 3	$-1{\cdot}8\times10^{-4}$
Feb. 3—Feb. 13	$5{\cdot}7\times10^{-3}$

and the inexperience of the observer, the result obtained as above shows the general mode of time-variation of the deformation of the triangle. These values of dS/S point to considerable horizontal deformation in the sliding earth mass.

Moreover, vertical displacements of two vertices of the triangle relative to the third vertex show that the triangle tilted to the N or NW. Such deformation of the sliding earth mass may probably damage houses, cause cracks in walls (cf. photo Fig. 9, Pl. LXXXIX), tilt pillars, and bend door sills.

4. As to the real cause of the present landslide, we have no direct evidence of any kind. But so far as our observations go, the phenomenon seems to be due in large measure to mechanical action of the materials constituting the present sliding earth mass and its neighbourhood.

According to Prof. Makiyama, the geological structure of this region consists, as Prof. Matuyama[5] has also described, of three layers, namely, a lower andesite which had come from some mature volcano in the south, an intermediate agglomerate or conglomerate, and an upper layer of recent andesite. In the upper layer, slaty jointing is the dominant feature (cf. photo Fig. 10, Pl. LXXXIX), its uppermost parts being so badly weathered that almost all of it has transformed into clay. In such a condition of things, a minute change in the field of gravity, or in that of the other mechanical forces at work in maintaining the present state

5) M. MATUYAMA, *Tikyû*, **17** (1932), 323, (in Japanese).

of the earth's surface, may produce phenomenon such as the present landslide. In the construction of a new highway, large quantities of earth have been removed from the southern side of the Yamatogawa, and it is possible that this has helped to precipitate the sliding movement.

We could compare the deformation of a sliding earth mass with the results of an experiment[6] that was made a few years ago at our Institute with layers of sand. The experiment consisted in disturbing horizontal layers of sand packed in a box made with sides of glass, by gradually pulling away with uniform speed one of the end sides of the rectangular box, when the sand mass slips down forming irregular step faults[7] (cf. photo Fig. 11, Pl. LXXXIX). These irregular formation of step faults may have been due partly to slight lack of homogeneity in the sand mass. In the actual case of the earth's crust, want of homogeneity, such as the varying surface configurations, different geological formations, and the presence of cocluded waters in the sliding earth mass, may complicate the mode of deformation of the mass even though it may be sliding as a whole with uniform mean speed, as seen in the records that were obtained by Mr. Nasu.[8]

In conclusion, the writer desires to express his sincere thanks to Professors T. Terada and M. Ishimoto of our Institute, and also to Professor M. Matuyama of the Kyôto Imperial University, for much valuable advices and suggestions received during the course of these studies.

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46. 大阪府堅上村峠に於ける地辷に關する調査報告

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昨年（1931 年）十一月の末頃から大阪府下堅上村峠附近の傾斜地に地割を生じ、それが次第に生長してゆく様に見えた。其後、この地域を通過する關西本線龜ノ瀬隧道にも龜裂を生じ、局部的には崩壞するに至つたので、關西本線の運行が停止されこの部分だけ徒歩によつて聯絡することゝなつた。

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6) T. Terada and N. Miyabe, *Bull. Earthq. Res. Inst.*, 4 (1928), 33; 6 (1929), 109; 7 (1929), 65.

7) These experiments thus far are not comprehensive enough to justify discussions of them as being in any way analogous to the phenomenon of the present landslide. Further experiments are contemplated.

8) N. Nasu, *Bull. Earthq. Res. Inst.*, this vol., *loc. cit.*, (4).

筆者は二月初旬から中旬にかけて調査を命ぜられた。本文はその結果の簡單な報告である。

第二圖は滑落地域における龜裂の分布を示したものであるが、龜裂の大いさ、數等は其後次第に增加しつゝあるので現在の龜裂の分布とは多少異るかもしれない。

二月中旬には、地域內の家屋が損傷を被るやうになり、壁の龜裂（寫眞第九圖）、柱の傾斜、敷居の撓曲等が見られた。これは、恐らく滑落地域內の土地の變形によるものであらうと思はれる。地域內に設けた假の三角形につき、その邊長の時變化からその附近の土地の變形を算出したものは第一、二表に示されてゐる。これによつても、可成の程度の變形があつたことを推察することが出來る。

この地辷の眞因は今のところ不明であるが、今まで見た所では、土地を構成する地層の性質が關係の深いことは推察出來る。この附近の土地の上層なる安山岩層中には第一〇圖寫眞に示す樣なスレート樣節理が發達して居て、崩れやすく、最上層は殆ど風化して粘土化してゐる。

かく地層の構成が崩れやすく壞れやすいところへ、この地形を保つてゐる外力に些少の變化でも起つたならば、この樣な地辷りが起り得るのではなからうか。例へば、大和川南岸の縣道工事に際して切取られた土の mass の有無といふやうな事でも、このやうな現象を起す爲めの所謂 triggar action となり得る可能性があるかもしれない。

この地辷りと類似な現象の一つとして、吾々が曾つて行つた砂層の崩壞に關する實驗の結果を想起することが出來る。

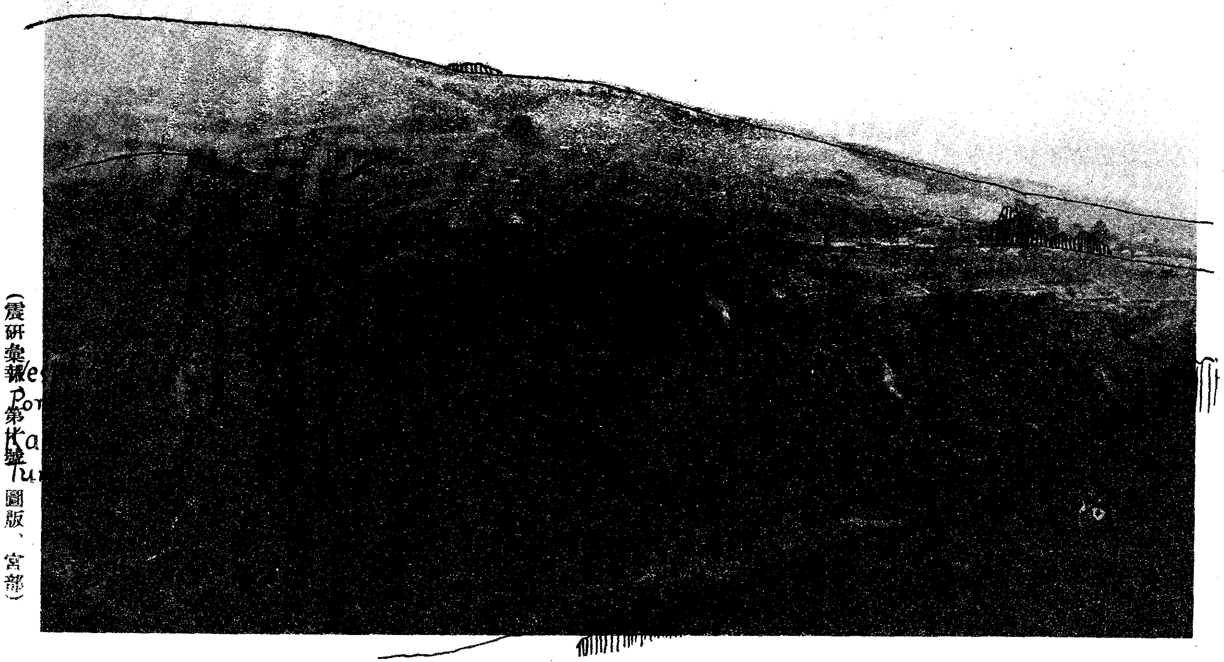

Fig. 5. General view of the sliding area.
(Photo. on the 13th of February, from SW across the Yamatogawa.

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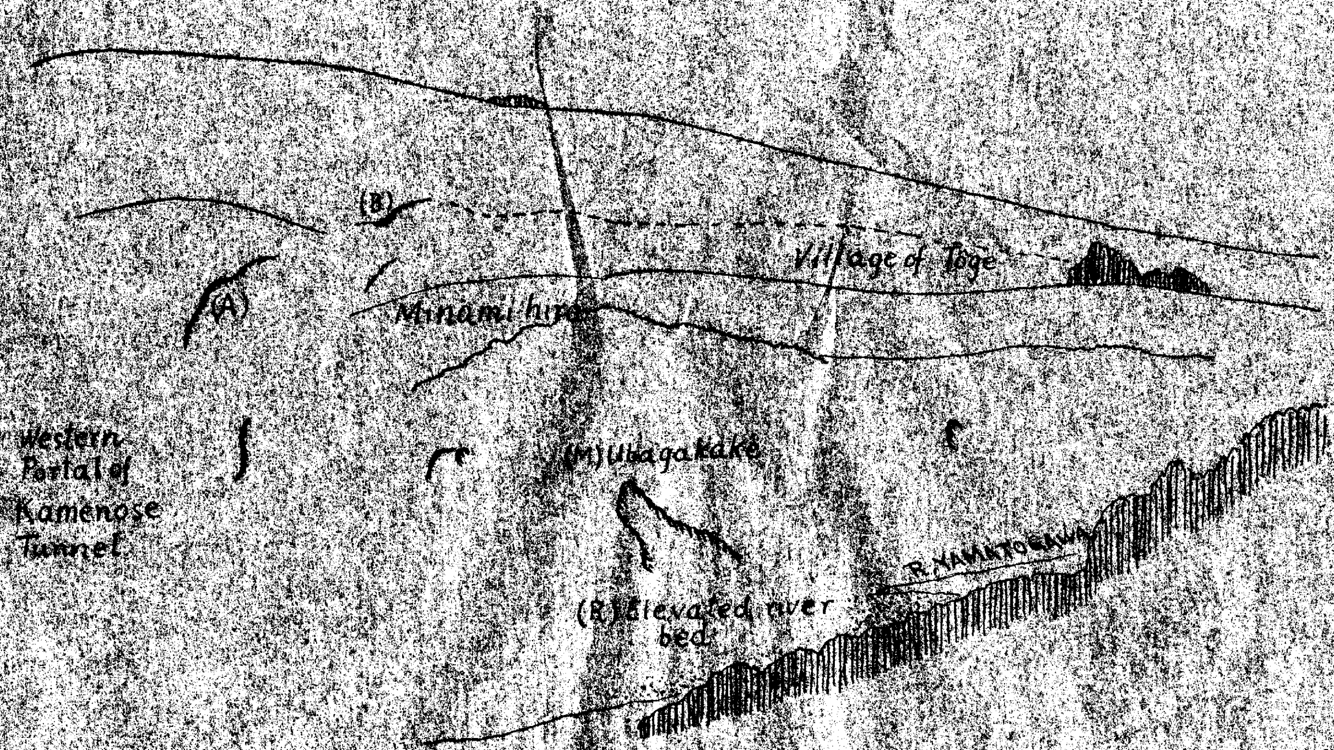
Village of Toge
(B)
(A)
Minami-hira
Western Portal of Kamenose Tunnel
(M) Ubagakake
R. YAMATOGAWA
(R) Elevated river bed

Fig. 5. General view of the sliding area.
(Photo. on the 13th of February, from SW across the Yamatogawa.

(震研彙報、第十號、圖版、宮部)

Fig. 6. Crack near C, where Mr. Nasu's self-recording instrument was installed.
(Photo. on the 3rd of February).

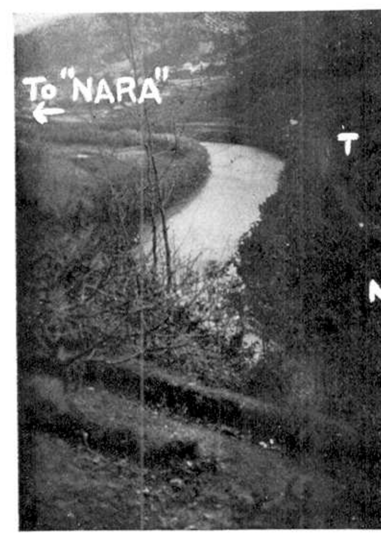

Fig. 8. The Yamatogawa viewed from Minamihara.
(Photo. on the 3rd of February).

Fig. 7. Crack in the sliding area.
(Photo. on the 3rd of February).

(震研彙報、第十號、圖版、宮部)

Fig. 9. A house attacked by the deformation of the earth's mass.
(Photo. on the 13th of February).

Fig. 10. Slaty Joints.

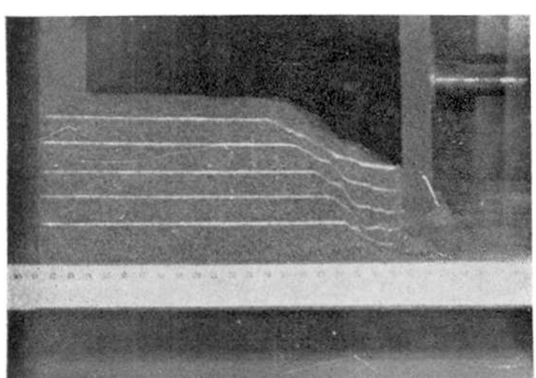

Fig. 11. Deformation of the Sand mass produced by receding the wall.