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Tide-Forming Forces and Earthquakes

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It is possible to formulate the following four general regularities concerning the liberation of seismic energy from the interior part of the Earth in relation to the tide-formation effects:

The earthquake frequencies in the new and full moon become especially great under the condition that the perigean and apogean segments of the Moon's orbit are spaced in these zones and provided that the role of the perigee in comparison with the apogee is much greater; the perigean and apogean segments appear to be the ones which are most liable to facilitate earthquakes in the syzygeal zones, whereas the intermediate stretch exhibits the least participation in quakes.

The earthquake frequency in the new and full moon zones decreases when an intermediate (between perigee and apogee) stretch of the Moon orbit is revealed in these zones.

In the quarternary zones of the Moon phases the earthquake frequency severely increases in cases when an intermediate (between perigee and apogee) stretch of the Moon orbit is discovered.

In the quarternary zones of the Moon phases the earthquake frequency reaches its minimum when the perigean or especially the apogean third of the Moon's orbit is detected.

The earhquake frequency changes in relation to the tide-formation forces, precisely within the range of many dozen and hundreds of percent. This has been revealed in regard to normal, intermediate, and deep-foci earthquakes throughout a vast period of observations and is based on materials pouring in from many areas of the world.

The possibility of the effect of the tide-forming forces on the spacing of earthquakes had been predicted long ago. However, this influence has been ascribed to the increase of earthquake frequencies under the most favorable cosmic environmental conditions in comparison with the less favorable ones, which commonly amounted merely to 5–15%.

Table I exhibits the distribution of statically homogeneous material covering the earthquakes in the Transcaucasian area during a period of one-third of a century from 1917 to 1950. It is evident from the table that the frequency of earthquakes in the syzygy zone is 3% higher and in the quadrature zone it is 3% lower than observed in the case of a uniform spacing of earthquakes when there is no connection with space conditions. These variations are very insignificant and deserve little attention. A very much similar picture is observed with earthquakes when compared with the perigee (106%) and the apogee (94%) zones. The frequencies of earthquakes in the syzygy-apogean and the quadrature-apogean zones amounts to 93–94% and in the quadrature-perigean zone it amounts to 101%. The earthquake frequency slightly increases only in the

syzygy-perigean zone and reaches 112%. It is natural enough that many scientists under conditions of a similar or analogous trifling increase (and at times decrease) of earthquake frequencies as a rule fail to acknowledge, or almost totally discard, the role of space factors in the liberation of seismic energy coming from the interior part of the Earth. And, indeed, the increase

TABLE I

SPACING OF EARTHQUAKES IN TRANSCAUCASIA DURING THE PERIOD OF 1917–1950

Zone or cumulation of zones	Number of earthquakes	Earthquake frequency (%)
Syzygy zone	621	103
Quadrature zone	584	97
Perigee zone	641	106
Apogee zone	564	94
Syzygy-perigean	337	112
Syzygy-apogean zone	284	94
Quadrature-apogean zone	280	93
Quadrature-perigean zone	304	101

of earthquake frequencies by 5–10% is not to be regarded as a sound reason for acknowledging the specific role of the tide-forming factors. The role of the latter forces could be demonstrated with full conclusiveness had the earthquake frequencies been increased by many dozen and by hundreds of percent under favorable space conditions.

It has usually been assumed that the earthquake frequency increases in the new moon and full moon zones and decreases in the first and last quarters of the moon phase zones. Apart from this it has been believed that earthquakes are more frequent in the perigean part of the Moon's orbit than in the apogean part. At initial approximation it seems to be so. However, in reality it appears that the connection of earthquakes with the tide-forming forces is of a much more complex nature. This problem, in its general aspects, was dealt with by the author of this communication back in 1956 (Tamrazyan, 1957) and more thoroughly somewhat later at the 5th Symposium devoted to problems of planetology assembled by the Geographical Society of the USSR (Tamrazyan, 1965). At this point the author intends to dwell more thoroughly on the problem.

The earthquake frequency in the new and full moon zones does not always increase; under certain circumstances it shows a substantial decrease. Earthquake frequency during the quadrature moon phase does not always reduce; under certain circumstances it sharply increases. Thus, the comparative investigation of earthquake frequency throughout the syzygy and quadrature zones often reveals merely trifling differences, for the quadrature zone exhibits patches of very high earthquake frequencies and patches with a lower number of earthquakes are spaced in the syzygy zone. These phenomena experience superpositioning and screen the complex interrelations arising between earthquakes and the tide-forming forces and at times may act as the causal factor responsible for the negation of the actually existing relations. And, nevertheless, the connection sought does exist and appears as a distinct and well-defined one.

Analysis of the immensity of factual material concerned with earthquakes in different areas of the Earth has enabled us to reveal and formulate the following four general regularities concerning the liberation of seismic energy from the interior part of the Earth in relation to the tide-formation effects:

(a) The earthquake frequencies in the new and full moon become especially great under the condition that the *perigean* and *apogean* segments of the Moon's orbit[1] are spaced in these zones and provided that the role of the perigee in comparison with the apogee is much greater; the perigean and apogean segments appear to be the ones which are most liable to facilitate earthquakes in the syzygeal zones, whereas the intermediate stretch exhibits the least participation in quakes.

[1] The Moon's orbit is divided, for the purposes of this paper, into three more or less equally extended stretches: the perigean, the apogean, and the intermediate stretch spaced between them.

(b) The earthquake frequency in the new and full moon zones decreases when an intermediate (between perigee and apogee) stretch of the Moon orbit is revealed in these zones.

(c) In the quarternary zones of the Moon phases the earthquake frequency severely increases in cases when an intermediate (between perigee and apogee) stretch of the Moon orbit is discovered.

axis and the syzygy lines coincide or are spaced close by each other.

At this point the author intends to review the above-mentioned general regularities based on the cited factual material covering the earthquakes observed in Transcaucasia during the period of 1917–1950. The spacing of these earthquakes is shown in a diagram (Fig. 1). The entire area of the diagram is subdivided into 121

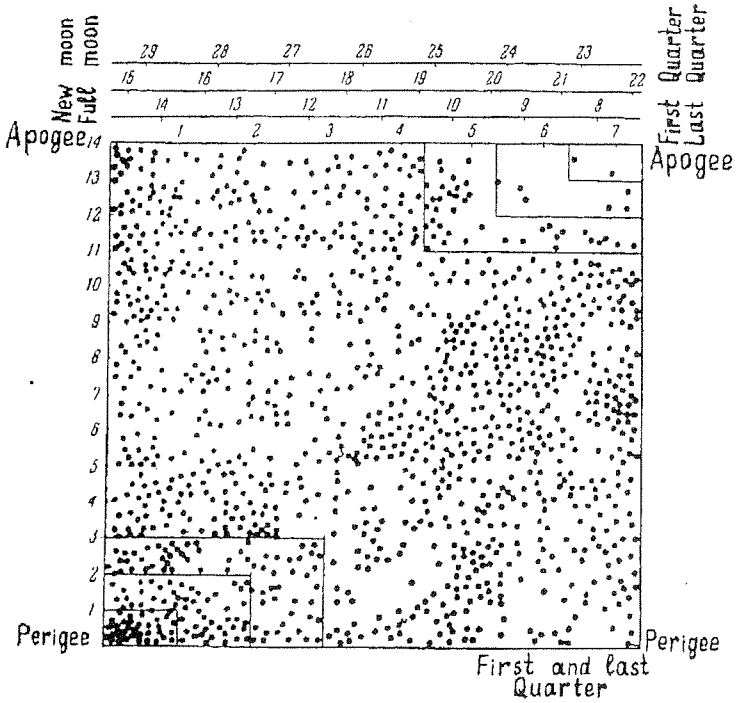

FIG. 1. The spacing of the total number of earthquakes in Transcaucasia during 1917–1950 in relation to the variation of tide-forming effects. The Moon's phases are plotted along the abscissa, the time intervals between earthquakes and the Moon's passage via the orbit's perigee are plotted along the ordinate; symmetric positions of the Moon's phases in relation to the straight line running through the Sun, the Earth, and the Moon and in relation to the Earth's orbit are matched.

(d) In the quarternary zones of the Moon phases the earthquake frequency reaches its minimum when the perigean or especially the apogean third of the Moon's orbit is detected.

These four general regularities ought to be regarded as a resultant of the combined effect of the Moon's and the Sun's tide-forming influences and are connected with sufficient gradients of these efforts in the course of transition from the syzygy zone to the quadrature zones when the apse

squares (11×11) and the number of earthquakes per square is calculated. As seen from Fig. 1 the greatest number of earthquakes is ascribed to the lower left corner (the new and full moon zones and including the perigee), whereas the lowest number is observed in the upper right corner (the zones of the first or last quarters including the apogee). For example, during the time interval of ± 3 days ranging from the new or full moon and from the perigee the number of earthquakes amounted to 157, whereas during the time

interval of ±3 days ranging from the first or last quarter and from the apogee the number of earthquakes comprised only 46. If one examines much narrower time lapses than ±3 days (namely such time intervals under which the favorable or unfavorable cosmic space conditions ought to be still more distinct and have a pronounced visual effect), the connection between earthquakes and tides within the Earth's hard mantle becomes even more explicit (Fig. 2). For example, during the time interval

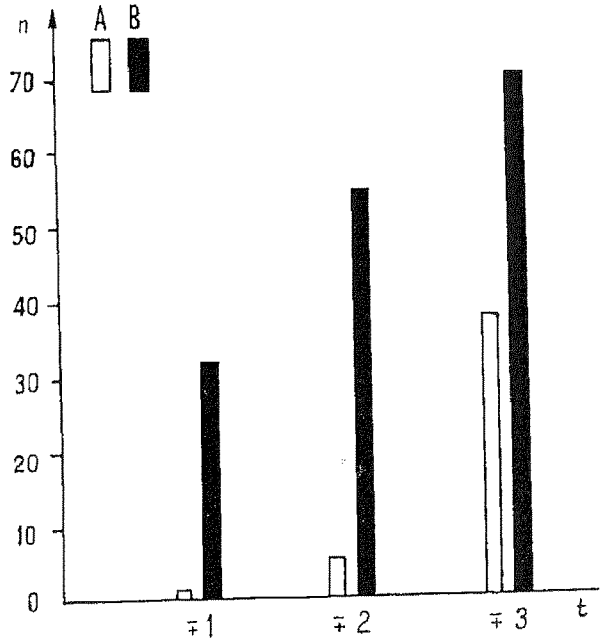

FIG. 2. Connection between earthquake frequencies and time range intervals under most and least favorable cosmic space conditions. A, for the first and last quarter of the Moon's phase and for the apogee; B, for the new and full Moon cases and the perigee; n, number of earthquakes; t, time interval (days) between the moment of an earthquake and the most and least favorable cosmic space conditions.

of ±1 day the number of earthquakes (32 earthquakes) under most favorable cosmic space conditions (new or full moon and perigee) exceeded the number of earthquakes by 16 times (two earthquakes) under the least favorable cosmic space conditions (the first and last quarter and apogee). This is the very evidence showing with explicity and contrast the true connection between earthquakes and the lunar–solar tides developing in the Earth's crust and in the underlying mantle.

An areal diagram (Fig. 3) for revealing the systematic variations of repeated earthquakes and for a severe reduction of the role of accidental factors facilitates the study of earthquake frequencies with the aid of sliding average rates (the mean number of earthquakes per square is calculated and regarded as the average of the proper square and the surrounding eight squares).

Figure 3 exhibits a distinctly pronounced semicircle where earthquakes are rare, extending from the right top corner towards the middle of the left side and further stretching to right lower corner. It is possible to note also a semicircle of concentrated earthquake spacing which is broken up by the semicircle in which earthquakes are rare and which extends from the left lower corner towards the middle of the right side and stretches on towards the left upper corner of the drawing.

The semicircle of rare earthquake occurrence reveals a zone of very rare earthquakes which corresponds to the most favorable cosmic space conditions suitable for earthquakes (the quadrature and the apogeal third portion of the lunar orbit). The escape zone which is relatively bare of earthquakes, though it coincides with the new and full moon, is spaced at the very top point of this semicircle.

The semicircle of earthquake foci reveals a zone of highly concentrated earthquakes (syzygy and perigean third stretch of the lunar orbit) and a zone of considerable earthquake frequency (quadrature and intermedial portion between the perigee and apogee of the lunar orbit's third part).

In the new and full moon zones the earthquake frequency at the perigeal section of the lunar orbit amounts to 150–210%, at the apogeal section it equals 110–150%, and at the intermediate section it amounts to 80–120%. The earthquake frequency in the zones of the first and the last quarters of the Moon's phases amounts to 30–70% at the perigeal stretch, 30–50% at the apogeal stretch, and increases up to 120–180%

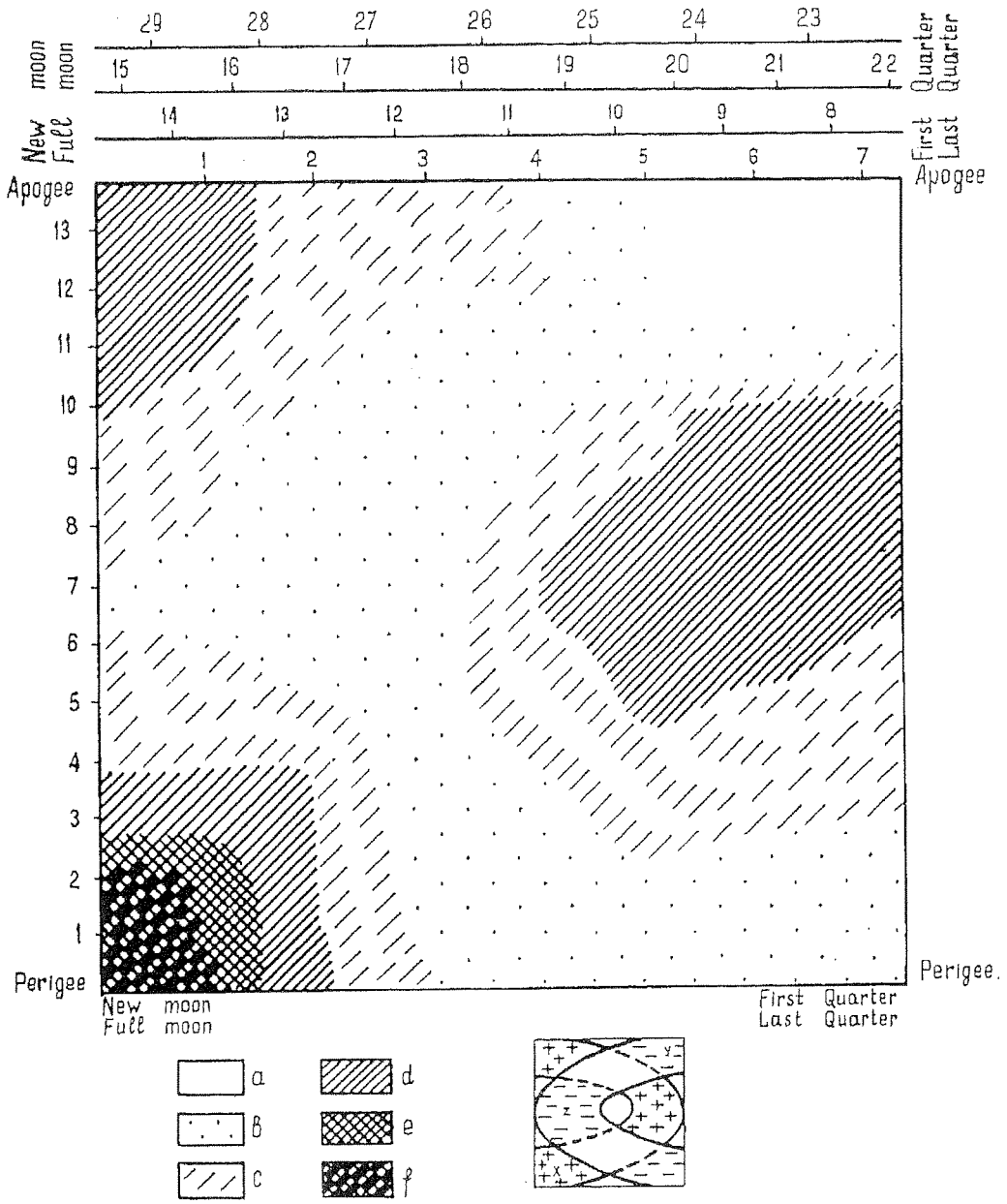

FIG. 3. The spacing of the total number of earthquakes in Transcaucasia during 1917–1950 in relation to variations of tide-forming effects in accordance with the method of sliding areas (the nine-square method). The spacing of parameters along the ordinates and the abscissa are similar to those in Fig. 1. Average number of earthquakes per area unit comprises (Fig. 3 spaces 121 similar area units) the following: a, 3–6 earthquakes; b, 6–9 earthquakes; c, 9–12 earthquakes; d, 12–15 earthquakes; e, 15–18 earthquakes; f, 18–21 earthquakes.

at the intermediate section of the Moon's orbit.

Hence, the patch of very high earthquake frequency which enjoys second place in the series of cosmic space conditions which facilitate the liberation of seismic energy (Table II) is spaced in the quadrature zone. Thus, under most favorable conditions which facilitate earthquakes on the part of the tide-formation efforts (new moon, full moon, and the perigean third portion of the lunar orbit) the earthquake frequencies (150–210%) exceed the earthquake frequencies under the least favorable conditions by 3–7 times (i.e., by hundreds of percentages) and surpasses the earthquake frequency, under these least favorable conditions (the quarternary

TABLE II

THE SPACING OF 1205 EARTHQUAKES IN TRANSCAUCASIA IN THE PERIOD OF 1917–1950 IN RELATION TO THE VARIATION OF TIDE-FORMATION EFFECTS

Lunar phase zones	Segments of lunar orbit	Earthquake frequencies (%)
New and full moon zones	Perigean third part of orbit	150–210
	Intermediate third part of orbit	80–120
	Apogean third part of orbit	110–150
Zones of first and last quarter	Perigean third part of orbit	30–70
	Intermediate third part of orbit	120–180
	Apogean third part of orbit	30–50

zones of the lunar phases and the apogeal third part of the lunar orbit) by 30–50%.

Such radical difference in earthquake frequency (by several times and hundreds of percent) under varied cosmic space conditions is in full agreement with the variation of tide-formation acceleration rate, which changes under extreme values by hundreds of percent (up to 3–4.5 times).

And, thus, the earthquake frequency changes in relation to the tide-formation forces, precisely within the range of many dozen and hundreds of percent and this appears to be one of the new contributions to the problem of the relation between earthquakes and cosmic space conditions (effects) introduced during the recent decade. This has been shown in regard to normal, intermediate, and deep-foci earthquakes throughout a vast period of observations and is based on materials pouring in from many areas of the world.

It has also been shown that there is a definite relation not only between earthquakes and tide-formation forces but also with the depth of the quake foci (Tamrazyan, 1958, 1959). The connection between earthquakes and new and full moon has distinctly been shown at depths up to 350–400 km. The earthquake frequency increases especially under most favorable cosmic space conditions (syzygy and perigee). When the depth is lower than 400 km. the connection between the earthquake frequency and the Moon's phases is weakened.

The resultant effect of rigid tides is especially significant in relation to the Earth's crust, for in this case the intense geological processes (particularly the tectonic ones) sharply change the tension conditions in the interior parts of the Earth and either emphasize or screen the influence of cosmic space conditions and their effects on the environmental situation and the time of earthquake origin. It seems that deeper in the Earth's mantle, there are being unfolded conditions under which the influence of other rigid tides is noticed almost without the interference of tectonic processes which are so characteristic for the Earth's crust.

CONCLUSIONS

On the basis of an immense amount of factual material (of both macroseismic and instrumental origin) it has been shown that there exists a most distinctly pronounced relation between earthquake frequency and the variation of tide-formation effects. However, this relation is of a complex and multiform nature and in the present communication the author has cast light merely on the separate links of this relation.[2]

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[2] The possible seismic shocks developing in the Moon (lunarquakes) are probably also connected and to a greater extent, with the tide-formation forces, particularly with those which are conditioned by the influences coming from the Earth. This also concerns volcanism phenomena (of Earth, lunar, and planetary origin).

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