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Principal Regularities in the Distribution of Major Earthquakes Relative to Solar and Lunar Tides and Other Cosmic Forces

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Magnitudes of strong earthquakes in the period 1903–1956 fall into two ranges: an upper of magnitude 8.4–8.9 and a lower of magnitude 7.9–8.3. Earthquakes of the upper range are distinctly related to (a) rotational parameters of the Earth (the so-called V numbers) and (b) lunar declination at culmination. Earthquakes of lower magnitudes do not reveal this relationship. Annual and diurnal trends in the seismic activity of the Earth's crust and the upper parts of the mantle are considered. Changes of seismic activity are compared with those of tide-generating forces, these changes reaching some 100%. The storing of seismic activity, its intensification and dimunition within different structural levels in the Earth's crust and mantle at different times, and the approximate coincidence of seismic events in various tectonic levels of continental and oceanic border regions are discussed. Characteristics of the changes of seismic activity are related to the fixed position of the Earth (i.e., the Greenwich Meridian relative to the Sun). Regularities in the distribution of seismic activity are related to the axes of the Earth's deformation. The association of the strongest earthquakes with the position of maxima of geoid amplitudes in circumsolar space is described.

Seismic activity of the Earth undoubtedly is characterized by regularities which are poorly understood at present.[1] The indirect approach to attempt to solve the problem of the regularities of seismic activity of the Earth may hopefully be supplanted by more direct ways in the near future.

I. Tide-Generating Forces and the Major Earthquakes

Major earthquakes of the Earth show a distinct connection with the change of tide-generating forces. Depending on the variation of tide-generating forces, the frequency and energy of earthquakes may change many hundreds of percent, not just in units or tens of percent as was previously believed. Tide-generating forces effect the frequency of earthquakes in the crust and mantle.

Variations of the tide-generating forces most strongly relate to the major earthquakes (Table I). Thus, for example, during the 1903–1956 near-perigee position of the Moon (± 2.5 days from perigee), the earthquake energy per unit time in the period of syzygy relative to the period of quadratures comprised 267% for earthquakes of magnitude 7.9–8.3 and sharply increased to 982% for the strongest earthquakes of magnitude 8.4–8.9.

In general, the distribution of earthquakes shows an irregularity within each synodic (as well as the reduced anomalistic) month. Usually, two maxima and minima of seismic activity occur during a month which may be displayed on an earthquake distribution

[1] Hedervari (1964) discusses the distribution in time of strong earthquakes for separate regions of the Earth. Relationships among different geophysical parameters are examined.

TABLE I

DISTRIBUTION OF STRONG EARTHQUAKES (M = 7.9–8.7) DURING THE SYNODIC MONTH FROM 1903 TO 1956 OCCURRING NEAR PERIGEE (±2.5 DAYS)

Number of the earthquakes during—								Earthquake energy $E(\times 10^{23}$ ergs) during—							Percent earthquake energy per unit time	
Magnitude M	New moon	First quarter	Full moon	Last quarter	Quadratures	Syzygy	Total	New moon	First quarter	Full moon	Last quarter	Quadrature	Syzygy	Total	Quadratures	Syzygy
8.7	—	—	1	—	—	1	1	—	—	70.8	—	—	70.8	70.8		
8.6	—	—	1	—	—	1	1	—	—	50.1	—	—	50.1	50.1	100	982
8.4	3	1	2	—	1	5	6	75.4	25.1	50.2	—	25.1	125.6	150.7		
8.3	2	1	3	—	1	5	6	35.6	17.8	53.4	—	17.8	89.0	106.8		
8.1	—	1	2	2	3	2	5	—	8.9	17.8	17.8	26.7	17.8	44.5	100	267
7.9	5	1	3	1	2	8	10	22.5	4.5	13.5	4.5	9.0	36.0	45.0		
Total	10	4	12	3	7	22	29	133.5	56.3	255.8	22.3	78.6	389.3	467.9	100	495

diagram. This displacement is quite regular and systematic.

This relationship may be shown on a synoptic diagram. In one such diagram (Fig. 1) two groups of earthquakes are distinguished, one of magnitude 7.9–8.3 and one of magnitude 8.4–8.9. The lower magnitude group of earthquakes tends to concentrate into separate belts. These belts are drawn parallel from the lower left corner to the upper right corner.

The phase–perigee diagram may be represented as a spiral diagram. Each of these spiral diagrams consists of four spirals of two seismoactive belts (numbers 1 and 3) and two seismopassive belts (numbers 2 and 4).

For example, Fig. 2 illustrates a spiral diagram for the earthquakes of the Transcaucasus. Here, 1932 large earthquakes were registered during the years 1900–1950; they are rather distinctly distributed in the spiral diagram. Although, for major earthquakes the spiral pattern is not very distinct (Fig. 3), it can nevertheless be seen.

The relationships of earthquakes with tide-generating forces are shown not only in a secular sense (during the first half of the twentieth century) but also within yearly periods.[2] Thus, for example, the earthquake distribution of 1963 at syzygy and quadrature compares well with the analogous distribution of major earthquakes during the 1903–1956 period (Fig. 4). With increase of tide-generating forces during the syzygy period, the number of earthquakes sharply increases. In this period, 77% to 81% of all major earthquakes of 1963, as well as some of the strongest earthquakes of 1903–1956, occur. With decrease of the tide-generating force at quadrature, the number of earthquakes sharply decreases (19% to 23% of the earthquakes of 1963 and of 1903–1956).

With increase of the tide-generating forces in the syzygy period, the seismic energy released also sharply increases, reaching at near perigee 87% for the strong earthquakes of 1963, as well as for the strongest earthquakes of 1903–1956. With the reduction of the tide-generating forces at quadrature, the quantity of released energy sharply decreases, comprising only 13%. Thus, variations of tide-raising forces are closely connected with the intensity of earthquakes. At syzygy, the intensity of strong earthquakes increases six to seven times that at quadrature when tidal effects are minimal.

The increase of energy of earthquakes by hundreds of percent depending on the variation in magnitude of tide-generating forces clearly demonstrates the genetic

[2] The distribution of seismic activity also commonly shows a similar relationship.

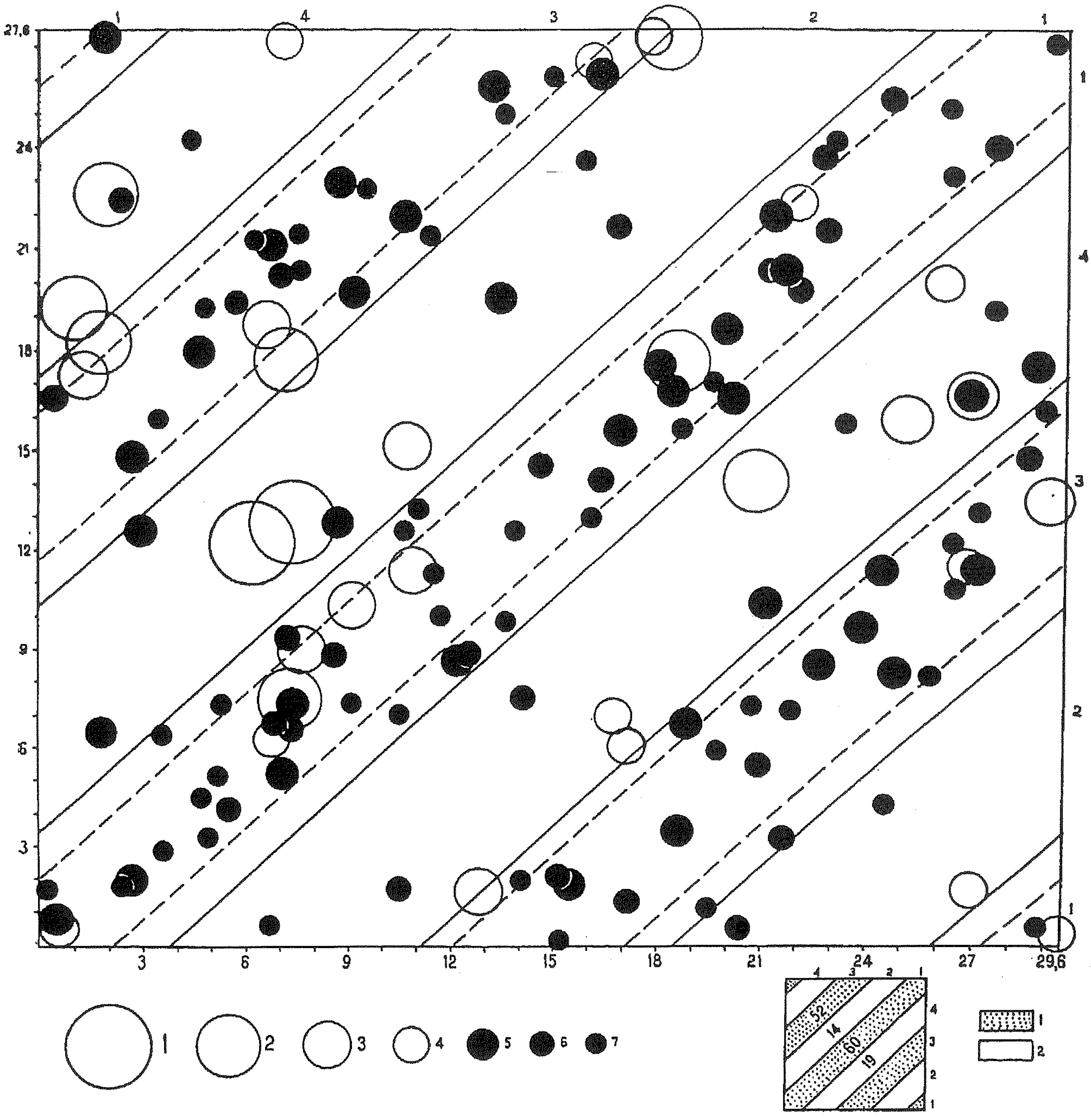

FIG. 1. Distribution of the strongest earthquakes of $M \geq 7.9$ during 1903–1956 depending on the average synodic and reduced anomalistic age. Days of the average synodic month are on the horizontal line. Days of the reduced anomalistic month are on the vertical line. Earthquake magnitudes are 1, 8.9; 2, 8.7; 3, 8.6; 4, 8.4; 5, 8.3; 6, 8.1; 7, 7.9. *Key to legend in lower right hand corner:* 1, seismically active zone; 2, seismically passive zone. Figures indicate the number of earthquakes occurring within each zone. On the borders of the diagram the numbers of the belts corresponding to the corresponding spirals of the spiral diagram are shown.

association of seismic activity with such forces. In the past this relationship was sought for and disputed. Proponents conceded that if such a relationship existed, it would be generated by variations of seismic activity within values of only 5% to 15%. We show this relationship does exist and the chance of seismic activity, which depends on the variation of the tide-generating force, will vary many hundreds of percent.

The influence of tidal forces on earthquakes depends to a certain extent on how

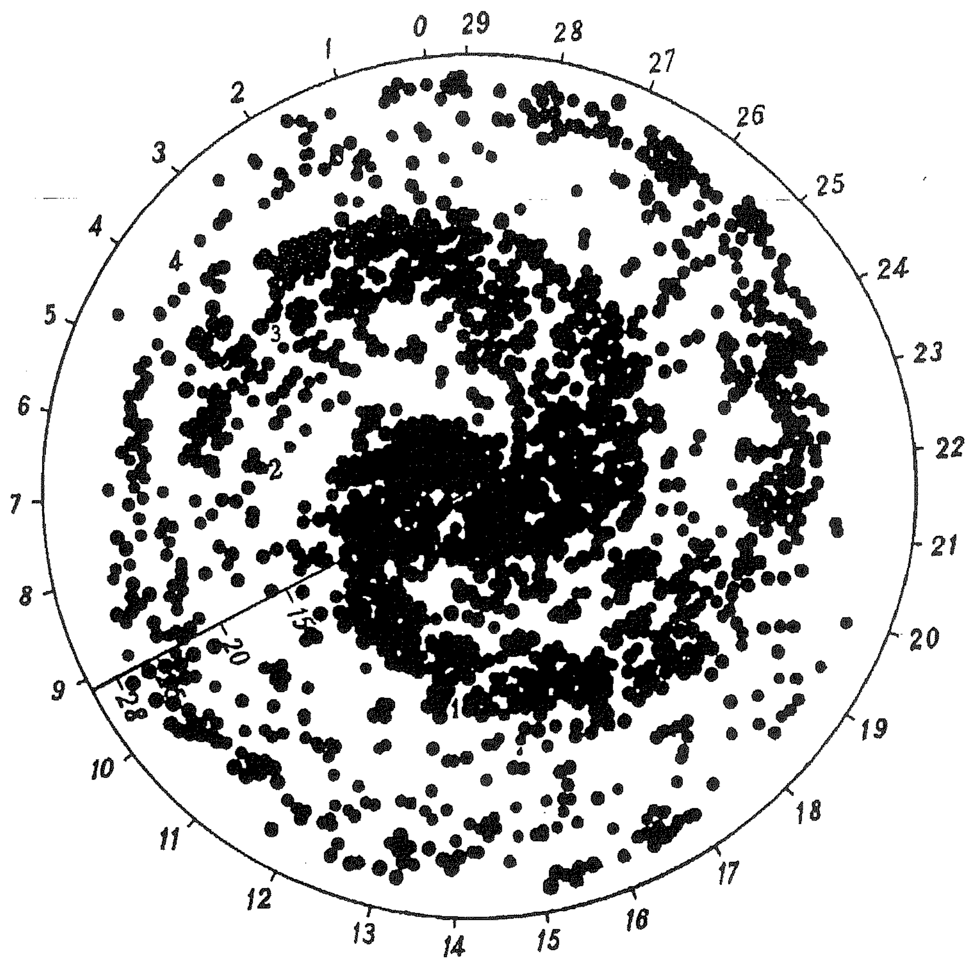

FIG. 2. Spiral diagram of the change in seismic activity in the period 1900–1950 in the Transcaucasus area. The circles indicate the observed earthquakes detected by macroseismic techniques. Dates of the average synodic month are indicated on the circumference. Dates of the reduced anomalistic month are indicated on the radius. The synodic and reduced anomalistic age of the earthquake define its position in the diagram.

close the Moon lies to the ecliptic plane (Fig. 5).

In general, the greatest major earthquake energy is released at low values of lunar declination at culmination (α). At a declination less than the value of the obliquity of the Earth's equator to the ecliptic, the quantity of the energy released is almost double (187%) that when the declination is greater than this obliquity (α greater than 23°27′). However, different regions of the Earth do not react similarly to the declination parameter. In America, especially in South America, the maximum quantity (82–93%) of the seismic energy of the twentieth century was released at small values in declination (α less than 23°27′); in Eurasia the maximum quantity of energy (65%) was also released at small values of α. However, the northwestern part of the Pacific Ocean behaves otherwise and even oppositely. Here, more seismic energy (56–59%) is released at α greater than 23°27′. In general, the northwestern part of the Pacific Ocean reacts exactly opposite to that of the southeastern part of the Pacific Ocean relative to the variations of tidal forces associated with changes of lunar declination at culmination.

The maximum energy of the strongest earthquakes (magnitude $\geq$ 8.4 and even magnitudes equal to 8.3) is released in all global regions predominantly at the northern (positive) declination of the Moon (α_1). During 1940–1964, 80–88% of the energy of highest magnitude earthquakes (M $\geq$ 8.3)

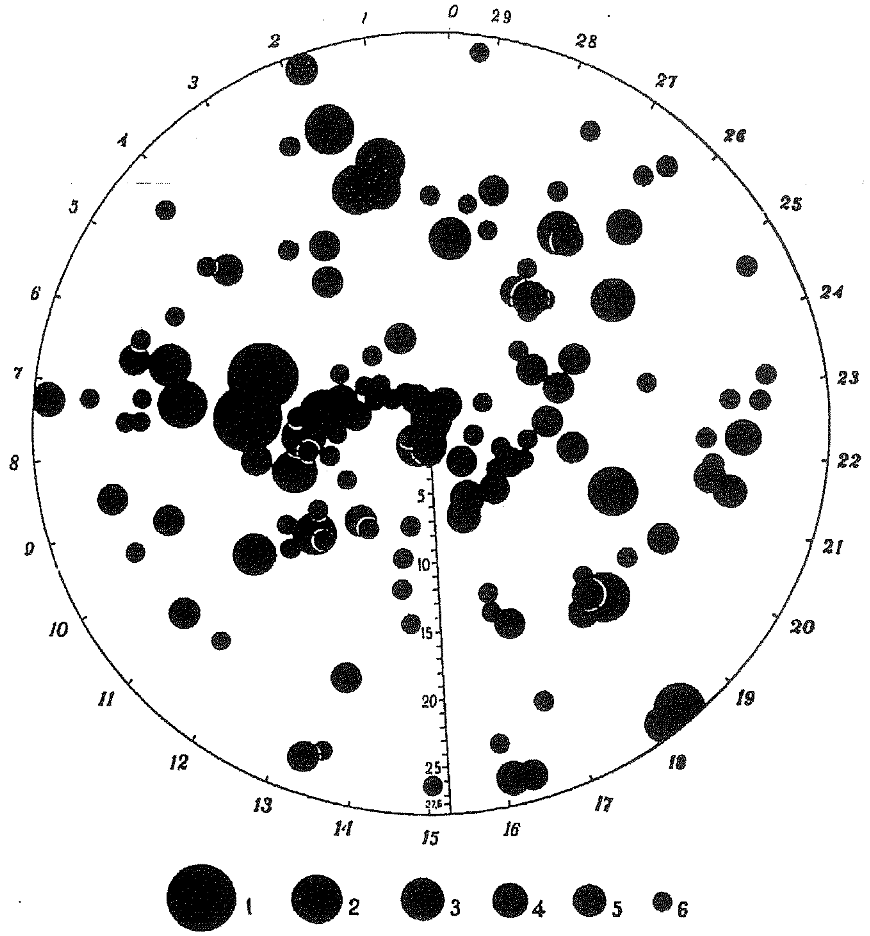

FIG. 3. Spiral diagram of the change of seismic activity depending on the change in tide-generating force during 1903–1956. Magnitudes are 1, 8.9; 2, 8.7; 3, 8.6; 4, 8.4; 5, 8.3; 6, 7.9–8.1.

was released during the period of northern declination. For earthquakes of magnitude 7.9–8.2 the release of seismic energy in general does not depend on the sign of the lunar declination and is approximately equal to the northern and southern declinations. On the whole, during 1940–1964, 73–76% of the energy of earthquakes of magnitude 7.9–8.9 was released during northern declination of the Moon. Thus, global regularities of the release of seismic energy of the highest magnitude (≥ 8.3) occur when the Moon is over the northern hemisphere of the Earth. This relationship is of major significance.

II. V NUMBERS AND THE STRONGEST EARTHQUAKES

Conditions controlling the change of the Earth's rotation change in a complex manner. As a first approach, these conditions may be characterized by the change of V numbers which represent the product of the difference of the coordinate (x) of the present day polar movement (expressed in milliseconds of arc for 1/10 of a year) to the difference of the observed Wolf numbers (for 1/10 of a year). V numbers are shown in Fig. 6C.

As is seen in Fig. 6C, V numbers change rather erratically. These numbers attain maximum values in the following epochs within the period 1930 to 1956:

Epoch	V number
1904.5–1911.5	2000–3500 and greater
1916.0–1923.0	2000–3500 and greater
1916.0–1923.0	2000–3500 and greater
1929.0–1930.5	1500–2500
1937.5–1942.0	2000 and greater
1946.0–1953.0	3000–4500 and greater

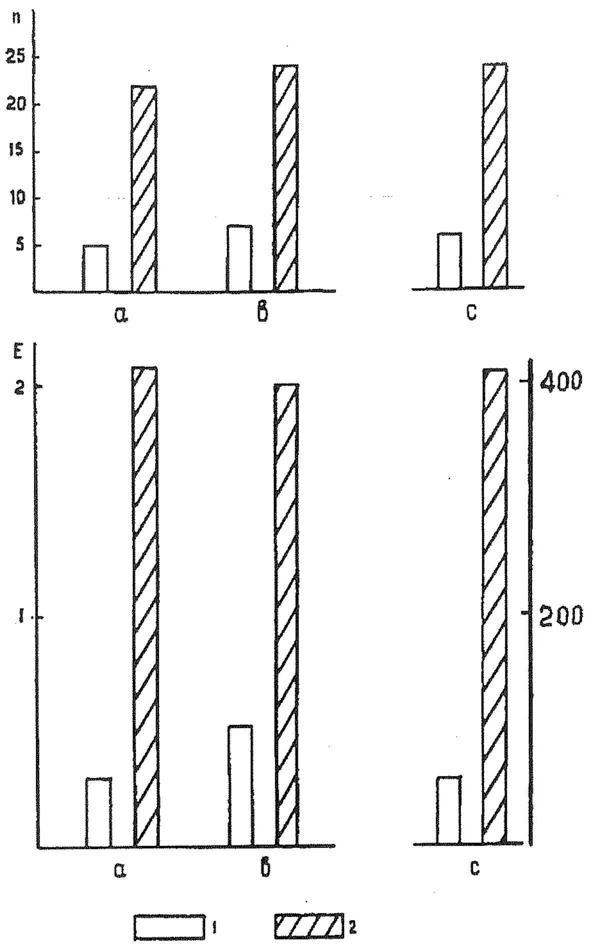

FIG. 4. Distribution by zones of syzygy and quadratures of strong and less strong earthquakes occurring near perigee or apogee of the lunar orbit: a and b, less strong earthquakes during 1963, $M \geq 6$; c, strong earthquakes during 1903–1956, $M \geq 7.9$; a and c, earthquakes occurring near perigee during 24.6-3 days of the reduced anomalistic month; b, earthquakes occuring near apogee during 10.8–16.8 days of the reduced anomalistic month. 1, Earthquakes of the zone of quadrature; 2, earthquakes of the zone of syzygy; n, number of earthquakes; E, earthquake energy in 10^{23} ergs.

The duration of these active epochs constitutes 27 years, i.e., half the time interval of 54 years under consideration (1903–1956). The remaining 27 years correspond in general to the passive epochs of Earth history.

The reality of the active and passive epochs are extremely significant in understanding the release of seismic energy from the Earth. Data recorded within this time period of 1903–1956 show that 32 of the strongest earthquakes occurred with magnitude equal to or greater than 8.4. Of these, 27 earthquakes (84%) occurred during the active epochs and only five earthquakes (16%) took place during the passive epochs i.e., at low V numbers. Within the period of the active epochs the seismic energy released by the strongest earthquakes under consideration ($M \geq 8.4$) constitutes 81% (134×10^{24} ergs). Within the passive epochs the seismic energy released is only 19% (31×10^{24} ergs).

Earthquakes of lower magnitude of 7.9–8.3 and even 7.0–7.7 are almost independent in general relative to variations of V numbers. However, since the bulk of seismic energy is released during the strongest earthquakes it follows that the seismic activity of the Earth is in general closely connected with V numbers.

The strongest earthquakes of magnitude ≥ 8.4 in the first half of the twentieth century are defined by two active (1904.5–1923.0 and 1937.5–1953.0) phases and one passive (1923.0–1937.5) seismic phase. These are closely related to three stages of variations of V numbers, i.e., the minimum V numbers correspond to periods of seismic quiescence.

Of the 32 strongest earthquakes of magnitude ≥ 8.4, 28 correspond to the two active phases and only four correspond to the passive phase. The frequency of earthquakes in the active phase is 2.5–3.5 times greater than in the passive phase (Fig. 7). The released energy in the active phase (33.1×10^{23} and 48.5×10^{23} ergs/year) is two to three times greater than for the passive phase (16.6×10^{23} ergs/year).

Intermediate earthquakes also disclose a relationship with V numbers, particularly for the range of magnitudes 7.9–8.9. Of 24 intermediate earthquakes of magnitude ≥ 7.9, 23 earthquakes occurred during the active phase and only one of them took place in the passive phase.

Normal earthquakes reveal the association with V numbers primarily for the most intensive earthquakes of magnitude 8.4–8.9. Earthquakes of lesser magnitude (≤ 8.3) are equally abundant in the active and passive phases within the continents of the eastern hemisphere (15×10^{23} ergs/year)

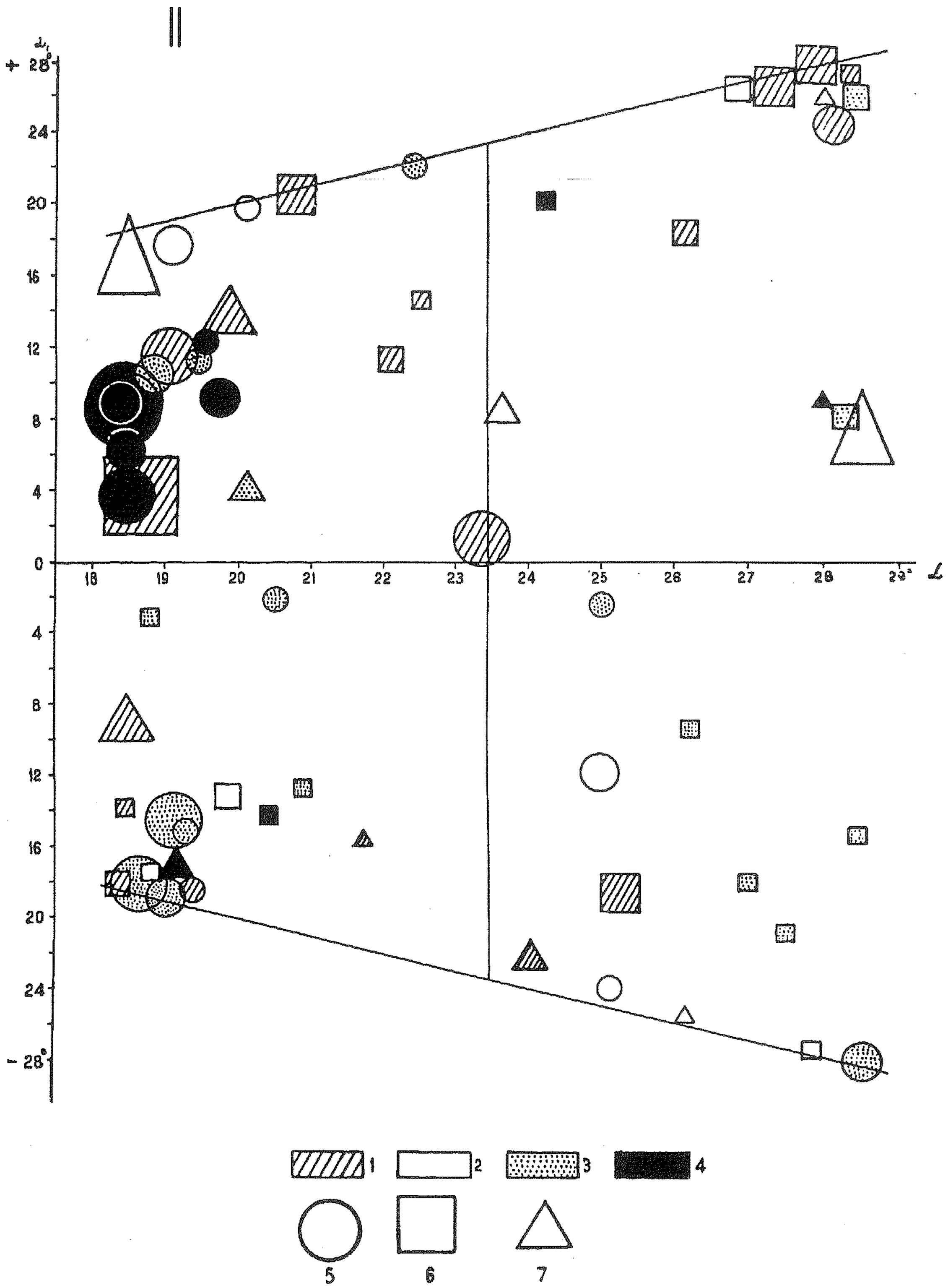

FIG. 5. Distribution of strong earthquakes in the period 1940–1964 relative to the value of the lunar declination at the time of the earthquake (α_1) and at culminations (α). Epicenters are located: 1, to the north of Lat. 29°N; 2, between Lat. 29°N and the equator; 3, between the equator and Lat. 29°S; 4, to the south Lat. 29°S; 5, America; 6, western Pacific; 7, Eurasia and oceans exclusive of the Pacific Ocean. The size of the symbols corresponds to earthquake magnitude, the largest size to 8.7–8.9, intermediate size 8.4–8.6, small size 8.1–8.3, and smallest size to 7.9–8.0.

but are somewhat different in distribution for the Americas, where the energy released during the active phase was 1.5 times greater (6.7×10^{23} ergs/year) than in the passive phase (4×10^{23} ergs/year). Thus, the western hemisphere reacts to the change of *V* numbers not only with regard to earthquakes of magnitude 8.4–8.9 but, in contrast to the eastern hemisphere, also with earthquakes of magnitude 8.0–8.3, possibly indicating a greater dynamic sensitivity to the triggering of earthquakes in the western hemisphere.

In the seismically passive period from 1923.0–1937.5 the length of the year has been shortened. In the seismically active period of 1904.5–1923.0, characterized by a maximum of seismic energy release, the length of the year has been increased.

The strongest earthquakes of each seismic phase fall into two ranges within which the released energy decreases with the decrease of magnitude. The lower range of magnitude 7.9–8.3 is not a continuation of the upper range of magnitude 8.4–8.9 but overlaps the lower values. The upper range of earthquakes of the Earth's crust, as well as of the mantle, is most closely related to the *V* numbers. In the lower range this relationship only applies to earthquakes of the mantle and is almost unrelated to earthquakes of the crust or the base of the crust.

III. Structural Levels in the Process of Intensification, Attenuation, and Migration of Seismic Activity in the Earth

Let us examine the intradiurnal distribution of the strongest earthquakes as a function of Greenwich time (Fig. 8). The diagram shows a distinct regularity in this distribution: two maxima and two minima. Seismic maxima correspond to the interval 0–6 o'clock and other 14–20 o'clock. The energy release for these 12 hours corresponds to 147×10^{23} ergs/hr, whereas during the remaining 12 hours it is about 83×10^{23} ergs/hr. During the 6 hours of maximum seismic activity, from 0–3 o'clock and from 15–18 o'clock the average amount of seismic energy released (174×10^{23} ergs/hr) exceeds the average quantity of seismic energy released during the 4 hours of the minimum seismic activity from 7 to 11 o'clock (40×10^{23} ergs/hr) by a factor of 4.

Figure 8, showing the distribution as a function of time of the strongest earthquakes, may be split into its component parts. First, we may note earthquakes according to regional provinces. Then, we may separate normal shallow earthquakes associated with the Earth's crust and its base from earthquakes with their foci in the mantle. As is shown in Fig. 9, processing the data in this way does not lead to a loss of the regularities shown by the intradiurnal distribution of earthquakes but, on the contrary, permits an even more distinct analysis of the data and a disclosure of new features.

We note seismic levels of activity and seismic events in these levels at different times within specific geographical provinces. The maxima and minima of seismic energy release in the Earth's crust and the upper parts of the mantle usually do not coincide in time. This activity shifts from one place to another in each major seismic province of the planet.

In the western Pacific region the maxima of seismic energy release in the Earth's crust and the base of the crust correspond to the minima of the seismic energy release of the mantle. Mainly from 15 to 21 o'clock and less so from 1 to 6 o'clock, these maxima correspond to 80% (873×10^{23} ergs) of the total energy of the normal earthquakes of the region and at the same time only 18% of the earthquake energy with foci in the mantle. In this area the maximum seismic energy released for one given event corresponds to 51% (555×10^{23} ergs) of the earthquake energy in the Earth's crust and only 4% (18×10^{23} ergs) of the maximum of a single earthquake event in the mantle.

Maxima of the seismic activity of the mantle in this area occur in 5 hours within the following hours (6–7, 11–12, 13–15, and 21–22 o'clock). Within these times 73% (325×10^{23} ergs) of the total seismic energy of the mantle has been released. During the same 5 hours, less than 9% (93×10^{23} ergs) of the normal earthquake energy of the

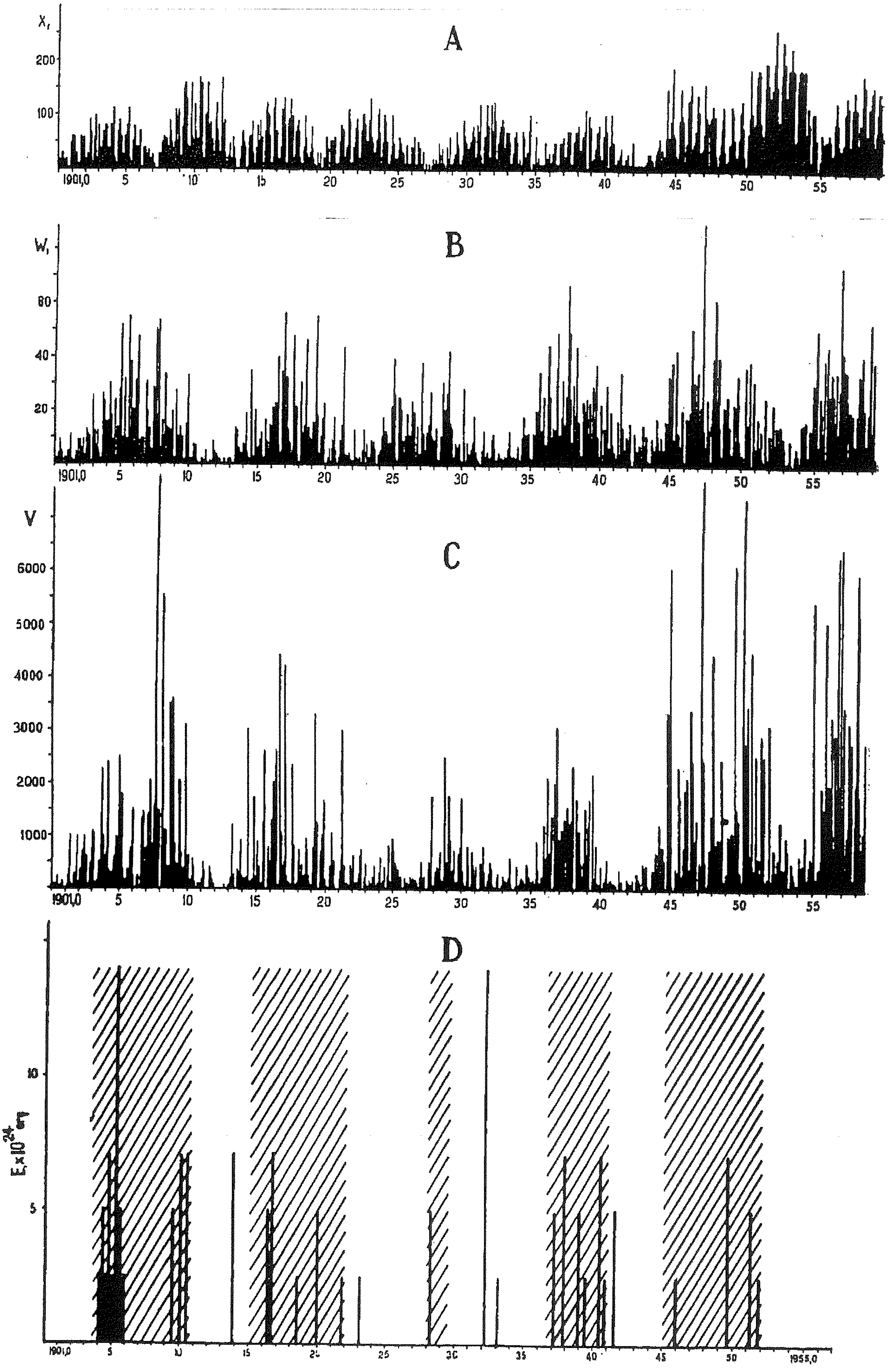

Fig. 6. Change of difference of coordinates of the present pole of the Earth's rotation to difference of Wolf numbers of solar activity, V numbers, and strong earthquake distribution: (A) Change of the absolute

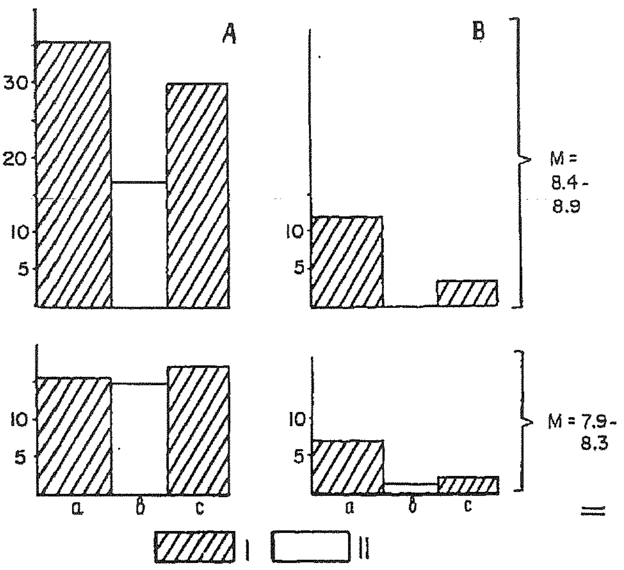

FIG. 7. The distribution of energy of all the strongest shallow (A) and intermediate (B) earthquakes of $M \geq 7.9$ in phases distinguished on the basic of V numbers from 1904.5 to 1953.5. Phases where I is active and II is passive: a, first active phase 1904.5–1923.0; b, passive phase 1923.0–1937.5; c, second active phase 1937.5–1953.0. Normal or shallow earthquakes show a distinct connection with V numbers for $M \geq 8.4$ and intermediate earthquakes for all magnitudes of 7.9–8.9. E is energy in 10^{23} ergs/year.

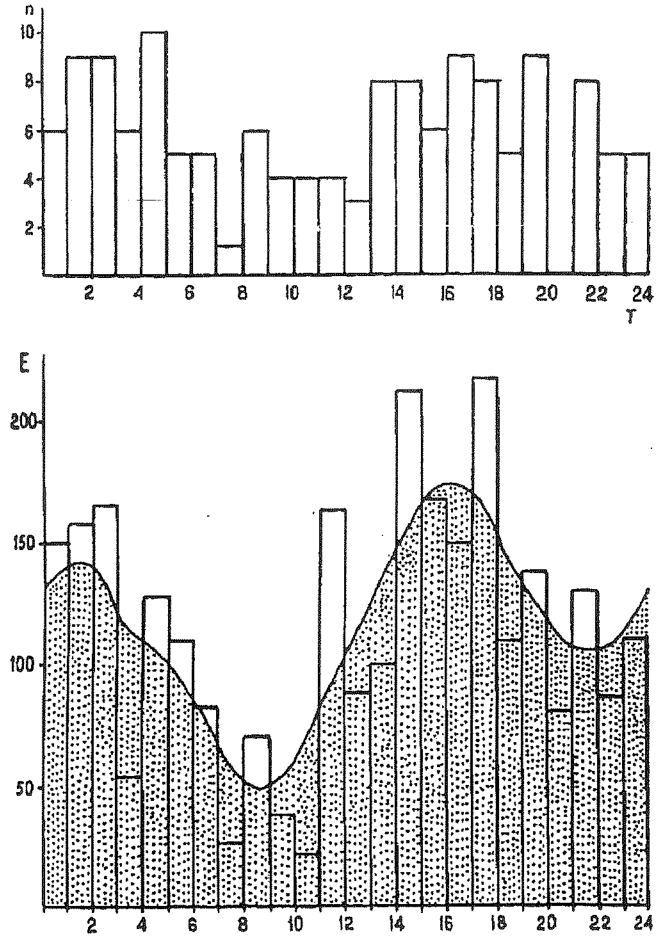

FIG. 8. The intradiurnal distribution of all the strongest earthquakes as a function of time (Greenwich) from 1903 to 1956: n, number of earthquakes; E, energy of earthquakes in 10^{23} ergs; the curved line shows the change of the value under consideration averaged over a cumulative 3-hour period.

crust in the western Pacific region has been released. The contrast is striking.

In western America from 1 to 6 o'clock and 15 to 21 o'clock, 64% (325×10^{23} ergs) of the crustal earthquake activity and, at the same time, 40% (18×10^{23} ergs) of the mantle earthquake energy has been released. Within the 5-hour time period mentioned above, about 40% (18×10^{23} ergs) of the earthquake energy in the mantle for South America and at the same time only 10% (49×10^{23} ergs) of crustal earthquake energy has been released, the latter all within Central America.

Tectonic levels of seismic activity are also demonstrated in the continental Eurasian area. Here almost all seismic activity is related to the crust of the Earth. Within the maxima energy release from 11 to 15 o'clock and from 21 to 3 o'clock, earthquake foci in the mantle were practically inactive. Only one mantle earthquake occurred, of magnitude 8.1. During the minima of seismic activity of the Earth's crust and

values (x) of the difference of coordinate "x" of the movement of the immediate pole relative to its average position estimated by data given by the International Latitude Service expressed in milliseconds of arc for each one-tenth of a year. (B) Change of solar activity. The absolute value of the monthly difference in Wolf numbers is shown as W. (C) Change of V numbers, i.e., the product of the absolute values of the difference of coordinates of the movement of the immediate pole and the difference of the observed Wolf numbers per one-tenth of a year. (D) The distribution of energy of the strongest earthquakes of $M \geq 8.4$ during 1903–1956. Shading shows time intervals of the maximum V numbers symbolizing the most active periods.

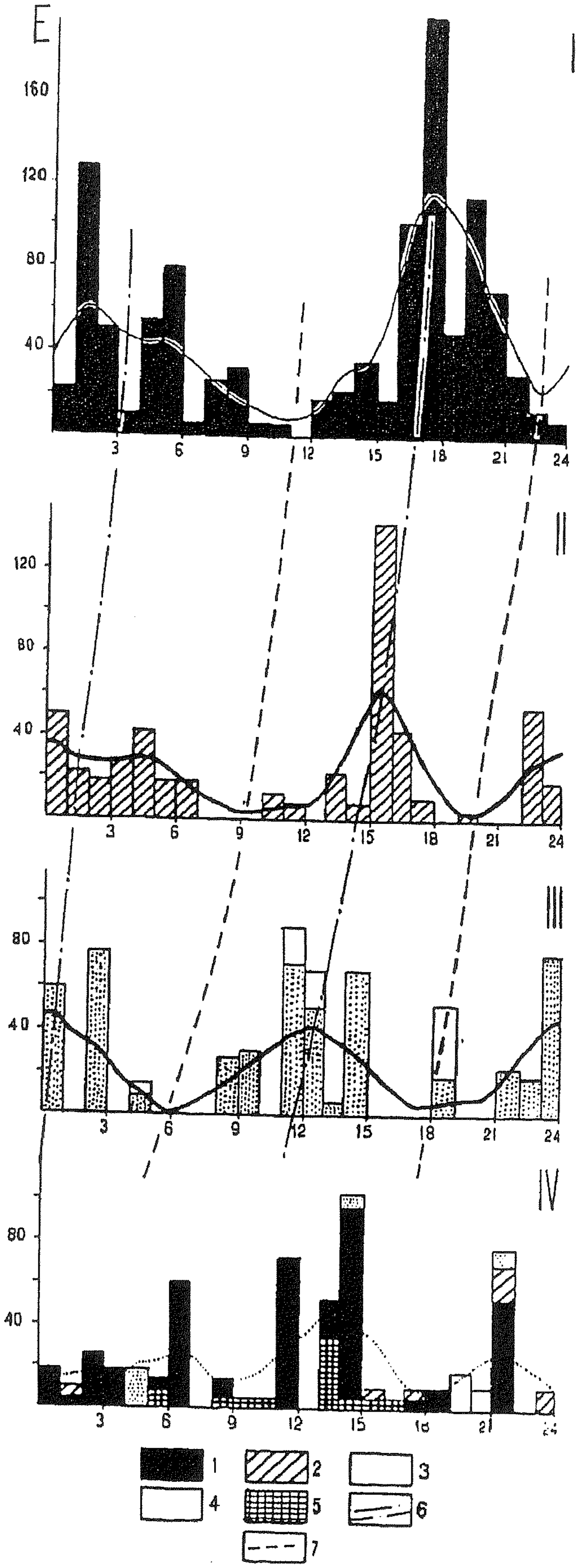

FIG. 9. The intradiurnal distribution by Greenwich time of the energy of strong earthquakes of $M \geq 7.9$ of specific regions of the world from 1903 to 1956. Earthquakes with foci in the Earth's crust and its base (normal earthquakes): I, western Pacific; II, western American; III, Eurasian; IV, earthquakes with foci in the upper parts of the mantle (intermediate earthquakes). 1, western Pacific; 2, western American; 3, Eurasian; 4, foci of the Indian and Atlantic Oceans; 5, deep-focused earthquakes; 6, maxima of seismic activity; 7, minima of seismic activity.

its base, on the other hand, earthquake foci in the mantle were active and within this time period 85% of the total earthquake energy of the region was evolved.

The occurrence at different times of the intensification and diminution of seismic activity in similar structural levels on the borders of the Pacific Ocean (the western Pacific and western America), on one hand, and in the immense mainland Eurasian region on the other, is marked (Fig. 9). The maximum energy release in the Earth's crust and its base in the Pacific region corresponds to the minimum in the Eurasian region and vice versa. In the Pacific seismic ring, the maximum seismic energy release occurs, in general, during the evening from 15 to 21 o'clock, whereas in Eurasia at this time a minimum is recorded. The minimum release of energy in the Pacific from 7 to 15 o'clock corresponds to the significant maximum of the seismic energy release in Eurasia (Fig. 9). In general, crustal earthquakes of Eurasia are essentially distributed differently than those of the Pacific.

Also, in general the Pacific ring of seismic activity differs in that it is fairly uniform relative to Eurasia. Within 11 hours (1–6 and 15–21 o'clock) 75% (1198×10^{23} ergs) of the total energy of crustal earthquakes of the Pacific ring was released. Within the remaining 13 hours, only 25% of the energy was released. The borders of the Pacific Ocean, however, differ somewhat from each other. This difference lies in the fact that in the western Pacific region, the main maximum occurs during evening, whereas in the western American region it occurs later during the night by Greenwich time.

In the mantle seismic energy release also takes place at different times in different regions. Because of the distinctly dominant contribution of released energy of the mantle as a function of time in the western Pacific region (81%) and only a negligible contribution for the remaining two regions, the picture of the release of seismic energy at different times in the mantle is not as clearly revealed for the other two regions because of insufficient statistical data. In spite of this, within the main maximum time of release of mantle energy in the western Pacific region from 11 to 15 o'clock, almost no earthquakes with foci in the mantle in the other two regions occurred. The few earthquakes in Eurasia tended to take place mostly during the second half of the day.

An approximate simultaneity of the intensification and diminution of seismic activity exists in different structural levels of the Earth's crust and mantle in the large mainland Eurasian region and the borders of the Pacific Ocean. The simultaneous release of maximum seismic energy of the mantle of the western Pacific region with the maximum seismic energy release of the Earth's crust and its base in Eurasia from 11 to 15 o'clock Greenwich time is noteworthly (Fig. 9, III and IV).

A gradual intradiurnal migration of seismic energy release in the Earth from east to west of the seismic maxima of the Earth's crust and its base is observed. The maximum seismic energy release begins earlier in Eurasia (11–15 o'clock) and somewhat later in western America (13–18 o'clock) and later yet in the western Pacific (15–21 o'clock). The second maximum of seismic energy release also shifts and extends within a day toward the west; from around midnight in Eurasia (21–3 o'clock) to around midnight to after midnight in western America (22–5 o'clock), and from past midnight to early morning in the western Pacific region (1–6 o'clock). This trend of migration of maxima and minima seismic energy is shown in Fig. 9 by dotted lines.

We also note the intradiurnal shifting of the seismic energy envelope in the western Pacific region from the mantle to the Earth's crust. In this seismic region of the Earth (Fig. 9), the main pulse of the maximum of seismic energy release begins in the mantle (11–15 o'clock) and then rises higher, reaching the Earth's crust and its base from 16–21 o'clock.

IV. Some Peculiarities of the Distribution of Seismic Activity in the Fixed Position of the Earth's Orbit

Features of the intradiurnal distribution of seismic energy are closely connected and coordinated with each other. In addition to regularities predominantly characterizing the distribution of seismic activity with time, there also exist somewhat obscure regularities in the distribution of seismic activity with respect to the axes of the Earth's deformation. The most important of these regularities are the following:

(1) The strongest earthquakes of the Earth's crust and its base tend to become more frequent and intensified under conditions of maximum contrast of vertical relief of fundamental tectono-morphological elements of the Earth's crust and of the tidal spheroid. The most highly elevated portions of the Earth's surface, i.e., the largest mainland regions, intensify their seismic activity when coincident with the lowest ebbtides on the tidal spheroid and diminish their seismic activity during coincidence of the highland areas and the maximum tide of the Earth's spheroid.

(A). The strongest earthquakes of the largest mainland region, Eurasia, occur chiefly under conditions of ebbtide on the tidal spheroid. Being 1 hour late, they correspond to 16–22 and 4–10 o'clock by local solar time. Within these 12 hours, 86% of the energy of the strongest earthquakes with foci in the Earth's crust and its base and up to 80% of the energy of all the strongest earthquakes of the Earth's crust and of the mantle are released.

(B). The strongest earthquakes of the Pacific seismic ring are related to the borders of the ocean with its generally negative geomorphological form. These earthquakes chiefly occur under conditions of high tide of the spheroid. Being 1 hour late, they correspond to 10–16 and 22–4 o'clock by local solar time. Within these 12 hours 62% of all the energy of the strongest earthquakes

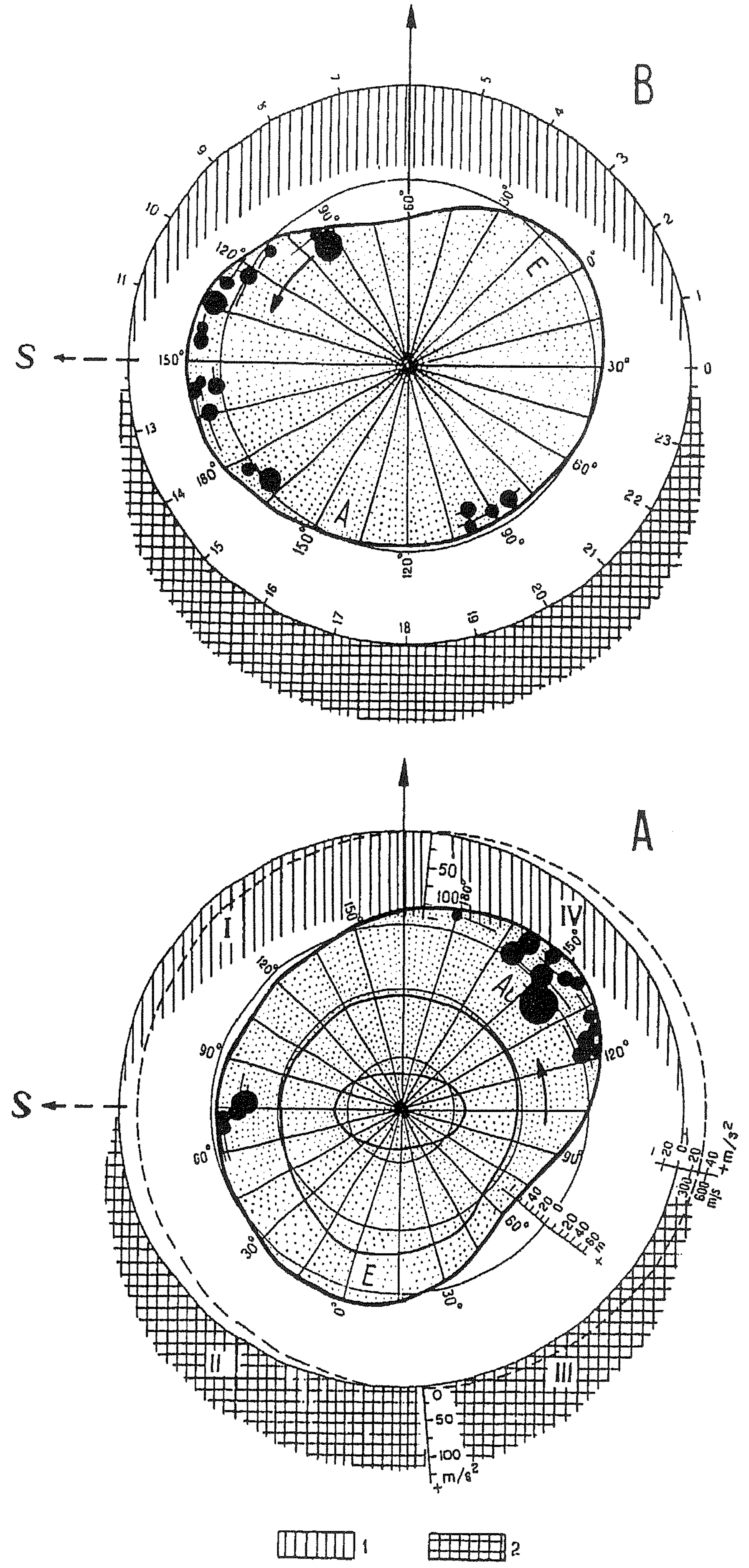

FIG. 10. The strongest earthquakes and the position of the Earth in the circumsolar orbit. Upward pointing arrows indicate the direction of the Earth's movement in its orbit. To the left is the direction of the Sun.

of the Earth's crust and its base in the Pacific ring have been released. However, the relationship of the tide-generating forces to seismicity of the Pacific ring is less clearly defined.

(2) The strongest earthquakes in the world are essentially dependent on the displacement of the fundamental harmonics of the geoid by the movement of the Earth in circumsolar space (Fig. 10).

Analysis of the data of observations of Kaula (1964) of artificial satellites showed the presence of two maxima of the height of the geoid. One of them, the Australian, is the most clearly shown with maximum vertical displacement of the geoid surface up to 52 meters. This maximum is situated to the northeast of Australia with the crest approximately near longitude 150°E. The other maximum, the European–South Atlantic region, is less well developed with maximum heights of the geoid up to 35–36 meters, and this is located near the Greenwich meridian. The crest of the European section of this maximum is located approximately 10°E from the Greenwich meridian. The best developed Australian maximum at 88°E is, however, less extensive, encompassing only the Western Pacific region. The less well developed European–South Atlantic maximum of the geoid amplitude is more extensive, stretching along the meridian of the geoid at 160° and encompassing the seismically active areas of Europe, Western Africa, and Southwestern Asia, etc.

At different latitudes the latitudinal sections of the geoid have characteristic profiles. At the equator the Australian maximum is distinctly shown, whereas near latitude 50°N the best developed is, on the contrary the Eurasian maximum (Fig. 10). An essential fact is that the crests of the geoid displacements are not strictly antipodal, but are situated about 140–150° from each other on one side of the Earth and 210–220° on the opposite side.

From this point on we wish to compare the relationship of discrete regions of the Earth with the various and almost invariable spatial fields of the planet to its orbit in circumsolar space. We shall define four quadrants in the plane of the ecliptic along the orbit of the Earth. The first and second quadrant are turned to the Sun and the third and fourth are in the opposite direction. The first and fourth quadrants are on the leading or stoss side of the Earth in its movement along the ecliptic and the second and third quadrants are on the lee side of it (Fig. 10A).

(A). The strongest earthquakes of the Earth's crust and its base in the Pacific ring are more frequent and intensified when the crests of the geoid pass through the regions of increased negative values of acceleration of the Earth's surface points in their movement in circumsolar space.

As soon as the Australian geoid maximum enters the fourth quadrant with its increasing negative values of acceleration, the strongest earthquakes of the Pacific ring become more frequent and intensive and within 2 or 3 hours a series of similar earthquakes take place. When the European-Southern Atlantic maximum of geoid displacement enters this fourth quadrant, again an increase of seismic activity takes place and soon a second series of earthquakes ensues.

These two phases of seismic activity are connected to the entry of crests of the geoid into the regions of increasing negative

The Earth is shown in its equatorial section as the geoid with some meridians marked. The section of the geoid near Lat. 50°N is also shown by the inner curved line. Here, the horizontal scale is 1/25 000 that of the elevation, which is actually 1/300 000 000. The geoid heights are given according to Kaula (1965). The acceleration of equatorial points during the Earth's movement in the circumsolar space is in m/sec². Outer scale: 1, negative; 2, positive. The change of the velocity of near equatorial points in circumsolar space is shown by the dotted line in m/sec. The scale is given in a radial position in the drawing. *The Earth's position by Greenwich time:* A, at 17 o'clock; B, at 2 o'clock. Black circles indicate that earthquakes occurred ±1 hour by the Earth being in a position A or B. Centers of these circles indicate the position of the foci of the earthquake at the moment of A or B. The beginning of the arc directed to the center of the circle indicates the time of the earthquake by local time. The maxima of geoid height: E, European–southern Atlantic; Au, Australian.

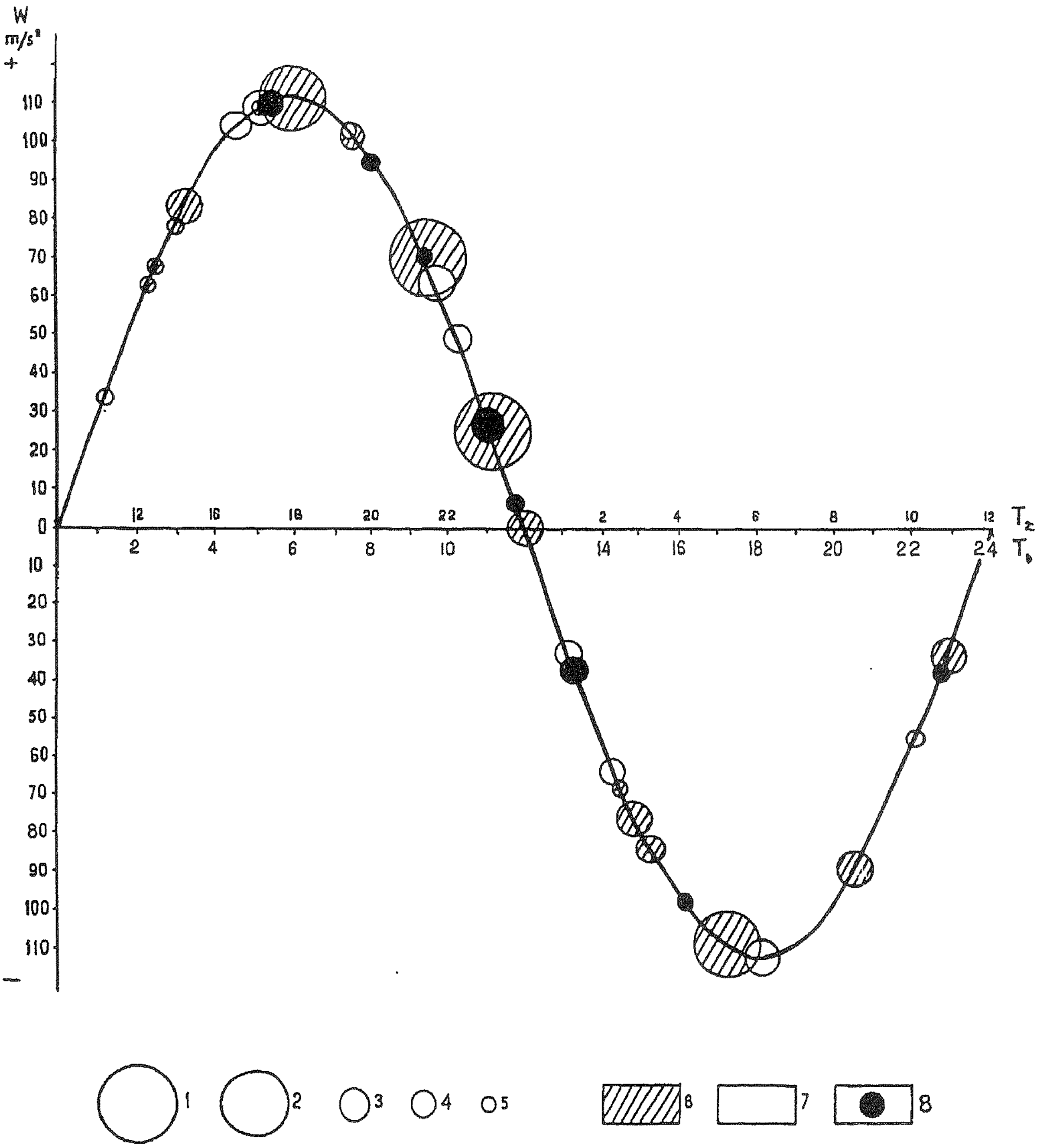

FIG. 11. The distribution of the strongest intermediate and deep-focused earthquakes during 1903–1956 on the curve of the change of acceleration of the equatorial points of the Earth in circumsolar space. Horizontal lines show the average solar time reckoned from midday, T_{-}, and the local time reckoned from midnight, T_2 (upper scale). Vertical lines show acceleration W in m/sec². Magnitudes of the earthquakes are as follows: 1, 8.7; 2, 8.6; 3, 8.4 and 8.3; 4, 8.1; 5, 7.9. Intermediate earthquakes: 6, western Pacific region: 7, other regions; 8, deep-focused earthquakes, all of the Pacific region.

values of acceleration and, during 14–21 and 1–6 o'clock Greenwich time, comprise 77% (1238×10^{23} ergs) of all the seismic energy of the Earth's crust and its base in the Pacific ring in 54 years of observation. On the other hand, for the remaining 12 hours of the same 54 years the frequency is only 23% (3.3 times less). When the European–south Atlantic maximum of geoid displacement enters the fourth quadrant, 65% of seismic energy is released (330×10^{23} ergs). The seismic activity is, as compared with the other half of the day, increased by a factor of 2. When the Australian

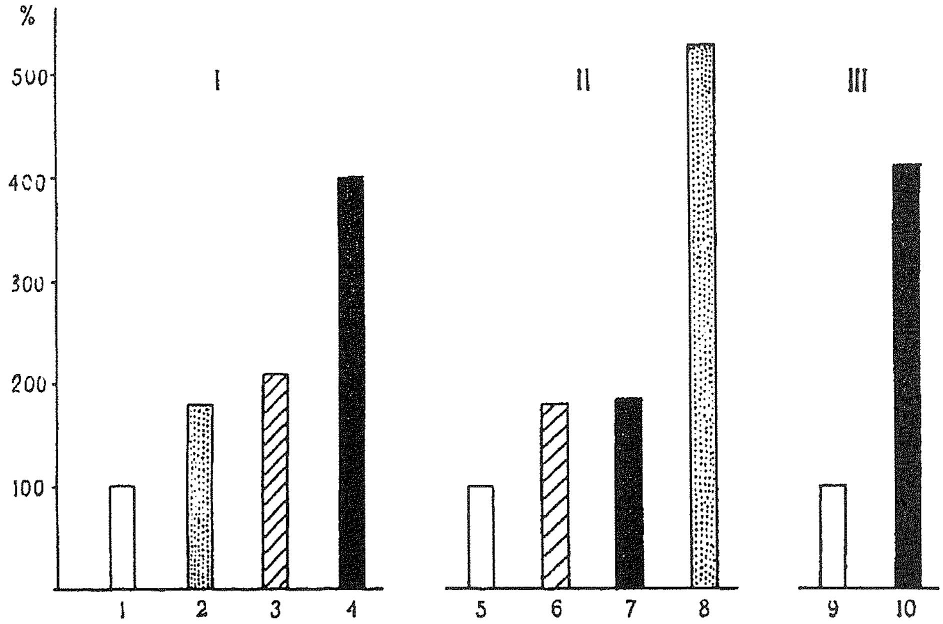

FIG. 12. The change of energy of the strongest ($M \geq 7.9$) intermediate and deep-focused earthquakes of the world, 1903–1956, as a function of the passage of the geoid crest through the third quadrant. The planet's sector in the plane of its orbit with the reduction of the positive values of acceleration of the equatorial points on the Earth at its movement in circumsolar space is pronounced. I: 1 the hourly seismic energy release during 0–17 o'clock local time taken as 100%. The seismic energy release during each hour within 17–24 o'clock local time, i.e., approximately within the third quadrant, in the regions: 2, Eurasian; 3, western American; 4, western Pacific. II: the hourly seismic energy release at the European–southern Atlantic maximum of the geoid height in the interval 18–22 o'clock Greenwich time, i.e., approximately at the passage through the third quadrant, in the regions: 6, western American; 7, western Pacific; 8, Eurasian. III: the hourly seismic energy release in the western Pacific region (10) at the Australian maximum of the geoid height in the interval 6–15 o'clock Greenwich time, approximately in the third quadrant; 5 and 9 indicate the quantity of energy taken at 100%, released hourly in the interval of 15–18 and 22–6 o'clock Greenwich time.

maximum of geoid displacement enters the fourth quadrant, 83% (909×10^{23} ergs) of energy is released and it follows that the seismic activity relative to the other half of the day increases almost 5 times.

Since the entry of the zone of maximum geoid deformation into the region of increasing negative values of acceleration takes place at the same time as the maximum of the tidal bulge (Fig. 10), it would appear that seismic activity is connected only with tidal stresses. But in this case the picture would be repeated in 12 hours. However, this does not take place and one phase follows another in 14–15 hours and the last series of events follow the first in 9–10 hours (Fig. 8). In these time intervals both positive crests of the geoid follow each other.

All of this indicates that the seismic activity of the Earth's crust and its base, within the limits of the Pacific zone, depend on the reciprocal situation of the maximum of geoid deformation and of the increasing negative values of acceleration of near-surface points of the Earth in their movements in circumsolar space. Tidal stresses complicate this picture.

The distribution of the height of the geoid, as is known, is not connected with the main elements of the Earth's surface (mainland and oceans). Maxima and minima of the height of the geoid occur on the oceanic as well as on the continental regions and, therefore, the geoid heights are associated with deeper layering of the mantle, creating dissimilarities of the gravitational field.

The intensity of seismic activity of the Earth's crust and its base is associated with the entry of geoid crests into the region of increasing negative values of acceleration only for the Pacific ring and mainly for its northwestern border. Hence, maximum tectonic stresses of the Earth are presently tied to these borders and the most significant of them, the northwestern, is a zone of deepest penetration into the Earth, possibly because it is weakest there. In this region more than anywhere on the Earth, the seismicity of the Earth's crust and its base is associated with processes taking place deep in the mantle and at the same time associated with the movement of the Earth in circumsolar space. The seismicity of the Earth's crust and its base in other areas does not disclose this association. For example, the strongest earthquakes of magnitude ≥ 7.9 for Eurasia appear to be subordinate to the other causes of seismic activity and, as we have seen, this appears to be the case. The seismicity of Eurasia is associated most strongly with tidal forces.

(B). The strongest earthquakes of the mantle in the Pacific ring, chiefly the western Pacific region, are more frequent and intensified by passage of the positive waves of geoid through the region of general decrease of acceleration of that portion of the mantle in its movement through circumsolar space, these being in areas of decreasing positive and increasing negative values of acceleration.

The seismicity of the mantle increases in the third quadrant, where a decrease of the positive values of acceleration of the movement of the Earth in circumsolar space takes place from 18 to 24 o'clock local time. Seismicity of the mantle also increases partly in the fourth quadrant with a further decrease of acceleration of the mantle in the fourth quadrant taking place by virtue of increase of its negative value. This relationship is clearly seen in Fig. 11, from which it follows that the greatest seismic activity occurs on the descending line of the acceleration change curve. Maximum seismic activity occurs, firstly, at the extreme values of the acceleration change curve and, secondly, to the descending line of the acceleration change curve. In the first case in the short time intervals of 6 ± 1 o'clock and at 18 ± 1 o'clock local time, the release of seismic energy during 1903–1956 was 38.4×10^{23} ergs/hr; and for the second case in the interval of 19–5 o'clock the release of seismic energy was 30×10^{23} ergs/hr. The least amount of seismic activity occurs on the ascending line of the acceleration curve. In the interval 7–17 o'clock, only 9.7×10^{23} ergs/hr of energy were released.

All the strongest deep-foci earthquakes of the western Pacific region are timed to the acceleration change curve on its descending line and partly at its maximum, whereas on increase in acceleration almost no earthquakes occur. Only one deep-focus earthquake occurred in South America (Fig. 11).

In the interval between 17 and 24 o'clock local time the quantity of released energy from the mantle exceeded the released energy during other hours of the day: 1.8 times for Eurasia, 2.1 times for western America, and 4 times for the western Pacific region (Fig. 12-I).

The increase of seismic activity of the mantle at the end of the day by local time (17–24 o'clock) coincides with the tidal tidal bulge and, therefore, one is tempted to link it with tidal phenomena. But the daily tidal bulge (about 12 o'clock local time) is not in any was accompanied by similar increase of the seismic activity of the mantle. The phenomena is therefore not related to tides.

Thus, any large seismically sensitive region of the mantle tends to become more active in passing through quadrant three, irrespective of whether or not the crest of the geoid is situated in this quadrant (Fig. 12, II, III).

In the passage of the European–South Atlantic portion of the geoid through quadrant three, the seismic activity of the mantle increases approximately 1.8 times on the two borders of the Pacific Ocean, but within the limits of Eurasia the seismic activity increases sharply up to 5.3 times. This is due to the close association of Eurasian earthquake foci in the mantle to the European–Southern Atlantic maximum of geoid deformation.

In the passage of the Australian maximum through the third quadrant, the seismic activity of the mantle increases approximately 4.1 times only because the western Pacific region is directly associated with it.

During this time other seismic regions not associated with this maximum of the geoid height are different by having low seismic activity.

When the vast European–Southern Atlantic maximum of the crest of the geoid passes through quadrant three, the seismic activity of the mantle increases not only within the limits of the Eurasian region but also within the western Pacific region. Seismic activity in the latter region coinciding with the Australian maximum of geoid deformation may be due to a resonance mechanism.

These data, which pertain predominantly to the strongest earthquakes, suggest a periodic increase in the Earth's tectonic stress and to global phases of release of elastic energy. Specific correlations and regularities are presented, testifying to the effect of cosmic conditions triggering simultaneous energy release in foci often at considerable distance from each other and creating the impression of seismic activity over large distances. Cosmic or extraterrestrial conditions promote the release of stresses in close time intervals in different regions, sometimes forming a series of earthquakes of strong and less strong intensity.

V. Summary

In general, basic regularities in the distribution of earthquakes are connected with different phenomena and processes in a complicated manner. Susceptibility of various concentrations of earthquakes in time and space and of different magnitudes occurs. In some cases a distinct correlation between the strongest earthquakes and some Earth rotational process reflected mainly by *V* numbers is disclosed. In other cases with less strong earthquakes, this correlation is lost. However, correlation exists with other phenomena, i.e., combinations of tide-generating forces. These phenomena also influence the triggering of the strongest earthquakes. These complex intercombinations of processes are even more complicated by the influence of the position of the Earth in circumsolar space and by the displacement of the crest of the geoid relative to the Earth's orbit.

VI. Postscript

In 1964 the National Geophysical Research Council and the Academy of Sciences of the United States published a report on basic geological relationships. In the foreword to this report the President of the National Academy of Sciences of the United States remarked, "The present report envelopes a range of problems without solution of which we cannot understand what our planet is like. . . . I am ardently recommending the present report to all who deal with the future scientific problems in the realm of solid Earth physics and with the researching of new ways in their solutions" (NAS-NRC, 1964). In this report a thorough study of the boundary conditions of seismic phenomena with triggering forces, such as Earth tides, etc., is recommended.

The above report mentions some recent results of research carried out by the author during the last 10 years. This research relates to the understanding of some of the more important and interesting problems which may help in the solution of some significant geophysical questions.

The regularities revealed are simple and this by itself is significant. Perhaps, they will permit a clearer analysis of the facts. The essence of their meaning will become clearer in the future. The criterion of reliability of any theory, as we know, rests in its ability to predict the future course of events. The results published here are related to such a prognosis which, however, falls outside the scope of this paper.

In general, earthquakes "mature" as result of a continuous development of a planet's interior. The causes of earthquake generation, however, are different; they are polygenetic. Earthquake generation, perhaps, is a result of the combination of many phenomena whose coordination is dictated by the fine hand of Nature.

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