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ON THE SEISMICITY AND SEISMIC POTENTIAL OF THE ZHAMBYL REGION OF KAZAKHSTAN

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Abstract. The article is devoted to the analysis of the seismic situation in the territory of Zhambyl region. To ensure the safety of the population, it is important to specify the level of seismic hazard, which is associated with the rapid growth of urbanized areas. Conducted Regional and local seismicity of the Zhambyl region were studied. The earthquake representativeness is estimated by accumulating the number of earthquakes over different observation periods. Macroseismic manifestations of strong earthquakes and patterns of attenuation of the intensity of concussions in the study area are studied. Maps of earthquake epicenters and epicenter densities were constructed, which led to the conclusion that the main seismic activity is observed in the southern and southeastern parts of the region, confined to the Kyrgyz and Talas Alatau ranges, with the western end of the Ile

Alatau and with the transition to the Shu-Ili Mountains. In the eastern and western parts of the Zhambyl region, seismic activity is moderate, while the northern part of the territory is characterized by a relatively low level of seismicity. Maps of probabilistic seismic hazard assessment (VSO) for the territory of Zhambyl region in MSK-64(K) scores were developed using the Open Quake Engine software. Maps are presented in two versions: a) - with a probability of exceeding the estimated intensity of earthquakes of 10% within 50 years (the average period of occurrence of earthquakes of 475 years); b) - with a probability of exceeding the estimated intensity of earthquakes of 2% within 50 years (the average period of occurrence of 2475 years). Thus, the seismic potential of the Zhambyl region is quite high – the possible magnitudes of strong earthquakes with foci in these zones are up to 6.5, while the intensity of concussions in the south of the region can reach up to 8-9 points. Maps of probabilistic seismic hazard assessment (VSO) for the territory of Zhambyl region in MSK-64(K) points have been developed and can be used in the development of building codes and regulations during construction.

Keywords: earthquake, seismicity, seismic regime, isoseists, seismic generating zones, seismic hazard

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ЖАМБЫЛ ОБЛЫСЫНЫҢ СЕЙСМИКАЛЫҚ ЖАҒДАЙЫ МЕН СЕЙСМИКАЛЫҚ ҚАУІПТІЛІГІ ЖАЙЛЫ

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Анотация. Мақала Жамбыл облысындағы сейсмикалық жағдайды талдауға арналған. Халықтың қауіпсіздігін қамтамасыз ету үшін сейсмикалық қауіптілік деңгейін нақтылау өзекті мәселе болып табылады, өйткені урбанизацияланған аумақтардың жылдам өсуі байқалады. Жамбыл аймағының аймақтық және жергілікті сейсмикалығы зерттелген. Жер сілкіністерінің өкілдігін бағалау әртүрлі бақылау кезеңдеріндегі санының жиналуы әдісімен жүргізілді. Қуатты жер сілкіністерінің макросейсмикалық көріністері және тербеліс интенсивтілігінің әлсіреуі заңдылықтары зерттелді. Жер сілкіністерінің эпицентрлері мен эпицентрлер тығыздығының карталары құрылып, оның негізінде аймақтың оңтүстік және оңтүстік-шығыс бөліктерінде сейсмикалық белсенділік байқалатыны туралы қорытынды жасалды, бұл белсенділік Қырғыз, Талас Алатауы, Іле Алатауының батыс сілемдері мен Шу-Іле тауларына жақын орналасқан. Жамбыл облысының шығыс және батыс бөліктерінде сейсмикалық белсенділік орташа, ал солтүстік бөлігінде салыстырмалы түрде төмен сейсмикалық деңгей байқалады. Open Quake Engine бағдарламалық жасақтамасын пайдалана отырып, Жамбыл облысы аумағында сейсмикалық қауіптіліктің ықтимал бағасы (СҚИ) карталары MSK-64(K) балдарында жасалды. Карта екі нұсқада ұсынылған: а) – 50 жыл ішінде жер сілкінісінің есептелген интенсивтілігінің 10%-дан асып кету ықтималдығымен (жер сілкіністерінің орташа қайталану кезеңі 475 жыл); б) – 50 жыл ішінде жер сілкінісінің есептелген интенсивтілігінің 2%-дан асып кету ықтималдығымен (орташа қайталану кезеңі 2475 жыл). Осылайша, Жамбыл облысының сейсмикалық потенциалы өте жоғары – осы аймақтардағы күшті жер сілкіністерінің магнитудалары 6,5-ке дейін жетуі мүмкін, ал облыстың оңтүстік бөлігінде тербеліс интенсивтілігі 8-9 баллға дейін жетуі мүмкін. Жамбыл облысының аумағы үшін ықтимал сейсмикалық қауіптілік карталары (СҚИ) MSK-64(K) балдарында құрылып, құрылыс нормалары мен ережелерін әзірлеу кезінде пайдаланылуы мүмкін.

Түйін сөздер: жер сілкінісі, сейсмикалықтық, сейсмикалық режим, изосейстер, сейсмогенераторлық аймақтар, сейсмикалық қауіп

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О СЕЙСМИЧНОСТИ И СЕЙСМИЧЕСКОМ ПОТЕНЦИАЛЕ ЖАМБЫЛСКОЙ ОБЛАСТИ КАЗАХСТАНА

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Аннотация. Статья посвящена анализу сейсмической обстановки на территории Жамбылской области. С учётом быстрого роста урбанизированных территорий актуальной является задача уточнения уровня сейсмической опасности для обеспечения безопасности населения. Изучены региональная и локальная сейсмичность Жамбылского региона. Представительность землетрясений оценена по динамике накопления их числа за различные периоды наблюдений. Рассмотрены макросейсмические проявления сильных землетрясений и закономерности затухания интенсивности сотрясений. На основе построенных карт эпицентров и их плотности установлено, что основная сейсмическая активность наблюдается в южной и юго-восточной частях региона, приуроченных к хребтам Киргизскому, Таласскому Алатау, западным окончаниям Иле Алатау и Шу-Илийским горам. Восточная и западная части области характеризуются умеренной сейсмической активностью, а северная — относительно низким уровнем сейсмичности. С использованием программного обеспечения OpenQuake Engine разработаны карты вероятностной оценки сейсмической опасности (ВОСО) в баллах MSK-64(K): а) при вероятности превышения расчётной интенсивности сотрясений 10% в течение 50 лет (период повторяемости 475 лет); б) при вероятности превышения 2% в течение 50 лет (период повторяемости 2475 лет). Таким образом, сейсмический потенциал Жамбылской области достаточно высок: возможные магнитуды сильных землетрясений достигают 6,5, а интенсивность сотрясений на юге региона — до 8–9 баллов. Разработанные карты ВОСО могут быть использованы при подготовке строительных норм и правил для проектирования сооружений на сейсмоопасных территориях.

Ключевые слова: землетрясение, сейсмичность, сейсмический режим, изосейсты, сейсмогенерирующие зоны, сейсмическая опасность

Introduction. The specifics of the natural conditions of the Zhambyl region are such that none of its residents are immune from the seismic hazard and the associated risk of a strong earthquake. In modern conditions, the relevance of this problem is growing due to population growth, the construction of high-rise buildings, and the increasing number of objects of strategic importance and the development of settlements in the region. The official map of the general seismic zoning of Kazakhstan was created in 2017. According to the map 80% of the region's

territory is affected by earthquakes with the intensity of shaking the earth's surface from 6 to 8 points. Thus, to ensure seismic safety of the population, it is necessary to conduct detailed seismic zoning of this territory. Studies of the regional and local seismicity of the Zhambyl region were carried out according to the catalogues of strong and weak earthquakes.

In this paper, the seismic hazard assessment is carried out using modern methodologies and analysis tools, as well as the most complete and up-to-date information available for the territory under consideration. Conducting analysis in a probabilistic setting and for quantitative parameters is a new direction for Kazakhstan. For solved this aim was used the Open Quake Engine program («Open Quake Engine» software) - an open software for calculating seismic hazard and risk.

Materials and methods of research. The information base of the research was catalogues of strong and weak earthquakes in the Zhambyl region and adjacent territories, which were compiled from macroseismic and instrumental data. Reliable macroseismic data have been available since the second half of the 20th century. Regional instrumental observations of the Zhambyl region and adjacent areas have been carried out since 1927, and detailed observations (by a network of highly sensitive stations) have been carried out since 1950. Studies of the regional and local seismicity of the Zhambyl region were carried out according to the catalogues of strong and weak earthquakes in the south and south-east of Kazakhstan compiled at the National Scientific Center for Seismological Observations and Research based on the data of the Republican Seismological Network, in addition, the unified catalog of Tien Shan earthquakes (Dzhanuzakov et al., 1997), created by seismologists of Kazakhstan, Kyrgyzstan and the Seismological Bureau of the XUAR of the People's Republic of China, as well as a catalog of earthquakes in Central Asia (Earthquakes in Northern Eurasia in 1992-2000, 1997-2004). Further refinement of the earthquake catalog was carried out within the framework of the international projects CASRI and EMCA (Mikhailova et al., 2003). To assess the seismic hazard, we used the "Representative Earthquake Catalog", released in early 2022 as part of the CASHA (Central Asia Seismic Hazard Assessment (CASHA)) project. The listed data made it possible to create a single earthquake catalog for the study area. It should be noted that in some catalogues, the classification of earthquakes by magnitude is performed using magnitude, and in others-using energy scales. To switch from energy efficiency (according to Rautian) scales to the magnitudescale, the relations of their interrelation obtained in the works (Mikhailova, et al.,1986;1999):

$$K=1.8\ MLH+4.0\ (M<5.5); \quad (1)$$
$$K=1.5\ MLH+5.6\ (M\geq 5.5)$$
$$K=5.44+1.52\ MS\ (K>12.6);$$
$$MS=1{,}0MLH-0{,}1;$$
$$K=2.13\ MPVA+0.66;$$

where K=lgE (J) is the energy class of the earthquake; MS is the magnitude determined from the vertical component of the surface wave using medium-period

equipment; MLH is the magnitude determined from the horizontal components of the surface wave using medium – period equipment; MPVA is the magnitude determined from the vertical component of the longitudinal wave using short-period equipment in the near (MPVA) zone.

When studying the seismic situation, the reliability of conclusions significantly depends on the representativeness of earthquakes for different periods of observation, separately for strong and weak earthquakes. At the same time, great importance is attached to the assessment of the K-minlevel, which is associated with the practical majority of seismic events in the Zhambyl region in the earthquake catalog since the early 50s, since this level changes over time due to changes in seismic observation systems. Data on strong earthquakes are more reliable due to their presence over a longer period of time. The estimation of their representativeness in the Zhambyl region was carried out by accumulating the number of earthquakes for different observation periods, which correlates well with the main stages of development of seismological observations in Central Asia and Kazakhstan. To estimate the representativeness of weak earthquakes, the following parameters of the seismic regime were used: time series of earthquakes with foci of different energies (Nk), graphs of the accumulation of earthquake numbers with different K(ΣNk) and their ratios (ΣNk/ΣNk+1).

In this paper, the seismic hazard assessment is carried out using modern methodologies and analysis tools, as well as the most complete and up-to-date information available for the territory under consideration. Conducting analysis in a probabilistic setting and for quantitative parameters is a new direction for Kazakhstan, which continues to develop and improve methodically, taking into account the world achievements implemented in the Open Quake Engine program (Open Quake Engine) - an open software for calculating seismic hazard and risk. This software is developed, maintained, and distributed by the Global Earthquake Model Foundation (GEM), which uses the methodology (VSO) originally proposed by Cornell (Cornell, 1971), but using the methodological formalism of Field et al (Field, et al, 2003).

Results. *Elements of tectonics.* The region is susceptible to strong earthquakes with foci located both on the territory of the region itself and beyond. Local foci are confined mainly to mountainous areas in the south of the region, which belong to the so-called young tectonic structures[*)]. Tectonic movements here are very intense, which creates an increased level of seismic activity. The Karatau Mountains in the west of the region, which belong to the ancient (Caledonian-Hercynian) folding, which has already passed its active phase, are more calm in terms of seismic activity. "Overgrown" and consolidated faults predominate here, so the level of seismicity is relatively low (Bekzhanov, et al., 2000). The Shu-Ili Mountains in the east of the region are also tectonically part of the very ancient Caledonian fold of the Central Asian Fold Belt. The centers of "transit" earthquakes are associated with seismically active zones in Uzbekistan, Kyrgyzstan and the Almaty region of Kazakhstan.

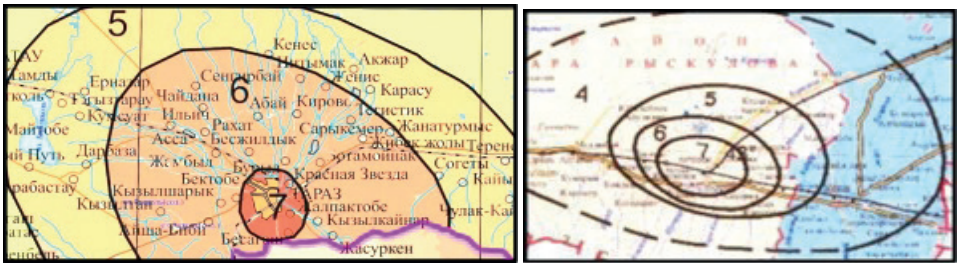
Seismic history of the region. According to information (Nurmagambetov, et al., 2006), the first reliable mention of a strong earthquake in the Zhambyl region dates back to March 22, 1865. The source of this earthquake was located in the foothills of the Kyrgyz range at a distance of ~25 km from the village of Merke. In the epicenter, the intensity of Earth's surface tremors was ~ 8 points, and in the village of Merke-7-8 points.

The devastating Belovodsk earthquake, which occurred on August 3, 1885 with its epicenter in the northern foothills of the Kirghiz range, as a result of which the settlements of Kirghizia Belovodsk and Karabalty were completely destroyed, was manifested in the territory of Zhambyl region with an intensity of concussions up to 6-7 points. So, in Merka, it appeared with an intensity of 6 points, and in Zhambyl-5 points. The most reliable information is available about the Tashkent earthquake of January 31, 1908 with a magnitude of M=5.3, which was recorded by the Tashkent seismic station operating at that time. Its epicenter was located at a distance of ~15-20 km south of Zhambyl (now Taraz), where the intensity of concussions was 7 points, and in the city itself it manifested with an intensity of 6-7 points.

On October 30, 1930, in the west, and on September 27, 1937, in the east of the region, significant earthquakes occurred with approximately the same intensity in the epicenter (about 6 points).

Since then, until 1971, strong earthquakes with foci in the region and near it were not observed. However, at different times, transit earthquakes were felt here, the epicenters of which were located in adjacent seismically active zones. The most significant event in the seismic history of the Zhambyl region is the strong earthquake of May 10, 1971. Its epicenter was located on the southern outskirts of the city of Zhambyl, in the zone of junction of the Kyrgyz ridge with the city of Karatau (Fig. 1a). This earthquake was felt in the vast territory of Central Asia. In the epicentral zone, it appeared with an intensity of up to 7 points.

13 years later, on February 2, 1984, residents of Zhambyl felt another strong underground shock, but with much less force than in 1971. Its epicenter almost coincided with the epicenter of the May 10, 1971 earthquake. This time, the intensity of the concussion was one point less than in the previous one, and mainly old buildings that had deformations from the earthquake of May 10, 1971 were affected.



a) b)

Fig. 1-Diagram of the distribution of concussions as a result of an earthquake (isoseist maps): a-May 10, 1971; b-May 23, 2003.

On May 23, 2003 in T. Ryskulov region was another strong earthquake, named Lugovskoe. Its epicenter was located in the area of Lugovoye station and it was an extremely important event in seismic life not only in Zhambyl region, but also in Kazakhstan as a whole. The significance of this earthquake was determined primarily by the severity of its consequences. As a result of the earthquake, three people were killed. In a limited area within the epicentral zone, the intensity of its manifestation on the Earth's surface reached 7-8 points. After the main impact, many aftershocks occurred, the number of which reached 40 in the first day alone (Fig.1b).

Based on the analysis of the above data on the manifestation of strong earthquakes, a scheme of consolidated isoseists is constructed, reflecting the total picture of the distribution of the observed concussions on the Earth's surface (Fig. 2). The basis of this scheme consists of isoseists of both local and transit earthquakes, which manifested themselves with the greatest intensity in the territory under consideration.

Thus, during the period from 1865 to the present, one earthquake occurred in the territory of Zhambyl region with the intensity of concussions in the epicenter I_0=8 points, one-with the intensity in the epicenter I_0=7-8 points, two-with I_0=7 points, and five earthquakes with I_0= 6 points. In addition, numerous transit earthquakes were felt with the intensity of shaking the earth's surface of 6-5 or less points.

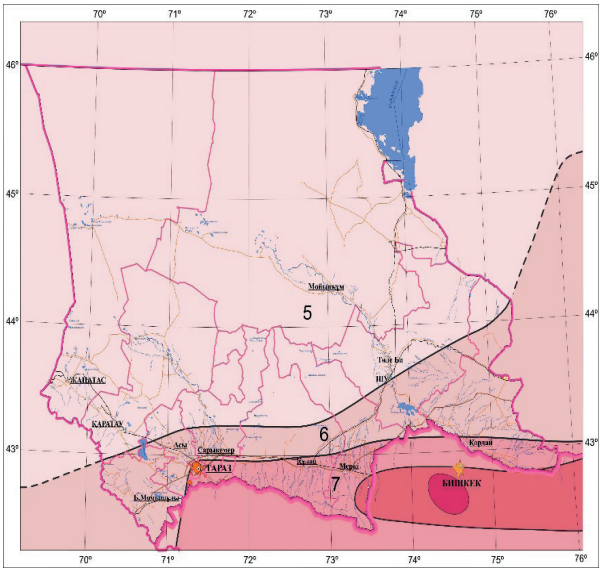


Fig.2 Map of the maximum concussion intensity observed on the territory of the region (figures – concussion intensity in points)

Modern seismic environment. A strong earthquake is a rare event and it is very difficult to assess the level of the current seismic situation in a particular area. Weak tremors come to the rescue. Based on them, you can quickly accumulate

observational material that is sufficient for statistical conclusions. This material can be compared with data for strong earthquakes and find common patterns for both. In addition, a detailed study of the entire population of earthquakes, both strong and weak, can help in assessing the degree of seismic hazard for individual territories and in developing methods for predicting strong earthquakes.

Seismic stations annually register many weak tremors in the region, the foci of which are unevenly distributed. As we can see from the figure (Fig.3), with such a chaotic arrangement of epicenters of weak shocks, it is very difficult to identify certain patterns in their distribution. In general terms, it can be concluded that the main seismic activity is observed in the southern part of the region, in the eastern and western parts it is moderate, and the northern part of the territory is characterized by a relatively low level of seismicity.

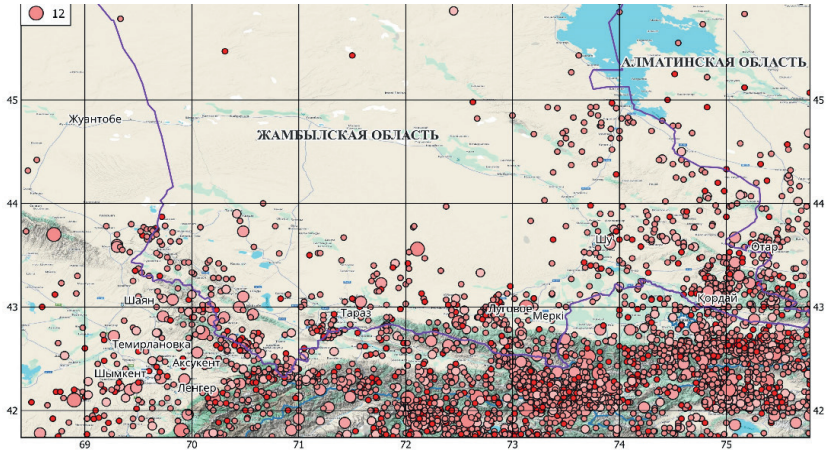


Fig.3 Map of earthquake epicenters with K=7.6÷12.5 (M≤4.8) from 1961 to 2024

A more visual picture of the spatial distribution of seismicity is provided by the map of the density of earthquake epicenters (Fig. 4). This density map shows the epicenters of major earthquakes that have occurred. As you can see, the highest density of epicenters is characterized by the southern regions of the region, confined to the zone of the Kyrgyz ridge. Local maxima of epicenter density are observed in the areas of the Shu-Ili Mountains, near the village of Merke, Taraz and khr. Karatau. The Shui Valley is characterized by the lowest values of epicenter density. The lines of maximum density of epicenters are oriented in the near-latitude, north-eastern, and north-western directions. Near-latitude epicenter density anomalies are mostly confined to the Kyrgyz Ridge and extend eastward to the Ile and Kungei Alatau ridges. The density lines of the epicenters of the northwestern strike are quite clearly visible in the west (Karatau Cr.) and in the east (Shu-Ili Mountains).

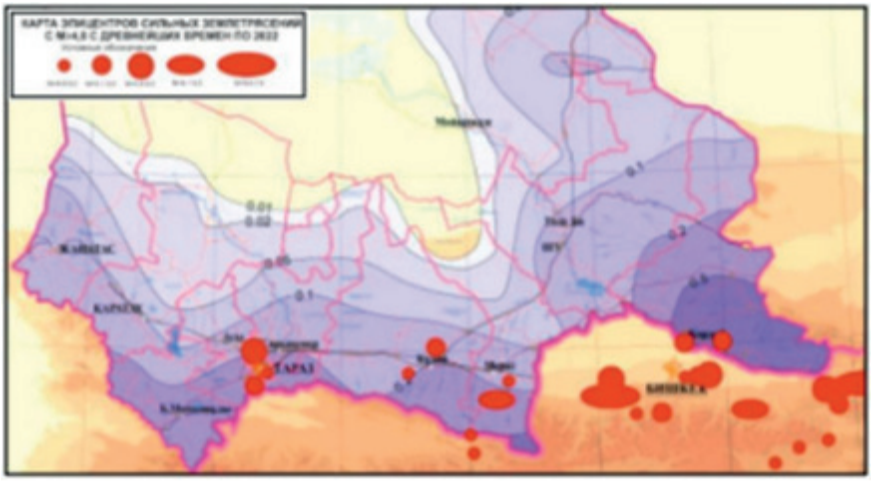


Fig. 4 Map of the density of earthquake epicenters with epicenters strong M≥4.8 from earliest times to 2022

As we can see from Figure 4, in those places where strong earthquakes occurred, the density of epicenters of weak tremors is relatively high. This is one of the fundamental patterns of the spatiotemporal distribution of weak earthquakes.

Indicators of the level of current seismic activity in the region as a whole and individual seismically active zones are parameters of the seismic regime, which are estimated using the earthquake repeatability graph (Sydykov, 2004; Sadykova, 2012). Figure 5 shows graphs of earthquake frequency for the Northern Tien Shan territory as a whole and for individual zones for which there are sufficient initial data for plotting. As can be seen from this figure, the graphs are straight in the range of energy classes K=8-13. The level of seismic activity in the eastern part of the Kyrgyz Range is comparable to the level of seismic activity in the territory of Ile-Kungei Alatau.

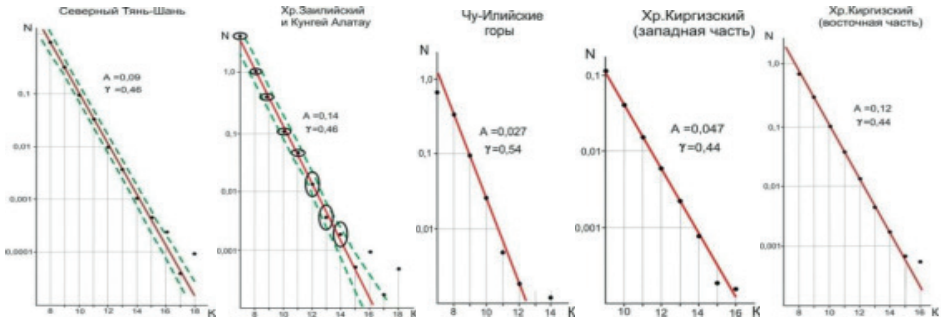


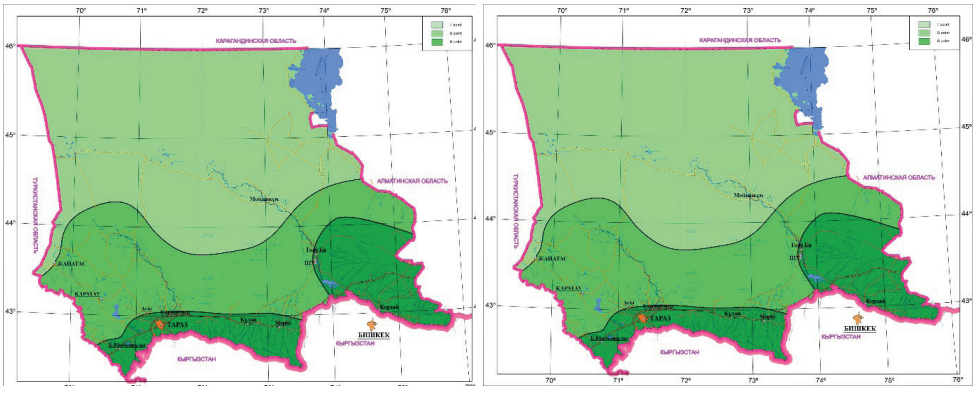
Fig. 5. Graphs of earthquake frequency for different seismically active zones of the region

Discussion

Assessment of the level of seismic hazard is aimed at identifying the seismic generating zones, determining the parameters of their seismic regime, and finally calculating the seismic effect on the earth's surface created by them. These studies are based on a detailed and comprehensive study of the deep structure of the Earth's crust, seismotectonics, regional seismicity, and engineering seismology.

In the practice of seismic hazard assessment, two approaches are used: deterministic and probabilistic. The deterministic campaign was the standard and was used in Kazakhstan in earlier times, until the end of the 20th century. In the 21st century, the second approach is mainly used – probabilistic, which brings the domestic methodology closer to the international one, which has long been generally accepted in many countries when assessing seismic hazards. The methodology of seismic hazard assessment based on the probabilistic approach applied to seismically active regions of Kazakhstan is described in some detail in a number of publications (Silacheva et al, 2023; Allen et al, 2012; Bindi et al, 2011). In general terms, it is reduced to determining the maximum seismic impacts expected with a certain probability in a given territory in a given time interval and due to the frequency of earthquakes.

Following this methodology, using the Open Quake Engine software (Open Quake Engine software), taking into account linear and areal sources, probabilistic maps of the seismic hazard assessment of the Zhambyl region were obtained for two probability levels of 10% and 2% over 50 years in points of the MSK-64(*K*) scale, which are presented on a scale of 1:1,000,000 in Figures (Fig.6 a, b).



a) b)

Fig. 6 - Maps of seismic hazard assessment for the territory of the Zhambyl region in points of the MSK-64(K) macroseismic scale with a probability of exceeding the calculated intensity: a -10% for 50 years (average repeatability period of 475 years); b-2% for 50 years (average repeatability period of 2475 years)

As can be seen from the map for the 475-year repeatability period of seismic shocks (Fig.6a), the maximum intensity of concussions (9 points) occurs in a small area south of. Merke village (western dip of the Kyrgyz ridge) and in the north-east

of Kordai village (Shu-Ili Mountains). The less intense (8-point zone) is extended in a north-northeasterly direction. The map for the period of occurrence of seismic shocks of 2475 years (Fig.b) differs markedly from the previous one, where the zones of shocks occupy large areas. So, the area of the 7-point zone practically extends up to the northern borders of the region.

Conclusion

To study the nature of seismicity and its manifestation in the territory of Zhambyl region, an information seismological database was formed based on macroseismic materials and regional catalogs of earthquakes of various levels. The sufficient length, uniformity, and high quality of these data made it possible to analyze the patterns of seismicity occurrence on large spatio-temporal scales, and the computer-readable form of catalogs made it possible to use various methods of mathematical statistics for their analysis. Spatial and temporal patterns of earthquake occurrence are investigated not only within the Zhambyl region, but also on a larger scale - within a single seismically active belt, which is more appropriate when studying the nature of the seismic process, and which is difficult or even impossible to do with only local or regional studies. Analysis of macroseismic consequences of strong earthquakes and maps of isoseists of the region under consideration and adjacent seismically active zones according to historical data showed that in the historical period of time, the magnitude of seismic impacts in the territory of Zhambyl region reached 7-8 points. A comparative analysis of the results on the spatial distribution of the density of foci of numerous weak earthquakes and epicenters of strong earthquakes ($M \geq 4.8$) showed that the latter are confined to areas with high densities or to their marginal parts. The seismic hazard assessment of the territory of Zhambyl region was carried out in a probabilistic setting and for quantitative parameters using the Open Quake Engine - an open software for calculating seismic hazard and risk, which is a new direction for Kazakhstan.

Thus, the potential seismic hazard of the territory of the Zhambyl region is determined by the seismogenic zones in the south and southeast of the territory, geographically connected with the Kyrgyz and Talas Alatau ranges, and the western end of the Ile Alatau range, which passes into the Shu-Ili Mountains. The seismic potential of these zones is quite large – possible earthquake magnitudes, with foci in these zones, reach up to M=6.5, while the intensity of concussions in the south of the region can reach up to 8-9 points.

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