# 4. *On Swarm Earthquakes.*

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From the middle of February 1930, remarkable trains of swarm earthquakes began to be felt in the vicinity of Itô on the eastern coast of Idu Peninsula which showed maxima of frequency in March and lasted to the middle of April. The activity was resumed from the beginning of May and lasted to the end of the same month. Towards the middle of November another swarm was commenced in northern parts of Idu and culminated in the destructive shock of 26th. Nov. The activity lasted towards the beginning of January 1931. Though somewhat similar phenomena occurred in 1899 at Arima, in 1917 and 1920 at Hakone and in 1922 at the Suwa Lake districts, they are surpassed in frequency and duration as well as in intensity by the recent case of Idu earthquake-swarms with their catastrophal climax of 26th. November.

Fig. 1 will illustrate the characteristic mode of fluctuation in the daily numbers of shocks. In these examples, the earthquakes are crowded within a well defined interval of time and form an apparent group or swarm. Though the daily numbers show a considerable fluctuation we may roughly compare the graph with a kind of probability curve with a definite mean value and dispersion.

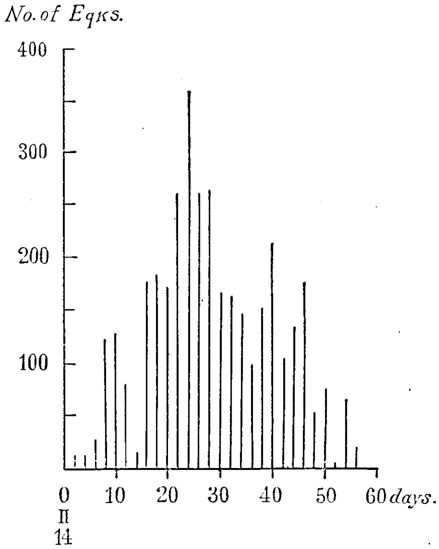

Fig. 1. Itô Earthquakes, Feb. 14–Mar. 11. Sum of successive two days are plotted against the day.

It is the shortness of the intervals of successive shocks that this kind of swarm-earthquakes draw our attention as an unusual phenomenon. If the time scale be magnified sufficiently people will take no notice of these swarms as such. It is, therefore, of some interest to inquire whether a similar swarm cannot be found with different scales of time and space. For an example, we take the monthly numbers of conspicuous earthquakes in Kwantô Districts which are plotted in Fig. 2. The data for 1920–1927 are taken from Honpô-

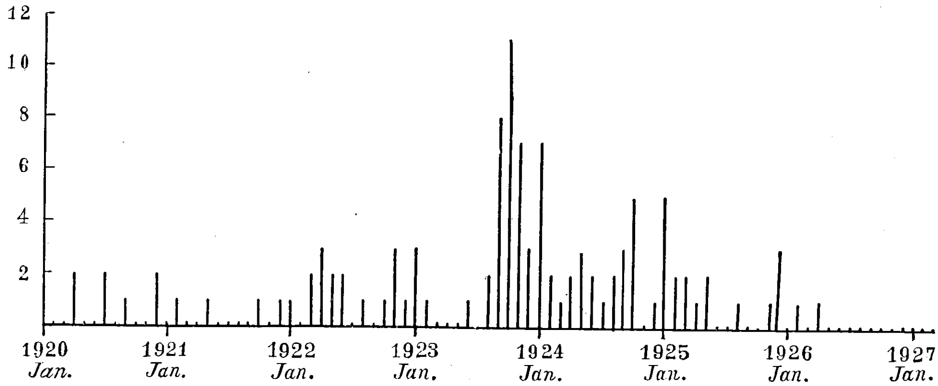


Fig. 2. Earthquakes in Kwantô District 1920–1927.

Kentyo-Disin-Hyô, compiled by the Authorities of the Central Meteorological Observatory. The earthquakes here chosen are those which are classified as "kentyo (conspicuous)" and "yaya kentyo (rather conspicuous)" according to the usual terminology. Among these earthquakes those were picked up of which the epicentres are located within Kwantô Plain and its neighbouring districts such as Idu Peninsula, mountainous regions of Kai and Sagami, Bôsô Peninsula, river basins of Tonegawa etc., Utunomiya and Nasu districts, and Province of Iwaki. Only those were taken which originated in the inland area, though the Tôkyô Bay and Uraga Channel were counted as within this area.

Comparing the epoch 1922–1926 of Fig. 2 with Idu Earthquake-swarm of Fig. 1, we may remark a similarity in features of graphs in spite of the remarkable difference in scales of the coordinates. If such a comparison may have any physical sense, we are led to the inference that the Kwantô earthquake-swarm in question was already begun as early as in the end of 1921, though the climax occurred in September of 1923 which is known as the Great Kwantô Earthquake.

In the case of purely statistical occurrence in which the probability of occurrence of a number $n$ is determined by its mean value $\nu$ alone, we usually resort to Poisson's formula. In the case when the probability $p$ of each element turning out favourable is very small, while the number of the elements, $N$, concerned is very large so that the mean value $\nu=pN$ is finite, the above assumes the form similar to Gauss's law. In the present case, we may tentatively compare the number, $n$, of earthquakes in a given day with the number of elementary volumes of a colloidal solution containing a given number of particles. In the latter case the actual statistical distribution will also show some irregularity when the total number of the volume elements taken is finite. The distribution curve in such case cannot, however, be expected to show such a remarkable quasiperiodic fluctuation as shown in Fig. 1 or 2. Hence, we may suspect that there are some causes which give rise to such a characteristic distribution curve.

Among the natural phenomena there seems to be some class which show a quite similar statistical distribution. One of the remarkable examples is afforded by the daily number of falls of camelia flowers. In the last spring, the present writer and Mr. T. Utigasaki of the Institute of Physical and Chemical Research made some observations regarding the fall of this flower. Fig. 3 and 4 show some examples of

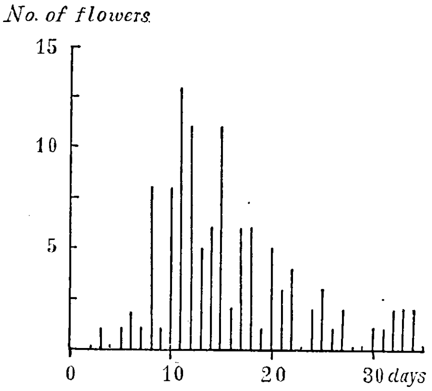


Fig. 3. Fall of camelia flower (Terada).

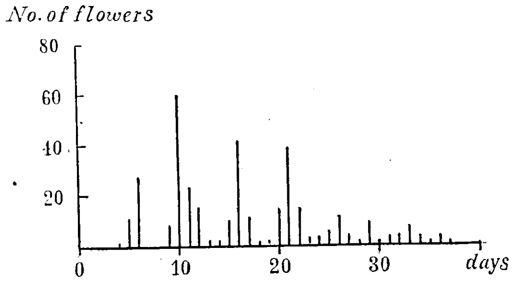


Fig. 4. Fall of camelia flower (Utigasaki).

the results obtained. It will be seen that the time-distribution curves resemble to those of earthquakes shown in Fig. 1 and 2 in many essential points, i. e. the curve shows a quasi-periodic fluctuations of remarkable amplitude and also a similar unsymmetry with regard to the maximum point.

In the case of the flower the meaning of the statistical distribution observed is in some measure apparent. Thus, there are a number of elements for which the average *life* is assigned and the actual falls take place scattered about this mean. There must, however, be present some cause which gives rise to such a remarkable fluctuation of the distribution curve as is actually observed. Firstly, the weather conditions may considerably affect the fall. It was, however, observed that the number of fall is not necessarily large after a windy or rainy days as may be commonly expected. A very remarkable fact is that the fall takes place almost exclusively during the night hours. Even in a very windy day the fall during the day time is quite rare. Only towards the end of the flower period some of the flowers are rotten before falling, in which case the normal mode of fall is not followed but the pistil and calix drop off attached to the petals. These rotten flowers are sensitive to winds. The normal mode of fall of the petals seems, however, to be determined by some other intrinsic causes. As it is known that the *turgidity* of plants shows a great difference in day and night, we may suppose that the fall of flowers is somewhat connected with it. On the other hand, the fall of a large number of flowers within a short time cannot be without some influence upon the turgidity of the entire organism and therefore affect the later fall in some or other way.

Returning to the case of earthquakes, we may venture a similar conjecture. Thus, we may suppose a group consisting of a large number of "latent" origins of earthquake which are gradually "ripening" or approaching a critical state. The time of attaining such state is distributed about the mean value according to some statistical law. Besides, we suppose that the occurrence of an earthquake has an influence on the entire system of the latent sources such that the probability of occurrence of the next earthquake is thereby decreased in some measure. In such a hypothetical case the occurrence of the earthquake may show a statistical distribution somewhat similar to the actual swarm.

It seems possible to construct even a mechanical model of the system above considered. Suppose, for an instance, a vertical cylindrical vessel containing water, provided with a large number of horizontal side-tubes attached to the wall at nearly constant heights. The end of each tube is provided with a stop such that it is pushed off when the pressure of water inside of it attains a certain value which is not quite constant for all the tubes but varies within a range about the mean value. The stop is connected to a ball or conical secondary stop which lies in the inside of the mouth of the tube, and when the external primary stop drops out this second stop comes in action and completely shut off the mouth after allowing a certain quantity of water to be discharged, before the complete stoppage is effected. We may also introduce in some part of the tube, between the vessel wall and the stop, some kind of viscous resistance by which means the effect of dropping of a stop upon the water content of the vessel may be made to lag. Suppose now that the vessel is at first empty and water is gradually poured in from above. When the pressure at the depth, where the tubes are arranged, approaches the mean critical value the stops will begin to drop out before the mean value is attained. Others will remain after the mean critical pressure is reached and a few will drop out only when the pressure has considerably surpassed the mean critical value. On account of the discharge of water due to the dropping of a stop the rate of increase of the water head in the main vessel will be retarded. When a large number of stops drop out nearly simultaneously, it may happen that the water head falls down in spite of the continuous supply. In this latter case the further dropping out of the stops may be suspended for a certain time. As, however, the stops which have dropped out are replaced by the inner stops after discharging definite amount of water, the water head soon resumes rising and gives rise to the dropping of another group of stops and so on. The viscous friction in the side-tube as above assumed will serve as a factor which gives some time-lag to the effect of the side-discharge upon the water head of the main vessel and also *smoothes* out the effects of successive discharges.

In the above model, all the stops are finally put into action and completely shut up by the second inner stops so that the water head in the main vessel may rise indefinitely if the rate of supply is kept constant. We may, however, easily modify the above model such that the rate of supply is governed by the total number of dropped stops, or simply conceive an over-flow of which the height are varying with time in a statistical manner. We may also make the same model resume a second period of activity, if the stop of each side-tube consists of a chain of balls made of some substance such as pitch. Under the constant pressure from the inside, the viscous stop will slowly flow out of the mouth opening though in every instant it is a solid stop in the ordinary sense of the words. After the lapse of a certain time average strength of the stops will decrease to a critical amount which is given by the water-head of the main vessel which is assumed here to be fluctuating as above supposed due to some other external causes. When these second stops drop out the third ones will serve as the complete stop in the next period of repose, and so on.

The above mechanical model could also be replaced by an electrical model in which sparkings of numerous spark gaps replace the dropping out of stops. The destruction of each spark gap after sparking may be attained, for example, by choosing a soap bubble as one of the electrode. A semi-conductor will then play the part of the viscous resistance in the mechanical model.

The practicability of these models are, however, not at all essential in the present discussion, which is aiming at the description of a "Gedankenexperiment" carried out with the purpose of investigating one of the possible mechanism of swarm earthquake.

In comparing the above models with the case of earthquakes the correspondence of the working parts will be quite evident. Thus, falling of each stop represents an earthquake by which the probability of occurence of the next earthquake at the same spot is reduced to zero for a certain time. The water head represents the average state of strain in the entire system including all the latent seismic origins. Each single earthquake is then assumed to contribute to a certain decrease of the average strain of the entire system. The viscous resistance of the model will also correspond to the viscosity of the crustal materials.

Thus, it will be seen that the above model may deserve notice at least as one of the plausible alternatives. The quantitative formulation of this kind of model seems not quite easy as far as the usual method of statistics is resorted to, since the mutual influence of the elements plays here the most essential role, while the usual statistics holds mostly for the case of utterly independent elements. The effect of after-effect as is taken into account in the theory of fluctuation such as applied to the molecula phenomena is of a quite different nature from that here in question.

# 4. 地 震 群 に 就 て

地震研究所 寺 田 寅 彦

昭和五年伊豆地方に起つた地震群と比較さるべき地震群が、異なる時間的のスケールに於て關東大地震前後に起つた事に注意を喚起し、又此れと形式的に類似した群起的現象が他の方面にも存在する一例として椿の花の落花数の日々變化を例示し、別に此等に相應ずべき器械的模型を想像して此れに關する思考實驗の經過を述べてある。