THE ATLAS OF EARTHQUAKES IN KYRGYZSTAN

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Atlas of earthquakes in Kyrgyzstan

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The Atlas represents catalogue of earthquakes (K≥10) of the territory of Kyrghyzstan and nearest territories since ancient times untill 2005. It also represents the catalogue of strong earthquakes (K≥13) since ancient times until 2008 and the catalogue of the most significant landslides.

Besides, the present issue represents description of geodynamics of the Kyrgyz part of Tien Shan and the main seismicity regularities. There is also classification of landslides processies in mountainies areas and their examples on the territory of Kyrgyzstan. The Atlas describes the history of development of instrumental seismic observations in Kyrgyzstan. There is also the scale of the earthquake intensity and the list of seismic stations.

In preparation of the Atlas were used archive materials and scientific publications of the Instite of Seismology of the National Academy of Sciences of the Kyrgyz Republic (IS NAN KR), Ministry of Emergency (ME KR) and the Ministry of Natural Resources of Kyrgyz Republic (MNR KR).

The Atlas is recommended for the specialists and the public interested in seismicity problem on the Kyrgyzstan territory.

Contents

Preface

The United Nations declared the 1990-2000 years the International decade devoted to mitigate natural disasters. The work carried out during this decade made clear that the elimination of consequences of different kinds of calamities only is not sufficient to provide secure life and sustainable development. It is necessary to learn how to reduce the risk related to natural disasters that may take place anywhere and any time. After having included - the problem of risk prevention in the program of sustainable development, the United Nations developed the "International Strategy for Disaster Reduction (UN ISDR)". This strategy - aim at helping members of the world community to become more stable in their resistance to natural calamities, and to turn from simply elimination natural calamities consequences to really managing risk. The main idea of this strategy was to make the population of any separate country or a region aware of disasters risk, and to assist in taking measures to reduce risk.

The Central Asian region is subjected to risk related to earthquakes, landslides, rockfalls, avalanches, debris flows, floods, outbreaks of dammed lakes, and manmade catastrophes. Taking into account the climate change, it is necessary to bear in mind that the amount of natural calamities will increase. Many countries are already facing this increase. That is why the idea of creating the Atlas of Earthquakes in Kyrgyzstan offered by UN ISDR Secretariat Office in Central Asia is quite timely. It will help in taking real actions to reduce natural risk.

The high level of seismicity of the territory of Kyrgyzstan is an everyday threat to people's safety influencing all the spheres of social and economic life of the country. That is why information about earthquakes is of interest not only for academic researches, but also for state bodies (the Ministry of Emergency and other institutions) taking decisions in the domain of prevention and elimination of consequences of emergencies. Currently information about earthquakes is mainly kept in scientific works and archives of the National Academy of Sciences of the Kyrgyz Republic. The existing published catalogues are disconnected and are often known only to scientists. For this reason, it is hard to get a comprehensive concept of seismicity of the territory of the Kyrgyzstan.

The main idea of the Atlas was to create a reference, aiming to inform the public about former and recent earthquakes that occurred on the territory of Kyrgyzstan, and about general characteristics and statistics of seismicity and dangerous phenomena related to them. At the same time, the material of the Atlas is directly based on scientific results, so it may be helpful in different kinds of researches.

For the preparation of the Atlas, archive materials were used as well as scientific publications of the Institute of Seismology of the National Academy of Sciences of the Kyrgyz Republic (IS NAS KR), of the Ministry of Emergency (ME KR) and the Ministry of Natural Resources of Kyrgyz Republic (MNR KR).

The Atlas has been prepared by the staff of CAIAG: Dr. Kalmeteva Z. A. (the principal investigator) compiled the seismological part of the Atlas, Dr. Mikolaichuk A.V. expounded the geological aspects of the seismic activity of the territory of Kyrgyzstan. Dr. Moldobekov B.D. and Mr. Meleshko A.V. collected and generalized data on dangerous phenomena related to earthquakes and mountain hazards of the territory of Kyrgyzstan. Mr. Jantaev M.M. and Dr. Zubovich A.V. developed the project of geo-informational system of the Atlas, its design and publishing . Dr. Moldobekov B.D. was responsible for the general management of the work.

The authors express their deep gratitude to the staff of the IS NAS KR for their support in creating the digital version of the Atlas. We are sincerely grateful to Prof. Abdrachmatov Kanat, director of IS NAS KR for his permission to use archive materials of the Institute. These contain also unpublished data for the last period that were included in the catalogue of strong earthquakes. We also express our gratitude to Dr. Dzanuzakov Kenesh for discussion of materials on macroseismic research and on the development of seismic observations within the territory of Kyrgyzstan. We express gratitude to Russian seismologists Lyubov Chepkunas and Nina Frolova for useful comments. We are especially grateful to staff members, who presented photos of seismologists who contributed to the development of seismological research in Kyrgyzstan. Kenesh Dzhanuzakov presented the picture of Evdokia Rozova with young seismologists. The photo of Peter Skuinsh was presented by his daughter Tatiana Green - the head of the seismic station "Frunze", two pictures (the group of scientists, discussing the map of detailed seismic zoning, and the picture of Bektash Ilyasov) were presented by his wife - Ajarkul Ilyasova, the former employee of routine data processing group.

The authors express their deep gratitude to the MNR KR for the opportunity to use archive materials on landslides in the development of the e- version of the Atlas.

The creation of the e-version of the Atlas would not be possible without financial support of UN ISDR Secretariat Office in Central Asia. We are grateful for benevolence, professional management, and favorable working atmosphere to Senior Advisor of the Secretariat Goulsara Pulatova, and the project manager Vladimir Kuimov.

1. Historical view on earthquakes

Strong earthquakes are the most destructive natural phenomena. Through the history they scared people, leaving their footprints in nature, and people told legends about earthquakes. Each civilization created its own version of earthquakes origin. One of ancient Japanese legends said that the Japanese Islands were located on the back of a huge sheat-fish whose movements made the Earth to shudder. North American Indians believed that a huge turtle carried the Earth, so it quivered each time when the turtle waddled. In some Asian legends the frog was blamed for earthquakes, in Indian ones the gigantic mole, in Chinese it was the bull supporting the Earth. Russian chronicles said that it was a huge whale who carried the Earth. According to Turkmen's legends, when a monstrous dragon was walking on the Earth, trees around him broke with crackle making the Earth to shudder. The Georgian epos told about a giant Amiran chained to rock, who was shaking the Earth trying to tear off his fetters [Gere and Shah, 1988].

Scientific explanations or hypotheses of earthquakes origin were depending on the level of development of natural science, geological knowledge, and general ideas of the structure and geological processes taking place inside the Earth.

The first known efforts (hypotheses) to explain scientifically the origin of earthquakes were made in the middle of the first millennium BC. The high seismicity of the Greek archipelago was the reason why the ancient philosophers were interested in earthquakes. The so-called "neptunists" associated the origin of earthquakes with water. For example, Anaximen and Anaxagoras believed that water washed out hollow spaces inside the Earth, and their crush caused earthquakes. Aristotle considered that the origin of earthquakes was related to the pressure of vapor and gases inside the Earth. The so-called "volkanists" believed that earthquakes occurred due to inner warmth of the planet. Heraclites and Strabon associated earthquakes with volcanic eruptions. Anaximandr saw the reason for earthquakes in the Earth cooling and development of cracks due to that. Pliny believed that the weather was the reason of earthquakes; according to him, thunder and lightning did not only occur above the Earth, but also inside it. Efforts of lightning to come out of the Earth resulted in earthquakes [Encyclopedia, 1894].

Earthquakes were often considered as visitations of Gods for people's sins. Even in the XVIII century priesthood said: "Earthquakes usually occur in big cities. The punishing whip is directed not to bare cliffs and uninhabited seashores but to the places where people live, in order to prevent their malicious deeds." The earthquake that took place in Lisbon in 1755 caused a lot of deaths, because of a series of shakes, fires and huge tsunami. An English priest said that the earthquake was the punishment for dissoluteness and debauchery of the Lisbon citizens. But at the same time, some people accused the damned inquisition, emphasizing the fact that the Palace of Inquisition was the first building exposed to destruction during the earthquake [Gere and Shah, 1988].

In the Renaissance, scientists again raised the question about the origin of earthquakes. In 1660 Hooke defined the law of proportional relationship between stress and strain. In 1668, he expressed the idea, that earthquakes represented an elastic reaction to geological phenomena. However, only after a long period this idea was introduced into the theory of earthquake source.

In the XVIII - XIX centuries several hypotheses were proposed to explain Earth development and tectonic movements. "Neptunists" explained geological processes by water activity; "plutonists" explained tectonic movements by inner fire of the Earth; A. Humboldt and L. Buch explained the formation of mountains by the influence of vertical movements; a hypothesis of contractions was based on of Kant-Laplas theory of liquid fiery of the Earth core. According to the contractions hypothesis, owing to gradual cooling of the Earth and decreasing of its volume, dislocation phenomena occur and they lead to the formation of cracks and wrinkling of the Earth crust in folded mountains.

In the XIX century Gilbert and Suess were the first who clearly formulated the interrelation between earthquakes and dynamic rupturing. They found out that the main seismic areas were located in the zones of geologically young mountains. Those are the areas with large fault lines in the Earth crust, where tectonic (or formation of mountains) processes are still active. The notion of the so-called "tectonic earthquake" was finally confirmed. Unlike earthquakes induced by 'collapce' or volcanic activity, tectonic earthquakes affect greater territories and are more destructive [Batyushkova, 1959]. Agreeing with the idea that the origin of earthquakes can be connected with three factors: collapse of air holes, volcanic eruptions and dislocations in the Earth crust, K.I. Bogdanovich [1909] noted: "The first two factors are clear, as far as relation of earthquakes with tectonic processes, it can be established only theoretically as human's life is short and we can not directly observe these processes".

Atmospheric phenomena accompanying earthquakes: thunderstorms, drop of temperature in focal area, rise and drop of ground, anomalous behavior of animals, supported also another aspect of the nature of seismicity. Gopher (1855), for example, advanced the electricity hypothesis. It was not by chance that at The International Congress of meteorologists in Rome in 1879 the Italian geologist M.S. De Rossi suggested to single out research of seismic phenomena into a special science and to call it "endogenous meteorology". At the end of the XIX and the beginning of the XX century, in some European countries metallic cones were installed to perform the role of seismic conductors alike to lightning conductors. Some scientists (Branka, Gerland and others) believed that the importance of tectonic phenomenon was exaggerated, but the role of volcanic phenomena underestimated. They understood "volcanic" not only as eruption of magma, but also as aggregate of processes occurring in the bowels of the Earth accompanied by sudden release of energy [Encyclopedia, 1894].

These argues lasted for a long time. In 1910, after the strong earthquake, which happened in San Francisco in 1906, H.F. Reid formulated a hypothesis of "elastic rebound" as the model of tectonic earthquake source, which even nowadays serves as the basis for all the models of earthquake source. However, Rotpletz stated a supposition that this earthquake was caused not by the fault motion, but by intrusion. He based his view on the fact that considerable shift in the fault plane was seen only on a small area, which could not happen if elastic deformations had accumulated over a large area [Encyclopaedia, 1914]. Different phenomena, causing shocks, were considered in works of other scientists. For example, A.P. Orlow [1887] considered a causal relationship between the occurrence of earthquakes and the position of the Earth with respect to the Sun and the Moon, changes of atmospheric pressure, terrestrial magnetism, and an electric condition of the atmosphere.

The title "endogenous meteorology" didn't exist for a long time. A more adequate title was suggested: seismology, the science of earthquakes (from Greek – seismo - shaking of the Earth). Regular observations were determined as a primary task for seismology. "Studying strong earthquakes alone would not help to clarify the laws of seismic phenomena, just as the studyies of hurricanes alone would not allow the meteorologist to understand laws of complicated natural phenomena in the atmosphere," said I.V. Mushketov [1899].

A special notion "INTENSITY" was introduced to classify the observed earthquakes. The first scale of seismic intensity was introduced in 1883 by two independently working geologists: M.S. De Rossi (Italy) and F.A. Forel (Switzerland). Later, they united their results and created the Rossi-Forel X-degree intensity scale. People's perception, degrees of damage of buildings and the earth's surface as well as the level of change of area relief were taken into account for classifying earthquakes according to degrees. Along with the development of the technical progress this scale was becoming obsolete. Besides, it appeared too oriented to specifics of European constructions. Many other scales were created in which drawbacks of previous scales, the change of construction principles and development of seismology were taken into account. The modified Mercalli scale (MM scale) is used in the USA nowadays. Since 1905 until 1958 this scale underwent several modifications. In the second half of the XX century in Europe and the USSR scientists started to use XII-degrees MSK-64 scale of seismic intensity (see Appendix), named after seismologists, who proposed it: Medvedev (USSR), Sponheuer (GDR), and Karnik (CSSR). This scale is still used in the countries of the former Soviet Union. In Europe it was modified and is known as EMS98. In Japan they use their own 7-degrees scale of seismic intensity, proposed by the Japan Meteorological Agency – JMA.

The intensity of one and the same earthquake is different in different areas. To determine the intensity(ies) of an earthquake, its effects are studied in the field. The results are mapped, which means that the figure of degrees representing the earthquake intensity in the givenplace is put on the map next to the name of the place. After that, the areas of the same rate of shaking (the same degree of intensity) are delimited by lines - isoseismals. The isoseismal delimiting the area of maximal shocks is called pleistoseismal, the territory inside the pleistoseismal is called "pleistoseist area" or the area with the highest level of distruction. The intensity of the earthquake inside the pleistoseist area is marked as **Io** and the given earthquake is registered under this mark.

As it was mentioned above, discoveries in mathematics and mechanics became the basis for theoretical seismology. In 1660 Hooke discovered the law of stress-strain relationship. In 1830 with the help of the equation of motion and the law of elasticity Poisson proved that only two types of waves (longitudinal and shear) can spread inside a homogeneous solid body. In 1887 Rayleigh found the additional solution of elasticity equation for solid bodies with free surface. The solution stated that elastic waves can spread on the Earth surface similar to waves on a water surface caused by a thrown stone. These waves are known as Rayleigh surface waves. In 1911 Love described mathematically another type of surface waves, which are known now as Love waves. Invention of devices for recording ground shaking promoted the development of seismology. In 1875 Filippo Cecchi created the first seismograph recording the motion of a pendulum relatively to the Earth as time function. In 1889 in Potsdam (Germany) they produced the first accurate record of the distant strong earthquake in Japan. Soon the construction of seismographs was started in Italy, Russia, Austria and Japan. In 1892 John Milne constructed a rather compact seismograph, registering the horizontal motion on the Earth surface. By 1900 he installed the seismographs in 40 places in Europe and Japan. This event may be considered the starting point of instrumental observation of earthquakes and the beginning of accumulation of seismological data.

The prototype of modern seismic apparatus was the seismograph created by Galitzin B.B. (1902). He put a pendulum into magnetic standoff, which turned mechanic movement of the pendulum into electric current with the help of coil winding, The same way, current generated a mirror galvanometer motion. With the help of a light spot directed to the galvanometer mirror it was possible to register the rate of motion on photographic paper. The use of magnetic standoff solved such technical problem as removal of eigen frequency of pendulum that provided the possibility to register ground motion only. This principle turned to be so effective that it became the basis for the construction of seismographs all over the world. Moreover, this principle gave rise to the construction of modern digital seismographs, where the mirror galvanometer was substituted by a digital voltmeter.

Through analyzing earthquakes records scientists obtained important data on the internal structure of the Earth within a relatively short period of time. They established that the Earth consists of the core (R.D.Oldham, 1906 and B.Gutenberg, 1913), inner core (I.Lehmann, 1936), mantle and crust (A.Mohorovicic, 1909). It was revealed that earthquakes might occur at a depth of several hundred kilometers. On continents, earthquakes mostly occur in young mountain areas (of alpine age).

Small instrumentally registered earthquakes cannot always be felt by people and marked by effects on the surface of the Earth. That is why it is impossible to determine their intensity according to the classical method. The "Richter Magnitude" which is known nowadays all over the world was proposed in 1935. It can be explained on the basis of the following example. Everyone who has observed a strong earthquake could see that hanging things are waving, such as an electric bulb on the ceiling. In other words, it behaves like a pendulum. It was said before that the seismograph is actually a pendulum, but the difference with the bulb is that the seismograph is equipped with the device recording these oscillations. Scientists afterwards study these records called seismograms. It seems logical that the stronger the earthquake the higher is the amplitude of oscillation. The magnitude of an earthquake is a nondimensional relational estimate of its size. Richter suggested to classify earthquake magnitudes by comparing the peak amplitude of several earthquakes records that were made at the same distance from the seismic source. He defined that an earthquake with a peak amplitude of 1 mm at a distance of 100 km, registered by a standard apparatus of Wood-Anderson was taken as a reading measure **M=0**. An increase of magnitude by one unit is marked by a ten times higher peak amplitude in the same place. The magnitude is sometimes called an energy assessment because it is determined by amplitude measurement. The amplitude of the wave allows calculating the amount of energy of seismic waves. It should be noted that mass media often misuse terminology. In mass media they use the phrase: "There was the earthquake of intensity six "**according to Richter scale".** This leads to confusion, as it is unclear whether '6' refers to the magnitude or to the intensity of the earthquake. An approximate correlation of these two properties is represented in Table 1. The effect of destruction on the surface (intensity) depends not only on the magnitude of the seismic event, but also on the depth of the earthquake, and the type of soil. Therfore, the correlation between *M* and ***Io*** should be considered for different depths.

With the lapse of time, many other magnitude scales were proposed, in which the mode of waves, type of recording and the territory affected by the earthquake are taken into account. Four basic magnitude scales are in use today: M_L, m_b, M_S and M_W.

M_L – local magnitude. It is the first seismic magnitude scale developed by C. Richter and was motivated by his desire to issue the first catalogue of California earthquakes. M_L in its original form is rarely used today because Wood-Anderson torsion instruments are uncommon and, of course, because most earthquakes do not occure in southern California. However, M_L remains a very important magnitude scale because it was the first widely used "size measure", and all other magnitude scales are tied to M_L to preserve catalogue uniformity. Further, M_L is a very useful scale for engineering. Many structures have natural periods close to that of Wood-Anderson instrument (0.8 sec) and the extent of earthquake damage is closely related to M_L.

m_b - body-wave magnitude. The Richter magnitude was developed to classify regional earthquakes (for distances between the seismic station and the earthquake of less than 600-1000 km). Because of the very complicated wave form in these distances, the body-wave magnitude scale was developed as only the very first oscillations (longitudinal waves) amplitudes are needed to determine the m_b -value.

M_S – surface-wave magnitude. In distances of more than 600 km intensive surface waves appear on the seismogram of shallow (source depth is not more than 15 km) earthquakes which amplitude can be measured easily.

M_W - moment magnitude. All above mentioned magnitude scales have some restrictions. M_W is calculated based on the seismic moment and can be determined for the whole range of distances and source sizes. Though, the determination of the seismic moment is a complicated procedure but the usage of modern digital seismic instruments allows a routine providing the M_W. Today M_W is calculated for all global events larger than $M_W = 5$.

In the Kyrgyz Institute of Seismology, different kinds of magnitude are defined: local magnitude, coda wave magnitude, surface-wave magnitude and for a very small part of the territory also the moment magnitude.

Besides the methods of earthquake classification by intensity and magnitude, some other methods for estimation of energy of seismic waves exist. In the middle of the last century, on the basis of generalized empirical data, the soviet seismologist T.G. Rautian proposed an earthquake classification according to its energy class [Bune and others, 1960]. She developed the nomogram to determine the energy klass K (K=1gE, joules) of earthquakes in Central Asia. This characteristic was applied in the USSR and China, (nowadays it is used in the countries of the former Soviet Union).

So by the end of 1940th years the basic results of seismological researches were the following:

- technical means for recording earthquakes and methods for interpreting records were developed,
- the first world map of earthquake epicentres was created to identify the main seismic zones of the globe,
- basic information on the inner structure of the Earth was obtained.

Table 1

Approximate correlation of magnitudes M and Io for shallow-source earthquakes (http://seismos-u.ifz.ru\building.htm)

Conventional name of size of event	**Approximate correlation of *M* and *Io* for shallow-source earthquakes**	
	Interval of Richter 's magnitudes M	**Intensity Io MSK-64 scale**
Weak	**2.8 - 4.3**	**3 - 6**
Moderate	**4.3 - 4.8**	**6- 7**
Strong	**4.8 - 6.2**	**7 - 8**
Very strong	**6.2 - 7.3**	**9 - 10**
Catastrophic	**7.3 - 9.0**	**11 - 12**

However, seismology was still the science made by enthusiasts. Tests of nuclear bombs and the necessity to find out their location became the stimulus for the rapid development of seismology to become a contemporary science. In 1963, 116 countries signed the agreement on the limitation of nuclear tests. The World Wide Standard Seismographic Net (WWSSN) was created to develop methods of disclosure of nuclear explosions. The Integrated System of Seismic Observations (ISSO) was established in the Soviet Union. Many countries allocate considerable funds for seismic research and the development of modern digital equipment. First international networks of digital seismic stations and centers for data processing were created in 1970-1980 years. **Fig. 1** demonstrates the poster on the USA site - IRIS – Incorporation Research Institutions for Seismology. It represents the key points in development of seismology starting from the Hooke's Law until the first international network of modern digital stations IRIS.

Nowadays scientists believe that the origin of seismicity is related to slow movements taking place in the lithosphere (upper solid Earth crust).

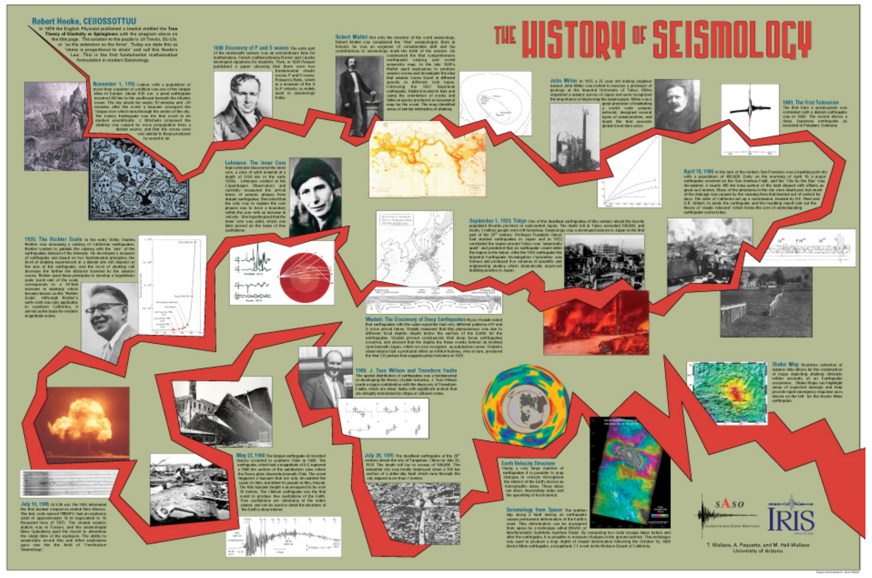

Fig 1. Main stages in seismology development (www.iris.edu).

This layer is rather thin – about 70-150 kilometers. Its thickness could be illustrated by the following example: if the Earth could be diminished to the size of an egg, then the upper solid Earth crust will be equal to the egg's shell. The upper solid Earth crust is not homogeneous: it consists of big parts called plates (**Fig. 2**). Under the lithosphere, there are forces, making plates to move with the velocity of several centimeters per year. The nature of those forces is not clear. That could be slow movements of a plastic substance in the bowels of the Earth as the result of heat convection. In some places, a new substance is moving up and pushing plates aside. In some places plates slide along each other, but there are areas where one plate moves under another. Plates can move in different directions, making cracks, creating earthquakes. About 90 % of earthquakes on the Earth take place along the Pacific Ocean coast (the border of the Pacific Ocean plate). 5-6% of all earthquakes take place in the Alpine belt, which is also called transcontinental. It extends from the Mediterranean Sea to the East via Turkey, Iran, Northern India (it separates the Eurasian plate from the African and Indian-Australian plates). The rest 4-5% of earthquakes take place along mid-oceanic ridges or inside plates [Gere and Shah, 1988].

Tien Shan earthquakes are the events which take place inside the plate. The main problem of research of Tien Shan nowadays is the lack of common point of view on factors controlling the deformation of the Tien Shan, e.g., on the correlation of collision of plates and the deep-seated processes beneath the mountainous ranges.

Since 1960 years, the USA, Japan, and the USSR started research on the prediction of strong earthquakes within frameworks of their national programs. Observations by geophysical methods (gravity field, thermal field, magnetism, atmospheric electricity) allowed to reveal peculiarities of location of strong earthquakes sources within these fields. At this time scientists developed basics of seismotectonics – the section of geology studying tectonic movements and conditions generating seismic activity. They introduced the notion of active faults, along which earthquakes may take place in future. They achieved considerable success in understanding processes taking place in the earthquake source zone long before a destructive earthquake shock occurred. They revealed many different phenomena forestalling strong earthquakes (earthquake precursors). Generalization of theoretical research, testing of samples, and experimental observations results led to the creation of theoretical models of nucleation and propagation of rupture (earthquake source). As it has already been

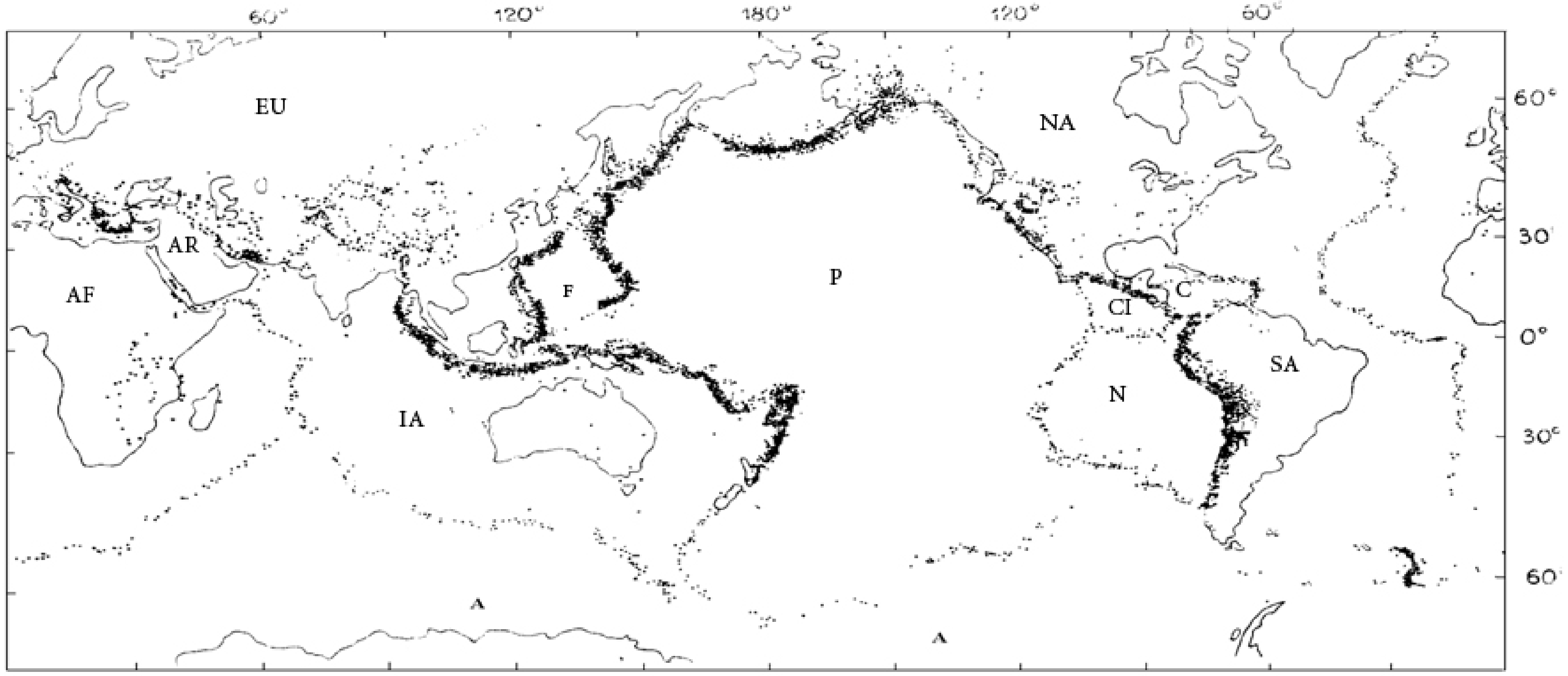

Fig. 2. Main Earth plates contoured by the earthquake epicenters, by [Lay and Wallace, 1995]: AF-African, AR-Arabian, EU-Euroasian, IA-India-Australian, F-Philippine, P-Pacific, NA-North American, CI-Cocos islands, N-Naska, C-Caribbean, SA-South American, and A- Antarctic.

mentioned, the basis for all these models was Reid's hypothesis about elastic rebound when slow tectonic movements (deformations) go along with the growth of stress. When stress exceeds the limit of material solidity, failure starts; as a result, the accumulated elastic stresses liberate (elastic rebound). This process depends not only on absolute stress values, but also on their distribution in the area. It is practically impossible to predict the scenario of rising instability and its development, as for that it is necessary to know in detail the physical properties of the source area, the structure and physical conditions not only within the region of the forthcoming earthquake but also outside [Mukhamediev, 2008]. It is possible to fix a lot of preliminary indications (there are more than hundred of them), but the earthquake may still not occur when predicted. There are cases when a large shock takes place without any preliminary harbingers. That is why nowadays, successful prediction of an earthquake is more an exception than a rule. In 1975, the large Haichen earthquake was predicted in China. People were evacuated and nobody suffered. The next year, 100 km away from the previously predicted one, the Tan Shan earthquake took place. The Chinese seismologists did not dare to predict it as the preliminary precursors were not clear. This earthquake killed several hundreds of thousands of people.

"Unexpected" strong earthquakes in Gazli and Suusamyr (USSR), Tan Shan (China) illustrate the incompleteness of our knowledge on the nature of seismicity. One of the reasons is that we do not obtain enough data. Seismology is a comparatively young science. As it has already been mentioned, the period when observations were carried out with the help of instruments makes about one hundred years, though temporal units used in geology are thousands and millions of years.

Predicting earthquake hazard according to today's methods means, defining the probability of future occurrence. For example, they can say that within one or three months an earthquake of magnitude 6-8 may happen in the south-western part of the country with a probability of e.g. 50%. Nevertheless, the earthquake may not occur. What to do in a situation when there is no certainty? It is possible to sympathize with the authorities who will have to take decision: to act or not to act. If to act, then it will be necessary: to reinforce buildings, to send the most vulnerable population to safer regions, to organize rescue teams, to establish supply of food, water, medicine. Many people can sell their property and leave the region where the disaster is expected. In such situation some great social and economic infringes may happen. That is why by the end of the last century scientists of the whole world came to the conclusion that the best way to prevent losses due to earthquakes is to get prepared for it. It means that it is necessary to train population, to improve the quality of constructions and the equipment for saving people, to create mechanisms allowing for a rapid elimination of earthquake consequences, etc. [Gere and Shah 1988].

What does it mean – to train population? People should understand the character of earthquakes and be always ready for them if they are living in a seismic region. One of the important things to train population in is to provide trustworthy information on seismic danger. No one can tell for certain, how to plan preparations for earthquakes, though understanding of their character may help to prevent adverse effects of earthquakes.

The present publication briefly describes geological processes in the Tien Shan giving rise to earthquakes, it outlines the regions in Kyrgyzstan where strong earthquakes may occur and how much danger is related to them. Two catalogues of earthquakes are attached in the appendix. One of them informs on large earthquakes, of magnitude 5-6 and higher. These earthquakes are felt by people. From these events may result only small cracks on the plaster or complete changes of the Earth's surface. In the other catalogue the events are enumerated starting from energy class K=10. People feel such earthquakes very seldom - when the source approaches the Earth's surface and is close to populated localities. They are not disastrous. Since 1950 the network of seismic stations has become sufficiently dense to register all the events of such energy level.

It is very important to know about secondary earthquakes effects. It became clear that even high quality construction in mountainous regions does not solve the problem of seismic safety. Very often deaths of people and material losses take place due to such secondary effects such as landslides, rockfalls, mountain torrents, soil liquefaction. Often earthquakes do not directly cause dangerous slope phenomena, but only speed up the development of processes, which may last over a long period of time. Active slope movements may not only occur close to earthquakes but also far away from the epicentre [Babaev, Ischyuk, Negmatullaev, 2008]. In the given issue, we publish information on activity of landslides, rockfalls, mountain torrents, and present the catalogue of landslides registered in Kyrgyzstan.

2. Geodynamics and seismicity of Kyrgyzstan

> *"…as far as the relation of earthquakes with tectonic processes is concerned, it can be established only theoretically as we cannot directly observe these processes due to the shortness of a human life".*
>
> *[K.I.Bogdanovich, 1909]*

2.1. Geodynamics of Kyrgyzstan and geologic methods of seismic hazard evaluation

Kyrgyzstan is a mountainous country. Everybody knows from a school course of geography that the total area of foothills, alpine meadows and ranges exceeds 70% of the Republic's territory. Consequently, the increased seismic hazard at the mountain areas is as natural as spring thunderstorms or snowing in September. But if we want to study the main patterns of strong earthquakes we cannot avoid an excursus into geodynamics of Kyrgyzstan (**Fig. 3**).

The greater part of the Republic is within Tien Shan and only the most southern territories of Alai region of Osh Province already belong to Pamir. Meaningful differences in the history of formation of the mountainous countries are behind these names. Pamir is included in the Alpine-Himalayan fold system formed at the place of paleocean Tetis as a result of approaching of Hindustan and Eurasian plates. Paleocean Tetis was closed about 50 million years ago, but displacement of the plate northwardly was continuing later also in the so-called collision stage. As a result, complexes forming the Trans Alai of Pamir were moved northwardly by more than 300 km [Trifonov, 1999; Burtman, 2000]. According to the data of GPS this process keeps going on until now. Hindustan plate keeps moving to the north with the velocity of ~35 mm per year [Zubovich et al., 2009].

Tien Shan, as Altai and Sayan Mountains, is related to the category of intracontinental (or intraplate) orogens. The origin of the formation has not yet been entirely understood and is in the focus of leading geologists and geophysicists. The main peculiarity of the mountain systems of this type consists in the fact that they are located not at the border but in the internal part of the lithosphere plate.

According to [Molnar and Tapponnier, 1975] the majority of research of Tien Shan consider that orogenic processes here also occur due to the collision of Hindustan and Eurasian plates. The opponents of this concept assign a determinative part in formation of mountains to gravitational instability in the upper mantle and lithosphere of Tien Shan [Sadybakasov, 1990; Bakirov, 1999; Kurskeev, Shatsilov, 2000; Trifonov et al., 2008]. It is not really possible to select just one of the alternative scenarios of the development of Tien Shan as this mountain system consists of three segments; each of these segments possesses its structural peculiarities.

The border between the Eastern (Chinese) and Central Tien Shan is located along the meridian of 80º E longitude that passes though the highest mountain massif with peaks of Khantengry and Pobeda. The border between the Central and West Tien Shan are the NW-SE oriented ranges (anti Tien Shan): Fergana, Atoinok, Talas and Bolshoy Karatau [Burtman, 2006]. This border corresponds also to the Talas-Fergana fault known as one of the largest strike slip faults of the Eurasian continent with a cumulated horizontal shift 200 km [Burtman et al., 1963]. Tens of leading researchers of Tien Shan paid a particular attention to studying this fault. One can find full information on this issue in the monography "Geodynamics of Talas-Fergan fault…", [Mamyrov et al., 2009].

The western Tien Shan is fully in the sphere of influence of Pamir-Himalayan collision. According to the geological preconditions formulated already in 1964, the structure of the Western Tien Shan, including Fergana basin and its bordering mountains, is marked by the counter-clockwise rotation of the Fergana block along the Talas-Fergana strike slip fault (**Fig. 4**). These movements began in Late Paleozoic (~ 270 million years ago) and reactivated in the Neotectonic stage (~ 30 million years ago) [Bakirov, 2008]. Later A.A. Nikonov, V.K. Kuchai, V.G. Trifonov, V.I. Makarov established in their works that tectonic deformation in the West Tien Shan are stimulated by the pressure of Pamir offset to Tien Shan and especially actively developed in Pleistocene and Holocene (~ 2 million years ago) [Makarov, 2005]. According to paleomagnetic data this process started a bit later, at the end of Triassic-Early Jurassic (~ 200 mln. years ago). And in Pleistocene the movement of the Pamir indenter leads to the turn of Fergana block by an angle of about 20° counter-clockwise. Rotation is marked by dextral offsets along the Talas-Fergana fault. The structures of the orientation of the Chatkal range changes from E-W to NE-SW. The uplift of the Fergana Range and thickening of earth's crust under it take place;a gentle warp of the structures of the South Tien Shan is forming. Alpine offsets by the Talas-Fergana fault are differentiated by the amplitude – from zero to the west of Chatkal triangle up to 100-120 km in the north of Fergana; further to the east the amplitude of the offset falls down to zero near Tarim, where fault changes to the system of crush movements of the southern vergence [Bazhenov, 1993]. Data of GPS confirm (**Fig. 5**) that the pressure of the Pamir offset and rotation of the Fergana block counter-clockwise continue at the present time [Zubovich, 2005; Reigber Ch. et al., 2001]. This block includes the Fergana basin, Chatkal range (CHR) and a part of Alai range.

The mountain system of the Central Tien Shan (CTS) relative autonomous and is developing under the conditions of transpression, [Cobbold et al., 1994; Delvaux et al., 2001], stimulated by sinistral shift of Tarim relative to the Kazakh platform. Transpression means a mode of deformation combining the effect of compression and lateral shear. The main structural units of CTS are NE-SW oriented zones of stable uplifts and stable subsidence (refer to **Fig. 3**). Uplifts of a length of 340-600 km and a width of 25-70 km consist of chains of imbricate joined ranges. The largest intermontane basins of CTS (Chui, Issykkul, Naryn and Aksai) have a width of 40-80 km and an extension of 250-380 km. They are filled up by Mezozoic-Cenozoic deposits while the Paleozoic basement of the basins is submerged to the depth of 3-4 km below sea level [Makarov, 1977; Sadybakasov, 1990; Chediya, 1986]. The aforementioned relations of ranges and basins are being observed in the western part of CTS. To the east, approaching to Khantengri mountain massif, the ranges run together (**Fig. 6**) and sutures are left at the continuation of basins. Neotectonic faults limiting ranges and intermountain basins of CTS completely take over the pre-existing structures corresponding to Paleozoic strike slip

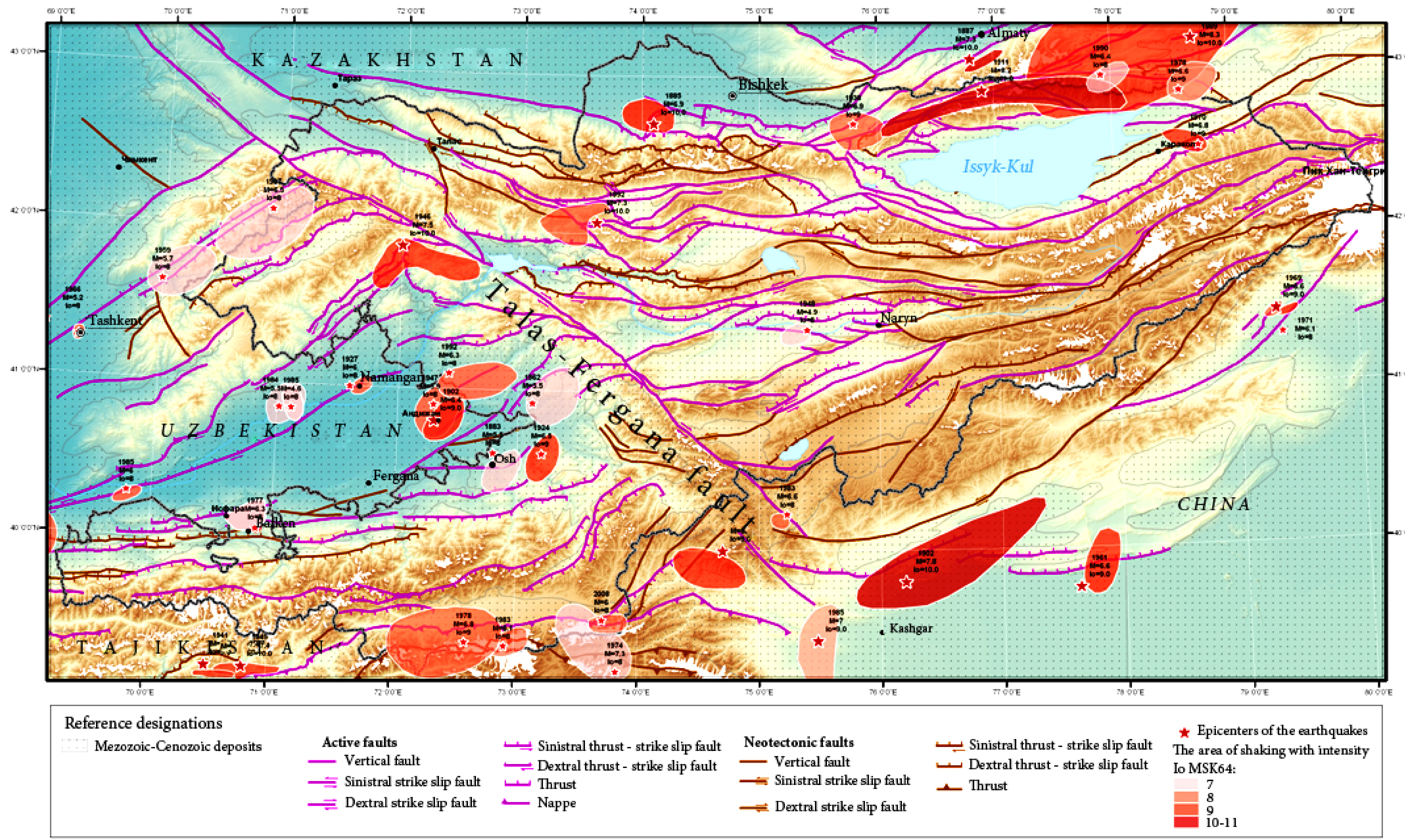

Fig. 3. Scheme of destructive earthquake source zones located on the seismo-tectonic map of the Kyrgyz Tien shan composed on the basis of data from [Djanuzakov et al., 2003; Abdrakhmatov et al., 2001; Bajenov, Mikolaichuk, 2004; Geological map…, 1980; Ibragimov, 1980; Makarov et al., 2005; Nikonov et al., 1983; Tektonical map…, 2007; Trofimov et al., 2002; Chedia, 1986; Geological map…, 1985]

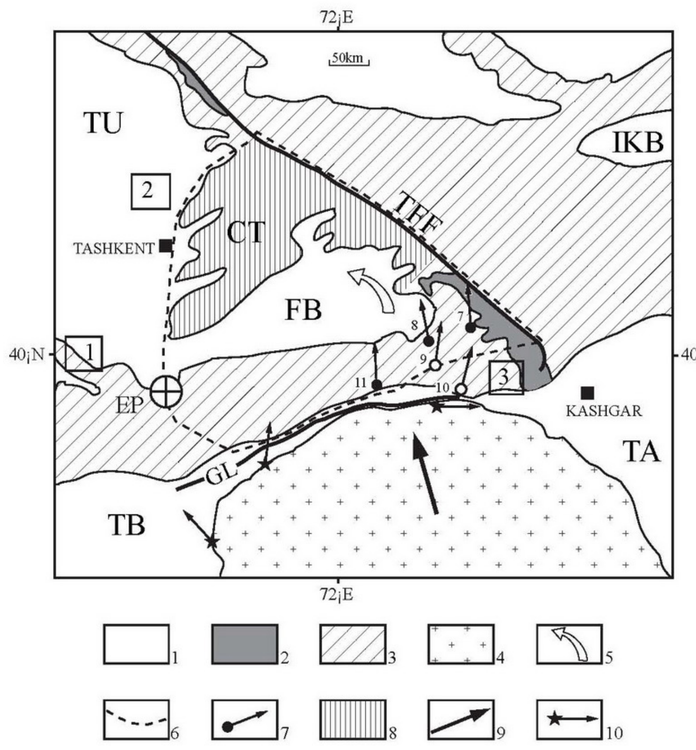

Fig. 4. The scheme illustrating the rotation of the Fergana block (after [Bazhenov, 1993]). Legend: 1-Cenozoic cover; 2-Jurassic basins conjugated with the TFF; 3-the Tien Shan domain (mainly Paleozoic); 4-the Pamirs domain; 5-direction of the proposed rotation of the Fergana block; 6-the boundary of the rotated block; 7-some sampling localities in the Tien Shan numbered as in the text: solid circles - rotated, open circles- unrotated, measured paleomagnetic directions; 8-the compensation structures (compensation triangles) accommodating rotation of the Fergana block (CT, Chatkal triangle); 9-the direction of the Pamirs movement; 10-Cretaceous sampling localities from the Pamirs External zone and paleomagnetic directions [ibid]. Numbers in rectangles denote the areas presumed unrotated with respect to Eurasia according to the proposed model. Abbreviations: IKB - Issyk-Kul basin; TFF - Talas-Fergana fault; TU - Turan plate; FB - Fergana basin; TA - Tarim platform; GL - the Gubin Line thrust; TD - Tadjik depression; EP - Euler pole position shown as large crossed circle.

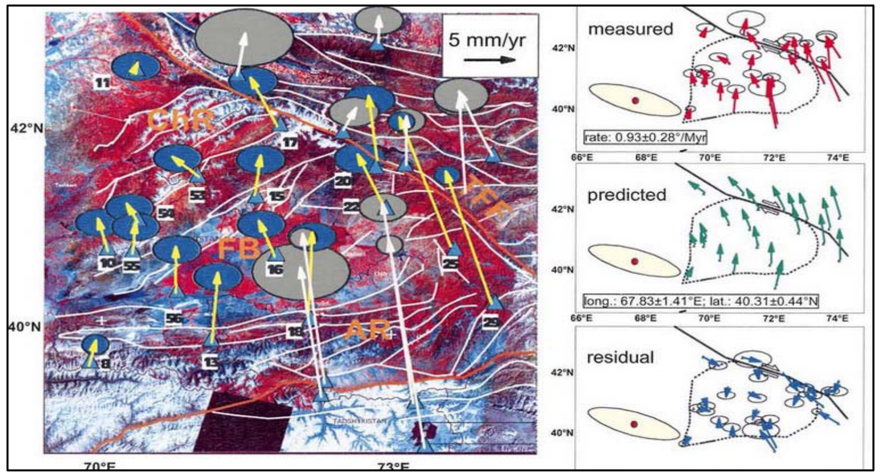

Fig. 5. GPS data providing evidence of counter-clockwise rotation of Chatkal range and Fergana basin. White lines reflect active faults position. Pictures on the right: ellipse with red point in the centre reflects Euler's pole (rotation pole) with 95% authenticity. Central right-hand picture shows shifting velocity of Fergana block relative to Talas-Fergana fault. Velocity decreasing inside the Fergana block due to deformation along active faults is shown at the bottom of the right picture [Reigber et al., 2001].

faults with offsets reaching tens of kilometers. Along the Neotectonic faults, the shear component is one order less or even absent at all. This fact is confirmed by direct geological observations and by paleomagnetic researches as well [Bazhenov, Mikolaichukds, 2004].

Outcrops of Mezozoic-Cenozoic deposits are established also in elevated massifs, where they are found in intermontane basins, the basement of the basins is always located at an altitude above sea level [Chediya, 1986]. These morpho-structures do not have their own importance and they are a constituent part of tectonic slices which form structures of a palm tree (palm tree structures) in the transpression mode from Late Pliocene [Mikolaichuk et al., 2008]. The comparison between the location of earthquake epicenters and neotectonics of the region shows that rather often earthquakes are grouped along neotectonic faults. Therefore, these neotectonic faults can be considered as seismogenic structures. The effects of large earthquakes can be directly observed along the activated faults because they ruptured the Earth surface. Exploration data allowed us to define a category of **active faults** which movements can be expected at present time and in the near future. As short active periods alternate with long inactive periods, the evaluation of the lifespan of an **active fault** is not an easy task. Special researches established that the fault can be considered potentially earthquake prone if its activity took place within Late Pleistocene-Holocene that is approximately 100000 years. By that it is allowed that the formation of the fault could relate to earlier times [Abdrakhmatov et al., 2001; Trifonov et al. 2002; Makarov et al., 2005]. The scale of potential earthquakes is proportional to the length of the active fault and depends on the type of fault rupture (refer to **Fig. 7**). Considering all other conditions equal, the maximum magnitude is more likely under thrust faulting type of earthquakes [Trifonov, 2000; et al.]. The degree of development of active faults in the Tien Shan is reflected on the map (**Fig. 3**). For the west part of CTS there is a more detailed scheme received by the results of specialized research (refer to **Fig. 8**).

Thus, if the length of an active fault and the type of motion by the fault are known, one can calculate the maximum possible force of an expected earthquake. These are the theoretical foundations of seismotectonics. In practice it is rather complicated. One cannot always map the entire fault or prove that the fault is actually an active one. **T**here are regional features due to which corrections to the detected regularity are introduced. It is preferable to take into account velocities of movements by the faults, but their assessment requires significant financial costs. That is why studying and mapping paleoseismic dislocations – the residual displacements from earthquakes that occurred in prehistoric times are important for the evaluation of seismic hazard [Abdrakhmatov, Tomson, 2005; Utirov, 1997; Strom, Abdrakhmatov, 2004]. An example of such a map is shown in **Fig. 9.** The occurrence of strong and destructive earthquakes depends on many factors. A correlation has been established between the location of sources of strong earthquakes with: gradient zones of

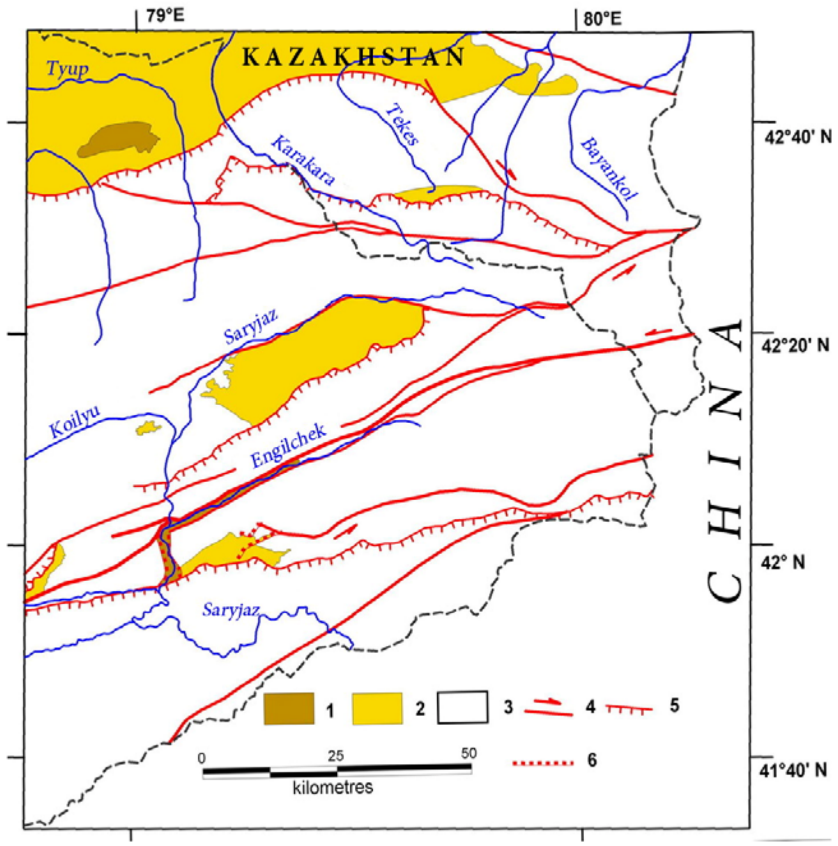

Fig. 6. Neotectonic scheme of Sarydjaz river basin and adjoining territories. 1-Upper Pliocene- Lower Pleistocene, 2-Mesozoic-Cenozoic deposits, 3-Paleozoic basement, 4-strike-slip, 5-thrust, uplift, 6-normal.

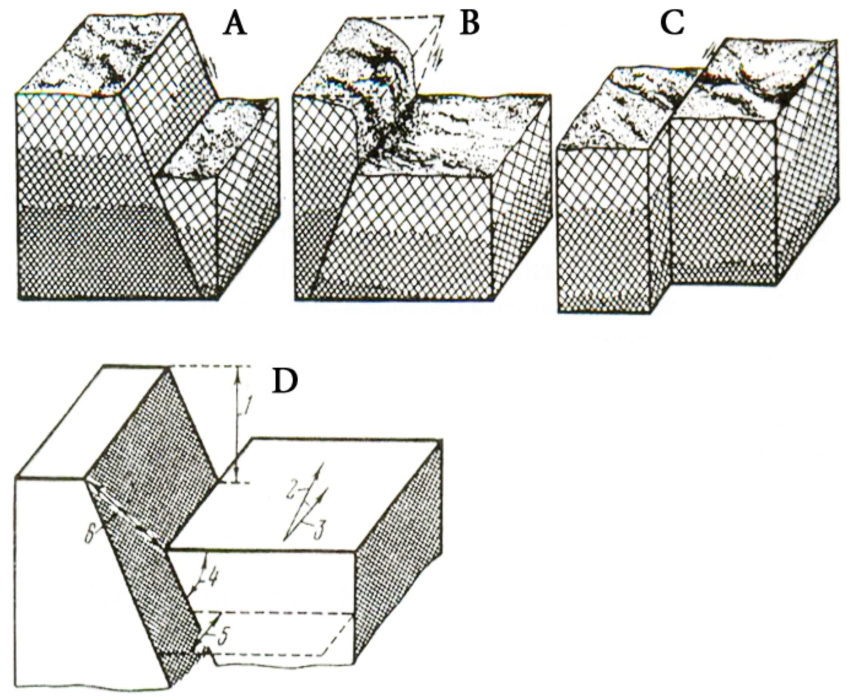

Fig. 7. Offset types along active faults. A - normal; B – uplift or thrust; C – strike-slip; D - oblique displacement: 1-vertical component, 2-slip azimuth, 3-total displacement azimuth, 4-inclination angle of shifter, 5-strike-slip component, 6-total displacement. According to [Trifonov, Karahatyan, 2008]

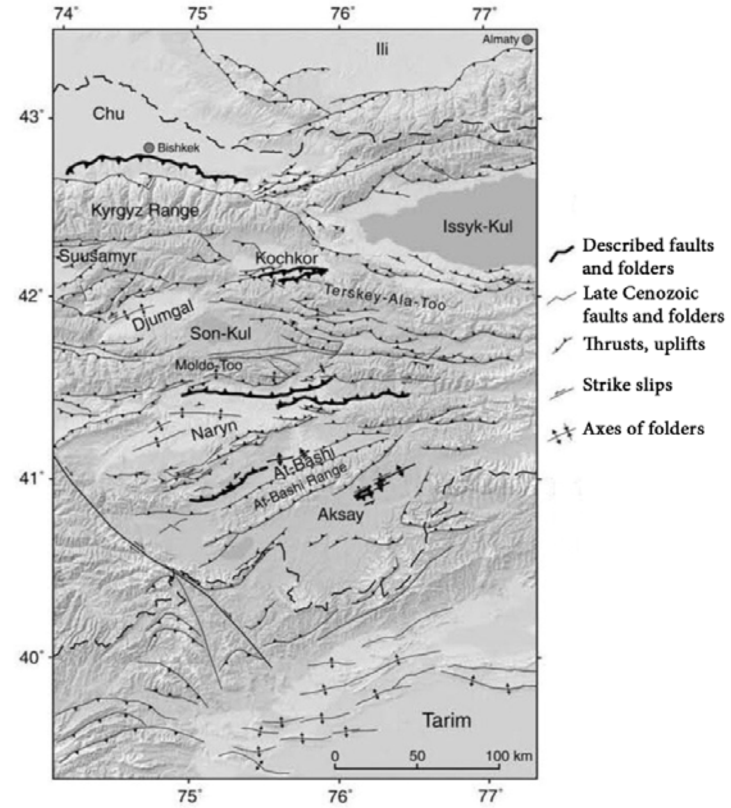

Fig. 8. Active faults and folds of the Central Tien Shan, according to [Abdrakhmatov et al., 2008]

neotectonic and modern movements [Gzovskiy, 1975; et al.], structural and formational complexes of the earth's crust [Knauf, 1982; Knauf et al., 1985], earth's crust wave guides [Adamova, Mirkin, 2006], mantle inhomogeneities [Sabitova et al., 2009], gradient zones of different geophysical fields [Tokmulin (edit.), 1992], temporal variations of the field of absorption of seismic waves in the lithosphere [Kopnichev, Mikhailova, 2000].

Attempts to integrate the whole amount of data are undertaken when drawing up maps of seismic zoning, using two methods, one based on a "formalized approach" [Borisov, Reysner, Sholpo, 1975] and one based on a "traditional" (deterministic) application of expert evaluations [Knauf, 1988]. The first map of seismic zoning of Kyrgyzstan based on the combined analysis of geological, geophysical and seismologic data was created in 1976 [Djanuzakov et al., 1977]. Almost all destructive earthquakes that occurred after publication of this map confirmed the predictions and all strong earthquakes occurring with the first 10 years after publication were located inside the zones of possible Occurrence of Earthquake Sources (OES). This means that their magnitude did not exceed the maximum predicted one. The exception was the Suusamyr earthquake of 1992, its magnitude turned out to be 2 units higher than the predicted one. Actually, this earthquake was unexpected for seismologists and seismotectonists of the whole world. Therefore, a large number of scientists of the world took part in the studies of this event. Taking into consideration new data a new version of the map of seismological zoning was issued in 1996 [Turdukulov, 1996]. This one is now the reference for construction organizations of the Republic.

In accordance with the last map of seismic zoning [Turdukulov, 1996], there are 23 seismic zones (or zones of OES) in the Kyrgyz Republic. Inside these zones, the maximum seismic hazard is outlined for areas where the occurrence of earthquake sources with a destructive effect at the surface marked by an intensity 9 and more on MSK64 scale is possible. As a result of such earthquakes, a series of surface deformations (e.g., surface rupture and gravitational movements) can occur. The North Tien Shan, Aramsu, Djumgalo-Terskei, Chatkal-Fergan, Tarsko-South Fergana and Gissar-Kokshal regions are such zones. The last one consists of the Darvaz-Karakul and Kokshaal segments. Each of the zones possesses its peculiarities of geological structure and differences in geodynamic environment. Some destructive earthquakes from the listed seismic zones are described below as an example. Hundreds of destructive earthquakes occurred and were recorded in

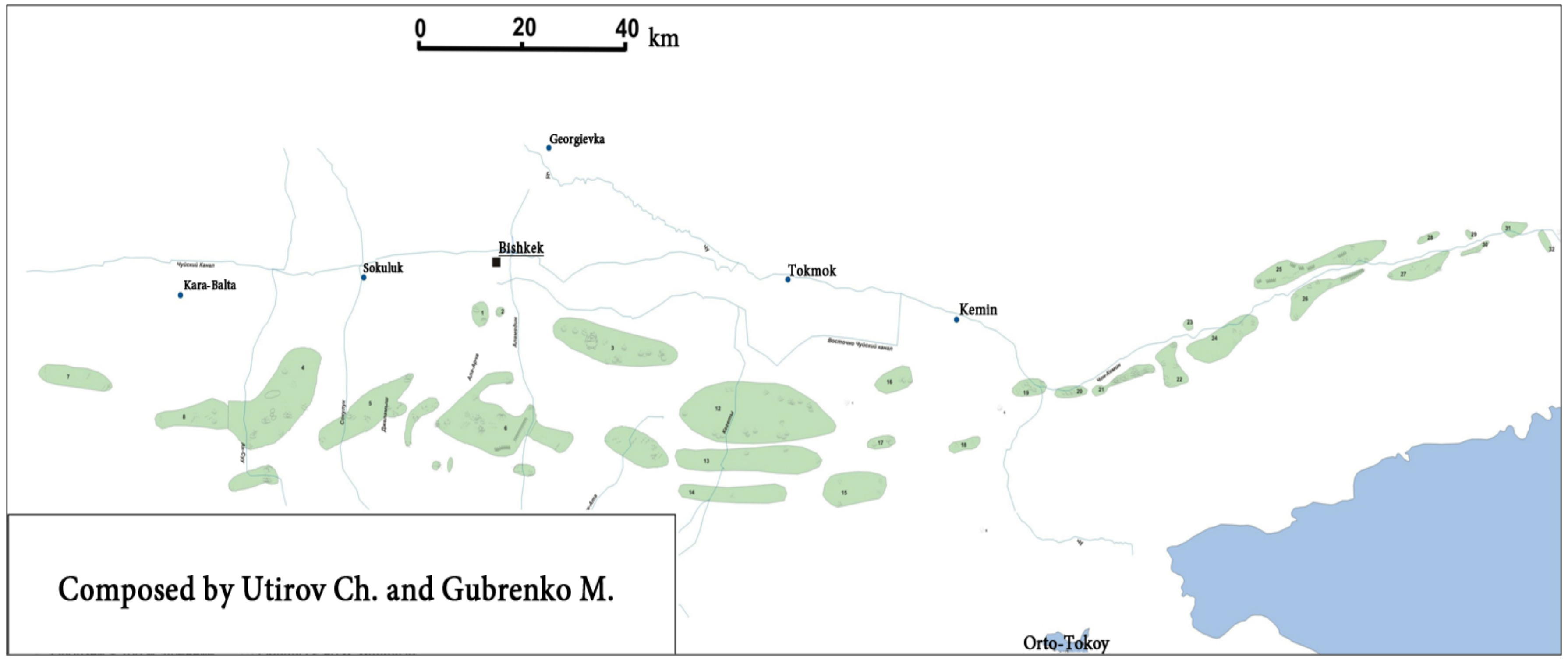

Fig. 9. Paleoseismic dislocations in Northern Kyrgyzstan, according to [Gubrenko, 2010].

Kyrgyzstan over the historical period. Their list is given in the catalogue of strong earthquakes of the current publication (refer to Appendix 2). One can find sufficiently complete information about the strongest of them in the book of K.D. Djanuzakov with co-authors [2003] **"Strong earthquakes of Tien Shan".** In this connection, we restricted ourselves to the description of seismic events that have been studied more in detail.

2.2. Examples of destructive earthquakes

2.2.1. The 1911 Kemin earthquake (M=8.2; Io = 10-11 MSK64)

A range of destructive earthquakes took place within the Northern Tian Shan seismic zone during the XIX and XX centuries. These are the1885 Belovodsk earthquake (M=6.9; Io=9-10 MSK64), the 1887 Verniy earthquake (M=7.3; Io=9-10 MSK64), and the 1889 Chilik earthquake (M=8.3; Io=10 MSK64). The final "accord" of this Pluto requiem was the Kemin earthquake of 1911. This was the "accord" because it was not one seismic event but a lasting seismic process embracing the areas of two great mountain ranges of the Tien Shan: the Trans-Ili Alatau and Kungei Alatoo. 452 people were killed during the Kemin earthquake [Bogdanovich et al., 1914]. This fatality count can be considered as very low because during earthquakes with a magnitude of M>8 in densely populated areas the number of dead may be dozens or hundreds of thousands of people.

This is a report of one of the founders of modern seismology, B.B. Golitsin about that earthquake: "… just like Verniy one (the earthquake in June 9th 1887) it started at 04:40 in the morning by local time." After the arrival of the S-waves the records (*set on the Pulkovo station – note of authors*) became saturated and the galvanometer was disabled, the steel needle fell out of the pendulum of the mechanical recorder. … Two days prior to this large-scale earthquake, namely in January 1, 1911, two weaker earthquakes took place in the same area at about 10:24 a.m. and 15:05 p.m. … Pendulum clocks in many areas of the European part of Russia on the night of January 3 to 4 had stopped. None of the buildings were left intact in Vernyi town: wattle and daub houses were fully destroyed, masonry houses were split. There appeared deep soil ruptures on the surface. Landslides were recorded on the right bank of Alamatinka river. 44 people were killed and 100 injured in Vernyi town itself and the surrounding Cossack villages. Big rocks were falling down and thrown from Almatinka peak. … Rockslides had been triggered in the Trans-Ili Alatau mountain range which buried people and livestock. ... A big number of villages on the northern bank of the Issyk-Kul lake suffered from this, which included Sazanovka, Alekseevka, Folbaumskiy, Mihailovka et al.. … As to the nature of the seismic ground motion all reports say that this earthquake ended in vertical tremors. … (*to learn from eyewitnesses*: the ground surface looked like hunches of a running camel.) … There are no reports providing information about the underground 'boom' which could be heard in 1887 and had caused a big panic." [Golitsin, 1960].

The Kemin earthquake was accompanied by numerous aftershocks. During half a year, repeated earthquake shocks were felt in Vernyi town (300 earthquakes in all.) The strongest of them took place in January 9, 12, and 14, 1911. As a result of the aftershock on January 14th 1911, a rockslide, 14-20 m in height, took place near Talgar village. Its length was 1,700 – 1,800 m and 80-100 m in width [Djanuzakov et al., 2003].

Several months after this seismic event, the epicentral area of the Kemin earthquake had been investigated by a group of geologists under the supervision of professor K.I. Bogdanovich [1914]. It was established that the basic seismodislocations are centered within Chon-Kemin and Chilik river basins as well as in interfluve of Chon-Aksu – Chon Baisoorun, along the northern side of the Issyk-Kul basin. All these results were further used in all seismotectonic works (see **Fig. 10**). And only in 1996 new specialized studies of active faults were carried out. In the frame of this research seismodislocations which had not moved since 1911 were studied [Delvaux et al., 2001]. According to the results of these works, the description of the source zone of the Kemin earthquake is given.

A narrow transpression suture zone of EN-E extension goes along Chon-Kemin river and further Chilik river, which is represented by two sub parallel sinistral strike slip faults: Chiliko-Kemin northern (**1 on Fig.10**) and Chiliko-Kemin southern one (**2 on Fig.10**). They are connected in the western Chon-Kemin basin tracking along foothills of the Kyrgyz mountain range as the Shamsi fault (**3 on Fig.10**). This fault system had already been formed in

Late Palaeozoic but it underwent repeated reactivation during Cenozoic stage [Bajenov, Mikolaichuk, 2004]. The Aksuu fault system (**4 on Fig.10**) [Chediya, 1990] joins the Chiliko-Kemin faults in the area of Chiliko-Kemin saddle. Its kinematics have been studied insufficiently. One work is known only [Korjenkov, 2006] which describes sinistral shear displacement of a few meters on the walls of Kamen fortress of VIII-XII along the valley of Chon-Baisoorun river.

The Kemin earthquake was accompanied by a complicated system of seismic dislocations which occurred on separate segments of the aforementioned active faults [Delvaux et al., 2001]. The Djil-Aryk segment, the most western one, is located at the confluence of the Chon-Kemin river and Chu river. Displacements caused by the earthquake are observed over the distance of 20 km. Fault planes that are visible on outcrops dip 45-60° to the where the thrust component of motion dominates. There is a small strike slip offset along steep displacement plane.

An activation of both Chiliko-Kemin southern and Chiliko-Kemin northern faults have been identified in the Djay tract area (middle stream of Chon-Kemin river.) Seismic dislocations can be found along the faults within an epicentral distance of 62 km for the southern and 40 km for the northern one. There is also recorded vertical thrusting of up to 4-5 m and sinistral shear displacements of the river streams with an amplitude of 5-10 m.

Chiliko-Kemin saddle: A range of ruptures with a total extension of 46 km was mapped during the expedition of K.I. Bogdanovich in the upper river of Chon-Kemin and Chilik. The biggest part of this segment is located on the territory of Kazakhstan, but there is no detailed information about the nature of movements on this fault.

The Chon-Aksuu segment of Aksuu fault stretches in E-W direction from Aksuu Pass in the west to Kok-Bel Pass in the east along the southern slope of Kungei-Alatoo. The total length of seismic ruptures makes 40 km. Thrusts are a common characteristic of the described segment, where thrust planes dip towards the north at an angle of 60°. The maximum height of the scarp is 10.5 m but it usually ranges between 4-6 m. Strike-slip component over fault is no more than 1 m. The eastern Aksuu segment of the same fault strikes in SE direction from Aksuu river to the Issyk-Kul shores on the other side of Ananyevo village (Sazonovka.) This rupture is recorded on the surface along 34 km. It gradually dips towards north with a vertical displacement of 3-5 m.

The descriptions of the Kemin earthquake mentioned a wide development of landslides, rockslides and mudflows. Unfortunately these features were not mapped and the geographical location of many of them is not known anymore. Mainly the location of two large rockslides (>10 10^6 m^3) is still known . They are shown on the map in **Fig.10**. The first is the Kaindinskiy (Chon Kaindinskiy) rockslide located at the eastern end of the Chonkemin basin, and the Ananyevo rockslide situated near the village of the same name. The latter was thoroughly explored by an international group of engineering geologists and geophysicists [Havenith et al., 2003]. As a result of the executed work the exact location of seismic rupture as well as morphometric parameters of Ananyevo rockslide were established. The scarp of this rockslide dips towards the south and has a height of 200 m. The total height and length of the rockslide from the toe to the crown are 500 and 900 m, respectively . The rockslide consists of fragments of varying in size from fine-grained arenite to weathered granite blocks of the size of a house [Havenith et al., 2003].

All data certify that during the Kemin earthquake the displacements were originated as a result of connected faults of sublatitudinal and southern and eastern strike. The movement involved a large block of the earth's crust; the seismic activity related to this movement was lasting for about half a year.

2.2.2. The Belovodsk earthquake of 1885 (M=6.9; Io = 9-10 MSK64)

Just like the Kemin seismic event the Belovodsk earthquake struck the same Tien Shan seismically activezone but its intensity was significantly weaker. Therefore one could neglect this event. But information about the Belovodsk earthquake may be very interesting data for the audience because it took place in the Neotectonics structure close to Bishkek and its surroundings. Therefore if we want to know what the aftermaths of the earthquake could be if it occurred in Bishkek we have to study the character of the surface destructions as well as failures of different types of buildings within the pleistoseist area of the Belovodsk earthquake and … transmit this picture 50 km eastward.

To be more sure about this thesis let's consider more detailed location of the pleistoseist area of the described earthquake in the geological structure of the region. As it can be seen in the attached scheme (see **Fig. 11**) the source of the Belovodsk earthquake was localized in the western end of lower foothills which called the Sokuluk step [Trofimov et al., 1976]. This morphostructural unit is cored by Cenozoic deposits. They have been involving in the process of uplifting since late Pleistocene and moving along the Aksuu fault on the even-aged sediments of Chui basin (**1 on Fig. 11**). The Serafimov unit **(2 on Fig. 11**) is upthrown (uplift) on the Sokuluk one. The Serafimov unit is bounded to the East by the following tectonic block. The nature of this structural group is discussed with more details in the article [Mikolaichuk et al., 2003]. Here we could note that the similar tectonic displacements look like ice floating on the river in spring.

Movement of connected tectonic blocks is usually caused by a large-scale regional strike-slip. Therefore, they are called as **strike-slip duplex separation** in structural geology. In our case such a phenomenon is a regional fault (**3 on Fig. 11**) separating Palaeozoic complexes of the Kyrgyz ranges and Cenozoic deposits of Chui basin.

The Belovodsk earthquake was felt over a vast territory from Djarkent (Panfilov) in the east to Tashkent in the west, from Balkhash in the north to the northern and western Chinese provinces in the south. This earthquake caused widespread destruction and human victims, especially in the pleistoseist area where Belovodskoye, Karabalta and Sokuluk rural areas were thoroughly destroyed and buildings in the neighbouring regions were partially damaged. The force of the earthquake was so great that it caused damage not only in the neighbouring Pishpek, Tokmok and Boom gorge but in the Issyk-Kul valley as well.

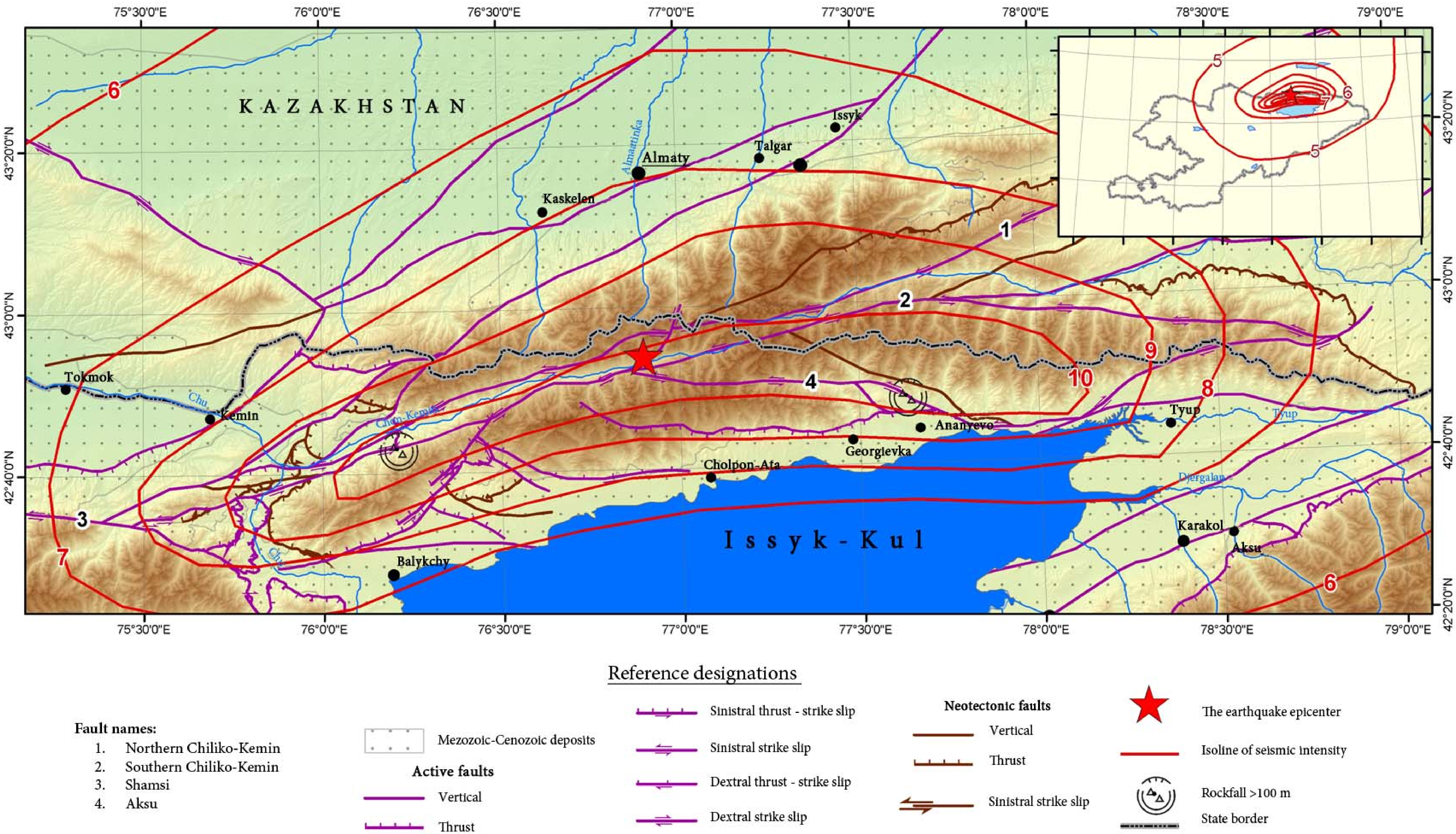

Fig. 10. Neotectonic scheme of 1911, M=8.2, I_0=10-11 MSK64 Kemin earthquake's source area.

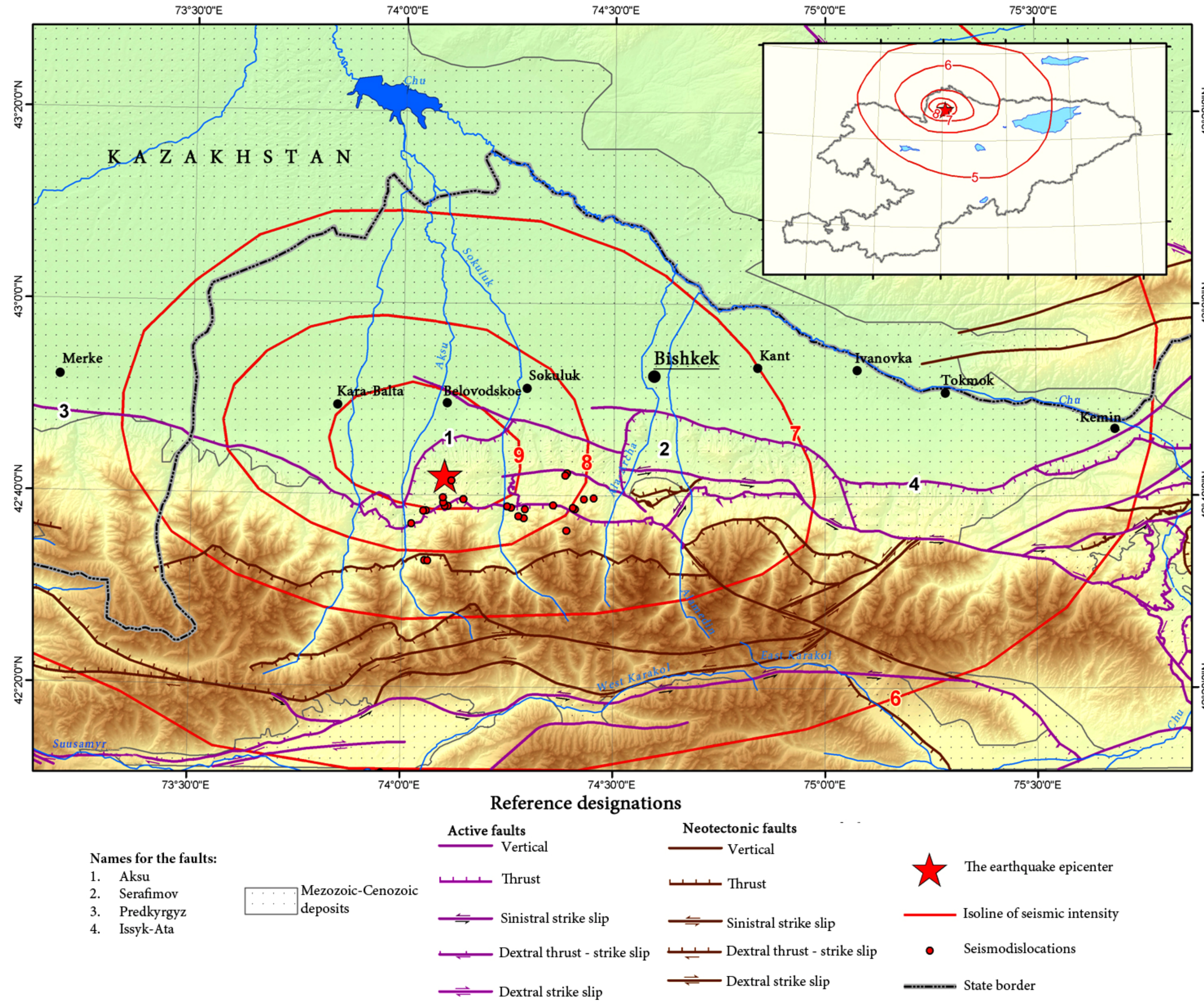

Fig. 11. Neotectonic scheme of 1885, M=6.9, I_0=9-10 MSK64 Belovodsk earthquake's source area.

The fracture of 20 km in length striking along the foothills till Aksu River was formed on the left side of Sokuluk River. Its width was something between 15-20 cm and 2 m. Earthquake shocks in the foothills caused fractures on the soil cover which were placed in parallel with the strike of mountain range or, as it was seen in Ura-Bashi tract (near Belovodskoye), it created crossing systems where blocks were put one by one in the depth of 1.5 – 2.5m. An earthquake in the foothills of Kyrgyz mountain range caused a number of rockslides, screes and landslides. As a result of a big number of rockslides a pass close to the Aksu River sources was blocked [Djanuzakov et.al., 2003].

The main shock of the Belovodsk earthquake was accompanied by a range of aftershocks which were felt every day in the epicentral zone during the next 5-6 months. The strongest aftershocks took place in August 3 and October 25; the first one was recorded in Pishpek (Bishkek) with almost the same force as the main shock [Goryachev, 1954; Djanuzakov et al., 2003].

Seismodislocations within the epicentral zone of the earthquake were studied and measured and then catalogued using GIS-technologies [Utirov, Gubrenko, 2003]. There are 57 rockslides and landslides in the interfluve of Djelamysh-Aksu that can clearly be attributed to the seismic event. However, special research on the largest rockslides (Belogorka and Aksu River) reaching a volume of ~ $20x10^6$ m^3 and ~ 1.5 km^3, respectively, could not clarify if those mass movements were really associated with this earthquake [Strom, Abdrakhmatov, 2004; Strom, Stepanchikova, 2008]. The above-mentioned authors do not reject the seismic nature of these rockslides but could not find any conclusive evidence of their origination during the Belovodsk earthquake. The Belovodsk earthquake triggered a second landslide that blocked Aksu River; behind this dam a temporary lake had formed [Strom, Abdrakhmatov, 2004; Strom, Stepanchikova, 2008]. Consequently the seismicity of this area had been reactivated several times. In this connection it is necessary to note about the first works on detailed seismic zoning of Chui basin. V.I. Knauf and O.K.Chedia already in 1975 came to the conclusion that the foothills of Kyrgyz mountain range would regularly affected by seismic shocks but the force of those would not exceed intensity 8-9 MSK64 [Green et al, 1975]. Later, it was established that destructive earthquakes had been taking place here already in the XV century [Chediya et al., 1998]. The results of investigations of the zone of Issykata fault (**4 on Fig. 11**), revealed in a series of trenches burial of petrifactions and Paleosoils aged of 5250 ±60; 5130±50; 3530±40; 3180±40; 2830±50; 2410±50; 1850±40 years [Chedia et al., 2000; Thompson, 2001]. These took place during the movement and collapse of Pleistocene sediments. These age markers were also interpreted as a result of seismic events which took place in the lower foothills of the Kyrgyz mountain ranges.

2.2.3. The 1992 Suusamyr earthquake (M=7.3; Io = 9-10 MSK64)

The earthquake began with a strong underground 'boom' as if there was an explosion. This 'boom' and earth cracking were so strong that it was not heard how domestic things, chimney pipes, furnaces were falling; walls and roofs of the houses went to pieces. The shaking of soil was throwing people sitting on the ground, and those who tried to stand up – couldn't keep their balance. Waves ran over the ground, ruptures appeared, massive avalanches, rock falls and landslides started, pieces of up to 0.5 m in diameter were "shot" from the rocks [Djanuzakov et al., 2003]. There are no settlements in the pleistoseist area, consequently, the description is given by the evidences of the dwellers of villages located by the southern slope of Suusamyr range. This unexpected event left a scar in their memories even until today.

Large destructive earthquakes are always unexpected for the population but not for the specialists.. Generally, specialists know where future earthquakes may occure, but they do not know when. The Suusamyr earthquake fortunately occurred in a weakly populated area and victims of its impact are minimal. However, it completely destroyed confidence of the specialists in the accuracy of evaluations of seismic hazard of Tien Shan. Before this event multiple arguments were given in favor of the fact that internal regions of Tien Shan orogene are weakly seismic. In particular, seismo-statistical data for the whole period of instrument observations were confirming that Suusamyr valley would be seismically safe (**Fig. 12**). That is why this event attracted the interest of specialistsnot only from Asia, but also from Europe and America. Seismological aspects were investigated by [Mellors et al., 1997; Djanuzakov et al., 1997; et al.] while surface effects in the epicentral area had been studied by [Bogachkin et al., 1997; Ghose et al., 1997; Havenith et al., 2000; Su Zongzheng et al., 1996].

This region is located in the North-East of the Talas-Fergan dextral strike slip fault (**1 on Fig. 13**), where two systems of faults, differed by sinistral and dextral offset, developed. The direction of the offset was determined by slickenside in the zones of faults [Burg, Mikolaichuk, 2008]. The Suusamyr-Toluk fault (**2 in Fig. 13**) is parallel to the Talas-Fergan strike slip fault and is also characterized by dextral offset. The faults of sub-latitudinal strike are characterized by sinistral offset in the eastern part of the region (**3 and 4 on Fig. 13**) and dextral offset in its western part (**5 and 6 on Fig. 13**). Dextral offsets of 5-6 mm/year [Makarov, Abdrakhmatov, 2005] occurred in Late Pleistocene-Holocene along the Karakol fault (**6 in Fig. 13**).

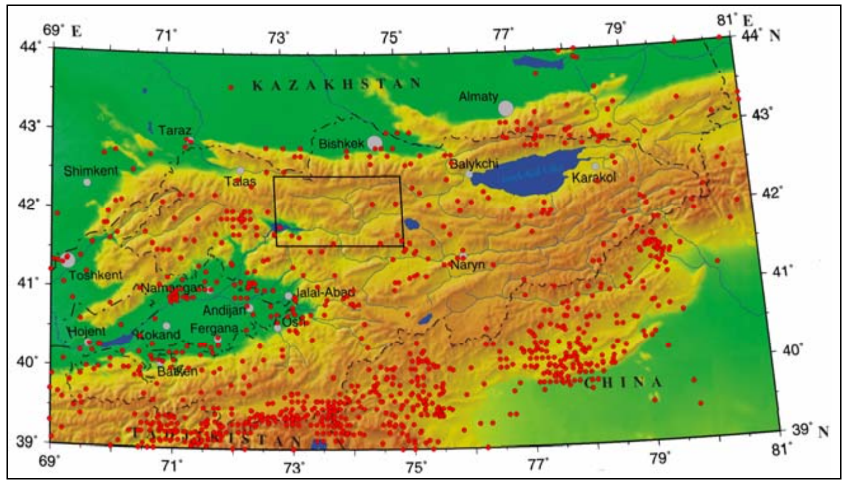

Fig. 12. Map of the earthquake epicenters with M_{LH} ≥4.5 occurred since historical time untill the occurrence of the 1992 Suusamyr earthquake.

According to instrumental data the epicenter of the earthquake is in the heads of the rivers Aramsu West and Aramsu East, spatially related to strike-slip faults of sub-latitudinal strike South-Aramsu and Kyzyloy (**7 and 8 on**

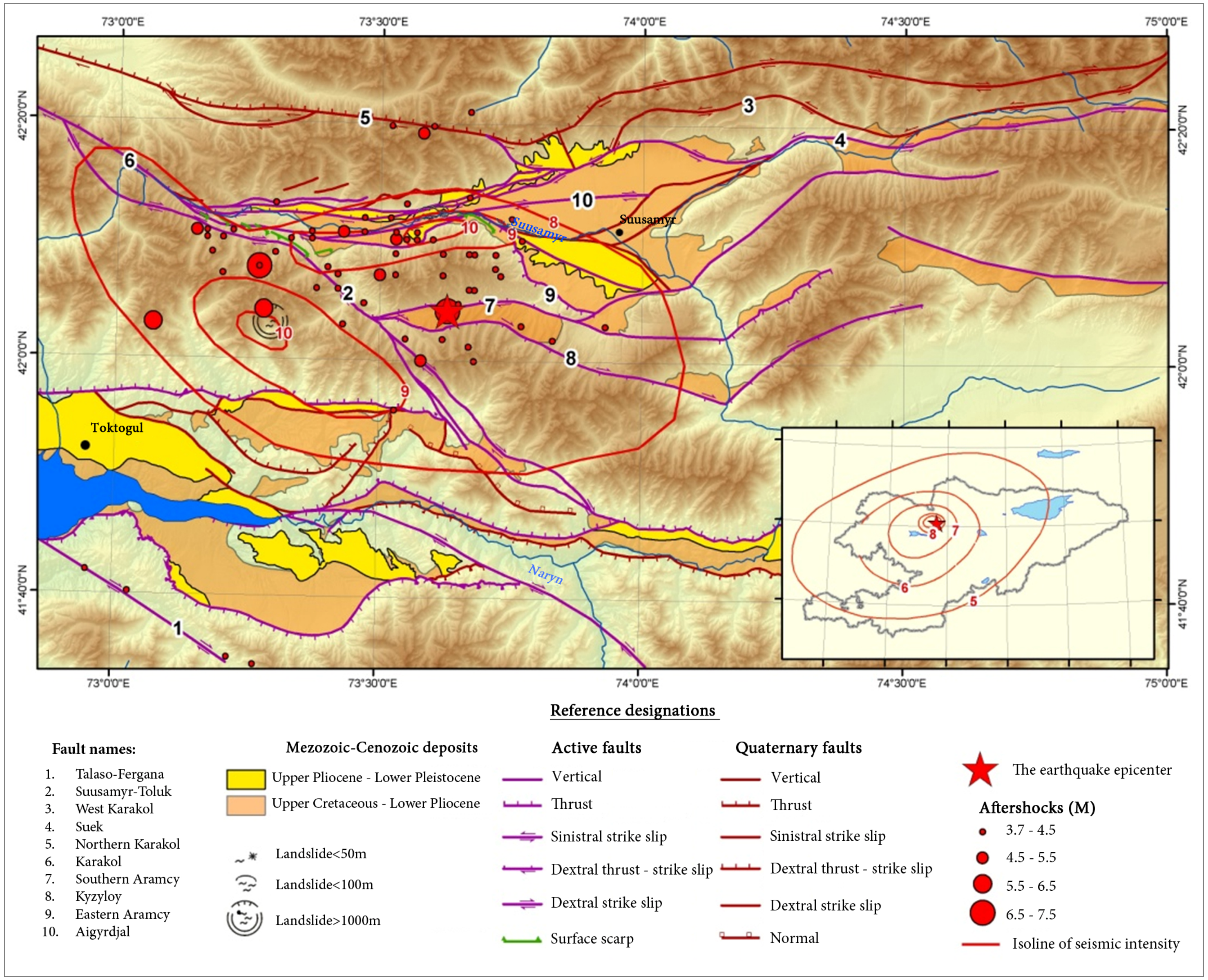

Fig. 13. Neotectonic scheme of 1992, M_{LH}=7.3, I_0=9-10 MSK64 Suusamyr earthquake's source area.

Fig. 13 accordingly). Following the main shock there was an aftershock with a magnitude of M=6.7. It is located in south-west of the Suusamyr-Toluk fault. In the same section, but in the north-east part of the Suusamyr-Toluk fault (Djalpaksuu river) the fault activated by the Suusamyr earthquake ruptured the surface. It can be traced over more than 6 km and is represented by a series of imbricate fractures, cutting not only morains but also proluvial cones and touches rock outcrops. In kinematic terms it is a thrust with a small (10-15 cm) dextral displacement. The shift plunges by an angle of 30° [Bogachkin et al., 1997; Su Zongzheng et al., 1996].

The second seismic disruption appeared 25 km to the east, at the junction of East-Aramsu and Aigyrdjal faults (**9 and 10 on Fig.13 respectively**). It consists of a series of fractures of a total extent of up to 4 km. The most prominent seismic surface rupture is located in the flood plain of Suusamyr river, in the region of 162 km of Bishkek-Osh highway. As in the first case it is a dextral thrust strike slip rupture. Maximum vertical displacement was 2.7 m, horizontal offset is up to 20-30 cm [Bogachkin et al., 1997; Ghose et al., 1997].

The area of secondary disturbances of earth's surface covers the territory of more than 4,000 km^2 square. This data is generalized and presented in a view of isolines [Korzhenkov, 2006].

Isolines usually form an ellipse with a long axis in parallel to the strike of the active fault. A.M. Korzhenkov [2006], analyzing the distribution of the isoline of intensity 8 MSK64, clearly outlined its asymmetry. He supposes a progradation of the seismic rupture to the west that seems to be confirmed by the migration of aftershocks [Djanuzakov et al., 1997]. According to our observations, however, there are two isolated sources (of earthquakes) outlined by isolines of intensity 9. One of them is latitudinal, it strikes in parallel to Aigyrdjal fault. The eastern seismic rupture falls into the pleistoseist zone. The second pleistoseist zone is elongated in parallel to the Suusamyr-Toluk fault and includes the western seismic rupture of Djalpaksuu river. Taking into the consideration that the aftershock of M=6.7 occurred shortly after the main shock (delayed by 1 hour and 8 minutes) ,one should speak about a double shock, the first one leading to motion along a sub-latitudinal fault, the second one inducing a NW-SE oriented rupture. As both systems are dextral thrust-strike slip faults, the double shock induced a counter-clockwise rotation of the range (block) of Aramsu. This model was suggested already by the results of primary investigation of the source area of the Suusamyr earthquake [Bogachkin et al., 1997]. In confirmation we would like to add that mud eruptions appeared exactly within the perimeter of the activated Aramsu block, and the maximum density of aftershocks was recorded in this internal part (**Fig. 14**).

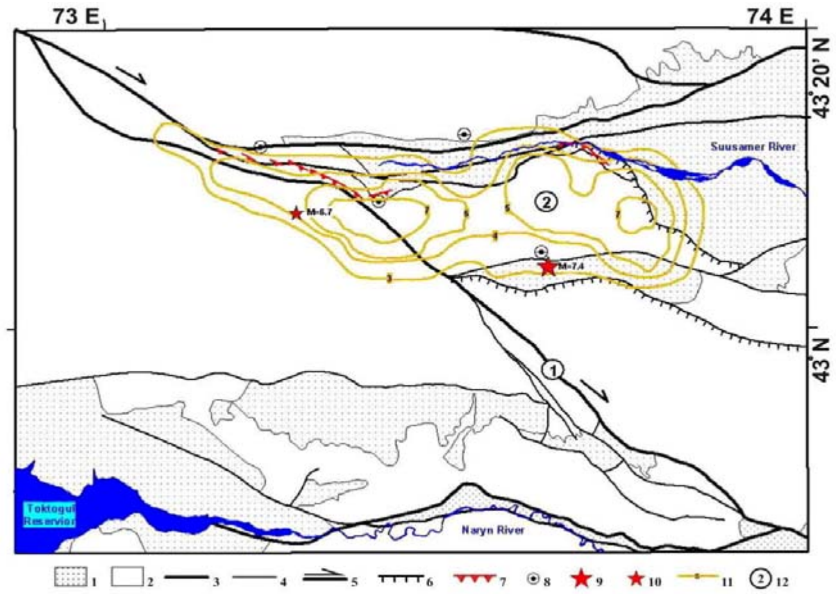

Fig. 14. Seismotectonic scheme of the Suusamyr earthquake, according to [Mikolaichuk and Kalmetieva, 2008]. 1-Pre-Quaternary Cenozoic deposits; 2-Paleozoic basement; 3-main faults; 4-secondary faults; 5-strike slip; 6-thrust; 7-surface rupture; 8-mud volcanoes; 9-10 – epicenters of: 9-main shock; 10-aftershock with M_{LH}=6.7; 11-lines of equal aftershock epicenters density; 12-structural units mentioned in the text.

Generalization of the materials by seismicity, paleo-seismology and geology of the region allowed to draw up a map of seismic hazard, from which it appears that the Suusamyr earthquake is not the strongest one out of potential ones for Aramsu seismic zone (**refer to Fig. 15**).

2.2.4. The Chatkal earthquake of 1946 (M=7.5; Io = 9-10 MSK64)

The Chatkal earthquake occurred within the Chatkal-Fergana seismic zone [Turdukulov, 1996]. This zone has in plan corner-shaped form covering parts of the NW-SE oriented Fergana and Atoinok ranges and the SW-NE oriented Chatkal range. The NW-SE orientation of this seismic zone is abnormal for the Neotectonics of the Tien Shan and is fully controlled by the Talas-Fergan dextral strike slip fault. The Chatkal event is the strongest one among the known earthquakes in this region and is related to the junction of Talas-Fergana, Atoinok and West Karasu faults (**1, 2 and 3 on Fig.16**, respectively).

In the epicentral area the force of the earthquake was not less than intensity 9 on MSK64 scale. This earthquake affected the whole Tien Shan and even damaged hundreds of buildings far from the epicenter in Tashkent city. In Namangan city, located at half the distance from the epicenter, as well as in Djambul (Taraz) city (at similar epicentral distance), the earthquake induced far less damage. This shows that more seismic energy was propagated along the strike of the main geological structures than perpendicular to them. Therefore, isolines drawn on the basis of observations are elongated in parallel to the strike of the Chatkal range [Goryachev, 1954]. The pleistoseist area of the Chatkal earthquake (extent is 80-100 km, average width is 15 km) covered the southern part of Ketmen-Tyube basin, the zone near Naryn river before inflowing of Karasu river (western), the region of Sary-Chelek lake and At-Oinok massif as well.

The most significant rock falls and landslides in clay and loams occurred on the right bank of the Naryn River. After the occurrence of one rockslide, Naryn River got dammed and formed a reservoir in the lower part of the Ketmen-Tyube basin. A possible outbreak/filling was threatening the village of Toktogul The rock fall with a length of 30-50 m and a thickness of of 10-15 m was observed in the zone of Toktogul-Tashkumyr. Two landslides in loam deposits occurred near Karabashat settlement. Their length was 200 m, the width 50-80 m and

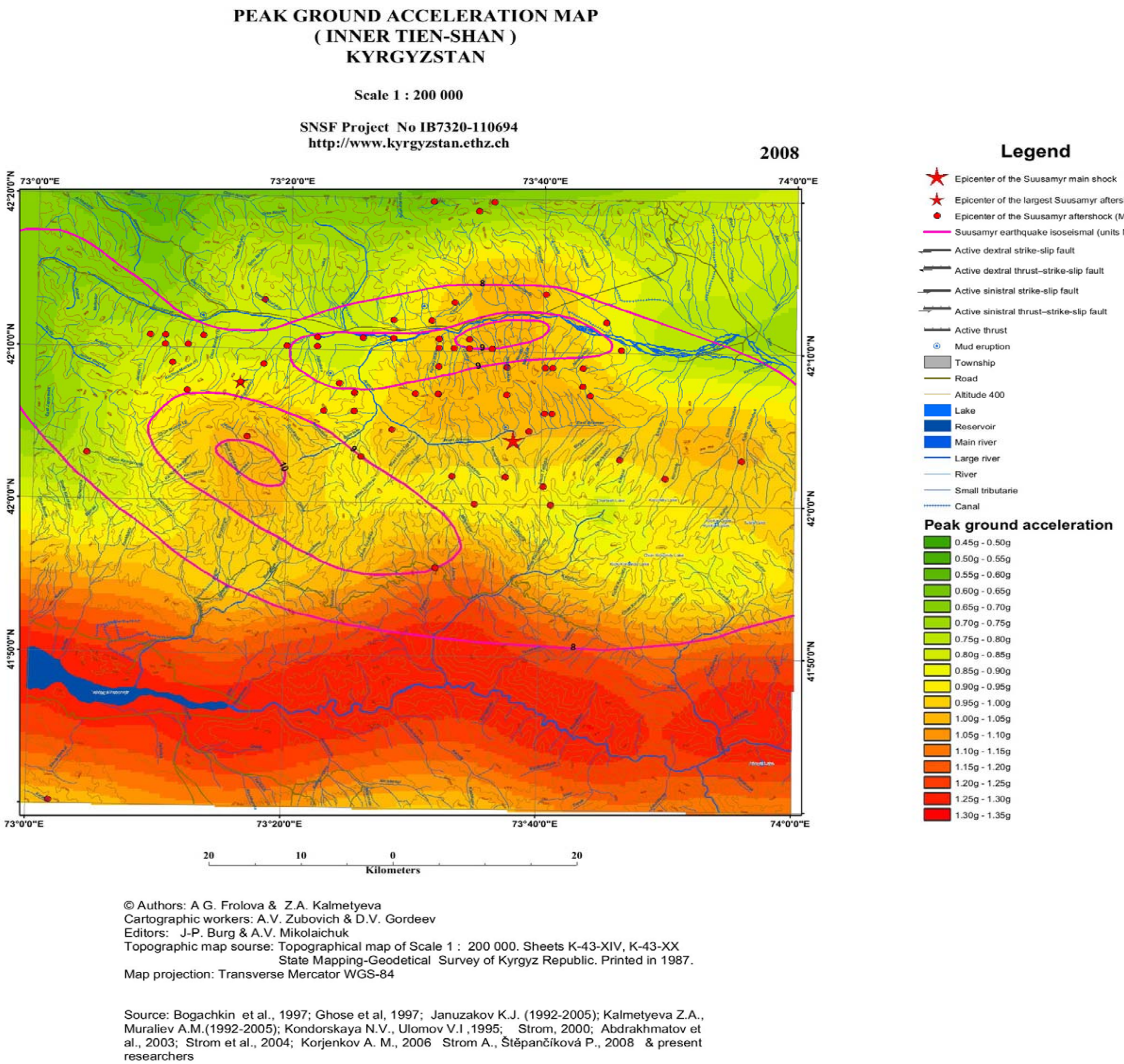

Fig. 15. Map of seismic hazard in terms of peak accelerations, according to [Burg, Mikolaichuk, 2008].

the depth 15 m. These landslides were triggered from a slope with a height of 100 m. Widespread surface deformation was also recorded in the region of Sary-Chelek lake. At the watershed between Sary-Chelek lake and the valley of Aflatun river (southern) there appeared large (up to 100 m length) NW-SE oriented fractures. On the western slopes of the watershed of Karasu and Khodja-Ata rivers a range of large 200-300 long fractures formed. The width of some subsidence between fractures reached 15-20 m. A large rockslide dammed Karasu river (western) 3 km downstream from Karasu lake, and dammed a small lake. Another lake on Itokar river was formed also as a result of rockfall of about 50 m width. Most of the surface effects were related to the zones of tectonic contacts. The strike of fractures coincides with the direction of tectonic ruptures, only in a few case they were oblique to them.

Almost all populated areas located within the pleistoseist zone of 1500 km², were destroyed by 70-100%. Villages in the western part of the pleistoseist zone, in the upper course of Khodja-Ata river were most severely damaged. The villages Shuduger, Kichitovar, Chontovar, located in the south-eastern foothills of the Chatkal range were ruined. Large destructions were also observed in Uspenovka village to the west of Bozbo-Tau range. The largest destruction of constructions in the south-east part of the epicentral zone occurred in the populated areas located in the south of KetmenTyube basin and sections of the valley of Naryn River (up to the mouth of Toktobek-Sai river) adjacent to it. The villages Tomatere, Toktobek and Sarykamysh (Upper and Lower) located on the right bank of Naryn river were completely destroyed. Only two wooden houses were undamaged in the settlement of Ketmen-Tyube while all adobe block, wattle-and-daub and other constructions were damaged [Churoyan et al., 1949; Butovskaya et al., 1948; 1961; 1964; Leonov, 1970; Djanuzakov, 1964 – it is quoted by Djanuzakov et al., 2003].

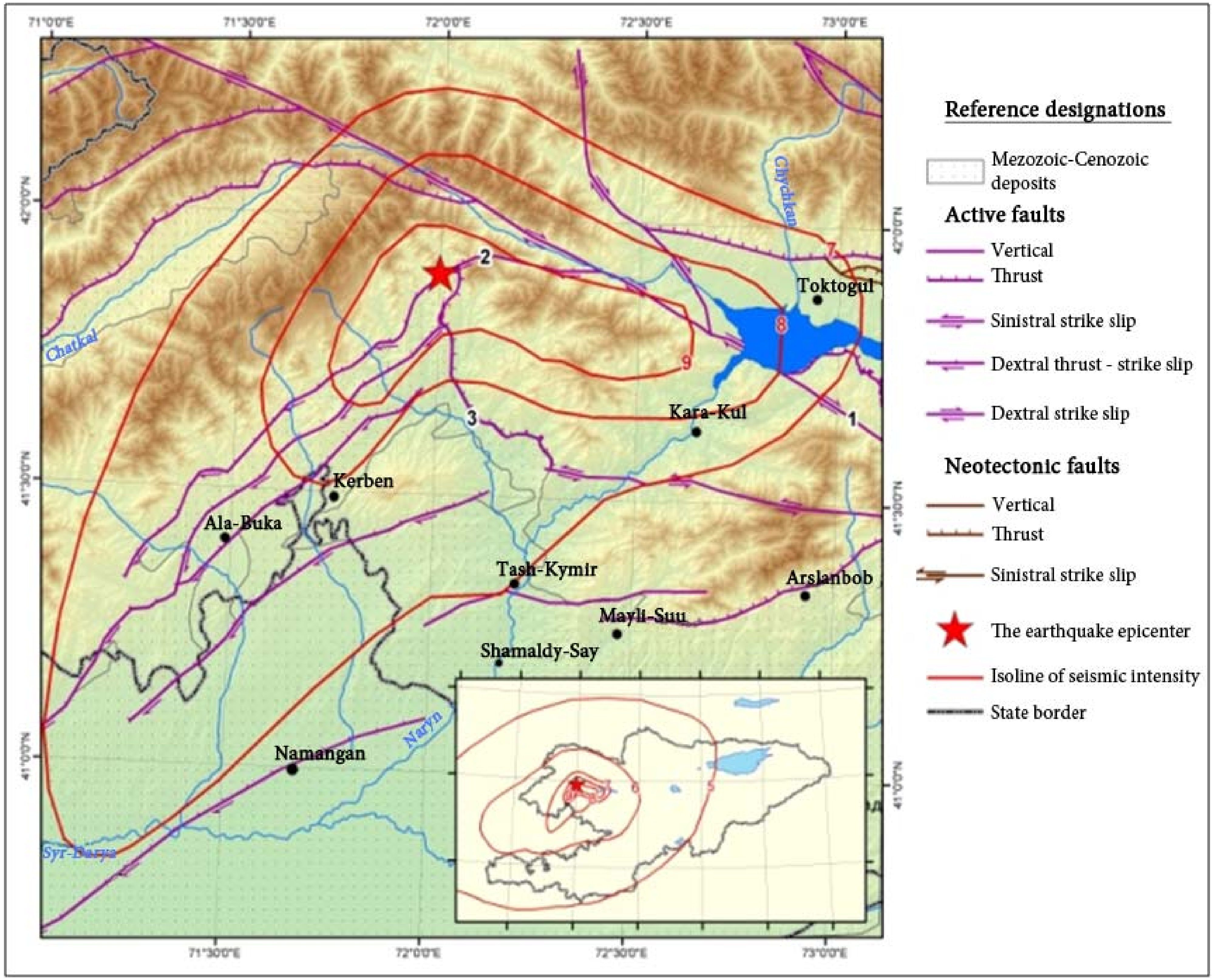

Fig. 16. Neotectonic scheme of 1946, M_{LH}=7.5, I_0=9-10 MSK64 Chatkal earthquake's source area.

Unfortunately, we do not have information about the number of human losses during the Chatkal earthquake. But considering the severity of destruction of the infrastructure and settlementswithin the pleistoseist area, we can get a general idea about the scale of the tragedy.

Only if objective information about the aftermath of destructive earthquakes is provided, one can hope that the corresponding measures of prevention of the consequences of future earthquakes will be taken. And in this case data on the pleistoseist region of the Chatkal earthquake also deserves careful attention. The research by V.K. Kuchai [1971] showed that within the contours of the pleistoseist region of the earthquake of 1946 Late Pleistocene and Early Holocene seismodislocations are widely developed. In Upper Quaternary times the impacts of earthquakes were stronger than in recent times. To the south-east of the pleistoseist zone, along the Talas-Fergana fault, an aggregation of large seismodislocations were identified in the region of Karasu lake while in the space between these regions (in the area of Kokbel Pass) no significant seismodislocations could be detected. The author comes to the conclusion that over significantly long periods of time the strongest earthquakes recur in the same places. The modern research [Strom, Abdrakhmatov, 2004] discovered that the described sequence of the development of rockslides and landslides is regular for the whole Tien Shan. These authors call this phenomenon the clustering of large-scale slope failures. In particular, along theTalas-Fergana fault such a cluster is formed by the rockslides of Karasu and Kapkatash lakes. The areas of increased concentration of large rockslides near the zone of Talas-Fergana fault are located in the lower courses of Karasu river (eastern) and in the valleys of its left tributaries, in the vicinities of the Sary-Chelek lake, in the ranges of Akshiyryak-West and Djamantau [Mamyrov et al., 2009]. We will remind that the age of the considered seismodislocations cover a time interval of ~ 50000 years, and people who are not familiar with seismo-tectonics perceive this data rather sceptically. As a matter of fact, in practical life we are interested in the predictions for … 20, let's say for 50 years, maximum for 100 years. Indeed, the existing methods of evaluation of recurrence of earthquakes are based on seismic statistics and studies of surface effects of earthquakes in the zones of active faults. The precision of estimates changes from hundreds up to thousands of years. On one hand, this is not sufficient for the practical use of these forecasts. On the other hand, mapping of sites where no large rockfalls have been observed during tens of thousands of years can provide helpful information that should not be neglected.

The form of the pleistoseist region of the Chatkal earthquake is similar to that of the Suusamyr earthquake. It was shown in the latter case that the bend of isolines is related to the motion of two adjacent faults providing a counter-clockwise rotation of the Aramsu block (see above). For this reason it makes sense to analyze the Chatkal earthquake and its Late Pleistocene predecessors in the structure of North-East Fergana.

The results of interpretation of data of GPS are given in **Fig. 5**; these data present a logical explanation why large avalanches did not occur all along the fault but only along some segments of it. The eccentric form of the Fergana block under rotation will locally induce compression and extension. One of such compression zones is the northern corner of the Fergana block close to the connection of Talas-Fergana and Atoinok faults where accumulated tectonic stresses periodically discharge in a form of catastrophic earthquakes. In this regard it is relevant to recall a short comment to the map of seismic zoning of Kyrgyzstan of 1977. The authors note that in the area of mountains of Bozbutau the North-Fergana zone (almost completely lying within the territory of Uzbekistan) branches off from Chatkal-Fergana zone to the south-west [Djanuzakov et al., 1977]. In other words the authors of the map did not see sharp borders dividing seismogenic zones, and the names used were fixed according to administrative and geographic names. In the light of the suggested interpretation, the seismic zones of Fergana are the borders of the rotating block and in kinematics shall have the same seismo-tectonic characteristics.

2.2.5. The Isfara-Batken earthquake of 1977 (M=6.3; Io = 7-8 MSK64)

It occurred within the South-Fergana seismic zone that from a morphostructural point of view corresponds to the northern foothills of Turkestan and Alai ranges. A strong earthquake was felt on 31st of January, 1977 at 14:26 p.m. (by Greenwich) in many populated areas of Uzbekistan, Tajikistan and Kyrgyzstan. An underground 'boom' preceded the main shock. Many people noticed light emission over the horizon that inclined to the peaks and southern slopes of Guzan mountains. Inhabitants of Oftobrui and Dagana noted that light emission was moving from the east to the west. In epicentral zone people witnessed that at the beginning they felt a sharp vertical shock, and then **horizontal jerks of meridional direction** (*comments by the authors*) of the same force. The zone of maximal shocks in intensity 8 by MSK64 scale is traced in a form of narrow interrupted strip of a 1-2 km width and a total extension of about 20 km between Sokh and Isfara rivers. Settlements of Oftobrui, Kyzyl-Pilal, Dagana, Bazar-Bashi, Kyzyl-Bel and Karabak were most severely damaged. The walls of constructions and fences oriented in latitudinal and sub-latitudinal directions were the most damaged. Fractures of up to 1 m width appeared in the ground (refer to **Fig. 17)**. Houses made from clay and straw were almost completely destroyed [Djanuzakov et al., 2003; Kasymov et al., 1981].

The source zone of the Isfara-Batken earthquake located in the trans-border territory was investigated by three independent groups [Kalmurzaev et al., 1977; Kasymov et al., 1981; Mirzobaev et al., 1981] who published three different maps of isolines. We got the impression that the final drawing of isolines given by these authors is not only based on the results of explorations of surface deformation and shaking effects, but also on a priori ideas about the orientation of earthquake source within the seismogenic zone. Moreover, isoseists of intensity 7 and 8 MSK64 are not shown in these maps. By this reason, we carried out isolines of the highest seismic intensity taking initial data published in the given works. For this purpose we outlined populated areas in the map marked, according to the aforementioned publications, by maximal damage (intensity 8 MSK64), as well as intensity 7 MSK64. Starting with intensity 6 MSK64 isoseist we used the drawing of the research of the Institute of Seismology of Kyrgyzstan [Djanuzakov et al., 2003]. Isoseists received in such a way look rather unusual (**Fig. 18**). As a rule, for a certain seismic event every following isoline of lower intensity includes a larger area which remains by the form similar to the previous one. In this case, the isolines of intensity 7-8 MSK64 have a clear sub-latitudinal strike, the 7- intensity acquires a trapezoidal form whereas a long axis of intensity 6 MSK64 isoline is already extended in NW-SE direction. The first isoline, the epicenter of earthquake, as well as a significant part of aftershocks are clearly grouped along Katransky (North-Katransky) fault **(3 on Fig. 18, A**) that is probably the activated one [Kalmurzaev et al., 1977; Knauf et al., 1985]. However, the following isolines cross almost orthogonally the elevations and basins of the foothill zones. A discrepancy between the isolines of the Isfara-Batken earthquake and the Neotectonics of the region was already found by the Kyrgyz seismologists at the preliminary stage of research though it may be not so obvious [Kalmurzaev et al., 1977], and the given phenomenon was studied over a period of years. By the results of geological and geophysical research, it was established that real complexes of Paleozoic basement had a larger influence on the structure of source zone of this earthquake [Knauf et al., 1985; Kalmetyeva, Lesik, 1983; Kalmurzaev (edit.), 1984]. Here a complicated combination of granite-gneiss complexes and accretion complexes *(tectonic fault zones with lenses of gabbrides and ultrabasites)* can be observed. This ensemble formed as a result of Hercynian orogenesis finished 270-300 mln years ago. Consequently, Mezozoic-Cenozoic cover lying on the basement with sharp angular unconformity, opens a new page in the history of development of this region having nothing in common with the previous stage (refer **to Fig. 18.A and B**). It could be found that heterogeneities of the Paleozoic basement are at the origin of the anisotropy of the geophysical properties of the basement rocks. This anisotropy at depth was responsible for a changed emission of the seismic energy at greater distance from the Isfara-Batken earthquake and, and the related orientation of isoseists [Knauf et al., 1985].

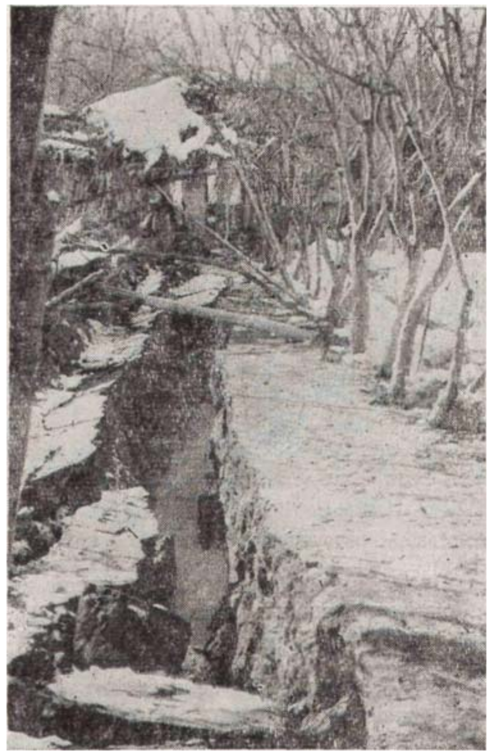

Fig. 17. Destruction in soil on left bank of Pastaryk river; fall of the end wall of the building made by clay and straw in the vil. Oftobruy (in bottom), according to [Kasymov et al., 1981].

One more fact attracts attention. The depth of the aftershocks, being maximal along the Katransky fault, gradually decreased in the N direction. One of nodal planes of the earthquake source has the same orientation. Motion is determined as thrust with significant strike-slip component [Abramova, Lopatina, 1981]. It is relevant to recall that the local inhabitants being in the epicentral region firstly felt a sharp vertical shock, and then horizontal shocks of meridional direction of the same force [Kasymov et al., 1981]. The vertical shock is clearly associated with the motion by Katransky fault due to the thrust motion in meridional direction. This thrust, most likely, was associated with the activation of Paleozoic faults by which plastic tectonic lenses of basite-ultrabasite composition were thrust over granite-gneissic formations of the Middle Tien Shan. Thus, the example of Isfara-Batken shows that active faults can be "blind", i.e. they are not outcropping. And it means that similar active faults will never be taken into account or evaluated, if the seismotectonic zoning is restricted to studies of surface structures.

2.2.6. The Nura earthquake of 2008 (M=6.6; Io = 8 MSK64)

On 5th of October, 2008 at 15:52 p.m. Greenwich time, in the eastern segment of Alai basin (Kyrgyzstan) a strong earthquake occurred. A large territory including Osh, Batken, Jalal-Abad and Naryn Provinces of Kyrgyzstan as well as border areas of Uzbekistan, Tajikistan and China were affected by seismic shaking. Nura settlement was completely destroyed, 74 people were killed. Houses built from clay and straw were completely destroyed (152 constructions), panel wooden houses were only slightly damaged. Through cracks appeared in the building of the hospital built from burnt brick. The ruptures of 5 cm width arose on the asphalt road to the south and north of the bridge. They were repeated there every 90 m generating folds of "consolidated" wave of deformation (**Fig. 22**). Between these ruptures small cracks of up to 1 cm width appeared and were repeated every 30 m [Abdrakhmatov et al., 2008]. Nura earthquake occurred as a result of the movement of Trans Alay range onto Alai basin. due to NNW-SSE oriented compressional stresses, induced by the movement of the Indian plate towards the north with a velocity of ~35 mm/year with respect to the Eurasian plate [Zubovich et al., 2007]. The main morphostructural elements of this region are Alai basin and Alai and Trans Alay ranges.

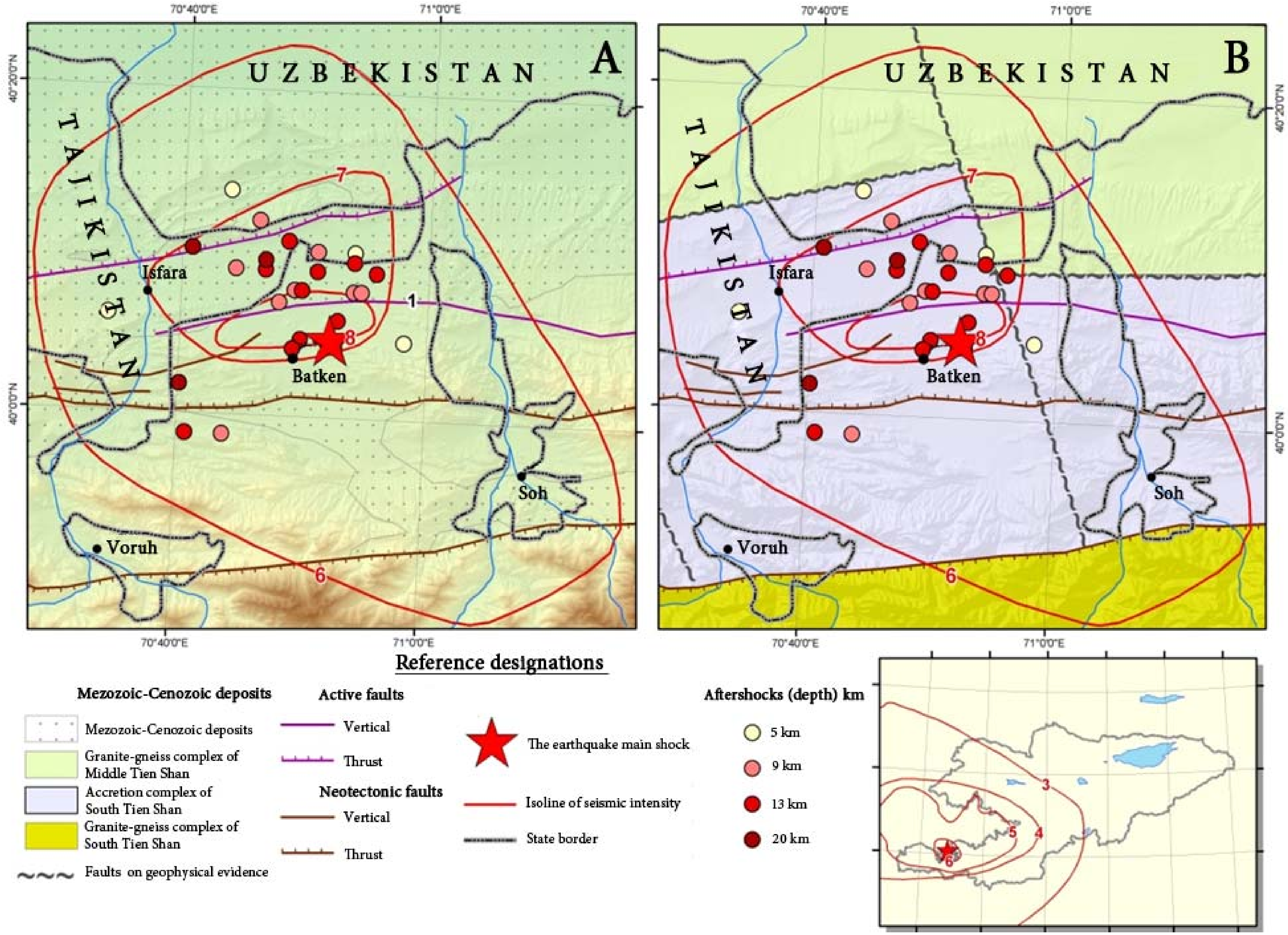

Fig. 18. Neotectonic scheme (A) and scheme of Paleozoic basement (B) of 1977, M_{LH}=6.3, I_0=7-8 MSK64 Isfara-Batken earthquake's source area.

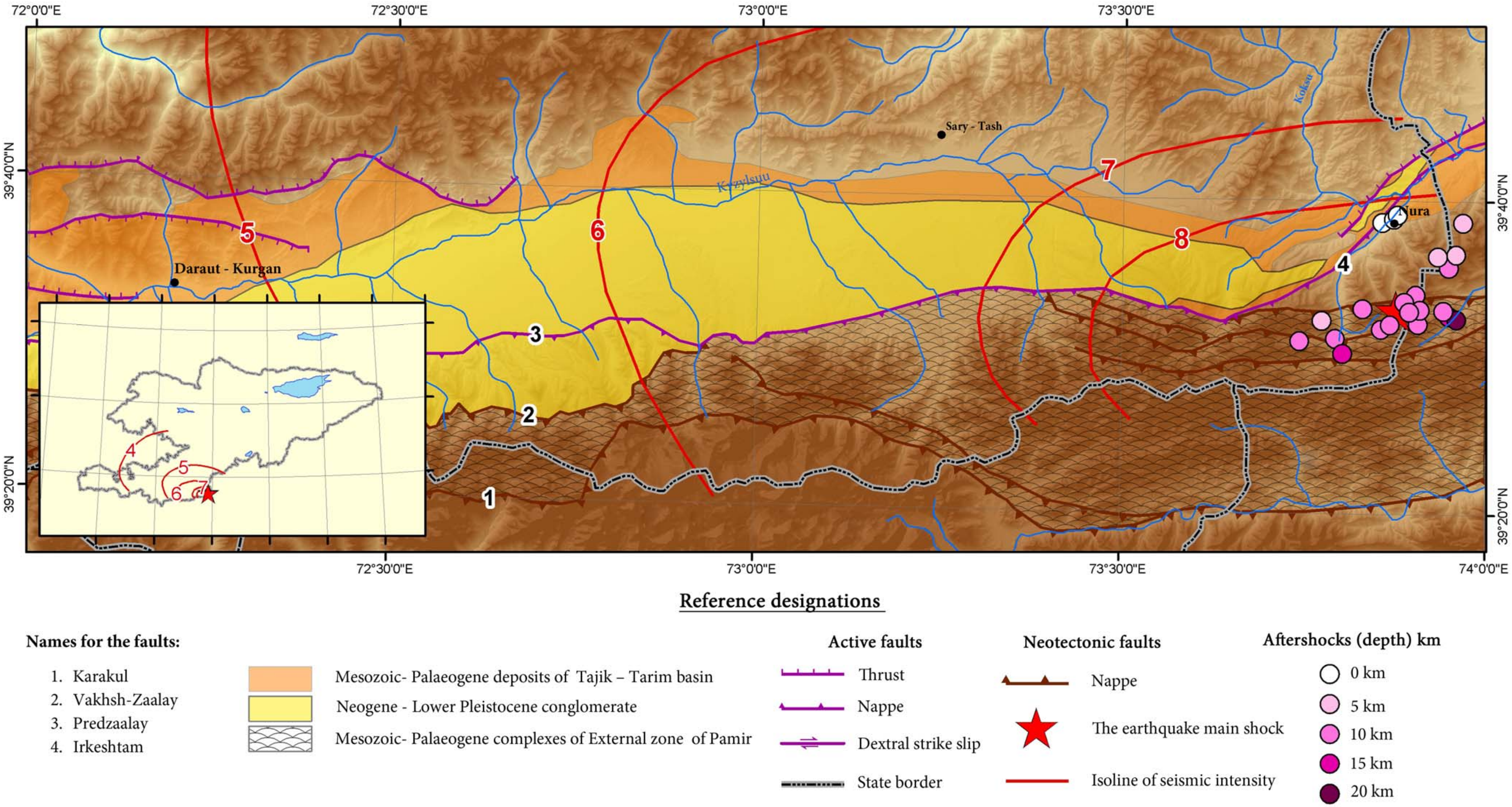

Fig. 19. Neotectonic scheme of 2008, M_{LH}=6.6, I_0=8 MSK64 Nura earthquake's source area.

Alai range is made of Paleozoic rocks of the South Tien Shan. Cretaceous-Paleogene sedimentary rocks of Tajik sea and continental deposits are discordantly bedded on the southern slope of the Alai range [Burtman, 2000]. The southern part of this region is limited by a watershed and the southern slopes of Trans Alay range. Paleozoic complexes of the North Pamir moved along Karakul thrust (**1 on Fig. 19**) to the north by more than by 300 km. They tectonically overlapped the southern zones of the Cretaceous-Paleogene Tajik basin [Burtman, 2000; Trifonov, 1999; Strecker et all.,2003]. The external zone of Pamir is represented by a cascade of overthrust masses made of Jurassic, Cretaceous and Paleocene deposits. These masses are compressed into asymmetric and overtilted folds formed as a result of the Pamir offset in the front part of Karakul nappe [Trifonov, 1999]. The Northern border of Pamir is the Vakhsh-Trans Alay nappe (**2 on Fig. 19**); related overthrust masses overlap relatively undeformed deposits of Cretaceous-Paleogene section of the bottom of Alai basin [Burtman, 2000; Trifonov, 1999; Nikonov et al. 1983]. The basin is made of Neogene-Early-Pleistocene conglomerates along the northern slope of Trans Alay range; these are also involved in uplifts, making a new series of thrusts. These are the youngest nappes (**3 on Fig. 19**), in essence, being the further development of cascades of nappes of the Pamir External zone. [Trifonov, 1999; Strecker et al., 2003].

Surface deformation in the pleistoseist areas of strong earthquakes show that these thrust faults have been reactivated in modern times, thus inducing the seismicity of the region [Nikonov et al., 1983]. The seismic zone at the connection of Pamir and Tien Shan is one of the most active of the world in terms of frequency of occurrence, density of epicentres and intensity of earthquakes (**Fig. 3**) [Nikonov et al., 1983]. The intensity of earthquakes can reach Io ≥ 9, for maximal possible magnitude of M ≥ 7,5 [Bune, Gorshkov (edit.), 1980; Turdukulov, 1996]. The width of the seismically active zone is 30 km. All pleistoseist areas of the strongest events are part of it. Here, earthquakes of magnitude M≥6 occur more often than in other seismically active regions of Central Asia: 1949 M=7.4 Khait earthquake, 1974 M=7.3 Markasui, 1978 M=6.8 Daraut-Kurgan and 1983 M=6.1 Alai. For the earthquakes with M < 6, the majority of motions are also thrusts and strike slips [Kalmetieva, 2005; 2006; Kuchay, Bushenkova, 2008; 2009].

The Nura earthquake in the region of Alai valley was recorded by several temporary stations of the German Research Center for Geosciences (GFZ), equipped by digital broad-band seismometers. It allowed to determine rather accurately the location and depth of the hypocenters of the main shock and aftershocks [Zubovich et al., 2009]. The hypocenter of the main shock is located at the depth of 10 km and in the place of the larger accumulation of aftershocks, formed a strip of EN-E strike of 15-20 km width. Along this zone some faults rejuvenated from the south to the north are marked. The settlement Nura destroyed by the earthquake is located close to the outcropping of Irkeshtam thrust fault which is the most northern and youngest of the aforementioned series. Several shallow aftershocks occurred close to it. The hypocenters of the other aftershocks are shifted to the south. Their depth is increasing towards the south. It is obvious that aftershocks activity is related to a fault zone plunging obliquely to the S-SE with hypocenters located at a depth of more than 15-20 km. On the basis of the depth of the main shock and its distance from the line of Irkeshtam thrust one can estimate the slope angle of the fault zone equal to ~ 45°. This slope angle is confirmed by the solution of the focal mechanism of the main shock defined in the Center of Data of the Geological Service of USA (**www.neic.cr.usgs.gov**).

The main source of information about modern geodynamics of this region is based on GPS data. Vectors of deformation velocities were calculated according to observational data of the Scientific Station (SS RAS) and Seismological Bureau of Xinjiang-Uigur Autonomuos Region [Abdrakhmatov et al., 1996; Zubovich et al., 2004] (**Fig. 20**). The results show the velocity of movement of Pamir towards the Tien Shan is at least 7 mm/year. The velocity of deformation is also shown in the figure. In contrast to vectors it does not depend on the reference system and therefore allows us to better outline some details. One of the zones of increased deformation extends along the border between Pamir and Tien Shan, but as it can be seen in Figure 20, the main shock of the Nura earthquake occurred outside deformation zone, at its eastern flank. Most probably, it is not accidental. Data of GPS measurements allow detecting slow creep movements that are not registered by other non-geodesic methods. The detected zone of increased deformation at the front section of the Pamir indenter reflects, probably, creep movements related to the thrust of Pamir on Alai that shall lead to constant discharge of stresses in this area. There are no such movements along the lateral borders of the zone. Therefore, elastic strain energy is not continuously discharged and its accumulation creates conditions for the preparation of the earthquake. The earthquake occurred on 5th of October 2008 near the mountain settlement Nura when the level of stresses exceeded the limit of rock strength.

The Nura settlement was completely destroyed (**Fig. 21**). Only the new school building was left undamaged (in the left part of the figure) and several panel houses were less damaged. There were fractures in the ground (**Fig. 22**).

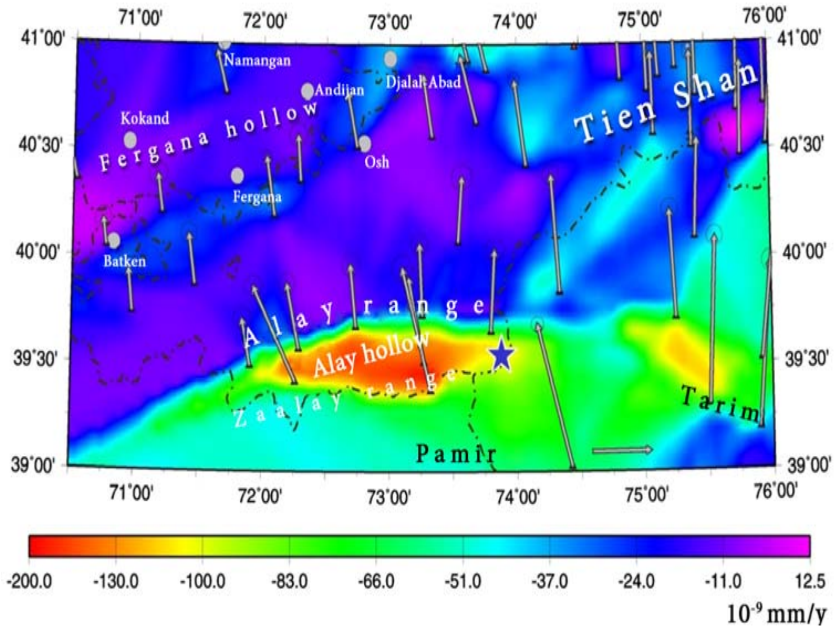

Fig. 20. Map of velocity vectors (arrows) and velocities (in color) of deformation. Blue star is the epicenter of the Nura earthquake.

Fig. 21. The Nura settlement after the earthquake (photo of Meleshko A.V.)

Fig. 22. Cracks (upper part of photo) and “waves of deformation” (lower part) were observed in the vicinity of Nura settlement at distances up to 2-3 km (foto of Meleshko A.V.).

3. Observations with the help of instruments

"If we study only strong earthquakes, we shall not be able to determine the immutable laws of seismic phenomena, just as the exclusive study of hurricanes would not let us understand the laws of meteorology and the complicated phenomena of the atmosphere".

[I.V. Mushketov, 1899]

3.1 Historical development of instrumental observations

Before the Soviet period in Central Asia and Kazakhstan, instrumental seismic observations started in Tashkent, and Verny (Almaty). During the first years under Soviet governance the construction activity was growing rapidly in Central Asia. New cities and industrial enterprises were constructed there, that is why the task of studying the seismicity of the region became very important. In 1927, the director of the newly established Seismological Institute of Academy of Science of the USSR, Nikiforov P. M., created a device for recording regional earthquakes that was simple in use and reliable. In the same year, such devices were installed in the cities of Almaty and Frunze (nowadays Bishkek) in connection with the construction of Turkestan-Siberian railway. Those were the first regional seismic stations in the USSR. Between 1929 and 1939 five more stations were installed in Andizhan, Dushanbe, Chimkent, Samarkand and Semipalatinsk. By the year 1951, 24 seismic stations had already been working in Central Asia, four of them were on the territory of Kyrgyzstan (Frunze, Naryn, Przhevalsk, and Ribachje).

In 1928-1930, the student of Leningrad University, Rosova Evdokia Alexandrovna, who was undergoing a probation in the Seismological Institute of Academy of Science of the USSR, was sent to process and generalize materials of observation of the Central Asian network. Until the end of her life, Mrs. Rosova's activities were attached to Central Asia. After her studies in 1930-1935, she defended a thesis of candidate of physics-mathematical science devoted to the issue of the crust velocity structure in Central Asia, and to the development of methods for determining basic parameters of earthquakes. Her further work was devoted to the analysis of observation materials in Central Asia and Kyrgyzstan. When she defended her doctoral thesis, she was sent by the Presidium of Academy of Science of the USSR to Kyrgyzstan to establish there the new Department of Seismology.

1956 year. E.A. Rosova and the staff of the Seismology Department. From left to right: Dzhanuzakov K.Dj., Trubenko G., Rosova E.A. and Kurmanalieva G.

She had to start from nothing. Prof. Rosova composed the averaged hodograph (travel-time curve) of the region, created a "crossing-method" for mass determination of earthquakes epicenters (1936), and studed seismicity [1957]. Even nowadays, her hodograph has not lost its relevance. But, the network of stations was not dense at that time therefore, initially she believed that earthquakes sources could reach depths of 400 km in the region. Later, more dense observation networks demonstrated that sources are located mainly in the upper half of the Earth's crust. Only in the Pamir earthquake sources can be located under the earth's crust (at a depth of 60-80 km), and under the Hindu Kush their depth can reach 300 km. Nowadays, it is clear that the accuracy of determining the source depth is about half of the distance between two points of observation.

Strong earthquakes in 1946 (Chatkal, M_{LH}=7,5, Io=9-10 MSK64) and in 1948 (Ashkhabad, M_{LH}=7,3 Io=9-10 MSK64) revealed serious deficiencies in the seismic service in the USSR. Methods of seismic zoning were not efficient (a year prior to this event, Ashkhabad was transferred from the I_0=8 zone to the I_0=7one). There was no adequate equipment for making records in the near-field zone (during the Ashkhabad earthquake all seismic stations of the Central Asian network failed to record the shaking; at the nearest stations in Andizhan and Samarkand the suspensions of the galvanometers penduli were broken). There was no service for warning about the destructive earthquakes. The government had not been informed by seismologists about the terrible Ashkabad earthquake but by the military men

In 1949, the Council for Seismology within the Presidium of Academy of Sciences of the USSR was established for the overall management and coordination of research in the field of seismology. The two main directions of research were identified: the study of seismicity and the search for precursors of strong earthquakes (seismic, geophysical and atmospheric factors, electric currents, variations of the electromagnetic field of the Earth, gravity and topographic changes of the Earth surface). In order to solve the problems of creating a network of stations, a common network of Integrated System of Seismic Observations in USSR (ISSO) was developed to study the seismicity in the USSR and the rest of the world. They also started to organize regional networks for research in seismically active regions. The seismic stations of Frunze, Naryn and Przhevalsk were included in the network of ISSO. In addition, broadband seismographs of Kirnos had been installed. Data from these stations were processed, bulletins were compiled, and then sent to Moscow. Regional stations were equipped with narrow-band devices named VEGIK and Kharin seismograph. On the territory of Kyrgyzstan, the Aral station was installed in 1960 and the station Rybachje was transferred to Kaji-Sai in 1961.

At the same time, in order to solve problems of prediction, the Institute of the Earth Physics of the

Academy of Sciences of the USSR creates a special Complex Seismological Expedition (CSE), which proceeds to the detailed observations at the Garm test site in Tadzhikistan. The first years of the expedition were devoted to methodical aspects. Dozens of thousands of measurements of seismic wave parameters had been made. They developed a new technique of "isochrones pallet" to locate of the sources (Riznichenko U.V.). The nomogram was compiled to determine the energy class of earthquakes (Rautian T.G.). The necessity to standardize the equipment was recognized. The book "Methods of detailed study of seismicity" [Bune et al., 1960] was the result of these works. The book became the manual for organization and functioning of local networks. Local networks of such style were established after that. They placed depending on current tasks related to the assessment of the seismic hazard in areas selected for construction of civil and industrial structures or for the investigation of the aftershock activity of strong earthquakes. On the territory of Kyrgyzstan such works were first held jointly with CSE by the Naryn teams studying the seismicity of the Naryn River basin [Nersesov et al., 1960]. The initiator of the local and mobile network in Kyrgyzstan was Valery Petrovich Green who had gained a large experience at the Garm test site. Since 1960 the local network organized by V.P. Green had been conducting detailed seismological research in different parts of the territory of Kyrgyzstan. Those were Kirov, Papan, Chui and Sarykamysh groups. Ilyasov B.I. and Kossobudsky S.B. dealt with the installation and launching of the seismic stations. Besides solving applied tasks for the area where the local network was situated, the work of expeditions contributed to the detailed study of seismicity for the whole Kyrgyz territory. Until the 70s the regional network was very loose, that is why the setup of local networks considerably increased the accuracy and completeness of the catalogue of the earthquakes all over the territory of Kyrgyzstan. The digital stations KNET of the Consortium of USA Universities can also be included into local networks. This network was established in 1991 and is functioning until now.

The accuracy of earthquake epicenters determination was changing with of the increasing density

Ilyasov B.I., 1965 year. Beginning of the Papan net installation.

of observation networks. Up to 1957 the earthquakes in Central Asia were divided into two groups: class "A" with an accuracy of determination of the epicenter ≤ 25 km and class "B" with an accuracy of ≤ 50 km. Within the areas where the local networks were installed, all the earthquakes, depending on the accuracy of positioning and estimation of the source depth, were classified into class "a", "b", "c" and "no class" during the operation of these networks:

"a" – the error in determining the coordinates of the epicenter does not exceed ±3 km.

"b" – the error in determining the coordinates of the epicenter does not exceed ± 5 km.

"c" – the error in determining the coordinates of the epicenter does not exceed ± 7km.

" no class" – the error in determining the coordinates of the epicenter does not exceed ±10km. The earthquakes for which the source depth could not be determined due to

Table 2

Local seismological networks that had been running on the territory of Kyrgyzstan

Name	Work terms	Location
Naryn group, 1-st site*	*1957-1958*	*40,5° -42,5° & 72,0° -74,5°*
3-d site	*1962-63*	*40,5° -42,5° & 72,0°-73,3°*
4-th site	*1964-68*	*41,2° -42,0° & 71,2° -74,0°*
Kirovski group	*1964-1965*	*42,4° -42,9°& 70,9° -7 2,3°*
Ravatski and Sochski groups**	*1964-1966*	*40,0°-41,4° & 70,5° -73,5°*
Papanski group	*1965-67*	*39,5° -42,5° &71,6° -73,5°*
Chuiski group	*1967-76*	*42,3° -43,3° &72,5° -76,0°*
Sary-Kamish group	*1970-72*	*42,3° -43,0°& 78,2° -79,0°*
Toktogul net***	*1978*	*41,9° & 72,8°*
KNET	*from 1991*	*42,0°-43,3°& 73,6°-76,3°*

*- the 2-d site was on the territory of Tadzhikistan. Its data were not used in the data processing in Kyrgyzstan.

** - groups of the Uzbek Institute of Seismology, their data were partially used in data processing in Kyrgyzstan.

***- Toktogul network was operating in the area where the Toktogul hydro-electric power station was located, 6 analogue American and 4 Soviet stations were installed there.

some reasons were also referred to 'no class' [Ilyasov et al., 1980]. Coordinates of earthquake sources which were not observed by those groups were determined as it was done before with the accuracy "A" or "B".

In 1969, on initiative and under the head of Prof. Rosova's disciple – Dzhanuzakov Kenesh Dzhanuzakovich, the creation of the Kyrgyzstan regional network had been started. P.A.Skuinsh was the person who installed all 24 stations of the regional net. He also provided standard instrument-response curves

Skuinsh P.A., 1969.

(amplitude-frequency characteristics) for them. Dzhanuzakov K.D. and Skuinsh P.A. thoroughly thought over the configuration of the network that could allows to solve the main tasks of seismology: research on the overall seismicity in the region and research in the field of seismology studing the inner Earth structure. To solve the first task it was necessary to spread the stations evenly on the territory of Kyrgyzstan. Long profiles were required for the solution of the second task. Looking at the scheme of stations location (**Fig. 23 and Appendix 4**) it is possible to see that in spite of the mountainous relief the task of placing stations was solved perfectly. By the beginning of the 80-s the creation of the regional network of seismic observations was mainly completed. The standard apparatus of Kirnos with the standard amplitude-frequency characteristics – SKM-3 (Kirnos seismograph modernized, band pass 0,3 – 1,25 sec and amplification 20 000), and SKD (Long period Kirnos Seismograph with the band pass 0,3-20.0 sec and amplification 1000) was installed in all stations. The creation of the regional network allowed to register earthquakes with K≥8 (M≥2,2) all over the territory of Kyrgyzstan.

Painful years of 'perestroika' started after the disruption of the Soviet Union, when structures and traditional connections existing before were broken – also in the field of seismology. 10 stations were closed due to insufficient financing. Nevertheless, perestroika brought also other kinds of changes. By 1990 all stations of the ISSO of the USSR were equipped with analogue devices of Soviet production. Since the 1970s the testing of instruments of the new generation with digital registration has been carried out in the rest of the world. By the end of the 70s, the first world wide network of digital stations had been established. One station of this network has been installed in 1990 in the gallery of the geophysical observatory "Alaarcha" of the Institute of Seismology of the Academy of Sciences of the Kyrgyz Republic under agreement with Kyrgyzstan. Later, this station was included into the International Monitoring System for nuclear explosions verification within the framework of the Comprehensive Nuclear-Test-Ban Treaty Organisation. (CTBTO). In 1991, in accordance with the tripartite Agreement among the Consortium of the USA Universities, Russia and Kyrgyzstan, the local network of digital seismic stations (KNET) was established. Materials of observations provided by these stations were used by the Institute of Seismology jointly with the data of analogue stations to form the earthquakes catalogue, which assists to increase the accuracy of the determination of earthquakes parameters. In 2007 the Norway as the State Partie of CTBTO suggested the Kyrgyz Institute of Seismology on the basis of gratuitous help to equip 10 stations with the digital apparatus - GURALP.

Seismology does not know state borders. During the Soviet period, close cooperation of seismological institutions in Central Asia could be explained by their belonging to the same state. Nowadays, when these institutions are located in independent states, we continue working in close cooperation, as it gives the possibility to determine parameters of earthquakes on our territories with greater precision. In 2004, the Central Asia Institute for Applied Geosciences (CAIAG) was established in Bishkek in accordance with the agreement between Germany and Kyrgyzstan. This provided new possibilities for cooperation in Central Asia. In 2008, the German Organization for Development of International Potential (InWent) in close cooperation with the German GeoforschungsZentrum (GFZ) and CAIAG and with the financial support of the German Ministry of Foreign Affairs started the creation of CAREMON (Central Asian Real-Time Earthquake Monitoring Network) within the project "Cross Border Natural Disaster Prevention in Central Asia". Broadband digital stations of GURALP type were installed in Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan. Their data are being collected through the satellite in the central point and then transmitted to all project participants. The software SeisComP3 – the new technology of collecting and exchanging data, determining epicenter and magnitude of earthquakes in real time mode will also be installed in each of those states. In 2008-2009, CAIAG installed in Kyrgyzstan along the border with China three own seismic stations, equipped with broadband digital equipment STS-2, passing data to Bishkek via satellite in real time mode (**Fig. 23 and Appendix 4**).

So, in 2008 a new stage of instrumental seismic observations was started in Central Asia.

3.2. The main regularities of seismicity

The main practical task for seismology is seismic hazard assessment. Maps of seismic zoning serve as a long-term prediction of strong earthquakes. On the maps, parts of the territory where sources of destructive earthquakes can arise are marked. Maximum possible intensity of earthquakes and their frequency of occurrence are also noted on the maps.

The first maps of seismic zoning of Central Asian territory were developed by geologists at the end of the XIX century, and only data of tectonics of the region and the source areas of past disastrous earthquakes were mainly taken into consideration. With the development of instrumental observations and accumulation of earthquake data, new maps were designed (maps of the years: 1933, 1035, 1946, 1951, 1955, 1957). Mainly seismostatistic data were considered in the creation of those maps, that is why

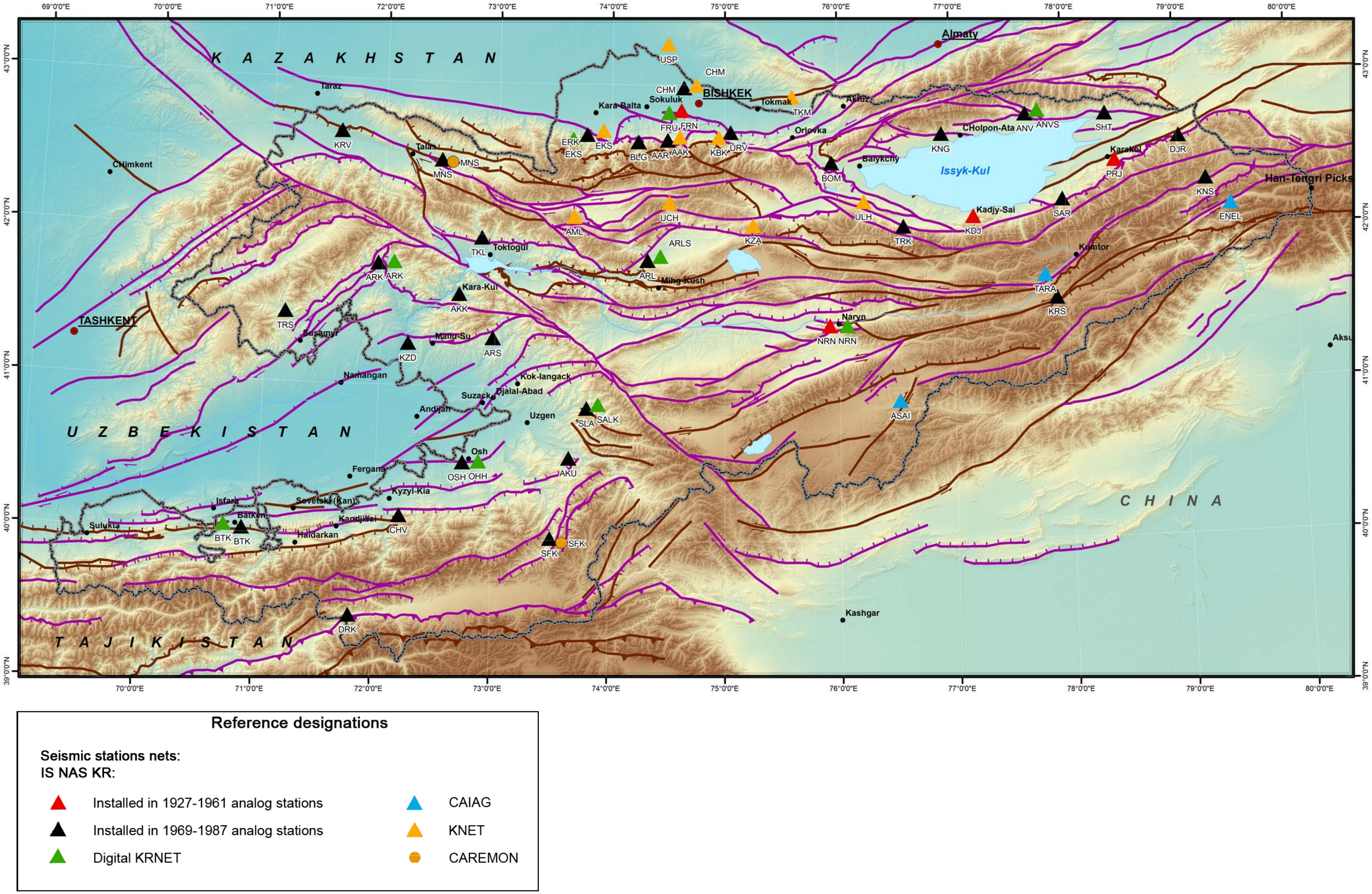

Fig 23. The scheme of location of seismic stations on the territory of Kyrgyzstan

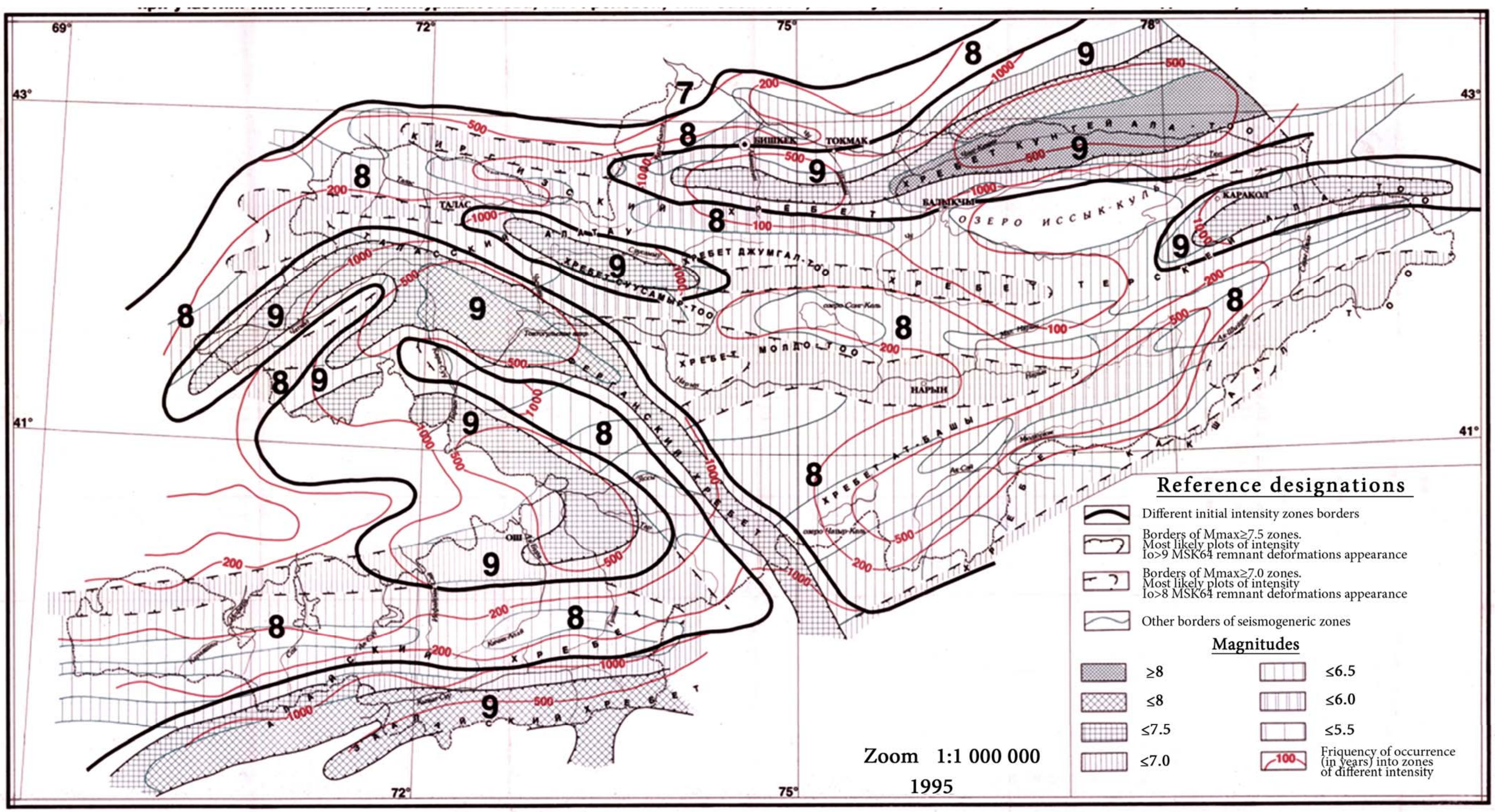

Fig. 24. The seismic zoning map for the Kyrgyz Republic territory, compiled by K.Djanuzakov, O.Chedia, K.Abdrakhmatov, A.Turdukulov with participations of I.Lemzin, K.Nurmanbetov, A.Frolova, T.Sabitova, E.Musienko, N.Bagmanova, K.Sadykova and T.Charimov. Natural scale is 1:1 000 000. 1995 y.

on each new map the areas where dangerous earthquakes could arise became larger. As a result of heated discussions, a new seismic hazard mapping approach was developed. The idea of complex approach to seismic zoning of the territory of Kyrgyzstan was applied to the map of detailed seismic zoning of Chui Basin [Green et al., 1975; Green et al., 1980]. This approach was later developed [Kalmurzaev (editor), 1984] and applied to design maps of detailed seismic zoning of the territories of Eastern Kyrgyzstan [Knauf (edit.), 1988], Issyk-Kul Basin [Abdrakhmatov (edit), 1993] and the general map of seismic zoning of the Republic [Kalmurzaev (edit), 1977]. On the photo, it is possible to see the leading scientists of this research.

1971. Discussion of the map of detailed seismic zoning of the Chui Basin. From left to right: Green V. P., Trofimov A. K., Knauf V. I. and Chedia D. C.

Figure 24 demonstrates the last reference map of seismic zoning of the Kyrgyz Republic [Turdukulov (edit.), 1996]. The data of earthquakes that happened after 1977, when the the previous map had been designed, were taken into account in creating this map. Furthermore, results of special research of kinematics of faults were also taken into account there [Abdrakhmatov and others, 2001]. On the map one can see, that actually all the territory of Kyrgyzstan could be subjected to disastrous earthquakes. The event of intensity 9 MSK64 and higher can affect a considerable part of it. Only in the North-West, on Kazakh territory, the intensity of possible events is 7 MSK64. In section 2, some disastrous earthquakes which happened in this territory in the past were described.

The complex approach to produce a map of seismic zoning envisages that first independent research is carried out in three directions: seismotectonic, geophysical and seismological. Then, the results of the research are analyzed together. Below we explain the results of the seismological research.

Any seismological research starts from the earthquake catalogue. It enumerates all the earthquakes registered by seismic stations of the region, contains basic information about earthquakes including the occurrence time of the event, the geographical coordinates, depth of the source and magnitude (and/or energy class). Considering the information given in the catalogue it is possible to design maps of earthquake epicenters, and so to study peculiarities of spatial distribution of earthquakes. It is possible to design different temporal graphs and to study temporal behaviour of seismicity. Then records of earthquakes are analyzed to study special aspects.

We start with the description of the map of earthquake epicenters. **Fig. 25** presents the map of epicenters for only for 10 years, the period of observations when the network of analogue stations was most dense. The map reflects the basic peculiarities of spatial location of earthquakes. It is clearly seen that the northern part of the territory, where epicenters of earthquakes are located, is separated from the southern regions of high level of seismicity by a relatively weak active strip, passing approximately through localities: Batken, Osh, Naryn, Karakol. The second peculiarity is that the Talas-Fergana fault plays the role of partition of the Kyrgyz part of Tien Shan according to the level of its seismic activity. To the west of it, 3-5 times more earthquakes occur then to the east [Bune, Gorshkov (editors), 1980]. The weak seismicity of the basins is one of the main peculiarities of Tien Shan. **Fig. 25** clearly demonstrates that within Issyk-Kul, Fergana, Naryn, Chui and other basins there are no earthquake epicenters. A lot of earthquakes occur along the faulted zones separating the basins from the ranges. For example, sources of famous earthquakes: 1883 Osh, 1902 Andizhan and 1903 Aim coincide with the flexure-faulting zones separating basins from ranges. The tendency of grouping weak earthquakes epicenters on comparatively small areas is clearly seen there. These territories are called seismoactive plots, when the seismicity of the territory is being described.

When grouping small and strong earthquakes it is possible to determine the main seismoactive zones. First of all this is the Northern Tien Shan zone. It includes northern Issyk-Kul, Sarykamysh, southern Issyk-Kul and southern Chu seismoactive plots, which all have approximately the same level of seismic activity. To the south, in the Central Tien Shan there are: the Son Kul zone which is in the middle of the Naryn river on the southern slope of Moldotay ridge, and the Djumgal-Suusamyr zone situated in Djumgal and Suusamyr ridges. Farther to the south there is the Chatkal Fergana zone, consisting of Sary Chelek, Naryn and Karasuu seismically active points spatially associated with Atoinok, Chatkal and Fergana ridges. The North-Fergana zone occupies a broad strip, covering the northern part of Fergana mountain surroundings, presented by the strip of low hills at foots of mountains (so called “adyrs”). It also consists of several plots, two of which - the Andijan-Osh and Osh-Uzgen are located in the eastern part of the Fergana Basin, the third one - Namangan-Tashkomyr is located in the north-western part of it, and covers a vast area of Namangan region in Uzbekistan and considerable areas of Djalal Abad region in Kyrgyzstan. Within the South-Fergana zone extending along the “basins of the 40 degrees parallel”, four seismically active plots are distinguished: Isfara-Batken, Khaidarkan, Iski-Naukat and Fergana [Dzhanuzakov, 1984; Turdukulov (edit.), 1996]. The Gissar-Kokshaal active zone extends along the southern border of Kyrgyzstan. The western part of it (Darvaz-Karakul) occupies the Tien Shan and Pamir junction area, the eastern one verges on Tarim basin.

Let us now compare this map with the map of strong earthquakes (**Fig. 3 and Fig. 26**). As it has already been mentioned, we call strong earthquake events with a maximum intensity of 6 or more of MSK64 scale. In other words – these are the earthquakes that can damage buildings (small damage in the form of cracks or total collapse), induce surface effects. The epicentral areas of the strongest earthquakes (intensity from 8 to 11 MSK64) which occurred during the past 200-300 years were located along relatively narrow bands. Probably they occurred there even earlier, because geologists see their traces (paleoseismic dislocations) on the surface of the earth [Bune, Gorshkov (edit.), 1980] (**Fig 9**). Famous historical earthquakes (see the Catalogue of strong earthquakes, Appendix 2) were also located within these bands. Areas of maximum destruction (areas inside of pleistoseismal zone) of these events seemed to take place along the northern and southern boundaries of the so-called Tien Shan block. In the North, these are the maximal destructive areas of Chilik (1889, M=8,3, I_O=10 MSK64), Kebin (1911, M=8,2, I_O=10-11 MSK64), Verny (1887, M=7,3, I_O=9-10 MSK64), Suusamyr (1992, M=7,3, I_O=9-10 MSK64), and Chatkal (1946, M=7,4, I_O=9-10 MSK64) earthquakes; in the South, the Khait (1949, M=7,4, I_O=9-10 MSK64), and Kashgar events (1902, M=7,8, I_O=10 MSK64). Along the North-Eastern border of the Fergana Basin and along its southern edge, the earthquakes of smaller magnitude produced a maximum intensity of 8 MSK64. Here can be mentioned the earthquakes of Osh (1883, M=5,5, I_O=7-8 MSK64), Andizhan (1902, M=6,4, I_O=9 MSK64), Namangan (1927, M=6,0, I_O=8 MSK64), Kurshab (1924, M=6,5, I_O=8-9 MSK64), and Isfara-Batken (1977, M=6,3, I_O=7-8 MSK64). Two of them with intensity 9, took place close to the Earth surface that is why their destructive force further from the epicenter was rapidly decreasing. The weakest among strong earthquakes (I_0=5-6 MSK64) are relatively evenly distributed over the territory of Kyrgyzstan (see **Fig. 26**).

Sources of earthquakes in the Kyrgyz part of the Tien Shan are inside the Earth crust, and they are unevenly distributed on a vertical section. The largest number of sources is located at a depth of 5-15 km. Below a depth of 15 km the number of is constantly decreasing. The maximum depth of sources (25-30 km) are observed in the Kemin-Chilik and Fergana-Chatkal seismoactive plots. Deep sources (20-25 km) are also observed in South-Chui, North-Fergana and South- Fergana zones. In the

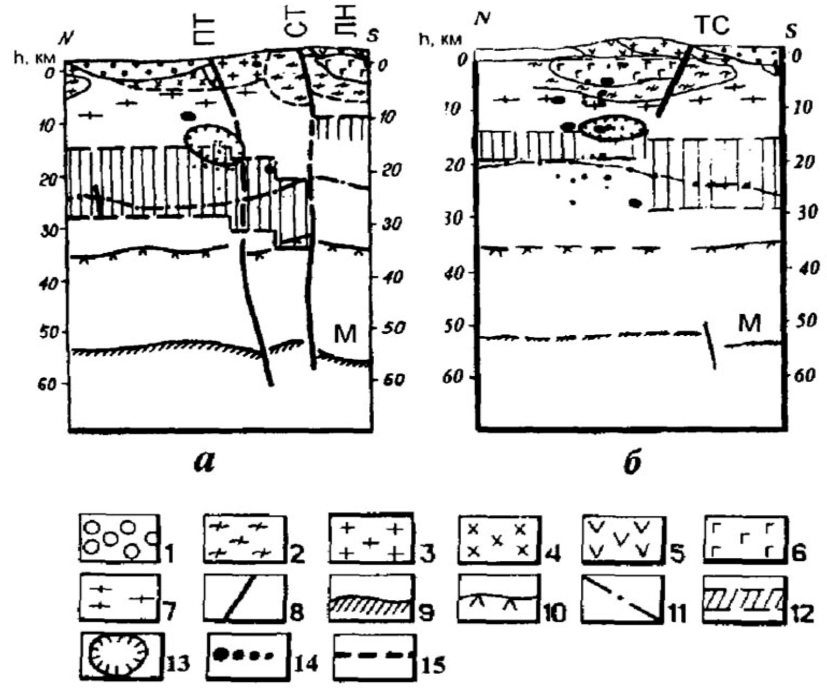

Figure 27.Geophysical models of sources of strong earthquakes. a) – Sarykamysh 1970 year Lat.=42N, Lon.= 78.72E, H-15 km, K=16; b) Jalanash-Tyup 1977 year, Lat.=42.88N, Lon.=78.58E, H=10-24 km, K=15. 1– Cenozoic deposits; 2-4 – Rocks of Upper Pre-Cambrian and Paleozoic: 2 – schist, 3 – granite, 4 - syenite, 5 – diorite, effusive rocks, 6 –gabbro, ultrabasic rocks, 7 – gneisse, 8 – faults: ПТ - Predterskei, СТ - Central-Terskei, ЛН- line of Nikolaev, ТС –Taldysui, 9-12- Mohorovicic boarder, 10 – foot of intermediate layer, 11 – roof of intermediate layer, 12 – low resistivity layer, 13 – ruptured area of the main shock, 14 - ruptured area of the aftershocks of energy class 12-9, 15 – isotherm 400° C.

investigated areas, the sources deeper than 30 km are very rare. [Bune, Gorshkov (edit.), 1980; Turdukulov (edit), 1996]. Sources of earthquakes in the Central Tien Shan do not reach large depths. Consequently, shaking intensity at the surface is decreasing more rapidly than forearthquakes in the northern Tien Shan [Bune, Gorshkov (edit.), 1980].

Some peculiarities of seismic activity were revealed by detailed observations carried out by local networks. It was noticed that seismic processes do not happen regularly within a certain seismoactive plot. Seismicity develops in the form of temporal and spatial "clusters" of earthquakes. i.e. during a long period of time earthquakes occur in separate places. These places are not overlapping, but located close to areas seismically activated in the past [Green et al., 1978]. It was also noticed that shallow earthquakes are more widespread than deep ones, i.e. the upper layer of the earth crust of about 10-15 kilometers is seismoactive almost everywhere. Two earthquake sources activated almost at the same time are often located far from each other but at the same depth level and probably are connected through a certain horizontal border in the Earth crust. Deeper earthquakes (15-30 km) are often related to known rupture zones [Green, Kalmetieva, 1978]. It was noticed that weak earthquakes could be subdivided at least into two types. One type corresponds to movements on the existing plane of rupture. All the characteristics of emissions of their sources (P- and S-waves amplitude/frequency ratio, velocity of rupture propagation, fault plane solution) coincide with the results obtained under laboratory models of shifts on an existing rupture. It looks like the other group represents the development of new ruptures. They are characterized by accumulation of epicenters in a certain area for a relatively short period followed by a seismic silence afterwards. Earthquakes of the first type occur as single events or migrate along some definite lines [Gorbunova, Kalmetieva, 1988]. It should be noted, that records of earthquakes taking place in different parts of Tien Shan territory have peculiar features. Sometimes just by looking at the record, an experienced seismologist can determine the region, where an earthquake has taken place. For instance, a sharp first arrival (beginning of record) of seismic waves is characteristic for the northern part of the Tien Shan region. Records of most earthquakes in the south-western part of Tien Shan (to the south of Talas-Fergana fault) often start with a slack, vague arrival which is difficult to determine. The 2008 Nura earthquake is the striking example of this kind of earthquakes. Earthquakes with dual arrival occur along the South – Fergana faults system, for example 1977 Isfara-Batken earthquake.

The works carried out on F.N.Yudakhin's initiative on making of geophysical models of strong earthquakes sources produced interesting results [Tokmulin (edit.),

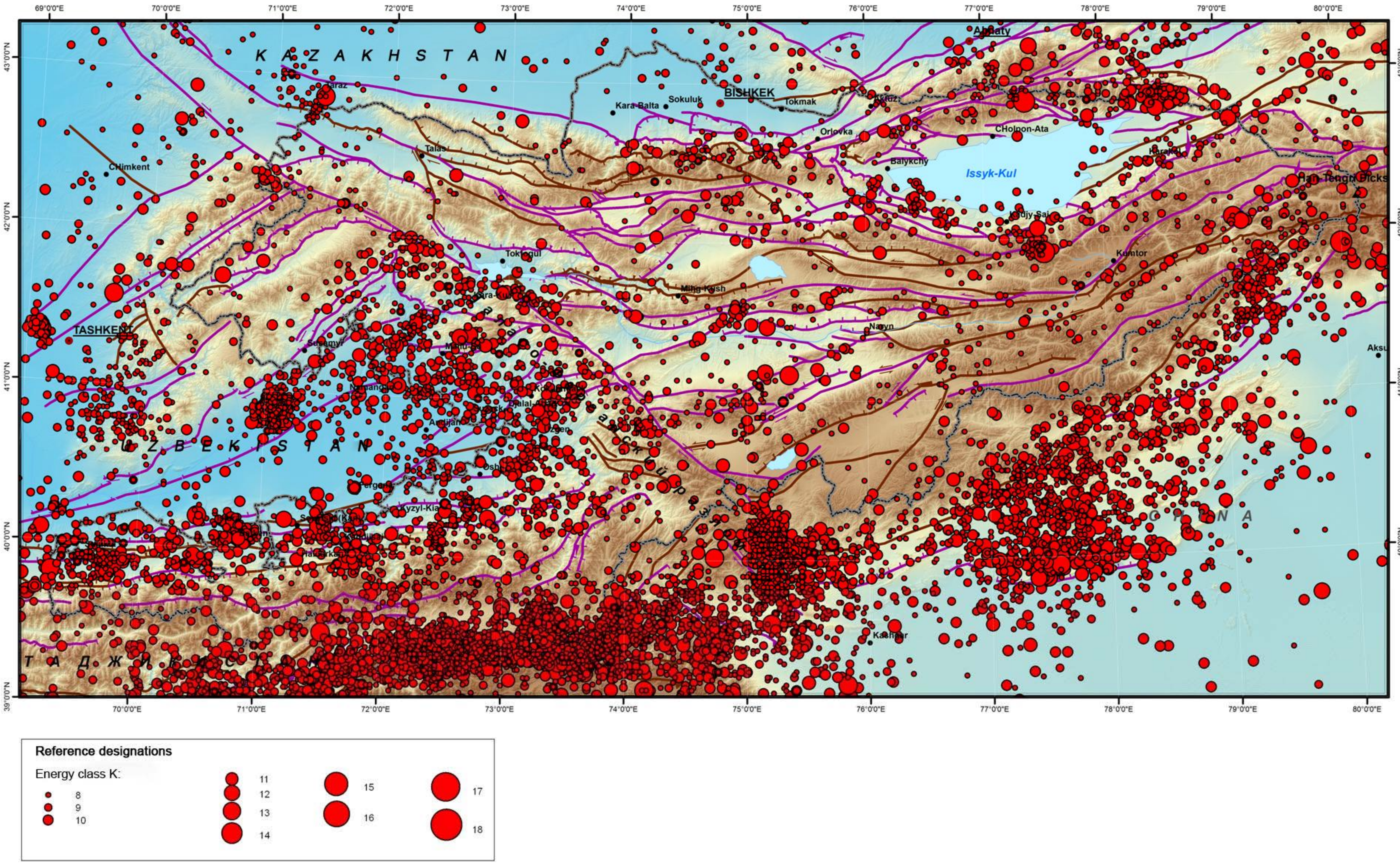

Fig 25. The map of the earthquakes epicenters for 1976-1985 years.

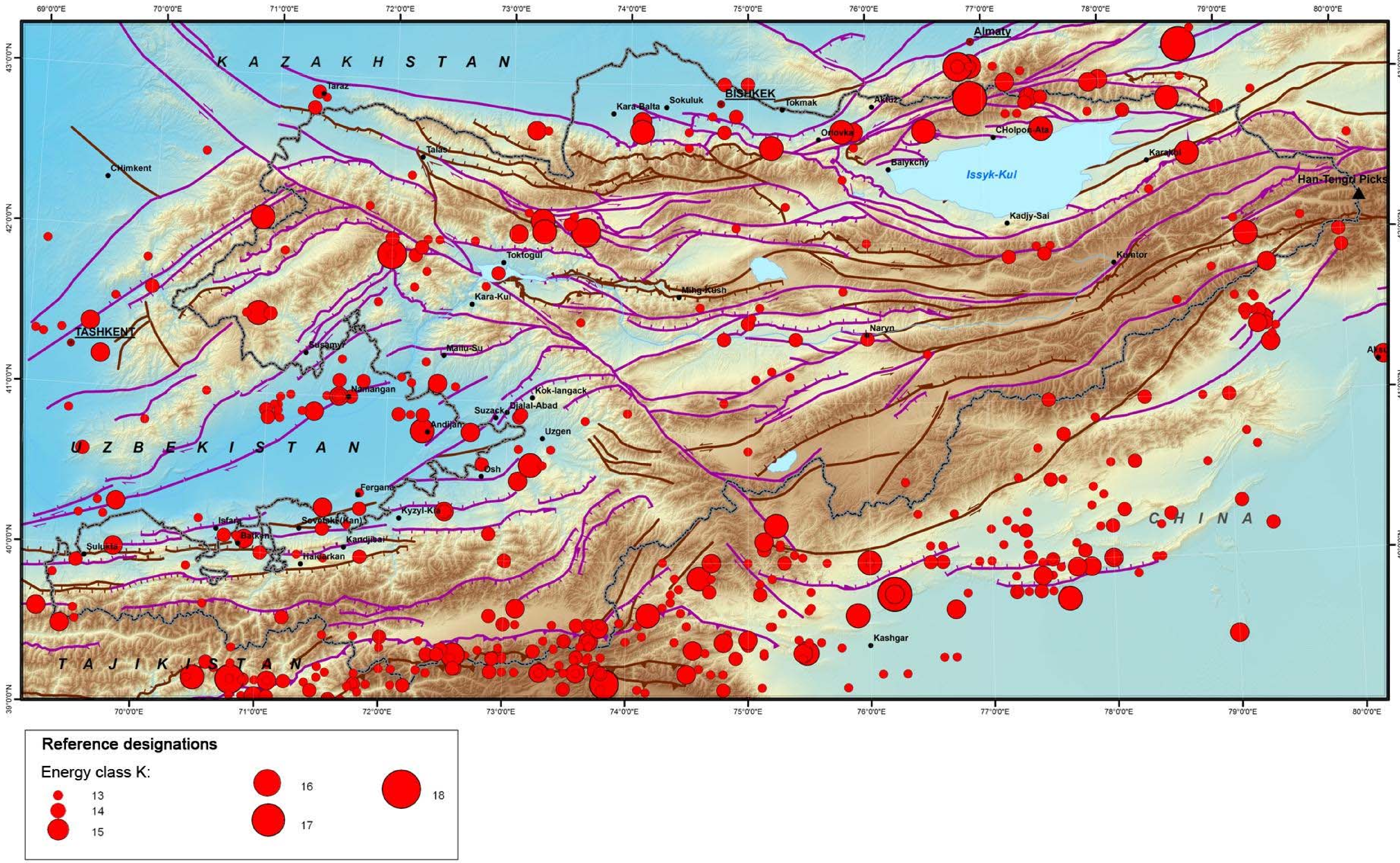

Fig 26. The map of epicenters of strong earthquakes of M≥5 (K≥13; Io=5-6 MSK64) since historical times to 2008.

1992]. Main shocks of all strong earthquakes, which were studied (Sarykamysh, 1970, Jalanash-Tyup, 1978, Isfara-Batken 1977, and others) were placed on the upper boundary of electro-conductive layer, approximately at the depth of 10-15 km. Aftershocks periodically plunge down to the bottom of the seismoactive layer (up to 30 km), and then rise to the surface. These data appear to be even more interesting if compared with the results of the depth structure investigation of the Tien Shan orogen and the weakly active Kazach shield and Turan plate [Tokmulin (edit), 1992]. Significant distinctions were revealed in geophysical characteristics of the Earth crust. They are especially different in electroconductive properties. The strongest catastrophic earthquakes happened in the areas where the Tien Shan orogen joins the Kazach shield and Turan plate. Geophysical models of earthquakes in Sarykamysh, 1970 and Jalanash-Tjup, 1978 on **Fig. 27** are given as an example.

A few words should be said about temporal regularities. In the process of analysis of detailed observation data, it had been revealed that seismic activity is not a stationary process. Definite cycles in activation of earthquakes of M=3.9 (I_0=3-4 MSK64) happen every 15-20 years. It was observed in the northern part of Tien Shan, along the Kyrgyz Range [Green and others, 1978].

It appeared that the spatial-temporal behavior of seismicity within the limits of different tectonic zones (plots) is different. Thus, the spatial-temporal behavior of seismicity may be used as additional information, but sometimes more trustworthy criteria for separating seismogenerating zones are needed [Green and Knauf, 1978].

The study of periodicity is of great importance for the understanding of seismicity and for the development of prediction methods. In the last century research revealed the existence of a correlation between periodic changes of the seismic activity on the planet and such processes as the Sun activity, changes in angular velocity of the Earth rotation, variations of the absolute value of gravity and other natural phenomena [Khain and Khalilov, 2008; and others]. All the listed processes somehow influence stresses of the solid cover of the Earth. According to the data on the mechanisms of earthquake sources, it is possible to determine the directions of compressive and tensional forces in the area of an earthquake source. The mechanism of an earthquake (fault-plane solution) is understood as two mutually orthogonal planes; one of them is associated with the sliding plane of the earthquake source. The fault-plane solution gives us information about the orientation of these two planes and of the compression and tension stress axes that induced the seismic rupture. According to geological data, the Tien Shan is developing under horizontal submeridian compression (look chapter 2). However, data on the mechanisms of earthquake sources indicate that the compression axis is varying periodically between a horizontal and an inclined orientation, 6-year cycles of such changes could be revealed. There are also 2 - 3-years cycles and also 15-years cycles which could be related to long-term changes. We cannot speak about longer periods due to the short observation period (we have data on focal mechanisms only since 1970). The following tendency is noted. During the periods when the compression axis is oriented horizontally, the seismic level increases and is shown by large number of earthquakes of moderate force M=5-6, that proves the hypothesis about the collision nature of Tien Shan development. When the compression axis starts to deviate from the horizontal position, either no strong or very strong (M≥6.5) earthquakes are registered. These data lead to the conclusion that the Tien Shan stress field has two components. Processes in the deep layers of the Tien Shan determine the first component. The second one has an oscillating character connected with planetary phenomena and triggers stress release in the Earth crust as a result of tectonic activity in an area of modern orogenesis. [Kalmetieva et al., 2003; Kalmetieva, 2005; 2006].

At this point, we can finish the brief description of the seismicity mechanisms of the Kyrgyz part of the Tien Shan. A lot of interesting published works on the seismisity of the Tien Shan present more details than this overview. For those who would like to know more about the conditions of earthquake occurrence in the Tien Shan we could recommend the monograph “Modern geodynamics of intracontinental collision orogenesis regions” [Makarov, 2005], written by the group of authors mainly from Kyrgyzstan and Russia. This book will help to learn more about the great diversity of factors determining seismic effects on the territory of our Republic.

3.3 Creation of the catalogue of earthquakes

The catalogue of earthquakes in Kyrgyzstan (Appendix 1) includes data on earthquakes since 250 BC. The information about historical earthquakes was first collected and systematized by members of the Geograpical Society of Russia [Mushketov, Orlow, 1893]. When the first seismic station in Kyrgyzstan had been established (station Frunze) Evdokia Alexandrovna Rosova was engaged in the processing of earthquakes records in Central Asia [Rosova, Green, 1950; 1955]. Later, the data processing and compilation of the catalogue in Kyrgyzstan were accomplished under the leadership of E.A. Rosova’s disciple Dzhanuzakov Kenesh Dzhanuzakovich. He elaborated the Mushketov and Orlow’s catalogue and created the unified catalogue of earthquakes in Kyrgyzstan.

The first annual catalogues of earthquakes based on instrumental data were worked out in the Seismological Institute of the Academy of Science of the USSR. These data were periodically summarized and published [Savarenski, Soloviev, Kharin (edit.), 1962; Kondorskaya, Shebalin (edit.), 1977]. In 1962, on N.V.Kondorskaya initiative, they started an annual publishing of the catalogue “Earthquakes in USSR”; since 1992, this yearbook was renamed “Earthquakes in Northern Eurasia”. These publications include also data on earthquakes on the territory of Kyrgyzstan starting from $M_{LH} \geq 2.8$ (K.D. Dzhanuzakov remained the author of this section until now). At the same time, information about earthquakes in Kyrgyzstan was published in other catalogues in different years. In 1979, the Central Asian Center established on the basis of the Tajik Institute of Seismic Resistant Construction and Seismolgy started the annual publishing of the catalogue “Earthquakes in

Central Asia and Kazakhstan". To prepare the catalogue the Central Asian Centre carried out the data processing of aggregated materials of seismic stations located in Tajikistan, Uzbekistan, Kyrgyzstan, and Kazakhstan. It included seismic events, from M_{LH}≥3.3. The Center stopped functioning because of the civil war in Tajikistan. On Iliasov's initiative, the Institute of Seismology of the Academy of Sciences of the Kyrgyz Republic and later the Recearch-Methodological Seismological Expedition (RMSE) of the Institute of Seismology also published catalogues including even the smallest seismic events, registered by the network of seismic stations of Kyrgyzstan [Ilyasov et al., 1980; 1992; 2003; 2004; Kalmetieva et al., 2006].

It is quite natural that not all events which occurred before the beginning of instrumental observations, especially those which happened in ancient times, were included into the catalogue. Only the strongest earthquakes, which were told about in mythology, or in written documents were included into the catalogue. Even strong earthquakes of intensity 8-9 MSK64 were included into the catalogue without omission for only the last 200 years. Gradually the density of stations network was increasing (see section "History of instrumental observations"), making it possible to register more and more weaker earthquakes. Table 3 shows starting years of recording all earthquakes with M>=Mc. Table 3 demonstrates that out of the weak earthquakes not always felt by people, the longest period of representativeness (54 years) have the events of magnitude M_{LH}>3. Considering this, the earthquakes starting from M_{LH}=3 were included into the given Atlas.

Until 1980 epicenters of earthquakes were determined manually, by graphic "crossing-method" developed by Mrs. Rosova [1936] using regional network stations data (Y.Shukurova headed the routine data processing). Data of local networks were processed by using Yu.V.Riznichenko's method of "isochrones scale" [Bune et al., 1960]. T.A. Lopatina headed the routine data processing. When computers appeared, a software realizing the analytical method of determining main parameters of earthquakes was developed and installed. [Dzhanuzakov, Gorbin, 1983]. In 1999 the program HYPOELLIPSE developed in the USA [Lahr, 1994] was installed in the Computing Centre of RMSE. Using computers Moldobekova S. was determining parameters of earthquakes and compiling the catalogue, while Sokolova N.P. headed the routine measurements on analog seismograms. Observation data of seismic stations in Kazakhstan, Uzbekistan, Tajikistan, located closely to the border of Kyrgyzstan were also used to achieve higher precision in determining the earthquakes parameters (till 1993). Some data of Xinjiang-Uigur Chinese State Seismological Bureau were used as well.

Table 3

Earthquakes representativeness development

K	Mc	Starting year of recording all earthquakes with M>=Mc
16	6,5	1770(separate events from 500y.)
14-15	5,5-6,1	1865
13	5,0	1911
12	4,5	1929
10	3,3	1955
8-9	2,2-2,8	1980

Mc = Magnitude of completeness

Below follows the description of the meanings of the parameters presented in the catalogue.

N –order number

Year, Month, Day, Hour, Minute, Second – date and time of earthquake event. The column "Hour" shows Greenwich Time.

The Geographic coordinates of earthquake epicenter:

φ - Northern latitude

λ - Eastern longitude

Accuracy class. Here the accuracy class has the values from 1 to 6 and is attributed to the events considering the following conditions:

1 – the epicenter is well surrounded by seismic stations; at the distance of 10 km from the epicenter there is at least one seismic station; clear arrivals of waves were identified on the seismogram; the depth of the epicenter can be determined (corresponds to class "a" of local observations, hereinafter refer to 3.1);

2 - the epicenter is well surrounded by seismic stations; at the distance up to 25 km from the epicenter there is at least one seismic station; the depth of the epicenter can be determined (corresponds to class "b");

3 – one-sided surrounding of the epicenter by seismic stations; at the distance up to 25 km from the epicenter there is at least one seismic station; the depth of the epicenter can be determined (corresponds to class "c");

4 – one-sided surrounding of the epicenter by seismic stations, the nearest station is located not farther than 50 km (corresponds to the category "no class"). Usually, earthquakes on the border with Tajikistan are part of this category;

5 – one-sided surrounding of the epicenter by seismic stations, the nearest station is located at the distance not farther than 100 km (corresponds to class "A", refer to 3.1);

6 - does not correspond to any of the enumerated conditions (corresponds to class "B").

As it can be seen, the network configuration mainly determines the accuracy class, i.e. how well is surrounded the epicenter by observation points, and how far are the nearest stations from the epicenter. This agrees well with the results of research carried out in the Harvard Data Center. To develop criteria of determining the accuracy class of earthquake location depending on the configuration of network they used the catalogue including 2000 seismic events (earthquakes, explosions), values of source parameter of which were known exactly [Istvan et al., 2002]. The result was the following: it is possible to claim with 95% probability that an epicenter is determined with accuracy of ± 5 km, if:

- there are more than 10 stations within a range of epicentral distances of 0-250 km;
- the maximal angle between two points of observations (gap) for direct waves does not exceed 110°;
- the gap for head waves does not exceed 160°;
- within the epicenter distances of 0-30 km there is at least one point of observation.

According to these criteria epicenters of earthquakes in Kyrgyzstan could be determined with an accuracy of 5 km in only case, if they are located within the network of observation (refer to **Fig. 23,25,26**). Such earthquakes make about 30% of the total number of seismic events. Then, it possible to think that all the earthquakes in the southern and South-Eastern part of the Kyrgyzstan territory are determined with an accuracy of 25, 50 or more kilometers. To be sure of this, we compared three catalogues of earthquakes of the south-eastern part of the Kyrgyzstan territory: the catalogues of RMSE, the catalogue of Seismic Bureau of China and the catalogue of Renseller University in the USA. The two last meet the foregoing criteria of 5 km accuracy. It appeared that the values of epicenter coordinates coincide with each other in the limits up to 5 km for 40% of earthquakes, for 20 % - up to 10 km, and for 20% - up to 20 km. A difference between the data of these three catalogues makes 20 km or more for only 20 % of earthquakes [Iliasov et al., 2004]. Therefore, an accuracy of 25 km could not be made for all the earthquakes in the South-Eastern part of Kyrgyzstan. Besides, the experience of routine data processing demonstrates that the precision in epicenter determination depends not on the configuration and condition of observation network only. The travel time curve of seismic waves (or velocity model) is also of great importance in determining the source localization. Sometimes there are earthquakes which epicenters can be determined only with an acccuracy of 10 km or more even if they are placed within the limits of a dense network. At the same time epicentres of other earthquakes are defined with precision of ± 2 km. And on the contrary, sometimes there are events for which initial data good coincide even if there is one-sided surrounding of epicenter by stations. So, we should admit that the reason of such phenomenon is the character of radiation of seismic waves from sources of these events. It is true even for earthquakes of Kok-Shal. That is why, in the catalogues [Iliasov et al., 2003; 2004; Kalmetieva et al., 2006], besides the main parameters of earthquakes, such characteristics as root-mean-square residual of origin time and of epicenter coordinates were also shown. We included also: the distance from the nearest station, the number of stations taking part in parameters determination, and the gap. The enumerated characteristics characterize both the configuration of observation points with respect to the earthquake epicenter and the coincidence of initial data. Now in the world they refuse a class of accuracy and prefer to show values of residual. Not looking on it, we have decided to leave a class of accuracy to have the homogeneous catalogue

H - depth of source (in km) from the surface. For historical events, the depth of seismic sources was identified based on the isoseismal map. The shallower the source is the faster the intensity of earthquake decreases (marking smaller distances between neighboring isoseismal). By using an empirical correlation linking the intensity of an earthquake with its magnitude and the depth of the source, it is possible to assess approximately the depth of a source [Dzhanuzakov et al., 1977]. Since 2002, the depth of an earthquake-source was defined with respect to the sea level. Even nowadays, the low density of the stations network does not allow defining this parameter with adequate accuracy all over the investigated territory. That is why this parameter is not marked in the catalogue for all earthquakes.

K – the energy class of the earthquake source. K= 1g E (joules), where E is the energy spent for producing seismic body waves in the source. A nomogram to determine K value was made by T.G. Rautian in 1960 [Bune et al., 1960]. Earlier K values put in the catalogue were calculated in accordance with MLH magnitude by applying a correlation ratio: K=1,8 MLH + 4.

MLH – the earthquake magnitude defined using of Love surface wave amplitude measurements [Kondorskaya et al., 1981]. Before appearance of Rautian's scale of energy class determination, the classification of earthquakes in Kyrgyzstan was only made by magnitude. The magnitude of any historical earthquake was determined by an empirical correlation between intensity, magnitude, and source depth according to the method mentioned above. In 1960-1995 both K and M parameters were defined. Since 1996, three types of magnitudes were defined: MLH (for earthquakes of energy class K≥12), MPV and coda magnitude (for earthquakes of energy class K≥10). To preserve the homogeneity of the given catalogue the MLH magnitude is shown only.

4. Earthquakes and phenomena related to them

"The aggregate of our knowledge about the Earth must be united into one basic science, called science of the Earth in the broadest sense of the term. But the Earth properties are so diverse that they cannot be the subject of research of only one science. The complexity of the Earth's phenomena calls for detailed studies of totally different aspects and with different methods. Therefore, the science of the Earth that was born in ancient times was divided into separate specialized domains of research due to the gradual widening of observations. Now, these fields have developed into independent sciences."

[D.I.Mushketov, 1934]

Confirming D.I.Mushketov's words it is possible to say that recent tectonic activity is studied by a section of geology called "Neotectonics". The science of seismology studies earthquakes, while, e.g., landslides are studied by specialists of engineering geology although these processes are inseparable in fact. Moreover, now it became obvious that it is not enough to study only the Earth to understand the nature of tectonics and seismic activity. Long-term researches have shown a correlation between the periods of increasing seismic activity and the time of activation of such phenomena as solar activity, the tidal phenomena, etc. And in turn, earthquakes can also cause a lot of processes which we perceive as natural disasters.

As the experience shows, considerable losses and fatalities can be associated with secondary effects of earthquakes if they occur in mountainous areas. There, earthquakes often cause rockfalls and landslides leading to the formation of dammed lakes and flooding of territories or causing catastrophic flash floods and debris flows in case of an outbreak. The role of the earthquake as trigger of the landslide is obvious if a landslide or rockfall happens during a strong earthquake. Some research is devoted to studying the mechanism of such influence. For example, a conceptual model for the triggering of rockslides by earthquakes has been proposed by [Havenith et.al., 2002; Havenith, 2003]. The key factor controlling the ground motion around the rockslide is the presence of superficial low-velocity layer of varying thickness according to these authors. Nevertheless, many things still remain unclear if we consider the interrelation between seismic and slope movement phenomena. For example, why rockslides are not distributed uniformly in seismic zones? Some zones with very high concentration of rockslides of different age are located along the borders of theTien Shan while vast spaces between them are practically not affected by such phenomena [Strom and Abdrakhmatov, 2004]. How can we explain the occurrence of landslide motion before (20-50 hours) strong earthquakes [Torgoev et al., 2008]. There is also an opinion that not only strong earthquakes can cause slope phenomena. Since many earthquakes affect the mountainous regions of the Tien Shan (see the map of earthquakes of 1976 – 1985, **fig. 25**), they are common and regular natural phenomena. Without any exaggeration, we can say that the Earth within the Tien Shan is never quiet in terms of seismicity. Very often earthquakes do not cause dangerous slope phenomena directly but just speed up such processes [Babaev et al., 2008].

The tasks related to this research are very complicated due to the complex interaction between the causes of slope instability processes in mountain areas. For example, the logic tree representing the possible development of processes depending on the steepness of the slope, mechanical properties of the landslide mass, climatic influences and groundwater conditions is presented in [Keefer, 1993].

4.1. Landslides – general information

The territory of Kyrgyzstan is made of mountainous regions located between altitudes of 400 to 7000 m or even higher. 56% of the territory of Kyrgyzstan is located at altitudes of 2500 m or higher. The highest absolute altitude is 7439 m – the Peak of the Victory.

The modern relief of Tien Shan is formed by the interaction of endogenous and exogenous processes. This means that the process of mountain development is still going on. The strong relief of the Tien Shan and its high elevation are responsible for particular natural conditions. The mountain regions are marked by a large diversity of climatic conditions, soils, and vegetation, which can induce an increased susceptibility to slope failure and thus make the access difficult to the higher territories. The strong relief and high tectonic activity of the Tien Shan also contribute to the general instability of the mountains which, combined with climatic changes, atmospheric and anthropogenic influences, can cause the development of dangerous gravitational movements of mountainous slopes: landslides, rockfalls, avalanches and their transient processes.

The most active landslides processes in Kyrgyzstan are observed in the southern areas:

Jalal-Abad Province – including the basins of the rivers Kugart, Mailuu-Suu, Kara-Unkur, Kara-Suu, Sumsar and Chatkal;

Osh Province - including the basins of the rivers Jassy, Kara-Kuldja, Tar, Gulcha, Ak-Bura, and Kyrgyz-Ata;

Batken Province – in the South-West of Kizil-Kia town, Kadamjai settlement, and Sulukta town.

In other Provinces of the Kyrgyz Republic slope processes are less active:

Chui Province – landslide can affect the area around Bishkek city (Orto Sai, Chon-Aryk), the southern and northern slopes of the Kyrgyz ridge, in Suusamyr, Chon-Kemin basin and Boom gorge..

Naryn Province - landslides are isolated cases there, but they threaten by the damming of rivers and the burying of roads;

Issyk-Kul Province - landslides often occur in the mountain zone of the ridges Terskei and Kungei Ala-too and in the basins of the rivers Ton and Djergalan. Their influence on infrastructure of localities is relatively small;

Talass Province - landslides occur in the headwater of the left-bank tributary of the river Chiimtash but are in general not dangerous for the population.

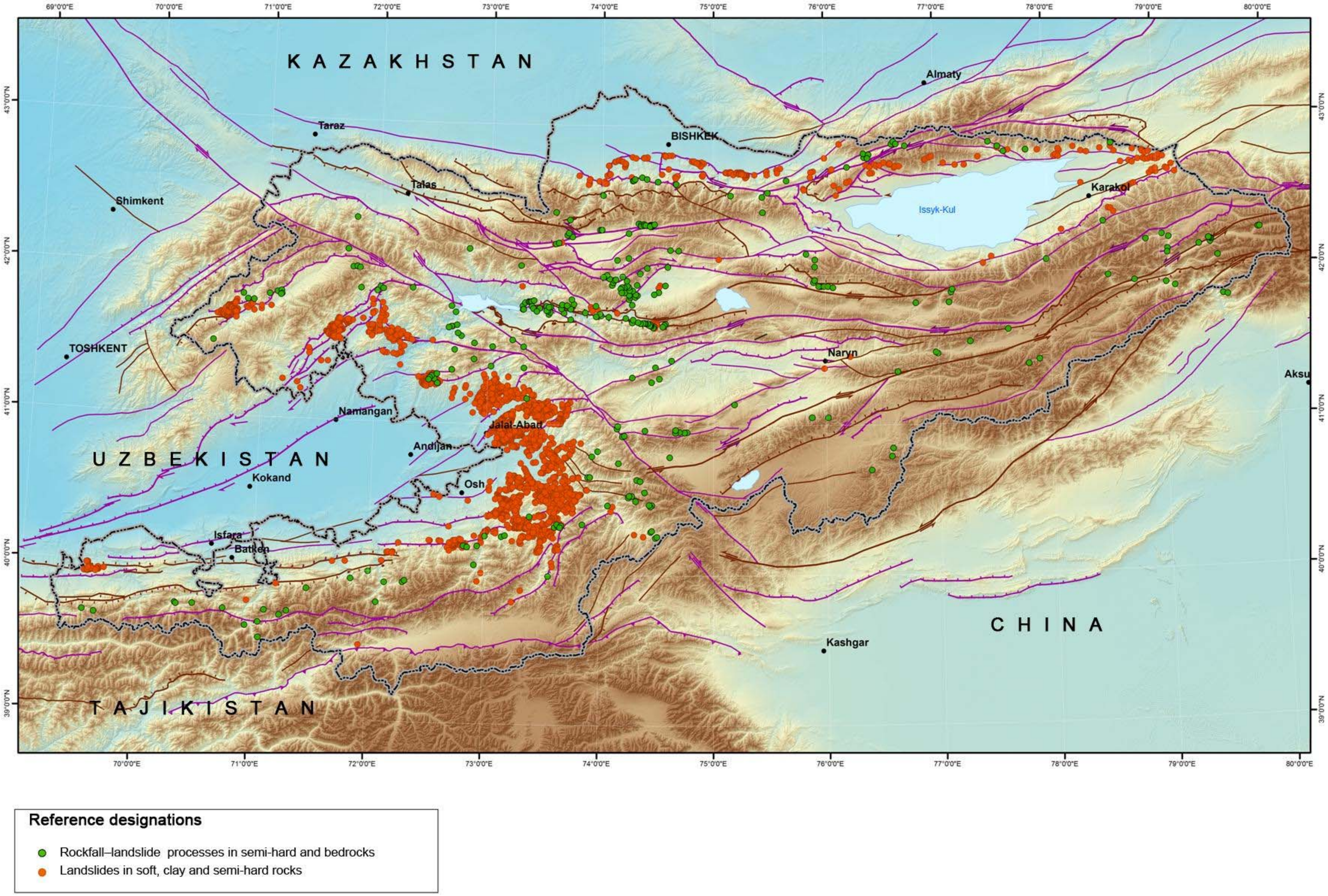

Fig. 28. The map of landslides in Kyrgyzstan

4.2. Categories of slope processes

Rockfall – is a type of mass movement (generally limited in size) formed by falling rocks related to the instability of a steep cliff.

Landslide – is a mass movement formed by rocks or soil sliding along a surface.

Rockfall–landslide processes - are processes combining free falling and sliding of soil and rocks on a surface.

Many factors influence the formation and activity of sliding and falling processes, such as: the structure and character of bedding of the unstable rocks, the morphologic and morphometric characteristics of the relief, rocks fracturing, recent tectonic movements, the humidity of slopes, daily and seasonal temperature gradients, the groundwater level, freezing characteristics, etc.

Many works were devoted to the issue of the development of sliding and falling processes. The authors of these works underlined the important role of earthquakes in these processes that are considered as seismic dislocations. Slides and falls do not develop everywhere or by chance. During earthquakes and in some other cases, they are formed on definite parts of slopes, where the interaction with other factors leads to the weakening of the slope and the initiation of failure.

There are more than 5000 active landslides covering the territory of the Kyrgyz Tien-Shan (**Fig. 28**). If ancient and stabilized rockfall-landslide blocks are taken into account, their number is even higher. These are large-scale landslides and rockfalls, which take place rarely, but their consequences are disastrous. Until now not all landslide movements could be mapped over the Kyrgyz territory of the Tien Shan. Geological surveys were only performed on single sites close to populated areas, aiming to prevent disasters that could affect infrastructure of localities and mining enterprises. Because of the inaccessibility of the mountainous relief and restricted possibilities of making (or acquiring) high-resolution satellite images, we do not have full information on the location of ancient and modern landslides all over the country. they could be subdivided into two categories: Though each rockfall or landslide has its own peculiarities, (1) landslides of soft and semi-hard rock layers (Mesozoic-Cenozoic deposits), and (2) landsliding and falling processes in semi-hard and hard rock layers (terrigenous, metamorphic, more rarely intrusive formations) caused mainly by seismic activity.

Slides of soft and semi-hard rock layers

About 80% of active landslides take place in bordering parts of large depressions within the areas made of Mesozoic-Cenozoic formations. In Mesozoic-Cenozoic formations the development of landslide processes is related to two main factors: (1) the presence of a large amount of fine dispersed rocks - clays, argillites, loams, and (2) the level of natural moisture (groundwater level, precipitations) if the annual amount of precipitations exceeds the average annual norm. Such a combination of conditions is met along the rim of the Fergana Basin and locally in the Eastern part of the Issyk-Kul Basin.

Landslides occur at different altitudes, but most of them are located in the low - middle mountainous zone at an altitude between 1100 and 2200 meters. Between these altitudes, along the border of large depressions, mainly Mesozoic-Cenozoic deposits are developed. Abundant precipitations and the presence of Mesozoic-Cenozoic rocks covering large parts of the Fergana Basin rim create favorable conditions for landslides in these areas. More than 80% of the total amount of active landslides are located there (**Fig. 29-33**).

About 70% of all the landslides are developed in Paleogene and Cretaceous deposits, represented by layers of clays, argillites, siltstones, sandstones, marls, limestones, gypsum and conglomerates. Those layers are often covered by Quaternary loess deposits. Landslides mainly take place on the limbs of folds made of clay and argillite. The main reasons for the formation of slides are: the high wetness of rocks related to atmospheric precipitations and the high groundwater level. They are usually formed in places of contacts between permeable rocks and impermeable clays and argillites. When the level of atmospheric precipitations is up to 20% higher than the average over a long period, generally an activation of existing landslides is not bserved or is very small. An activation oflandslide processes is higher than the average, when the level of atmospheric precipitations exceeds 40% of the long-term average norm.

According to the results of research of sliding processes [Emeljanova, 1972; and others], each of them is at a different stage of development at a certain moment, because they develop not synchronously.

The stage of preparation for the first movementcan be identified by the:

- appearance of water (springs, wet ground, moisture-loving plants) in the lower parts of unstable slopes;
- formation of knolls, mounds, or depressions within the area of a developing landslide;
- development of ruptures within the contour of the forming landslide;
- subsidence along landslide ruptures;
- deformations of the slope within the forming landslide in the form of small earth flows and wash-out

The stage of the first movements:

- the landslide is in motion;
- the landslide is in temporarily stable condition, having shifted from the initial position, but not achieved a state of stability.

The stage of secondary movements:

The secondary sliding stage is completed after the first displacements of the landslide body. In this stage the deformation could be developed as a failure until the slope is stable again; it can also be a deformation of separate blocks influenced by newly activated exogenous processes.

The stabilization stage – the landslide achieved the state of stability, and is not influenced by exogenous and endogenous processes.

The duration of the total landslide cycle and its constituent stages depends on the intensity and periodicity of the influence of the natural factors. It is also depends on the reaction of the in-situ rock and the local geological conditions, and it varies both over short- and long-terms: from several seconds to dozens of years and even longer.

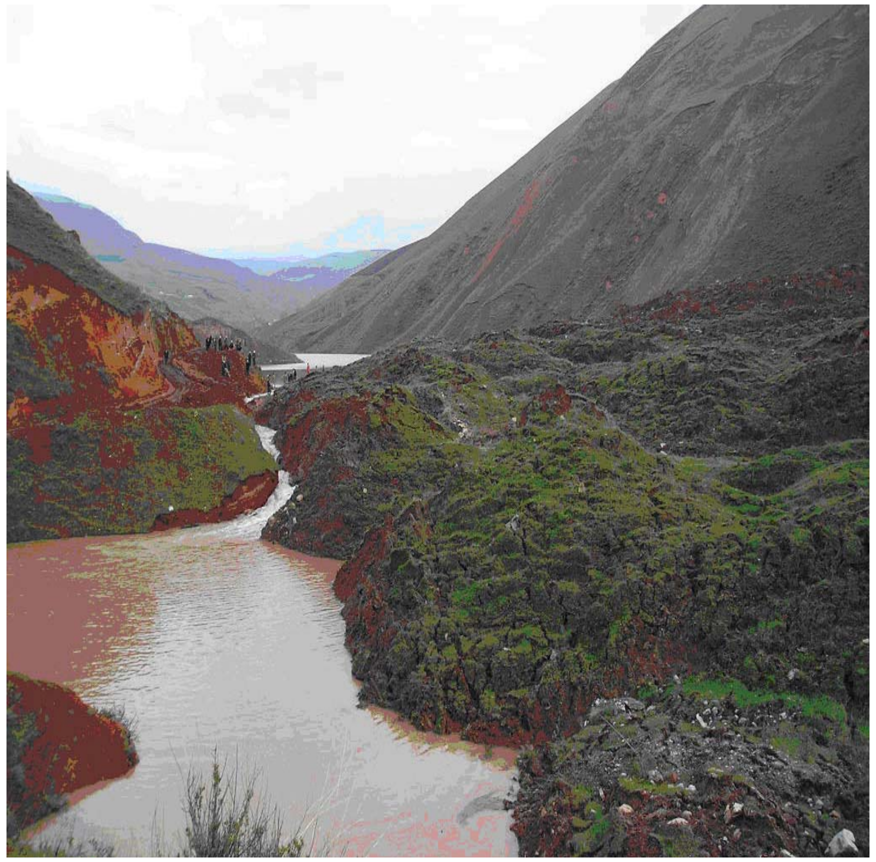

Fig. 29. The rockslide took place in 2004, closed Kara-Guz River in Karakuldza region and a dammed lake was formed. The subsequent outbreak caused a flash flood and debris flow.

Landslides in bedrocks

Rockslides and rockfalls tend to be located close to tectonic faults and seismic zones on the territory of Kyrgyzstan. The existing rockfalls and rockslides of this category can be very large, but are generally in a stable or temporarily stable state. In case of repeated seismic actions, extreme exogenous or anthropogenic processes, secondary deformations are possible: movements of the whole rockfall body or its separate parts. For many seismogenic

Fig. 30. The landslide in loessial sediments took place in 1994, in Komsomol village of Uzgen region and killed 26 people.

Fig. 31. The landslide in Gulcha village took place in 2000, the volume is 14 mln. m³. 148 residential houses, technical structures and utility lines of the village were destroyed.

Fig 32. The Landslide in Maili-Suu city, took place in 2004, the volume is 80 000 m³. 1 house was destroyed, 2 people were killed.

Fig 33. Landslides in loessial rocks in the valley of Achi River of Suzak region threatening to destroy residential houses.

rockfalls and rockslides (**Fig. 35, 37**) initial failure is immediately triggered by the seismic action. However, often the final mass movement develops only after some time, weeks, months or years after the earthquake, according to the influence of other exogenous processes. In some cases, aftershocks or later earthquakes are the final "trigger' of the total failure of the rockslope that was initiated by the main shock. The range of mass movement velocities is rather wide, from slow creeping of several mm/year up to 100 m/sec in case of rockfalls.

In reality, all movements of this kind take place episodically or in cycles. During some periods, the slope stays relatively stable, but during others its stability decreases and the movement starts again. It becomes catastrophic when the slope looses its stability, and kinetic energy of the moving rockfall increases. The activation of massive movements could be caused by such regular phenomena as seasonal rains, snow melting, thawing ground, earthquakes, solar activity and so on.

In conditions of strong relief, landslides are rather common phenomena. Their sizes are not considerable, the largest are rare and often related to the category of seismogravitational slides. Seismically triggered movements of large masses with a volume of 10 mln m³ or more generally occur along fault zones. Examples of such landslides are: a rock avalanche near Belogorka village (**Fig. 35)** caused by the M=6.9 1885 Belovodsk earthquake and rockfalls-rockslides triggered by the M=8.3 1911Kemin earthquake the volume of one of them in Dzjarilgan-Too in the area of Ananievo is 7 mln m³.

Gigantic catastrophic rockfalls of the volume of more than a billion of m³ may also occur in mountains areas. For instance, the Sarez earthquake of 1911 triggered the 2,2 bln m³ Usoy rockslide which dammed the river of Murgab. The Sarez dammed lake formed with a water volume of 16 km³, and a surface of about 89 km². The Sary-Chelek lake, lakes in the upper reaches of Kara-Suu river (eastern part), Kara-Suu lake and some other in Kyrgyzstan were formed approximately in the same way.

Landslide-prone mountain slopes are situated on some parts along the roads: Bishkek – Osh, Osh-Horog, Ala-Buka - Kanysh-Kia, along the railroad Bishkek-Balikchi, and in some open-pit mines Makmal, Kumtor and others. Intensive development of rockfalls is observed on steep mountainous slopes, high rock faces of gorges and canyons of the rivers Naryn, Kokomeren, Kara-Suu, Tar, Goulcha and many others (**Fig. 31, 34, 36, 38,39)**.

Fig. 34. Landslide above the railway gallery on the 115-th km of the Bishkek – Balykchi road in Boom canyon (photo made by S.A.Erochin). This active landslide threatens to destroy the gallery. They regularly clear off the blocks moving down to the gallery.

Fig. 35. Seismic rock avalanche of the 1885 earthquake in Belogorka village of Sokuluk district (photo by I.A.Torgoev).

Fig. 36. Forming landslide above the center of Goulcha village of Kara-Kuldja district threatening parts of the village (photograph by A.A. Ermolov).

4.3. The history of significant events

Different from the southern regions, the landslides in the north of Kyrgyzstan (Talass, Kyrgyz, Kungei, Terskei ridges, Suusamyr hollow) are not of clustered. They occur in separate places along the foothills, mostly in clay – marl and plastic rocks of Pliocene age, Neogen – Quaternary sediments. Because of the small thickness of the Quaternary sediments coveringthe mountainous slopes in the north of Kyrgyzstan, the landslides are comparatively small, and generally develop as earth flows and superficial wash-out.

As it can be seen on the satellite images, a considerable amount of ancient landslides are in a stable state. Nevertheless, the change of climatic conditions in the last period of time, i.e. the increase of average annual temperature, the increase of precipitation in spring and autumn, draughts in summer, has already affected the activation of sliding processes. The research executed by MNR KR since 2002 shows that there was a significant reactivation of ancient landslides in the northern region of the Republic, and new ones were formed.

In mountainous areas, the processes of gravitational movements are not extraordinary phenomena, but reflect the naturally developing 'geological life' of this or that region. That is why it is necessary to expect in future the appearance of similar phenomena and to predict them in order to prevent dangerous consequences with the purpose of reducing the economic, ecologic and social losses.

In different periods, the problem of protection of the population from natural disasters was solved by different agencies: the Ministry of Natural resources (earlier Geology Administration of the USSR), the Ministry of Agriculture and Water Management Ministry, the Ministry of Transport and Communications, the Ministry of Construction, the Ministry of Energy of the USSR. During the last years, the Emergency Ministry is responsible for the protection from dangerous exogenous geological processes and for the monitoring of dangerous rockfall and landslide activity.

The landslide service has been established in 1954 within the Department of Geology of the Kyrgyz Republic, based in Jalal-Abad and since year 1968 in Osh.

According to the results of previous research it was established that a large amount of landslides took place in the years when there were a lot of atmospheric precipitations: 1953-1954, 1969, 1978-1979, 1988, 1994, 1998, 2002-2004, and also in the years when strong earthquakes took place. On the territory of Kyrgyzstan there are more then 300 localities, which are in the zone of possible landslides of different size. The catalogue of the most considerable landslides is presented in Appendix 3.

In the conclusion of this part, it is necessary to speak about the calamities caused first of all by human activity.

Figure 40 shows the places of storage of toxic and radioactive wastes which started in 1940. Currently there are more than 90 dangerous burial places of radioactive and toxic wastes in Kyrgyzstan. The risk of their destruction induces a potential danger of pollution of the environment. The mountainous relief and tectonic activity of the region determine factors, which considerably increase the risk, among them are:

- earthquakes,
- processes of soil erosion, typical for mountainous floods, mountain torrents, landslides,
- close locations of burial places to river-beds.

Figure 41 shows the parts of the territory, which will be contaminated in case of damage of burial places. It is seen that not only the territory of Kyrgyzstan is under the risk, but also parts of territories of Tajikistan, Uzbekistan and Kazakhstan [Kyrgyzstan Uranium Tailings, 2008].

Fig. 37. Seismic fall near Ylai-Tala village of Kara-Kuldja district (the photograph made by A.V. Meleshko).

Fig 38. The ancient landslide in Kara-Kuldja district on the left bank of Tar river (the photograph made by A.V.Meleshko).

Fig. 39. Ancient and recent landslide slopes. Kara-Kul city of Toktogul District (the photo made by A.V.Meleshko).

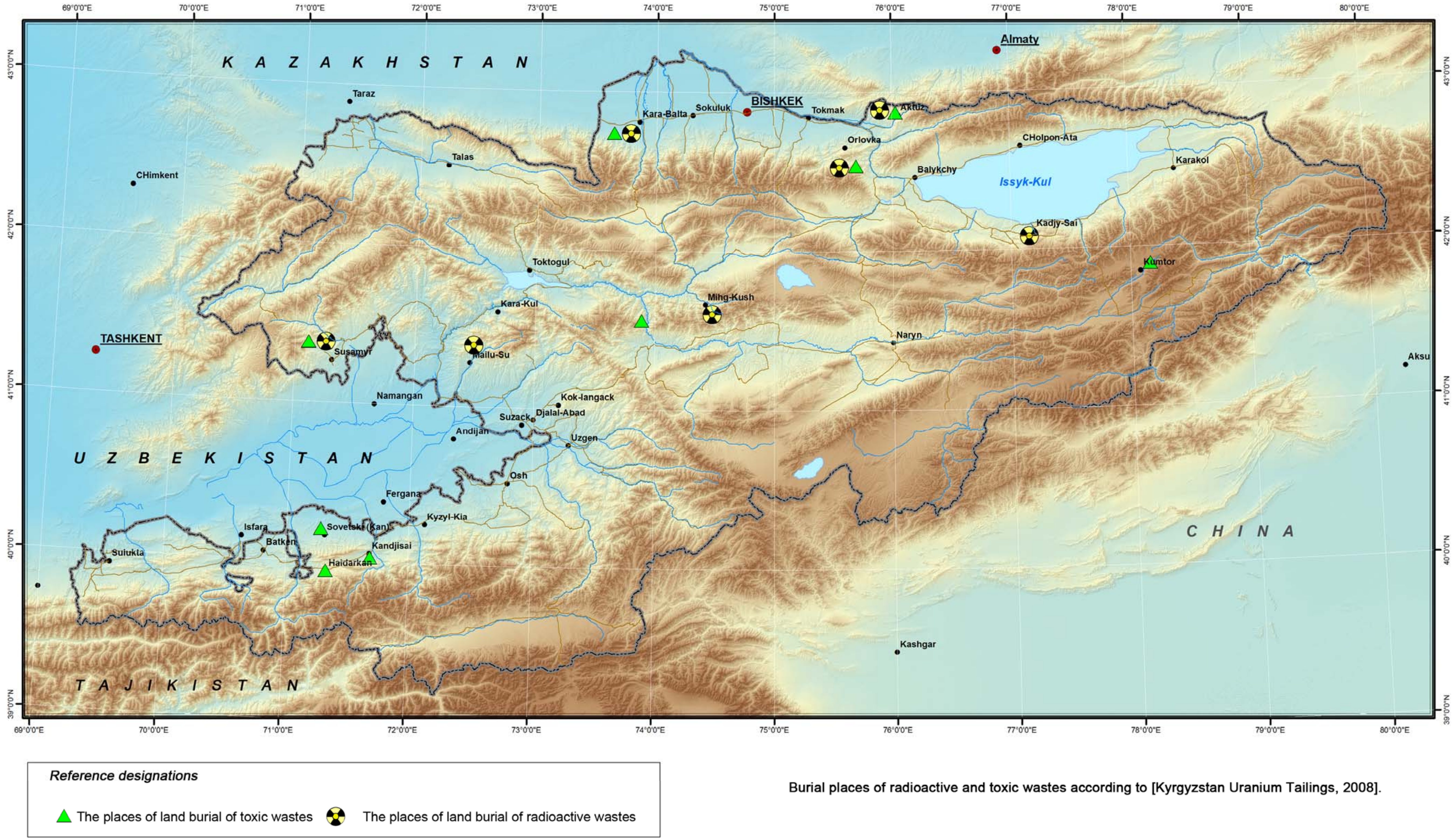

Fig. 40. Burial places of radioactive and toxic wastes according to [Kyrgyzstan Uranium Tailings, 2008]

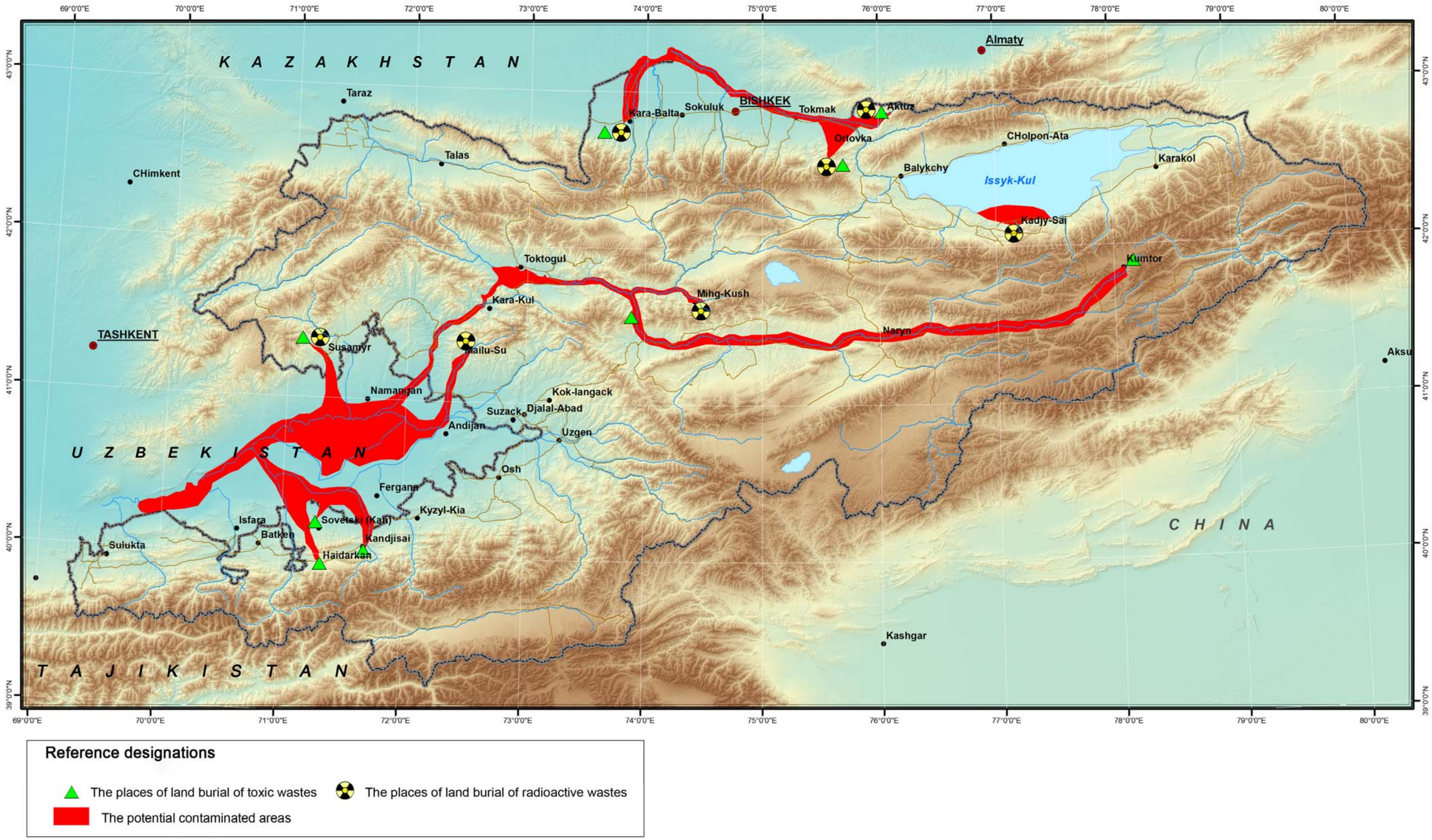

Fig.41. The potential contaminated areas in case of the tailings breake off according to [Kyrgyzstan Uranium Tailings, 2008]

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Annex 2.

The catalogue of strong earthquakes from ancient time until 2008

Year	Month	Day	Hour	Min	φ,°N	λ,°E	H, km	K	Mlh	Io MSK64	Title	Coment after [Djanuzakov et al., 2003]
-250	0	0			42.70	77.50	20	16.1	6.7			
500	1	1			42.70	76.50	20	15.7	6.7			
838	1	1			40.30	71.80	10	13.6	5.3			
1475	1	1			42.60	75.20	20	15.6	6.4			
1494	1	1			41.00	71.60	6	13.2	5.1			
1600	1	1			40.00	76.00	30	14.8	6			
1620	1	1			40.90	71.40	6	14.6	5.8			
1716	1	1			43.20	81.00	30	17	7.5	-	Aksuyskoe	
1770	1	1			42.77	74.10	15	14.8	6			
1786	6	18			44.00	80.80	15	15	6.5			
1807	1	1			43.10	76.90	20	16	6.7			
1822	9	0			40.30	71.50	12	15.2	6.2			
1823	1	1			40.30	71.50	12	15.2	6.2			
1853	11	1			39.00	76.20		13.8	5.5			
1865	3	22			42.70	73.20	15	15.5	6.4			
1868	4	3	21	15	41.20	69.60	18	15.5	6.5			
1868	8	29	8		42.70	75.90	20	15.3	6.4			
1869	3	25			39.90	69.50	30	13.9	5.5			
1874	1	18	15		42.90	77.40	20	14.6	5.9			
1880	12	1	23	30	43.10	76.90	14	14.3	5.7			
1883	11	14	17		40.60	72.80	12	13.9	5.5	7-8	Oshskoe	The earthquake was accompanied by an underground ‘boom’. There were destructions and victims. Strong shocks continued for 10 days.
1884	3	13	5	7	42.80	78.20	20	14.4	5.8			
1885	8	2	21	20	42.70	74.10	15	16.5	6.9	9-10	Belovodskoe	The villages Belovodskoe, Kara-Balta and Sokuluk were completely destroyed. Cracks of a width of about 2 m, rockfalls, landslides and debris falls were observed. The next day a shock of almost the same force occurred.
1885	9	19	20		41.70	75.80	14	13	5			
1886	11	8			43.00	75.00	28	13.7	5.4			
1886	11	29	4	13	41.40	69.50	26	15.5	6.7			
1887	6	8	23	35	43.10	76.80	20	16.6	7.3	9-10	Vernenskoe	5 min after a forshock of 5 MSK64 intensity an underground ‘boom’ was heard, strong shocks also took place. Verny town was completely destroyed and about 400 repeated shocks, numerous cracks, landslides and surface movements occurred over one year. 330 people were killed.

1888	9	16	19		42.70	74.80	20	13.7	5.4			
1888	11	28	6	40	40.00	69.80	20	15.3	6.3			
1889	2	25	6	8	43.10	76.90	15	13	5			
1889	7	11	22	14	43.20	78.70	40	18	8.3	10	Chilikskoe	About 3000 constructions were destroyed, rivers Tup and Djergalan changed their canals, many people and cattle were killed. The earthquake was felt even in Pavlodarth., The shore belt was shrunken in the form of huge stair, fountains of sand were formed and water up to 1.5 meters high jetted. Aftershocks were lasting for two years. Many huge avalanches and debris falls were formed.
1889	7	18	20	30	42.80	74.90	20	14.5	5.8			
1890	2	25	17	30	43.00	78.00	40	15	6.4			
1893	11	4	4	28	42.70	75.80	15	15	6			
1893	11	5	3	30	39.50	69.40	40	14.6	5.9			
1893	12	25		30	41.20	80.30		15.3	6.5			
1894	7	28		30	41.00	71.20	10	13	5			
1895	12	18	13	4	40.00	73.00	15	14.5	6			
1896	1	15	18	40	41.50	70.90	23	15.7	6.6			
1896	9	27	16	27	39.60	73.60	18	14.1	5.6			
1896	11	1	5	1	39.67	75.90	25	15.6	6.6			
1897	9	17	15	10	39.70	69.00	25	15.3	6.5	8	Uratubinskoe	It started with a loud underground 'boom'. In the foothills of the Turkestan ridge rockfalls and cracks up to 30cm wide occurred in loess-covered slopes.
1898	6	22		1	39.70	76.70	20	15	6.1			
1902	2	13	3	56	41.40	76.00	15	13.7	5.4			
1902	4	17	21	10	40.00	71.00	30	14.4	5.8			
1902	8	22	3	1	39.80	76.20	40	17.6	7.8	10	Kashgarskoe	
1902	8	22	15		39.80	76.20	40	15	6.1			
1902	8	22	17	50	39.80	76.20	40	14.7	6			
1902	8	24	1	30	39.80	76.20	30	15.2	6.4			
1902	8	28	18	30	39.80	76.20		14.1	5.7			
1902	9	15		30	39.80	76.20	40	14.8	6			
1902	9	15	2	36	39.80	76.20		14.6	5.9			
1902	9	16	11	40	39.80	76.20	30	14.9	6.2			
1902	9	18	16	45	39.80	76.20		14.4	5.9			
1902	12	16	5	7	40.80	72.30	9	15.6	6.4	9	Andijanskoe	There were three strong shocks: the first of intensity 8-9 MSK64, the second of intensity 9 MSK64 (1hour after the first one) and the third of intensity 8-9 MSK64 happened after another 30min. During the first two days aftershocks occurred. In Andizhan and its vicinities, the relief had changed, cracks up to 70 cm. wide occurred, sand and pebble fountains formed, rails of the railroad were curved. 26000 constructions were ruined, 4562 men were killed. About 7000 farm animals were killed.
1902	12	19	14	50	39.80	76.20	30	14.9	6.2			
1903	2	4	21		40.00	78.00	30	15	6.1			
1903	3	28	8	55	40.80	72.70	14	15	6.1			

1903	10	19	3	10	39.30	74.50	25	15.2	6.2			
1904	2	4	21		40.00	78.00	30	15	6.1			
1905	3	14	10	42	40.00	76.00	30	14.8	6			
1907	3	11	1	34	41.50	75.00	20	14.1	5.6			
1907	9	15	17	46	40.30	72.50	10	14.6	5.8			
1907	9	19	19	14	40.30	72.50	14	13.9	5.5			
1907	10	21	4	23	38.50	67.90	35	17	7.5	9	Karatagskoe	Landslides, rockfalls and surface ruptures of the fault occurred; 150 settlements were destroyed, more then 1500 people were killed. The formation of two sources in Mechetli mountains and on the southeastern slope of the Surkhantau range is associated with the earhquake event.
1908	1	31	4	50	42.80	71.30	14	13.6	5.3			
1908	3	24	22	7	40.90	71.00	26	13.7	5.4			
1910	12	25	19		43.00	74.80	10	13.6	5.3			
1911	1	3	23	25	42.90	76.90	25	17.8	8.2	10-11	Keminskoe	Huge rockslides (in Chon-Kaindy, a scarp with a height of 400 m had formed) occurred. Some rocks broke off and vertical displacements along fault ruptures (8m in Uital) affected the surface over a length of up to 200 km. Hanging subjects' oscillation and stopped of pendulum clocks were observed even at a distance of up to 1000 km. 540 people were killed.
1911	2	18	18	41	38.20	72.80	25		7.1	9	Sarezskoe	The hypocenter depth was 70-75 km. Huge blocks of rock crashed down on the right bank of Murghab river and caused the formation of two lakes - Sarez and Shapau. 140 men were killed.
1912	1	23		25	41.00	71.70	12	13.6	5.2			
1912	12	24	15	2	40.80	70.00	25	13.4	5.2			
1913	2	23	11		44.00	80.00	15	14.3	5.7			
1914	1	13	21		40.30	71.80	20	13.7	5.4			
1914	10	18	20	46	40.70	73.10	16	13.2	5.1			
1915	12	17	7	5	42.00	79.20	40	16	6.7			
1916	2	28	13	16	43.00	77.20	25	15	6			
1916	2	29	18	55	40.60	78.20	20	14.4	5.8			
1918	12	1	2	35	39.00	73.00	30	15.3	6.5			
1918	12	1	10	35	39.00	73.00		15.7	6.5			
1919	7	24	2	3	40.00	76.00	30	15.7	6.7			
1920	6	14	13	8	40.00	76.00		13.3	5.2			
1920	9	25		8	41.50	71.00	10	14.1	5.6			
1923	8	10	1		41.00	77.50	20	13.7	5.4			
1923	8	10	2	17	41.00	77.50	20	14.4	5.8			
1923	12	20	15	13	39.50	72.00	15	14.1	5.6			
1923	12	28	22	24	39.60	69.20	18	15.3	6.4			
1924	1	1	15	16	41.00	70.50	20	13	5			
1924	1	4	12	21	39.20	71.40	20	13.2	5.1			
1924	5	11	22	16	40.00	76.00		13	5			

1924	7	6	18	31	40.50	73.10	22	15.3	6.4			
1924	7	12	15	12	40.60	73.20	14	15.6	6.5	8-9	Kurshabskoe	The Kurshab settlement turned into the heap of ruins. To the south of the settlement, landslide occurred, the water level in wells rose. 1729 houses were destroyed, 26 men were killed.
1925	8	5	20	11	40.00	77.50	20	13.7	5.4			
1926	1	18	11	20	43.00	75.00	15	13.7	5.4			
1926	4	11	6	26	40.60	69.50	18	13.7	5.4			
1926	5	2	10		39.50	72.00	10	13.5	5.3			
1926	5	16			40.00	76.00		13	5			
1926	5	16	16		40.00	76.00		13	5			
1926	5	28	22	31	40.90	73.10	9	13.6	5.3			
1926	8	26	10	30	39.00	73.00	20	13	5			
1927	1	20	8	47	41.50	70.80	20	13.4	5.2			
1927	3	24	7	41	40.00	78.00	20	13.5	5.3			
1927	4	30	13	56	39.50	79.00	20	15.3	6.3			
1927	5	29	10	28	41.20	75.20	15	13	5			
1927	8	12	10	22	41.00	71.60	14	14.8	6	8	Namanganskoe	Landslides along the banks of Syr-Daria river occurred, near Chartak settlement water appeared in a newly formed crack. 1461 houses were destroyed, 35 people were killed.
1927	8	12	16	16	41.00	71.60	20	13.9	5.5			
1927	10	29	1	24	39.00	75.00	20	13.4	5.2			
1927	10	31	23	30	40.00	76.60	20	13.7	5.4			
1928	1	5	14	9	43.50	78.50	20	14.1	5.6			
1928	1	15	8		39.70	75.50		13	5			
1928	2	7	9		39.50	75.60		13	5			
1928	2	17	22		40.00	75.00		13	5			
1928	3	18	1	33	39.80	77.60	20	13.4	5.2			
1928	3	30	1	1	42.00	72.30	20	13.4	5.2			
1928	4	12	9		39.60	74.50		13	5			
1928	4	28	8		40.20	77.00		13	5			
1928	6	18	14	10	39.00	75.00		13.3	5.2			
1928	7	11	10		40.30	76.40		13	5			
1928	8	23	3	53	41.80	72.90	21	13.9	5.5			
1928	12	15	7		41.50	73.60		13	5			
1929	1	10	10		40.20	77.20		13	5			
1930	1	7	17	27	39.20	72.10	10	13.5	5.3			
1930	2	8	6	28	39.40	74.90	20	14	5.5			
1930	3	1	5	35	40.00	75.30	20	13.7	5.4			
1930	3	6	15	44	39.00	72.00	10	13.7	5.4			
1930	3	14	10		40.00	76.90		13	5			
1930	4	9		43	40.10	77.10		13	5			

1930	4	10	14	24	40.00	76.50	20	14	5.5			
1930	7	9	9		40.20	75.20		13	5			
1930	8	9	22	41	39.20	73.80	20	13	5			
1930	9	24	2		40.30	76.70		13	5			
1930	10	12	15	6	40.20	69.70	12	13.1	5.1			
1930	10	30	16	15	39.30	76.30		13	5			
1930	11	18	22		40.00	76.00		13	5			
1930	12	18	9	27	43.00	78.70	15	13	4.6			
1930	12	25	13	49	41.90	69.10	15	13	5			
1931	2	2	12	0	40.30	77.30		13	5			
1931	8	15	4	0	39.40	76.60		13	5			
1932	4	20	20	5	41.00	74.80	20	13	5.1			
1932	10	29	11	8	39.20	72.20	20	14.5	5.9			
1932	12	24	4	17	42.80	78.20	23	14	5.6	7	Tupskoe	Before the earthquake a 'boom' was heard, 4 shocks were registered. Ice cracked near creek Przhevalsk's wharf.
1932	12	30	21	20	42.80	78.20	20	13	5.1			
1933	3	22	2	22	42.60	74.50	20	13.4	5.2			
1933	9	9	19	34	40.10	70.70	26	13.6	5.5	6-7	Near Batken	A 'boom' was heard before the earthquake; hanging subjects oscillated, plaster flaked off from ceilings and walls. Walls of houses were cracking, utensils were ringing.
1933	12	17	23	4	42.80	79.00	15	13.9	5.5			
1934	7	28	2	6	41.00	77.50	20	14.2	5.7			
1934	9	3	10	19	39.20	70.90	10	13	5			
1934	9	23	1	24	39.30	71.10	10	13	5.2			
1934	9	27	22	51	42.40	75.80	18	13	4.9			
1935	7	29	23	16	39.50	73.50	20	14.3	5.7			
1935	7	31	9	58	39.50	73.50	20	13	5.3			
1935	9	29	6	36	40.70	77.40	20	13	5.2			
1935	10	26	21	17	39.30	73.30	20	13.9	5.5			
1935	12	11	12	11	42.60	75.90	15	13	5.2			
1936	4	9	0	53	39.60	73.10	5	13	5.2			
1937	11	10	19	42	41.80	78.90	5	13	5			
1937	11	18	4	39	42.60	80.10	20	13	5.1			
1937	12	18	13	18	42.10	70.90	20	15.6	6.5	7-8	Pskemskoe	The earthquake epicenter was located in a weakly populated area. A 'boom' similar to the buzz of a tractor was heard.
1938	6	20	23	50	42.70	75.80	21	16	6.9	8-9	Kemino-Chuyskoe	The earthquake was the most strongly felt in Kyzyl-Bairak village. In Lesozavod and Kyzyl-Bairak settlements cracks were formed. Normal faulting of a length of 150 m took place in the vicinity of Dzhal-Aryk. Next to Lesozavod village a rockfall occurred. Unlike the previous strong earthquakes there were no aftershocks.
1939	2	23	15	41	42.60	80.60	20	15	5.9			
1939	3	17	12	12	42.50	80.50	20	14	5.5			
1939	3	20	1	56	42.40	80.60	20	13.6	5.2			

1939	4	17	19	15	41.30	76.50	5	13	5			
1939	5	30	0	52	39.40	76.70	20	13.4	5.2			
1939	5	30	10	7	39.00	70.45	6	14.1	5.8			
1939	10	10	20	42	39.30	69.00	15	13	5			
1940	1	26	23	11	41.90	77.20	15	14	5.5			
1940	12	2	12	8	40.50	76.30		13.3	5.2			
1941	4	5	9	58	39.30	72.10	20	13	5			
1941	4	20	17	38	39.20	70.50	8	15.6	6.4	9	Garmskoe	10 large rock and soil falls took place from hillsides of valleys of the rivers Yasman and Kamarou. An underground 'boom' was heard. Houses were destroyed in 60 settlements, 700 men were killed.
1941	4	26	23	10	39.30	70.60	10	14	5.5			
1941	5	6	16	55	39.30	70.60	10	14.1	5.6			
1941	8	13	0	55	40.90	71.30	20	13	5.1			
1941	9	5	17	10	40.00	74.30	20	13	5			
1942	1	8	13	31	39.40	72.90	20	13	5.2			
1942	1	18	16	36	41.10	71.60	21	14	5.9	7	Yartepskoe	An underground boom was heard. There were destructions in the area of intensity 7MSK64.
1942	2	14	10	44	40.90	72.10	15	13.9	5.5			
1942	2	28	4	54	39.20	70.90	10	14	5.5			
1943	4	5	1	56	39.30	73.30	20	14.6	6.3			
1943	6	2	2	55	39.20	71.80	10	13.7	5.6			
1943	7	15	11	53	40.00	78.40	20	13.5	5.4			
1944	1	3	9	49	41.00	79.00	20	13.6	5.3			
1944	3	15	5	3	39.70	73.10	20	14.6	6			
1944	3	15	6	17	39.60	73.00	20	14	5.4			
1944	9	2	2	30	39.30	72.00	20	13	4.9			
1944	9	27	16	25	39.00	74.80	30	15.6	6.7			
1944	9	27	16	52	39.10	75.00		14.6	5.9			
1944	9	30	5	9	39.30	74.80	20	13	5			
1944	9	30	7	41	39.20	74.80	20	13.7	5.4			
1944	10	17	21	17	39.20	71.80	10	13	5.1			
1945	4	19	17	46	42.90	77.50	20	14	5.7			
1946	6	6	19	4	43.00	80.90	15	13	4.8			
1946	6	24	4	11	42.00	76.00	15	13	5.2			
1946	11	2	18	28	41.90	72.00	25	17	7.5	9-10	Chatkalskoe	All constructions were destroyed in the area of 1500 km². Buildings in Osh, Dzhalal Abad, Tashkent, Andizhan and other cities were strongly damaged. Large rockfalls, landslides and loams break off had dammed rivers. Cracks with a length of up to 300 m and a width up to 30 m appeared.
1946	11	3	13	34	41.70	72.20	20	13.5	5.3			
1946	11	4	10	22	41.90	72.00	20	13	5.2			
1946	11	7	15	54	42.00	72.00	20	14	5.7			

1946	11	10	0	46	40.50	77.50	20	14	5.5			
1946	12	9	12	26	42.80	77.90	15	13	5.1			
1947	4	8	0	6	41.80	72.30	26	13.5	5.3			
1947	6	1	18	56	41.10	72.20	10	13	5			
1947	6	2	6	40	40.90	72.30	13	14.5	5.9	8	Naymanskoe	Some constructions crashed down, walls fell down, doorframes were lopsided.
1947	8	16	5	53	40.50	77.60	20	13.4	5.2			
1948	7	28	8	0	41.40	75.40	6	13.6	4.9	7-8	Kulanakskoe	All the buildings in the area of intensity 7-8 MSK64 were damaged, some of them were destroyed completely. An underground boom, cracks, landslides, rockfalls were observed.
1948	9	10	12	2	41.90	72.20	20	13.7	5.4			
1948	11	3	15	2	42.50	70.40	14	13	4.4			
1948	12	14	16	2	42.80	74.70	20	13	5			
1949	3	17	2	47	42.00	72.70	15	13	5			
1949	7	8	7	50	39.20	70.80	28	13	5.1			
1949	7	8	8	2	39.20	70.80	18	14	5.6			
1949	7	10	3	53	39.20	70.80	16	17	7.4	9-10	Khaitskoe	Huge landslides, rockfalls and mudflows destroyed everything in the area of length 65 km . Khait and another 32 settlements were buried. On the surface of river terraces and hillsides large cracks appeared. Before the earthquake a vertical shock with a boom was felt. 20000 people were killed.
1949	7	10	7	18	39.30	70.80	10	13	5			
1949	7	10	10	43	39.30	70.80	10	13	5			
1949	7	10	10	57	39.20	70.80	10	13	5.1			
1949	7	10	11	57	39.10	70.80	10	13	5.1			
1949	7	10	14	13	39.20	71.10	10	13.6	5.4			
1949	7	10	15	7	39.10	70.90	10	13	4.9			
1949	7	10	15	19	39.10	71.00	10	14	5.8			
1949	7	10	15	49	39.20	71.10	19	15	6.2			
1949	7	10	16	24	39.10	71.00	14	15	6.2			
1949	7	11	1	12	39.40	70.80	5	13	5			
1949	7	11	3	55	39.20	70.90	10	13	5			
1949	7	13	10	13	39.20	71.00	10	13	5.1			
1949	7	13	18	28	39.20	70.80	10	13	5.1			
1949	7	19	17	42	39.10	71.10	10	14	5.8			
1949	8	12	7	38	39.80	76.80		13.3	5.2			
1949	8	23	22	3	39.20	71.10	25	13.5	5.3			
1950	7	6	7	3	39.30	73.30	20	13	5.2			
1951	4	14	4	10	39.10	71.60	25	14.5	5.9			
1951	4	14	4	52	39.10	71.60	10	13	5			
1951	5	12	22	7	39.60	71.20	25	13.8	5.4			
1951	8	3	23	35	39.10	71.70	15	13	5.1			
1953	2	11	23	22	39.80	77.40	15	14	5.5			

1953	3	15	3	9	40.20	77.90	15	13	5			
1953	3	16	17	35	39.90	78.20	15	13	5.2			
1953	7	9	19	2	40.20	78.00	20	14.5	5.8			
1953	7	9	20	43	40.30	78.10	20	13.7	5.4			
1953	12	4	7	50	40.10	77.70	20	13	5.1			
1954	4	19	16	53	39.10	75.00		13	5			
1954	10	27	21	48	40.10	77.30	20	13	5.1			
1954	12	3	21	38	41.40	74.80	15	14	5.4	7	Durbeljinskoe	There were destructions of constructions. Cracks in the ground, rockfalls, landslides and debris falls were formed in area of Durbeldjin.
1955	4	15	3	40	39.90	74.60	52	16.4	7.1			
1955	4	15	4	13	40.00	74.70	50	15.5	6.6	9	Ulugchatskoe	In the pleistoseist area occurred rockfalls. The energy emitted in the source area appeared rather weak on surface and the very low attenuation testified of the deep location of the hypocenter (80-100 km).
1955	4	27	11	48	40.00	74.68	5	13	4.8			
1955	6	5	15	43	39.90	75.20	40	13	5.3			
1955	6	15	1	3	39.27	71.57	5	13.1	5			
1955	6	23	11	19	41.90	71.10	20	13.3	5			
1955	7	26	22	10	39.90	74.70	5	13.4	4.7			
1956	11	18	5	19	40.10	76.50	15	13	5			
1957	5	1	0	45	41.60	78.60	15	13	5			
1957	5	8	14	24	41.60	74.60	7	13	4.8	7	Kavakskoe	A strong shock reminding an explosion was felt. Men sitting on the land were tossed up in air. Stones were falling from ridges and rocks, debris-falls occurred.
1957	8	30	16	18	39.30	72.90	46	14	5.5			
1958	2	19	10	33	39.10	74.90	20	13	5.2			
1958	6	24	4	48	41.00	78.30	20	14	5.5			
1958	10	13	8	58	41.60	75.10	12	13	5.2	6-7	Sonkulskoe	An abrupt push and strong shaking was felt. Stones about a tractor size were falling from mountains. The rocks cracked, debris and rock falls occurred. Wooden houses were strongly shaking, creaking and lopsided. Clay houses were cracking, plaster was falling off.
1959	6	27	19	11	42.00	79.98	25	14.5	5.7			
1959	7	12	19	21	41.70	72.80	14	12.9	5	6		Booming was heard. One push from the south and two vertical pushes took place. Cracks in some houses were formed. Hanging subjects were waving.
1959	9	13	19	15	39.50	74.40	5	13.1	5			
1959	9	21	12	19	40.70	75.00	15	13	5			
1959	10	24	23	40	41.63	70.00	13	14	5.7	7-8	Brichmulinskoe	It started with a strong vertical shock, followed byt strong shaking. At the same time a loud boom was heard reminding the sound of a flying helicopter or a tank movement. There were strong destructions in the settlement Brichmulla. Stoves cracked and departed from walls, floor shrank down.
1960	3	3	14	15	40.60	78.00	5	13	4.9			
1960	10	18	10	26	42.30	78.40	17	12.8	4.9	6	Prjevalskoe	A strong push and underground boom was felt, cracks were formed. Chimneys fell

												from some roofs. The tableware jingled, floors and doors creaked.
1961	4	1	15	18	39.95	77.82	20	15.5	6.6			
1961	4	4	1	17	39.90	74.40	5	13	4.8			
1961	4	4	9	46	39.95	77.70	15	15	6.4			
1961	4	5	6	47	40.00	77.50	20	13	5.1			
1961	4	6	1	33	40.00	78.00	20	13.6	5.5			
1961	4	7	21	17	39.65	72.88	26	13.9	5.5	6-7	Alayskoe	A strong vertical push with a boom was felt in the zone of Sary-Mogol settlement of intensity 6 MSK64. There were cracks in all houses.
1961	4	13	16	34	39.75	77.63	30	15.6	6.6	9	Pychanskoe	
1961	7	5	6	34	39.90	77.50	5	13	5			
1961	12	30	7	8	39.80	77.50	20	13.3	5.2			
1962	7	1	21	23	39.87	75.10	25	13	5.2			
1962	8	3	11	4	40.92	73.12	20	14	5.5	7-8	Markayskoe	Numerous falls of sandstones and conglomerates blocked the footpath and part of the river. Stones were falling from slopes of mountains. Walls fell in many houses, in some of them through cracks appeared. nderground boom had only heard in the mine. From one of the wells water disappeared.
1962	11	26	5	29	39.80	77.20	20	14	5.6			
1963	8	29	8	53	39.67	74.18	40	15.9	6.4			
1963	10	19	6	46	41.23	71.62	8	12.6	4.7	6-7	Tergauchinskoe	
1964	2	13	13	53	39.45	72.97	44	13.1	5.1			
1964	6	27	2	28	40.52	77.23	5	13	5			
1965	3	17	13	14	40.85	69.37	12	13	5.5	7	Koshtepinskoe	A strong vertical push accompanied by a boom was felt. In many houses glasses were broken. Parts of walls broke apart and fell down.
1965	5	4	8	34	41.82	79.37	23	15	5.8			
1965	9	25	15	47	41.53	75.03	25	13	5.1	6-7	Sonkulskoe	Boom, crash then two pushes were felt, small rockfalls occurred. In buildings, doors, boxes moved away from walls. There was a feeling as if "the ground was leaving from under feet".
1965	10	18	10	21	41.97	77.55	15	13	5	6-7	Barskaunskoe	The push with a boom was felt. All old houses cracked, chimneys fell down, heavy damage of beaten cobwork houses occurred.
1965	12	7	14	50	39.30	73.10	25	13	4.8			
1966	1	28	8	52	39.30	73.00	5	13.4	5			
1966	4	25	23	22	41.35	69.27	8	13.3	5.2	8	Tashkentskoe	One-stor bten cobwork houses and those made of sun-dried bricks were completely destroyed. In 2- 3-floor houses through cracks were formed.
1966	4	30	13	41	41.10	71.80	20	13.6	5	6-7	Balykchinskoe	Buildings were shaken, boom was heard.
1966	5	12	11	42	40.20	78.40	20	13	5			
1966	7	16	19	43	40.93	74.00	15	13	5			
1967	1	5	10	7	39.32	72.62	30	13.6	5.2			
1967	2	2	7	37	39.80	75.10	80	13.7	5.7			
1967	5	11	14	50	39.50	73.70	28	15	6.3			

1967	5	14	9	0	39.33	73.75	20	13.6	5.2			
1967	5	18	9	0	39.32	73.75	20	14	5.2			
1967	5	18	11	31	40.62	70.75	25	12	4.6	6-7	Supetauskoe	A loud boom was heard. Cracks occurred in houses. Water rose in the river, then fell down and waves appeared.
1967	5	20	8	47	39.40	72.70	5	13.3	4.5			
1967	9	28	2	53	42.10	79.67	18	13.5	5.1	6-7	Sarydjazskoe	The earthquake epicenter was located in a remote, weakly populated district. Pushes were sharp. Rockfalls and avalanches were observed along the glacier.
1967	11	30	11	44	43.00	77.43	10	12.2	4.5	6	Chilikskoe	In the head of the Chilik river, 3 vertical pushes with a boom and a crash were felt. Wooden houses creaked.
1968	3	20	7	54	41.15	75.07	17	12.6	4.9	5-6	Durbeljinskoe	Strong pushes were felt in buildings and outside, glasses and dishes were jingling, things were falling from shelves.
1968	9	12	15	36	40.33	77.83	5	13	5			
1969	2	11	22	8	41.47	79.32	25	15	6.6	9	Kokshaalskoe	
1969	8	28	3	58	39.10	73.40	10	14	5.7			
1969	9	14	14	46	39.48	75.00	25	14	5.5			
1969	9	14	16	15	39.52	75.00	15	14.8	5.6			
1970	1	19	0	31	41.05	69.22	25	12.1	4.4	7	Pskentskoe	
1970	3	29	3	48	39.68	75.28	34	13	5			
1970	6	5	4	53	42.52	78.73	15	15.6	6.8	8-9	Sarykamyshskoe	Numerous disruptions, cracks up to 1,5m wide, multiple rockfalls and landslides occurred. In some places big trees were grubbed out, tops of many of them were broken. In many houses, roofs fell down, walls and corners of buildings were broken. The earthquake was preceded by a foreshock; so, people had run outside and 2 men were killed.
1970	7	29	5	50	40.05	77.77	13	14	5.9			
1970	9	14	9	43	39.90	77.20	20	13.4	5.2			
1971	3	23	9	52	41.43	79.25	20	14.5	6			
1971	3	23	20	47	41.32	79.37	20	15	6.1	8	Kokshaalskoe	
1971	3	24	21	1	41.42	79.42	58	13.2	5.1			
1971	5	10	14	51	42.90	71.33	20	13.8	5.7	7	Djambulskoe	The boom similar to thunder was heard. Heavy things fell down in houses. Constructions made of air bricks were damaged, in brick houses through cracks appeared.
1971	6	15	7	39	41.43	79.33	42	13.7	5.2			
1971	6	15	22	4	41.52	79.28	12	14.2	5.8			
1971	6	16	0	58	41.52	79.23	29	13.2	5.6			
1971	6	19	17	23	41.62	79.23	12	13.5	5.3			
1971	7	24	11	43	39.40	73.00	19	13.3	5.1			
1971	7	26	1	48	40.02	77.32	15	14.4	6.7			
1971	10	28	13	30	41.95	72.25	17	14	5.6	6-7	Chankalskoe	In reinforced concrete and frame houses cracks appeared in the plaster. The water level in wells had changed.
1971	12	27	20	59	39.98	73.02	55	13.4	5.2			
1972	1	15	20	21	40.33	79.07	15	14.4	6.2			

1972	3	17	9	17	40.28	69.65	20	13.5	5	6-7	Leninabadskoe	A boom reminding an explosion was heard. In brick buildings through cracks appeared. A landslide occurred on one of the slopes.
1972	11	16	4	57	43.30	81.00	5	13	5			
1972	12	3	8	54	39.42	75.13		13	5.2			
1973	1	3	14	31	39.15	71.83	10	13.4	5.2			
1973	6	10	16	8	39.55	74.83		13	5			
1973	6	27	13	11	40.68	79.22		13	4.5			
1974	1	4	9	27	40.78	77.62		14.2	5.1			
1974	1	22	6	8	40.20	71.70	24	12.7	5	7	Kadamjaiskoe	Three vertical pushes with a boom were heard. In buildings made of sun-dried bricks through cracks appeared, in reinforced concrete buildings cracks in plaster appeared.
1974	2	20	11	43	40.70	73.37	20	13.2	4.9	6-7	Kurshabskoe	A boom similar to rockfall was heard, big trees were shaking. There were through cracks in houses made of sun-dried bricks and breaking off of plaster in buildings made of burnt bricks.
1974	7	2	16	41	42.23	75.32	15	12.9	4.9	6-7	Kochkorskoe	
1974	7	23	7	11	39.30	72.30	15	13	4.7			
1974	8	11	1	13	39.23	73.83	7	16.6	7.3	7-8	Markansuiskoe	Rockfalls occurred. From some mountain tops ice and snow caps fell down. Everywhere snow avalanches and renewal of some old ruptures were observed. Bright luminescence in mountains was seen, a boom reminding a cannonade was felt. Tourists on Korjenevski glacier observed soil slides.
1974	8	11	2	37	39.30	73.40		13	4.9			
1974	8	11	5	12	39.30	73.60	15	13.6	5.2			
1974	8	11	5	19	39.20	73.50	15	13.6	5.3			
1974	8	11	5	23	39.30	73.80	15	13.8	5.5			
1974	8	11	5	33	39.30	73.60	61	13	4.6			
1974	8	11	7	2	39.40	73.60	15	13.6	5.3			
1974	8	11	9	8	39.10	73.70	15	13	5			
1974	8	11	20	5	39.60	73.70	15	14.4	5.8			
1974	8	11	21	21	39.30	73.60	15	14.7	6.3			
1974	8	12	14	14	39.60	73.80	5	13	4.9			
1974	8	12	21	17	39.40	73.70	20	13.1	5			
1974	8	27	12	56	39.58	73.78	15	14.9	6			
1974	8	27	17	33	39.40	73.80	15	13.4	5.1			
1974	9	3	19	41	39.50	73.70	15	13.7	5			
1974	9	29	15	51	40.45	77.85	26	13.4	5.5			
1975	2	12	13	34	43.30	78.80	10	13	5.1	6	Toruaigyrskoe	A shock accompanied by a boom was felt. Through cracks appeared in houses made of rubble concrete as well as cracks in the plaster in framehouses. Rockfalls and landslides occurred in the mountains.
1975	5	26	18	1	40.40	77.93	35	13	5			
1975	9	9	18	32	40.27	78.48	20	13.6	5.5			
1976	8	3	7	50	40.88	77.88	18	13	5.3			
1976	11	11	2	20	39.50	74.00		13.1	5			

1977	1	31	14	26	40.08	70.87	20	15.5	6.3	7-8	Isfara-Batkenskoe	A boom and a vertical push with horizontal fluctuations and luminescence above the horizon were observed. Almost all the houses were damaged in the epicentral zone, many houses made of "guwalyak" broke down completely. Cracks with a width up to 1 m appeared on the ground.
1977	6	3	1	5	40.00	71.82	15	14.2	5.2			
1977	8	3	7	50	40.88	77.88		13	5.2			
1977	12	6	10	52	41.57	69.70	15	13.2	4.9	7	Tavaksaiskoe	
1977	12	18	16	47	39.90	77.42		14.9	5.9			
1977	12	20	7	27	39.82	69.32	10	13	5			
1978	3	12	8	29	41.90	80.00	40	13.9	5.3			
1978	3	24	21	5	42.87	78.58	20	15.6	7	8-9	Jalanash-Tupskoe	Rockfalls and snow avalanches appeared in the pleistoseist area. Some boulders moved almost on a horizontal place. Through cracks and partial inbreaks appeared in houses made of sun-dried bricks. In the ground cracks up to 10 cm width appeared.
1978	10	8	14	20	39.50	74.80	50	15	6.1			
1978	11	1	19	48	39.40	72.60	30	16	6.8	8-9	Daraut-Kurganskoe	In the pleistoseist zone (low populated district) there were seismodislocations, and small rockfalls. Debris flows and craters of a diameter of 3-25m appeared due to adit inbreaks in a glacier. Plenty of aftershocks occurred. Settlements and sheepyards were damaged.
1978	11	1	19	59	39.38	72.58	5	13.3	5.2			
1978	11	2	6	24	39.43	72.50	25	14	5.6			
1978	11	2	11	15	39.40	72.38	10	13.6	5.4			
1978	11	8	0	57	39.40	72.47	20	13.8	5.2			
1978	12	15	5	34	39.53	74.13		13.4	5.2			
1979	4	6	18	30	41.97	77.43		13.5	5	6	Barskoonskoe	A loud boom reminding the sound of an automobile driving uphill was heard. Snow avalanches occurred. Hanging subjects were shaking in houses, in clay houses threadlike cracks appeared.
1979	5	9	18	41	42.10	79.10		13.1	4.8			
1980	1	13	5	54	39.43	72.80	10	13.4	5			
1980	7	5	20	25	41.92	77.50	20	13.8	5.6	6-7	Kadjisaiskoe	A horizontal push took place, and a boom reminding the sound of a heavy loaded automobile was heard. Hanging subjects were shaking in houses, thin cracks in adobe houses appeared.
1980	7	31	19	3	39.60	75.20	44	13.1	5.3			
1980	12	6	2	45	40.00	78.35	26	13	5.3			
1980	12	11	14	35	41.33	69.05	10	13.5	5.3	8	Nazarbekskoe	A loud underground boom and a luminescence of the atmosphere accompanied the main shock. Series of aftershocks followed. In many houses made of sun-dried bricks through cracks appeared, parts of walls collapsed, some houses crashed. Numerous cracks of 3cm width appeared on loessial ground.
1981	3	3	5	52	39.32	72.60	15	13.8	5.4			
1982	5	6	15	42	40.17	71.50	20	14.4	5.8			

1982	12	31	19	46	42.87	77.37	15	13.6	5.2	6-7	Cholponatinskoe	
1983	2	13	1	40	40.23	75.23	20	16.1	6.6	8	Kyzyl-Suiskoe	
1983	2	13	1	52	40.08	75.13		13.6	5.7			
1983	3	30	6	46	40.05	75.38	32	13.4	5.1			
1983	3	30	16	13	40.10	75.27	30	13.1	5			
1983	4	5	6	50	40.13	75.13	28	14.6	6			
1983	6	5	10	39	39.22	75.82	23	13	5			
1983	8	20	17	15	39.47	73.70	5	13.1	5			
1983	8	25	11	5	39.18	74.17	32	13.5	5			
1983	12	16	13	15	39.38	72.92	15	14.5	6.1	7-8	Alaiskoe	There were two pleistoseist areas. One of them was at the foothills of peaks where snow avalanches occured. Another area included settlements. Some houses made of sun-dried bricks cracked, in other houses parts of walls collapsed. In the zone of intensity 6 MSK64, through cracks appeared in houses. In one of the springs water disappeared, in the other one the water level fell down by half a meter.
1983	12	21	19	30	42.07	77.45	15	12.5	4.1	6	Kadjisaiskoe	A boom was heard. Thin cracks appeared in the plaster in some buildings made of burnt brick.
1984	2	2	15	14	42.87	71.40	15	12.6	5	6	Djambulskoe	A vertical push with a boom was felt. In some houses through cracks appeared and walls fell away from the main part of buildings. In Dzhambul all the houses made of adobe bricks were damaged and subsided. Only thin cracks in plaster appeared in the houses constructed using cross-ties.
1984	2	17	23	26	40.85	71.02	25	14	5.5	8	Papskoe	Deep cracks appeared in framehouses. Within the zone of intensity 6-7 MSK64 small cracks appeared in cobwork houses. Numerous foreshocks preceded and aftershocks followed the earthquake.
1984	10	26	20	22	39.20	71.23	15	14.5	6.3			
1985	4	27	4	49	40.90	71.10	20	13	5.1			
1985	8	23	12	41	39.43	75.48	20	16.5	7	9	Kashgarskoe	
1985	9	11	20	45	39.43	75.45	35	14.8	6.6			
1985	9	11	21	8	39.43	75.13	28	13	5			
1985	9	11	21	9	39.50	75.50	5	13	5			
1985	10	13	15	59	40.28	69.80	10	14.6	6	8	Kairakkumskoe	Sharp, strong vertical pushes and horizontal vibrations accompanied by a boom were felt after. The better constructions and the road-way were damaged, the dam and coast-proteckting structures were deformed. There were numerous landslides, rockfalls, cracks and sand volcanoes. In buildings made of burnt brick without antiseismic strengthening cracks up to 15 cm wide appeared, breaking of inner walls, sometimes damage of basements and the beddings were observed.
1986	4	25	16	12	40.18	77.28	25	14.2	5.4			
1986	5	20	6	2	41.00	78.78	20	13	5.2			
1987	1	24	8	9	41.43	79.27	13	14.7	6.1			
1987	1	24	8	13	41.52	79.17	5	13.6	4.3			
1987	3	26	11	56	41.82	69.95	5	13.1	4.7	7	Altyntubinskoe	
1987	4	30	5	17	39.82	74.68	25	14.5	5.7			

1988	1	6	15	31	39.72	75.52	5	13.1	5.1			
1988	3	13	13	48	42.08	75.47	7	12.6	4.2	6	Kochkorskoe	In some houses made of sun-dried bricks, cracks in plaster and its flaking off were observed. New houses were not damaged.
1988	6	17	13	30	42.93	77.40	21	12.9	4.9	6-7	Cholponatinskoe	In old houses made of sun-dried brick cracks and breaking of plaster, destruction of chimneys were observed.
1988	8	12	18	58	39.80	74.37	31	13.3	5.2			
1988	9	23	4	46	39.68	74.45	15	13	4.9			
1988	12	14	11	45	39.27	71.80	5	13.3	5.2			
1988	12	21	8	21	41.23	72.32	10	12.9	4.8	6	Shamaldysaiskoe	Before the earthquake, a boom was heard. Hanging subjects were oscillating. In 3 storey buildings cracks appeared and plaster crumbled.
1990	3	29	16	19	39.43	73.25	21	13.7	5.3			
1990	4	17	1	59	39.45	74.55	29	15	6			
1990	11	3	16	39	39.15	71.45	10	13.8	5.2			
1990	11	12	12	28	42.98	77.92	15	15	6.4	8	Baisoorunskoe	In the zone of intensity 8 MSK64 the log-house moved from the basement by 10cm in one corner and 3cm in the other, the house warped, the stove was destroyed and shingles were cut off.
1991	2	25	14	30	40.18	79.32		14.2	6.1			
1991	3	7	1	13	40.00	75.65		13.4	5.2			
1991	4	26	22	23	39.08	70.98		13.3	5.2			
1991	10	31	2	29	40.17	72.87	15	13.6	5.3			
1992	5	15	8	7	41.10	72.42	10	15	6.3	8	Kochkoratinskoe	The largest damage took place in houses made of adobe and sun-dried brick houses. Many of them were destroyed completely, in the some houses 1-2 walls fell off. Cracks appeared in the ground. Next to Kara-Djigach stream, a subsidence crater with a diameter of 5m appeared. A tank with a capacity of 3000 l at the moment of earthquake was flipped up to 30 cm.
1992	8	19	2	4	42.07	73.63	20	17	7.5	9-10	Suusamyrskoe	The earthquake started with a loud underground boom reminding an explosion. The boom, noise, and crash were so strong, that the falling of domestic things, chimneys, stoves, collapsing walls and roofs of houses were not heard. The shaking of ground threw up people sitting on the ground, those who stood up could not keep on their feet. The ground was waving, water fountains up to 15m in height were observed in some places. "Shots" of rocks with a diameter of 0,5m occurred in some places. Some parts of the road subsided, some other parts were formed as waves. Massive rockfalls, landslides, debris flows, seismic breaks off and numerous cracks occurred. Uplift of an amplitude of 2,7m was formed.
1992	12	24	5	9	42.40	72.15		13.2	5.1			
1994	1	12	10	22	39.47	75.77		13.3	5.2			
1995	2	20	4	12	39.38	71.03	4	13.6	5.3			
1995	10	8	8	55	40.90	71.62	20	13.6	5.3			
1995	11	1	12	29	43.03	80.15		13.1	4.8			
1996	1	18	9	33	41.90	77.45	5	13.2	5			
1996	3	19	15		40.08	76.65		14.6	5.5			

1996	3	22	8	26	40.28	76.57		13.6	4.6			
1997	1	9	13	43	41.08	74.32	0	14.6				
1997	1	21	1	47	39.43	76.98		14.4	5.8			
1997	3	1	6	4	39.60	76.95		14.6				
1997	4	5	23	46	39.57	77.05		14.8				
1997	4	6	4	36	39.57	77.02		14.6				
1997	4	6	12	58	39.65	77.00		13.4				
1997	4	11	5	34	39.60	76.93		14.6				
1997	4	12	21	9	39.58	76.87		13.8				
1997	4	15	18	19	39.67	76.97		15				
1997	5	17	3	58	39.30	76.92		14.3				
1997	8	13	14	30	41.87	79.48		13				
1998	3	19	13	51	40.13	76.65		13.6				
1998	5	29	22	49	41.35	75.60		13.6				
1998	8	2	4	40	39.48	76.98		14.8				
1999	12	6	7	33	42.67	76.27	0	13	5.2			
2002	9	5	11	3	39.78	71.97	2	13	5.2			
2003	2	24	2	3	39.32	77.18		14.9	6.1			
2003	2	24	21	18	39.40	77.23		13.2				
2003	2	25	3	52	39.40	77.40		13.8	5.5			
2003	3	12	4	47	39.52	77.30		14.6	5.5			
2003	5	4	15	44	39.40	77.20		14.2	3.3			
2003	5	16	14	29	39.18	77.05		13	5.2			
2003	5	22	18	11	42.97	72.77		13.8	5.6			
2003	9	26	23	36	40.23	77.32		13.8	5.5			
2003	12	1	1	38	42.95	80.55		14.5	5.7			
2003	12	1	1	38	42.95	80.55		14.3	5.6			
2005	2	14	23	38	41.85	79.47	23	14.9	5.5			
2005	2	15	11	16	41.77	79.42	32	13.1	5			
2006	7	6	3	57	39.17	71.73		13.7	5			
2006	12	24	1	58	39.68	74.30		12.8	5			
2006	12	25	20	0	42.08	76.03	13	14.2	5.5			
2007	1	8	17	21	39.70	70.35		14.8	5.8			
2007	4	15	13	59	39.42	72.75	18	12.6	4.7			
2007	7	21	22	44	39.02	70.77		13.6	5.4			
2007	12	26	4	45	40.32	73.03	13	12.8	5.1			
2008	1	1	6	32	40.32	73.03	16	13.2	5.3			
2008	10	5	15	52	39.62	73.67	15	14.8	6.6	8	Nurinskoe	Nura settlement was destroyed complitely. 74 people were killed.

Annex 3.

The catalogue of most important landslides

№	Date	Site	Comments
1	15. 04. 2009	Aksy district, Raikomol village	Size makes 200000 м^3. 3 houses were crushed; 16 men were killed
2	Spring, 2009	Alamedin district, Near Chonkurchak	There was reactivation of old landslide. The size makes 6800000 м^3 . There was a threat for the houses and sheepyard
3	Spring, 2001	Boom gorge, "Gallery" plot of the rail way Bishkek-Rybachee	There was reactivation of an ancient landslide. There was a threat for the gallery and highway placed near gallery.
4	2004 – 2009	Djumgal district, Minkush village	Reactivation of ancient landslide occurred close to radioactive tailing. Displacement of ancient landslide separate blocks of size up to 1000000 м^3 happened.
5	2001-2009	Jail district, highway Bishkek-Osh	There was yearly activation. Threat of blockage and damage appeared for highway.
6	24. 04. 2004	Alay district, Kainama village	Size makes 2000000 м^3. 11 houses were crushed; 33 men were killed.
7	17. 04. 2004	Karasu district, Kara-Sogot village	Size makes 63000 м^3 . 5 men were killed
8	20. 04 2003	Uzgen district, Kara-Taryk village	Size makes 1500000 м$^{3.}$ 13 houses were crushed; 38 men were killed.
9	Spring, 2002	Alamedin district, Ortosay village	Treat for houses in Ortosay village created.
10	27. 04.2000	Kara-Kuldja district, Gulcha village	Reactivation of an old landslide of size 14000000 м^3 happened. 148 houses and the province's Center communication were crushed.
11	27.05.1999	Osh province, Sary-Bulak village	Size makes 4500000 м$^{3.}$ 9 houses were crushed.
12	26.06.1998	Kara-Kuldja district, Budalyk village	Reactivation of an ancient landslide of size 2000000 м^3 happened. 32 houses and schoolhouse were damaged.
13	4.07.1994	Alay district, Arto-Suu village	Size makes 5000000 м^3. 28 houses were crushed.
14	26.03.1994	Uzgen district, Komsomol village	Size makes 500000 м^3. 26 men were killed.
15	8.08.1994	Uzgen district, Tosoy village	Size makes 1000000 м^3. 15 houses were crushed in Zerger river valley; 50 men were killed.
16	Spring, 1994	Osh, Djala-Abad and Batken provinces	1000 new landslides originated due to doubled precipitation during autumn and winter.
17	4.07.1992	Mailisuu city	Landslide of size 900000 м^3 dammed the river Mailisuu. It resulted in origination of a basin which flooded 4 two-story buildings and crushed the city's communication.
18	1988	Osh and Djalal-Abad provinces	110 new landslides originated, 12 among them were large (of size 500000-2000000 м^3).
19	April, 1988	Suzak district, Kainar village	Landslide 'Kainar' of size 5000000 м^3 traveled 9,5 km along the valley and crushed 3 houses.

20	March, 1988	Kara-Kuldja district, Altynkrok village	Two landslides of size 1500000 and 2000000 $м^3$ respectively originated. 8 houses and sheepyard were crushed; shepherd and flock of sheep were killed.
21	April, 1979	Alay, Kara-Kuldja and Uzgen districts	After continuous drizzling rain 263 landslides occurred during 4 days.
22	May, 1973	Suzak district, Oloke-Kolot village	Landslide 'Oloke-Kolot' of size 5000000 $м^3$ dammed the river Kugart. There was no damage.
23	September, 1973	Suzak district, Kaldarbay village	Landslide 'Kaldarbay" of size 2500000 $м^3$ extended on a distance in 1 km. One man was killed.
24	November,1976	Kok-Jangak city	Landslide "Sary-Bulak" (Kok-Jangak) of size 4500000 $м^3$ extended along a valley of streamlet on a distance of 4.5 km. 180 houses were crushed; 2 men were killed.
25	29. 02.1988	Mailisuu city	Landslide "Tectonic" of size 500000 $м^3$ dammed the river; the road and city's communication were crushed.
26	February, 988	Osh province, Tokubay village	Size makes 1500000 $м^3$. There were considerable human toll and material losses.
27	17.03.1969	Maylisuu city, Sennoy side street	Size makes 500000 $м^3$. 44 houses were crushed.
28	April, 1969	Bazar-Korgon district, Beshbadam village	Size makes 6000000 $м^3$. Length of the landslide body makes 4.5 km. There were considerable human toll and material losses.
29	1911	Issyk-Kul district, Ananevo village	Landslide of size more then 7000000 $м^3$ was induced by 1911 year M=8.3 Kemin earthquake.
30	1885	Sokuluk district, Belogorka village	Landslide of size more then 10000000 $м^3$ was induced by 1885 year M=6.9 Belovodsk earthquake.

Annex 4

Seismic stations on the territory of Kyrgyzstan:

Analog stations of the Institute of Seismology, National Academy of Sciences of Kyrgyz Republic

№	Name	COD	COORDINATES		H, м	ACTION PERIOD		EQUIPMENT
			φ°N	λ°E		from	till	
1	Ala-Archa	AAR	42,637	74,495	1680	16-V-1983	2003	СКМ, СКД
2	Ananievo	ANV	42,786	77,666	1860	20-IV-1971	-	СКМ, СКД, СМТР, СБМ
3	Aral	ARL	41,846	74,324	1640	1-V-1`960	-	СКМ, СКД
4	Arkit	ARK	41,799	71,967	1280	X-1969	-	СКМ, СМТР, СКД*
5	Arslanbob	ARS	41,323	72,982	1510	VIII-1970	-	СКМ, СМТР
6	Akkia	AKK	41,608	72,682	960	1-I-1983	-	СКМ
7	Alaiku	AKU	40,542	73,655	1940	1987	-	СКМ
8	Batken	BTK	40,057	70,820	1020	XII-1977	-	СКМ, СБМ, СКД*
9	Belogorka	BLG	42,625	74,236	1450	7-XI-77	1996	СКМ, СКД
10	Boom	BOM	42,485	75,943	1800	1-VI-69	-	СКМ
11	Daraut-Kurgan	DRK	39,481	71,805	2320	1-X-1985	-	СКМ, СКД
12	Djergalan	DJR	42,610	79,022	2120	25-II-81	1996	СКМ, СКД
13	Kadji-Sai	KDJ	42,123	77,188	1880	XII-61	-	СКМ, СКД, СБМ
14	Kara-Sai	KRS	41,578	77,903	3360	26-VII-81	1994	СКМ, СКД
15	Ken-Suu	KNS	42,324	79,245	3018	21-VI-81	2009	СКМ
16	Kirovka	KRV	42,658	71,608	980	1-XI-81	2001	СКМ, СКД
17	Kyzyl-Djar	KZD	41,278	72,247	660	3-VII-1976	-	СКМ
18	Kungei	KNG	42,667	76,920	2050	VIII-86	1999	СКМ
19	Manas	MNS	42,487	72,504	1515	V-1973	-	СКМ, СКД
20	Naryn	NRN	41,417	75,967	2120	1950	-	СКМ, СМТР, СБМ, СКД*
22	Osh	OSH	40,524	72,785	980	1977	-	СКМ, СБМ, СКД*
23	Prjevalsk	PRJ	42,484	78,400	1835	VIII-1950	-	СКМ, СМТР, СКД*
24	Salam-Alik	SLA	40,871	73,804	1710	24-X-80	-	СКМ
25	Saruu	SAR	42,221	77,976	2060	6-IV-1981	1994	СКМ, СКД
26	Sopu-Korgon	SFK	40,013	73,503	2160	VII-1973	-	СКМ, СМТР, СБМ, СКД*
27	Terek-Sai	TRS	41,463	71,171	1640	8-VII-1976	-	СКМ
28	Terskei	TRK	42,064	76,571	2200	1986		СКМ, СКД
29	Toktogul	TKL	41,983	72,87	1320	1-VI-1981	-	СКМ
30	Frunze (Bishkek)	FRN (BIS)	42,833	74,617	830	1927	-	СКМ, СМТР, СБМ , СКД*
31	Chauway	CHV	40,145	72,211	2120	1-VII-1978	-	СКМ
32	Chumysh	CHM	42,992	74,754	655	16-XI-1977	2002	СКМ, СКД
33	Shaty	SHT	42,775	78,375	2170	15-VII-84	1992	СКМ
34	Erkin-Sai	ERK	42,668	73,786	1180	1-VI-71	-	СКМ, СКД, СМТР, СБМ
35	Yurievka	URV	42,689	75,052	1175	15-VIII-78	2001	СКМ, СКД

* From 1995 only these stations continued to use СКД seismograph

Digital stations of the Institute of Seismology, National Academy of Sciences of Kyrgyz Republic (KRNET)

№	Name	COD	COORDINATES		H, м	ACTION PERIOD		EQUIPMENT
			φ°N	λ°E		from	till	
1.	Bishkek	FRU	42,833	74,617	830	11.2007	-	CMG-3ESP + DM24
2.	Erkisay	EKS	42,669	73,785	1180	11.2007	-	CMG-3ESP + DM24
3.	Naryn	NRN	41,422	75,970	2120	06.2008	-	CMG-3ESP + DM24
4.	Ananievo	ANVS	42,786	77,667	1860	11.2007	-	CMG-3ESP + DM24
5.	Aral	ARLS	41,854	74,329	1540	07.2008	-	CMG-3ESP + DM24
6.	Osh	OHH	40,524	72,785	700	03.2008	-	CMG-3ESP + DM24
7.	Arkit	ARK	41,800	71,967	1420	03.2008	-	CMG-3ESP + DM24
8.	Salom-Alik	SALK	40,883	73,821	1672	03.2008	-	CMG-3ESP + DM24
9.	Batken	BTK	40,057	70,818	980	07.2009	-	CMG-3ESP + DM24

Digital stations of Consortium of USA Universities (KNET),

№	Name	COD	COORDINATES		H, м	ACTION PERIOD		EQUIPMENT
			φ°N	λ°E		from	till	
1	Ala-Archa	AAK	42,637	74,495	1680	1991	-	STS-2 + REF TEK 72-08
2	Almaly-Ashu	AML	42,13	73,677	3400	1991	-	STS-2 + REF TEK 72-08
3	Chumysh	CHM	42,999	74,751	655	1991	-	STS-2 + REF TEK 72-08
4	Erkin-Say	EKS	42,661	73,777	1310	1991	-	STS-2 + REF TEK 72-08
5	Karagay-Bulak	KBK	42,656	74,948	1744	1991	-	STS-2 + REF TEK 72-08
6	Kyzart	KZA	42,078	75,250	3520	1991	-	STS-2 + REF TEK 72-08
7	Tokmok	TKM	42,920	75,597	2020	1991	-	STS-2 + REF TEK 72-08
8	Uchtor	UCH	42,227	74,513	3840	1991	-	STS-2 + REF TEK 72-08
9	Ulakhol	ULH	42,229	76,225	2040	1991	-	STS-2 + REF TEK 72-08
10	Uspenovka	USP	43,267	74,500	740	1991	-	STS-2 + REF TEK 72-08

Digital stations of Central_Asian Institute for Apply Geosciences, real-time mode

№	Name	COD	COORDINATES		H, м	ACTION PERIOD		EQUIPMENT
			φ°N	λ°E		from	till	
1.	Aksay	ASAI	40,918	76,521	3023	25.07.2009		STS-2 + EDL PS6-24
2.	Taragay	TARA	41,729	77,805	3530	14.08.2008		STS-2 + EDL PS6-24
3.	Enelchek	ENEL	42,153	79,455	2741	22.09.2008		STS-2 + EDL PS6-24

Digital stations of Central_Asian monitoring net (CAREMON) , real-time mode

№	Name	COD	COORDINATES		H, м	ACTION PERIOD		EQUIPMENT
			φ°N	λ°E		from	till	
1.	Manas	MNS	42,487	72,504	1515	2009		CMG-3ESP, CMG-5T +CMG-DM24S6+CMG-EAM
2.	Sufi-Korgon	SFK	40,013	73,503	2160	2009		CMG-3ESP, CMG-5T +CMG-DM24S6+CMG-EAM

Annex 5

Summary of the MSK-64 Intensity scale (http://seismos-u.ifz.ru/building.htm)
Authors: S.V.Medvedev (USSR), G.Shponhojer (GDR), V.Karnik (Czechoslovakia)

- **Types of constructions and buildings without antiseismic amplifications:**
  Type A - buildings from adobe brick, rural constructions;
  Type B- brick, small-block, large-block buildings;
  Type C – reinforced concrete, panel, cut log huts.

- **Classification of damages:**

  1 degree - Weak: cracks in plaster;
  2 degree - Moderate: small cracks in walls, chimneys;
  3 degree - Heavy: deep cracks in walls, falling of chimneys;
  4 degree - Destructions: through cracks, crushing of parts of buildings and internal walls;
  5 degree - Collapses: full destruction of buildings;

The description of seismic effect:

I point - Imperceptible. It is registered by devices;
II point - hardly appreciable. Fluctuations are felt aonly by some people on the top floors of buildings;
III point - Weak earthquake. Is felt by some people; easy rocking of hanging subjects;
IV point – Appreciable shaking. Is felt inside buildings; rocking of hanging subjects;
V points - Awakening. It is felt inside buildings, on open sites, rocking of hanging subjects is observed, damage of 1-st degree to buildings of type A is possible;
VI points - Fright. The furniture falls, people are frightened and run out on the street; damage of 1-st degree is observed in some buildings of type B and many buildings of type A, single cases of landslides are possible;
VII points - Damage of buildings. Fright and panic. Many people are hardly kept on legs. Observation of damage of 1st degree in many buildings of type C, of 2nd degree in many buildings of type B and of 3rd degree in many buildings of type A. Landslides and cracks on roads are observed;
VIII points - Strong damage of buildings. Observation of damage of 2nd degree in many buildings of type C, of 3rd degree in many buildings of type Band of 4th degree in many buildings of type A. There are cases of breaks of joints of pipelines, landslides and cracks on roads;
IX points - Widespread damage of buildings. Observation of damage of 3rd degree of type C, of 5th dgree in many buildings of type A. There are cases of breaks of underground parts of pipelines, of curvature of rail ways;
X points - General destruction of buildings. Observation of damage of 4th degree in many buildings and 5th degree in some buildings of type C. There are buildings of type B with damage of 5-th degree, and the majority of buildings of type A damage are affected by 5-th degree damage. Severe damage of dams or even dam failure can occur as well as curvatures of underground pipelines. There are cracks in the ground from 0,2 up to 1,0 m. Big landslides may occur along the river banks;
XI points - Accident. Destruction of buildings of good quality, bridges, dams, rail ways, highways become unfit for use. Mountain slopes collapse;
XII points - Change of a relief. Strong damage, destructions of all types of buildings and underground constructions. Radical changes of the topographic surface.

What support is provided by the European Commission?

Starting from year 1992 the European Commission Humanitarian Aid Department (ECHO) provided financial support to millions of those suffered from natural calamities and man caused catastrophes beyond the bounds of the European Union. The assistance was directed to the most vulnerable population, independently of race, ethnic group, religion, gender, age, nationality and political views.

Increase of awareness among population is a part of mission of the department.

Cooperation with partners in field conditions.

To provide humanitarian aid the ECHO cooperates with more than 200 acting partners, including subdivisions of the UN, Red Cross and Crescent society, and nongovernmental organizations (NGOs).

The basic donor

The European Commission is one of the largest sources of provision humanitarian aid around the world. In 2008 this organization allocated 937 million Euro for humanitarian programs. This figure does not include, the support, provided separately by 27 the EU member-countries. The aid of the European Commission was directed to realization of projects in more than 70 countries. The given funds were earmarked for humanitarian aid provided as food, clothes, shelters, medicines, drinking water, urgent repairing work and mine clearing. The European Commission also finances activities for preparation and alleviation of negative circumstances in regions, subjected to risk of natural calamities.

International Strategy for Disaster Reduction

The secretariat of the International Strategy for Disaster Reduction provides coordination in the UN system for development of communities resistant to natural calamities, by means of rendering assistance in instruction on the important function of decreasing of natural disasters as an inalienable part of sustainable development. The aim of this program as an integral part of stable development is to decrease human, social, economical and ecological losses, which are the results of natural anthropogenic and ecological disasters. For this purpose, the ISDR UN promotes to the development of contacts, collaboration and coordination in taking measures to decrease natural disasters in social-economic and humanitarian spheres and in the sphere of development.

ISDR UNO functions as the international platform for decreasing the risk, promoting to development of complex strategies, exchange of information, planning instructive activities, publishing of articles, journals and other propaganda materials aimed to decreasing of natural disasters.

The head office of the ISDR in Geneva provides instructive programs via its regional departments in Latin America, Africa and Central Asia. The Central Asian instructive office is located in Dushanbe (Tadzhikistan). The aim of the Central Asian department of the ISDR UN is to render assistance in adaptation and acceptance of the leading principles of the Chiog Program of Activites (CPA) in the corresponding countries and to enhance coordination both on the regional and national level.