36. *Crustal Blocks.*

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Crustal blocks, in the following discussion, are defined strictly in the same sense as in geology and geomorphology. Studies of the mode of crustal movements by Imamura, extending over a period of two years, and still being continued, have disclosed, as shown by the annexed examples, that some of the so-called blocks can exist only in imagination.

(1) Precise measurements of elevated shorelines in Sakhalin, Korea, and Japan proper have shown that, in a distance of about three hundred kilometres, there were only two faults; the hypothesis that in Japan the crust generally consists of blocks with dimension of several kilometres must be rejected, seeing that raised beaches are, practically speaking, the results of Nature's precise levelings that have been going for vast periods of time.

(2) Ōmisima archipelago, situated in the heart of Setouti (Inland Sea), southwest Japan, has been supposed to consist entirely of Horsts and Grabens, with coastal terraces on some of the islands. From detailed studies made in the autumn of 1937, what has been reported as fault scarps, turned out to be the results of differential erosion, the supposed coastal terraces being nothing more than local planation surfaces in weak rocks. Thus the topography of Setouti is strongly affected by the exposure of granite, which easily weathers away in the somewhat semi-arid Setouti climate.

(3) Investigations of the impermeable stratum by means of wells sunk on the surface of two plateaux, Musasino and Sagamino, near Tokyo, have indicated that this stratum could be used as an excellent key-bed for the study of young faults, and that, consequently, these two plateaux have never experienced any young fault movements that could result in geodetic or geomorphologic blocks.

Whether the alleged numerous geodetic blocks¹⁾ in Sagamino really exist or not, is still an open question, and in order to solve it, Kotani calculated the probability that a group of triangulation points, through their independent vertical movements, would give the impression of block formation.

In the first place, we consider the two-dimensional case. Let $y_1, y_2, \dots, y_n$ be the vertical displacements measured at n -points $x_1, x_2, \dots, x_n$ lying on a straight line, and let

$$(1) \quad y = Ax + B$$

1) Miyabe, N: Bull. Earthq. Res. Inst. **11** 1933 639-692.

be the straight line determined by the n -points $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ by the method of least squares. The value

$$(2) \quad u = \frac{1}{n} \sum_{i=1}^n (Ax_i + B - y_i)^2$$

may be taken as an indicator of deviation of these n -points from the straight line (1).

We now determine the probability $P_n(c)$ that u is smaller than a given positive number c^2 . If y_i takes any value between $-\infty$ and $+\infty$, it is impossible to determine $P_n(c)$. Therefore, in the present case we assume that y_i obeys the Gaussian distribution law, that is

$$(3) \quad p(y) = \frac{1}{\sqrt{\pi} a} e^{-\frac{y^2}{a^2}},$$

and we have

$$(4) \quad P_n(c) = \int \int \dots \int_{u < c^2} p(y_1) p(y_2) \dots p(y_n) dy_1 dy_2 \dots dy_n.$$

From (1) and (2) we get

$$(5) \quad u = \frac{1}{n \sum_{(i,k)} (x_i - x_k)^2} \sum_{(i,j,k)} \left\{ (x_j - x_k) y_i + (x_k - x_i) y_j + (x_i - x_j) y_k \right\}^2.$$

Let us transform the co-ordinates $(y_1, y_2, \dots, y_n)$ in the n -dimensional space into new rectangular co-ordinates $(Y_1, Y_2, \dots, Y_n)$ by the rotation of the axes of co-ordinates, so that the quadratic surface $u = c^2$ takes the canonical form

$$\frac{Y_1^2}{A_1} + \frac{Y_2^2}{A_2} + \dots + \frac{Y_n^2}{A_n} = c^2,$$

then, after rather lengthy calculations, we obtain from (5)

$$(6) \quad u = \frac{1}{n} (Y_1^2 + Y_2^2 + \dots + Y_{n-2}^2).$$

From (4) and (6) we get

$$(7) \quad P_n(c) = \frac{1}{\pi^{\frac{n-2}{2}} a^{n-2}} \iint \dots \int_{(Y_1^2 + Y_2^2 + \dots + Y_{n-2}^2 \leq nc^2)} e^{-\frac{Y_1^2 + Y_2^2 + \dots + Y_{n-2}^2}{a^2}} dY_1 dY_2 \dots dY_{n-2}.$$

On the other hand, the volume $V_m(R)$ of the m -dimensional sphere with the radius R is

$$(8) \quad V_m(R) = \frac{\pi^{\frac{m}{2}}}{\Gamma\left(\frac{m}{2} + 1\right)} R^m,$$

and we get from (7)

$$(9) \quad P_n(c) = \frac{1}{\pi^{\frac{n-2}{2}} a^{n-2}} \int_0^{\sqrt{n}c} e^{-\frac{R^2}{a^2}} \frac{dV_{n-2}(R)}{dR} dR.$$

From (8) and (9) we obtain

$$P_n(c) = \frac{1}{\Gamma\left(\frac{n}{2}-1\right)} \int_0^{\frac{nc^2}{a^2}} e^{-x} x^{\frac{n}{2}-2} dx.$$

In the three-dimensional case, the probability $Q_n(c)$ that n -points lie on a plane with the deviation

$$w = \frac{1}{n} \sum_i (ax_i + \beta y_i + \gamma - z_i)^2 \leq c^2$$

may be determined just in the same way; that is, we get

$$Q_n(c) = P_{n-1}\left(\sqrt{\frac{n}{n-1}}c\right).$$

In the case of Sagamino, the vertical displacements of triangulation points (given in centimetres) are by no means independent of one another, but instead, have a pronounced tendency to northward declination, as shown in Fig. 1 a. In order to satisfy the condition of equation (3) fairly well, a plane was determined by the method of least squares, and the deviations of each of these triangulation points from this plane were counted (Fig. 1 b).

Fig. 1 a.

Fig. 1 b.

In Fig. 2 is shown the distribution of $Q_n(c)$,¹⁾ the "doubtful blocks"²⁾ being put into the area where $Q_n(c) \geq 0.5$. Moreover, the vertical displacements are too small compared with the magnitudes of the supposed blocks for the purpose of proving the existence of faults, while the plan of some of the blocks are so odd that they can hardly exist in nature. In short, the block hypothesis for the case of Sagami is much more complicated than is really necessary.

The followings are the main conclusions:

- (1) No faults, no blocks.
- (2) Although blocks do exist, they are not so numerous as those "geodetic blocks."

(3) Since the absence of any young faults in Sagami has been proved beyond doubt as the results of intensive field studies, calculation of $Q_n(c)$ is only of secondary importance so far as the problem under discussion is concerned.

(4) In the study of elevated shorelines, the value of c/a is very small, because a has generally a large value, so that $Q_n(c)$ becomes small; crustal deformations determined by measuring uplifted shorelines are very likely real.

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Fig. 2. Geographical Distribution of $Q_n(c)$.

- 1- $Q_n(c) > 0.5$
- 2- $Q_n(c) = 0.2 \sim 0.5$
- 3- $Q_n(c) < 0.2$

1) For the most of the "blocks," the numerical value of c is of the order of few centimetres.

2) Out of the nearly 100 triangulation points in question, Miyabe omitted about 20 of them owing to doubts of their being doubtful blocks.