ISSN 1028-334X, Doklady Earth Sciences, 2009, Vol. 424, No. 1, pp. 175–179. © Pleiades Publishing, Ltd., 2009.
Original Russian Text © B.W. Levin, E.V. Sasorova, 2009, published in Doklady Akademii Nauk, 2009, Vol. 424, No. 4, pp. 538–542.

**GEOPHYSICS**

# Bimodal Character of Latitudinal Earthquake Distributions in the Pacific Region as a Manifestation of Global Seismicity

Corresponding Member of the RAS **B. W. Levin**[a] **and E. V. Sasorova**[b]

Received August 27, 2008

**DOI:** 10.1134/S1028334X09010383

Quantitative presentation of seismicity as the energy released per square unit during a time unit was for the first time introduced by M. Bath [1]. Application of this characteristic with a clear physical sense allows us not only to compare the seismic activity in different parts of the world but also to form concepts about the nature of the seismic process. The influence of external tidal forces on activation of the seismic process and magmatism has recently attracted the attention of geophysicists and geologists [2].

The search for global regularities in the latitudinal distribution of earthquakes even in the epoch of the formation of seismological science demonstrated a clear inhomogeneity in the distribution of epicenters over the Earth despite low representativeness of the observational material in the middle of the 20th century [3].

It was shown that the seismic activity of the planet, which is almost absent at the poles and polar caps of the Earth, increases significantly at mid-latitudes reaching the maximum in the region of 40°–50° N and 10°–20° S with a stable local minimum near the equator.

Quantitative estimates of earthquake distribution by latitudinal zones of the planet based on electronic catalogues recently obtained in [4] demonstrated an almost complete absence of seismic events in the polar zones and two clear maxima of seismic activity at mid-latitudes.

[a] *Institute of Marine Geology and Geophysics, Far East Division, Russian Academy of Sciences, ul. Nauki 1b, Yuzhno-Sakhalinsk, 693022 Russia*

[b] *Shirshov Institute of Oceanology, Russian Academy of Sciences, Nakhimovskii prospekt 36, Moscow, 117997 Russia; e-mail: levinbw@mail.ru*

The objective of this work is to find statistically reliable regularities in the latitudinal distributions of earthquakes of different energy in representative regions characterizing the global seismicity of the Earth taking into account the contribution of the modern kinematics of the boundaries between lithospheric plates.

The Pacific region (PR), in which more than 80% of all seismic events in the world occur, was selected as the object to study the latitudinal distributions of earthquakes. The Pacific region is defined as the ocean basin with island arcs, inland seas, and land regions over subduction zones. We used the data from the International Seismological Catalog (ISC) with preliminary standardization of magnitudes and removal of aftershocks. We processed the earthquakes with magnitudes $Mb \geq 4.0$, which occurred from 1964 and 2004 (a total of more than 200 000 events). Since the events of different energetic levels can differ in the character of latitudinal distributions, in this work we considered the distributions separately in six magnitude ranges $4.0 \leq Mb < 4.5$, $4.5 \leq Mb < 5.0$, $5.0 \leq Mb < 5.5$, $5.5 \leq Mb < 6.0$, $6.0 \leq Mb < 6.5$, and $Mb \geq 6.5$. The whole PR was divided into 18 latitudinal intervals, each 10° wide.

Despite the distribution of the total number of events, we considered the distributions of normalized values (as the ratio to the total number of events in the given magnitude range). Previous attempts to normalize the number of events by the square of the latitudinal zone were ineffective and physically wrong due to a strong irregularity in the distribution of earthquakes within the latitudinal zones of the PR. Taking into account the fact that the earthquakes occur generally along the boundaries of the lithospheric plates and that the modern kinematics of the plate boundaries is studied quite well [5, 6], we applied normalizing the number of events in the latitudinal zone by the total length of the plate boundaries in the given zone. This parame-

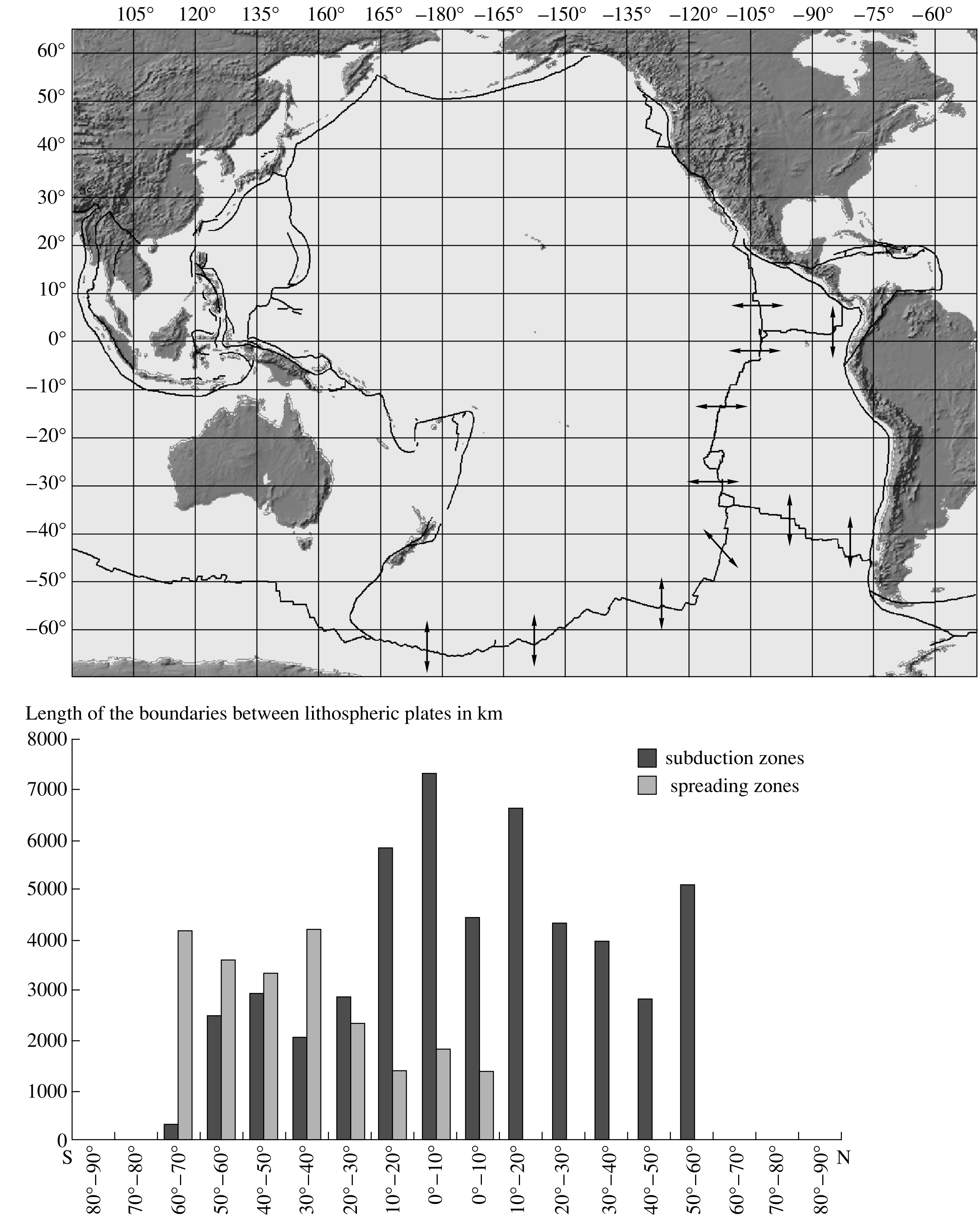


**Fig. 1.** Chart of the PR with the boundaries of lithospheric plates (spreading zones are marked with arrowed intervals) and distribution of the length of boundaries between lithospheric plates (km) in latitudinal zones for the spreading and subduction zones.

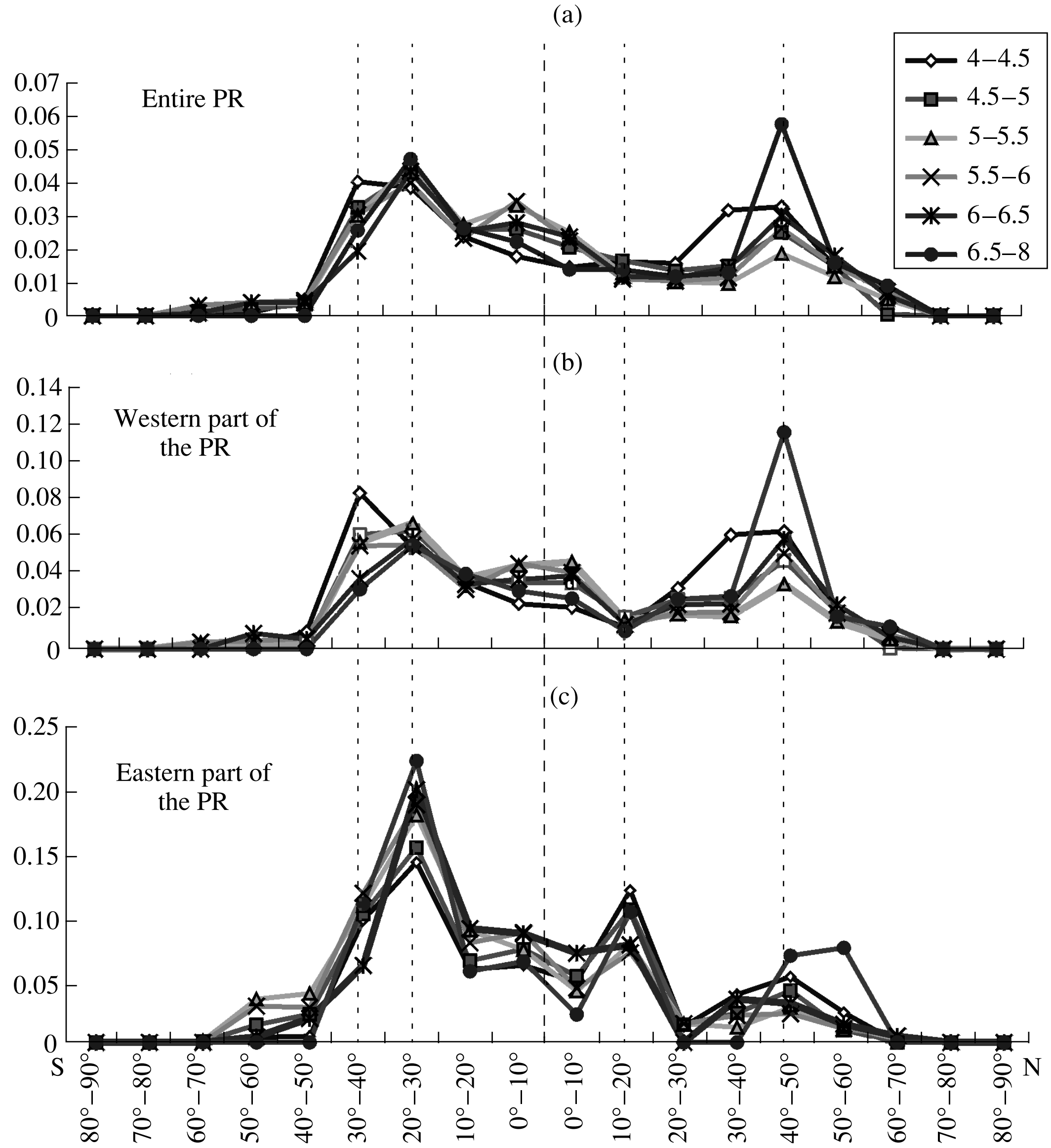


**Fig. 2.** Double normalized latitudinal distributions of earthquakes in the PR.

ter characterizes the seismic activity at the boundaries of lithospheric plates in the given latitudinal zone.

Figure 1 shows a chart of the PR with the boundaries between lithospheric plates. Figure 2 shows the distribution of the number of earthquakes by the latitudinal zones in the PR normalized by the total number of events in the magnitude range and by the total length of the boundaries between plates within the interval as well as double normalized distributions of events in the western and eastern parts of the PR. The number of earthquakes in the spreading zones does not exceed 2% of the total number of events in each latitudinal zone (less than 1% in the majority of the zones). Thus, while normalizing the boundaries between lithospheric plates by their length, we did not take into account the spreading zones.

The problem of time stability of these distributions is one of the debatable problems in the works on global seismicity. Therefore, we specially analyzed the latitudinal distribution over 10-year time intervals. The results of the analysis for four 10-year intervals in the western part of the PR are shown in Fig. 3. The bimodal character of distributions is generally conserved in all intervals considered. The most pronounced stability is found for the latitudinal distributions of the mean values over all magnitude ranges for four 10-year intervals (Fig. 3e). Analysis of shorter time intervals is not reasonable (the samples for strong events would be weakly filled).

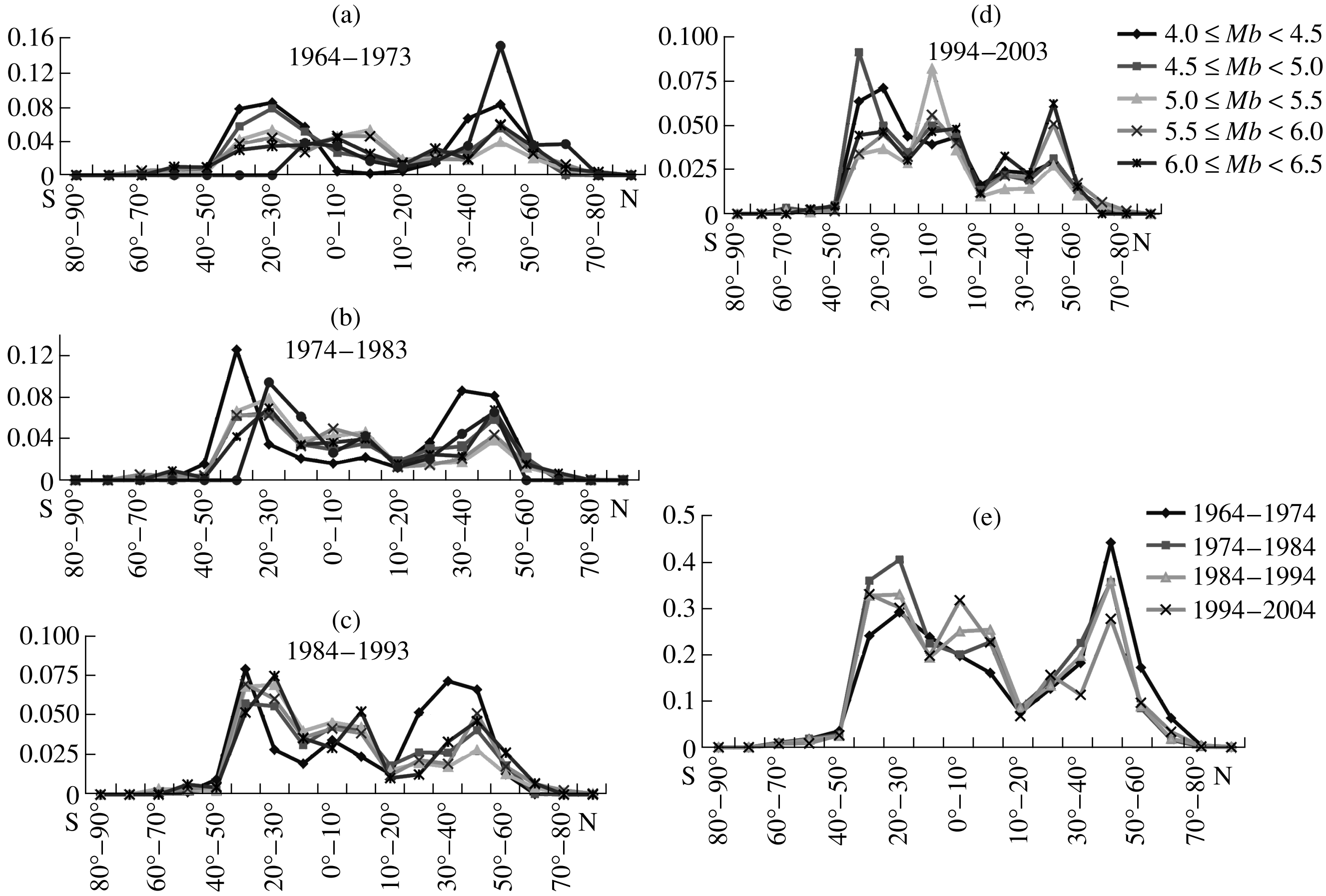


**Fig. 3.** Latitudinal distributions of earthquakes in the western part of the PR for different time intervals. Latitude intervals are laid off as abscissas. The relative numbers of events (after double normalizing) are laid off as ordinates. (a)–(d) Double normalized distributions of events by latitudinal zones for different magnitude ranges over 10-year periods. (e) Distribution curves of the mean value calculated from all magnitude ranges over four 10-year periods.

Detailed analysis of the results demonstrates that latitudinal distributions of earthquakes for the mean values over all magnitude ranges and for each of the distinguished energetic ranges practically demonstrate the conservation of the bimodal distribution form. Two characteristic maxima in the mid-latitude region, a local minimum near the equator, and almost zero values in the regions of the polar caps are distinguished. A similar pattern is observed also in the separate analysis of the western and eastern parts of the PR. It is worth noting that amplitudes of the tides and calculated theoretical distribution of the total energy of tidal forcing of the Earth by the Sun and the Moon [7] reveal maximum values in the region of 45° in the Northern and Southern hemispheres, and minimum values at the equator and poles.

Such coincidence between the distribution forms of recorded events and calculated values of tidal energy (Fig. 4) gives an additional argument supporting the long existing hypothesis about the correlation between seismicity and tidal interactions [8]. It can hardly be random. Statistical analysis demonstrated that none of the latitudinal distribution presented here can be considered uniform with a probability greater than 0.999.

It is worth noting here that the widely accepted concept about the dominating influence of the geothermal flux energy and convective mass motion in the interior of the Earth on the generation of the seismic process becomes vulnerable in light of the observations presented. The attempts to explain the distinguished irregularity in the distribution of earthquakes on the planet using only the effects of endogenic forcing of the heat flux do not seem convincing. Obviously, some of the seismic events (predominantly deep ones) appear owing to the energy generated by the heat flux uniformly distributed over the geospheres, while other seismic events, generally the crustal earthquakes, are to a large extent initiated by the tidal processes with their typical energy distribution of a bimodal character. The stability of the presented time distributions of earthquakes (Fig. 3) is also an additional argument supporting the tidal character of the origin of global seismicity.

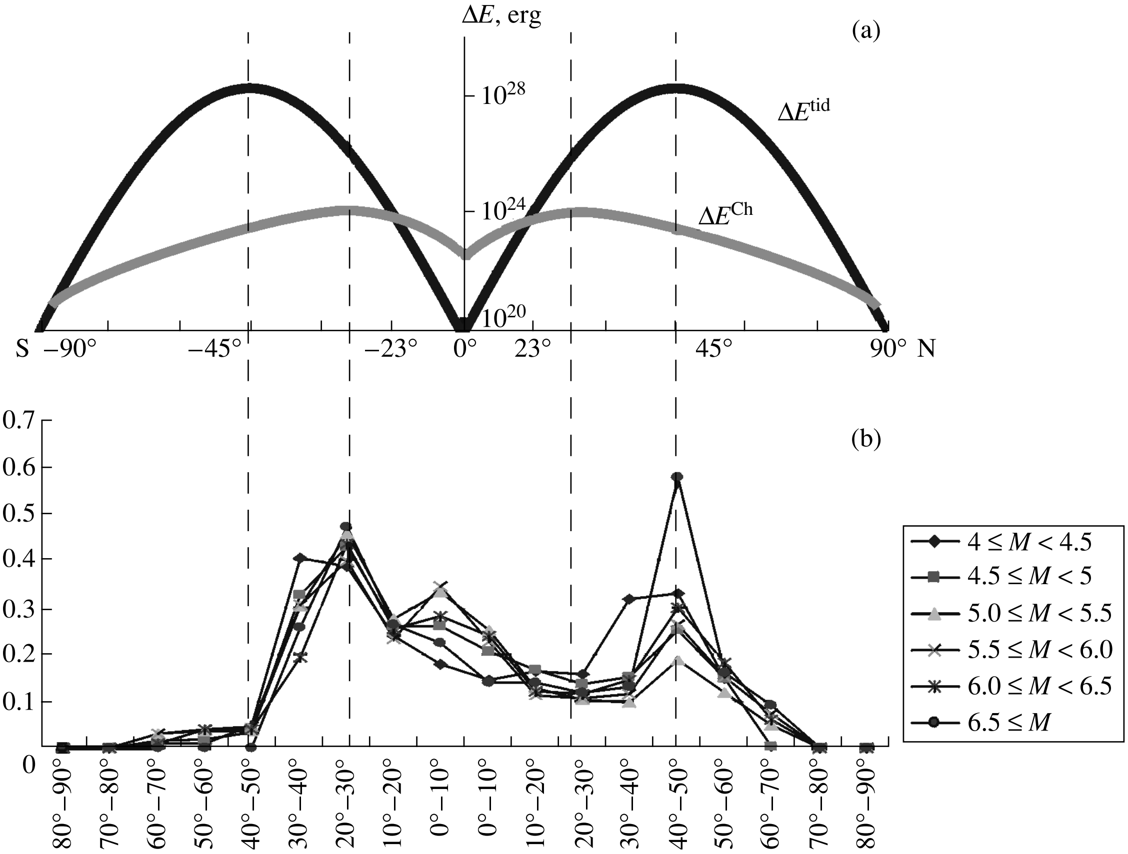


**Fig. 4.** Upper panel: latitudinal dependence of variations in the density of free energy for tidal perturbations and Chandler wobble based on model concepts [7]; Lower panel: distributions of seismic events by latitudinal zones for six magnitude ranges normalized by the length of the boundaries between lithospheric plates in each latitudinal zone and the number of events in each magnitude range.

ACKNOWLEDGMENTS

The authors thank V.V. Adushkin, G.S. Golitsyn, and Yu.I. Zetser for useful discussions and valuable recommendations. This work was supported in part by the Russian Foundation for Basic Research (project nos. 07-05-00142, 07-05-00363, and 08-05-99098).

REFERENCES

1. M. Bath, in *Weak Earthquakes* (Bulletin of the Seismological Society of America, 46 (1956); Inostr. lit, Moscow, 1961, pp. 526–528).
2. Yu. N. Avsyuk, A. Ya. Saltykovskii, and Yu. S. Genshaft, Dokl. Earth Sci. **413**, 178 (2007) [Dokl. Akad. Nauk **413** (1), 66 (2007).
3. K. Mogi, *Earthquake Prediction* (Academic Press, Tokyo, 1985; Mir, Moscow, 1988).
4. B. W. Levin and Ye. B. Chirkov, Phys. and Chem. Earth **26** (10/12) Part C, 781 (2001).
5. L. I. Lobkovskii, A. M. Nikishin, and V. E. Khain, *Modern Problems of Geotectonics and Geodynamics* (Nauch. Mir, Moscow, 2004) [in Russian].
6. M. Kogan and G. Steblov, J. Geophys. Res. **113**, B04416 (2008).
7. B. V. Levin and V. P. Pavlov, Izv. Phys. Solid Earth **39** (7), 601, (2003) [Izv. Akad. Nauk, Fiz. Zemli, No. 3, 71 (2003)].
8. I. Kant, *The History and Philosophy of Earthquakes (1756)* (Samtlliche Werke **6**, 227 (1839); Mysl, Moscow, 1964).

**SPELL OK**