STRONG AND DESTRUCTIVE EARTHQUAKES AND SEISMIC ACTIVITY OF THE AZERBAIJAN SSR AND THE CASPIAN WATER AREA

By

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SYNOPSIS

The paper presents the main results obtained in studying seismic activity, the maximum possible earthquakes, macroseismical data, and the seismological features of strong and destructive earthquakes for the purpose of seismic zoning of the region under study.

During the period of 1961 to 1972 up to 20 strong and destructive earthquakes occurred within the territory of the Azerbaijan SSR as well as in the adjoining territories and in the Caspian water area /1,2,a.oth./. The seismic effects of many of these earthquakes have been evaluated according to the MSK-64 scale /3/. It has been established that the distribution of the numbers of buildings according to this scale based on the amount of damages inflicted on them is close to the normal distribution /4/. Starting from this, a method of seismic microzoning has been developed, based on the extents to which the buildings are damaged. The method has been developed with the use of the results obtained while analyzing macroseismical data on a number of strong and destructive earthquakes of Middle Asia, Azerbaijan, and Yugoslavia /4–8/. For the first time the method has been used within the territories of the towns of Makhachkala (Dagestan), Skople (Yugoslavia) /5,6/ and in many areas of Baku /4,7/. Based on the average values of the degrees of damages determined from representative selected data on various types of buildings in areas with different geological engineering conditions, a convertion was accomplished to the earthquake manifestation intensity in terms of magnitudes /7,10/.

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Thus one can determine the intensity increment due to the types of structures and the soils under their foundations /4,5/. The direct statistical method of seismical microzoning allows also to establish the dependence of the extent to which buildings can be damaged by earthquakes on the ground water level and the surface slope /4-10/. The relative increase of the extent of damages in cases of major slopes of up to 70° consisting of rocky grounds may reach an average value of up to 1.5, whereas in cases of slopes of up to 60° consisting of non-rocky grounds the average value amounts up to 2. The extent of damages also grows when the buildings are located on hills, or near high river banks and scarps; it also depends on the orientation of the slopes and buildings with respect to the earthquake focus, and on other factors too /7,10/.

For the purpose of studying the earth structure with the use of the earthquake investigation results based on the established relationships /4-10/, all the above factors distorting the macroseismic field of an earthquake are eliminated. Such a reduction of macroseismic data to a single average "level"(i.e. to average geological engineering conditions for a representative type of buildings, etc.) allows to obtain isoseismic line shapes predetermined mainly by the structure of the focus zone and the tremor area /1,11/. As shown by the macroseismic data on a number of strong and destructive earthquakes studied in Azerbaijan and in the Caspian water area (Fig.1) during the last 11 years, distinct zones stand out in which over large areas sharp increases are observed in the attenuation coefficient of the intensity of seismic oscillations. These zones are in good correlation with the well-known West-Caspian and East-Kura deep faults oriented submeridionally, and the Vandam deep fault having a close-to-latitudinal trend /1,11,12/. From the macroseismic data one can also determine the spatial arrangement of the fault (the depth of occurrence and penetration, and the fault plane dip) to a sufficient accuracy (±0.5 km as compared with the data obtained by deep seismic sounding)/11/.

The high seismicity (A_{10}=0.07, =-0.45) and the arrangements of earthquake epicentres and seismically active zones of the region under study (obtained from instrumental data for 1951-1970) are confined mainly to the transition zones of major tectonic structures and faults /13/. The activity level of the Great Caucasus zones (0.5 A_{10} 1.0) is higher than that of the Kura depression zones (A_{10} 0.5). A relatively low seismic activity amounting to A_{10} 0.05 is observed in the Caspian water area (Fig.2). It is reflected to a certain extent on the map of $K_{max.}$, the maximum possible earthquakes of Azerbaijan and the

Caspian water area (Fig.3). The map has been developed on the basis of the correlative relationship between the activity A_{10} and $K_{max.}$ found for this region: $\bar{A} = 2.74 + 0.22$ ($K_{max.} \geq 15$). As can be seen from the $K_{max.}$ map (Fig.3), the depression zones are characterized by the absence of epicentres of destructive earthquakes in the past and by no indications that such earthquakes are expected to occure in future. For example, in the Kura depression, earthquakes mainly with K 13 occurred, in the Caspian water area, earthquakes with K 14 have been recorded, whereas in the eastern part of the Great Caucasus the earthquakes are characterized by K 16-17 (the earthquakes of the eastern part of the Minor Caucasus are known to be those with K 15-16).

The above distribution of zones characterized by strong and destructive earthquakes of the past, and that of the zones of possible future earthquakes are accounted for to a certain by the mechanisms of the foci (by the distribution of axes of strains active in them) and by the geological features of the foci zones. The territory of Azerbaijan and its adjoining areas are included in the part of the Asian-Mediterranean seismic belt which, according to the map of elastic strains of the Earth /14/, is in a state of horizontal non-uniform compression oriented mostly at right angles to the structures. This regularity manifests itself in the earthquake foci of the Great Caucasus and the Apsheron Peninsula (Fig.3). However, the areas of both the Caspian Sea and the Kura depression, in the earthquake foci of which strains of horizontal extention are active mostly at right angles to the structure strikes, represent a kind of impregnation of continental rift zones in the geosyncline areas of the mountain regions of the Caucasus and Middle Asia /15,16/. It has been established that the ultimate shearing strength of mountain rocks under compression is 10 to 15 times as high as that under extension conditions /18/. Therefore, it can be deemed that the energy released by an earthquake focus in an area of relative compression is higher than that released by an earthquake focus in the case of extension, all other things being equal to the geological features of foci zones: the earthquakes of the Great Caucasus involved mainly horizontal shifting movements along the planes of powerful thrusts and overthrust sheets, and planes of contact between sedimentary beds and consolidated parts of the Pre-jurassic base; the Caspian and Kura earthquakes - vertical shifts to shear in zones of tectonic steps-deep faults (Fig.4). An analysis of the geotectonic features has also shown an additional load above the seismogenic suture in the pleistoseist zones of the majority of strong and destructive earthquakes of the Caucasus (the Shemakha, Zangezur, Zurnabad and other earthquakes), the additional load being due to thick over-

thrust sheets, young intrusive or effusive bodies, as well as to the replacement of the lithofacies of plastic rocks by dense and competent rocks /18/. Thus, where the seismogenic suture is covered with dense and competent rocks, the tectonic shift requires additional energy to overcome the weight of the rocks covering the suture. Calculations have shown that the geostatic pressure exerted on the seismogenic suture of the southern slope of the Great Caucasus characterized by the strong earthquakes of Shemakha, Gori, and Telavi, is twice as high as that in the Zakatali, Vartashen, and Kutkashen zones having a relatively slight seismic manifestation.

Investigation of the modern seismic dislocations in the Shemakha zone has allowed to reveal their being genetically different from usual Holocenic fissures. The former have a high entrenchment amplitude and extend to long distances, sometimes including bedrocks (shales, clay-marl). They represent a series of parallel fissures (spaced at 1 to 1.5 km) or fissures substituting each other in an echelon-like way and extended along the pleistoseist zones of strong and destructive earthquakes (Fig.4). In their expansion range they adhere to the tectonic disturbance zones of high seismic activity. It has been established that the modern formation of seismic dislocations takes place within the zones of strong and destructive earthquakes. In cases of earthquakes of magnitude seven, seismic dislocations are encountered as landslides, long-formed break-off fissures, downfalls, hillside wastes, and soil disturbances. In earthquakes of magnitude nine, series of fissures (extension fractures, compression joints and other types) are formed, which affect bedrocks too.

In the authors' opinion, the data presented in this paper are eventually importance for forecasting of seismic effects exerted on buildings and structures.

REFERENCES

1. Sh.S.Ragimov. Problems involved in studying the Earth structure, Baku, 1966.

2. Earthquakes in the USSR in 1968. The "Nauka" Publ.House, Moscow, 1971.

3. S.V.Medvedyev. The International Scale of Seismic Intensity. See the book "Seismical Zoning in the USSR", Moscow, 1968.

4. N.V.Shebalin, F.T.Kuliyev. On the possibility of statistical interpretation of earthquake magnitudes. See Coll.Art."Strong Earthquakes in Middle Asia and Kazakh-

stan",Dushanbe,1970.

5. N.V.Shebalin,Yu.V.Bistritskaya,R.A.Levkovich,I.L.Revelis. The earthquake of May 14,1970 and its manifestation in the territory of the town of Makhachkala.See Coll.Art. "Seismical Microzoning of Makhachkala",Makhachkala,1970.

6. N.V.Shebalin,M.Stoikovich. Local intensity effects within the territory of the town of Skople and the focus of the earthquake of June 26,1963.Voprosi inzhenernoi seismologii ("Problems of engineering seismology"), Issue 15,Moscow 1972.

7. F.T.Kuliyev. A direct statistical method of seismical microzoning."Voprosi inzhenernoi seismologii"("Problems of engineering seismology"),Issue 13,Moscow,1970.

8. N.V.Shebalin. On the macroseismical basis of seismical microzoning."Voprosi inzhenernoi seismologii" ("Problems of engineering seismology"),Issue 13,Moscow,1970.

9. F.T.Kuliyev,Sh.S.Ragimov. Methods of seismical microzoning based on analyzing the seismic effects exerted on buildings and structures. Heads of reports presented to the All-Union High-School Conference on Providing Seismically Stable Structures. Tashkent, 1966.

10. F.T.Kuliyev. Dependence of the extent of building damages by earthquakes on the surface slope (based on macroseismic data). Transactions of the Institute of Geology of the Acad.of Sci.of the Azerbaijan SSR"),Baku, 1972.

11. F.T.Kuliyev,I.V.Anan'yin,O.B.Baba-zade. The problem of studying earth crust faults with the use of macroseismic data. DAN Azerb.SSR,No.12,1969.

12. R.A.Agamirzoyev,E.K.Gyul'. On deep-seated structures of Azerbaijan,using macroseismic data as the basis. Proc. of the sitting of the Interministerial Council on Seismology and Seismically Stable Construction,Moscow, 1971.

13. V.I.Kulikov,F.T.Kuliyev,V.A.Kasparov. Seismically active zones of Azerbaijan relative to the earth crust structure and development.Heads of reports presented to the 8th General Assembly of the European Seismological Committee (in English),Brashov (Rumania),1972.

14. L.M.Balakina,A.V.Vvedenskaya,L.A.Misharina,Ye.I.Shirokova. Strained states in earthquake foci and the Earth field of elastic strains.Izv.AN SSSR,"Fizika Zemli",

No.6,1967.

15. E.B.Agalarova. Orientational features of strains active in the earthquake foci of the Apsheron Peninsula and the Caspian Sea, Izv.AN SSSR, "Fizika Zemli",No.7, 1969.

16. E.B.Agalarova. On the orientation of strains in the earthquake foci of the Kura lower-course lowland. Izv.AN SSSR, "Fizika Zemli", No.2,1971.

17. A.M.Viktorov. Ultimate strength of mountain rocks when compressing along the cylinder generatrix. See Collection of articles "Physico mechanical properties of mountain rocks in the upper part of the earth crust". The "Nauka" Publishing House, Moscow, 1968.

18. R.A.Agamirzoyev. The geological conditions and the mechanisms of strong earthquakes in the Shemakha zone. Proceedings of the sitting of the Interministerial Council on Seismology and Seismically Stable Construction, Moscow,1971.

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FIGURE CAPTIONS for the paper "STRONG AND DESTRUCTIVE EARTHQUAKES AND SEISMIC ACTIVITY OF THE AZERBAIJAN SSR AND THE CASPIAN WATER AREA"

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Fig.1 - Map of isoseist of strong earthquakes of Azerbaijan during 1961-1971 (based on data obtained by Sh.S. Ragimov,V.P.Kuznetsov,F.T.Kuliyev,R.A.Agamirzoyev, and oth.).

Fig.2 - Map of earthquake epicentres and seismic activity of the Azerbaijan SSR and the Caspian water area during 1951-1970 (drawn up by F.T.Kuliyev a.V.A.Kasparov).

Fig.3 - Map of maximum possible earthquakes, $K_{max.}$ (drawn up by F.T.Kuliyev a.V.A.Kasparov) and orientations of the axes of the main strains in the earthquake foci of Azerbaijan and the Caspian water area (based on data obtained by E.B.Agalarova a.Ye.I. Shirokova).

Fig.4 - Map of modern seismic dislocations in the Shemakha zone.
1- macroseismic epicentre and year of earthquake;
2- isoseists,magnitude and year of earthquake;
3- mud volcanoes; modern seismic dislocations;
4- overthrusts and upthrusts;
5- extensions;
6- off-splits;
7- moving apart;
8- soil disturbances;
9- downfalls,hillside wastes;
10- landslides;
11- supposed hypocentre of earthquake;
12- tectonic profile breaks (drawn up by R.A.Agamirzoyev).

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КАРТА ИЗОСЕЙСТ СИЛЬНЫХ ЗЕМЛЕТРЯСЕНИЙ АЗЕРБАИДЖАНА ЗА 1961-1972

THE MAP OF ISOSEISTS OF STRONG EARTHQUAKES OF THE AZERBAIJAN SSR BY 1961-1972

КАРТА ЭПИЦЕНТРОВ ЗЕМЛЕТРЯСЕНИЙ И СЕЙСМИЧЕСКОЙ АКТИВНОСТИ АЗЕРБАЙДЖАНСКОЙ ССР И АКВАТОРИИ КАСПИЯ ЗА 1951-1970гг.
THE MAP OF EPICENTRES OF EARTHQUAKES AND OF SEISMIC ACTIVITY OF AZERBAIJAN SSR AND A WATER AREA OF THE CASPIAN SEA BY 1951-1970

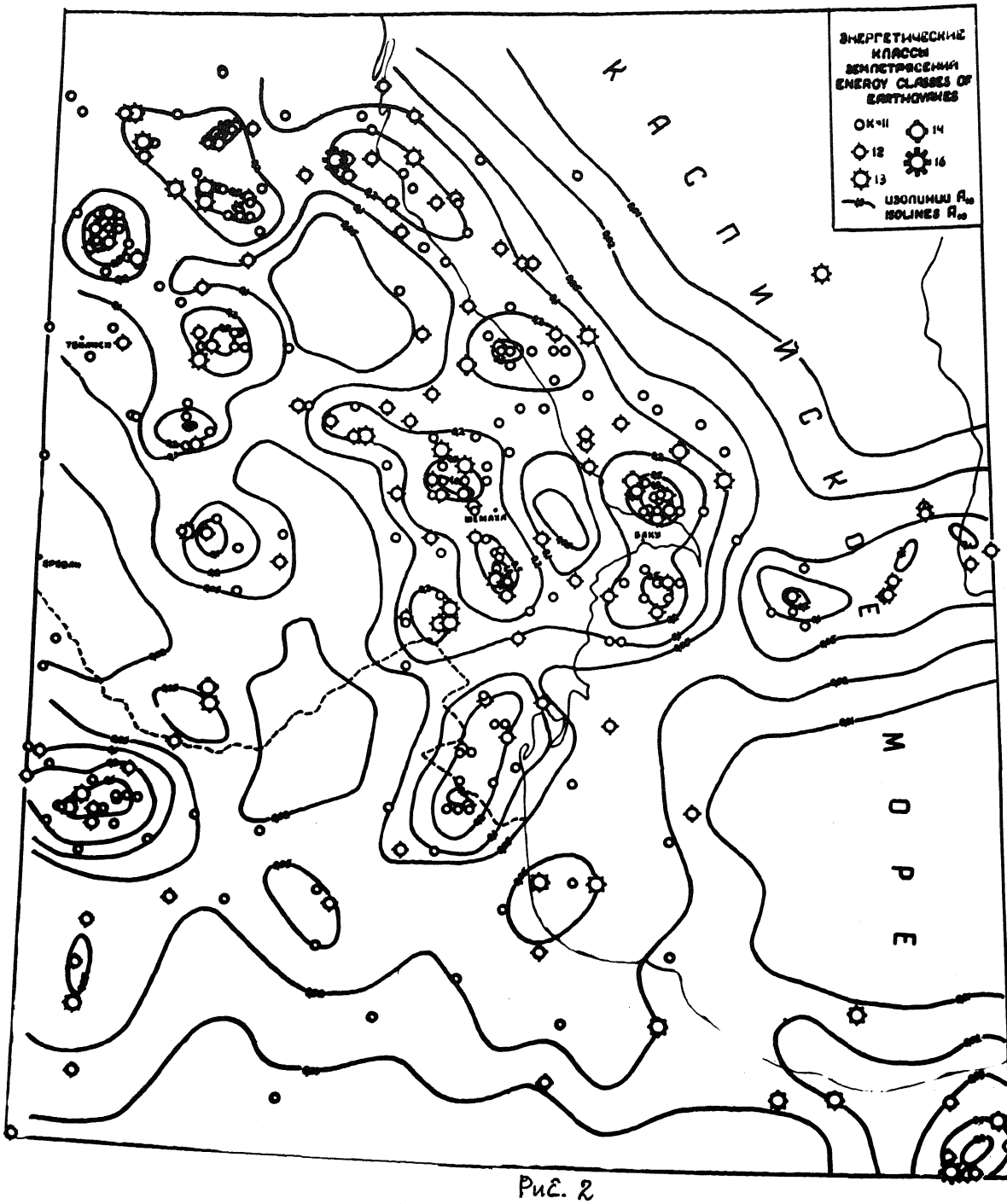
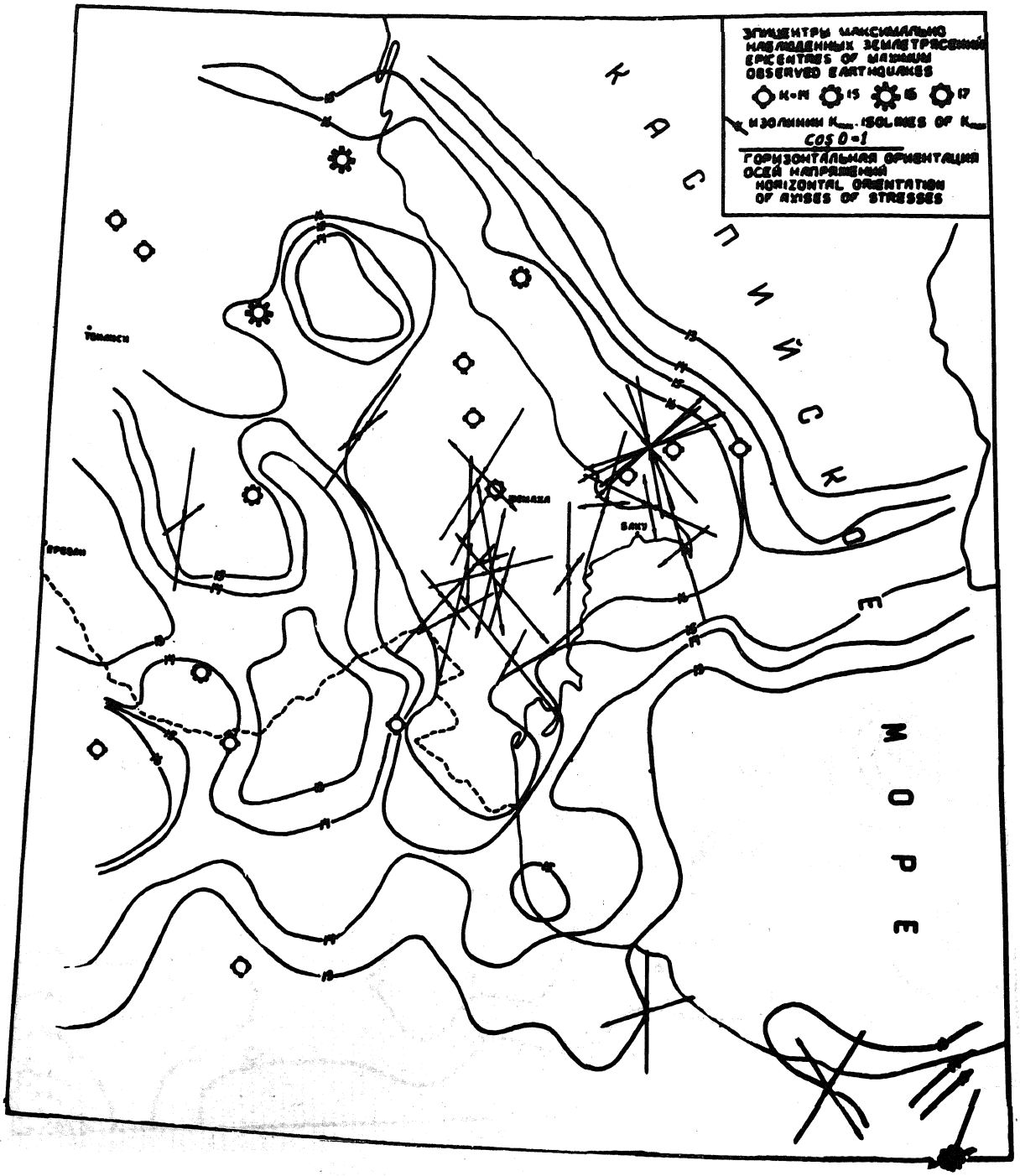


Рис. 2

КАРТА МАКСИМАЛЬНЫХ ВОЗМОЖНЫХ ЗЕМЛЕТРЯСЕНИЙ (K_{max}) И ОРИЕНТАЦИЙ ОСЕЙ ГЛАВНЫХ НАПРЯЖЕНИЙ В ОЧАГАХ ЗЕМЛЕТРЯСЕНИЙ АЗЕРБАЙДЖАНА И АКВАТОРИИ КАСПИЯ
THE MAP OF MAXIMUM POSSIBILITY EARTHQUAKES (K_{max}) AND ORIENTATIONS OF AXISES OF MAIN STRESSES IN FOCUSES OF EARTHQUAKES OF AZERBAIJAN AND A WATER AREA OF THE CASPIAN SEA



КАРТА СОВРЕМЕННЫХ СЕЙСМОДИСЛОКАЦИЙ ШЕМАХИНСКОЙ ЗОНЫ И ГЕОЛОГИЧЕСКИЕ РАЗРЕЗЫ

THE MAP OF RECENT SEISMODISLOCATIONS OF SHEMAKHA ZONES AND GEOLOGICAL SECTIONS