Corresponding Member of the Academy of Sciences of the USSR Yu. V. RIZNICHENKO

1964

SovietRxiv

Abstract

Full Text

GEOPHYSICS

Corresponding Member of the Academy of Sciences of the USSR Yu. V. RIZNICHENKO

ON THE RELATION BETWEEN THE ENERGY OF MAXIMUM EARTHQUAKES AND SEISMIC ACTIVITY

In the quantitative determination of seismicity by means of the "law of earthquake recurrence" $N = N(E)$, where N is the frequency of recurrence and $E = 10^K$ is the seismic energy of the source ([1,2]), the principal parameters determining this law in the zero approximation are ([3]): the seismic activity A, the conventionally constant parameter $\gamma = -d\lg N/dK$ of the decrease of N with increasing E, and the energy $E^{\mathrm{l}}_{\max} = 10^{K_{\max}}$ of the maximum earthquake possible in one region or another. The quantities A and γ, determined from weak or moderate earthquakes, which occur frequently, are established with sufficient reliability, and in recent years the activity A in many regions of the USSR has already been mapped ([2,4]) and others. To map the quantity $E_{\max}$ on the basis of direct observations alone is practically impossible, since strong earthquakes, close to the maximum, occur extremely rarely. In this connection there arises the question of the **calculation** of maximum possible earthquakes, i.e., of establishing the quantity $E_{\max}$ from indirect data–seismic data on weaker earthquakes, geodetic, geological, and other data ([5]). Of course, it is understood that information on $E_{\max}$, where it can be obtained, must be incorporated into the basis of the calculation method.

As a development and concretization of considerations expressed earlier ([5]), we present here, to begin with, some results of correlating the observed quantities A and $E_{\max}$ for a number of regions of the USSR, bearing in mind that, if a sufficiently close relation between these quantities is found, it can be used for probabilistically justified mapping of $E_{\max}$ on the basis of maps of A, possibly supplemented by other data, even in those places where direct data on $E_{\max}$ are lacking. A method for carrying out this correlation, based on a number of physical assumptions, is proposed here. A way is indicated for using the obtained dependences to calculate $E_{\max}$ and to construct maps in isolines of this quantity (or $K_{\max}$) from maps of seismic activity A. The method has been tested on factual material.

At the present stage of the investigation, the following assumptions were adopted in the correlation (a discussion of these and of some other possible assumptions will be given in another, more extensive communication). The observed maximum earthquakes in a given region were considered the maximum possible. As A there was taken the mean value $\overline{A}$ of the activity over a certain area "responsible" for the earthquake $E_{\max}$. This area was taken in the form of a circle of radius r (or of an equal-area square) with its center at the epicenter such that $E_{\max} = cr^3$, where c does not depend on E; it was thereby assumed that the mean density of the energy $E_{\max}$, distributed in the volume of the responsible region (a hemisphere), is the same for all $E_{\max}$. The correlation problem was solved in the variant of a linear regression of $\overline{A}$ on $K_{\max}$: for a series of corresponding points $(K_i, \lg \overline{A}_i)$, a fitting straight line was found with a given value of the parameter c. The solution was carried out repeatedly, for different values of this parameter. As the final, "optimal" solution it was proposed to accept the solution at that value of c for which the scatter of the observed points $(K_i, \lg \overline{A}_i)$ is the smallest. The measure of scatter was slu-

the mean deviation

$$\left(\sum_{i=1}^{n} |\Delta \lg A_i| \right) / n$$

of the points from the averaging straight line; n is the number of points. We saw the meaning of such optimization of the solution in the fact that both excessively small and excessively large dimensions of the area responsible for any earthquake must be regarded as physically unjustified.

In this way data were processed from 4 maps of seismic activity, namely: from the maps of I. L. Nersesov et al. ([4]) for the Central Tien Shan, including the Fergana region: 1) from observations of the network of Central Asian seismic stations for 1950–1956, and 2) from detailed but short-term observations of the Naryn detachment of the Tajik Complex Seismic Expedition in 1957–1958; 3) from the map of I. V. Gorbunova ([6]) for the Eastern Tien Shan and Dzungaria; 4) from Gorbunova' s map for the Altai-Sayan region ([7]). Data on the maximum earthquakes, such as the Kemin earthquake of 1911, the Mondy earthquake of 1950, and others, 21 earthquakes in all with $K = 12$—17, were taken mainly from ([8]); in converting the magnitude M to the energy class K, the formula of T. G. Rautian ([2])

$$K = 8 + 1.1M$$

was used.

Within the investigated limits of variation of c, namely $0 \leq 1/c < 1.3 \cdot 10^{-10}$ J^{-1}km^3, a minimum was found in cases 1) and 3) at $1/c = 0.3 \cdot 10^{-10}$ J^{-1}km^3. In case 2), within these limits a monotonic decrease of the scatter with increasing $1/c$ was observed, but, beginning approximately with the same value $0.3 \cdot 10^{-10}$ and higher, the decrease in scatter slowed down. In case 4) the scatter proved to be practically constant because the corresponding map A had been constructed in advance with large averaging areas. Under these circumstances, as the final value, and the same for all four cases, $1/c = 0.3 \cdot 10^{-10}\ \mathrm{J}^{-1}\mathrm{km}^3$ was chosen, which corresponds, for example, for the Chilik earthquake of 1889 ($K = 16.5$) to a radius of the responsible area $r = 100$ km.

After constructing correlation graphs for each map separately, an attempt was made to combine all the data. This led, however, to an unjustifiably large total scatter of points, chiefly because of the disagreement between the data of maps 1) and 2) for one and the same region, which moreover differ greatly from each other. Therefore we restricted ourselves to combining data only for maps 3) and 4), where 14 earthquakes regarded as maximum were noted. For them the following averaged dependence (regression equation) was obtained:

$$\lg \overline{A} = \lg \alpha + \beta(K_{\max} - K_{\alpha}), \tag{1}$$

where, for $K_{\alpha} = 15$, we have $\lg \alpha = 2.8$; $\beta = 0.2$. Here $\overline{A}$ is measured in units of recurrence of earthquakes of class $K = 10$ ($E = 10^{10\pm0.5}$ J) per year over an area of 1000 km^2. The distribution of the deviations $\Delta \lg \overline{A}_i$ near (1) is close to normal. For more than 75% of the earthquakes considered (10 out of 14), the deviations do not exceed $|\Delta \lg \overline{A}_i| = 0.2$. With the obtained value of the slope β of the averaging straight line, a deviation $\Delta \lg A = \pm 0.2$ corresponds to $\Delta K_{\max} = \pm 1$. This determines the accuracy with which the value of $K_{\max}$ can be determined from a given $\overline{A}$ by equality (1), at the same confidence probability level of 75%. The result obtained appears at this stage to be quite satisfactory.

The idea of the proposed procedure for constructing a map of the maximum possible earthquakes $K_{\max}$ on the basis of a map of seismic activity A and in accordance with a correlation dependence of the form (1) is as follows. On areas $S = \pi r^2$, to which definite values $E_{\max} = cr^3$ correspond, for each point of the map $\overline{A}$ is determined for different values of $E_{\max}$ and, consequently, different $K_{\max}$. In the coordinate system $K_{\max}, \lg \overline{A}$ we construct a curve. Its intersection with the straight line (1) gives the desired value $K_{\max}$ or, in other cases, $K_{\min}$.

As an experiment based on this principle, we have constructed a map in isolines of $K_{\max}$ for the Altai–Sayan zone. Naturally, the initial "maximum" earthquakes shown on it fit satisfactorily into the resulting field $K_{\max}$. In it, however, several well-known strong Baikal earthquakes of the end of the last century and the beginning of the present century also fit well, for which only the intensity was known; M and K were not determined.

It should be emphasized once again that these results must be regarded only as the beginning of concrete investigations in the direction of calculating the maximum possible earthquakes from indirect data ([5]).

The work was carried out mainly on the basis of materials ([3,6,7]) from observations of the Complex Seismological Expedition of the O. Yu. Schmidt Institute

of Physics of the Earth, Academy of Sciences of the USSR. The author is sincerely grateful to I. L. Nersesov and I. V. Gorbunova and to other members of the expedition for discussion and assistance in the work.

Institute of Physics of the Earth named after O. Yu. Schmidt
Academy of Sciences of the USSR

Received
28 V 1964

REFERENCES

1. Yu. V. Riznichenko, *Izv. AN SSSR, ser. geofiz.*, No. 9 (1958).
2. V. I. Bune et al., *Tr. Inst. fiziki Zemli im. O. Yu. Shmidta AN SSSR*, No. 9 (1960).
3. J. V. Riznichenko, I. L. Nersessov, *Ann. Geofisika*, **16**, No. 2 (1961).
4. I. L. Nersesov et al., *On the Seismic Zoning of the Naryn River Basin*, Academy of Sciences of the Kirgiz SSR, Frunze, 1960.
5. Yu. V. Riznichenko, *Tr. Inst. fiziki Zemli im. O. Yu. Shmidta AN SSSR*, No. 25 (1962).
6. I. V. Gorbunova, ibid., No. 25 (1962); No. 32 (1964).
7. S. I. Masarskii, I. V. Gorbunova, ibid., No. 32 (1964).
8. *Earthquakes in the USSR*, Publishing House of the Academy of Sciences of the USSR, 1961.

Note: Figure translations are in progress. See original paper for figures.