45. *A Study of the Osaka Landslide.*

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(Read Feb. 16, 1932.—Received June 20, 1932.)

Introduction. On November 27 last year, several rows of earth cracks, a few centimetres long and about a half centimetre wide, were noticed by the people of Katakami, a village 20 km. southeast of the city of Osaka. These cracks, which were on an orchard of recently cultivated slanting ground dipping towards the River Yamatogawa, gradually increased in both length and width with time. Later, other cracks were found in the neighbourhood. It was then recognized that the land block on which the village was situated, about 330,000 m^2. in area, was slowly sliding downwards in a southerly direction. Thenceforth, the sliding speed increased daily until Feb. 20, when it reached maximum, after which it showed a gradual decrease. The sliding land mass is an irregularly shaped area, bounded on all sides except on the southeast by a zone of cracks. In the beginning of June, as the result of the present sliding movement, the cracks at the front of the sliding area grew as large as 20 m. in width. In the course of time, since the cracks were first noticed, a huge trench-like hollow, 500 m. long and 80 m. wide, had formed at the western margin of the slipping area. About the end of January, local upheavals of the river-bed and of road surfaces along the river banks became noticeable. The gradual upheaval of the river bed, together with avalanches of large quantities of rock and earth into the nothern side of the river, thus narrowing it and at the same time raising the level of the upper stream, created fears of flood among the inhabitants. The houses in the sliding area having listed heavily to one side, owing to the earth-tilts that accompanied the landslide. Many of them were rendered uninhabitable.

Outline of the topography and geology of the slipping region. The district that is slipping is situated on the northern side of the River Yamatogawa, which cuts across a mountain range running in a north-south direction. This mountain has the form of a saddle, in the hollow of which is situated the hamlet of Tôge. The slope of the sliding region is about 15°.

Fig. 1. Map showing the slipping district. (From a Government Railway map.) Points E and W indicate the positions of self-recording instrument; P the photographic recording instrument; T the tiltmeter station.

According to Professor Makiyama, the uppermost surface of the sliding area is covered by younger andesite. Below it is a layer of agglomerate and gravel with the older andesite underneath it. This older andesite is well developed in a wide region lying to the south of this district.

Observation of the landslide. To measure the extent of slide with reference to time, different methods have been used by different observers. Professor Matsuyama, of the Kyôto Imperial University, carried out triangulations and ran precise levels over the whole of the affected area, and determined the directions in which the bench marks were moving and the time in which they did so. It might incidentally be mentioned that, on the basis of these observations, he has predicted settlement of

1) M. MATSUYAMA, "Observation of the Katakami Landslide," *Tikyû*, 17, No. 5 (1932), (in Japanese).

the ground and cessation of the present movement in course of time before it gets very serious.

For studying the sliding movement, we used two similar-typed self-recording instruments, specially constructed for the purpose, the details of which will be given later. The motion of the sliding mass was found to be very rapid; the speed at its maximum probably exceeded 15 mm. per hour, making the daily amount of displacement more than 300 mm. Such a rapid motion could easily be recorded by a simple arrangement. With this instrumental arrangement was measured the rate at which the largest crack of all was widening–the crack that bordered the slipping area, not the one in the area itself. It was continued for 80 days. The rate of motion of the sliding area itself could only be determined by triangulation and levelling, and this was done by Professor Matsuyama. Upon comparing his results with ours, it was found to agree fairly well, so that the method which we had employed was useful in checking the results of the other method.

The two self-recording instruments were installed, widely separated, at two places near the crack. The position of these points are shown in Fig. 1. The instrument is shown in Fig. 2. A wooden post H,

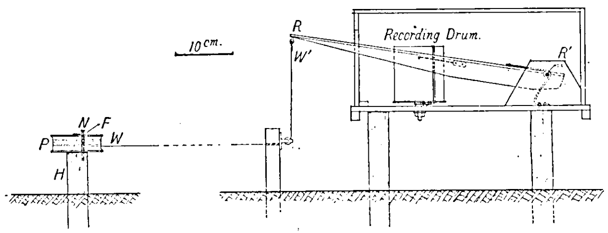


Fig. 2. Side-view of the self-recording instrument.

about 1 m. long, is driven into the sliding ground some distance from the margin of the crack. On the top of this post is attached a pulley P with its rotating axis vertical. A nail N driven through hole F in the pulley into the top of the post prevents rotation of the pulley except when required, when it is withdrawn. A steel wire, 0·4 mm. diameter and a few metres long, is wound around this pulley. The end of this wire is fixed to the end of the lever arm RR'. An inked pen is fixed to the middle point of RR'. The recording drum encloses an ordinary Richard's clock which makes one revolution a day. The arm RR' rotates in a vertical plane about the horizontal axis, passing through R'. Around the axle of the lever arm is wound a steel wire in the form of a helical spring, one end of which is fixed to the wooden stand and the other end to the arm. The elasticity of the spring causes the arm always to leap upward and produce tension on the wire WW'. The recorder is placed on the undisturbed side of the crack.

When the land slides, the wooden post H changes its position relatively to the recording apparatus, so that the extent to which the wire is pulled is a measure of the length the land has slipped. The arm RR' then goes down and the motion of the ground is registered on the drum on the reduced scale of one-half. After expiration of 24 hours of observation, the nail on the top of the post is withdrawn, when by unwinding the wire, the pen can be brought back to zero position.

In our first observation we used two such instruments, but at the western station the daily amount of sliding grew so large that the recording pen eventually went off the paper within 24 hours from the beginning of the daily observation, indicating that at this station the record must be taken on a more reduced scale than one-half. For this purpose, another arrangement was set up alongside the instrument just mentioned. As shown in Fig. 3, in this arrangement the wire from post H was fastened to end L of the new lever arm, LL'. The lever rotates in a horizontal plane about the vertical axis passing through O, the arm ratio LO to $L'O$ being 2·5: 1·0. The wire from the recording arm RR' is fixed to L'. This enabled the motion to be registered on the scale of one-fifth.

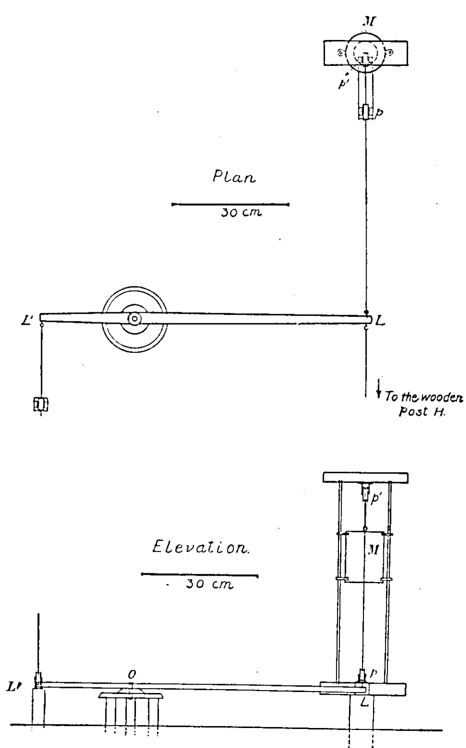


Fig. 3. Arrangement added to the instrument at E-Station.

Another advantage from this arrangement is that the wire between post H and arm RR' in the old arrangement, as shown in Fig.

2, was often shaken by strong winds, with the result that the curves were zigzag, thus making it impossible to determine the motion of the ground. The difficulty was increased with the lengthening of the wire between H and RR'. To avoid it, a stronger tension was applied to the wire. To effect this, another wire is fastened to L and stretched to the opposite side of the wooden post H, passing over two pulleys p and p'. At the end of this wire is suspended a heavy mass M, weighing 4 kg. The weight moves upward along the two guides when the post moves away from the recorder. The tension of the wire may be varied by changing the weight. In this way, we managed to keep the wire always taut and free from wind effects.

In setting up the instrument, the direction of the sliding motion of the ground was carefully ascertained and the wire stretched in such a way that its direction shall always coincide with the direction of sliding. In this work the direction of the motion of the wooden post was first measured by a dial-compass and wire stretched in that direction. To roughly estimate this direction of the sliding motion, it is sufficient to measure the direction of the line joining any two points, one on each side of the crack, that were formerly closer together. In doing so, the angle of dip of the slide may be determined. In the present movement, slickensides were found at several places. For example, at station-E, the tracks of the sliding mass found on the slickenside had a strike of N 35°-45° W—S 35°-45° E with a dip of 30°-35° S.

Our observations were begun on Feb. 1 at the W-station and on the following day at the E-station. The daily amount of displacement was measured on the record obtained at both stations E and W. The following lists give the daily amount of the displacement and the hourly rate of sliding.

It was found that the width of the cracks increased with fairly constant speed. As can be seen from Fig. 4, a, b, c, d, the records of the motion are nearly straight lines, although close examination reveals minute waviness of the lines, suggesting more or less fluctuation in the rate of the sliding motion. The sliding speed as determined with the self-recording instrument, and given in Lists 1 and 2 may be said to be the mean value.

From the beginning of the observations, the mean speed increased gradually until Feb. 20, when the sliding motion reached maximum, after which the motion declined rather slowly, a feature that was also pointed out by Professor Matsuyama.[2] Professor Matsuyama calculated

2) M. MATSUYAMA, *loc. cit.*

List 1.

The Daily amount and the hourly rate of sliding at the E-station.

Date	Daily amount sliding	sliding 6 hours				Hourly rate of sliding			
		0^h-6^h	6^h-12^h	12^h-18^h	18^h-24^h	0^h-6^h	6^h-12^h	12^h-18^h	18^h-24^h
	mm	mm	mm	mm	mm	mm	mm	mm	mm
Feb. 1	—	—	—	—	—	—	—	—	—
2	60	14	14	16	16	2·33	2·33	2·67	2·67
3	65	15	17	17	16	2·50	2·83	2·83	2·67
4	72	18	18	18	18	3·00	3·00	3·00	3·00
5	78	19	19	20	20	3·17	3·17	3·33	3·33
6	85	20	21	22	22	3·33	3·50	3·67	3·67
7	91	22	22	23	24	3·67	3·67	3·83	4·00
8	97	24	24	25	24	4·00	4·00	4·17	4·00
9	104	25	25	27	27	4·17	4·17	4·50	4·50
10	110	27	27	28	28	4·50	4·50	4·67	4·67
11	117	28	29	30	30	4·67	4·83	5·00	5·00
12	124	31	31	31	31	5·17	5·17	5·17	5·17
13	126	32	32	32	30	5·33	5·33	5·33	5·00
14	—	—	34	34	34	—	5·67	5·67	5·67
15	—	34	34	—	35	5·67	5·67	—	5·83
16	142	35	35	36	36	5·83	5·83	6·00	6·00
17	144	36	36	36	36	6·00	6·00	6·00	6·00
18	143	36	35	37	35	6·00	5·83	6·17	5·83
19	146	36	36	37	37	6·00	6·00	6·17	6·17
20	151	38	38	38	37	6·33	6·33	6·33	6·17
21	150	37	37	38	38	6·17	6·17	6·33	6·33
22	148	37	37	37	37	6·17	6·17	6·17	6·17
23	145	37	36	36	36	6·17	6·00	6·00	6·00
24	146	37	36	36	37	6·17	6·00	6·00	6·17
25	140	35	35	35	35	5·83	5·83	5·83	5·83
26	139	35	35	35	34	5·83	5·83	5·83	5·67
27	138	34	35	34	35	5·67	5·83	5·67	5·83
28	133	34	34	33	32	5·67	5·67	5·50	5·33
29	125	32	32	30	31	5·33	5·33	5·00	5·17
March 1	118	30	30	29	29	5·00	5·00	4·83	4·83
2	113	29	28	28	28	4·83	4·67	4·67	4·67
3	108	28	27	26	27	4·67	4·50	4·33	4·50
4	102	26	26	25	25	4·33	4·33	4·17	4·17
5	96	25	24	23	24	4·17	4·00	3·84	4·00
6	90	25	24	20	21	4·17	4·00	3·33	3·50
7	87	22	23	22	20	3·67	3·83	3·67	33·3
8	85	22	22	21	20	3·67	3·73	3·50	33·3
9	78	20	21	19	18	3·33	3·50	3·17	30·0
10	71	18	18	17	18	3·00	3·00	2·83	30·0
11	72	18	18	18	18	3·00	3·00	3·00	30·0

(to be continued.)

List 1. *(continued.)*

Date	Daily amount sliding	Distance slid in 6 hours				Hourly rate of sliding			
		0^h—6^h	6^h—12^h	12^h—18^h	18^h—24^h	0^h—6^h	6^h—12^h	12^h—18^h	18^h—24^h
	mm	mm	mm	mm	mm	mm	mm	mm	mm
12	70	17	17	18	18	2·83	2·83	3·00	3·00
13	69	16	18	18	17	2·67	3·00	3·00	2·83
14	66	17	17	17	15	2·83	2·83	2·83	2·50
15	64	16	16	16	16	2·67	2·67	2·67	2·67
16	58	14	15	14	15	2·33	2·50	2·33	2·50
17	56	14	14	14	14	2·33	2·33	2·33	2·33
18	55	14	13	14	14	2·33	2·17	2·33	2·33
19	50	13	13	12	12	2·17	2·17	2·00	2·00
20	50	12	14	12	12	2·00	2·33	2·00	2·00
21	48	12	12	12	12	2·00	2·00	2·00	2·00
22	42	12	11	9	10	2·00	1·83	1·50	1·67
23	41	11	10	9	11	1·83	1·67	1·50	1·83
24	42	10	11	11	10	1·67	1·83	1·83	1·67
25	43	11	11	11	10	1·83	1·83	1·83	1·67
26	42	10	10	11	11	1·67	1·67	1·83	1·83
27	37	11	8	10	8	1·83	1·33	1·67	1·33
28	30	7	6	8	9	1·17	1·00	1·33	1·50
29	35	9	10	9	7	1·50	1·67	1·50	1·17
30	37	9	11	8	9	1·50	1·83	1·33	1·50
31	35	10	10	8	7	1·67	1·67	1·33	1·17
April 1	32	8	8	8	8	1·33	1·33	1·33	1·33
2	35	9	9	9	8	1·50	1·50	1·50	1·33
3	31	8	7	8	8	1·33	1·17	1·33	1·33
4	32	8	8	8	8	1·33	1·33	1·33	1·33
5	29	7	7	8	7	1·17	1·17	1·33	1·17
6	26	7	6	6	7	1·17	1·00	1·00	1·17
7	24	6	6	6	6	1·00	1·00	1·00	1·00
8	25	7	6	6	6	1·17	1·00	1·00	1·00
9	24	6	7	6	5	1·00	1·00	1·00	0·83
10	20	5	5	5	5	0·83	0·83	0·83	0·83
11	18	5	4	5	4	0·83	0·67	0·83	0·67
12	20	5	5	5	5	0·83	0·83	0·83	0·83
13	21	6	5	5	5	1·00	0·83	0·83	0·83
14	20	5	5	5	5	0·83	0·83	0·83	0·83
15	22	5	6	5	6	0·83	1·00	0·83	1·00
16	19	5	5	5	4	0·83	0·83	0·83	0·67
17	18	5	4	4	5	0·83	0·67	0·67	0·83
18	22	5	5	6	6	0·83	0·83	1·00	1·00
19	22	6	6	5	5	1·00	1·00	0·83	0·83
20	18	5	5	4	4	0·83	0·83	0·67	0·67

List 2.

The daily amount and the hourly rate of sliding at the W-station.

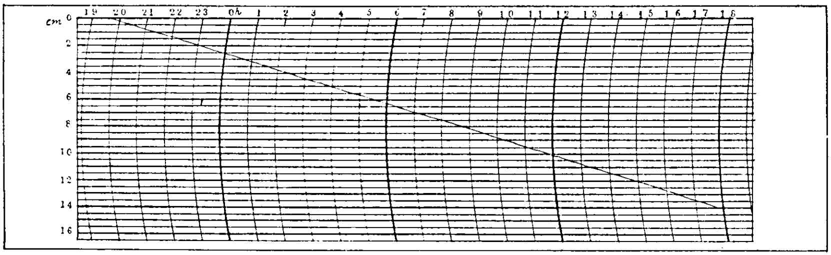
Date	Daily amount of sliding	Distance slid in 6 hours				Hourly rate of sliding			
		0^h—6^h	6^h—12^h	12^h—18^h	18^h—24^h	0^h—6^h	6^h—12^h	12^h—18^h	18^h—24^h
	mm	mm	mm	mm	mm	mm	mm	mm	mm
Feb. 1	101	22	24	28	27	3·67	4·00	4·67	4·50
2	130	28	30	36	36	4·67	5·00	6·00	6.00
3	149	35	39	39	36	5·83	6·50	6·50	6·00
4	166	40	40	46	40	6·67	6·67	7·67	6·67
5	166	40	38	43	45	6·67	6·33	7·17	7·50
6	185	46	45	47	47	7·67	7·50	7·83	7·83
7	197	49	47	51	50	8·17	7·83	8·50	8·33
8	207	50	52	54	51	8·33	8·67	9·00	8·50
9	229	52	52	62	63	8·67	8·67	10·33	10·50
10	245	60	60	65	60	10·00	10·00	10·83	10·00
11	255	63	62	62	68	10·50	10·33	10·33	11·33
12	281	68	68	73	72	11·33	11·33	12·17	12·00
13	290	72	72	73	73	12·00	12·00	12·17	12·17
14	298	71	73	76	78	11·83	12·17	12·67	13·00
15	312	76	76	77	83	12·67	12·67	12·83	13·83
16	337	78	82	87	90	13·00	13·67	14·50	15·00
17	332	83	84	82	83	13·83	14·00	13·67	13·83
18	322	80	80	82	80	13·33	13·33	13·67	13·33
19	319	79	78	78	84	13·17	13·00	13·00	14·00
20	333	84	84	82	83	14·00	14·00	13·67	13·83
21	—	83	—	—	84	13·83	—	—	14·00
22	320	85	89	74	72	14·17	14·83	12·33	12·00
23	286	75	74	67	70	12·50	12·33	11·17	11·67
24	—	75	82	—	67	12·50	13·67	—	11·17
25	292	63	77	77	75	10·50	12·83	12·83	12·50
26	297	77	75	75	70	12·83	12·50	12·50	11·67
27	279	73	71	68	67	12·17	11·83	11·33	11·17
28	280	76	70	68	66	12·67	11·67	11·33	11·00
29	256	65	65	63	63	10·83	10·83	10·50	10·50
March 1	246	62	62	62	60	10·33	10·33	10·33	10·00
2	228	59	55	57	57	9·83	9·17	9·50	9·50
3	222	57	57	55	53	9·50	9·50	9·17	8·83
4	210	53	53	53	51	8·83	8·83	8·83	8·50
5	188	50	48	45	45	8·33	8·00	7·50	7·50
6	177	45	47	45	40	7·50	7·83	7·50	6·68
7	—	45	—	—	—	7·50	—	—	—
8	—	—	—	40	38	—	—	6·67	6·33
9	146	33	38	40	35	5·50	6·33	6·67	5.83
10	146	33	38	40	35	5·50	6·33	6·67	5·83
11	125	33	32	30	30	5·50	5·33	5·00	5·00

(to be continued.)

List 2. (*continued.*)

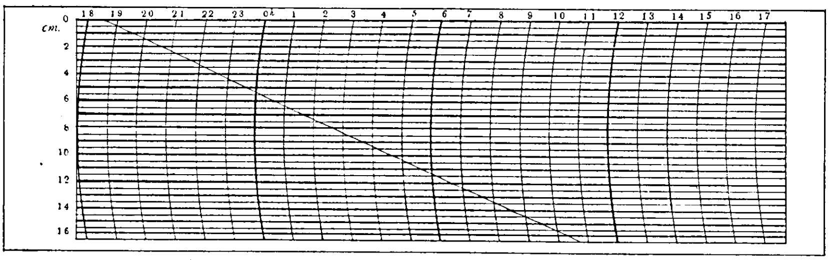
Date	Daily amount of sliding	Distance slid in 6 hours				Hourly rate of distance slid			
		0^h-6^h	6^h-12^h	12^h-18^h	18^h-24^h	0^h-6^h	6^h-12^h	12^h-18^h	18^h-24^h
	mm	mm	mm	mm	mm	mm	mm	mm	mm
March 12	—	—	—	—	26	—	—	—	4·33
13	115	30	30	25	30	5·00	5·00	4·17	5·00
14	112	27	35	25	25	4·50	5·83	4·17	4·17
15	109	32	27	25	25	5·33	4·50	4·17	4·17
16	107	30	30	25	22	5·00	5·00	4·17	3·67
17	—	24	22	—	20	4·00	3·67	—	3·33
18	88	22	23	20	23	3·67	3·83	3·33	3·83
19	88	22	26	22	18	3·67	4·33	3·67	3·00
20	85	20	22	21	22	3·33	3·67	3·50	3·67
21	88	20	23	20	25	3·33	3·83	3·33	4·17
22	68	18	20	15	15	3·00	3·33	2·50	2·50
23	75	20	20	17	18	3·33	3·33	2·83	3·00
24	70	20	15	18	17	3·33	2·50	3·00	2·83
25	79	20	25	17	17	3·33	4·18	2·83	2·83
26	61	16	17	15	13	2·67	2·83	2·50	2·17
27	—	15	17	—	10	2·50	2·83	—	1·67
28	67	15	17	18	17	2·50	2·83	3·00	2·83
29	77	22	18	17	20	3·67	3·00	2·83	3·33
30	63	22	15	13	13	3·67	2·50	2·17	2·17
31	60	17	15	13	15	2·83	2·50	2·17	2·50
April 1	54	15	15	12	12	2·50	2·50	2·00	2·00
2	—	10	15	—	—	1·67	2·50	—	—
3	—	—	—	—	—	—	—	—	—
4	—	—	—	—	12	—	—	—	2·00
5	47	12	13	12	10	2·00	2·17	2·00	1·67
6	45	12	13	10	10	2·00	2·17	1·67	1·67
7	—	8	10	—	—	1·33	1·67	—	—
8	—	—	—	—	—	—	—	—	—
9	—	—	—	—	10	—	—	—	1·67
10	42	10	12	12	8	1·67	2·00	2·00	1·33
11	41	11	10	12	8	1·83	1·67	2·00	1·33
12	34	8	8	8	10	1·33	1·33	1·33	1·67
13	32	12	6	6	8	2·00	1·00	1·00	1·33
14	41	12	9	10	10	2·00	1·50	1·67	1·67
15	39	9	9	11	10	1·50	1·50	1·83	1·67
16	37	12	10	6	9	2·00	1·67	1·00	1·50
17	34	12	8	7	7	2·00	1·33	1·17	1·17
18	36	10	7	10	9	1·67	1·17	1·67	1·50
19	43	9	15	8	11	1·50	2·50	1·33	1·83
20	43	10	15	8	10	1·67	2·50	1·33	1·67

a



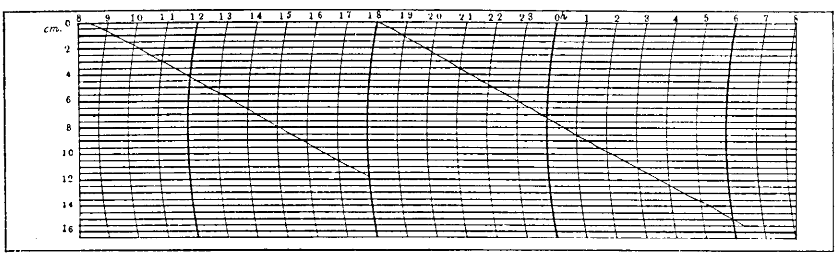
From Feb. 4. $19^{h}45^{m}$ to Feb. 5. $17^{h}40^{m}$.

b



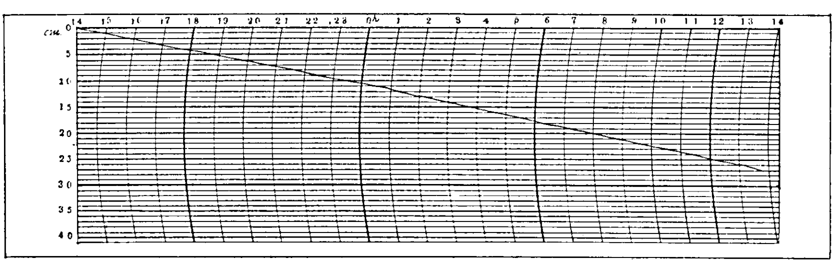
From Feb. 9. $18^{h}30^{m}$ to Feb. 10. $10^{h}50^{m}$.

c



From Feb. 14. $8^{h}30^{m}$ to Feb. 15. $6^{h}15^{m}$.

d



From Feb. 27. $14^{h}00^{m}$ to Feb. 28. $13^{h}40^{m}$.

Fig. 4. Records of the widening motion of the crack taken at W-station. Figures about 1/3 actual size.

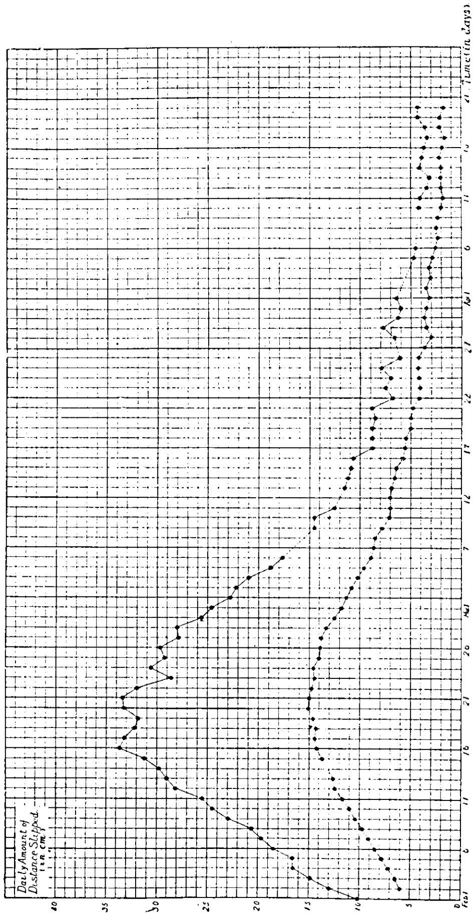


Fig. 5. Diagram showing the daily amount of distance slid.
upper curve: W-station.
lower curve: E-station.

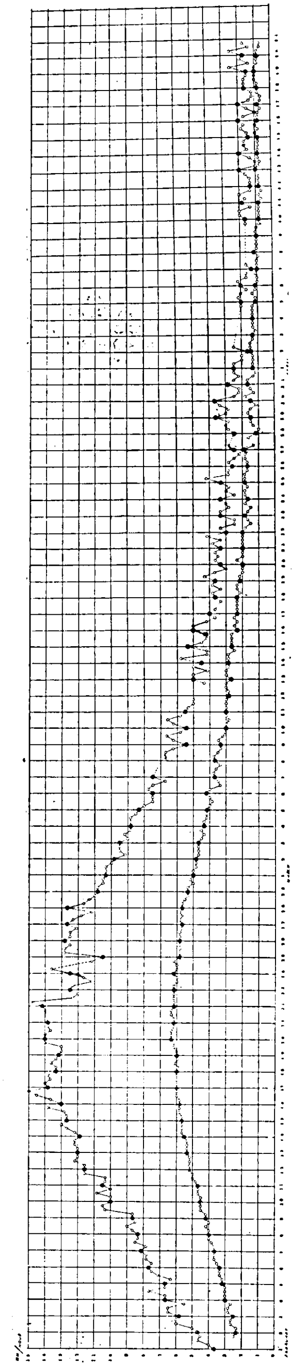


Fig. 6. Hourly rate of sliding.
upper curve: W-station.
lower curve: E-station.

the displacement of the geodetic point that he had established near station-W and showed that our result agrees well with his results of triangulation.

Photographic recording of the landslide. As already stated, there are certain instantaneous changes in the rate of the sliding motion. We therefore made attempts to observe the motion of the ground with a new instrument designed to record the motion speedily and with high magnification. The details of this instrument are as follows. A wooden post is driven into the sliding side of the ground, as in the case of the former instrument. A wire is clamped to the top of this post, and to the other end of this wire is suspended a heavy mass of about 5 kg., as shown in Fig. 7. The wire passes over a steel roller RR', the axis of which lies horizontally. On this axis a lens-mirror (focal length=50 cm.) is attached. When the wire is pulled as the result of the sliding motion the mirror rotates about its axis. The diameter of this axle is 2 mm. A recording drum with photographic paper wrapped around it is set at a distance of 1 m. from the surface of the mirror. A point-source lamp illuminates this mirror. The distance between the mirror and the lamp is 1 m. The recording drum makes one revolution in about 4 minutes, the diameter and the length of the drum being 18 cm. and 25 cm., respectively. Thus the rate of registration in one minute is about 14 cm. The magnification of the motion thus obtained is 2,000. The direction of the wire coincided with the direction of the sliding motion. The records of the motion were obtained at the station, the position of which is shown in Fig. 1. These records are shown in Figs. 8, a, b, c, d.

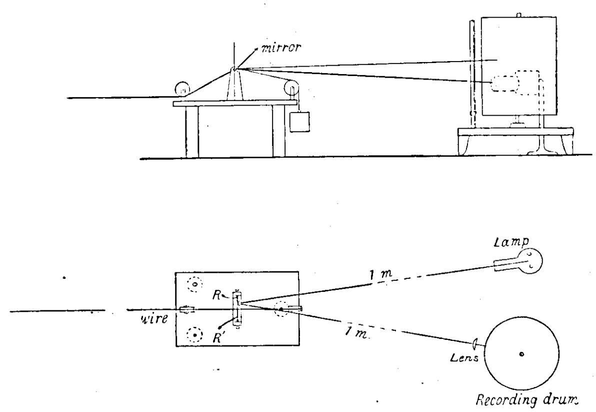


Fig. 7. Photographic recording apparatus for landslide observation. Upper=elevation, lower=plan.

From these records it is apparent that the motion did not have a constant speed, but varied considerably from time to time. In the figures are seen several sudden changes in the inclination of the curve. The fluctuations in the sliding speed were also confirmed in the following manner.

Observation of the sliding motion by means of the dial-gauge. As is well known, the displacement of the contact point of the dial-gauge is measured by reading the displaced amount of the indicator on the graduated circle. In our case a displacement of 1 mm. of the contact point is equivalent to one revolution of the indicator. The circumference of the circle is divided into 100 divisions. In this observation, the wire is stretched in the direction of the sliding motion of the ground as in the previous observations. To the end of the wire from the wooden post, a small hook is fastened, by means of which the wire is joined to the movable brass device *B*. This device moves in only one direction through rectangular opening *EFCD*, while to its opposite end a helical spring is attached. This spring gives the desired tension to the wire upon adjusting its length by means of the screw *S*. The brass stand is fixed to the ground by embedding the tripod firmly in it. When the land makes a sliding motion, it pulls the wire and moves the brass device. The contact point of the gauge touching this device rotates the indicator. The exact time required for a definite amount of sliding distance was measured by a stop-watch. The instrument being portable, the sliding speed could be determined wherever desired.

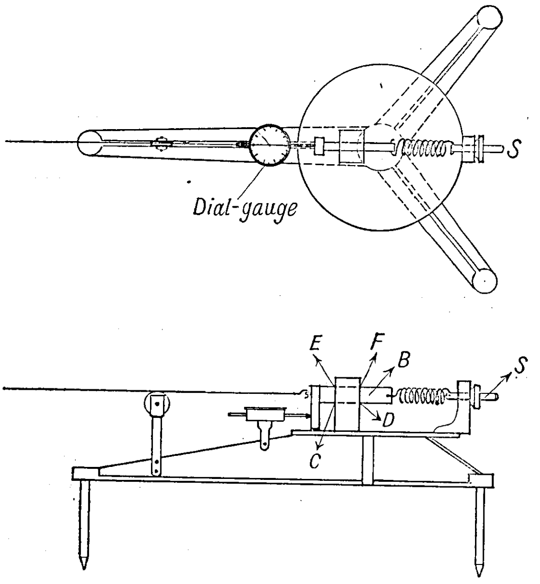


Fig. 9.

In the case of the present landslide, the sliding speed was considerable. The time required to slide 1 mm. as measured at places where sliding was most active being less than ten minutes. Measurements were also made at places where the speed was not so great, in which case the time required to slide less than 1 mm. was measured.

It must here be added that in using this instrument, where the sliding speed is small, difficulties arise, for at such places, owing to the long time required for the observation, influences of temperature variation disturb the results. Our experience has shown, however, that when this instrument is set on firm (stationary) ground, the indicator of the gauge showed no deflection greater than one division during a half-hour or an hour, and that on the whole there is little effect of sunshine or wind.

Observations with this instrument were made twice during February; the first observation on the 18th and the second on the 28th. The sliding times and the sliding distances measured are shown in Lists 3 and 4. The direction and the magnitude of the hourly rate of the sliding distance at each point are shown in Figs. 10 and 11.

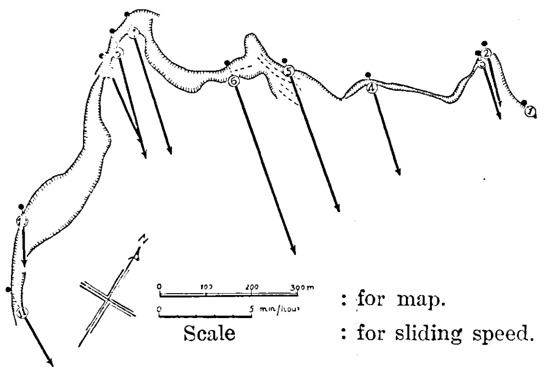


Fig. 10. Distribution of the sliding speed on Feb. 18.

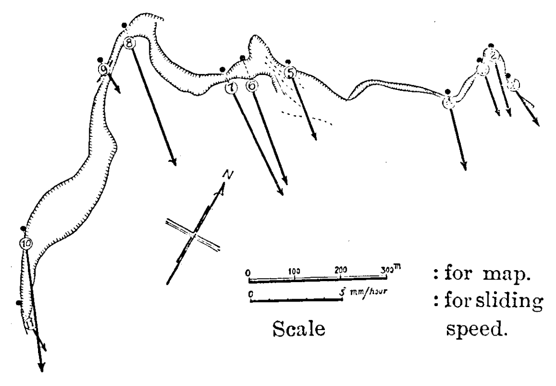


Fig. 11. Distribution of the sliding speed on Feb. 28.

The direction of the sliding motion at each station was determined by means of the dial-compass, which shows fair agreement with Professor Matsuyama's result. For example, Matsuyama's value of the sliding direction of bench-mark M_2[3] takes a value between S 50° E and S 54° E, while in our observation it was S 50° E at point No. 6 in Fig. 11; and at M_8,[3] one of Matsuyama's bench marks, the direction was between S 59° E and S 54° E, against which value we obtained S

3) MATSUYAMA's bench-mark M_2 was 80 m. away from point No. 6 (Fig. 11) eastward. Bench-mark M_8 was 50 m. away from point No. 11 (Fig. 11) north-eastward.

60° E. In the last two figures, the positions of the post are indicated with circles, together with their serial number, while the positions of the gauge are shown by dots. The arrows are drawn in the directions

List 3.

The first observation, Feb. 18.

Point	Distance slid	Time required		Hourly rate of slide	Direction
	mm	m	s	mm	
1	0·05	17	15	0·2	S 60° E
2	0·5	10	24	2·9	S 45° E
3	0·5	10	04	3·0	S 48° E
4	1·0	12	35	4·8	S 48° E
5	1·0	7	29	7·9	S 50° E
6	1·0	6	04	9·9	S 50° E
7	1·0	8	48	6·8	S 48° E
8	0·5	5	10	5·8	S 45° E
9	0·5	7	04	4·3	S 54° E
10	0·5	12	59	2·3	S 33° E
11	0·5	18	57	3·2	S 60° E

List 4.

The second observation, Feb. 28.

Point	Distance slid	Time required		Hourly rate of slide	Direction
	mm	m	s	mm	
1	0·5	13	12	2·3	S 60° E
2	0·5	9	56	3·0	S 45° E
3	0·5	12	41	2·4	S 50° E
4	1·0	17	50	3·4	S 55° E
5	0·5	7	51	3·8	S 50° E
6	0·5	5	25	5·6	S 50° E
7	0·5	4	42	6·4	S 55° E
8	1·0	8	34	7·0	S 45° E
9	0·5	22	57	1·3	S 58° E
10	1·0	8	46	6·8	S 60° E
11	0·25	11	45	1·3	S 37° E

of the sliding motion, their lengths being proportional to the sliding speed.

In Fig. 11, we see that at point No. 1, the eastern extremity of the zone of cracks, the motion was much slower than at any other place. In fact, the total amount of dislocation of the narrow pathway that passed through this point No. 1 was found to be about 50 cm. at the time it was observed on Feb. 18, beyond which the trace of the cracks could hardly be traced. It should be added that since this observation (Feb. 18) was made, the cracks appeared to extend farther to the east with increased sliding motion along the cracks, until at the beginning of June the dislocation of the pathway was as much as 3 m. or more. Stations Nos. 2 and 3 are situated near the top of the eastern projection of the sliding area, at which points the speed was much greater than at point No. 1, but further increase in speed could be discerned in the region at the top of the whole sliding area, that is near point No. 6. At points along the western margin of the crack, sliding speed diminished as the positions of the points approached south. At point No. 9, the motion of the depressed ground was in the direction S 23° E, dip 33° S.

The second observation shows that the speed was maximum at No. 8, instead of at No. 6 as in the first observation. There is more or less difference in the distribution of the sliding speed in these two observations, but the speed was greater at the top of the whole sliding area. The sliding speeds of all points in the second observation were smaller than those in the first.

It must here be remembered that the speed of point No. 6, as determined in the first observation, came out smaller than that determined by the self-recording instrument installed near this point. The former value is 9·9 mm./hour, while that of the latter is 11·2 mm./hour. There is nothing remarkable about this difference, since the sliding speed is not always a constant quantity, as we have already mentioned. As a matter of fact, we have found that the indicator of the gauge does not invariably move smoothly with constant speed; an irregular change in the motion of the indicator was noticed at every different place. For example, at point No. 6, the indicator sometimes travelled over five or ten divisions of the graduated circle in only two or three seconds, and afterwards moved leisurely at a rate of ten or twenty seconds to pass one division. At points where the motion was slower than at point No. 6, the number of divisions traversed within a given time diminished in proportion to the speed of the landslide. All these anomalies, of course, have nothing to do with instrumental peculiarities.

Variations similar to the foregoing, but in the sliding motion of the ground, takes place in comparatively long time-intervals, such as two or three hours. It was often found in the records obtained by the instrument first described, that the inclination of short segments of the curves showed different values for each segment of the curve. It is therefore to be understood that Figs. 11 and 12 show the distribution of the sliding speed for only a few hours. It might be added here that a series of our observation takes about 3 hours.

Observation of the sliding mass for earth-tilts. The fact that houses in the disturbed area, since the beginning of the sliding, had leaned so much out of the vertical as to render it difficult in the course of a month to close the doors, naturally suggested earth-tilt. For the purpose of measuring the tilts, we installed two horizontal component seismographs at T, see Fig. 1, and registered the two horizontal components of the tilting motion. These component pendulums were of the mechanical registration type, with natural oscillation periods between 2·0 and 6·0 seconds, their mechanical magnification being 20 times.

At the beginning of observations, that is Feb. 3, tilting went on at the rate of 1·49′ a day in the NS component and 0·74′ in the EW component. But since then the amount of the tilting incresed daily as the sliding speed increased. The pendulums, whose periods were first adjusted to 4·5 seconds, became too sensible to register such a large amount of tilting and often went off the smoked paper during a day's observation. The periods were reduced therefore to 3·5 seconds on Feb. 16. The daily amounts of tilt are given in List 5, with the changes

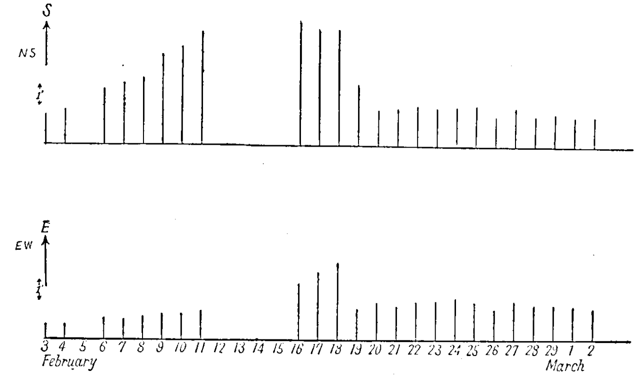


Fig. 12. Daily amount of tilting at T-Station.

List 5.

The daily and hourly amounts of tilt.
(Angle in minutes)

Date		NS comp. (dip S)		EW comp. (dip E)	
		ϕ/day	ϕ/hour	φ/day	φ/hour
Feb.	3	1·49′	0·06′	0·74′	0·03′
	4	1·76	0·07	0·72	0·03
	5				
	6	2·88	0·12	1·02	0·04
	7	3·17	0·13	0·89	0·04
	8	3·41	0·14	1·12	0·05
	9	4·59	0·19	1·23	0·05
	10	5·05	0·21	1·29	0·05
	11	5·89	0·25	1·44	0·06
	12				
	13				
	14				
	15				
	16	6·36	0·27	2·83	0·12
	17	5·92	0·25	3·48	0·15
	18	6·00	0·25	3·98	0·17
	19	3·05	0·13	1·58	0·07
	20	1·87	0·08	1·91	0·08
	21	1·88	0·08	1·69	0·07
	22	2·06	0·09	1·94	0·08
	23	1·91	0·08	1·99	0·08
	24	1·99	0·08	2·15	0·09
	25	2·04	0·09	1·94	0·08
	26	1·56	0·07	1·53	0·06
	27	1·95	0·08	1·95	0·08
	28	1·56	0·07	1·73	0·07
	29	1·67	0·07	1·76	0·07
March	1	1·51	0·06	1·69	0·07
	2	1·56	0·06	1·59	0·07

shown in Fig. 12. The total amount of tilt is unknown as no observation were made on Feb. 5 and during the 4 days following Feb. 12. inclusive. The direction of the tilting motion during the first half of Feburary was downwards towards the SSE, but in the latter half it veered to the SE.

Conclusion. This landslide, which is still going on, is believed to be the largest that has been experienced in Japan. From the view point of geology and geography, it has nothing new to teach us. The only serious aspect of it is the potential danger to civil engineering works. No landslide has yet been studied quantitatively with instruments of precision. It gave Professor Matsuyama an opportunity of establishing a method of studying the phenomenon of landslides in a scientific manner. Our method, however, which demands much less labour and smaller outfit, will be fou:.d convenient and suitable when nothing more than the general course of the sliding movement of the land mass is sought.

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45. 大阪地辷の研究

地震研究所 那 須 信 治

大阪府下峠區地辷の發現當初よりの經過の概要を述べ、地辷に對する簡單なる器械觀測方法を記して置いた。その大要は次の通りである。

地辷地帶の周緣部の主裂罅の運動を特殊の自記裝置により二箇所に於て二月一日より四月二十日に至る八十日間觀測した。その結果二月二十日頃地辷運動は最高潮に達し、日々移動量は三三・四糎に達した。それより順次減退を示してゐることがわかつた。

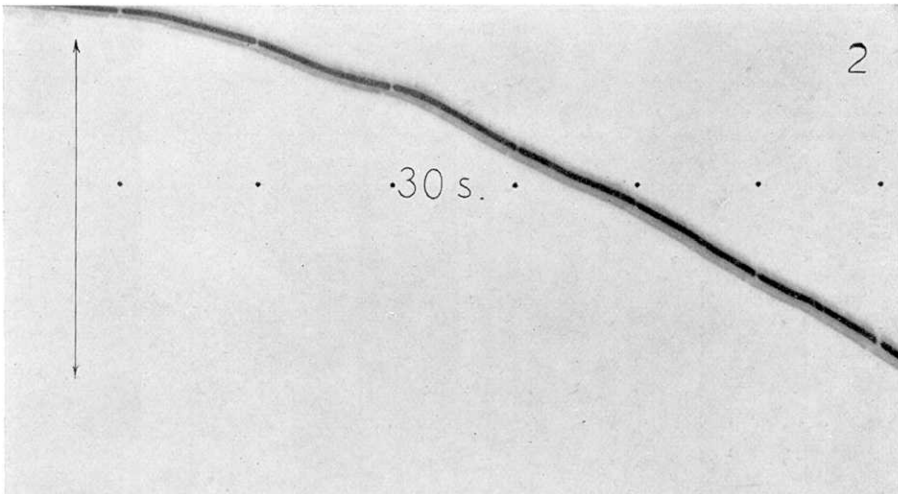
自記記錄によれば地辷り運動は比較的正しく直線に記錄されてゐる。即ち一日中の速度は略等速度のように見える。然しこれを瞬間的によく見るとやゝ不規則な速度變化がある。この現象を研究するために地辷運動を二千倍に擴大しこれを早廻しの寫眞記錄裝置により記錄した。その結果速度は前述の如く瞬間的には可成り大なる變化があることを認めた。

次にダイヤル、ゲージを裝置した携帶用の移動測定器を考案し、周緣部に沿つて十一箇所に於ける運動速度の大小を研究した。この測定では地辷速度の大なるところでは一粍を辷るに要する時間を、又速度が大ならざるところでは〇・五粍或はそれ以下を辷るに要する時間を測定した。この觀測は二月中二回施行した。これらの時間より各點に於ける一時間の地辷移動量を求めた。二回の觀測の結果、地辷地帶の上部(頂點にあたるところ)附近に於て移動量は最大であつた。

次に地表傾斜觀測を地辷地帶の中央部に於て二月三日より三月二日迄繼續して行つた。日々の傾斜量は地辷速度の增減と略同一步調を以て增減を示した。

此研究の主眼は地辷運動を記錄し、或はダイヤル、ゲージ等によりて測定し、比較的短時間中に於ける運動の消長を知るにある。日々移動量の測定等には三角測量及水準測量等を以てするを最良の方法とするも瞬時の運動の研究には本文に揭げたような方法を取るより仕方がない。しかしながら主裂罅より遠い地辷地帶内部の點の瞬間的の運動はこゝに述べてある方法を以てしては知ること

a



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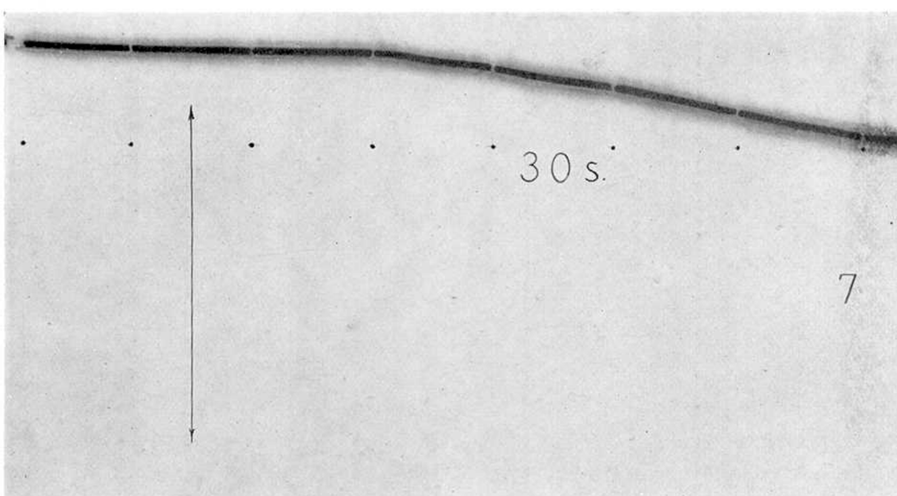

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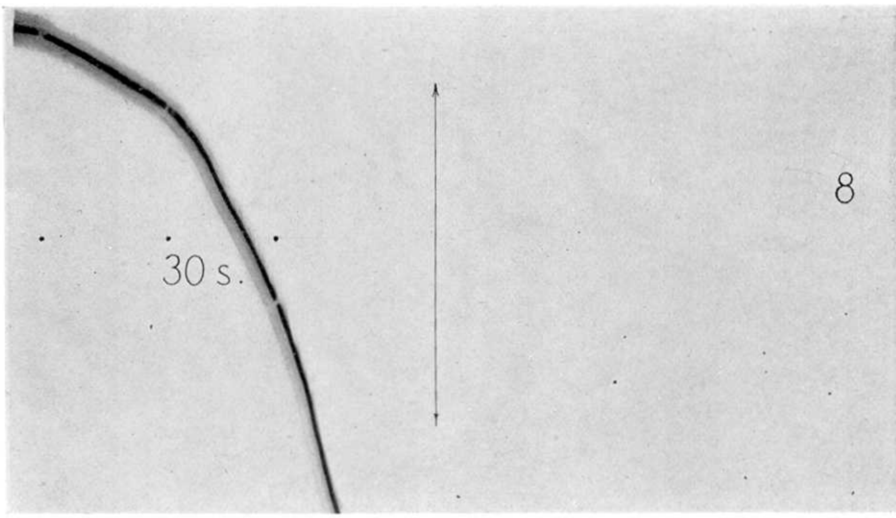
Fig. 8. a. b. Photographic records of the sliding motion. Lengths of arrows corresponds to the actual distance slid of 1/10 mm. Time between two dots = 30 sec.

c



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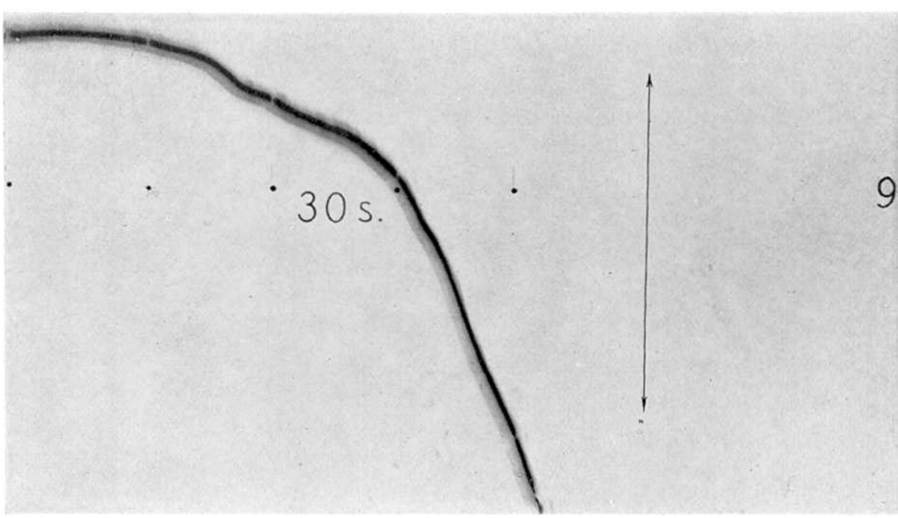
d



(3/14 of actual)

Fig. 8. c. d. Photographic records of the landslide. Length of the arrows corresponds to the actual distance slid of 1/10 mm. Time between two dots = 30 sec.

不可能である故に此研究は周縁部の運動に就いてのみ行つた。地辷運動全般の經過を知るには此の方法でも相當の結果を擧げ得ると思ふ。