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OPTIMUM NETWORK OF SEISMOGRAPHS DURING INVESTIGATION OF SEISMIC DANGER AT A SITE OF A NUCLEAR POWER PLANT

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The locations of seismic systems during investigations in the area of the Juragua Nuclear Power Plant in Cuba were chosen on the basis of calculations of the minimum energy class of seismic events recorded by a network of seismic systems. The magnification curves of seismographs were selected on the basis of measurements of microseismic noise. Investigations were performed by three seismic systems located at the apexes of a triangle with 30-km sides. One system operated at a magnification of 12,000 and the other two systems, at a magnification of approximately 30,000, with the magnification curves having shapes characteristic of the type II curves.

An estimate of seismic danger is important in investigations conducted prior to construction of nuclear power plants (NPP) in the regions of possible occurrence of earthquakes. A network of moderate-gain seismic systems is required for regions characterized by unreliable or incomplete data on seismicity. In particular, such systems operating for a sufficiently long time in regions with complex geological structure may be helpful in interpreting the data of seismotectonic and seismogeological investigations.

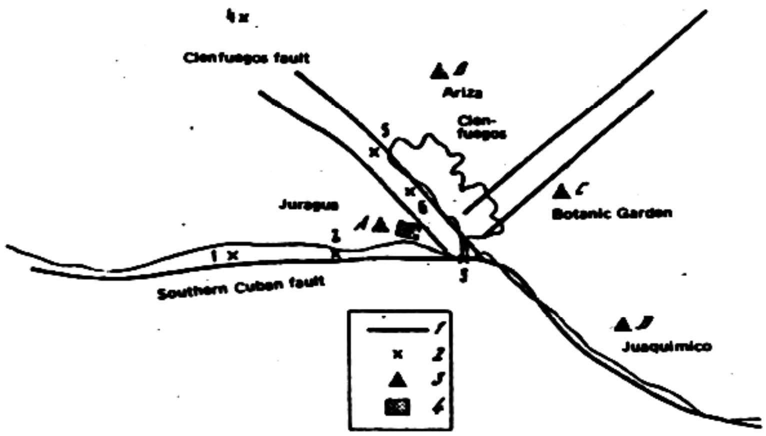

Fig. 1. Principal seismogenic structures (1) in the region of the nuclear power plant, arbitrary locations of epicenters (2), possible locations of seismic systems (3) and the site of the nuclear power plant (4).

The network of moderate-gain seismic systems should be capable of recording microearthquakes within a radius of several dozen kilometers from the NPP. This makes it necessary to optimize the location of seismic systems so as to minimize the energy class of the events recorded and to choose optimum magnification curves of seismographs.

Below, we will describe the method used in optimizing a network of moderate-sensitivity seismic systems used during investigations of the Juragua Nuclear Power Plant site in the Republic of Cuba. In addition to the authors, the following members of the Institute of Physics of the Earth AN SSSR participated in organizing and conducting observations: V. O. Andreev, B. P. Volin, A. D. Zav'yalov, D. N. Zargaryan, T. G. Ivanova, V. G. Mezhberg, V. P. Myznikov, V. M. Tsyganov and Ya. A. Shvartsburg.

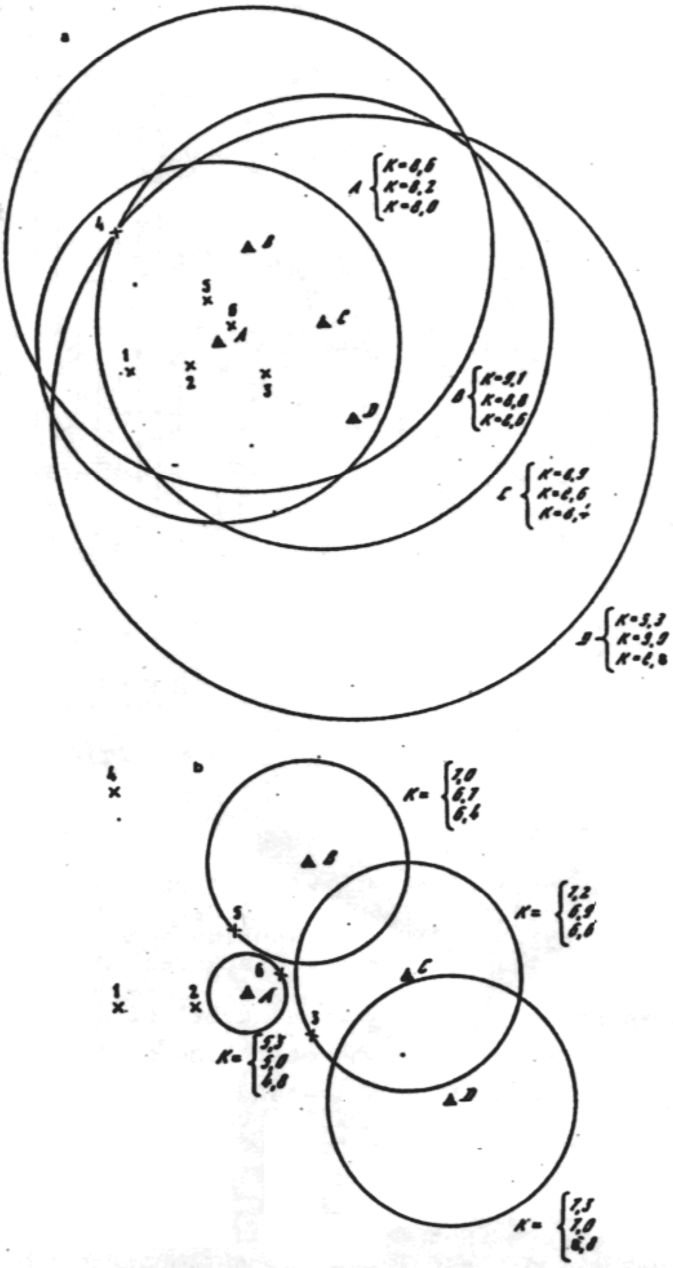

Fig. 2. Regions of K_{min} for A, B, C, D systems (see Fig. 1). The values K_{min} in the upper column correspond to a magnification V_0 = 10,000; those in the middle column, to V_0 = 15,000 and in the lower column, to V_0 = 20,000; a) maximum epicentral distances (40-70 km); b) minimum epicentral distances (5-20 km).

The Juragua Nuclear Power Plant is located within the boundaries of a tectonic inte section formed by a branch of the southern Cuban fault and a branch of the Cienfuegos Santa Clara dislocation zone (Fig. 1) [1]. In choosing the optimum configuration of a network of seismic systems, it was assumed that the main sources of earthquakes in the region of the nuclear power plant are probably the Cienfuegos fault and the coastal faul (Fig. 1). Four possible sites of seismic systems, Juragua, Ariza, Botanic Garden and Juaquimico were chosen from general considerations based on the accuracy of determining epicenters. Then, circular regions of K_{min} were calculated for the above listed sites

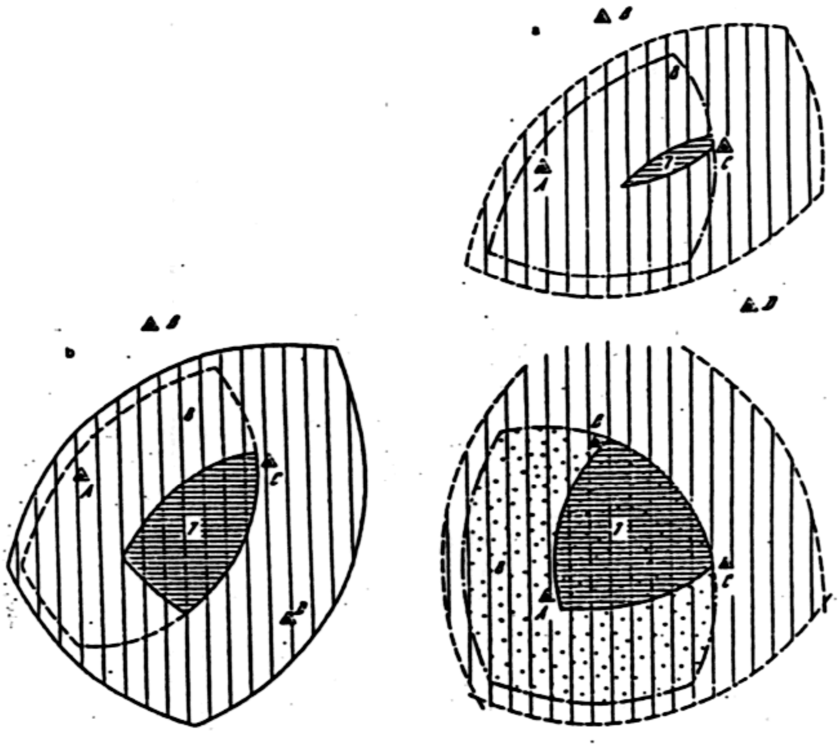

Fig. 3. Regions of K_{min} for magnification of $V_0 = 15000$.
a) For A, B, D systems; b) for A, C, D systems; c) for A, B, C systems.

and combinations of magnifications of seismographs of 10,000, 15,000 and 20,000. These calculations were performed for a number of arbitrary locations of hypocenters along the Cienfuegos and the coastal faults using Fautian's nomograms. The results of the calculations for maximum and minimum epicentral distances are shown in Fig. 2a, b.

Figure 3a shows regions of K_{min} for the set of Juragua, Botanic Garden and Juaquimico seismic system sites with seismographs operating at a magnification $V_0 = 15,000$. Analogous regions for the set of Juaquimico, Ariza and Juragua seismic system sites are shown in Fig. 3b, while that for the set of Ariza, Botanic Garden and Juragua are shown in Fig. 3c. The $K_{min} = 7$ zone in Fig. 3c is plotted for magnification $V_0 = 30,000$ at the Botanic Garden and Juragua (A and C) sites.

It follows from Fig. 3 that for the four seismic system sites and epicenters associated with the Cienfuegos and coastal faults, optimum recording can be achieved by the set of three seismic system sites at the Juragua, Botanic Garden and Ariza locations. This set of sites makes it possible to reliably determine epicenters of seismic events of energy class $K \geq 7$ at epicentral distances up to 100 km.

Selection of optimal magnification curves of seismographs requires the measurement of the background of microseismic noise at the seismic system site chosen. First data on noise in the region of the nuclear power plant (Juragua site) and at a site in the Botanic Garden were obtained during measurements of ground motion performed for seismic microzoning [1]. Seismographs with a flat magnification curve in the period range 0.05 - 1 s and peak magnification $V_0 = 17,000$ were used in these investigations. All records of microseisms acquired in the region of the nuclear power plant were characterized by a predominance of ground motion with average amplitudes on the order of 0.1 μm in the period 0.6-1 s (typical regular sea-generated microseisms). The amplitude of microseisms at a temporary location in the Botanic garden in the same period range did not exceed 0.03 μm. This was attributed to the long distance from the coast. The data acquired during investigation of ground motion were verified by data from a temporary seismic station operated during 1977 at a magnification of 10,000 in the period range 0.5-1 s. Later, special work was performed on measuring the background of microseisms in the vicinity of possible

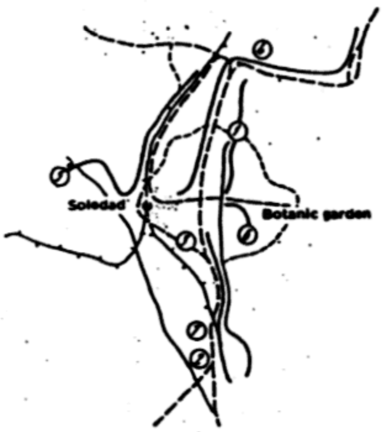

Fig. 4

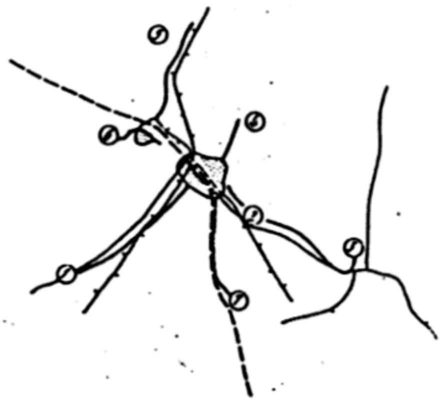

Fig. 6

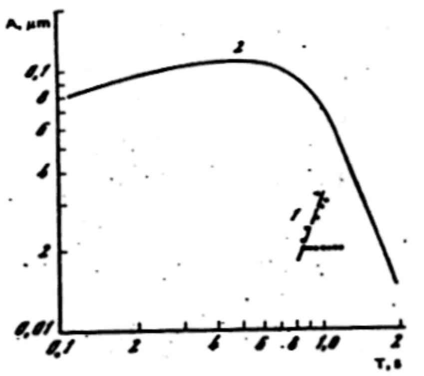

Fig. 5

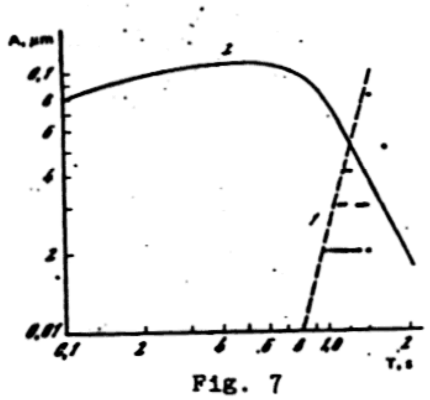

Fig. 7

Fig. 4. Noise measuring sites in the Botanic Garden region.

Fig. 5. Noise spectrum at point 6 (see Fig. 4). 1) noise spectrum, 2) type II magnification curve for V_0 = 10,000 at a tolerable noise level on the record of y = 1 mm.

Fig. 6. Noise measuring sites in the Ariza region.

Fig. 7. Noise spectrum at point 2 (see Fig. 6). (Legend is the same as Fig. 5.)

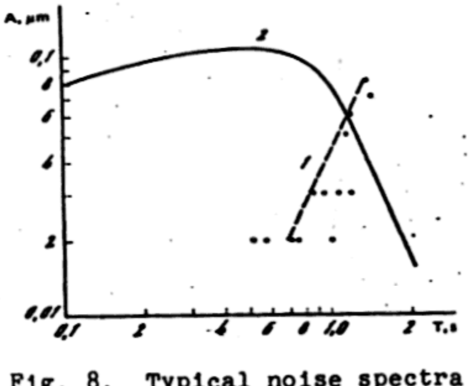

Fig. 8. Typical noise spectra in the Juragua region. 1) Noise spectrum, 2) type II magnification curve with V_0 = 10,000 at a tolerable noise level on the record of y = 1 mm.

sites of seismic systems. The seismic system used consisted of an SM-2 seismometer and a N-700 oscillograph equipped with GB-4 galvanometers. The seismographs operated at a magnification of 17,000 in the period range 0.05-1 s. The following results were obtained.

Botanic Garden. Point 6 in Fig. 4 was chosen to be the site of the seismic system on the basis of noise measurements and local conditions (distance from the roads and other sources of noise, winding loading, convenience of location and servicing). Continuous line in the same figure and on the same scale shows the standard, reduced type II magnification curve for a medium-sensitivity seismograph operating at V_0 = 10,000 at an allowable noise level on the record of y = 1 mm. The seismograph operated at a magnification V_0 =

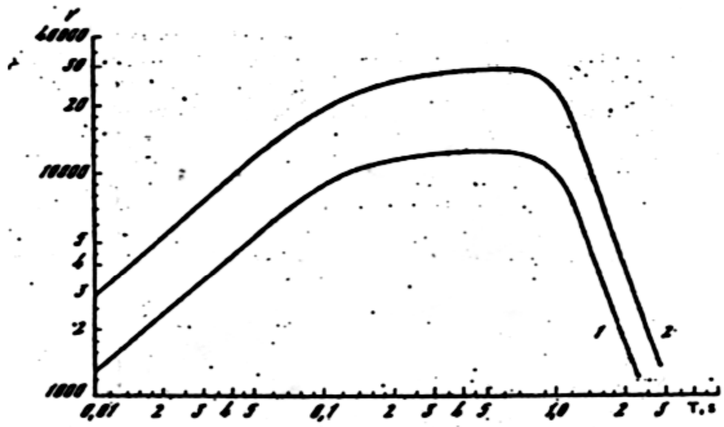

Fig. 9. Average magnification curves of seismographs at Juaragua (1) and Ariza and Botanic Garden (3).

≃ 30,000 in the period range 0.1-1 s.

Ariza. The noise measurement sites are shown in Fig. 6. The seismic systems were set up at point 2. The noise spectrum at this site is plotted in Fig. 7. The seismic systems was operated at a magnification $V_0 \simeq 30{,}000$ in the period range 0.1-1 s.

Juragua. Typical noise spectrum for the Juragua region is shown in Fig. 8. The seismic system was operated at a magnification of $V_0 = 10{,}000$ in the period range 0.05-1 s.

The data on microseismic noise at sites chosen for installation of seismic systems made it possible to use seismograph systems with SKM-3 seismometers and GK-VII galvanometers having standard type II magnification curves [2] operating at maximum magnification of approximately 12,000 at the Juragua site and approximately 30,000 at the Ariza and Botanic Garden sites. The mean magnification curves of seismographs are shown in Fig. 9. Maximum deviations between magnification curves of horizontal and vertical component seismographs at each site did not exceed 5%.

During the operation period between February and December 1978 the network of seismic systems recorded up to 150 seismic events per month. It recorded both distant and regional earthquakes as well as local seismic exploration and industrial explosions. A total of approximately 150 distant earthquakes, approximately 50 regional earthquakes and more than 600 local events were recorded.

The seismic systems reliably recorded 80 kg explosions at distances up to 10 km and 2 t explosions, at distances up to 100 km. The results of processing of records of explosions show that this corresponds to reliable recording of seismic events with energy class $K \geq 7$ within a radius on the order of 100 km from the Juragua Nuclear Power Plant region, thus verifying optimal capabilities of the network of seismic systems. Such networks make it possible to acquire data to evaluate seismic danger at nuclear power plant sites.

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