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MAPS OF SEISMIC SHAKING

GEOPHYSICS

1967

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Abstract

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UDC 550.340:550.341

GEOPHYSICS

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MAPS OF SEISMIC SHAKING

The system adopted in our country for assessing the degree of seismic hazard of territories—seismic zoning—is based on the concept of the maximum possible intensity $I_{\max}$ of seismic shaking. From the point of view of this system, the destructive Tashkent earthquake of 1966, for example, was a natural event: it was known in advance that Tashkent lies in an 8-point zone of $I_{\max}$, and, under unfavorable ground conditions, the calculated value of $I_{\max}$ should be increased, while under favorable conditions it should be decreased.

But in Tashkent, as in any other place, another question naturally arises: how often, on average, may earthquakes of such intensity recur here? Say, once in 50 years, or once in 5000 years? The existing seismic-zoning system does not answer such questions. But they can be obtained from an analysis of observational data on source seismicity. This is one of the tasks of the theory of shaking as the geophysical basis for improving the system of assessing the degree of seismic hazard—seismic zoning.

The fundamental principles of this theory were developed in ([1]), where theoretical examples were also given for calculating the magnitude of **shaking** B_i—the mean recurrence frequency at a given point of seismic shakings of a given intensity I. Source seismicity was specified by three parameters of the usual earthquake recurrence graph: A—seismic activity, γ—the slope of the graph, $K_{\max}$—the magnitude of the maximum earthquake. Here $K_{\max} = \lg E_{\max}$; $E_{\max}$ is the seismic energy of the source. In ([2]), examples were given of calculating shaking graphs $B = B(I)$ for individual points on the Earth' s surface from observational data on source seismicity and on the decrease in seismic-energy density with distance from the source. In the present communication, maps of shaking are published for the first time; they give the value of this quantity for many points of the region under consideration on the basis of seismic observations carried out there. This has been done for the territory of Eastern Uzbekistan, which includes the city of Tashkent.

Initial data. The basis for all calculations was provided by the earthquake catalogs of Uzbekistan for the period 1868–1964, compiled by E. M. Butovskaya and others.*

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The map of K_{max}—the maximum possible earthquakes for the given region—was constructed by correlating the values of K of the strongest observed earthquakes with the mean activity $\bar{A}$ in the vicinity of their epicenters, calculated over an area the larger, the greater K. The correlation equation used was

$$\lg \bar{A} = \lg \alpha + \beta(K_{max} - K_\alpha), \quad \text{where } \lg \alpha = 2.84;\ \beta = 0.21;\ K_\alpha = 15, \qquad (1)$$

obtained earlier from observations in other regions ([3]). The justification for this

* O. A. Ryzhkov, E. M. Butovskaya et al., Report on the topic "Seismicity of Uzbekistan and Its Mountain Framing," Tashkent, 1963. Archives of the Institute of Geology, Academy of Sciences of the Uzbek SSR.

may be the fact that, in our region, the values of A for the largest earthquakes observed here (the Chatkal earthquake of 1946 with $K = 17$ and the Andizhan earthquake of 1902 with $K = 16.5$) proved to be in good agreement with the parameters of equation (1).

The intensity I of shaking was taken in the form of the energy-flux density ε of seismic waves at a point on the Earth' s surface through an area perpendicular to the ray. The attenuation of the energy ε with hypocentral distance r was assumed in the form $\varepsilon \sim r^{-1.7}$, where 1.7 is the mean value, found from many observations in Uzbekistan [(4)], of the effective divergence exponent in the working distance interval $r = 10 \div 800$ km.

Algorithm for calculating shaking. The formula given in [(2)] for calculating the total frequency of shakings at a given point with intensity I_1 and higher has the form

$$B_\Sigma = \frac{1}{10^{0.5\gamma} - 10^{-0.5\gamma}} \iint\limits_S A\left(10^{-\gamma(K_1-K_0)} - 10^{-\gamma(K_{max}-K_0)}\right) dS. \qquad (2)$$

Here B_Σ is the complete total shaking at the given point from foci in the surrounding region S, with epicenters on all elementary areas $dS = r_0 dr_0 d\alpha$, located at different distances $r = \sqrt{r_0^2 + h^2}$ and in different azimuths α from this point; r_0 is the epicentral distance; h is the focal depth, taken on average as 10 km; $K_0 = 10$ is the fixed earthquake magnitude to which the determination of the activity A is referred; K_1 is the magnitude of the earthquake in the focus that causes, at the given point, shaking of intensity I_1; K_{max} is the maximum possible earthquake on the area dS.

The value K_1 was found from the above-mentioned dependence of the energy-flux density ε on distance r. The value K_{max} is determined by the map of K_{max}. In the present version of the calculation, the value A, for a known K_{max}, was

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determined by the correlation equation (1). Thus, the calculation of B_Σ here included not the particular value of the activity A on dS, but its mean value $\bar{A}$ over the area corresponding to the zone "responsible" for the preparation of a possible earthquake $K_{\max}$ with epicenter in dS.

For machine computation, the integration in (2) was replaced by summation

$$B_\Sigma = \sum_S A \frac{\left(10^{-\gamma K_1} - 10^{-\gamma K_{\max}}\right) 10^{\gamma K_0}}{10^{0.5\gamma} - 10^{-0.5\gamma}} \Delta S, \tag{3}$$

where the double integral over the variables r_0 and α is replaced by a single sum, since in this version of the calculation the intensity of shaking was taken to depend only on distance. The area ΔS was taken equal to $0.2^\circ \times 0.2^\circ$, i.e., $22 \times 16 = 352$ km^2—the same as in compiling the map of activity A for the given region. The value K_1 was determined from the equality

$$10^{K_1} = 4\pi R^2 (r/R)^{1.7} \varepsilon, \tag{4}$$

where $R = 10$ km is the radius of the sphere to which the seismic energy of the focus is referred. Substituting (4) into (3), we obtain the final formula for calculating shaking

$$B_{\Sigma_\varepsilon} = \sum_S A \frac{\left\{4\pi R^2 (r/R)^{1.7} \varepsilon\right\}^{-\gamma} - \left(10^{K_{\max}}\right)^{-\gamma}}{10^{0.5\gamma} - 10^{-0.5\gamma}} 10^{\gamma K_0} \Delta S, \tag{5}$$

where $\varepsilon \equiv I_1$ is the specified intensity of shaking. Formula (5) formed the basis of the algorithm of a standard program for calculating shaking maps on the M-20 computer. This program was composed in such a way that the intensity of shaking can be expressed not only in flux densities ε of energy, but also in other quantities, such as, for example, in maximum accelerations of a certain-

oscillation frequency, or else in standard points of the "strength" of seismic shaking.

Results. Two shaking maps were calculated: Fig. 1a—for a shaking intensity $\varepsilon = 10^{12}$ J/km^2, and Fig. 1b—for an intensity $\varepsilon = 10^{13}$ J/km^2. Shaking with intensity $\varepsilon = 10^{12}$ J/km^2 corresponds to an earthquake of magnitude 8-9, which may be produced at the epicenter, for a depth $h = 10$ km, by a focus with $K = 15$, i.e., with seismic energy $E = 10^{15}$ J. Shaking with $\varepsilon = 10^{13}$ J/km^2 corresponds to an earthquake of magnitude 9-10, which, under the same conditions, may be produced by a focus with $K = 16$, i.e., with energy $E = 10^{16}$ J (5). But the maps in Fig. 1, of course, take into account not only epicentral shakings.

Fig. 1. Shaking map of Eastern Uzbekistan in isolines of the recurrence period of shakings with intensity $\varepsilon = 10^{12}$ J/km^2 (a) and $\varepsilon = 10^{13}$ J/km^2 (b). Circles

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Fig. 1

Figure 1: Fig. 1

show the epicenters of earthquakes of energy classes K = 16–17 (1902) and $K = 17$ (1946).

From consideration of Fig. 1a it follows that the mean recurrence period of 8–9-point shakings at one and the same point in the Fergana depression is 40 years and gradually increases to the north and northwest to 500 years in the Talas Range and to 2000–4000 years in the Tashkent region. As for 9–10-point shakings (Fig. 1b), in the territory of the Fergana depression and the Southwestern Tien Shan their recurrence period is 1000 years, while farther north and northwest it increases to 10,000 years. In the city of Tashkent the recurrence of such shakings is equal to zero.

Let us recall that all these calculations have so far been performed under highly idealized conditions: with $K_{\max}$ correlated only with $\bar{A}$, under the assumption of circular isoseists, and for average soils. In the future, it is proposed to refine and detail such calculations.

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Received
14 II 1967

CITED LITERATURE

1. Yu. V. Riznichenko, *Izv. AN SSSR, Fizika Zemli*, No. 11, 1 (1965).

2. Yu. V. Riznichenko, *Izv. AN SSSR, Fizika Zemli*, No. 5, 16 (1966).

3. Yu. V. Riznichenko, *DAN*, 157, No. 6, 1352 (1964).

4. S. S. Seiduzova et al., *Tr. Inst. matem. im. V. I. Romanovskogo AN UzSSR*, No. 25 (1962).

5. I. L. Nersesov et al., *On the Seismic Regionalization of the Naryn River Basin*, Frunze, 1960.

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