



Soviet-era science, translated into English

Reports of the Academy of Sciences of the USSR

1963

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Fig. 1

Figure 1: Fig. 1

Abstract**Full Text****Reports of the Academy of Sciences of the USSR**

1963. Volume 153, No. 1

GEOPHYSICS**D. N. RUSTANOVICH****ON THE MECHANISM OF THE ASHGABAT EARTHQUAKE OF 1948, BASED ON MATERIALS FROM GEOPHYSICAL INVESTIGATIONS***(Presented by Academician D. I. Shcherbakov, 20 VI 1963)*

The earthquake of October 6, 1948, destroyed the capital of Turkmenia, Ashgabat, and populated localities in the adjoining regions. The epicenter of the earthquake was located in the northern foothills of the Kopet-Dag*, near the city of Ashgabat. The intensity of the earthquake in the epicentral zone reached 9 points. The magnitude was $M = 7.0$.

The distribution of displacement signs in the body waves caused by the Ashgabat earthquake at seismic stations of the Soviet Union and abroad showed that the compressive stresses acted in a direction almost perpendicular to the strike of the principal structures of the Kopet-Dag (Fig. 1). Of the two possible rupture planes, the first (*I*), a vertical variant of displacements, is excluded by the following data: 1. The results of repeated leveling (see below) indicated insignificant vertical displacements. 2. In the study of the destructive effects of the Ashgabat earthquake, vertical displacements were not observed as prevailing. 3. Geologically, the vertical variant contradicts the differentiation of vertical movements that is taking place.

Fig. 1. *a* —direction of the axes of the principal stresses along line *AB*. *b* —two possible rupture planes (*I* and *II*) and the directions of displacements along them in a vertical section passing through the focus along *AB* (after E. I. Shirokova)

The second (*II*) variant of horizontal displacements is confirmed by the basic

Fig. 2. Map of aftershock epicenters of the Ashkhabad earthquake.

Figure 2: Fig. 2. Map of aftershock epicenters of the Ashkhabad earthquake.

data: 1. Analyzing the aftershocks of the Ashgabat earthquake on the basis of the materials of the 1948 expedition ⁽¹⁾, the authors note that the amplitudes of the transverse waves \bar{S} were an order of magnitude greater than the amplitudes of the longitudinal waves \bar{P} , from which they infer that the main process in the excitation of the earthquakes occurred at the expense of shear deformation. A very sharp onset of the transverse wave \bar{S} was also observed, which particularly emphasizes the shear mechanism of the initial shock ⁽¹⁾. 2. Macroseismic materials showed that the destruction was produced predominantly by the horizontal component of the force of the earthquake.

* In tectonic terms, the Ashgabat region is located at the junction of two major structural complexes: the epigercynian platform in the north and the Alpine geosynclinal region in the south. Between them lies the Fore-Kopet-Dag trough, which is a transitional zone in the form of a relatively narrow depression with a steep southern flank and a gentle northern one. The trough is filled with a thick sequence of Mesozoic deposits, represented by sandy-clayey and carbonate rocks, beneath which, according to geophysical data, at a depth of 10–12 km, a monolithic Paleozoic basement is presumed, composed of metamorphic crystalline rocks.

The Alpine folded structure of the Kopet-Dag is displaced toward the epigercynian platform. As a result of compressional deformations, various kinds of crumpling of soft strata may occur here—growth anticlines (for example, the Bakhchikhadzhay, Kishenibayr, Pervomaiskaya anticlines), movements of rock masses (limestones) of the nature of thrusts and strike-slip faults in the northern flank of the Kopet-Dag, and other tectonic disturbances of the upper structural stage, apparently without involvement of the Paleozoic crystalline basement. The tendency of the Kopet-Dag uplifted massif to advance northward leads to a concentration of maximum stresses in the boundary zone—the Fore-Kopet-Dag trough. This is the principal cause of the high seismic activity of the region.

3. Very considerable horizontal displacements were established everywhere by triangulation measurements throughout the entire epicentral region of the earthquake. Their magnitude is almost six times greater than the leveling data. In 1952 a repeated class II leveling line was run along the Tedzhen—Krasnovodsk line ⁽²⁾. A zone of maximum uplift, +0.329 m, was noted northwest of Ashkhabad. A zone of subsidence, –0.219 m, was noted to the southeast of it.

Fig. 2. Map of aftershock epicenters of the Ashkhabad earthquake. *a* —seismic stations of 1949, —stations of 1953, —outcrops of bedrock, —axes of anticlines, —focal depth, —energy class

Thus, the western wing of the mobile block rose, while the eastern one subsided.

Fig. 3

Figure 3: Fig. 3

The city of Ashkhabad was located in the zone where positive and negative displacements of the earth's surface changed over. At 100 km north of Ashkhabad the elevation of the benchmarks remained unchanged.

High-precision triangulation measurements showed that in the region of the Ashkhabad earthquake the triangulation points underwent a maximum horizontal shift in a direction predominantly toward the north-northeast, by an amount from 0.7 to 1.78 m (!) with a decrease of deformation at the edges of the displaced block; moreover, the greatest horizontal shifts of the earth's crust, up to 1.78 m, occurred in the central part of the epicentral region of the Ashkhabad earthquake (Fig. 4)*.

Registration of aftershocks by the Ashkhabad seismic station began several days after the destructive earthquake. From October 20 to November 15 the station registered, with various azimuths to the epicenters (from 45 to 330°), 138 aftershocks, of which 8 of intensity 4-7 were registered with epicentral distances up to 35 km (¹). This indicated that the foci of the aftershocks were loca-

* The Ashkhabad first-class triangulation base network was laid out in 1945-1946. To estimate horizontal displacements, repeated high-precision triangulation measurements were made in 1958-1959 (³). To confirm the angular discrepancies in this region, triangulation was carried out twice according to the programs of classes I and II. An adjustment was made of the chain of second-class triangulation triangles between first-class points that had not undergone displacement as a result of the Ashkhabad earthquake and were taken as fixed. As G. N. Pevnev showed, the mean square error in the positions of the triangulation points was within 5 cm (maximum 15 cm). Repeated measurements of the base, located in the SW-NE direction in the Anau region, established its shortening by 5 cm.

were localized over a small area. A sharp decrease in the number of local shocks with time and an attenuation of their intensity were noted.

The study of the aftershocks of the Ashgabat earthquake by means of a network of seismic stations was carried out by the Geophysical Institute of the Academy of Sciences of the USSR in 1949 and 1953 (⁴, ⁵). Applying a more refined method, the author processed the materials of the 1953 expedition and redetermined the foci of the aftershocks of the 1949 expedition (⁵). The results of the processing

Fig. 3. Projection of earthquake foci onto a vertical section through the Pre-Kopetdag trough along the strike of the line of epicenters *CD* (compiled from seismic-prospecting and seismological materials (⁵). Geological basis—after I. A. Rezanov).

1—Neogene and Quaternary deposits, 2—Paleogene, 3—Upper Cretaceous, 4—Ap-

Fig. 4. Diagram of the mechanism of movements of the Ashgabat earthquake.

Figure 4: Fig. 4. Diagram of the mechanism of movements of the Ashgabat earthquake.

tian and Albian stages, 5—Upper Jurassic and Neocomian, 6—presumed Lower and Middle Jurassic, 7—Paleozoic, 8—fault of the northern slope of the Kopet-Dag, 9—fault at the contact of Mz and Pz deposits, along which, during the Ashgabat earthquake, a horizontal displacement occurred.

showed that the entire epicentral region of the aftershocks of the Ashgabat earthquake occupied a very limited area. The epicenters were localized in it predominantly in two closely spaced zones of meridional strike—west and east of Ashgabat (Fig. 2). The transverse belt of epicenters to the north apparently characterizes the limits of propagation of the tectonic disturbances. The release of stresses in the zones continued to remain considerable.

Study of the distribution of foci with depth showed that most of the aftershock foci in the zones considered lay at depths within 10–12 km (Fig. 3). Their position suggests that there were no disturbances of equilibrium at deeper horizons and that the principal movements did not extend beyond the roof of the crystalline basement. Such a distribution of aftershock foci indicates that the main disturbances during the Ashgabat earthquake occurred as a result of a rupture of continuity at the contact between the crystalline basement and the sedimentary cover.

The seismological and geodetic data presented show that the Ashgabat earthquake occurred in the zone of maximum coupling of the Kopet-Dag and the Pre-Kopetdag trough. Under the influence of the lateral horizontal pressure of the Kopetdag thrust, when the shearing stress exceeded the strength of the rock contact, a horizontal displacement of the “soft” sedimentary Meso-Cenozoic sequence occurred in the trough along the roof of the “rigid” crystalline Paleozoic basement. The principal rupture and maximum displacement appeared in the central area near Ashgabat and to the north of it. Here the residual stresses were completely relieved (there are no aftershock epicenters); in the area significant horizontal displacements of the Earth’s crust occurred, and on the Earth’s surface 9-point destruction was produced ⁽⁶⁾.

The displacement of the “block” occurred from south to north along two zones of rupture disturbances transverse to the strike of the Kopet-Dag, expressed by epicenters along the lines $D—C$ and $E—F$ (Fig. 2)*.

As the leveling data showed, in the course of the movements the western wing of the “block” was raised, while the eastern one subsided.

A comparison of seismological and geodetic materials is given in Fig. 4. The epicenters of aftershocks are given for foci with $K = 9$ and 10, where $K = \lg E$ (joules).

Fig. 4. Diagram of the mechanism of movements of the Ashgabat earthquake. 1 —horizontal displacements; the maximum displacement corresponds to 1.78 m; 2 —curve of relative horizontal displacements; 3 —curve of vertical displacements; 4 —epicenters of aftershocks; 5 —seismic stations of 1949 and 1953; 6 —the Kopetdag anticlinorium and the younger zone of the eastern Kopet-Dag (after I. A. Rezanov); 7 —9-point isoseist of the earthquake (after S. V. Medvedev)

The observed high seismic activity of the Ashgabat region shows that the Pre-Kopetdag piedmont trough has not completed its formation. With the continuing development of tectonic processes, the mechanism of earthquake formation here may involve not only processes of sliding (slipping) along the surface of the basement, analogous to the case considered, but also various rupture deformations.

The author expresses gratitude to M. V. Gzovskii for valuable advice.

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

Received
18 VI 1963

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* According to G. P. Gorshkov, in the piedmont belt in the area of old Nesa and west of the Firyuza gorge (zone $D-C$), young tectonic ruptures of meridional and northwestern direction have been identified, deforming the cover of loess-like loams.

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