17. *Upwarp Deformation of the Land in Tyūgoku.*

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1. It has been pointed out that the results of revisions of precise levels, crossing Tyūgoku in a N—S direction, show an upwarping deformation of the land.[1]

This statement should however be discussed from various angles in order to ascertain whether or not the above mentioned mode of deformation is real.

Since, in the former survey, the results of which were compared with that of the later survey to deduce the vertical displacements, staves of Russian alder were used, while, for the later surveys, invar tapes[2] were used, the question arises whether or not the scale divisions on the former staves expanded at the time of the former survey at the same rate as the latter staves.

Revisions of precise levels show that bench-marks situated at altitudes rose compared with those situated in lower land. If this upwarping deformation is not real but only illusory, then the differences in expansion of the staves may be one of the causes of the apparent upwarp deformation. The apparent upwarp of the land may therefore be regarded as having resulted from the following causes:

(i) The length of the standard scales used for calibrating the scale of the Russian alder staves expanded, although only slightly, compared with those used for calibrating the scales of the invar tapes.

(ii) The lengths of the standard scales used for calibrating the scales of the Russian alder staves expanded uniformly only at the time of the first surveys. They have shrunk so much since then that the difference between the lengths of the standard scales for the old and the new staves can no longer be distinguished.

(iii) The integrated effect of the deviations due to atmospheric refraction.

In the case of precise levels, the effect of atmospheric refraction is generally considered negligible, because the distance between the

1) C. TSUBOI, *Jap. Journ. Astr. Geophys.*, **10** (1933), 94~248.
2) Invar tape stretched on a rong slender frame, used for staves in precise levels.

telescope and the staves is sufficiently small. Moreover, since field work is generally done under a variety of atmospheric conditions, there is automatic compensation of the deviations in measured heights due to atmospheric refraction, so that the effect of atmospheric refraction is usually negligible.

Besides, it is not possible to detect the effect of difference in the unit lengths of the standard scales used for calibrating the scales of the staves if the uniform expansion of the unit length of the scale used for calibrating the Russian alder staves was only a temporary phenomenon that existed only at the time of the former survey. Only case (i), mentioned above, admits of being investigated further. Studies in this direction will soon be made and the results reported.

In this paper, however, we deal with the actual data of vertical displacements of bench-marks on the lines of levels crossing Tyūgoku in order to show how the vertical earth movements are correlated with the actual heights.

2. The lines of levels from which the relation between the vertical displacements and the heights are studied in this paper by means of the positions of the bench-marks, are those linking Hirosima with Sinzi, Okayama with Yonago, and Okayama with Tottori. The geographical situation of these lines of levels are shown in Fig. 1.

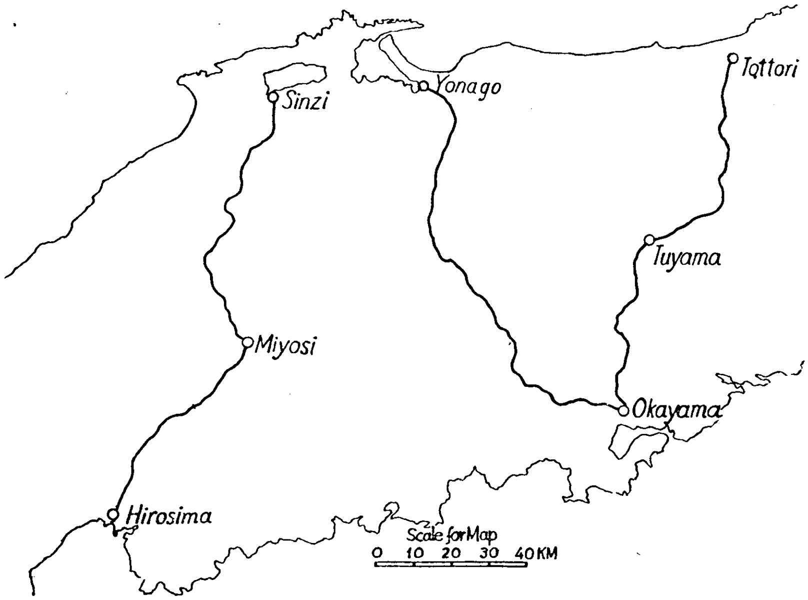

Fig. 1. Geographical situations of lines of levels crossing Tyūgoku.

Although in the present study, the vertical displacements are compared with the heights of the bench-marks, we take successive differences of the vertical displacements of contiguous bench-marks, (that

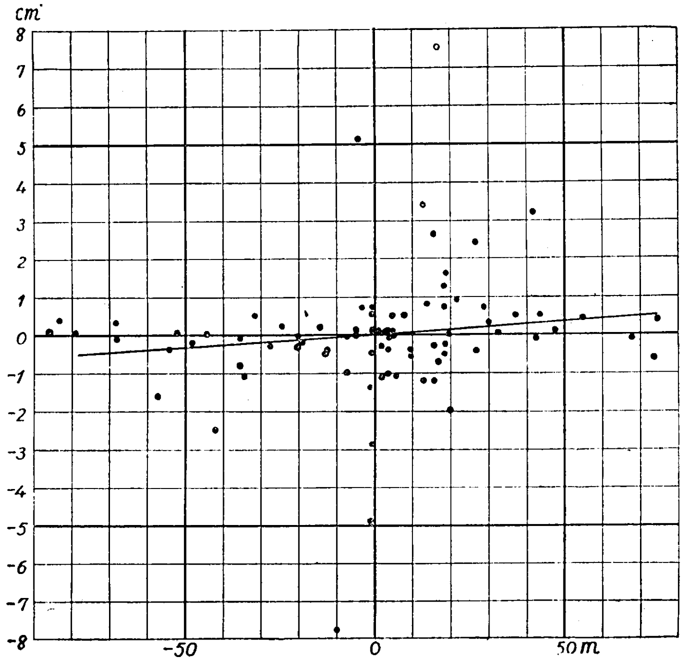

Fig. 2 a. Relation between w (1891~1921) and H for the line from Hirosima to Sinzi.

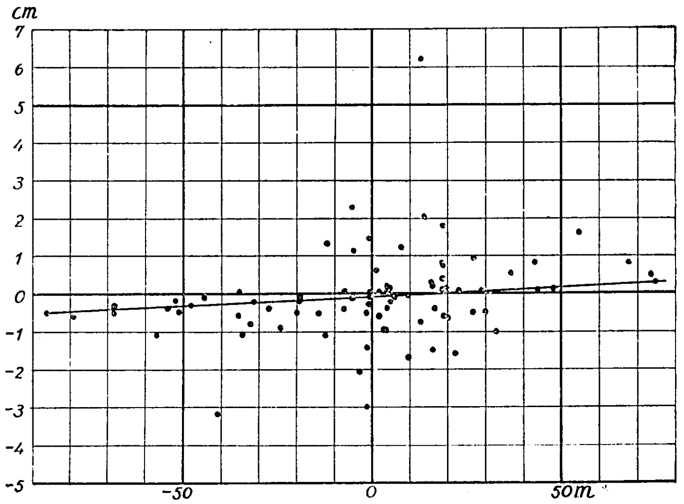

Fig. 2 b. Relation between w (1921~1935) and H for the line from Hirosima to Sinzi.

is, the differences between bench-marks A and B, B and C, C and D, etc., deduced from changes in their heights above the sea-level since the last survey) for comparison with the differences in the present heights above sea-level of the corresponding bench-marks.

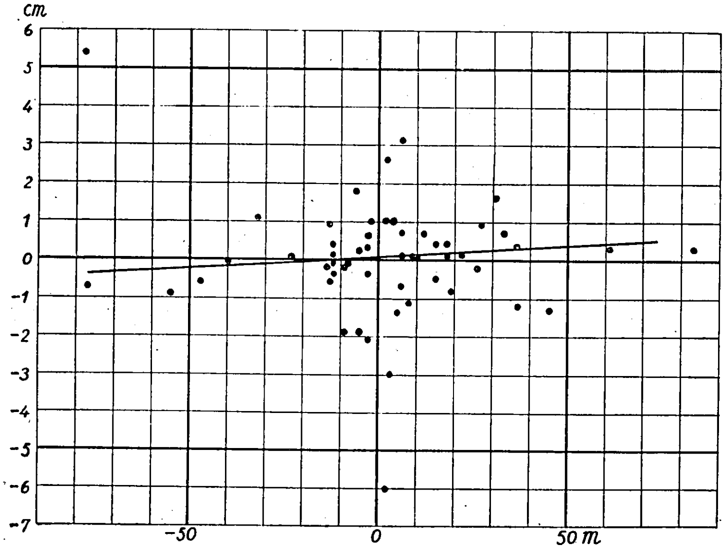

Fig. 3 a. Relation between w (1895~1929) and H for the line from Okayama to Tottri.

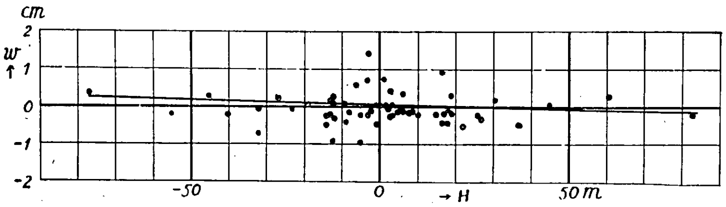

Fig. 3 b. Relation between w (1929~1935) and H for the line from Okayama to Tottri.

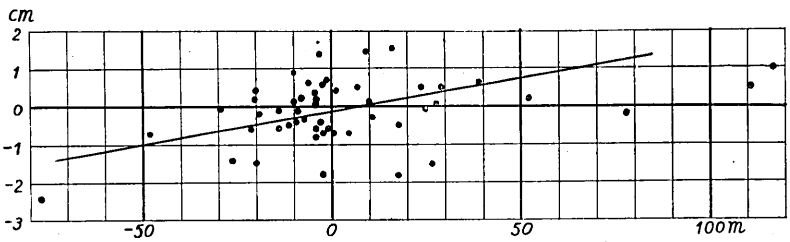

Fig. 4. Relation between w (1895~1935) and H for the line from Okayama to Yonago.

In Figs. 2~4, the successive difference between the vertical dispiacements of contiguous bench-marks are plotted against the successive difference between the heights of the corresponding bench-marks.

The line of levels from Hirosima to Sinzi was first run in 1891 and rerun in 1921 and also in 1935. The line from Okayama to Tottori was first run in 1895 and rerun in 1929 and 1935, while that from Okayama to Yonago was first run in 1895 and rerun in 1935. Consequently, for that line of levels from Hirosima to Sinzi, the vertical displacements during 1891∼1921 and those during 1921∼1935 were ascertained; these to be compared with their present heights, and, for the line of levels from Okayama to Tottori, the vertical displacements during 1895 ∼1929 and those during 1929∼1935 were obtained; these to be compared with the heights. For the line from Okayama to Yonago, however, the vertical displacements for comparison with the heights were obtained only for the period 1895∼1935.

In the surveys made in 1891 and in 1921 on the line linking Hirosima with Sinzi and in 1895 on the line linking Okayama with Tottori and that linking Okayama with Yonago, Russian alder staves were used, while, for the recent surveys, namely, those made in 1929 and 1935, invar tapes were used. Consequently, if the measured upwarp deformation of the land was only apparent, resulting merely from the uniform expansion of the scales of the staves used in the older surveys, it will be found that the relation between the vertical displacements during the period 1921∼1935 and the present heights for the line of levels from Hirosima to Sinzi is approximately the same as the relation between the vertical displacements during 1895∼1929 and the present heights for the line of levels from Okayama to Tottori, and also with the relation between the vertical displacements during 1895∼1935 and the present heights for the line from Okayama to Yonago. It is also probable that the relation between the vertical displacements and the presnt heights mentioned above differ entirely from the relations of the vertical displacements during 1891∼1921 (for the line from Hirosima to Sinzi) and 1929∼1935 (for the line from Okayama to Tottori) and their present heights. The vertical displacements of bench-marks on the line from Hirosima to Sinzi during 1891∼1921 were measured by using Russian alder staves.

To find the average relation between the two quantities, namely, w the successive difference of the vertical displacements of contiguous bench-marks and H, the successive differences in the present heights of contiguous bench-marks, we calculated the value of the constants that connect w with H, in the form

$$w=aH+\beta,$$

by the method of least squares.[3)]

The values of α and β thus obtained are given in Table I, the average relations of $w=\alpha H+\beta$ being shown by straight lines drawn in the graphs of Figs. 2∼4.

Table I.

Line of level	α		β	
	I	II	I	II
Hirosima-Sinzi	0·070	0·023	−0·11	−0·74
Okayama-Tottro	0·047	$-0{\cdot}003_3$	0·77	0·64
Okayama-Yonago	0·101		−1·23	

I: Values obtained with the data of w deduced as changes during the 1st and 2nd surveys.

II: Values obtained with the data of w deduced as changes during the 2nd and 3rd surveys.

In calculating the values of α and β, H was measured in metres and w in milimetres.

3. As already refered to, if the measured deformation, namely, the upwarp of the land of Tyūgoku, is nothing but an illusion caused by uniform expansion of the scales used in the 1891, 1895, and 1921 surveys, the values of the constants for the various lines of levels should turn out to be nearly equal. Actually however the values of the constant for various lines of levels differ more or less from one another.

It should also be noted that with regard to the line of levels linking Hirosima with Sinzi, the value of the constant α obtained by means of the vertical displacements during the time from 1891 to 1921 is about 3 times as large as the value of α obtained by means of the earth movements for the interval from 1921 to 1935, while, with regard to the line linking Okayama with Tottori, the value of α obtained by means of the earth movements during the interval from 1895 to 1929 and the value of α for the period from 1929 to 1935 have different signs, although the value α for the latter interval is very small.

The fact that the value of α, obtained in the line of levels that links Hirosima with Sinzi, are of the same sign even for different intervals of time, and that their amounts are approximately proportional

3) Values of α and β calculated by

$$\alpha=\frac{[wH]}{[HH]}\frac{1-\dfrac{[w][H]}{n[wH]}}{1-\dfrac{[H]^2}{n[HH]}},\quad \beta=\frac{1}{n}\frac{[w]-[H]\dfrac{[wH]}{[HH]}}{1-\dfrac{[H]^2}{n[HH]}}.$$

to the durations of the time intervals to which the vertical earth movements are due, may show that the measured upwarp movement of the land in Tyūgoku cannot be regarded as mere illusion resulting from using a scale that had expanded for calibrating the scales ot the Russian alder staves in the older surveys. The measured deformation of land in Tyūgoku contains, at any rate, a component of upwarp movements that really exist.

The following discussion on this point is from another point of view.

Since the bench-marks, which are imbedded in roads, are usually along valleys, when the road traverses mountaneous regions, the heights of the bench-marks do not show the general elevation of the profile in the region crossed by the line of levels. For this reason, contour lines of various altitudes are drawn with reference to the heights of the triangulation points only, thus smoothing the details in the actual topography. From the configuration of these contour lines, the heights of bench-marks are estimated.

The heights of bench-marks thus estimated and those measured by

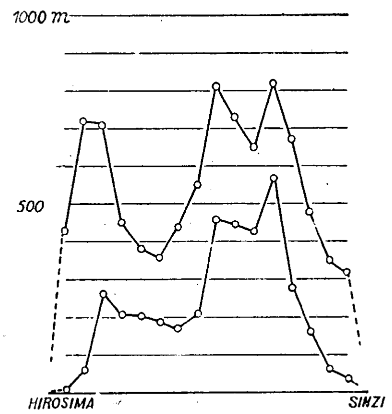

Fig. 5 a. Topographical profiles along the line of levels from Hirosima to Sinzi.

Upper curve: Referring to estimated heights of bench-marks.
Lower curve: Referring to true heights of bench-marks.

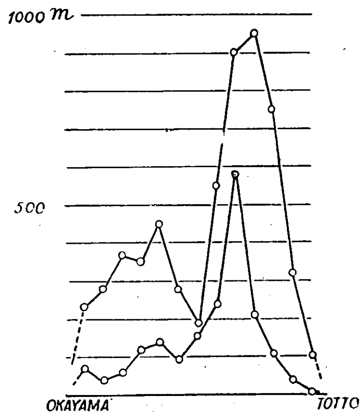

Fig. 5 b. Topographical profiles along the line of levels from Okayama to Tottori.

Upper curve: Referring to estimated heights of bench-marke.
Lower curve: Referring to true heights of bench-marks.

levellings, as designated by numerals on the odinary 1/50000 topographical maps, do not agree, as will be seen from the graphs compared in Fig. 5.

The differences in the heights of every tenth bench-mark was then compared with the differences between the vertical displacements of the corresponding bench-marks. The graphs given in Figs. 6~8 show the relation between these two quantities.

The values of the constants α that connect the difference in the vertical displacements of every tenth bench-mark with the difference in the heights of the corresponding bench-mark are than calculated as before.

It may then be expected that, if the measured deformation of the land be a mere illusion, the value of the constant thus obtained would differ remarkably from those obtained from data of the true heights of the bench-marks.

The values of α and β thus obtained are shown in Table II.

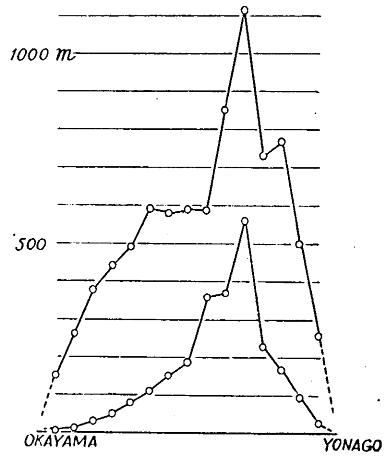

Fig. 5 c. Topographical profiles along the line of levels from Okayama to Yonago.

Upper curve: Referring to estimated heights of bench-marks.
Lower curve: Referring to true heights of bench-marks.

Although it cannot be concluded from these results that the upwarp deformation, as revealed in the results of relevellings in the Tyūgoku region, is real, neither is there any reason for regarding the

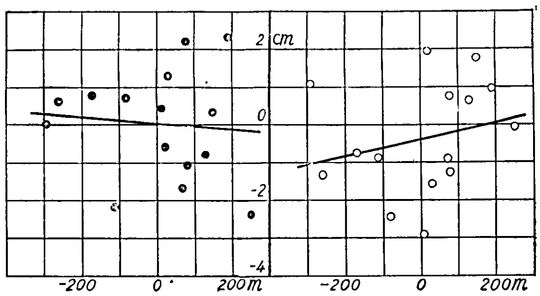

Fig. 6. Relation between w and H (estimated) for the line from Hirosima to Sinzi.

a. w (1891~1921) and H (estimated).　b. w (1921~1935) and H (estimated).

measured deformation as mere illusion, the result of the expanded standard scale used in calibrating the Russian alder staves used in the older surveys.

As to the lengths of the standard scales used for the old and recent levellings, the subject will be discussed in due course.

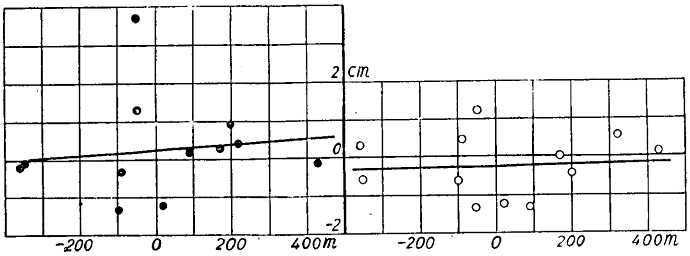

Fig. 7. Relation between w and H (estimated) for the line from Okayama to Tottori.

a. w (1895~1929) and H (estimated). b. w (1929~1935) and H (estimated).

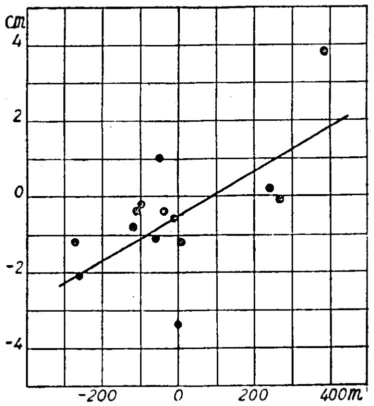

Fig. 8. Relation between w and H (estimated) for the line from Okayama to Yonago.

Table II.

Line of level	α	
	I	II
Hirosima-Sinzi	$-0{\cdot}009_6$	0·024
Okayama-Tottori	$0{\cdot}006_3$	0·0016
Okayama-Yonago	0·056	

Line of level	β	
	I	II
Hirosima-Sinzi	0·09	−4·17
Okayama-Tottori	2·76	−2·13
Okayama-Yonago	−4·97	

I: Values obtained with the data of w deduced as changes during the 1st and 2nd surveys.

II: Values obtained with the data of w deduced as changes during the 2nd and 3rd surveys.

In conculsion, the writer wishes to express his sincere thank to the Department of Education for the grant received for undertaking this study. His thanks are due also to Miss H. Maeda for her assistance in calculating the numerical data and preparing the figures.

17. 中國山地の隆起運動に就て

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中國を南北に連ねる水準線，廣島——宍道間，岡山——米子間，岡山——鳥取間の水準改測の結果によれば，それら各區間の中間部，換言すれば，比較的高い部分が兩端の低い部分に比して幾分隆起してゐる．この現象は，之を以て直にそのやうな地殼の變動があつたと見做すことも出來るが，若しも，前測量に用ゐられた標尺，乃至はその標尺の點檢に使用された標準尺が後の測量に用ひられた標尺，又は，その點檢に用ひられた標準尺に比して少しばかり長かつたとすればそれでも，その“高い場所が一層高まる傾向”を解釋することが出來る．

又，空氣層に於ける光の屈折の影響も考へられるが，普通の測量は，その影響の少ない時間にさうして，又，その影響の相殺される様な方法で行はれるから，光の屈折の影響は先づ無視してもよからうと思はれる．

標尺の相異は，若しも以前の標準尺の長さが，今日まで變化してゐなければ，今尺の標準尺と比較して之を求めることも出來るが，若し，さうでなければ，標尺に相異のあつたことを今日確めることは不可能である．

實際の變動量について見れば，若し，それが，新舊の標尺の相異から生れたものとすれば，高さと變動量との關係が，場所や，新舊測量間の期間の長さなどには殆ど無關係であり，3 回測量の行はれた，廣島——宍道間，岡山——鳥取間等に就いては，前期の變動量と後期の變動量とが著しく異る場合も起り得ると思はれる．殊に，前期の變動量と後期の變動量とが，夫々，その變動を生じたと見られる期間の長さに略々比例するといふやうなことは，極めて稀にしか期待し得ないであらう．これらの點を確かめる爲に，各水準線につき，次々の水準點の高さの差 H と變動量の差 w との關係を調べてみた．

$$w=\alpha H+\beta$$

とおいて，常數 α を求めてみると，その値は，水準線により，又期間により，幾分かづゝ相異することが認められる．

又，H に水準點の眞高の差を採らず，附近の三角點の高さを平滑した値を用ひて描いた等高線に基いて推定した水準點の高さの差をとつて，w と比較しても略々同様の結果を得る．

この結果により，標尺の相異による影響を否定することは不可能であるけれども，少くとも，叙上の如き地殼運動の實在することは，認めなければならないであらう．