9. *Elevated Shorelines and Precise Levelings in determining the Gradients of Crustal Deformations.*

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The maximum gradients of crustal movements since the Quaternary Period as revealed by tilts of elevated shorelines that were formerly horizontal, having been determined[1], these gradients were compared with those of the *fundamental* crustal movements that occurred with the formation of the Japanese Arc as found by repeated precise levelings. (That the Japanese Arc is still in process of formation is shown later in this paper.)

Although volcanic outbursts and severe earthquakes are frequently followed by marked changes of level, which may engage our attention, crustal movements as the result of deep-seated orogeny proceed steadily, quite independently of such superficial movements.

Therefore, for the purpose of our study, we selected from the published data of levelings, only such movements as satisfy the following conditions:

(1) The intervals of two successive levelings must cover a period of not less than 32 years.

(2) The size of the region in question must not be less than 11 km in diameter.

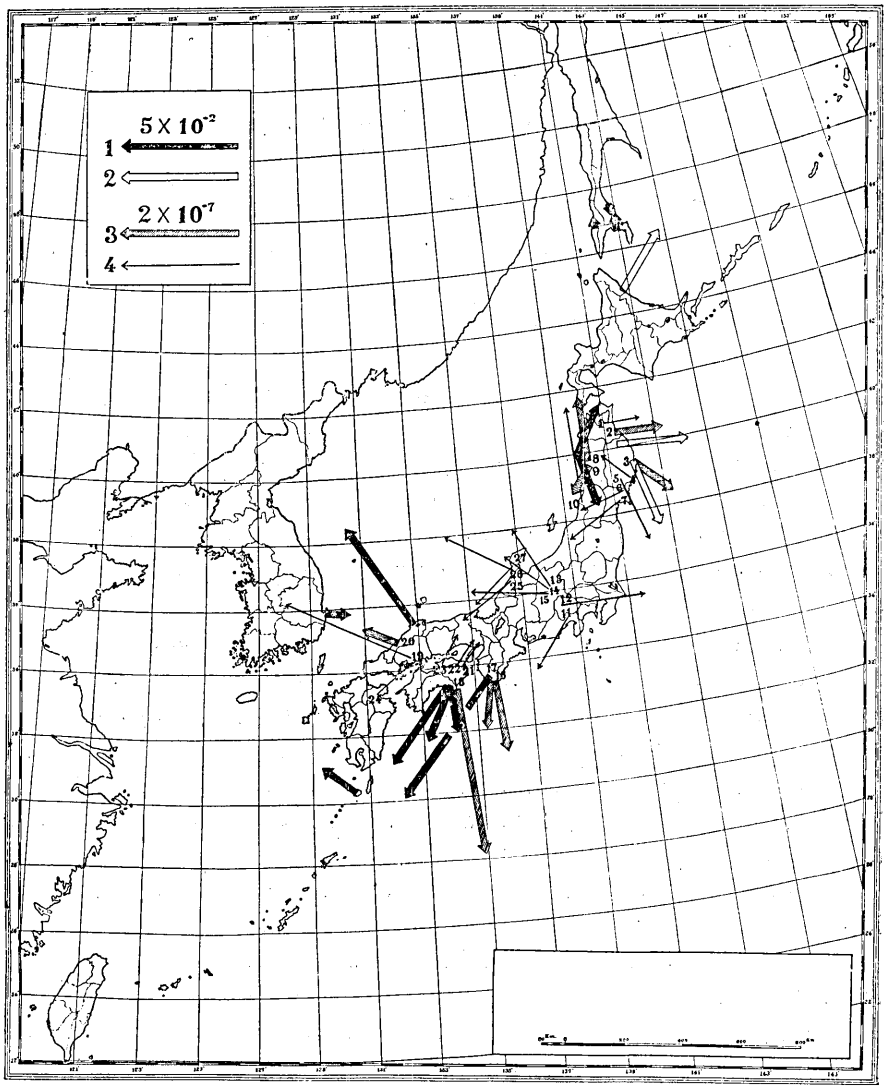
(3) The annual gradient of the crust treated must exceed $0{\cdot}5 \times 10^{-7}$.

(4) The angle between every two segments of the leveling routes, by means of which the gradients were calculated by us, must exceed 25°.

The data thus selected are arranged as in the annexed table and again shown in the accompanying figure, together with the gradients obtained from tilts of raised beaches.

From what has just been said, it follows that regions that were only recently disturbed by volcanic activities, such as Kyūsyū by the eruption of Sakurazima and Hokkaido by the eruption of Komagataké, for example, and regions disturbed by destructive earthquakes, such as

1) G. IMAMURA, *CR. Cong. Int. Géogr. Amsterdam.* 1938. [ii] (1938), 223~225.



Explanations of Figure.

1—Gradients as determined by the elevated shorelines.

2—Same as (1), with estimated approximate directions, the amount of which is unknown.

3—Gradients found by repeated precise levelings compared with (1) and (2), seeing that they happened to occur in the same place or in its neighbourhood.

4—Gradients calculated from repeated precise levelings. Data from raised beaches unobtainable in the neighbourhood.

The numerals in this figure correspond to those in the left-hand side column of the table.

Locality	Period	Diameter (km)	Gradient (10^{-7}/year)	Angle (degree)
1	1901~1935	23	0·5	90
2	1901~1935	13	0·8	80
3	1901~1933	12	0·8	40
4	1901~1933	13	0·6	60
5	1900~1933	11	0·8	30
6	1901~1933	12	1·1	50
7	1900~1933	11	1·1	70 & 30
8	1900~1935	13	1·1	50 & 30
9	1900~1935	11	0·6	70 & 45
10	1900~1934	26	1·3	70
11	1889~1932	20	0·9	50
12	1894~1926	17	1·4	80
13	1894~1927	14	1·2	65
14	1894~1927	14	1·1	25
15	1894~1927	16	1·3	90
16	1899~1931	35	1·2	70 & 40
17	1899~1931	25	0·8	60 & 40
18	1895~1929	27	2·3	55
19	1889~1937	14	2·3	80 & 30
20	1892~1929	20	0·6	65
21	1895~1937	20	0·5	70
22	1887~1937	17	0·5	80
23	1893~1937	27	0·6	60
24	1892~1936	15	0·8	85
25	1917~1928	35	0·9	50
26	1917~1928	20	1·3	30
27	1917~1928	15	1·1	50

Nos. 25, 26 & 27 are exceptions, which covers only 11 years.

Kwantō, Izu, Oku–Tango, etc., are excluded from this figure.

Our studies have led us to the following conclusions:

(1) So far as the directions of the maximum gradients are concerned, the two crustal movements are quite similar to each other, the levelngs indicating the continuations of crustal movements that originated in the geological past.

(2) The crustal deformations as determined by the folding of young strata differ entirely from the two kinds of crustal movements above mentioned. In southern Sakhalin, where intense foldings were found[2], we met with very gentle warpings that affected the elevated shorelines. In

2) Y. OTUKA: *Bull. Earthq. Res. Inst.*, **15** (1937), 1041~1046.

the outer zone of southwestern Japan[3], the directions of the maximum gradients, as obtained by geologic and geomorphologic methods, intersect with an angle of almost 90°.

(3) The age of the elevated shorelines is of the order of 10^5 years, as already supposed elsewhere[4], because every one of the raised beaches under discussion has a distinct and pronounced direction in its maximum gradient as the result of orogenic forces having deformed the shorelines, which were originally horizontal, into those of such strong gradients as 10^{-2}. It is evident, as also from conclusion (1), that shorelines are never formed at the beginning with such gradients as 10^{-1}～10^{-2}, as insisted by Y. Otuka[5].

(4) The absence in Japan of eustatic changes of level since the Quaternary is quite evident.

(5) The axis of the warping in southwestern Japan coincides with the geologic median line, and the negative gravitational anomaly.

(6) The Japanese Arc is still in process of formation to-day, with gigantic warpings, faulting being only an accessory phenomenon.

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9. 隆起汀線測定と精密水準測量とによる地殻運動の傾度の比較

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表題の二つの方法によつて得た結果を比較して下の結論を得た.

1) 最大傾斜の方向は略々一致する.

2) 兩者共新第三紀の褶曲の示すものとは全く別なものを表はす.

3) 隆起汀線は今から約 10^5 年以前に離水した.

4) 現汀線は水平であり, 隆起汀線は 10^{-2} である.

5) こゝで取扱つた期間中ではユースタテイツク運動は全く考へられぬ.

6) 日本島弧を形成する運動は今日も猶繼續中であり, それは斷層運動としてではなく, 大きな撓曲として表はれるのが普通である.

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3) Y. Otuka, *Bull. Earthq. Res. Inst.*, **9** (1931), 340～352.

4) G. Imamura, *Bull. Earthq. Res. Inst.*, **13** (1935), 80～84.

5) in Japanese.