4. *Measurement of a Land-creep in Wakayama Prefecture.*

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Introduction.

An area of about forty thousand square metres in Syôbata, Higasi-Nogami, Wakayama Prefecture, was found creeping down towards the River Nogami, a tributary of the Kinokawa (River). The land-creep was already described elaborately by T. Iwanisi,[1] so here a brief information will be given.

The creeping area lie on diluvial terrace covered with soil, and at the southern part of it there stand houses along a road (Figs 1, 2, 3 and

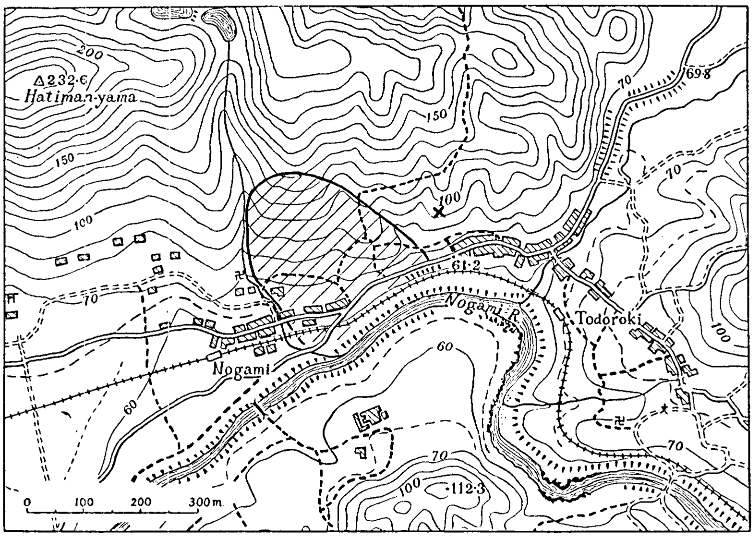

Fig. 1. Topographical map of the creeping area and its environment, (hatched area indicates deduced creeping area and cross the stating point of the closed traverse).

1) T. IWANISI, *Disin*, 2 (1930), 632, (in Japanese).

4). Outcrops of chlorite schist are seen without east and west sides of the district. In the creeping area the rocks under the soil are badly decomposed (Fig. 5), and the surface is cultivated mostly as mulberry-fields. The plane of the field gradually sinks and undulates, but no cracks were noticed except small fissures found under a floor of a house. Many houses in the creeping area inclined southward, and some stone walls swell out by the stress due to the deformation of the land. A well in the field was drained its water, and its section formally round deformed to oblong as shown in Fig. 6. Owing to the local subsidence a drain of the village along the road do not flow well, and the water stands at the middle of the drain in the area. So the drain is said to be repaired nearly every three years. The distance between the surface of the standing water of the drain and the plane of the road gradually changes, and it shows a result of a levelling carried out by Nature.

Measurement with a Theodolite of the Land-Creep.

The deformation of the land due to the land-creep was measured by comparison between results of the traverse surveys carried out in 1931 and 1932 with a theodolite and its attachments. The results of the comparison provisionally obtained are given below.

The Zeiss's Theodolite II. was used for the survey, because it is handy and can be used easilly by a few men. The instrument is supplied with vertical and horizontal circles which are divided into 0·5 grade throughout. The vertical circle is connected with an alidade bubble, sensitiveness of which is 30 sec. per 2 mm.

The writer decided his mind to survey the area by a method of closed traverse with the theodolite. Before the survey was carried out, fifteen surveying stations had been placed on the area early in April 1931 as shown in Fig. 7. The station No. 2 is the starting point of the traverse, and it was set in the surface of the schist which is thought as the base rock of the area and does not creep. The mark of these stations is a cross engraved on a round bolt head 2·2 cm. in diameter, and the bolt head is embedded in a concrete block. The block

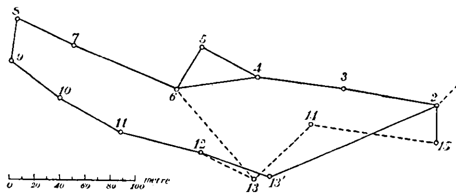

Fig. 7. Stations and routes of traverse (dotted lines surveyed only 1931).

was moulded in a shape of frustrum of triangular pyramid and buried in the ground. Or in other case, the bolt head is set in the rock and fastened with cement mortar.

The distances between stations were measured by the subtense method with the theodolite fitted with a tangential micrometer, and a horizontal distance staff.

Before the results of the survey are described, it is necessary to decide upon the standard of accurracy and the permissible errors which are justified by the local circumstances. The difference of micrometer readings of the staff points, say n_1-n_2, gives the horizontal distance between instrument and staff by following formula,

$$d=k\frac{L}{n_1-n_2},$$

where d is the distance, L the length of the staff in metre, and k a constant of the micrometer. For the instrument, the value of k is given as 20000. Then the equation of linear errors is found by

$$\frac{\Delta d}{d}=-\frac{\Delta n}{n_1-n_2}.$$

The staff 3 m. long was used in general. But the distance between station No. 2 and No. 15 was measured with another staff 1 m. long. Now putting 300 for the value of L in the above equation, the permissible error of the horizontal distance is calculated under following assumptions: $n_1-n_2=8400$ ($d=7138$ cm.) and $\Delta n=5$. Then

$$\Delta d=4{\cdot}25 \text{ cm.}$$

For this instrument, the value of $\Delta n/(n_1-n_2)$ is estimated to be less than 1/1000 by experiences, so the result has a error not exceeding 10 cm. An accuracy of such degree is sufficient for this study, for the displacement of the land is estimated as 10 cm. for a year by natives.

In the next, the precision of height will be discussed. The measurement of angles is more accurate in this case than that of lengths. Its closing difference was 1/100 grade at the first survey, in another expression 32.4 seconds of angle. At the second survey the measurement was done better, and angles closed just at the starting point. Errors of height measurement are calculated by the deviation of vertical angles multiplied by the distances between two stations. Then the permissible error would not exceed 1 cm., when the angular deviation is less than 1/100 grade and the distance assumed as 100 m.

M. Matuyama[2] measured land movements in the Kwansai District also with a theodolite. He put a Wild's Theodolite, which is more precise than the instrument used by the present writer, at two trigonometrical points set up by the Imperial Land Survey. Positions of signals erected on the land were determined at two or more times, and the displacements of signals were obtained by a graphical method. The accuracy of the survey is less than several milimetres for horizontal distances and 1-2 cm. for vertical. For other examples, land-creeps occurred in Niigata Prefecture were described by K. Nakamura.[3] According to his paper, the maximum displacement of the land from 1928 till 1930 amounted to 35 cm. But method and accuracy of the measurement are not stated in his paper. Then in regard to the accuracy, the measurement made by the writer would not be so worse as the above examples.

The positions of stations were determined with reference to several trigonometrical stations, and these positions and routes of the traverse are shown in Fig. 7. At the second survey made in July 1932, the position of the station No. 1 was not measured because the leaves of trees were so thick around the station that the signal of the station could not be sighted from the other stations. The stations Nos. 13 and 14 were removed out of the previous places, so omitted also at the second time. The former one was seen from the station No. 6 at the first survey, and the upper and the lower routes of the traverse were connected at there to check the result. Though the station mark No. 13 was put again near the old place as No. 13′ in Fig. 7, there are no stations on the two branches of the route which can be seen each other.

Comparison of First and Second Surveys.

The station No. 2 was put as the starting point of the traverse, and at the same time as the origin of rectangular coordinates which were determined referring to several triangular points. The signs of the coordinates are determined by two conventions:

(i) x-coordinates are considered as $\frac{+}{-}$ according as the point is $\frac{\text{east}}{\text{west}}$ of the origin.

2) M. MATSUYAMA, *Tikyû*, **17** (1932), 323, (in Japanese).

3) K. NAKAMURA, *Journ, Geol. Soc.*, Tokyo, **37** (1929), 411, and **38** (1930), 25, (in Japanese).

(ii) y-coordinates are considered as $\frac{+}{-}$ as according as the point is $\frac{\text{north}}{\text{south}}$ of the origin.

The horizontal distances between every stations were not changed within the allowable limit of errors of the subtence method. Then displacements of stations are to be found only with regards to changes of angles, for the accurracy of angles is greater than that of lengths in this case.

The distribution of the differences between the old and the new angles are systematic. It would seem that there have been no earth movements at the stations Nos. 2, 3 and 4, azimuths of which did not change. One of these stations, No. 2, is on the bed rock, so their positions would not be affected by the land-creep. Stations Nos. 8 and 9 which are also on the rock would not have change their positions.

Under the above-stated suppositions, and moreover assuming horizontal distances between two consecutive azimuth stations are not affected by the creep, displacements of the points Nos. 5, 6 and 7 are calculated. The calculated results are given in Table I.

Table I.

No. of station	Δx	Δy	Δz	Δr
	m	m	m	m
5	0·129	0·258	0·027	0·289
6	0·057	0 251	0·014	0·254
7	0·003	0·045	0·002	0·045

Δx, Δy and Δz represent three components of the displacements, and $\Delta r=\sqrt{\Delta x^2+\Delta y^2}$.

Next, displacements of stations of lower traverse route, Nos. 10, 11 and 12 are obtained. But Nos. 13 and 14 which were removed from the old place are ommitted from the calculation. In this case, the positions of the stations Nos. 8 and 9 are assumed unchanged as the above. The station No. 2 is too far to be refered as a fixed point, so errors of the results will be greater of No. 11 than No. 10, and No. 12 than No. 11. The following table gives the results of the calculation. But the accuracy of the results is less than that of the results shown in Table I.

Table II.

No. of station	Δx	Δy	Δz	Δr
	m	m	m	m
10	0·017	0·018	0·009	0·025
11	0·017	0·022	0·000	0·028
12	0·045	0·138	0·010	0·145

The results in Tables I and II are shown graphically in Fig. 8. It is obviously seen that displaced stations went downward in nearly normal direction to contour lines. In other words, the creeping area moved down southward along the slope on which it lays. It is interesting that the topographical features of the area suggests that the contour lines there have been projected southward by the creeping.

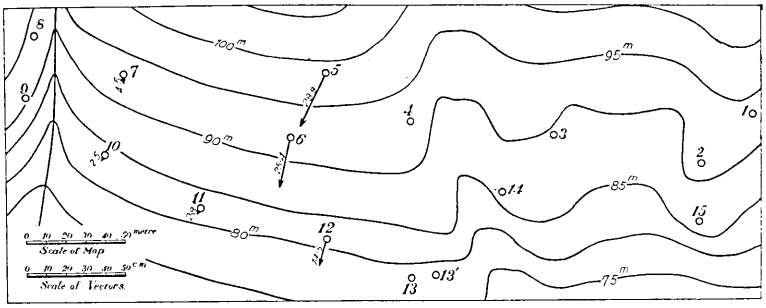

Fig. 8. Changes of positions of stations.

The land-creep was measured by another simple method in a place. Three crosses were marked on the schist across a small stream which runs between the stations Nos. 7 and 8 as shown in Figs. 1. and 8. These marks were put on a straight line in April 1931 (see Fig. 9); two marks, *A* and *B* in Fig. 9, are on a block of the rock, and the other, *C*, is beyond the stream on a different large block which consists eastern bank of the flow. The distance *AB* is about 91·6 cm., and *BC* about 51·3 cm. Relative displacement between two blocks was found in July 1932, that the mark *C* moved about 1·2 cm. northward relatively to the line *AB*.

Conclusion.

By the above results, the displacement of each station seems to indicate that unstable surface rock and soil creep down towards the

River Nogami. Or considering that the mark C displaced upward, a land block would go downward rotating clockwise around a vertical axis.

There are several land-creeps already known in the vicinity of the present place, and lately since the land-slide occurred in Nov. 1931 at Tôge, Osaka Prefecture, many creeping places[4),5)] were newly found. The distribution of these places is shown in Fig. 10.

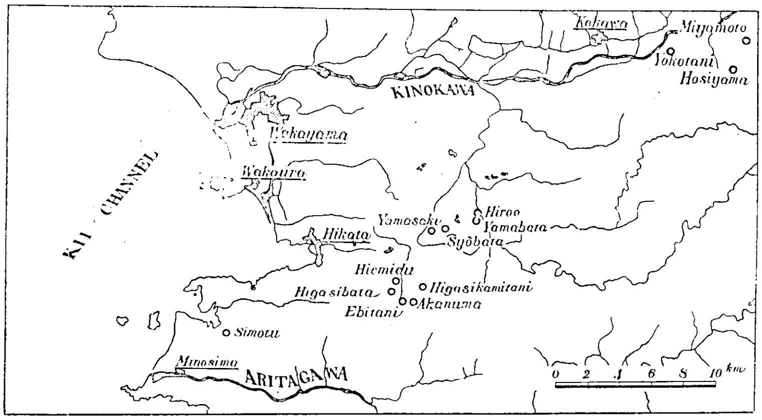

Fig. 10. Circles indicate places of land-creep.

The direction of movement of all the land-creeps nearly coincides with that of the inclination of the land. So the gravity will be the main force which causes these creeps. The writer inspected some of these places and found that the rock which was thought lying under the creeping area was decomposed or even broken into fragments. Then it will not be unreasonable to conceive that surface soil and rock lying on broken fragments commence movement such as creeping or sliding by some minute change in the stable condition. But further discussions have to be given by future studies.

In conclusion, the writer expresses his best thanks to Dr. Imamura for his interest in this study, and also Messrs T. Iwanisi, H. Imamura and Z. Kawase for their kind help during the survey. Thanks are also due to the authorities of the Earthquake Research Institute for aids by which he was enabled to measure the land-creep.

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4) T. IWANISI, *Disin*, 4 (1932), 163, (in Japanese).

5) S. Yehara reported some of these land-creeps at the meeting of the Geol. Soc. of Tokyo in November 1932. The creeping places seem to be on a tectonic line which was studied geologically by him.

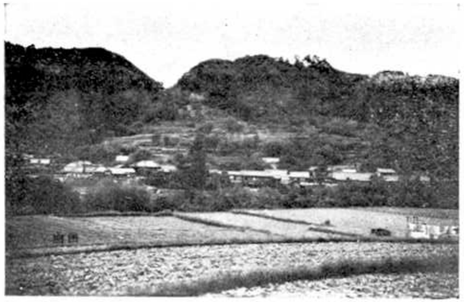

Fig. 2. General view of the creeping area from south across the River Nogami. (Photo. July. 1932)

Fig. 3. The creeping area. (Photo. eastward from near the station No. 8. April, 1931.)

Fig. 4. Photo. eastward from the station No. 9.

Fig. 5. Decomposed chlorite schist.

Fig. 6. A dry well. (Diameter is about 1m., photo. downward.)

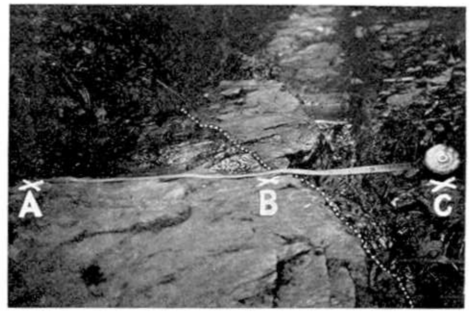

Fig. 7. Three marks curved in the schist. (Photo. by Mr. Iwanisi in 1932)

4. 和歌山縣に於ける土地潛動の測定

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和歌山縣那賀郡東野上町大字小畑の土地潛動に就いては，旣に岩西忠一氏によつて「地震」第二卷（昭和五年）に述べられてゐる．其處を昭和六年四月と昭和七年七月との二回測量して，得られた結果の比較から土地の變動を測つた．第一圖は其の潛動地域の大體の廣さと，其の附近の地形とを示したものである．

潛動地域及び其の附近に豫め十數個の測點を置き，「カール，ツアイス」會社製の經緯儀第二號型を用ひて，閉折線測量を實施した．其等の測點の位置及び測量線路は第七圖に示される．

二回の測量を比較した結果，測點第二，第三，第四，第八，第九，及び第十五は不動と推定され，其の他の測點の變動は第一表，第二表及び第八圖に示されてゐる．併し，第二回目の測量の際には測點第一は其の周圍は草木が繁つて見通しがよく出來なかつた爲，且重要な點ではないので省略し，第十三及び第十四は土地の人によつて取去られた爲に，其等の變動は求められなかつた．併し第十三のみは舊位置に近く，今後の爲に再び据えて置いた．

以上の測量の他に，西側にある谷川を越して，第九圖の如く岩石上に三箇の印 A, B 及び C をつけておいたものが，第二回目の時に見ると C が A, B に對し約 1·2 cm. 北方に移動した．

以上の結果から見ると，潛動地域は大體同高線に直角の方向に辷り落ちてゐる樣であるが，谷川の所では反對の方向に動いてゐるから或ひは一つの地塊が時計の針の動く方向に少し廻轉しながら辷り落ちてゐるのかも知れない．

和歌山縣下には他にも第十圖に示めされてゐる樣に十數個所の潛動地域が知られてゐる．其等は皆土地の傾斜に沿つて下方に動いてゐる樣である．又此等の基盤をなす岩石が甚しく風化されてゐる樣に見える．若し以上の推測が當つてゐれば，此等の潛動は基盤の支持力が小さくなり，重力によつて辷り落ちると考へられる．併し正確なことは將來の研究によつて知られるであらう．