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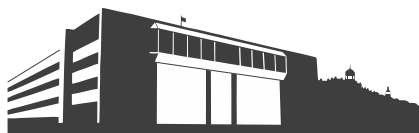
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МАЗМҰНЫ/ CONTENTS/ СОДЕРЖАНИЕ

<i>Абақанов Т., Ли А., Садыров Р., Абақанов А.</i> Қазақстандағы сейсмикалық қауіпсіздіктің жай-күйі мен перспективалары	
<i>Abakanov T., Lee A., Sadyrov R., Abakanov A.</i> Seismic safety state and prospects in Kazakhstan	
<i>Абақанов Т., Ли А., Садыров Р., Абақанов А.</i> Состояние и перспективы сейсмической безопасности в Казахстане	8
<i>Абдығалиев А.Е., Жакулин А.С., Жакулина А.А., Тоимбаева Б.М.</i> Су қаныққан негіз топырақтарының сипаттамалары	
<i>Abdygaliyev A.E., Zhakulin A.S., Zhakulina A.A., Toimbaeva B.M.</i> Water saturated foundation soil Features	
<i>Абдығалиев А.Е., Жакулин А.С., Жакулина А.А., Тоимбаева Б.М.</i> Характеристики водонасыщенных грунтов основания	17
<i>Алдуңгарова А., Жусупбеков А., Абишева А.</i> Іргетас деформацияларының құрылыс құрылымдарының тұрақтылығына әсері	
<i>Aldungarova A., Zhussupbekov A., Abisheva A.</i> Influence of deformations of foundations on the stability of building structures	
<i>Алдуңгарова А., Жусупбеков А., Абишева А.</i> Влияние деформаций фундаментов на устойчивость строительных конструкций	25
<i>Ашкей Е., Жусупбеков А.Ж., Досмухамбетова Б.К.</i> Талдау тығыздағыш тор «ЭКСПО-2017» (Нұрсұлтан, Қазақстан) құрылыс алаңы жүктеме астындағы сынақ талдамасы	
<i>Ashkey E., Zhussupbekov A.Zh., Dosmukhambetova B.K.</i> Analysis of O-Cell Loading Piling Test at construction site of Expo 2017, Nur-Sultan, Kazakhstan	
<i>Ашкей Е., Жусупбеков А.Ж., Досмухамбетова Б.К.</i> Анализ испытания свай по результатам O-Cell метода на строительной площадке ЕХРО-2017, Нур-Султан, Казахстан	40
<i>Жакулин А.С., Жакулина А. А., Жаутикова С. А., Есентаев А. У.</i> Қазақстан Республикасының құрылыс нормаларында «Геотехника-7» Еурокодын бейімдеу	
<i>Zhakulin A.S., Zhakulina A.A., Zhautikova S.A., Yessentayev A.U.</i> Adaptation of Eurocode «Geotechnics-7» in the Building Norms of the Republic of Kazakhstan	
<i>Жакулин А.С., Жакулина А. А., Жаутикова С. А., Есентаев А. У.</i> Адаптация Еврокода «Геотехника-7» в строительных нормах Республики Казахстан	48
<i>Жусупбеков А., Шин Е.Ч., Шахмов Ж., Тлеуленова Г.</i> Топырақты топырағын мұздату және еріту кезінде модельдік қадаларды эксперименттік зерттеу	
<i>Zhussupbekov A., Shin E.Ch., Shakhmov Zh., Tleulenova G.</i> Experimental investigations of model pile in freezing and thawing of soil ground	
<i>Жусупбеков А., Шин Е.Ч., Шахмов Ж., Тлеуленова Г.</i> Экспериментальные исследования модельной сваи при промерзании и оттаивании грунтового грунта	56
<i>Ивасаки Я., Петухин А., Танырбергеннова Г., Жусупбеков А.</i> Алматы метрополитені тұрғысынан Осакадағы жасырын ақауға және Кобе жер сілкінісінен болатын зақымға қарсы Метрополитен жүйесін Асейсмикалық жобалауға шолу	
<i>Iwasaki Y., Petukhin A., Tanyrbergenova G., Zhussupbekov A.</i> Overview of Aseismic Design of Subway System against Hidden Fault in Osaka and Damages by Kobe Earthquake in terms of Almaty Subway	
<i>Ивасаки Я., Петухин А., Танырбергеннова Г., Жусупбеков А.</i> Обзор асейсмического проектирования системы метрополитена против скрытого разлома в Осаке и повреждений от землетрясения в Кобе с точки зрения Алматинского метрополитена	62

<i>Кадыралиева Г.А., Джакунбеков Б.Т.</i> Тау-кен жұмыстарының әсер ету аймақтарындағы құрылыстардың орнықтылығын бағалау ерекшеліктері	
<i>Kadyralieva G.A, Dzhaqunbekov B.T.</i> Assessment peculiarities of the constructions stability in the areas of affected by mining operations	
<i>Кадыралиева Г.А., Джакунбеков Б.Т.</i> Особенности оценки устойчивости сооружений в зонах воздействия горных работ	74
<i>Калякин В.Н.</i> Анизотропты топырақтарға арналған Пуассон коэффициенттеріне қатысты кейбір бақылаулар	
<i>Kaliakin V.N.</i> Some Observations Regarding Poisson's Ratios for Anisotropic Soils	
<i>Калякин В.Н.</i> Некоторые наблюдения относительно коэффициентов Пуассона для анизотропных грунтов	83
<i>Линг Хое И., Линг Генри</i> Супертайфун кезінде жауын-шашыннан туындаған беткейдің бұзылу мысалы	
<i>Ling Henry, Ling Hoi I.</i> A Case Study of Slope Failure Induced by Rainfall During Super-Typhoon	
<i>Линг Хое И., Линг Генри</i> Пример разрушения склона, вызванного осадками во время супертайфуна	101
<i>Ли Лиминг, Хунг Чи-Яо</i> Түйіршікті ағын мен шекаралық эрозияны центрифугалық модельдеу	
<i>Liming Li, Chi-Yao Hung</i> Centrifuge modelling on granular flow and boundary erosion	
<i>Лиминг Ли, Чи-Яо Хунг</i> Центрифужное моделирование зернистого потока и пограничной эрозии	110
<i>Нозаки Т.</i> Жол теміржол тіреу қабырғаларына қадаларды сығымдау әдісі	
<i>Nozaki T.</i> Press-in Piling Method for Road/ Railway Retaining Walls	
<i>Нозаки Т.</i> Способ прессования свай для дорожных железнодорожных подпорных стенок	120
<i>Сонг К.Р., Ченг А.Х-Д., Остаз А.Аль, Мантена Р.</i> «Катрина» дауылынан кейінгі жағдай салдарының экономикалық тиімді модернизация әдістеріне екпін беруі	
<i>Song C.R., Cheng A.H-D., Ostaz A.Al, Mantena R.</i> Lessons Learned from Hurricane Katrina – With Emphasis on Cost Effective Retrofitting Techniques	
<i>Сонг К.Р., Ченг А.Х-Д., Остаз А.Аль, Мантена Р.</i> Уроки, извлеченные из урагана «Катрина» – с акцентом на экономически эффективные методы модернизации	127
<i>Тельтаев Б.Б., Суппес Е.А.</i> «Алматы-Бишкек» автомобиль жолының жер төсеміндегі температура мен ылғалдылық	
<i>Teltayev B.B., Suppes E.A.</i> Temperature and moisture in subgrade of the highway «Almaty-Bishkek»	
<i>Тельтаев Б.Б., Суппес Е.А.</i> Температура и влажность в земляном полотне автомобильной дороги «Алматы-Бишкек»	134
<i>Түлебекова А.С., Жусупбеков А.Ж., Жанкина А.К.</i> ASTM және ГОСТ стандарттары бойынша қадаларды сынау әдістері	
<i>Tulebekova A.S., Zhussupbekov A.Zh, Zhankina A.K.</i> Methods of testing pile by ASTM and GOST Standards	
<i>Түлебекова А.С., Жусупбеков А.Ж., Жанкина А.К.</i> Методы испытаний свай по стандартам ASTM и ГОСТ	141
<i>Шакирова Н., Жусупбеков А., Алибекова Н., Морев И., Боргекова К.</i> Бұрғыланған қадалардың тұтастығын екі әдіспен тексеру: төмен деформация әдісі және көлденең ұңғымалық акустикалық каротаж-қолдану тәжірибесі	150
<i>Shakirova N., Zhussupbekov A., Alibekova N., Morev I., Borgekova K.</i> Checking Integrity of Bored Piles Using Two Methods: Low Strain Method and Cross-Hole Sonic Logging - Experience of Application	150
<i>Шакирова Н., Жусупбеков А., Алибекова Н., Морев И., Боргекова К.</i> Проверка целостности буронабивных свай двумя методами: методом низких деформаций и поперечным скважинным акустическим каротажем – опыт применения	150



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Seismic safety state and prospects in Kazakhstan

Abstract. *A review of seismological studies in Kazakhstan is given, the condition, prospects and some results of research conducted by the Institute of seismology of the Republic of Kazakhstan. This investigation are important for understanding of the seismic safety statement of Republic of Kazakhstan. The paper presents of the history and present proceedings of seismic activity of different regions of Kazakhstan.*

Keywords: *earthquakes, seismic, deformation, monitoring, observation.*

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Seismic quiescence, currently observed in the territory of Kazakhstan, is temporary. Indisputably, probability of occurrence of violent earthquakes in the territory of Kazakhstan in the future is rather high. Especially the area of the Northern Tien Shanm, which encompasses the territory of Almaty region, including the Kazakhstan's largest megapolis - Almaty, is one of the most endangered regions for earthquakes in the whole Central Asia. In 1887, 1889 and 1911 three destructive earthquakes happened there, two of which (Chilikskoe 1889 and Keminskoe 1911) had a magnitude over eight, and were ranked as global seismic catastrophes. It should be specially noted that, according to the leading researcher's estimates, approximately 40 times more energy released from the source of the Keminskoye 1911 earthquake than from the source of the Armenian (Spitak, 1988) earthquake, which claimed the lives of 41 thousand people and shocked the world with its well-known deplorable consequences.

During the last two decades, more than 10 strong earthquakes with seismic intensity level over 7, occurred in the territory of Kazakhstan.

Special attention is paid to the southeastern territory of Kazakhstan by the seimologists, where the city of Almaty is situated and where the probability of powerful earthquakes has been rather high since 2016.

Kazakhstan and China are active in predicting earthquakes. The Institute of Seismology marks out the following three stages in its earthquake forecast:

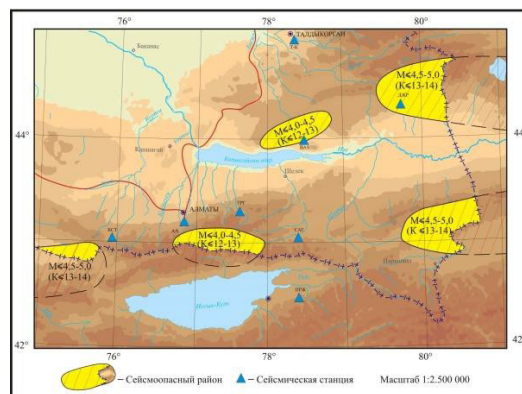
- long-term (from 5 to 7 years); medium-term (up to 1 year); short-term (up to 7 days).

However, the earthquake forecasting covers only the area of the city of Almaty and Almaty region. The matter is that the representative observation network for qualitative medium- and short-term forecasting was created only for the earthquake-prone Almaty region.

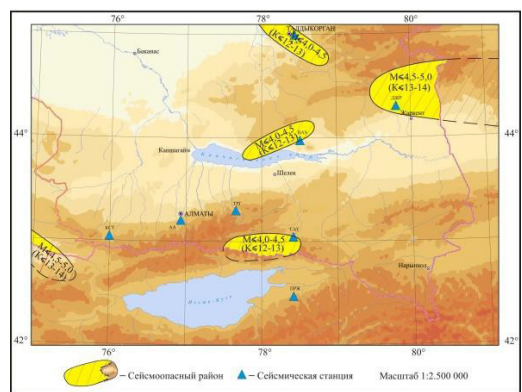
In terms of long-term and medium-term prediction of earthquakes, the Kazakhstani seismologists made certain progress. The long- and medium-range earthquake forecasts within recent years, including 2004, were hold up. The Institute predicted no severe earthquakes for the mentioned territory, but marked out areas, where weak seismic events with seismic intensity up to level 7 according to the MSK-64 international seismic scale are probable. At the beginning of every year, including 2014, that data was timely furnished to relevant decision-making authorities. Figure 1 demonstrates the medium-term earthquake forecast 2011-2014, which is to be presented at the start of every year to relevant decision-making authorities of the Republic of Kazakhstan [1-4].

Various factors, having effect on activation of powerful seismic processes, constitute a subject of in-depth investigations. According to [5], collection, processing, analysis and interpretation of the data set, which shows consistence between the 11-year solar activity variations and stressed-deformed state of the earth's crust in the local earthquake endangered territory of the Northern Tien Shan, posing the highest threat to the city of Almaty, as well as retrospective data of confinedness of the most violent earthquakes in the territory to the period of the long-term minimum solar activity (Gleisberg Minimum), evidence that probability of a strong earthquake in the territory under investigation presently increases. And, starting from 2016, it has been rather high. Short-term forecast of earthquakes is quite a complex, broad-spectrum and pressing problem of contemporary natural science. The issue of short-term forecast is rather of research than practical nature.

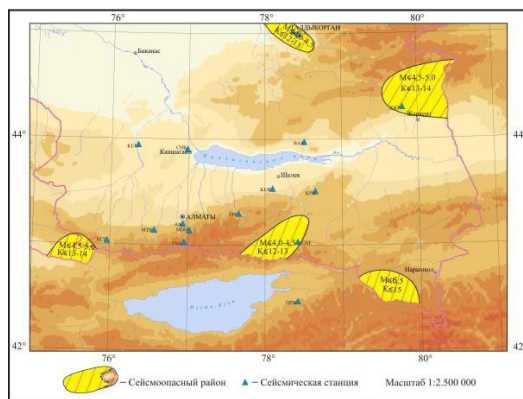
Absence of general premonitory symptoms, as well as instability of anomalous phenomena, preceding the earthquakes, predetermined the need for a package approach to its solution. For short-term forecasting of earthquakes, in the both countries - China and Kazakhstan - data of geomagnetic, electrotelluric, natural electromagnetic field variations; deformation parameters of debit, temperature, level and chemical composition of subterranean water; radon emanation and neutron flux emission rate; number of seismic microshocks; animal behaviour; sesismotectonic regime data taking into account the correlation between the geogenic and cosmogenic factors, is used [6-8].



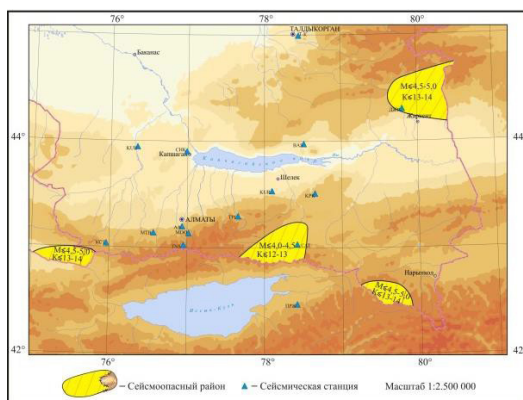
a) Map of Medium-Term Forecast of Violent Earthquakes for 2011



a) Map of Medium-Term Forecast of Violent Earthquakes for 2012



a) Map of Medium-Term Forecast of Violent Earthquakes for 2013



a) Map of Medium-Term Forecast of Violent Earthquakes for 2014

Figure 1. Map of Medium-Term Forecast of Violent Earthquakes for the Almaty Prognostic Testing Range over 2011-2014.

It is known that before powerful and destructive earthquakes, some prognostic parameters may change, and, accordingly, it is necessary to detect, decipher the same, and compare them with other prognostic parameters and to interpret them. It is a challenge for seismologists, and we tirelessly work on it. However, in the event of weak earthquakes, the prognostic parameters change rather slightly and do not manifest in the overwhelming majority of cases. It is no coincidence that the construction rules and regulations ignore earthquakes with intensity level below 7, as they pose no danger to the lives of people and facilities, other than beaten cob constructions, which may sustain damage and get cracks. For sure, the problem of short-term forecast of earthquakes requires extensive efforts, but there are also other not less fundamental and applied scientific problems in the field of seismology and antiseismic construction. For instance, seismic hazard assessment comprises development of seismic zoning maps of the territory of Kazakhstan and seismic microzoning maps for design and construction activities in the seismically active areas, where hazard sources and intensity of future earthquakes are given. Today the Institute of Seismology successfully works on the described problems.

At this period, the Institute is working on the implementation of the Research Programme «Development of the microseismic zoning map of the territory of Almaty on the basis of the new methodology.» The works will be completed in 2017. The map will be drawn according to international standards Eurocode 8 [9-10].

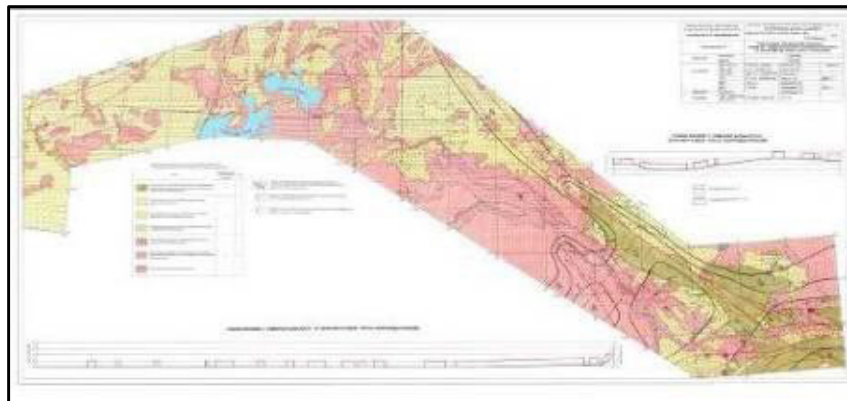
In 2015, the development of maps of seismic zoning of the Republic of Kazakhstan in accordance with international standards Eurocode-8 will be completed. Herein it should be noted that, unlike the known maps, the new set of maps in a deterministic and probabilistic positions, as well as in terms of peak accelerations, will be created [11].

Along with that, assessment works of the seismic hazard of national economic objects are carrying out (Figure 2).

The undisturbed operation of the oil and gas, mining and metallurgical complexes, operation and maintenance of the seismic safety of existing produce fields of hydrocarbons, where it is necessary to conduct permanent geodynamic (seismic) monitoring of produce fields, are the most important for the economic development of Kazakhstan. The effects of technogeneous earthquakes are presented on Figures 3 and 4.



a) The seismic zoning map of the oil pipe line Atasu- Alashankou



a) The seismic zoning map of the gas pipe line Beyneu – Shymkent

Figure 2. Assessment of the seismic hazard of national economic objects.



Figure 3. The effects of technogeneus earthquake in the area of Zhezkazgan on 01.08.1994 (M=4,7).



Figure 4. The effects of technogeneus earthquake in the area of Zhezkazgan on 24.06.2005 г. (M=3,9).

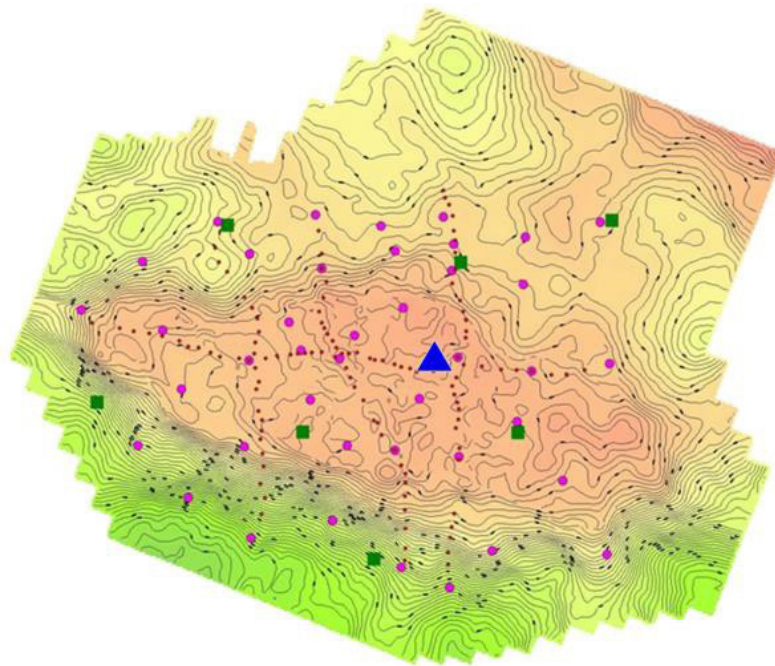


At the gas condensate field Karachaganak, the largest in Kazakhstan, the West Kazakhstan region Institute carries out continuous seismological monitoring, regularly gives recommendations for the safe hydrocarbon extraction. Here the development of new effective methods of monitoring the conditions of the resources on the territory of the field is the critical importance and currentness. For effective and focused monitoring of the geological environment the Seismology Institute has developed the methodology and the program of complex geodynamic monitoring and evaluation of the risk of seismo-deformational processes related to the development of the oil condensate field Karachaganak, which differ radically from the existing methods of controlling the resource conditions. If till that time the field only one or two types of research were monitored, then at the Karachaganak field, on the basis of the collection, processing, analysis and interpretation of the results of previous studies in the world and the Republic of Kazakhstan, it was proposed the comprehensive method of tracking the condition of the geological environment, consisting in the usage of all best practices including ground, mining method and satellite methods (Figure 5).

The complex geodynamic monitoring on the local site of the Karachaganak field will include, first of all, seismic observations of the manifestations of the natural and technogeneus seismics, as well as additional geodetic observations (satellite GPS and highly-accurate leveling) over the vertical and horizontal movements of the Earth's surface, geophysical (gravity, geomagnetic, geoelectric) and hydrogeodynamic observation.

The results of such complex monitoring will help to develop a field model, to conduct reliable control of geodynamic processes, to predict their evolution and to take the necessary measures to prevent technogeneus earthquakes.

Experimental and theoretical researches are intensively conducted to provide operational and seismic safety of strategic facilities, such as hydraulic and underground tunnels of underground



Map symbols:

- Earthquake-detection station
- Combined levelling and gravity station
- GPS station
- ▲ Cased hole for microseisms monitoring conduction

Figure 5. The map of geodynamical networking in the Karachaganak field.

railway systems, tunnels, water pipeline tunnels, industrial facilities like high-rise structures, ground oil storage facilities in the regions of extraction, processing and transportation of oil and gas [12-16].

The particular attention is paid to the problem of rapid response in case of a powerful earthquake.

In the Institute of Seismology of the Republic of Kazakhstan, the group of prompt response staff is organized for cases of powerful and destructive earthquakes in Kazakhstan.

Staff objectives are:

- Coordination of preventive measures in scientific and practical researches as for the treatment of powerful earthquakes;
- Operational collection and analysis of information about happened earthquake;
- Relationships with government and local authorities and the media;
- Assistance in the timely completion of epicentral and macroseismic investigations which take place after the earthquake.

The further development of the national system of seismic safety of the Republic of Kazakhstan is planned.

Therefore, National Center of Seismological Observations and Researches JSC (NCSOR JSC) was created; in the beginning it consists of LLP Institute of Seismology and LLP Seismological Experimental-Methodical Expedition. In future, it is planned to include of all organizations, involved, to any extent, into the problem of seismic safety in Kazakhstan to NCSOR JSC.

Planned course:

- Extensions of the seismological observation network in Kazakhstan twofold compared to the existing (to open 52 new seismic stations);
- Creation of a special international experimental center in Almaty region to study seismic processes and seismic stability of building objects;

- Providing of permanent geodynamic and engineering monitoring of the anthropogenic environment of the nuclear industry, oil&gas and mining&metallurgical complexes, as well as hydraulic engineering installations of the Republic of Kazakhstan;
- Ensuring of the seismic capacity of the main social infrastructure objects, life support systems, including educational and residential facilities located in earthquake-prone regions of the Republic of Kazakhstan.

In the event of a powerful earthquake in the city of Almaty, the backup Seismological Centre, which will collect in parallel information from the whole Kazakhstan, is planned to be created on the territory of Astana. In case of failure of the seismology system in Almaty due to the destructive earthquake, the backup seismological center in Astana, operating in the normal mode, will take the entire load.

Currently, the most representative network of seismological observations is concentrated in the region of Almaty, in the Southeast of Kazakhstan. In this regard, it is planned to open seismology branches in the South, the East and the West Kazakhstan regions.

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Аңдатпа. Мақалада Қазақстандағы сейсмологиялық зерттеулерге шолу, Қазақстан Республикасы Сейсмология институты жүргізетін зерттеулердің жай-күйі, перспективалары және кейбір нәтижелері берілген. Бұл зерттеулер «Қазақстан Республикасы сейсмикалық қауіпсіздігі туралы» ережені түсіну үшін маңызды. Мақалада Қазақстанның әртүрлі өңірлерінің сейсмикалық белсенділігінің тарихи және қазіргі заманғы зерттеулері ұсынылған.

Түйін сөздер: жер сілкінісі, сейсмикалық аймақ, деформация, мониторинг, бақылау.

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Состояние и перспективы сейсмической безопасности в Казахстане

Аннотация. Дан обзор сейсмологических исследований в Казахстане, рассмотрены состояние, перспективы и некоторые результаты исследований, проводимых Институтом сейсмологии Республики Казахстан. Эти исследования важны для понимания положения о сейсмической безопасности Республики Казахстан. В статье представлены исторические и современные исследования сейсмической активности различных регионов Казахстана.

Ключевые слова: землетрясения, сейсмика, деформация, мониторинг, наблюдение.

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