47. On Time and Space Distribution of Earthquakes.— A supplementary Note.

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Some discussions and objections on one of my recent papers[1], were given by Dr. F. J. W. Whipple in his paper, "On the Alleged Tendency for Great Earthquakes to occur sympathetically in widely separated Regions".[2]

He calculated the integrated frequency of the "preferential ratios"[3] with some assumptions. The integrated frequency to be expected according to his theory is represented by the stepped graph in the diagram. Smooth curves have been drawn through the corners of the steps.
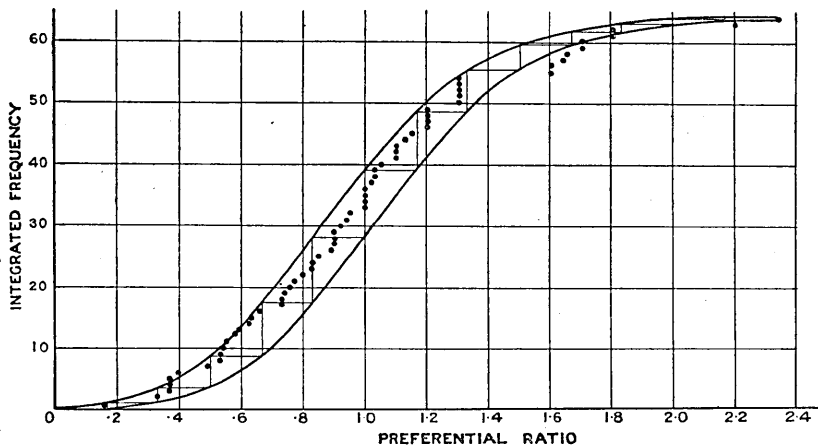

Fig. 1.

It will be seen that the great majority of the points representing Yamaguti's statistics are within the area bounded by these curves. The

1) *Bull. Earthq. Res. Inst.*, **11** (1933), 46.

2) *Monthly Notices of R. A. S., Geophysical Supplement*, **3** (1934), 233.

3) The ratio, $r = \dfrac{N_0}{N'}$ in my paper was called by this name.'

most striking exceptions are on the right, where five points are below the bottom curve. With this reason, he says that the aggregate of the preferential ratios in Table I, obtained by Yamaguti would be produced

Table   I.

		Region of the second of the two earthquakes							
		1	2	3	4	5	6	7	8
Region of the first of the two earth-quakes	1	1·8	0·94	1·03	1·3	1·2	0·37	0·16	0·73
	2	1·3	2·34	1·2	0·63	0·53	0·85	0·37	1·3
	3	0·59	1·0	0·66	1·65	0·53	0·33	1·3	1·64
	4	0·89	0·76	0·83	0·90	1·6	1·0	1·3	0·49
	5	0·94	0·80	0·95	1·1	0·92	1·1	1·15	1·05
	6	0·37	1·7	1·0	1·0	0·54	1·7	1·1	1·3
	7	1·13	0·55	0·58	0·77	1·03	2·2	1·6	0·90
	8	0·73	0·63	1·8	0·74	1·2	0·83	0·90	1·02

1. The neighbourhood of the Mediterranean Sea.
2. Continental Asia.
3. Japan.
4. The Philippines and neighbouring oceanic regions.
5. Australia, including the oceanic environment.
6. North America.
7. Central America.
8. South America.

by chance, the sequence of earthquakes in different regions being equally likely to occur in any order.

After examining Whipple's results and conclusion, I came to perceive that he might have misunderstood the true aim of my paper.

The preferential ratios such as, $r=1·64$ and $r=1·80$, may be produced in any pairs of regions by chance, as he says, but we can say nothing from his paper, why they happen in such particular sequences of regions as Japan→South America, and South America→Japan.

The event that the frequency of the preferential ratios takes the form of ordinary probability curve, is by all means different from the event that in some particular sequences of regions, the preferential ratios are greater than unity and in another particular sequences of regions, they are less than unity. These two events are obviously independent from each other.

For instance, in a game of shooting, some men will take much

better marks than the average, and some other men will take much worse marks. The existence of such two kinds of men might be equally probable, but we can say nothing of the skill of a certain individual from the mere distribution of men of various marks. It suffices to associate the occurrence of each pair of successive earthquakes with the champion representing that pair.

Our final aim is nothing but to find out the skillful men and the less skillful men among many players. Of course, they cannot be determined with certainty by a single or two trials, but may be determined approximately by taking sufficiently abundant materials.

In my original paper, such a preferential ratio, $r = N_0/N'$, which has the small expected number, N', say, less than 3, may have large fluctuation of its value with the variation of the actual number of occurrences, N_0, but those ratios which have, N', say, greater than 5, do not fluctuate actually so much as from 0.2 to 2.34. Thus, the two preferential ratios (1.8 and 0.5), one of which has $N_0 = 18$, and the other has $N_0 = 5$, both having $N' = 10$, may be considered at least to suggest some different physical relations.

For the sake of reference, the earthquakes, 420 in number in the original paper, were separated into nearly equal two parts according to time, Jan., 1900~Oct., 1918, and Nov., 1918~April, 1931, and the similar calculations for the preferential ratios, were made separately, as shown in Table II, a and b.

As the data are too scanty for this purpose, in this case, we can say nothing definite of the results, but such preferential ratios marked

Table II a.   Jan., 1900~Oct., 1918.

		Region of the second of the two earthquakes							
		1	2	3	4	5	6	7	8
Region of the first of the two earthquakes	1	2.5*	0.77	0	1.34*	1.28	0.53	0.32	0.77
	2	1.54	1.7*	2.1	0.73	0.28	1.16	0.35	0.84
	3	0.39	0.85	0.42	0.98	0.84	0.58	2.07	1.6*
	4	0.67	1.22	1.22	1.13	0.98	1.34	1.0	0.49
	5	1.54	1.03	0	1.46	1.12	0.67	0.69	1.4
	6	0	1.74*	0.58	1.34	1.0	0.8	1.4	0.58
	7	0.32	1.04	1.04	0.4	1.15	2.36*	1.68	0.69
	8	1.15	0	2.1*	0.25	1.69	0.58	0.69	1.7

Table II *b.*   Nov., 1918~April, 1931.

		Region of the second of the two earthquakes							
		1	2	3	4	5	6	7	8
Region of the first of the two earth-quakes	1	1·74*	0·96	1·33	1·33*	0·74	0·74	0	0·8
	2	0·96	3·7*	0·59	0·3	0·81	0·81	0·5	1·32
	3	0·8	0·88	0·65	1·79	0·3	0·9	0·56	1.9*
	4	1·33	0·3	0·65	0·49	2·1	0·45	1·39	0·48
	5	0·74	0·54	1·35	0·6	0·99	1·67	1·8	0·68
	6	0·74	1·65*	1·8	0·9	0·42	2·5	0	1·35
	7	1·82	0	0·28	1·39	1·03	1·54*	0·95	1·25
	8	0·4	1·32	1·43*	0·95	0·9	0·68	1·67	0·37

by *, give the values greater than 1·33, in both the cases, so that in such particular sequences of regions, we may be able at least to suggest that the earthquake seems to be liable to be followed by another. Among the others, the sequences of regions, Japan→South America, and South America→Japan, always give preferential ratios greater than 1·43 which result may be considered to support the statement that an earthquake seems to be liable to be followed by another in the antipodal region. This same result may also be obtained by the other method of investigation which is described in a previous paper[4], "Statistical Relation between the Frequencies of Earthquakes in Japan and Other Parts of the World."

For another example, we have calculated the preferential ratios which are given quite at random, by casting a die 400 times successively, and obtained the next table.

The result shows that the range of fluctuation of the value of the preferential ratio is limited between 0·68 and 1·43. Therefore, the pairs of regions which have the values of preferential ratios decidedly greater than 1·5 and less than 0·6, may at least be suspected to have some particular physical relation with regard to the sequences of earthquakes. Moreover, no pair of regions for which equally large ratios are obtained for the reversed sequences of earthquakes, such as between Japan and South America, is found in this artificial case.

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4) *Bull. Earthq. Res. Inst.*, 10 (1932), 36

N=400		Region of the first of two earthquakes					
		1	2	3	4	5	6
Region of the first of two earthquakes	1	1·22	1·11	0·86	0·97	1·05	0·86
	2	0·81	1·19	0·96	1·21	1·13	0·70
	3	0·95	1·13	0·81	1·07	0·87	1·14
	4	0·89	1·13	1·07	0·78	1·0	1·15
	5	0·68	0·72	1·36	0·72	1·38	1·17
	6	1·43	0·70	0·98	1·15	0·68	0·98

We are going to verify these results again after collecting sufficient data for the great earthquakes in future time.

By the way, the earthquakes recorded on the catalogue " Rikwa-Nenpyô ", are such destructive ones as caused a considerable number of death of men and animals, if they occurred in land, so that they may be considered not to include any aftershocks.

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47. 地震の時間的並びに空間的分布に就て ― 補遺的註釋

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　私の最近の論文（地震の時間的並びに空間的分布に就て）に對する反駁論が英國のホイツプル博士によつて發表された．彼は私が世界地震に就て計算した處の或 1 個所から他の個所に移つた實際の地震の數と理論上豫期される數との比を採用して，或る假定の下にその比の値の生起する總回數を計算した．而してその總回數を縱軸にとり比の値を横軸にとつて階段的の圖を畫いた．滑かな曲線はその隅々を結び付けたものである．

　山口の統計を表はす大部分の點は此の上下の曲線の間に入ると云ふ理由を以てホイツプル博士は，第 I 表に示される山口の求めたすべての比は全く偶然に起り得る．即ち地震は何れの地方にも勝手な順序に同樣に引き續いて起るといふことを述べてゐる．

　併しそれは彼が私の論文の眞の目的を誤解したのではなからうかと思ふ．即ち r=1·64 又は r=1·80 といふような比は彼の云ふ通り勝手な聯關した二つの地方に偶發的に起ることがあるかもしれないが，而してこれが何故に日本から南米へ，又は南米から日本へといふような同一な二地方に交互に生起するかといふことは彼の論文からは何も云ふことは出來ない．即ち之等の比の起る回數が公算曲線を以て表はされると云ふことゝ或る特別な 1 對の地方に於てその比が 1 より大であり他の特別な 1 對の地方に於てその比が 1 より小であると云ふことゝは自ら別問題である．

　例へば射撃大會に於て，或る人は平均點よりもはるかに良い點をとり，或人は，はるかに惡い點をとる者もあらう．而して斯かる 2 種類の人間の存在することは同等であるかも知れないが，單に斯

かる様々の點をとつた人の分布から各個人の上手，下手を論ずることは出來ない．我々の研究の目的は實にこれらの多くの射手の内にて誰が上手で誰が下手であるかを見出すに外ならない．勿論これは 1 回や 2 回の競技では確定することは出來ないが，充分澤山なる材料を以つてすれば，略決定することが出來ると思ふ．

$r = \dfrac{N_0}{N'}$ に於て $N' = 10$ なる時 $N_0 = 18$ 及び $N_0 = 5$ なる二つの比 1.8 及び 0.5 は少なくとも或異なつた物理的關係を暗示するものと考へられる．參考の爲め原論文に於ける 420 の地震を略々折半して前同樣多くの比の値を計算して見ると，日本より南米へ又は南米より日本へと云ふ樣な組合せに於ては二つの場合とも矢張り 1.43 以上の値を與へてゐる．それ故，斯かる特別な組合せに於ては 1 個所に地震が起ると引續いて他の個所に起り易いと云ふことを暗示することが出來るかと思ふ．

何 * 印のついてゐる組合せの地方に於ても同樣のことが云はれるかと思ふ．

これらの結果に就いては將來大地震に關する充分なる材料が集まつた後に於て再び證明したいと考へて居る．