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Studying of Kinematics and Elements of Tension of Blocks of the Massif According to Field Geological Observations

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Abstract

The description of the received new results of field geological (tectonophysical) study of massifs of rocks is provided: tectonic jointing, explosive and folded deformations, mirrors of slidings, tectonic motions of blocks of breeds. Reconstruction of fields of tension according to geological data of the certain massif of the Chatkalo-Kurama mountain area (Tien-Shan)—a coastal zone of the Charvak reservoir and the Almalyk mining industrial region is executed. The multidirectional motions of blocks of rocks in the massif of a coastal zone of the Charvak reservoir connected with tectonic and technogenic factors are revealed. The scheme of kinematics and the intense deformed condition of blocks of the Almalyk district is received. Here the regional field of tension with horizontal and submeridional orientation of an axis of the main normal tension of compression at the inclined provision of two other axes are observed. The received results testify to opportunities field the tectonophysical of methods for obtaining important data on kinematics and dynamics of massifs of rocks, tectonic blocks, and features of their deformation. Such studying of the massif of rocks before the beginning and in the course of performance of work on objects of the national economy is important for the choice of design and optimum parameters of laying of excavations, control of a condition of their boards and walls, definition of strategy of safety of conducting mining operations and also seismic stability of constructions.

Keywords

Massif of Rocks, Structure, Kinematics, Dynamics, Tectonophysics, Deformations, Mirrors of Slidings, Field of Tension

1. Introduction

In massifs of rocks under the influence of a force field there are motions of blocks which in mining literature call "displacement" of blocks. These shifts leave a mark in exposures of breeds on the planes of shifts in the form of various furrows, lines, strokes, forming small and large surfaces—mirrors of slidings (slickensides). They have quite wide circulation and are used by geologists when studying character of shifts on the separate planes of explosive violations, cracks, etc. Such data on mirrors of slidings have been used by certain researchers (J. Angelier, France) for reconstruction of stress of sites of crust [1] [2] and also the Russian researchers [3] [4]. Such approach has been used also by authors of article for reconstruction of fields of tension of crust of certain areas of the Western Tien Shan. However, in difference from the previous researchers on the basis of use of these mirrors of sliding the method of kinematic reconstruction of late Cainozoic shifts of tectonic blocks has been developed (R. Umurzakov). This method has been used for studying of a tectodynamics of certain regions of Tien Shan, also the epicentral of areas of strong earthquakes [5] and also massifs of boards of large reservoirs, areas of development of mineral deposits. The analysis of the published literature shows that on sites of developments of mineral deposits the geodynamic approach based on the analysis of data of a relief [6] is used so far. Such approach can't give a real picture of geodynamics and stress of the massif on sites of the developed fields. For ensuring stability of boards of pits, more fundamental approach with identification and accounting of tectonic factors is necessary for safety of conducting mountain developments. The importance of these researches for mining is defined as well by use of knowledge of tension in the search purposes. For example, for forecasting of location of the hidden ore bodies, definition of spatial orientation of the weakened zones and orientation of hydrodynamic processes, a fluid current. These data matter also at researches of parametrical factors of stability of tunnels [7], for forecasting of formation of a karst [8], research of zones of breaks [9], etc.

All this defines relevance and the practical importance not only separate local definitions, but also identification of regional features of the field of tension that is a subject of the special scientific direction in geotectonics and geodynamics—"tectonodynamics" [10] [11].

The description of the received new results of field study of tectonic jointing, other types of deformations, tectonic motions of blocks of rocks, reconstruction of fields of tension according to field geological data on the example of the certain massif of an orogen of Tien Shan (Chatkal-Kurama mountain area) is provided in this article.

2. Methodology and the Used Material

When studying kinematics of blocks of rocks data on shifts on mirrors of slidings (slickensides) were used. Receptions of the description and identification of useful information on mirrors of sliding are in details described in educational

geological literature. About opportunities of use of these mirrors of sliding on local points of observations for reconstruction of tension are described in works [1] [2] [3] [4] [5]. For reconstruction of kinematic motions of blocks the "technique of kinematic reconstruction of shifts of blocks" [12] developed by the author of the present article is used. It consists in definition of the general component of a motion for all studied block according to local data of separate points of observations. The technique allows studying features of kinematics of tectonic blocks of massifs of rocks of the bases of reservoirs, boards of pits and vicinities of excavations and also for the purpose of study of elements of geodynamics and a seism geodynamics of certain areas. Possibilities of use of a technique when determining the mechanism of the centers of earthquakes were discussed by us in work [5].

As the main material for definition of kinematics of blocks serve measurements of parameters of shifts (slickensides) in local points. In each point of observation the quantity is from 6 - 12 before measurements. Local points are grouped in tectonic blocks which are defined on the basis of geological inspection of the site. Features of section of massifs of rocks are studied by larger explosive violations, zones of breaks. On the basis of local these points the total component of the direction of a motion of the block is defined. For this block definition of axes of the main normal tension is carried out.

3. Results and Discussion

3.1. Studying of Kinematics and Dynamics of Blocks near a Reservoir

When study behavior of the massif of rocks of the basis of a dam in a coastal part of the Charvak reservoir (Uzbekistan, the Tashkent region) it has been established that separate blocks test multidirectional shifts. It is necessary to tell that study of deformation processes of boards of reservoirs has special relevance. It is connected, first of all, with the solution of tasks of ensuring geoecological safety. The Charvak reservoir is the largest in Uzbekistan. Water volume at the maximum filling can reach about 2 billion cubic meters. The bowl of a reservoir is dated for the Burchmulla hollow delineated by slopes of Ugam, Pskem, Koksu and Chatkal ridges. The river Chirchiq originates from the dam. On the site near a reservoir the valley is crossed by three largest zones of explosive violations of northwest pro-deleting which have distinct expression in a relief. On all three zones the left moving is characteristic that is visible also on signs in a relief. Noted zones of breaks form a step relief with different hypsometric situation the terrace of surfaces (Q_2) that testifies to comparative youth of movements.

The fact that the right board of a reservoir, and in a middle part, and at a dam, is put by powerful thickness of cenozoic deposits attracts attention. They are presented in the lower part of a section sandstone-gravelite and a lime-sandstone pack the paleogene-neogene of deposits on which the loess and loamy deposits, conglomerates and pebble of quaternary age lie. The left (southern) board of a

reservoir with traces of some complications is composed by Paleozoic educations which in places are blocked by MZ-KZ-deposits. All bowl of a reservoir, being in a zone of the largest breaks of N-W of orientation named by Kumbel-Ugam it is cut by explosive violations of different orders. Presence of shift shifts on the Kumbel-Ugam zone of breaks has led to narrowing of the valley Chatkal in the form of a canyon where actually and the dam alignment is dated. Detailed studying of a structural and dynamic situation of a coastal zone of a reservoir on the basis of a complex of structural and geological observations with attraction of methods of a field tectonophysics has allowed revealing the following.

It is revealed and studied several ranks of disjunctive violations: jointing of rocks and their kinematic parameters; large cracks, secants exposure, and shifts on them; large linearly—the extended zones of crushing of the massif of rocks with elements of shift shifts in the basis of a dam, left (southern) and right (northern) reservoirs of coastal boards.

The basis of a dam is put by strongly shattered breeds of middle paleozoic age (the lower carbon fabrics, mainly limestone). Directly at a dam alignment, in the item of point of observation (p.o.) 1 (**Figure 1**), they lie down with the dip azimuth 0˚ angle 60˚. To the South they gradually change falling on dip Az 15˚ angle 65˚ and further, in the item of p.o. 2 on dip Az 20˚ angle 55˚. In places they strongly shattered and weathered and bedding elements don't manage to be determined by primary observations. Exposure cuts a set of cracks of the different sizes and spatial orientation.

In a northern board of a reservoir near a dam, the multidirectional planes of cracks of northeast and northwest strike, with the prevailing falling of their planes to the southwest and the northwest are observed (p.o. 5, 6, 7, 8). Near the p.o.5 there passes the zone of the large break having meridional strike. She is found on strong crushing of breeds and traces of a dry topping. The site is cut by also large zones of crushing and a bearing (**Table 1**).

The southern board of a canyon near a dam is characterized by prevalence of northeast and submeridional strike of the planes of cracks with falling of the planes to the West and the East.

Exposure is transverse by two large zones of crushing up to 0.3 - 0.5 m wide on dip Az 110˚ angle 65˚, 200˚/35˚ - 40˚. The planes of breaks are established visually. They prove in the form of several repeating series through 120 - 130

Table 1. The most widespread deformation elements of a northern shore.

Type	Dip azimuth/ angle
Large fissure	300˚/50˚, 290˚/60˚, 90˚/55˚, 80˚/50˚, 50˚/45˚, 120˚/50˚
Shatter zone (conditional plane)	p.o. 5 - 280˚/50˚, 130˚/65˚
Sliding mirrors on the large planes	p.o.5 - 305˚/45˚, 260˚/60˚ п.н.6 - 260˚/60˚, 215˚/75˚, 230˚/75˚
Dip fault	320˚ - 340˚/40˚ - 45˚
Upthrust	240˚ - 260˚/35˚ - 45˚

meters. The largest plane has elements: dip Az 90˚ angle 60˚. Width of a zone of crushing reaches 30 meters.

The zone of crushing of breeds alternates through 50 - 120 meters. Three such zones of crushing are found. Hypsometric lower the p.o. 5, is closer to a surface of the water, in the paleozoic breeds presented by lime sandstones small accurate dumping with left-side to shift components is observed (dip Az. 40˚ angle 65˚).

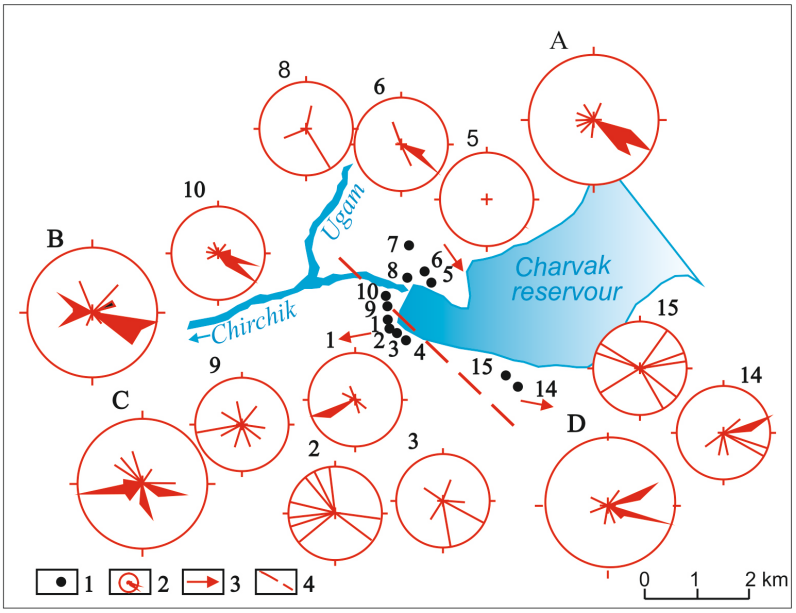
For studying of features of kinematics of boards of a reservoir measurements of elements of mirrors of sliding in local points have been executed and total values of "vectors" of motions for separate blocks are determined by the technique developed by the author [12]. It consists in definition of total "vector" (direction) of a motion of the tectonic block according to local data of separate points of observations. Such definitions are executed for the basis directly at the lower reach of a dam, a northern and southern board and also on some removal of the southern board of a reservoir. The obtained data are reflected in the **Figure 1**. Near a dam on the southern board of a canyon in the p.o. 1 and p.o. 2 "vectors" of shifts have orientation to the southwest. In the p.o. 1 orientation accurate, is localized strictly on an azimuth 250˚. In item 2 there is no such clearness, more along the subwidth axis and in N-W the sector is scattered. Approximately the same is found out in the item of 9 (**Figure 1**) though here the small confinedness of vectors to the subwidth direction and N-W to the sector is observed. In the item 3 prevails S-E the direction of vectors. The same picture is represented also in p.o. 5, 6, 8, 10.

In the dam basis at the lower reach cracks of S-W and N-W of falling prevail (the item of 9). In general the analysis of materials shows that near a dam strike of cracks tends north-east orientation when falling the planes to the southeast and the West (**Table 2**).

On the southern shore of a reservoir, in the p.o. 14 and 15, shifts of blocks are presented in the form of the upthrus-shifts and dip fault -shifts focused in the N-E, S-E direction. In item 15 dip fault -shifts prevail. The northern board near a dam is represented by p.o. 5 - 8, etc. In **Figure 1** it is visible that the northern site of the basis of a dam is displaced to the southeast. The southern site of the basis of a dam is displaced to the southwest. By detailed consideration it turns out that the line dividing multidirectional shifts has northwest strike, passes be-

Table 2. The most often met elements of deformations near a reservoir dam.

Type	Dip azimuth/anle
Large fissure	280˚ - 290˚, 335˚/55˚ - 60˚, 90˚.
Shatter zone (conditional plane)	280/50˚, 335˚/50˚, 60˚/60˚, 90˚/50˚
Sliding mirrors on the large planes	p.o. 9 - 10˚/70˚, 350˚/75˚ p.o.10 - 335˚/58˚, 335˚/55˚, 90˚/55˚
Dip fault	340˚/75˚, 335˚/60˚
Upthrust	p.o. 9 - 10˚/70˚, 350˚/75˚ p.o. 10 - 335˚/58˚, 335˚/55˚



Legend: 1—points of observations; 2—roses-charts of the directions of motions on mirrors of slidings: are designated by figures for local volumes of points of observations, the letters A, B, C, D have designated total charts for the respective sites: A—northern, B—basis at the lower reach, C—southern, D—southern, on some removal from a dam; 3—direction of a total motion of the respective site; 4—conditional line dividing diverse directional blocks of the massif of rocks.

Figure 1. Roses of the directions of shifts of mountain masses in local volumes of points of observations and certain sites of a coastal zone of the Charvak reservoir according to geological observations.

tween p.o. 9 and p.o. 10 at the dam basis, p.o 4 and p.o. 14 and p.o. 15 located to the east (Figure 1). Noted line corresponds to strike of one of a branch of a Kumbel-Ugam series of breaks.

Together with motions of the tectonic nature in certain sites motions of another, perhaps, technogenic character is found. Detailed study of exposures of rocks of points of observations allows noting distinct expressiveness of separate fresh furrows of slidings. For example, in the p.o. 9 surfaces of sliding (dip Az. 10˚ anle 70˚, 350/75˚) upthrust type differs from other surfaces markedly (which are characterized by prevalence of large waste surfaces—dip Az.340˚ angle 75˚, dip Az 335˚ angle 60˚). In the p.o. 10 increases in number of the planes of slidings with dip Az 335˚ angle 58˚, 335˚/55˚, 90˚/55˚. The value of visible shift on them reaches 80 sm that unambiguously is established on outlines and the drawing of wings. Education of the last (judging by outlines) belongs by the time of laying of a dam (1971-1972). These data testify in favor of presence of fresh shifts of blocks of rocks in a coastal part of a reservoir. And shifts of trailing wings are directed towards a reservoir. Such feature of distribution of the planes with mirrors of sliding allows to assume that the lower parts of blocks of rocks, being under pressure, are deformed, being kind of pressed through under overlying layers.

On the basis of field tectonophysics survey of boards of the Charvak water reservoir in a structure of an array of rocks of boards of a water reservoir the larg-

est zones of explosive violations which form a step relief with different hypsometric situation the terrace of surfaces (Q_2) that testifies to youth of movements are selected.

Closer to an alignment of a dam a series of the explosive violations which are logging in the Kumbel-Ugam zone is fixed. In general two directions of extension of cracking are characteristic of all region of a water reservoir: 1) azimuth of extension 10˚ - 20˚ (190˚ - 200˚); 2) azimuth of extension 80˚ - 85˚ (260˚ - 265˚). Falling of the planes on the southeast prevails and, it is slightly less, on the northwest. On a section near a dam 4 directions of orientation of the planes of cracks are marked: one, more expressed (Az. strike 10˚ - 15˚), also rub less expressed (Az. strike 80˚, 320˚, 90˚). Are selected with the largest planes of crushing near a dam such as dip Az 280˚angle 50˚, 335˚/50˚, 60˚/60˚, 90˚/50˚. On deleting from a dam on the southern board the width extension with various falling prevails.

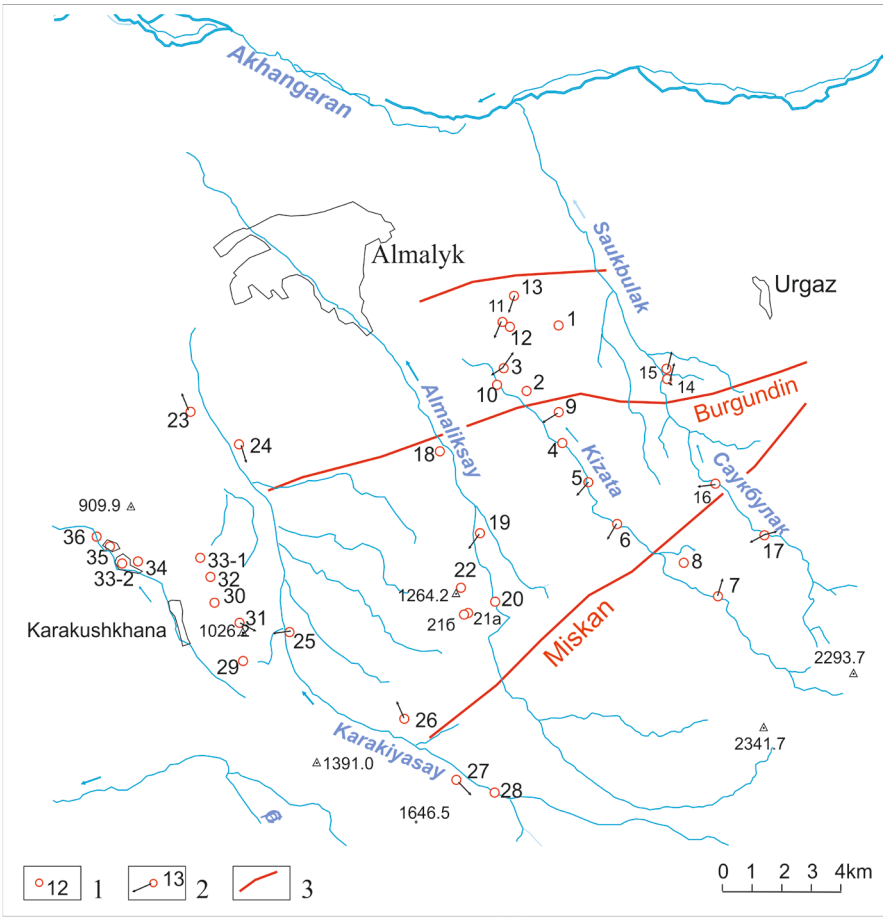
The following kinematic pattern is characteristic of boards of a reservoir. On a small section of the southern board of a canyon near a dam alignment vectors of offsets have orientation to the southwest. Northern board of a canyon experiences offsets preferentially to the southeast. In the southern board of a reservoir upthrus-shifts and dip fault-shifts have the direction on north-east and the southeast. On sections near a dam on northern and southern board of a canyon the increased frequency of occurrence of fresh mirrors of slidings is marked. Especially accurately they are shown at the lower reach of a dam on the planes: dip Az 335˚ angle 60˚, 90˚/55˚. In the majority of the planes of offset of trailing wings are directed towards a reservoir. The nature of residual deformations demonstrates that units of rocks of the lower part of a reservoir, are kind of pressed through under overlying breeds.

The analysis of all these data demonstrates that in the massif of rocks of boards of a reservoir there are active, rather young shifts of tectonic blocks. Connection of some of them with operation of a reservoir is supposed: the created external loading from a reservoir leads to redistribution of fields of tension of massifs of rocks of close located sites, or strengthening tectonic tension, or reducing them. It, in turn, strengthens deformation processes with the shift of tectonic blocks.

3.2. Studying of Kinematics and Dynamics of Blocks in the Mining Area

Similar researches have been conducted by us in the Almalyk mining district, on the square to the west from Urgaz (**Figure 2**). This area is in limits of northwest slopes of Kurama Ridge Tien Shan. Massifs of rocks are presented by paleozoic sedimentary, magmatic, volcanogenic and sedimentary formations of the lower and average carbon fabrics to a large extent, and in smaller—the lower perm. In a middle part of valleys of the rivers Almalyk Saukbulak in the width direction is stretched a large zone of the Burgundin break.

Closer to the southern part of the considered site in upper courses Kyzata and



Legend: 1—points of observations of mirrors of sliding in the local volume of the massif of rocks; 2—primary directions of motions of local volumes on sliding mirrors; 3—main braking structures.

Figure 2. The directions of motions in local points of observations of the massif of rocks in the Almalyk mining district (The Kurama ridge, Tien Shan).

Saukbulak is stretched in the northeast direction a zone of the Miskan break. These breaks of ancient laying, have played an important role in formation of an overall picture of a geological structure. Some researchers consider that they have no activity in the latest time [12]. However, signs of expressiveness of a zone in a relief and some other new data demonstrate modern activity of these zones.

In each point of observation from 5 - 6 to 20 measurements of furrows of slidings are executed. Calculations and constructions are executed by the technique described in works [13] [14]. For each point of observation summary roses charts of the directions of shifts of blocks of rocks which participated in the subsequent when determining the directions of total motions of large volumes, the corresponding tectonic blocks are received.

In the central and northern part of the site of the direction of motions in local volumes are mainly focused on the southwest, and less often to the west. Such picture is observed in valleys of the Saukbulak and Kyzata Rivers. In the southern part of the site, in Kyzata and Karakiya courses there are points of observa-

tions in which the direction of motions changes on northeast. They are dated for the southern wing of the Miskan break that allows considering about manifestation of multidirectional motions of wings. Signs of left-side shift are noted. In a northern and northeast part of the site several local volumes with change of the directions of motions also on northeast are found. These points are on a northern wing of the width Burgundin break that can demonstrate manifestation of right-hand shift of wings. The Burgundin break is border of different types of structures—the northern part of the site which is a little raised represents a horst—the anticlinal structure called Kalmakyr, southern lowered, represents a graben-syncline structure called Central [12].

On the basis of the obtained data on shifts on sliding mirrors for each local volume of the massif of rocks charts of orientations of axes of the main normal tension have been constructed.

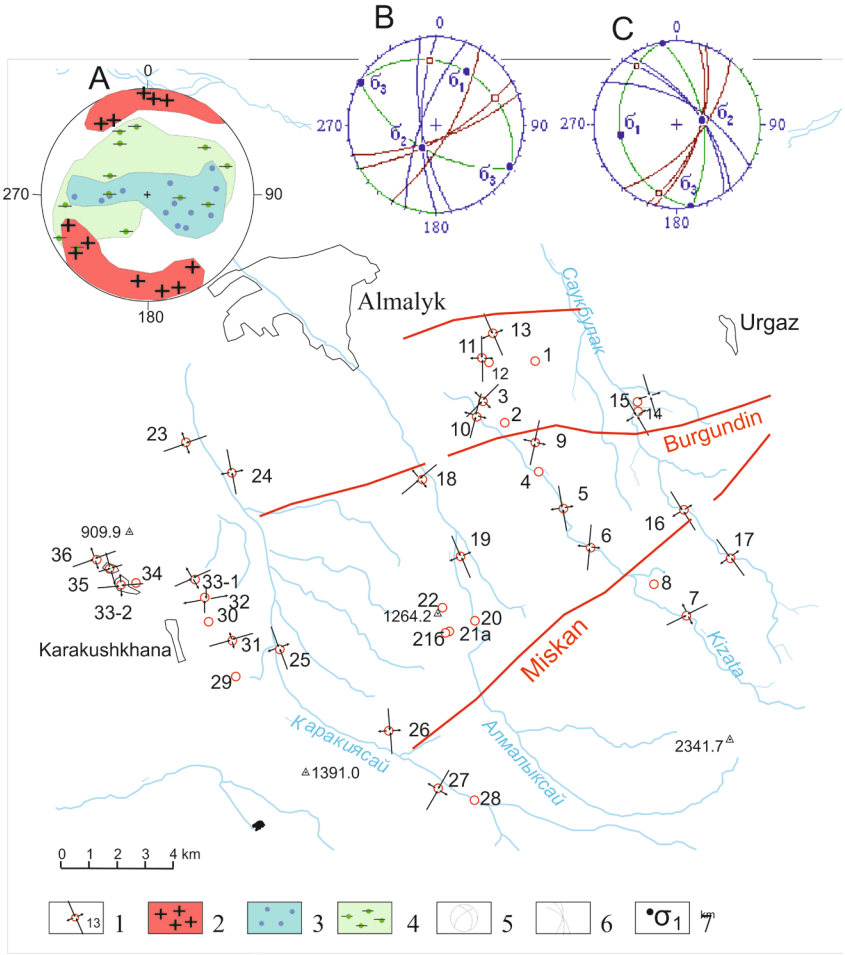
The circular chart A (**Figure 3**) is summary for all studied area and reflects distribution in Woolf's grid of points of an exit to the top hemisphere of axes of the main normal tension of compression, stretching and intermediate, points of observations received for local volumes. Axes of compression have meridional horizontal position, deviating to the northeast and the northwest. The stretching axis has vertical position more, being sometimes interchanged the position from intermediate. This chart confirms dynamic conditions when upthrus, upthrus-shift types of deformation elements are formed. This field of tension corresponds to the regional field of tension of the first rank which was received earlier and characteristic of all Chatkal-Kurama mountain area (**Figure 3(C)**). The general regional field of tension for western, Central Asian, parts of Tien Shan, received by us earlier according to geological data is characterized by the same type, but has northwest (southeast) orientation of an axis of compression (**Figure 3(B)**). The received picture of tension allows understanding kinematics and dynamics of the massif of the Almalyk district, in particular Entre Rios Saukbulak- Kyzata-Almalyk. They show that in the Central block shifts in southwest and partly in the western direction are noted. On the Burgundin break existence of right-hand moving is supposed. In the southern part of the site, in points located on different wings of the Miskany break confirm manifestation of left-side shift.

4. Conclusions

The analysis of the received materials allows drawing the following conclusions:

On the example of geological inspection of a coastal zone of the Charvak reservoir, the Almalyk mining area is shown the possibility of study of kinematics and dynamics of massifs of rocks of industrial regions.

The technique of reconstruction of fields of tension according to the kinematic analysis of structures of destruction in the conditions of an orogen of Tien Shan and the technique of kinematic reconstruction of motions of tectonic blocks according to local volumes of points of observations are tested. In massifs of rocks of a coastal zone of the Charvak reservoir presence of multidirectional shifts of boards, connected as with late Cenozoic tectonic processes, and tech-



Legend: 1—orientations of axes of tension of compression and stretching in the corresponding local volumes of points of observations, 2 - 4—on the circular chart A: areas of points of an exit to the top hemisphere of axes of tension of compression (2), stretching (3) and intermediate (4); 5—circular charts received on Woolf's grid, the top hemisphere; 6—on the charts B and C: dispersion split of surfaces; 7—projections of points of an exit to the top hemisphere of axes of the main normal tension (compression-σ_1—stretchings, σ_2—intermediate, σ_3—compression).

Figure 3. The scheme of orientations of axes of the main normal tension in local volumes of points of observations and charts of axes of tension of the lowest ranks, generalized for different volumes, according to geological data (A—for the considered massif of rocks of the Almalyk district on sliding mirrors; B and C regional, according to the statistical analysis of jointing [9]: B—summary for the western part of Tien Shan, C—for Chatkal-Kurama mountain area).

nogenic factors are established.

In the industrial mining Almalyk region where intensive mining is carried out, contrast upthrus, upthrus-shifts with formation of the folded and block, shattered structure of massifs of rocks are observed. Observed shifts on mirrors of sliding have allowed reconstruction of the field of tension of the Almalyk district which is characterized by horizontal, submeridional orientation of an axis of the main normal tension of compression, at inclined position of two others. It corresponds to the field of tension of the first rank for Chatkalo-Kurama mountain area and defines the general dynamic conditions of the area. To Entre Rios

Saukbulak-Kyzata-Almalyk, in the Central block are noted shifts in southwest and partly in the western direction. On the Burgundin break presence of right-hand shift is noted. In the southern part of the site, on different wings of the Miskan break are noted left-side moving. Such kinematics on breaks is caused by operation of the specified blocks of the squeezing efforts of submeridional orientation, external on the relation.

On studying dynamics of massifs of rocks are usually carried out by tool methods of measurement of pressure on small sites, directly in excavations. The difficult relief and tectonics don't allow carrying out them on big squares. From materials of this article it is visible that for studying of dynamics of massifs of rocks by geological methods it is possible to capture big sites. Besides, the genetic linkage of the obtained data with the general tendency of geodynamic development of the studied region is defined.

Thus, the received results testify to a possibility of receiving by geological, namely field tectonophysics methods of important data on kinematics and dynamics of massifs of rocks, tectonic blocks, and features of their deformation. Such studying of the massif of rocks before the beginning and in the course of performance of work on mining is important for the choice of design and optimum parameters of laying of excavations, control of a condition of their boards and walls, definition of strategy of safety of conducting mining operations and also seismic stability of constructions.

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