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DEVELOPMENT OF RESEARCH ON FORECASTING STRONG EARTHQUAKES IN THE NORTHERN TIEN SHAN

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ANNOTATION

The Tien Shan Mountain system is one of the most earthquake-prone areas in the Central Asian region, where the maximum strength of earthquakes reaches 10-11 points. Within its boundaries, several zones of possible occurrence of earthquake sources with a magnitude of 7-8.5 are identified. The main seismogenic structures are the North Tien Shan, Gissar-Kakshaal (Southern Tien Shan) and Central Tien Shan seismically active zones. The article discusses the main stages in the development of prognostic research in the Northern Tien Shan. The local telemetry network KNET, installed here in 1991, allows you to register earthquakes in digital form, collect and process seismic information in real time. Note that KNET has no analogues in the Central Asian region. At the same time, geophysical, geodynamic, hydrogeochemical, hydrodynamic and other types of monitoring observations are carried out in order to identify precursor anomalies of expected strong earthquakes.

Key words: telemetry network KNET, earthquake, seismicity, the Tien Shan Mountain system, epicenter map

ŞIMAL TYAN-ŞANDA GÜCLÜ ZƏLZƏLƏLƏRIN PROQNOZLAŞDIRILMASI ÜZRƏ TƏDQIQATLARIN INKIŞAFI

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XÜLASƏ

Tyan-Şan dağ sistemi Mərkəzi Asiya regionunda seysmik cəhətdən ən təhlükəli ərazilərdən biridir, burada zəlzələlərin maksimal gücü 10-11 bala çatır. Onun hüdudları daxilində 7-8,5 bal gücündə zəlzələlərin baş verə biləcəyi bir neçə zona var. Əsas seysmogen strukturlar Şimali Tyan-Şan, Hisar-Kakşaal (Cənubi Tyan-Şan) və Mərkəzi Tyan-Şan seysmik aktiv zonalarıdır.

Məqalədə Şimali Tyan-Şanda proqnostik tədqiqatların inkişafının əsas mərhələləri araşdırılır. 1991-ci ildə burada quraşdırılmış yerli telemetrik şəbəkə KNET zəlzələlərin rəqəmsal formada qeydə alınmasına, real vaxt rejimində seysmik məlumatların toplanmasına və emalına imkan verir. Qeyd edək ki, KNET-in Mərkəzi Asiya regionunda analoqu yoxdur. Eyni zamanda gözlənilən güclü zəlzələlərin xəbərverici anomaliyalarını müəyyən etmək məqsədilə

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Geofiziki, geodinamik, hidrogeokimyəvi, hidrodinamik və digər növ monitorinq müşahidələri aparılır.

Açar sözlər: KNET telemetriya şəbəkəsi, zəlzələ, seysmiklik, Tyan-Şan dağ sistemi, episentr xəritəsi

КОМПЛЕКСНЫЕ ПОЛЕВЫЕ СЕЙСМОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ И ПЕРСПЕКТИВЫ РАСШИРЕНИЯ СЕЙСМОЛОГИЧЕСКОЙ СЕТИ В РЕСПУБЛИКЕ КАЗАХСТАН

К. Э. Абдрахматов, А. У. Абдуллаев, А. М. Муралиев

АННОТАЦИЯ

Тянь-Шаньская горная система является одной из наиболее сейсмоопасных областей в Центрально-Азиатском регионе, где максимальная сила землетрясений достигает 10-11 баллов. В ее пределах выделяется несколько зон возможного возникновения очагов землетрясений с магнитудой 7-8,5. Главными сейсмогенными структурами являются Северо-Тянь-Шаньская, Гиссаро-Какшаальская (Южно Тянь - Шаньская) и Центрально-Тянь-Шаньская сейсмоактивные зоны.

В статье рассматриваются основные этапы развития прогностических исследований в Северном Тянь-Шане. Локальная телеметрическая сеть KNET установленная здесь в 1991 году позволяет регистрировать землетрясений в цифровом виде, собрать и обрабатывать сейсмической информации в оперативном реальном масштабе времени. Отметим, что KNET не имеет аналогов в Центрально- Азиатском регионе. Одновременно проводятся геофизические, геодинамические, гидрогеохимические, гидродинамические и другие виды мониторинговых наблюдений с целью выявления предвестниковых аномалий ожидаемых сильных землетрясений.

Ключевые слова: телеметрическая сеть KNET, землетрясение, сейсмичность, система гор Тянь-Шаня, карта эпицентров

Introduction

The sources of the 10-11 points Kemin in 1911 are confined to the North Tien Shan seismically active zone. (M=8.2±0.3), 10 points Chiliksky in 1889 (M=8.3±0.5), 9-10 points Belovodsky in 1885 (M=6.9±0.0.5), 9-10 points Vernensky in 1887 (M=7.3±0.5), 8-9 points Merkensky in 1865 (M=6.4±0.7), 8-9 points Kemin-Chuysky in 1938 (M=6.9±0.5) and other less weak earthquakes. Their hypocenters lie within the earth's crust and are distributed extremely unevenly vertically. The most widespread are sources with depths of 10-15 km, smaller ones - 16-20 km, and even smaller ones - more than 25 km (Fig. 1).

The Kemin catastrophic earthquake occurred in 1911 on January 3 in the North Tien Shan seismically active zone. It was recorded by a global network of seismic stations, its magnitude was estimated at 8.2, the depth of the hypocenter was 25 km. The maximum force of the shaking at the epicenter reached 10-11 points on the MSK-64 scale, 450 people died [New catalogue..., 1977]. Before the Kemin earthquake, the 10 points Chilik earthquake of 1889 was noted (M=8.3) in the eastern part of the North Tien Shan seismically active zone. The active period of occurrence between these two catastrophic events is 22 years, which determines the high seismicity of this zone during this period. These catastrophic and other strong earthquakes caused significant destruction over a large area, loss of life and enormous economic damage. To prevent such disasters today is almost impossible, but it is possible to reduce the degree of socio-economic damage and protect people to the maximum extent.

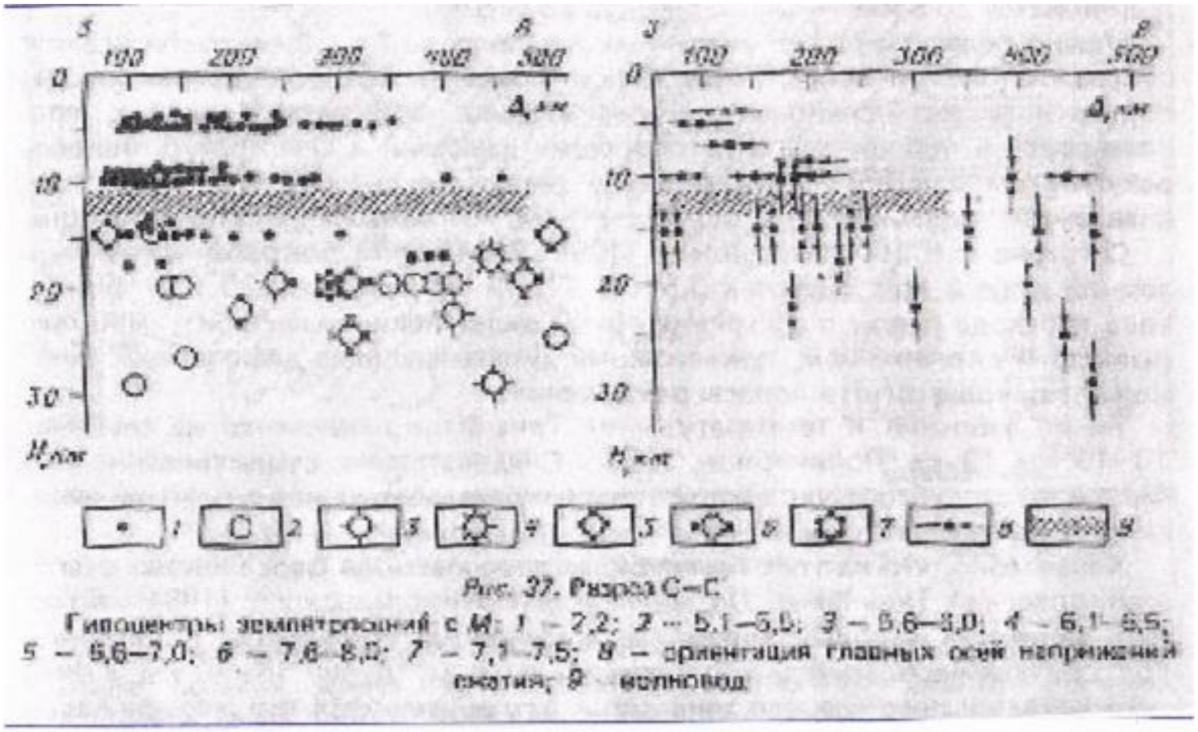

Figure 1 – Location of earthquake hypocenters and mechanisms for their implementation in Northern Tien Shan

In this regard, forecasting strong earthquakes and assessing seismic risk is the most pressing and sought-after problem in modern seismology. The solution to this problem involves predicting the location, strength and time of expected strong earthquakes. The problem of predicting the location and strength of expected events is solved by seismic zoning methods. At the same time, the problem of assessing the maximum possible earthquake in seismically active zones, as well as the parameters of ground vibrations during earthquakes, occupies a major place in complex studies on seismic zoning and ensuring the seismic resistance of structures. Forecasting the timing of expected strong earthquakes of varying urgency requires an integrated approach.

Research results

Below we will consider some results and the phased development of research on the forecast of strong earthquakes in Kyrgyzstan. The main studies are carried out within the North Tien Shan seismically active zone, where the Bishkek forecasting site is located, which includes the territories of the Chui and Issyk-Kul intermountain depressions and their mountain frames, as well as the southern part of the Ili depression (Fig. 2). The manifestation of high seismicity here is associated with ancient faults, rejuvenated in modern times, stretching in the sublatitudinal direction from the western part of the Kyrgyz ridge to the eastern border of the republic. The Northern Tien Shan is experiencing the youngest stage of deformation in the modern era and is therefore characterized by large earthquakes and low seismic activity due to weak earthquakes.

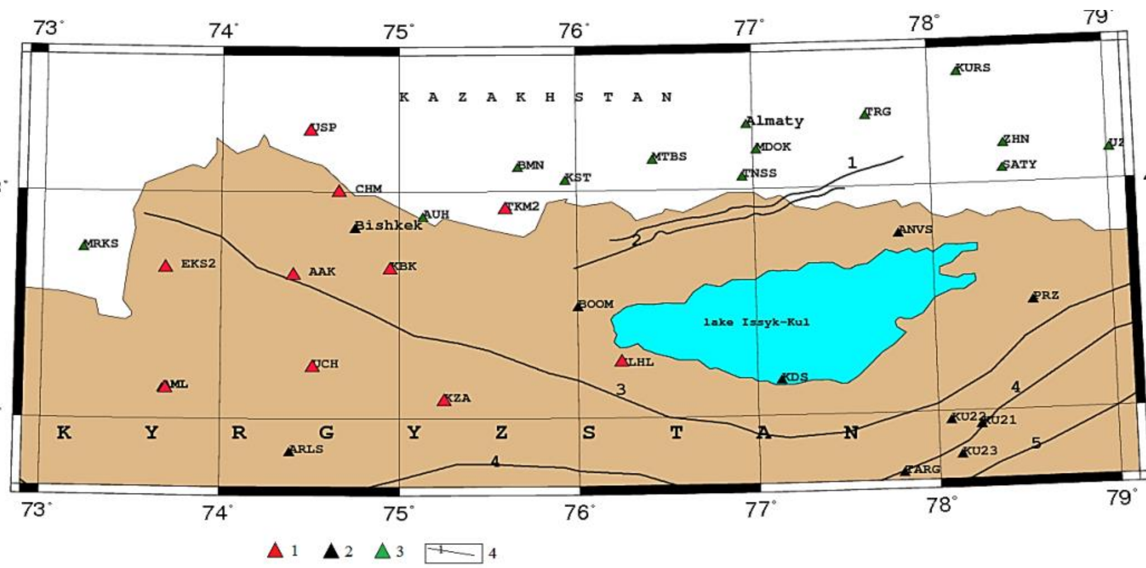

Figure 2 - Territory of the Bishkek forecasting site: (1) KNET station, (2) stationary seismic stations of Kyrgyzstan and (3) Kazakhstan; 4 - faults.

The development of prognostic research in the Bishkek and Almaty test sites is aimed, first of all, at the development of comprehensive seismic monitoring, the study of the main patterns of spatio-temporal distribution of sources of historical strong earthquakes and the features of the time course of seismic regime parameters.

On the territory of the test site, control of the seismic situation at the initial stage was carried out using 15 highly sensitive analog seismic, 7 magnetometric, 5 electrometric, 7 hydrogeochemical, 6 hydrogeodynamic, 2 autonomous seismic stations, as well as the Ala-Archa seismic geophysical observatory, class 1 leveling. In addition, several electrometric, magnetometric and light ranging stations of the NS RAS are located in the Chuisky section of the test site; regime electrometric studies are also carried out here using signals from a powerful MHD generator [Abdullaev et al., 1994]. Currently, some types of observations are temporarily suspended due to lack of funds. The main results of research on the search for earthquake precursors in the Northern Tien Shan are presented in many well-known works [4,7,8,11,12].

In 1990, specialist scientists from the Institutes of Seismology of the National Academy of Sciences of the Kyrgyz Republic and the Ministry of Education and Science of the Republic of Kazakhstan developed a new concept for the development of complex seismological observations. In the future, it is planned to operate four forecasting sites: Bishkek, Osh, Issyk-Kul and Naryn. In order to implement the stated concept, in 1991, an American-made local radio telemetry network KNET was launched at the Bishkek and Almaty forecasting sites [8,9].

The KNET local network, consisting of 10 observation points, plays a significant role in the development of seismological research, especially in the processes of collecting, processing and interpreting seismic data in real time.

Over the past 35 years, unique digital seismic data have been collected, which are successfully used to most accurately determine the focal parameters of earthquakes. Note that KNET has no analogues in the Central Asian region. In addition, geophysical, geodynamic, hydrogeochemical, hydrodynamic and other regime observations were carried out at all test sites in order to identify precursor anomalies before strong earthquakes [2, 3, 5, 10].

It has been established that in the North Tien Shan seismogenic zone the spatio-temporal pattern of seismicity is cyclical, manifested in the alternation of periods of activation with a period of relative seismic quiescence. The duration of these periods is 19-22±6 years [4,7]. The occurrence of sources of strong earthquakes along the North Tien Shan seismogenic zone is of a migratory nature. The direction of migration coincides with the strike of geological structures (edge faults) and seismogenic zones [4,7].

So, in 1865, in the western part of the test site, the Merken earthquake with M = 6.6 occurred, and 20 years later in 1885, at a distance of 80 km to the east in the village of Belovodsk, an earthquake with M = 6.9 occurred. It was followed, after a relatively short period of time, by the Vernensk earthquake with M=7.3 in 1887 (200 km east of the village of Belovodsk) and then even further east by the Chilik earthquake of 1889 with M=8.3. Thus, after the Merken earthquake, the epicenters moved from west to east at a speed of 19 km/year. After a period of revival of seismic activity due to strong earthquakes (M≥6.3), a 22-year period of calm followed until 1911. Kemin earthquake with M=8.2. 27 years later, to the west of the epicenter of the Kemin earthquake, in the area of the western immersion of Kungei Ala-Too, the Kemin-Chuya earthquake of 1938 occurred again. Average activity level A10=0.15. Several strong earthquakes occurred here in the past at short intervals: Merken 1865. with M=6.3, Belovodsk 1885. with M=6.9, Vernensk 1887. with M=7.3, Chilik 1889. with M=8.3, Keminsk 1911. with M=8.2, Kemin-Chuysk 1938. with M=6.9. In addition, numerous earthquakes with M≤4.6 have been recorded. Thus, the epicenters of strong earthquakes in the North Tien Shan seismogenic zone migrate in the sublatitudinal direction (Fig. 3).

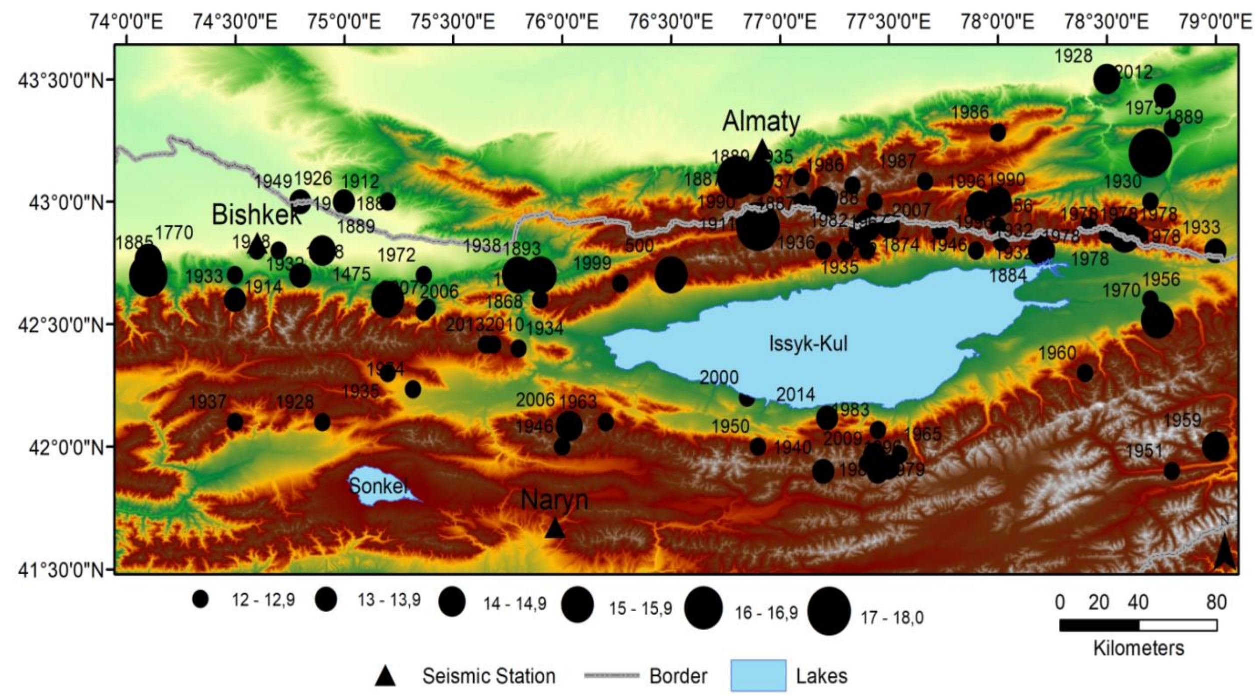

Figure 3 - Distribution of epicenters of strong earthquakes at the test site. The size of the circle corresponds to the energy class K=12 - 18.

The South Issyk-Kul zone stretches along the northern Teskey Ala-Too to the southern slope of the eastern part of the Kyrgyz ridge. It coincides with the Karakol and Pre-Teskey faults, as well as with the Central Teskey fault zone, which is associated with seismically active feather faults of northwestern strike.

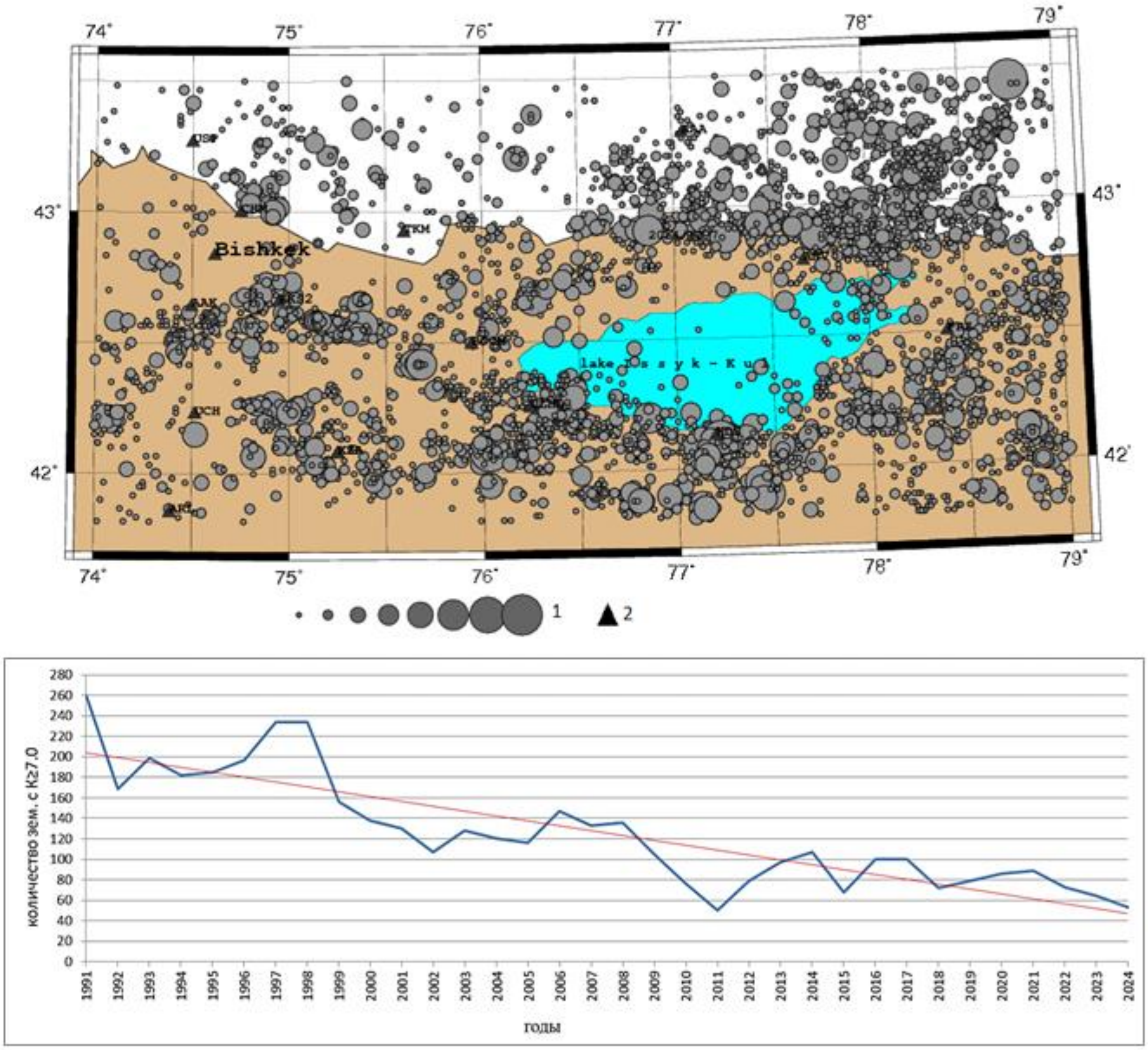

Figure 4 - Distribution of epicenters of earthquakes with energy class K=7-14 across the territory of the Bishkek prognostic testing ground for the period 1991-2024 (upper); change in the number of seismic events by year (lower), the red line shows the direction of the trend.

The South Issyk-Kul zone is also characterized by fairly high activity. The strength of observed earthquakes in this zone increases from west to east. The strongest of them is Sarykamysh 1970. with M=6.6 are confined to the eastern seismically active node (Fig. 2).

The following complex parameters of the seismic regime are studied on the territory of the test site: spatio-temporal distribution of historically strong earthquakes and the time course of the seismic process: migration of epicenters of strong earthquakes, seismic gaps, variations in seismic activity, slope of earthquake recurrence graph, changes in seismic wave velocity over time, as well as a set of geophysical (magnetometric, etc.), GPS and deformation processes, a full list of geochemical, hydrogeochemical and hydrogeodynamic observations.

Figure 4 shows the distribution of epicenters of weak and perceptible earthquakes with energy class K=8-14 on the territory of the Bishkek prognostic testing ground for the period from 1990 to 2024. The location of earthquake epicenters on the territory of the testing ground shows the existence of relatively narrow zones tracing in the sublatitudinal direction. The concentration of weak earthquake epicenters is observed within the North Tien Shan and South Issyk-Kul seismically active zones. The greatest concentration of weak earthquake epicenters is observed in the area of the epicenters of the Kemin 1911 and Chilik 1889 earthquakes, as well as in the south of Bishkek and the South Issyk-Kul seismically active zone (Fig. 3). The change in the number of weak earthquakes at the test site for the period from 1991 to 2024 is shown in the lower figure 3. We observe a trend (red line) showing a decrease in the number of weak earthquakes over time at the Bishkek prognostic test site over the past 33 years. If in 1991 the number of seismic events reached 260, then in 2024 there were 50. This may be due to a change in the stress-strain state of the earth's crust of the test site or the preparation of a strong earthquake.

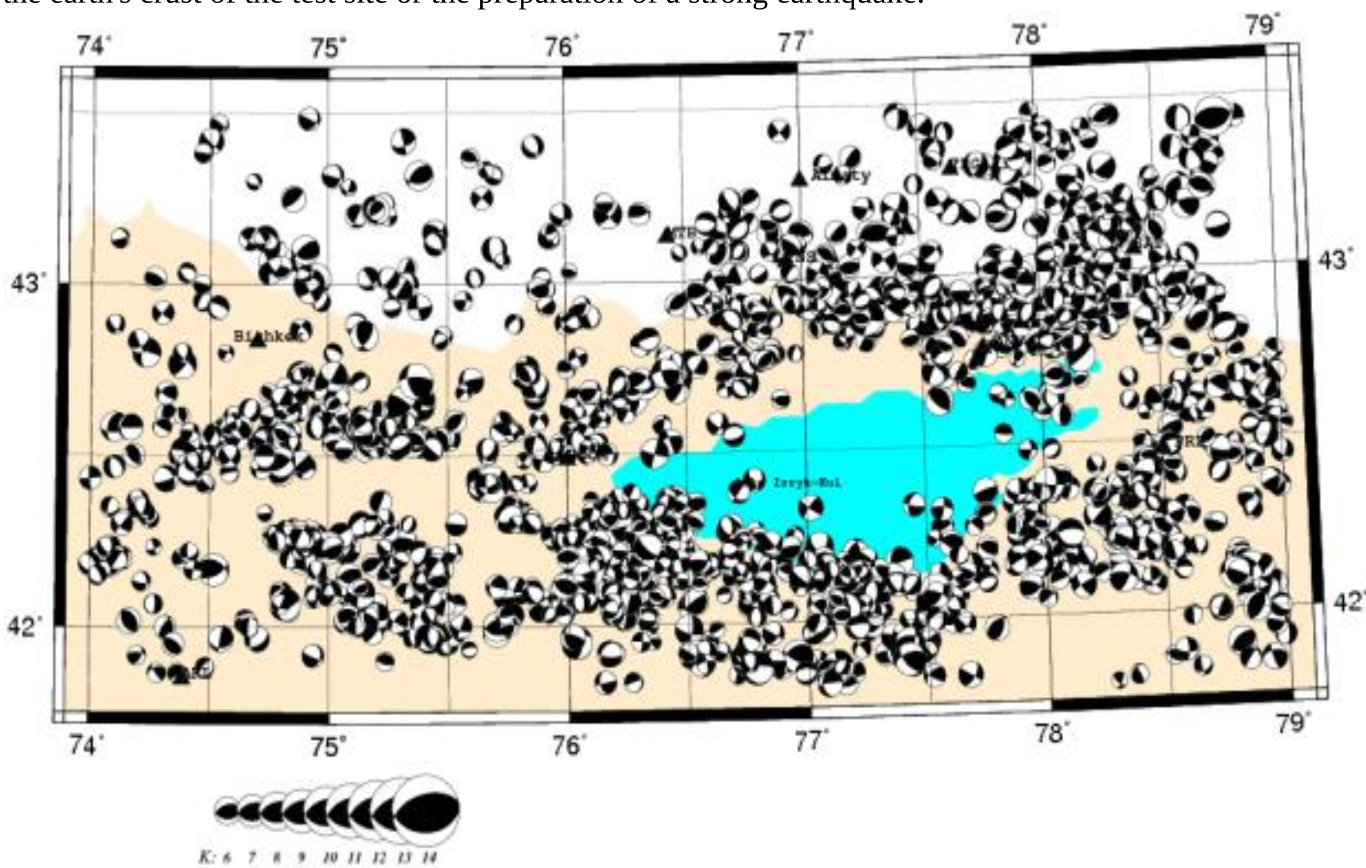

Figure 5 - Focal mechanisms of earthquakes in the polygon. Diagram of focal mechanisms of earthquakes with K=7-14 for the period from 1991 to 2024

To obtain a general idea of the modern tectonic stress field, we present some results of the study of the focal mechanisms of earthquakes at the test site. Figure 5 shows the distribution of focal mechanisms for 1736 earthquakes that occurred at the test site during the period 1991-2024.

In the foci of the studied earthquakes, reverse and strike-slip types of movements predominate. The position of the nodal planes, in general, coincides with the position of geological faults, tracing mainly from west to east. The axes of the main compression and extension stresses in the earthquake foci of the polygon show different orientations.

Apparently, the process of occurrence of strong earthquakes according to the analysis of earthquake foci mechanisms occurs in various types of seismotectonic deformations and stresses of the earth's crust. This is the subject of further research.

According to the new catalogue, 95 strongest and catastrophic earthquakes with energy class K=12-18 have occurred at the testing ground, starting from the historical period to the present day (Fig. 6). The analysis showed that in certain places (areas) strong earthquakes have not been observed for a long time. In other words, seismic gaps of the 1st kind are revealed on the territory of the testing ground (Mogi, 1988). In the North Tien Shan seismically active zone, 5 seismic gaps are noted, three of them are located in the south of Bishkek, two in the epicenter area of the Kemin 1911 and Chilik 1889 catastrophic earthquakes. The remaining seismic gaps, numbers 6, 7, 8, are in the South Issyk-Kul seismically active zone. Thus, 8 areas of expected strong earthquakes have been identified at the Bishkek prognostic testing ground. For example, it can be said that only in the Bishkek sector of the Northern Tien Shan, according to our analytical materials, it is possible to indicate the presence of 5 seismic windows (gaps), which is shown in Fig. 6.

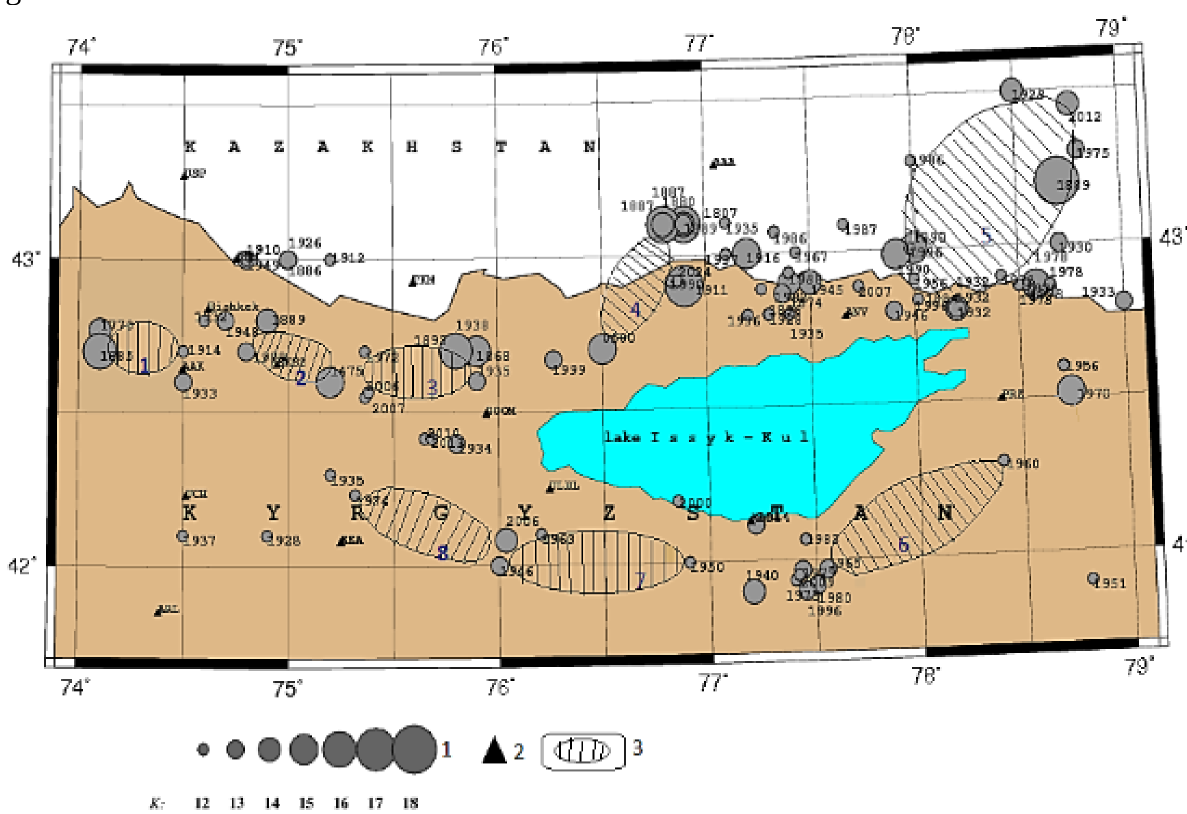

Figure 6 - Map-scheme of areas of expected strong earthquakes of the polygon based on the distribution of epicenters of 95 strong earthquakes. 1 - earthquake epicenters (K=12 - 18), 2 - seismic station, 3 - area of expected earthquakes.

Hydrogeochemical (HGH) studies in Kyrgyzstan have been conducted since 1978 on the basis of oil circulations of thermal waters Alamedin, Issyk-Ata, Jety-Oguz, Karaoi in zones of active faults. At HGH stations, continuous observations are carried out on wide complexes of parameters of self-flowing thermal waters: Rn, He, CO2, H2, Hg, F and others with an interval of measurements from continuous to once a day. At the observation stations of the test site, GGH precursor anomalies of more than ten strong earthquakes (K=13-17) were recorded, the period from the first days to months before the earthquakes at a distance of 30 to 350 km from the epicenter. Geochemical precursor effects are usually expressed in the form of bay- and peak-shaped and pulsed concentration bursts of components (15-100%) against the background of their stable time course with rapid attenuation of anomalies after the events. The prospects of the GGH method of searching for precursors, especially at the stage of short-term forecasting, require improvement of the methods for identifying precursor signals against the background of station regime observations of measured parameters.

Research into the fluid regime of groundwater with the aim of searching for hydrogeochemical (HGC) and hydrogeodynamic (HGD) precursors of strong earthquakes in Kazakhstan and Kyrgyzstan allows us to conclude that these indicators (flow rate, or pressure of self-flowing water and level in wells) are quite informative as precursors of earthquakes [3].

Conclusion

At present, the ideology of forecast observations should be based on tracking the dynamics of the development of major earthquake foci at complex forecasting sites. The experience of recent years has shown the need for centralization of observations and operational data processing in the center of expert assessment, taking into account the influence of external fields and the development of cyclic processes.

In this regard, in the future, forecast work should be based on the processing of a large array of data, taking into account the seismic patterns of the controlled territories.

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