ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 407A, No. 3, pp. 484–485. © Pleiades Publishing, Inc., 2006.
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GEOPHYSICS

General Law of Similarity for Earthquakes: Evidence from the Baikal Region

A. K. Nekrasova[1] and V. G. Kosobokov[1, 2]

Presented by Academician V. I. Keilis-Borok September 27, 2005

Received September 30, 2005

DOI: 10.1134/S1028334X06030305

INTRODUCTION

Studies of common characteristics of the earthquake sequences from different energy ranges and various seismoactive regions indicate the necessity of taking the usually ignored linear dimension range L_0 into account. In this case, the Gutenberg–Richter relation [1] in the range of magnitudes $M_- \le M \le M^-$ and dimensions $L_- \le L, L_0 \le L^-$ can be represented as [2]

$$\log N(M, L) = A + B(5 - M) + C\log L, \qquad (1)$$

where coefficients A and B have the same physical meaning as in the Guttenberg–Richter relation, and coefficient C locally characterizes the fractal dimension of a set of earthquake epicenter concentrations. The coefficient A normalized to 1 yr characterizes the expected mean number of earthquakes with the magnitude of 5.0 in a seismoactive area with a linear dimension equal to the unit length of the region $L_0 \times L_0$.

We have already carried out analysis of the unified scaling law for earthquakes (1) (hereafter, USLE) both for global [3] and several regional earthquake catalogues [4]. In this paper, we present results of an analysis and mapping of coefficients of the USLE in the Baikal region, one of the most seismoactive regions of Russian Federation with relatively high population density.

METHODS

We used the later version of an algorithm for evaluation of coefficients of the USLE, which allows us to stabilize the estimates of the parameters. The algorithm in general and the later modifications are scrutinized in [4].

[1] *International Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences, Varshavskoe sh. 79/2, Moscow, 117556 Russia; e-mail: nastia@mitp.ru*

[2] *Paris Geophysical Institute, Place Jussieu 4, Paris, 75005 France; e-mail: volodya@mitp.ru*

DATA

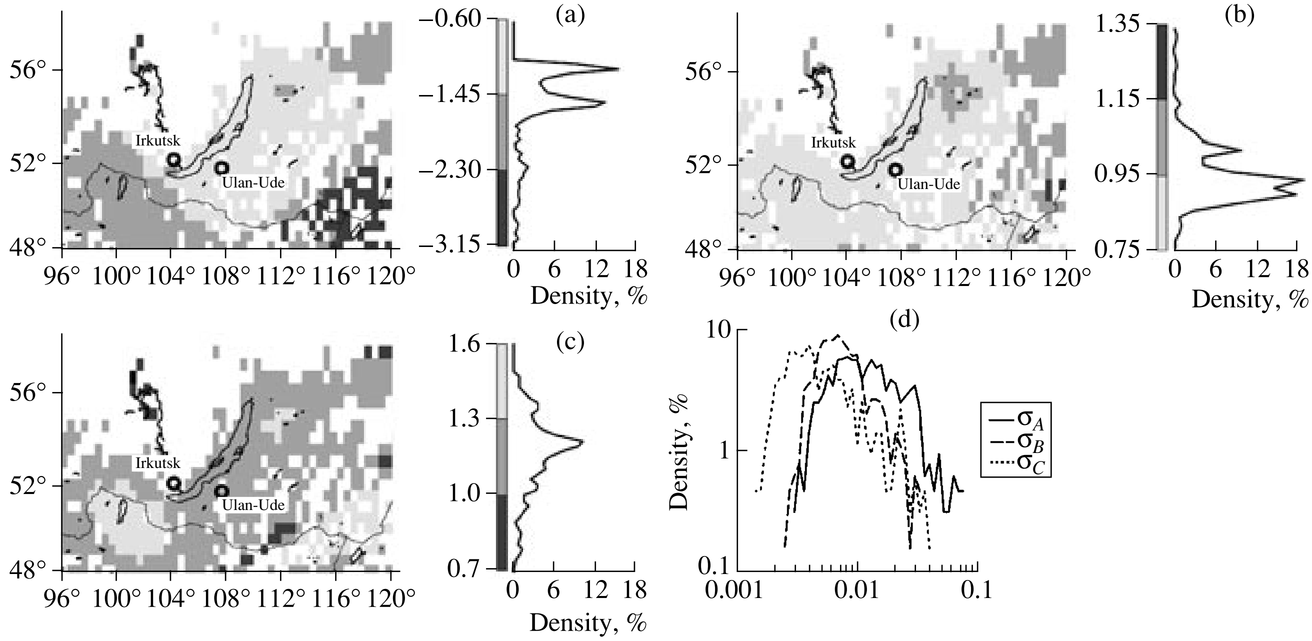
Seismicity of the Baikal region within the boundaries of the study region in the catalogue *Earthquakes in the Soviet Union* (48°– 58° N and 96°–120° E) in 1962–1997 is sufficiently completely represented by events with $M = 2.78$ (corresponding to the energy class $K = 9$ accepted in the Soviet Union) or higher. For the calculation of parameters A, B, and C, all such events at hypocenter depths down to 100 km were taken into consideration.

RESULTS

We calculated the USLE parameters for the Baikal region mentioned above in $\frac{1}{2}^\circ \times \frac{1}{2}^\circ$ grids of the meridian. Informal estimates of coefficients A, B, and C were obtained for 650 grids, where the number of recorded earthquakes turned out to be sufficient for a reliable application of the algorithm. Figure 1 presents the maps of estimates of parameters A, B, and C, their distribution densities, and errors in the determination of their values according to the statistics of one hundred random rotation of an area $8° \times 8°$ (Fig. 1d). A significant error (0.02 or more) is recorded in less than 1% of the total number of coefficient determinations, suggesting a high reliability of the mapped estimates.

The maps show that the seismic activity (parameter A) has two typical maximums in the study area. In the main rift (Baikal Lake) area, $A \approx -1.2$, which corresponds to six events of $M = 5.0$ in 100 yr. The second density maximum ($A = -1.6$) is related to the Eastern Sayan area, where the recurrence of earthquakes is three times less. Other seismoactive areas of the Baikal region are characterized by even lower recurrence ($A < -2.3$).

Parameter B, which characterizes the recurrence plot slope, varies from 0.75 to 1.35. The majority of the values lie within the range of 0.8–0.95. A value of 0.9 prevails in the Baikal region. The local maximum density of 1.1 has been recorded in the northeastern part of the Baikal rift zone. (The recorded areas with different



Spatial distribution of USLE parameters in the Baikal Region. (a) Evaluation of seismic activity (parameter A);(b) recurrence plot slope (parameter B); (c) fractal dimension of epicenter concentration set (parameter C); (d) density distribution of errors σ_A, σ_B, and σ_C. Empirical density of the distribution of A, B, and C parameters is given on the left side of each respective map.

values of parameter B may correspond to the asymmetry of seismic moment release on the northeastern and southwestern flanks of the Baikal rift zone [5].)

The fractal dimension of the epicenter distribution (parameter C) varies from 0.7 to 1.6. The spatial distribution of the coefficient C is less uniform than that of coefficients A and B (Fig. 1). One can clearly see the central deep-water part of the rift zone (with $C \sim 1.2$) that separates the area of ridges and valleys to the northeast of Lake Baikal (with relatively high values of fractal dimension, $C = 1.3–1.4$) from the vast seismoactive area to the south of the eastern Sayan region with dominant values of $C \sim 1.4$.

The maximal values of the parameter C (1.5–1.6) are localized near the area where the N–S strike of ridges gives way to a sublatitudinal strike area (at the upper reaches of the Muya and Upper Angara rivers). The maximal values are evenly distributed along Nerchinsk Ridge close to the border with China. This area is separated from the main Baikal Rift by a zone with low values of $C \sim 0.8–0.9$. The minimal values of the fractal dimension recorded in the Bratsk Reservoir area may be related to induced seismicity.

CONCLUSIONS

A traditional disregard of the fractal character of spatial distribution of earthquakes (including the widespread conventional practice of normalization to the area of a square kilometer in a seismic surveys) can lead to multiple underestimation of seismic zonation hazard. For instance, in Irkutsk ($A = –1.51$, $B = 0.88$, and $C = 1.38$) or Ulan-Ude ($A = –1.34$, $B = 0.89$, and $C = 1.17$), the conventional estimation of the recurrence of strong earthquakes within the 25-km periphery of a town based on their statistics in the Baikal region can be underestimated by $(L_0/25)^{2-C} \approx 10$ and 20 times, respectively. It is obvious that such a mismatch between the conventional and suggested estimates of the recurrence, as well as the significant variations in parameters A, B, and C, should be accounted for in a new edition of seismic zonation map of Russian Federation. In its present version [6], the map includes the whole axis of the Baikal Rift into a single zone of seismic intensity 10, while the largest towns of Irkutsk and Ulan-Ude are included in the surrounding zone of intensity 9.

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