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ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

♦

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

♦

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DEVELOPMENT OF THE REGENERATION TECHNOLOGY OF AM-2B ION EXCHANGE RESIN IN THE PROCESS OF SORPTION OF GOLD RECOVERY FROM POLYCOMPONENT GOLD-BEARING SOLUTIONS

Abstract. The principal technological scheme of desorption of gold and accompanying metal-impurities from the AM-2B resin phase used for the sorption processing of gold-bearing ores is considered. The proposed combined scheme, involving the use of two independent traditional methods of gold elution, involves desorption of metal impurities from the resin with alkaline solutions of sodium thiocyanate, and gold - with sulfuric acid solutions of thiourea.

The results of studies of the gold elution and impurity metals from anionite saturated with the following components are given, mg/g: Au = 2.6; Cu - 3.5; Zn - 1.3; Ni - 2.9; Co - 3.3. It is shown that the main amount of impurity metals is desorbed from the resin under its thiocyanate treatment, while the transition of gold into the eluate is negligible. The composition of the eluate in the thiocyanate treatment of saturated resin, mg/l: Au - 14.66; Cu - 669.2; Zn = 222.1; Ni - 493.0; Co - 412.6. Subsequent processing of the resin with sulfuric acid solutions of thiourea makes it possible to transit 98.67 % of gold from the ionite containing a small amount of impurities to the eluate. The resulting eluates containing ~ 377 mg/l of gold are target solutions for obtaining a valuable metal.

The ion exchanger resin was regenerated by washing with water and treating with an alkaline solution of sodium to convert it to an OH^--form, at which sorption of gold from cyanide solutions of heap leaching takes place.

Residual contents of components in the resin after regeneration were, mg/g: Au - 0.06; Cu - 0.02; Zn - 0.02; Ni - 0.01; Co - 1,2, which allows the successful use of the regenerated resin at the next stage of sorption.

Keywords: elution, desorption, combined technology, anion exchange resin, thiocyanate solutions, acid thiourea solutions.

Introduction. Gold-bearing productive cyanide solutions formed during heap leaching, in addition to gold, contain complex cyanide compounds of silver - $NaAg(CN)_2$ and metal impurities, of which the most characteristic are cyanide copper compounds $NaCu(CN)_2$, $Na_2Cu(CN)_3$ and $Na_3Cu(CN)_4$, of zinc $Na_2Zn(CN)_4$, nickel $Na_2Ni(CN)_4$, iron $Na_4Fe(CN)_6$ and cobalt $Na_4Co(CN)_6$ [1-4]. In this regard, saturated ion-exchange resins, along with gold and silver, contain impurity metals, which mass content in the resin is sometimes 2-3 times higher than the content of noble metals.

In the process of regeneration of anion exchange resin, it is necessary to achieve the most complete desorption of both noble metals and impurities. The impurities remaining on the resin when it is reused in the sorption process deteriorate the kinetics of the process, reduce the resin capacity of noble metals, and increase the loss of dissolved gold in the liquid phase of tails. As practice shows, the content of residual components in the anion exchange resin after regeneration can be: gold - no more than 0.1-0.3 mg/g, impurities - no more than 3-5 mg/g of air-dry sorbent [5].

Analysis of technologies for the desorption of gold from saturated ion-exchange resins showed that among the tested eluents the most suitable are alkaline solutions of zinc cyanide [6], sodium thiocyanate and ammonium [7], as well as solutions of thiourea in the presence of mineral acids [8].

However, zinc tetracyanate is effective as an eluent only for anion exchangers having guanidyl groups. The anion exchangers used in the CIS contain other functional groups, and zinc cyanide has low values. To reuse anion exchangers, a deep removal of zinc from the resin, which is carried out by solutions of mineral acids, is necessary. The process is ineffective and has not found industrial application [9-11].

On an industrial scale, mainly thiocyanate and thiourea solutions are used, while the latter is given preference in terms of technical and economic indicators. The costs of reagents for thiourea technology are 1.91 times lower than the costs of thiocyanate technology.

Acid-thiourea technology of gold desorption and resin regeneration includes several operations, the main ones are the treatment of the resin with a hot cyanide solution to remove iron and copper, sulfuric acid for desorption of zinc and nickel, sorption of thiourea, desorption of gold and silver directly with thiourea sulfuric acid solution, thiourea washing and transferring the resin to the OH-form by treatment with sodium hydroxide. All operations, except for aqueous washing of slurries, alkaline treatment and washing of alkali are conducted at a temperature of 55-60 °C and atmospheric pressure [5, 12].

In the operation of acid-thiourea resin processing technology, its serious drawbacks were revealed: when using strong hot cyanide solutions for desorption of copper and iron, gold and silver are partially desorbed from the ion exchanger; zinc and iron are incompletely desorbed and almost no cobalt is extracted. In this regard, zinc, iron and cobalt are accumulated in the ion exchange resin, which leads to a deterioration of its sorption properties; complexity and multi-operation scheme; a long duration of the sorption-desorption-regeneration cycle (250-300 hours) [5].

In order to eliminate these shortcomings, a study of the combined processing technology of saturated anionite proposed by the authors has been conducted. This technology includes three stages of desorption: the first and the second - selective elution of impurity metals, the third one - gold elution with the use of specific complexing reagents at each stage, and the regeneration of the ion exchanger with an alkali solution.

Instead of using strong hot cyanide solutions for desorption of copper and iron, it is suggested to use weak alkaline thiocyanate solutions that successfully desorb these impurity metals but leave gold in the resin [13], then desorb zinc and nickel with a solution of sulfuric acid with simultaneous conversion of the resin from thiocyanate form into sulphate, and then desorption of gold with the acid solution of thiourea. Also, the task was to maximally desorb cobalt from the resin, which according to the existing technology is almost not extracted.

The implementation of the combined technology will eliminate the shortcomings of the existing industrial technology and ensure the production of high-quality gold-bearing eluate without accompanying impurities, which will improve the quality of the finished product.

Methods of the research

Researches used the AM-2B resin produced by GC "Smoly" (Ukraine) [14]. AM-2B anionite is a macroporous ion-exchange resin based on styrene copolymer with divinylbenzene containing strong and weakly basic functional groups in its structure.

Studies on the combined technology of gold desorption and resin regeneration were carried out in dynamic conditions in a laboratory sorption column with a height of 160 mm and a diameter of 40 mm. The height of the resin layer was maintained to 140 mm, the volume of the resin was 60 ml. All the process steps were carried out by passing the solution through the resin layer in the bottom-up column. The flow rate of the solution was 100-120 ml/h, which corresponds to a specific load (SL) of 2-2.4 h^{-1}. The proposed technological scheme of the combined technology of gold desorption and resin regeneration is presented in figure 1.

After completion of the gold elution from the resin phase, the ion exchanger is regenerated by its successive washing with water at an elevated temperature of 55 °C and room temperature. Then alkaline treatment of the ion exchanger (3 % NaOH) is carried out in order to neutralize the sulfuric acid residues and transfer the resin to the OH^- -form, which is most favorable for the gold sorption from alkaline cyanide heap leaching solutions. Spent solutions from alkaline treatment are combined with solutions from acid treatment and aqueous washing from thiourea and are sent for neutralization.

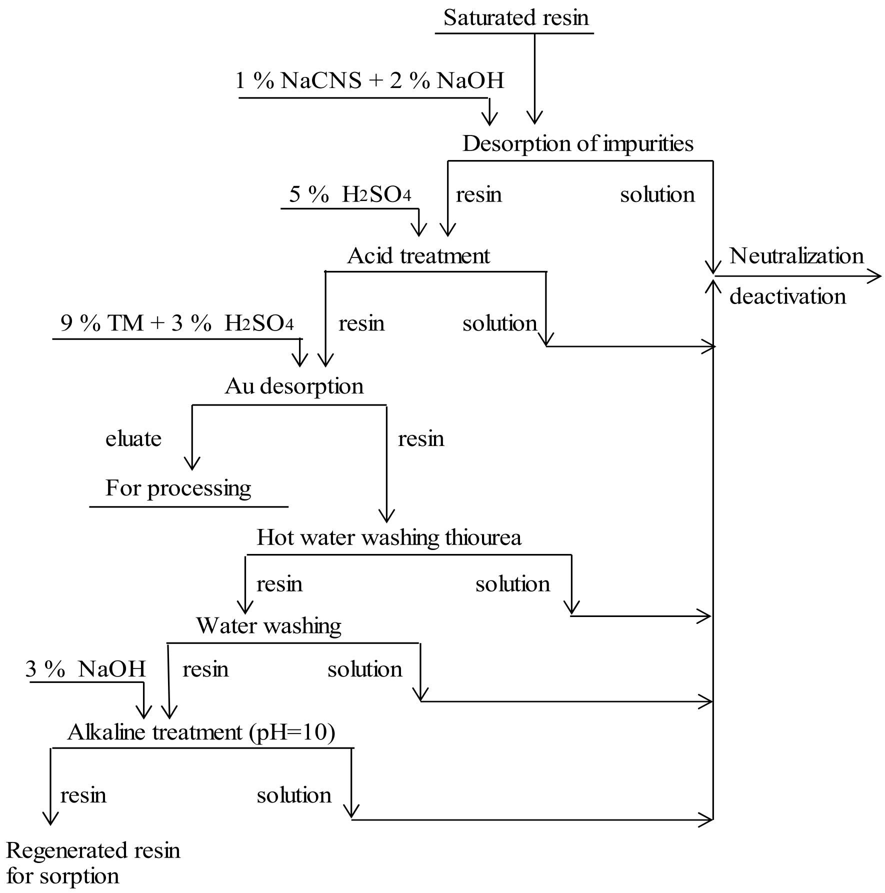

Figure 1 – Principal flow chart of the combined technology of gold desorption and AM-2B resin regeneration

Results of tests of combined thiocyanate-thiourea resin regeneration technology

Volume of the passed solution, sp.v.		Metal content in solution, mg/l					Residual metal content in the resin, mg/g				
in operation	in aggregate	Au	Cu	Ni	Zn	Co	Au	Cu	Ni	Zn	Co
Desorbing solution of 1 % NaSCN and 2 % NaOH											
1,97	1,97	1,45	589,0	184,0	192,5	296,0	2,59	0,45	1,95	0,30	1,77
1,97	3,93	4,87	65,10	220,0	18,4	62,0	2,57	0,11	0,81	0,21	1,45
1,90	5,83	4,80	5,88	65,0	4,0	11,0	2,54	0,09	0,48	0,19	1,39
0,47	6,30	3,54	9,21	24,0	7,2	43,6	2,54	0,07	0,45	0,18	1,34
Processing 5 % H_2SO_4											
1,93	1,93	0,98	1,13	6,80	0,09	3,28	2,53	0,07	0,42	0,18	1,32
2,17	4,10	0,0	1,38	35,60	3,90	0,14	2,53	0,06	0,22	0,16	1,32
0,40	4,50	0,0	0,37	16,2	2,10	0,05	2,53	0,06	0,20	0,15	1,32
Desorbing solution of 9 % $CS(NH_2)_2$ and 3 % H_2SO_4											
2,47	2,47	194,0	1,95	7,50	2,00	0,17	1,27	0,05	0,15	0,14	1,32
2,70	5,17	122,0	1,24	2,00	3,50	0,11	0,41	0,04	0,14	0,12	1,32
2,40	7,57	34,0	0,73	1,20	3,70	0,02	0,19	0,03	0,13	0,09	1,32
2,37	9,93	15,5	1,13	3,40	3,18	0,13	0,10	0,03	0,11	0,07	1,32
2,03	11,97	6,5	0,70	4,05	2,88	0,13	0,06	0,02	0,09	0,06	1,32
2,07	14,03	2,65	0,58	3,30	2,68	0,08	0,05	0,02	0,07	0,04	1,32
2,50	16,53	1,95	0,55	3,03	2,98	0,08	0,03	0,02	0,05	0,02	1,32
Washing H_2O											
2,00	2,00	0,84	0,24	1,53	2,20	0,02	0,03	0,02	0,04	0,01	1,32
2,50	4,50	0,30	0,04	0,33	1,50	0,00	0,03	0,01	0,04	0,01	1,32
Processing 3 % NaOH											
2,00	2,00	0,18	0,25	0,19	1,29	1,58	0,03	0,01	0,04	0,01	1,31
Note: The content of ions of metal-impurities in the regenerated resin, mg/g: Au = 0.06; Cu - 0.02; Ni - 0.01, Zn - 0.02; Co - 1.2.											

Results and their discussion

The results of the experiments are shown in table and in figures 2 and 3.

Figures 2 and 3 show graphical data on the desorption of metals by different eluting solutions.

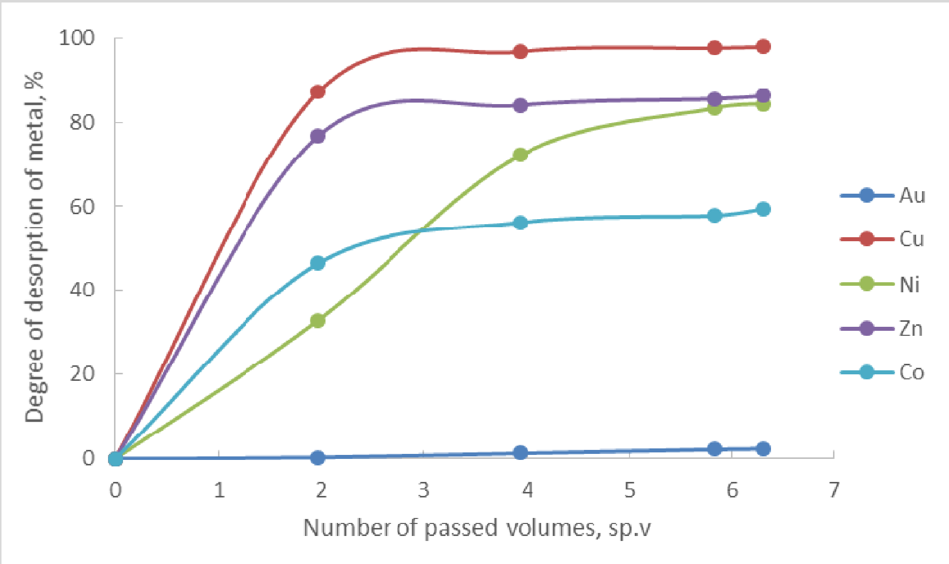

Figure 2 – Dependence of metal desorption on the volume of the passed solution upon desorption of metals-impurities with solutions of 1% NaSCN and 2% NaOH

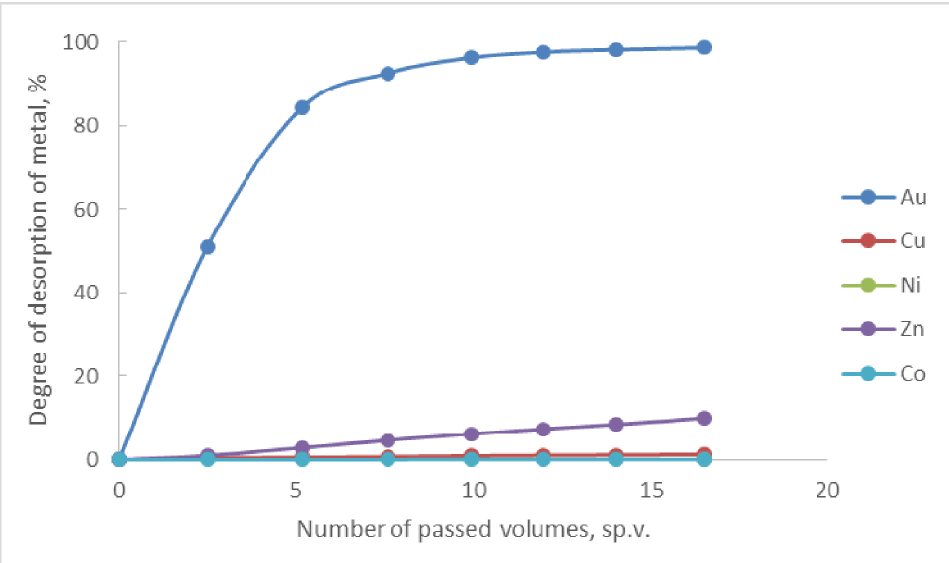

Figure 3 – Dependence of metal desorption on the volume of the passed solution upon desorption of metals-impurities by solutions of 9 % $CS(NH_2)_2$ and 3 % H_2SO_4

From the presented data, it can be seen that the majority of the metal impurities are desorbed using an alkaline thiocyanate solution. At the same time, to the eluate there are transferred, %: copper 97.88, nickel 84.32, zinc 86.18, cobalt 59.43. Further acid treatment of the ion exchange resin allows to desorb mainly nickel (from 84.32 % to 93.10 %) and zinc (86.18 % to 88.10 %).

Figure 3 shows the data using the acidic thiourea solution (9 % $CS(NH_2)_2$ and 3 % H_2SO_4) as the eluent. It can be seen that the metals-impurities are not desorbed practically, and gold is desorbed to 98.67 %.

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ПОЛИКОМПОНЕНТТІ АЛТЫНҚҰРАМДЫ ЕРІТІНДІЛЕРДЕН АЛЫНҒАН ШАЙЫРЛАРДАН АЛТЫНДЫ ДЕСОРБЦИЯЛАУ ЖӘНЕ ШАЙЫРДЫ ҚАЛПЫНА КЕЛТІРУ БАҒЫТЫ БОЙЫНША БІРІККЕН ТЕХНОЛГИЯСЫНДАМЫТУ

Аннотация. Алтынқұрамды кендерден алтынды АМ-2Б маркалы шайырынан десорбциялау және шайырды қайта өңдеудің біріккен технологиясын қолданудың негізгі технологиялық сұлбасы ұсынылған. Бұл сұлба алтынды десорбциялық өңдеуде қолданылатын екі дәстүрлі технологияны қамтиды.

Шайырлардан қоспа металдарды сілтілік роданидті ерітінділермен десорбциялау және алтынды қышқыл тиомочевинді ерітінділермен десорбциялауды қамтитын ұсынылған біріккен технологияны қолдану кезінде қоспа металлдардың әрекеті зерттелді.

Зерттеулер алтынды десорбциялау және ион алмастырғыш шайырды қалпына келтіру бағытында ұсынылған аралас технология бойынша өткізілді. Келесі компоненттермен қаныққан ион алмастырғыш шайыр пайдаланылды, мг/г: Au – 2,6; Cu – 3,5; Zn – 1,3; Ni – 2,9; Co – 3,3. Қалпына келтірілген ион алмастырғыш шайырдың қалдық құрамы, мг/г: Au – 0,06; Cu – 0,02; Zn – 0,02; Ni – 0,01; Co – 1,2.

Қоспаметалдардың басым мөлшері мен алтынның аз мөлшері сілтілі роданидті ерітінділерді қолдану кезінде элюатқа өтетіні көрсетілді. Роданидті өңдеу кезінде элюаттағы металдардың құрамы, мг/л: Au – 14,66; Cu – 669,2; Zn – 222,1; Ni – 493,0; Co –412,6. Ионит құрамындағы алтынның 98,67 % алтынқұрамды ерітінділерге өтеді, ал элюат құрамындағы алтынның құрамы 376,6 мг/л дейін барады.

Түйін сөздер: десорбциялау, біріккен технология, анион алмастырғыш шайыр, роданидті ерітінділер, қышқыл тиомочевинді ерітінділер.

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РАЗРАБОТКА ТЕХНОЛОГИИ РЕГЕНЕРАЦИИ ИОНООБМЕННОЙ СМОЛЫ МАРКИ АМ- 2Б В ПРОЦЕССЕ СОРБЦИОННОГО ИЗВЛЕЧЕНИЯ ЗОЛОТА ИЗ ПОЛИКОМОНЕНТНЫХ ЗОЛОТОСОДЕРЖАЩИХ РАСТВОРОВ

Аннотация. Рассмотрена принципиальная технологическая схема десорбции золота и сопутствующих металлов-примесей из фазы смолы марки АМ-2Б, используемой при сорбционной переработке золотосодержащих руд. Предлагаемая комбинированная схема, предусматривающая применение двух традиционных независимых друг от друга способов элюирования золота, включает десорбцию металлов-примесей со смолы щелочными растворами роданида натрия, а золота – сернокислыми растворами тиомочевины.

Приведены результаты исследований элюирования золота и примесных металлов из анионита, насыщенного следующими компонентами, мг/г: Au – 2,6; Cu – 3,5; Zn–1,3; Ni – 2,9; Co – 3,3. Показано, что основное количество металлов-примесей десорбируются со смолы при ее роданидной обработке, при этом переход золота в элюат незначительно. Состав элюата при роданидной обработке насыщенной смолы, мг/л: Au – 14,66; Cu – 669,2; Zn – 222,1; Ni – 493,0; Co – 412,6. Последующая обработка смолы сернокислыми растворами тиомочевины позволяет перевести в элюат 98,67 % золота от содержавшегося в ионите с небольшим количеством примесей. Полученные элюаты, содержащие ~ 377 мг/л золота, представляют собой целевые растворы для получения ценного металла.

Проведена регенерация ионита путем промывки водой и обработки щелочным раствором натрия для перевода ее в OH^- - форму, при которой осуществляется сорбция золота из цианидных растворов кучного.

Остаточные содержания компонентов в смоле после регенерации составили, мг/г: Au – 0,06; Cu – 0,02; Zn – 0,02; Ni – 0,01; Co – 1,2, что позволяет успешно использовать регенерированную смолу на следующий стадии сорбции.

Ключевые слова: элюирование, десорбция, комбинированная технология, анионит, роданидные растворы, кислые тиомочевинные растворы.

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NOVELTY PILLARED CLAYS FOR THE REMOVAL OF 4-NITROPHENOL BY CATALYTIC WET PEROXIDE OXIDATION

Abstract. One solution passes through the study of wastewater treatment by catalytic wet peroxide oxidation (CWPO).In this work, catalysts based on pillared clays with Zrcations have been prepared from nature clays of Kazakhstan, which were obtained from Zhambyl region of Karatau,Akzhardeposit, to be tested in catalytic oxidation of 4-nitrophenol, used as amodel pollutant. The Zr-pillared clay showed higher activity than nature clays in 4-nitrophenol oxidation.

Keywords: pillared clays, catalysis, catalytic wet peroxide oxidation, 4-nitrophenol, hydrogen peroxide.

Introduction. The years of independence in Kazakhstan have become the formationyearsof a completely new state system for ensuring environmental safety, environmental management and nature management - a well-organized and territorially ramified system of executive bodies in the field of environmental protection in the Republic of Kazakhstan. However, for many decades, Kazakhstan has been developing a raw material system of nature management with extremely high man-caused environmental stresses. Therefore, the most contaminated rivers Irtysh, Nura, Syrdarya, Ili, Lake Balkhash [1, 2]. Groundwater is also contaminated, which is the main source of drinking water supply for the population [3]. In European legislation,4-nitrophenol (4-NP), is one of 114 priorities of organic pollutants, 11 toxic and bio-refractory compound that candamage to the central nervous system, liver, kidney and blood of humans and animals. Its high stability pushes you out of undesirable consequences[4].The mechanism of 4-NP oxidation by techniques, such as photocatalysis, Fenton and intensified Fenton, involves the occurrence of oxidized intermediates, namely catechin, hydroquinone, 1,2,4-trihydroxybenzene and benzoquinone [5-8].

Zhanget al. [9], was done experiments on the photo oxidation of 4-nitrophenol (4-NP) in water by UV/H_2O_2 and the results showed that 4-NP in photo degradationis well. Also, 4-NP was tested on CWPO with rGOH in work [10] and was showed as reaction intermediates are hydroquinone, benzoquinone, catechol and several low molecular weight carboxylic acids (e.g., malonic, malic, maleic and acetic acids).

Pillared clays (PILCs) prepared with difference metal cationshave been alsotestedasacatalystfor the degradation of 4-NP with hydrogen peroxide. Pillared clays with Al–Fe, Al–Cu and Al–Cu–Fe used to degradate4-NP, following the evolution of reaction by measuring the pollutant, total organic carbon (TOC) and chemical oxygen demand (COD) removals (%) [11].Nowadays, the PILCs have received increased interest due to the low cost to obtain them and their textural and catalytic properties, resulting in effective materials to be usedas adsorbent or catalyst in wastewater treatment [12-15]. The pillared clay is a porous material developed by molecular design methods and obtained by exchanging the cations of alkaline, alkaline earth metals, located in the interlayer space of clays, into inorganic polyoxo (hydroxo) cations [16]. Itis concluded that PILCs are an interesting class of 2-dimensional microporous materials, due to their high surface area and permanent porosity.Thus,followingcharacteristics are importantfor pillared clays:

– thermal and hydrothermal stability;
– interlayer distance;
– pillar density;
– chemical nature of the pillars;
– chemical stability of the pillars

Here, the catalytic activity of natural clays was increased by active metals such as zirconium [17].

In this paper, we report the results obtained in the oxidation of 4-NP used as target pollutant with Zr-PILCs prepared from nature clays with zirconium tetrachloride. Nature clays of Kazakhstan were obtained from Zhambyl region of Karatau,Akzhardeposit.

Material and methods

Reagents and chemicals. Hydrogen peroxide solution (30% w/v), used asanoxidant in the treatment of the synthetic wastewater, was purchased from Fluka. Titanium (IV) oxysulphate ($TiOSO_4$, 15 wt.% in dilute sulphuric acid, 99.99%), hydrochloric acid (HCl, 37 wt.%) and sodium sulphite (Na_2SO_3, 98 wt.%) were purchased from Sigma-Aldrich. Sodium hydroxide (NaOH, 98 wt.%) was obtained from Panreac. 4-nitrophenol (98 wt %),and 4-nitrocatechol (98 wt.%), acquired from Panreac, Acros Organics andFluka, respectively were used to prepare working standard solutions for High-Performance Liquid Chromatography (HPLC). Methanol (HPLC grade), glacial acetic acid (analytical reagent grade) and acetonitrile (HPLC grade) were obtained from Fisher Chemical. All chemicals were used as received without further purification. Distilled water was used throughout the work.

Material and Solid Synthesis. Two natural clays with different characteristics from locations in South of Kazakhstan in Zhambyl region of Karatau and Akzhardepositswereused.Clays were washed with water several times at 50 ºC.The wash with HCl (37 wt.%) was also assessed at 50 ºC in order to eliminate residual content inside of the clays. Pillared clays were prepare from washed natural clay with acid washed. Pillared clayswere synthesized with zirconium tetrachloride as a source of zirconium polycations. The pillaring solution was prepared by slow addition of NaOH (0.2 M) to the solution containing Zr at room temperature until pH = 2.8 was obtained. The resultant solution was aged for 24 h at room temperature. The clay pillaring process keeps a ratio of 10 mmol of total metal per gram of washed clay. The final material was dried at 350 K for 24 h and calcinatedduring 2 h at 823 K considering a heating rate of 275 K min^{-1}.

Characterization Methods. To determine the physico-chemical characteristics of the nature clayswas used the X-ray spectral analysis method. An electron probe microprobe of the brand Superprobe 733 (Super Probe 733) from JEOL (Jael), Japan, was usedtodetermine the angular position and intensity of reflexes. Analyzes of the elemental composition of samples and photography in various types of radiation were performed using an Inca Energy with adispersive spectrometer from Oxford Instruments, England. UV-Vis absorption spectra were obtained using a T70 Spectrophotometer (PG Instruments, Ltd.) in the wavelength range of 200-660 nm, with a scan interval of 1 nm. SEM was performed on a FEIQuanta 400FEG ESEM/EDAX Genesis X4M instrument equipped with an Energy Dispersive Spectrometer (EDS). Transmission electron microscopy (TEM) was performed in a LEO 906E instrument operating at 120 kV, equipped with a 4Mpixel 28 × 28 mm CCD camera from TRS.

Catalytic Study. The catalytic oxidation of 4-NP in a diluted aqueous medium was carried out in a 250 mL well-stirred glass reactor and thermostatted at 323 K. The reactor was loaded with 100 mL of a 4-NP aqueous solution (5.0 g L^{-1}), the initial pH of solution was adjusted to 3 by addingH_2SO_4 and NaOH solutions (not buffer).The stoichiometric quantity of hydrogen peroxide for mineralization was added.The catalyst was loaded (2.5 g/L)afterhomogenization of the resulting solution, that moment being considered as t_0= 0 min. Allexperiments were conducted during 24 h.Several samples were withdrawn from themedium of reaction at previously selected times to follow the course of the 4-NP conversionand the appearance of the intermediate compounds that were measured by high-performance liquid chromatography (HPLC).For that purpose, a Jasco HPLC system equipped with a UV-Vis detector (UV-2075 Plus), a quaternary gradient pump (PU-2089 Plus) for solvent delivery (1 mL min-1) and a Kromasil 100-5-C18 column (15 cm x 4.6 mm; 5 µm particle size; reversed-phase) was employed.Total organic carbon (TOC) and H_2O_2 were also measured during experiences, by using a Shimadzu TOC-L CSN analyzer and a colourimetric method base on $TiOSO_4$, as described elsewhere [9].

Results and discussion

Characterization of nature and pillared clays. Table summarized the percentage of metals obtained by XRFanalysis.

The results of elemental analysis

Material	Mass of the element, %										
	O	Na	Mg	Al	Si	K	Ca	Ti	Mn	Fe	Zr
Karatau	52.9	0.8	2.3	6.6	21.1	2.3	7.7	1.6	0.2	4.6	n.d.
Zr-Karatau	n.d.	2.5	2.5	10.0	41.8	4.3	0.9	0.3	n.d.	2.7	35.1
Aкzhar	54.5	0.8	2.2	6.0	22.0	2.2	8.3	0.3	n.d.	3.6	n.d.
Zr-Akzhar	n.d.	2.0	2.5	9.8	40.5	4.8	0.8	0.5	n.d.	2.8	36.2

As can be seen,the composition of natural clays is rich on iron (3.6-4.6%) that will play an important role in the decomposition of hydrogen peroxide to produce hydroxyl radicals that may oxidize the pollutant in CWPO. As expected,thereisa predominance content on Si and oxygen in the natural clay from Karatau(Si = 21.1%) and Akzhar (Si = 22.0%). The Akzhar clays show a strong magnetically character with 8.34 % of Ca. The presence of Ca in natural clays confirm thepresence of carbonate [18] that seems to be exchanged by apillaring process for the Zr, since Ca content decrease strongly (from ca. 8% to close 1%).The quantity of the iron was also diminished lightly by pillaring with $ZrCl_4$, but the most significant decrement was observed for the oxygen content that was removed completely from the natural clays. On the contrary, the content of Na, Al, Si and K was found to increase after pillaring the natural clays. The increment on Na-content may be due to theutilization of NaOH in the pillaring process. As expected, the occurrence of Zrtakeplaces in pillaring process, as can beobserved in pillared clay samples when compared to natural clays. In Akzhar pillared clays the quantity of Zr is 36.32 % and in Karatau pillared clay is 35.07 %. The volume is very similar,and active metal obtained very well. Afterpreparing pillared clay with a$ZrCl_4$solution the quantity of Si (41.8%) and Al (10.0%) on Karataupillared, also in Akzhar pillared was 40.5 % and 9.7 % percent of metals.

The spectra obtained by X-Ray Diffraction (XRD) for natural clays from Karatau and Akzharare depicted in figure 1.

The analysis shows that studies of the mineralogical composition of clay mean that the clay of the Karatau deposit is a representative of the clays raw materials of the polymineral composition. To deter-

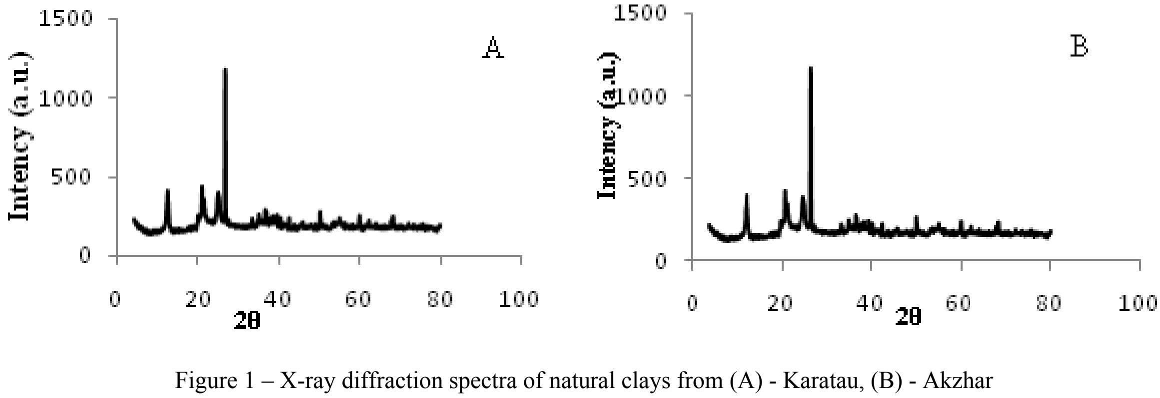
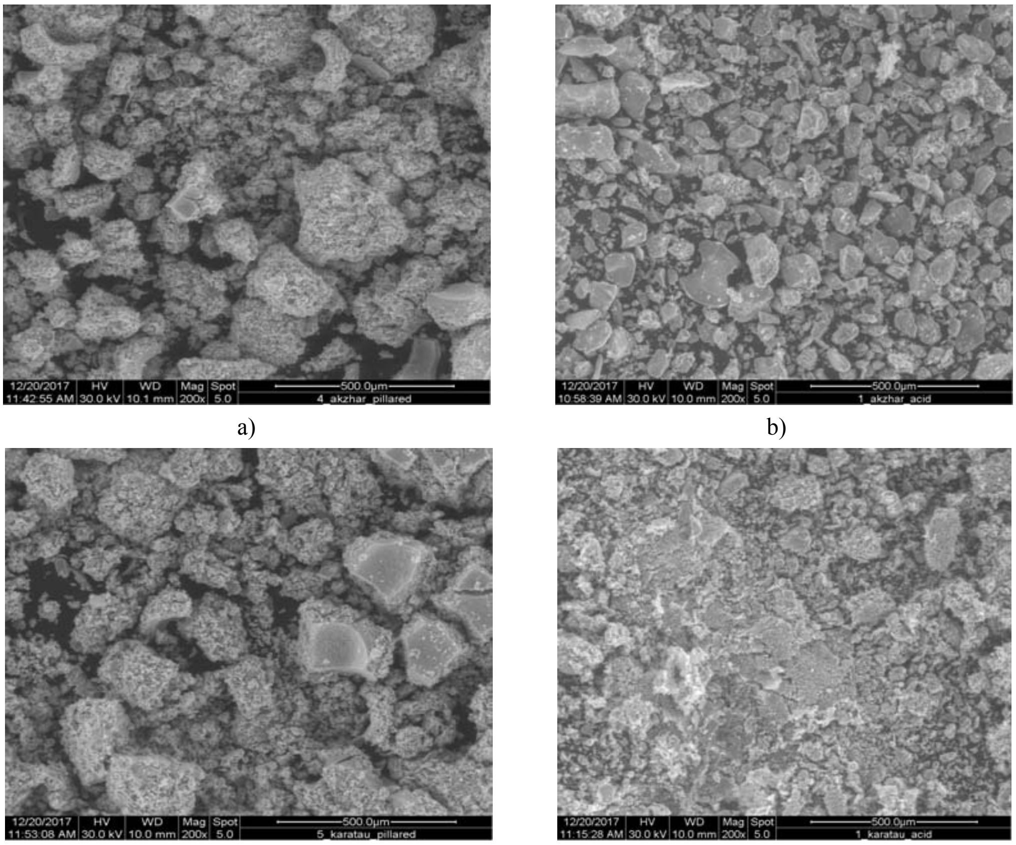


Figure 1 – X-ray diffraction spectra of natural clays from (A) - Karatau, (B) - Akzhar

mine the quantitative ratio of crystalline phases of clay, the samples were subjected to X-ray diffractometric analysis. The polymeric composition is confirmed by the appearance of the corresponding reflections on the X-ray patterns: montmorillonite (d = 14.73-14.56, 4.98-4.39, 2.54-2.60 Å), muscovite (d = 2.59, 2.38 Å), kaolinite (d = 7.09-7.04, 3.54-3.24, 2.56 Å)with formula$Al_2O_3 \cdot 4SiO_2 \cdot xH_2O$.Akzhar clays showed montmorillonite (d = 14.19 Å) and muscovite (d = 9.97, 2.56 Å). The pillared clays were examined on a scanning electron microscope (SEM) and element composition.

Surface morphology of natural and pillared clay obtained by SEM analysis is shown in figure 2.



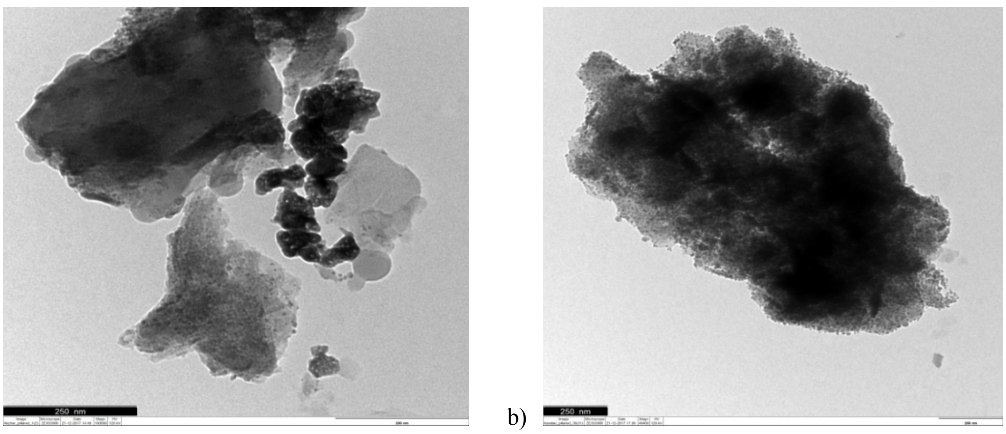
a) b)

c) d)

Figure 2 – SEM images: (a) Zr–Akzhar PILC, (b) Akzhar natural clay and (c) Z r– Karatau PILC, (d) Karatau natural clay

Accordingto microphotographs, obtained from SEM analysis, thenatural clays showed a layered and smooth surface (b and d).However, the surface became coarse and porous when pillared is done (a and c).

Figure 3 shows the microphotographs obtained by TEM analysis with pillared clays.



a) b)

Figure 3 – TEM images: (a) Zr – Akzhar PILC and (b) Zr – Karatau PILC

The bulky surface of columnar clays showed an increase in the active sites on the Zr-pillared surface, which made the catalyst more active [19].

CWPO of 4-NP with natural and pillared clays. The degradation efficiency of4-NP was found to be 62.7% and 77.1 % with Karatauand Akzharafter 8 hours, respectively. TOC removal was 2% and 1%, respectively. Results emphasized that natural clays had very less catalytic activity towards theremoval of 4-NP. Therefore, natural clays were modified by Zrcations.

Natural clays of Karatau and Akzhar prepared for pillarization with Zrcations possess excellent catalytic properties in the 4-NP oxidation reaction. The nature clays washed with acid modified with Zr species and results of oxidation 4-NP was better.Comparing of clays with washed water, acid and pillared clays of Karatau and Akzhar the best results were shown with clays which were modified with Zr. The oxidation of 4-NP with difference washed clays presented below in figure 6. Results weregiven with HPLC.

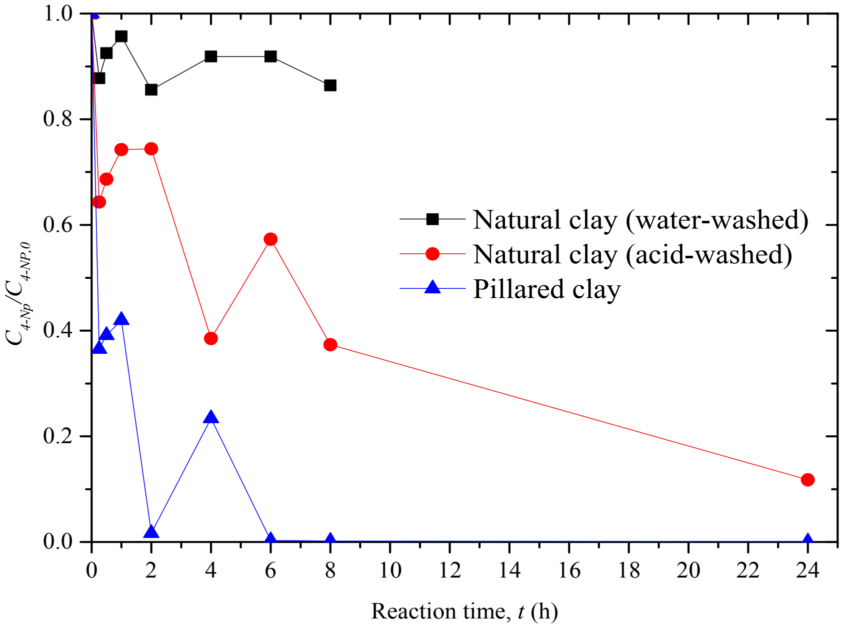


Figure 6 – Degradation of 4-NP in time byCWPO with Karatau clay
(4-NP: 5 g/L, 17.8 g/L of H_2O_2, 2.5 g natural clays,pH: 3.0 and temperature: 50°C)

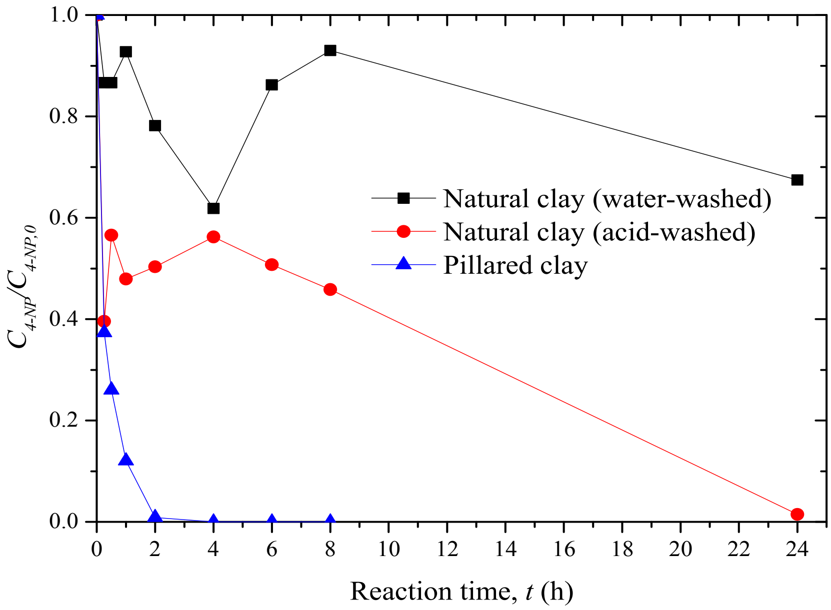


Figure 7 – Degradation of 4-NP in time with catalytic peroxide oxidation with Akzharclay
(4-NP: 5 g/L, 17.8 g/L of H_2O_2, 2.5 g natural clays,pH: 3.0 and temperature: 50°C)

According to the results in Figure 6, it can be seen that with the use of pillared clay Karatau, removal of the pollutant was achieved only after 6 hours of reaction. According to the results represented in figure 7, it can be seen that pillared clay Akzhar gives the removal of the contaminant only after 4 hours of reaction. According to the results of catalytic oxidation pillared clay, Akzhar showed the highest conversion in comparison with other catalysts. This once again proves that in the application of pillared clays in the purification of organic substances, is an effective option for use in these processes.

TOC results for pillared clays can also be noted. After the addition of the active metal, the TOC results were good than with natural clays.

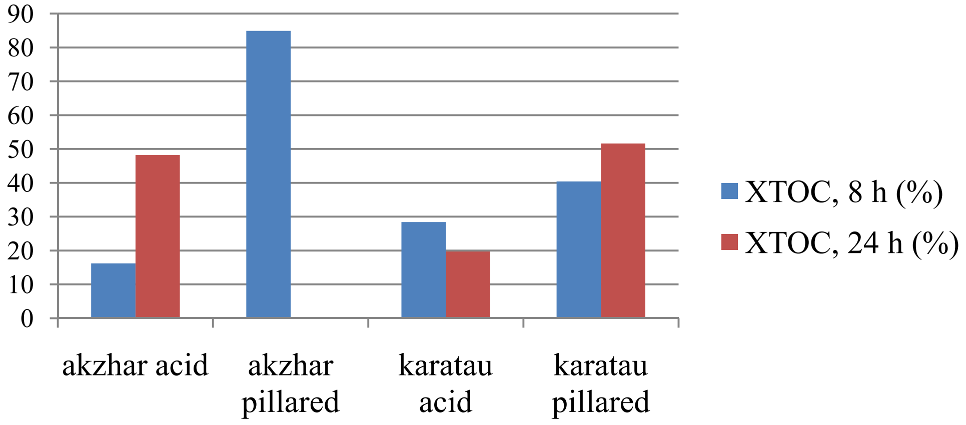


Figure 7 – Conversion of TOC in the oxidation of 4-nitrophenol with catalyst Akzhar and Karatau in 8 and 24 hours

As a result of TOC, the greatest result was shown by clay for 8 hours 84.9%. Natural clays showed only after 24 hours only 48.2%. From the above results, it can be said that the addition of Zr shows an excellent representation.According to figure 7, it can be said that the pillared clay Akzharis more active catalyst than the Karatau pillared clay. The authors of [20] presented the results of TOC Zr-bent on the oxidation of phenol. There, also, the results showed better with the addition of active metal Zr.

The content of Zr in pillared clays influences the physico-chemical characteristics of the material, as shown by the formation of a zirconium crystal at a high content giving a change in surface and porosity. These characteristics are important and the manifestation of the activity of the catalyst [21-23]. Pillared clays are used in catalytic peroxide oxidation more than for other oxidation processes. In many Kazakh-stan and foreign sources, pillared clays with active transition metals are used for catalytic peroxidation. The modification of pillared clay by various complexes of transition metals leads to the formation of regular porous structures possessing unique physicochemical properties. The pillared clay combines accessibility and reliability with a large surface area and catalytic activity. One of the main advantages of these clays is their high stability with minimal leaching of the active metal phase into the reaction medium, which allows them to be used for a long time without loss of activity [24].

Conclusions. The pillaring of Karatau and Akzhar nature clays is achievedby using $ZrCl_4$. The catalysts obtained by Zrcations pillaring are highly efficient for the 4-nitrophenol oxidation reaction in thediluted aqueous medium at mild conditions (323 K and atmospheric pressure). Pillared clays showed higher catalytic activity in the oxidation of 4-nitrophenol than natural clays.Complete removal of the contaminant after 4 hours is achievedwith pillared clay with zirconium is used as catalyst.The highest conversion results were obtained with catalysts based on the Akzhar pillared clay.

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ЫЛҒАЛДЫ КАТАЛИТИКАЛЫҚ СУТЕГІ АСҚЫНТОТЫҚПЕН ТОТЫҚТЫРУ АРҚЫЛЫ 4-НИТРОФЕНОЛДЫ ЖАҢА БАҒАНАЛЫ САЗБАЛШЫҚТАРДЫҢ КӨМЕГІМЕН ЖОЮ

Аннотация. Ағынды суларды тазартудағы зерттеулердің бір жолы - сутегі асқынтотығын қолдану болып табылады. Бұл жұмыста Қазақстанның сазбалшықтары, Жамбыл облысының Қаратау және Ақжар шөгінділерін қолданып, Zr^{4+} катионымен өңделген бағаналы сазбалшықтар негізіндегі катализаторлар алынып, ластаушы ретінде модельдік компонент болып келетін 4-нитрофенолға тотықтыру жүргізілді. 4-нитрофенолды тотықтыру кезінде Zr^{4+} бағаналы сазбалшықтары табиғи сазбалшықтарға қарағанда жоғары белсенділікті көрсетті.

Түйін сөздер: бағаналы сазбалшықтар, катализаторлар, ылғалды каталитикалық сутегі асқынтотықпен тотықтыру, сутегі асқынтотығы.

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НОВЫЕ СТОЛБЧАТЫЕ ГЛИНЫ ДЛЯ УДАЛЕНИЯ 4-НИТРОФЕНОЛА ПУТЕМ МОКРОГО КАТАЛИТИЧЕСКОГО ОКИСЛЕНИЯ ПЕРОКСИДОМ ВОДОРОДА

Аннотация. Одним из решений в изучении очистки сточных вод является окисление с помощью пероксида водорода. В работе были получены катализаторы на основе столбчатых глин с катионами Zr^{4+}, которые были получены из природных глин Казахстанских месторождений Каратау и Акжар Жамбылской области, и проведено каталитическое окисление 4-нитрофенола, который использовался в качестве модельного компонента загрязнителя. Столбчатые глины с Zr^{4+} показали более высокую активность по сравнениюс природными глинами при окислении 4-нитрофенола.

Ключевые слова: столбчатые глины, катализаторы, каталитическое мокроепероксидное окисление, 4-нитрофенол, перекись водорода.

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THE ACCUMULATION OF HEAVY METALS BY THE VEGETATION OF THE EAST KAZAKHSTAN

Abstract. In this article the questions of studying and assessment of the main regularities of accumulation of the heavy metals (HM): Cu, Zn, Mn, Co, Pb, Cd, in plants of the explored territory are considered at various conditions of maintaining and bioavailability of elements in the soil. The same species of a plant accumulates the different number of HM on different types of soils. The vibration amplitude of maintenance of the studied elements in species of the plants growing on various types of soils makes 1.1 – 6.3 times. Varying of the HM content in botanical plant families is in a small range. Zinc is characterized by a basipetal distribution along the morphological organs of plants, for the copper and manganese the acropetal distribution is characteristic. Cobalt, lead and cadmium are characterized by the greatest accumulation in roots with a decrease in leaves and stems. By the value of the coefficient of biological absorption Cu, Co refer to the elements of medium biological capture and weak accumulation in plants; Zn, Mn, Pb - to elements of strong biological accumulation; Cd - to elements of vigorous biological accumulation. The coefficient of biological absorption of all elements was the highest in plants of the family *Fabaceae Lindl.*

Keywords: heavy metals, biogenic migration, accumulation, botanical families, coefficient of biological absorption.

Introduction. Anthropogenic human impact on the biosphere is now global. Issues of local, regional and global dispersion and the penetration of many toxic substances with high concentrations, including heavy metals, have become very topical. A growing "metal press" on the biosphere is becoming a constantly operating environmental factor. Of great interest in this respect is the study area, which includes the territories of the former nuclear test site, as well as the lands of the reserve zone of the Abai Museum-Reserve (figure). Detailed studies in this area have not been carried out, therefore there is insufficient data on the background content of heavy metals in natural objects, including plants, which are used in most cases as a natural standard. In the presence of such data, the objectivity of assessing the emerging situation increases, it becomes possible to calculate the rate of pollution, which is necessary primarily for successful monitoring of the environment. At present, the study of the content in the environment of many toxic at high concentrations of substances is the largest social and economic problem. In connection with the growth of man's technogenic impact on the biosphere, there was a real danger of negative consequences on the environment. When solving practical problems of protecting the environment from anthropogenic pollution, an important place is occupied by information on the background content of toxic ingredients in natural objects, including plants, in a particular region. The most priority pollutants of the natural environment are heavy metals (HM), especially Pb, Cd, Zn, Cu. This is due to both the trends in the development of industry and physiological and biochemical features of HM, their high level of toxicity and the ability to accumulate in living organisms. In connection with the increase in the volume of

A map of Kazakhstan, highlighted in black - Eastern Kazakhstan

industrial production, a particularly important and urgent task is the development of scientific bases for monitoring the content of HM in natural objects, including plants, of great scientific and practical interest. Information on the background content of HM in natural areas of the study area is very valuable from a practical point of view: - give an estimate of ecosystem resilience and stability for possible climatic and geochemical changes due to global and regional anthropogenic influences; - make it possible to assume epidemic diseases among plants, animals and humans.

The problem of HM in the biosphere has two aspects - a biological one, associated with their deficiency as microelements and ecotoxicological. In this connection, it is necessary to control the content of HM in environmental objects of different regions, and first of all in plants that are the main source of most chemical elements for living organisms and a highly informative indicator of their level in the biosphere. In the scientific approach, another important circumstance is taken into account: the stably-unstable nature of the elemental composition of the plant. On the desire of living matter to retain in itself what was created by previous generations, the need to obtain current information about the environment is imposed in order to properly react to the changes occurring in it. The chemical composition of the plant has deeply specific features, as a result of the selective relationship of organisms to elements of content in the soil [1, 2]. In the geochemical environment, the conditions for redundancy or deficiency of the element for the plant are created. In different geochemical conditions, the chemical composition and metabolism of plants, even in the representatives of one species, can differ significantly [3].

Plants, extending their root system into fairly deep soil horizons due to biogenic accumulation, seem to pump chemical elements from the lower horizons to the upper horizons. After the mineralization of the plant remains in the upper horizons of the soil, those elements whose biological absorption coefficient exceeds unity are accumulated. The following factors influence the flow of TM into plants: plant specific features, soil type, concentration, form of HM finding, soil pH, its granulometric composition, organic matter content, cation absorption capacity in soil, availability of technogenic sources of ecosystem pollution [4-6]. The distribution of HM in the plant is in turn dependent on the physiological functions performed by the various organs of the plant, their morphological structure and the physiological functions performed by the chemical elements. Thus, the present selective absorption of chemical elements by plants should be considered more widely: not only as a choice of elements necessary for metabolism, but also as counteraction to the appearance of unnecessary ones. The vegetative organism has several levels of selective absorption: from less careful (on the border, the root to the environment) to the more rigid (in the terrestrial organs, especially on the border, the stem, the seed). Due to selective absorption, the chemical elements enter the plant in favorable for life proportions. The vegetation cover of the area under study is distinguished by a considerable variety and is typical of the steppe and partly desert-steppe zone.

The purpose of this study is to determine the regional background level of accumulation of HM by different species, morphological organs and families of wild vegetation of the study area.

Experimental

Zonal typical plants of the steppe and desert-steppe zone were studied, in total 100 plant samples, 18 species from six families, were studied. For tests there were taken samples of all of the genetic horizons of the soil profile. The samples of all of the genetic horizons of the soil profile were taken for investigations. Definition of macrocomposition of all tests of soils (pH, a humus, CO_2 of carbonates, granulometric composition) was carried out by standard methods [7-10]. The content of heavy metals in the explored soils was determined on the KFK-3 device by a photocolorimetric dithizone method by G.Ya.Rin'kis's recipe [6-8, 10-12]. The reproducibility of the method was equal to ± 4.2%. Selection of fractions of Pb and Zn was carried out by the method of parallel extraction. All analytical data were processed by mathematical analysis and mathematical statistics in soil science according to E.A. Dmitriev [7].

Results and discussion

Data on the ecological specifics of the accumulation of HM by the same species of plants on different types of soils are presented in table 1. As the results of studies have shown, the same plant species accumulates different amounts of HM on different soil types [7-11]. So, for example, the content of the investigated elements in plant species growing on different types of soils varies: copper - 1.1 - 3.5 times, zinc - 1.1 - 3.2 times, manganese - 1.1 - 2.5 times, cobalt - 1.1 - 2.0 times, lead - 1.1 -3.3 times, cadmium - 1.1 - 6.3 times.

The content of heavy metals in the plants in the region under investigation depends on their content in the soil, on the situation with mineral nutrition that develops in a particular soil. This is evidenced by the value of the coefficient of biological absorption (CBA), which allows one to indirectly judge the degree of

Table 1 – Content of heavy metals in plant species growing on various types of soils

Type of soil	Cu	Zn	Mn	Co	Pb	Cd
Artemisia terrae-albae Krasch						
Ch_1	1.4/0.1	13.6/0.8	84.2/0.1	0.9/0.2	1.3/0.1	0.24/0.53
M_1	1.1/0.1	14.5/0.6	61.1/0.1	0.6/0.1	0.6/0.05	0.46/0.56
S	3.8/0.2	4.6/0.2	153.9/0.2	1.2/0.2	2.0/0.2	0.2/0.1
Carex melanostachya Bieb. Ex. Wiild						
Ch_1	1.9/0.2	11.8/0.7	146.5/0.2	0.7/0.1	1.6/0.2	0.44/1.02
M_1	1.7/0.1	13.2/0.7	118.2/0.1	1.2/0.2	1.2/0.1	0.07/0.08
Goniolimon speciosum (L.) Boiss						
Ch_1	1.0/0.1	15.2/0.8	89.1/0.1	1.4/0.2	0.4/0.04	0.64/1.49
S	1.6/0.1	16.4/0.8	155.8/0.2	2.3/0.3	0.4/0.04	0.73/0.37
Limonium gmelini (Willd) O. Kuntze						
Ch_1	0.7/0.1	15.2/0.8	84.3/0.1	0.6/0.1	1.0/0.1	0.3/0.7
S	2.0/0.1	14.8/0.7	132.2/0.2	0.7/0.1	1.2/0.1	0.32/0.16
Salsola tamariskina Pall						
Ch_1	2.9/0.2	15.1/0.8	107.5/0.1	1.0/0.2	1.1/0.1	0.43/1.00
S	4.0/0.3	16.6/0.8	133.8/0.2	1.8/0.3	2.6/0.2	0.46/0.23
Stipa capillata(L.)						
Ch_1	1.7/0.1	9.4/0.5	9.4/0.01	1.7/0.2	2.2/0.2	0.19/0.72
S	3.0/0.2	10.6/0.5	10.6/0.01	1.8/0.2	4.0/0.3	0.37/1.5

Note. Ch_1 - light chestnut normal soils, M_1 - meadow light soils, S - solonchaks; in the numerator - the content of the element in the plant, mg/kg, in the denominator - the coefficient of biological absorption (CBA).

availability of elements in the soil for plants, as a rule, the higher the value of the CBA, the greater the content of the element in the plant.

Differences in the accumulation of HM by the same species on different soil types are due to both the biological characteristics of plants and the ecological condition-differences in the content and bio-availability of the elements in the soils [13-15].

According to the results of the research, the content of HM in the plants of the botanic families studied is distributed in the following order of decrease (table 2):

- on Cu: *Chenopodiaceae > Asteraceae > Cyperaceae > Poaceae, Limoneaceae > Fabaceae;*
- on Zinc: *Limoneaceae > Chenopodiaceae > Cyperaceae > Poaceae > Asteraceae > Fabaceae;*
- on Mn: *Cyperaceae > Fabaceae > Chenopodiaceae > Asteraceae , Limoneaceae > Poaceae;*
- on Co: *Poaceae > Fabaceae > Chenopodiaceae > Asteraceae , Limoneaceae > Cyperaceae;*
- on Pb: *Poaceae > Chenopodiaceae > Fabaceae > Asteraceae , Cyperaceae > Limoneaceae;*
- on Cd: *Asteraceae > Fabaceae > Limoneaceae > Chenopodiaceae > Cyperaceae, Poaceae.*

Varying the content of HM in the botanical families of plants is in a small range and amounts to an average: copper - 35.0%, zinc - 19.0%, manganese - 34.8%, cobalt - 46.7%, lead - 43.3% , cadmium - 51.5%.

Table 2 – The content of heavy metals in various botanical families of plants in the study area

Plant family	n	Cu	Zn	Mn	Co	Pb	Cd
Asteraceae Dumort. Asters	20	2.3±0.4 1.1-4.0 (53)	11.3±1.5 3.6-15.8 (42)	114.8±25.4 97.3-997.1 (70)	1.0±0.1 0.4-1.7 (44)	1.4±0.3 0.4-3.8 (64)	0.69±0.20 0.18 -2.07 (90)
Chenopodiaceae Vent. Chenopodiaceae	12	3.3±0.2 2.6-4.1 (18)	15.0±0.8 14.7-17.0 (13)	116.4±11.3 82.1-150.9 (24)	1.3±0.4 0.6-2.9 (69)	1.6±0.3 0.8-2.9 (51)	0.43±0.02 0.35-0.53 (15)
Cyperaceae Juss. Sedge	14	2.1±0.2 1.6-2.9 (24)	12.3±0.4 10.4-13.4 (9)	130.1±14.1 103.0-197.8 (29)	0.7±0.1 0.4-1.2 (39)	1.4±0.2 0.9-2.0 (30)	0.42±0.07 0.07-0.64 (45)
Fabaceae Lindl. Beans	18	1.6±0.1 1.1-2.0 (25)	10.7±0.7 7.8-14.1 (20)	128.4±13.9 91.2-188.7 (33)	1.5±0.2 0.8-2.6 (40)	1.5±0.1 1.0-2.2 (27)	0.56±0.15 0.12-1.63 (81)
Limoneaceae Lincz. Thrift	18	1.9±0.4 0.5-4.9 (66)	15.3±0.3 14.5-16.5 (6)	114.6±14.3 70.0-194.8 (37)	1.0±0.2 0.6-2.3 (55)	0.9±0.1 0.4-1.4 (44)	0.44±0.06 0.28-0.73 (42)
Poaceae Barnhart The bluegrass	18	1.9±0.2 1.4-3.0 (26)	11.5±0.8 7.7-15.9 (21)	11.3±0.6 10.3-13.8 (16)	1.6±0.2 0.6-2.3 (33)	2.0±0.3 1.2-4.0 (44)	0.42±0.05 0.19-0.73 (36)

Note. n is the number of samples; in the numerator - the arithmetic mean and its error, mg/kg; in the denominator - the range of variation, mg/kg, in parentheses - the coefficient of variation, %.

Due to selective absorption, chemical elements enter the plant in favorable proportions for life [8, 13, 14-17]. This is especially evident in various plant organs, where chemical elements have their specific function.

The distribution of HM content by plant organs is presented in table 3. It has been revealed that zinc is characterized by a basipetal distribution over the organs of plants, for copper and manganese it is acropetal. Cobalt, lead, and cadmium are differently distributed over the morphological organs of plants. They are characterized by the greatest accumulation in the roots with a decrease in leaves and stems. The stems contain a minimum number of them.

The revealed general patterns on morphological organs when considering them in the context of families (table 4) are confirmed only for one element - cadmium, for other investigated elements - they have not been confirmed. Thus, for example, the basipetal distribution of zinc and the acropetal distribution of copper and manganese by morphological organs are conserved in the family Asteraceae Dumort. and Chenopodiaceae Vent. and it looks different in other families.

Table 3 – The content of heavy metals in the organs of a common set of wild plants (n = 100)

Element	Root	Stalk (stem)	Leaf
Cu	2.6±0.3 0.5-6.3 (36)	1.8±0.3 0.5-6.3 (51)	1.7±0.3 0.5-4.1 (39)
Zn	11.8±0.7 3.4-15.8 (18)	13.9±2.8 3.5-26.6 (30)	15.1±1.0 2.7-21.2 (22)
Mn	135.7±23.7 8.6-677.6 (48)	83.5±15.2 6.3-274.7 (50)	78.4±6.7 10.0-189.0 (21)
Co	1.7±0.4 0.4-4.8 (62)	0.8±0.2 0.1-3.2 (69)	1.1±0.2 0.2-3.1 (43)
Pb	2.0±0.4 0.3-7.2 (51)	1.0±0.2 0.1-4.1 (58)	1.3±0.2 0.2-3.5 (39)
Cd	0.67±0.14 0,10-2.88 (58)	0.34±0.06 0.02-1.29 (56)	0.51±0.11 0.04-2.03 (54)
Note. n is the number of samples; in the numerator - the arithmetic mean and its error, mg/kg; in the denominator - the range of variation, mg/kg, in parentheses - the coefficient of variation, %.			

Consequently, the belonging of the plant to botanical groups (families) affects the content of the morphological organs of all heavy metals, except cadmium.

Table 4 – The content of heavy metals in the morphological organs of wild plants by family

Element	Root	Stalk	Leaf
1	2	3	4
Asteraceae Dumort- Asters (n=20)			
Cu	2.7±0.4 1.4-4.5 (50)	1.8±0.5 0.5-4.5 (78)	1.6±0.2 1.1-2.6 (31)
Zn	9.8±1.3 3.4-14.6 (40)	11.0±1.7 3.5-19.4 (49)	13.0±1.9 4.0-21.2 (46)
Mn	146.7±60.1 14.8-677.6 (98)	97.8±25.2 36.0-274.7 (81)	77.0±9.3 50.0-120.5 (32)
Co	1.4±0.3 0.8-3.7 (60)	0.7±0.2 0.1-1.9 (98)	0.8±0.2 0.2-1.8 (66)
Pb	1.6±0.3 0.3-3.6 (57)	1.3±0.3 0.5-4.0 (85)	1.4±0.1 0.7-1.8 (30)
Cd	0.96±0.27 0.21-2.88 (89)	0.45±0.12 0.09-1.29 (83)	0.79±0.26 0.24-2.03 (78)
Chenopodiaceae Vent - Chenopodiaceae (n=12)			
Cu	4.1±0.4 2.8-6.3 (31)	4.4±0.6 2.0-6.3 (46)	2.4±0.4 1.4-4.1 (40)

Continuation of table 4

1	2	3	4
Zn	14.6±0.7 11.2-15.6 (11)	14.8±1.2 9.8-17.5 (21)	16.2±0.6 13.6-18.0 (9)
Mn	180.8±13.7 130.6-208.9 (19)	87.1±23.9 42.1-174.1 (67)	81.3±3.3 69.6-89.4 (10)
Co	2.0±0.5 1.0-3.8 (54)	1.0±0.5 0.3-3.2 (98)	0.7±0.2 0.4-1.6 (69)
Pb	3.3±0.9 1.2-7.2 (65)	0.8±0.1 0.5-1.2 (36)	0.6±0.1 0.3-1.3 (55)
Cd	0.58±0.08 0.26-0.91 (36)	0.32±0.04 0.22-0.50 (34)	0.38±0.05 0.14-0.45 (32)
Cyperaceae Juss - Sedge (n=14)			
Cu	2.4±0.2 1.7-3.5 (26)	1.9±0.2 1.3-2.4 (24)	2.0±0.3 1.1-3.1 (34)
Zn	10.6±0.5 9.0-13.2 (13)	14.1±2.2 10.4-26.6 (41)	12.3±1.7 2.7-15.8 (36)
Mn	191.0±30.1 132.2-353.2 (42)	121.1±9.4 95.2-158.2 (21)	78.2±6.3 55.2-110.8 (21)
Co	1.3±0.2 0.5-2.7 (61)	0.3±0.01 0.2-0.4 (24)	0.6±0.01 0.4-0.8 (20)
Pb	1.5±0.2 0.9-2.7 (43)	0.4±0.1 0.2-0.6 (33)	2.1±0.3 1.1-3.5 (41)
Cd	0.62±0.11 0.10-1.01 (47)	0.25±0.06 0.02-0.43 (59)	0.38±0.07 0.09-0.67 (52)
Fabaceae Lindl - Beans (n=18)			
Cu	2.1±0.3 1.2-3.3 (38)	1.1±0.1 0.6-1.8 (34)	1.8±0.3 1.0-3.6 (46)
Zn	12.4±0.6 8.4-14.4 (15)	9.8±1.0 6.8-15.8 (30)	9.8±0.9 7.0-15.1 (28)
Mn	174.3±21.9 110.6-275.3 (38)	89.2±12.2 75.6-171.5 (41)	105.7±9.4 80.0-142.6 (27)
Co	2.2±0.3 0.8-3.3 (45)	1.1±0.3 0.2-2.8 (72)	1.2±0.1 0.7-1.6 (31)
Pb	2.0±0.3 0.6-3.3 (46)	1.3±0.3 0.6-3.1 (60)	1.5±0.1 0.9-2.0 (28)
Cd	0.82±0.23 0.12-2.43 (85)	0.35±0.08 0.09-0.91 (65)	0.52±0.14 0.04-1.54 (84)

End of table 4

1	2	3	4
Limoneaceae Lincz – Thrift (n=18)			
Cu	2.1±0.3 0.5-3.3 (46)	1.1±0.2 0.5-1.7 (44)	1.2±0.2 0.5-2.0 (48)
Zn	13.7±0.5 12.0-15.8 (11)	16.3±0.6 14.0-19.2 (12)	15.9±0.5 13.0-17.8 (9)
Mn	111.4±16.1 67.6-196.3 (43)	92.7±19.3 39.4-231.9 (62)	117.3±11.9 80.2-189.0 (30)
Co	1.6±0.4 0.6-4.8 (82)	0.6±0.1 0.2-0.8 (39)	1.1±0.2 0.6-1.5 (36)
Pb	1.3±0.2 0.5-2.0 (47)	0.6±0.1 0.1-1.0 (60)	0.9±0.2 0.2-1.5 (55)
Cd	0.55±0.08 0.30-0.92 (43)	0.32±0.03 0.30-0.60 (48)	0.45±0.06 0.30-0.75 (40)
Poaceae Barnhart – The bluegrass (n=18)			
Cu	2.2±0.2 1.1-2.80 (24)	1.6±0.4 0.8-4.9 (79)	1.8±0.3 1.2-2.8 (34)
Zn	9.9±0.5 8.6-13.6 (15)	12.9±1.2 10.6-18.2 (28)	11.1±0.3 10.0-12.1 (7)
Mn	9.9±0.5 8.6-13.6 (15)	12.9±1.2 6.3-18.2 (28)	11.1±0.3 10.0-12.1 (7)
Co	1.5±0.4 0.4-4.1 (73)	1.3±0.3 0.5-2.7 (73)	2.0±0.3 0.9-3.1 (38)
Pb	2.3±0.4 0.8-4.6 (50)	1.5±0.4 0.8-4.1 (74)	1.6±0.2 1.1-2.2 (28)
Cd	0.48±0.07 0.13-0.68 (45)	0.36±0.06 0.14-0.68 (47)	0.44±0.06 0.20-0.72 (38)

Note. n is the number of samples; in the numerator - the arithmetic mean and its error, mg/kg; in the denominator - the range of variation, mg/kg, in parentheses - the coefficient of variation, %.

The intensity of absorption (coefficient of biological absorption, CBA) [16, 18-22] of heavy metals by various organs and plant families as a whole has been studied.

On average for copper, zinc is characterized by intense absorption by stems, less leaves, roots: $CBA_{stalk} > CBA_{leaf} > CBA_{root}$; for lead, manganese - $CBA_{root} > CBA_{stalk} > CBA_{leaf}$; for cobalt, cadmium - $CBA_{root} > CBA_{list} > CBA_{stalk}$.

In the calculation formula, the CBA used the values of clarke elements for the soil.

According to the level of the mean value of the CBA, the plant families are arranged in the following descending order:

- on Cu: *Fabaceae* (1.9) > *Chenopodiaceae* (1.7) > *Poaceae* (1.4) > *Asteraceae, Cyperaceae* (1.1) > *Limoneaceae* (0.9);

- on Zn: *Fabaceae* (5.0) > *Limoneaceae* (3.8) > *Poaceae* (3.5) > *Chenopodiaceae* (2.9) > *Cyperaceae* (2.7) > *Asteraceae* (2.3);

- on Mn: *Fabaceae* (3.6) > *Cyperaceae* (1.6) > *Limoneaceae* (1.5) > *Chenopodiaceae* (1.4) > *Asteraceae* (1.1) > *Poaceae* (0.2);

- on Co: *Fabaceae* (3.5) > *Poaceae* (2.1) > *Cyperaceae* (1.8) > *Limoneaceae* (1.4) > *Chenopodiaceae* (1.2) > *Asteraceae* (1.0);

- on Pb: *Fabaceae* (3.8) > *Poaceae* (2.8) > *Chenopodiaceae* (1.5) > *Asteraceae, Cyperaceae* (1.3) > *Limoneaceae* (1.5);

- on Cd: *Fabaceae* (22.35) > *Asteraceae*(13.53) > *Poaceae*(13.93) > *Limoneaceae*(11.09) > *Chenopodiaceae*(8.46) > *Cyperaceae* (7.97).

As can be seen from these series, the CBA of all elements appeared to be higher in the plants of the family *Fabaceae Lindl.*

In general, for the area under study, it is characteristic that copper, manganese, cobalt, and lead are classified as a group of elements of average absorption by the level of biological absorption of plants; zinc, cadmium - to the group of elements of intensive absorption. For the latter, biogenic migration, apparently, can act as the main factor in the migration of these elements in the landscape.

Conclusion. As a result of the study, it was found that differences in the accumulation of heavy metals by the same species on different types of soils are due to both the biological characteristics of plants and the ecological condition - differences in the content and bioavailability of elements in a particular soil. The same plant species accumulates different amounts of heavy metals on different soil types. The content of the investigated elements in plant species growing on different soil types varies: copper - 1.1 - 3.5 times, zinc - 1.1 - 3.2 times, manganese - 1.1 - 2.5 times, cobalt - 1.1 - 2.0 times, lead - 1.1 -3.3 times, cadmium - 1.1 - 6.3 times. Varying of the content of heavy metals in botanical plant families is in a small range and amounts to an average: copper 35.0%, zinc 19.0%, manganese 34.8%, cobalt 46.7%, lead 43.3 %, cadmium - 51.5%. Zinc is characterized by a basipetal distribution according to the morphological organs of plants, and acropetal distribution is typical for copper and manganese. Cobalt, lead and cadmium are characterized by the greatest accumulation in roots with a decrease in leaves and stems (stalk). The stems contain a minimum number of them. For copper, zinc is characterized by intense absorption by stems, less leaves, roots, the coefficient of biological absorption (CBA): $CBA_{Stalk\ (stem)} > CBA_{leaf} > CBA_{root}$; for Pb, Mn – $CBA_{root} > CBA_{stalk\ (stem)} > CBA_{leaf}$; for Co, Cd – $CBA_{root} > CBA_{leaf} > CBA_{stalk\ (stem)}$. By the value of CBA Cu, Co refers to the elements of medium biological capture and weak accumulation in plants; Zn, Mn, Pb - to elements of strong biological accumulation; Cd - to elements of vigorous biological accumulation. CBA of all elements was higher in plants of the family *Fabaceae Lindl.*

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ШЫҒЫС ҚАЗАҚСТАН ӨСІМДІКТЕРІНДЕ АУЫР МЕТАЛДАРДЫҢ ЖИНАҚТАЛУЫ

Аннотация. Мақалада ауыр металдардың (АМ): Cu, Zn, Mn, Co, Pb, Cd зерттеу аймағындағы өсімдіктердегі топырақтағы элементтердің құрамдары мен биологиялық қол жетімділігі әртүрлі жағдайларда жинақталуының негізгі заңдылықтарын зерттеу және бағалау қарастырылған. Өсімдіктердің бір ғана түрі әртүрлі топырақта АМ-дың әртүрлі мөлшерін жинайды. Әртүрлі топырақта өсетін өсімдік түрлерінде зерттелген элементтердің құрамындағы ауытқулардың амплитудасы 1,1-6,3 есе. Ботаникалық өсімдіктер тұқымдастарындағы АМ-дың құрамдарының өзгеруі шағын ауқымда. Цинк өсімдіктердің морфологиялық мүшелері бойынша базипеталды таралумен сипатталса, ал мыс пен марганец – акропеталды. Кобальт, қорғасын және кадмий үшін жапырақтары мен сабақтарының төмендеуімен тамырлардағы ең көп жинақталу көрсетілді. Биологиялық сіңіру коэффициентінің мәні бойынша Cu, Co орта биологиялық басып шығару элементтеріне және өсімдіктерде нашар жинақтауға жатады; Zn, Mn, Pb – күшті биологиялық жинақтау элементтеріне; Cd – дәрменді биологиялық жинақтау элементтеріне жатады. Барлық элементтердің биологиялық сіңіру коэффициенті бойынша өсімдіктердің Fabaceae Lindl тұқымдасында ең жоғары болды.

Түйін сөздер: ауыр металдар, биогенді миграция, аккумуляция, ботаникалық тұқымдастар, биологиялық сіңіру коэффициенті.

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НАКОПЛЕНИЕ ТЯЖЕЛЫХ МЕТАЛЛОВ РАСТИТЕЛЬНОСТЬЮ ВОСТОЧНОГО КАЗАХСТАНА

Аннотация. В настоящей статье рассматриваются вопросы изучения и оценки основных закономерностей накопления тяжелых металлов (ТМ): Cu, Zn, Mn, Co, Pb, Cd в растениях исследуемой территории при различных условиях содержания и биодоступности элементов в почве. Один и тот же вид растения накапливает разные количества ТМ на разных типах почв. Амплитуда колебаний содержания исследуемых элементов в видах растений, произрастающих на различных типах почв, составляет 1.1 – 6.3 раза. Изменение содержания ТМ в семействах ботанических растений находится в небольшом диапазоне.

Для цинка характерно базипетальное распределение по морфологическим органам растений, для меди и марганца – акропетальное. Для кобальта, свинца и кадмия характерно наибольшее накопление в корнях с уменьшением в листьях и стеблях. По значению коэффициента биологического поглощения Cu, Co относится к элементам среднего биологического захвата и слабого накопления в растениях; Zn, Mn, Pb – к элементам сильного биологического накопления; Cd – к элементам энергичного биологического накопления. Коэффициент биологической абсорбции всех элементов оказался наиболее высоким в растениях семейства Fabaceae Lindl.

Ключевые слова: тяжелые металлы, биогенная миграция, аккумуляция, ботанические семейства, коэффициент биологического поглощения.

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DESIGN OF THE CENTRIFUGAL-GYRATORY MILL OF MINING PRODUCTION

Abstract. To provide the mining enterprises of Kazakhstan with a new type of mill, which has a reduced power consumption. Mining mills are the main consumers of electricity in the mining sector, so the task of reducing energy is very important. Centrifugal-gyratory mills are designed for grinding various mineral raw materials. Mills of this type have been known for a long time and have shown good results in the process, one of the main advantages of these mills is the reduced consumption of electric energy. In operational tests of this scheme, its main drawback was found to be a high probability of a driven crankshaft motion according to the unplanned law of motion, which leads to a breakdown of the mechanism. Even a small inaccuracy in the manufacture of the mechanism, backlash can lead to a gap of the driven crank with the leader, especially in the zone close to the extreme position.

In this paper, the design of the centrifugal-gyratory mill based on a rocking mechanism is studied. The mill has several advantages over analogues: simplification of design, high dynamic stability, energy costs reduced by 2 times, etc.

For the first time, operational testing of mills was carried out at the Scientific Research Institute of Mineral Processing of the National Center for Processing Mineral Resources of the Republic of Kazakhstan. The working principle of the mill is studied, which consists in a plane-parallel displacement of cylindrical grinding chambers - tubes in a plane perpendicular to their axis, at which each point of the grinding chamber moves along a circle with a radius equal to the length of the crank r of the mill mechanism [5]. The centrifugal force of the counterweights, the unbalanced dynamic force and moments, the force analysis are calculated.

Results. It can be seen from the research results that the proposed mills have a specific capacity index of 140 kg/kW or 8 kW/ton of production. According to this indicator, the proposed mills exceed the ball mills by 2 times [3]. In this scheme, the theoretical balance of the mechanism is obtained. There are significant design achievements: there is one crankshaft, there is no excessive bonds, no need for gears, which greatly simplifies the design. The mill has high maintainability.

Scientific novelty. The novelty of the results is the creation of centrifugal-gyratory mill constructions, which provide the optimum grinding process, energy intensity, metal consumption and mill productivity.

Practical significance. Based on calculations and experimental data, as well as in determining its rational design and technological parameters, it was revealed that in the process of the experimental-industrial period of the mill at the polygon of the State Research and Production Association of Industrial Ecology "Kazmekhanobr" (Almaty), which is part of the National Center for Complex Processing of Mineral Raw Materials of the Republic of Kazakhstan, that the mill has a low level of metal consumption, it has a low level of complexity structure, thereby reducing the cost of the mill compared with the ball ones approximately in 3 times, compared with existing centrifugal mills in 1.5 times. Tests of the mills showed their economy in energy consumption, which is the most important indicator.

Keywords: centrifugal-gyratory mill, grinding, mineral raw materials, metal consumption, energy intensity, design, productivity, milling, crank.

Centrifugal mills have a high level of grinding of raw materials at relatively low energy costs. Currently, existing centrifugal planetary mills are characterized by high complexity of construction and high cost. The developed new design of the centrifugal-gyratory mill also has a high complexity of construction and dynamic imbalance, which leads to rapid wear.

The author proposes a new design for the vibrator drive of such a mill, which is much simpler than analogues, it is dynamically well balanced, as a result of which the mill has a low level of vibration and low wear during operation. Low energy costs are explained by the use of centrifugal force of grinding bodies oscillations when milling. Getting such a force requires a much lower energy consumption than the use of the force of gravity used in ball mills or the compression forces of rolls in roller mills.

The principle of operation of such a mill consists in a plane-parallel displacement of cylindrical grinding chambers - tubes in the plane perpendicular to their axis, in which each point of the grinding chamber move-s along a circle with a radius equal to the length of the crank r of the mill mechanism (figure 1).

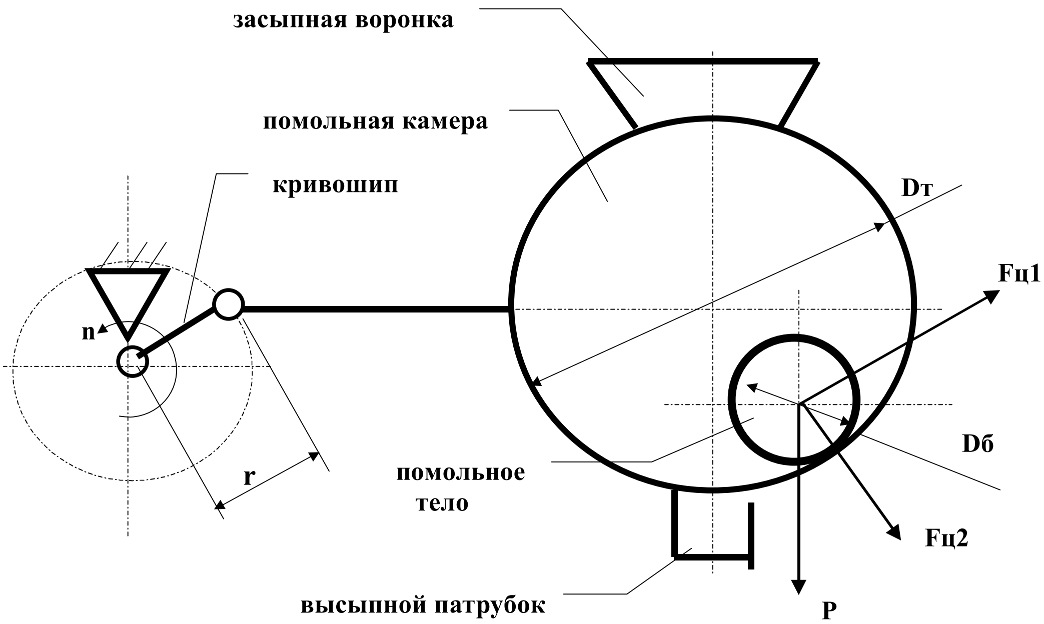


Figure 1 – Motion scheme of one grinding body in the grinding chamber

The plane-parallel displacement of the grinding chamber allows the hopper to be kept at the top all the time, and the discharge nozzle is at the bottom, which creates a great convenience for backfilling the raw materials and unloading the finished product from the grinding chamber. Such movement of the grinding chambers creates a sufficiently strong and vigorous mixing of the cylindrical grinding bodies in the grinding chamber.

Let us consider the motion of a single cylindrical grinding body with mass m and diameter $D_б$ in the grinding chamber-tube with a diameter $D_т$ when the crank is rotated with radius *r* at a frequency *n* (figure 1). When rotating the crank on the grinding body, the following applies: 1. The gravity P=mg, directed always downwards. 2. Centrifugal force $F_{ц1} = mr\ (\pi n/30)^2$, which is parallel to the crank position and rotates together with the crank in the same direction with the same frequency *n*. Under the action of this force, the grinding body begins to move along the inner surface of the grinding chamber-tube. The motion occurs along a circle with $R_к = (D_т – D_б)/2$ in the same direction as the rotation of the crank. The force $F_{ц1}$ is directed along the tangent to the circumference of the motion of the grinding body. In this motion, the second centrifugal force $F_{ц2}$ appears, which is directed along the radius of the grinding chamber-tube, its value is $F_{ц2} = mR_к\ (\pi n/30)^2$. This force always presses the grinding body against the wall of the grinding chamber-tube. From these considerations, it is clear that the grinding body in the general case has three forces. All these forces are involved in the grinding of raw materials entering the grinding chamber. Forces P and $F_{ц2}$ press the raw materials, and the force $F_{ц1}$ breaks the raw material, we have a combined effect on the product of the grinding.

Let us consider the interaction of several identical grinding bodies in the grinding chamber (figure 2). It can be seen from the figure that the force $F_{ц1}$ and the gravity P act on all the grinding bodies. The grinding bodies occupy different positions in the tube of the grinding chamber, therefore only one body can occupy such an arrangement when its force $F_{ц1}$ is directed to the circumference of the movement, and only for this body, it is a completely moving force. In figure 2, this is the body 3. For the remaining bodies, the force $F_{ц1}$ is partially moving, this body is 2, which does not have a moving value, the body 4, the opposing motion, the body 1. In this case, it turns out that only one grinding body is fully driven, acts as the engine of the entire system of grinding bodies. Some bodies help it in this action, some counteract. Naturally, the rotation of the entire grinding body system occurs at a frequency n_1 much inferior in frequency *n*, because in this case there is an opposition to certain bodies. If the values of the rotation frequencies do not coincide, all grinding bodies of the system are in the role of the engine of the entire system in order. In this case, the forces in the system are equal: $P = mg$; $F_{ц1} = mr\,(\pi n/30)^2$; $F_{ц2} = mR_к\,(\pi n_1/30)^2$. Since the forces $F_{ц2}$ are aimed in different directions, their vector sum is small, and in practical calculations, their influence on the equilibrium of the mill is not taken into account.

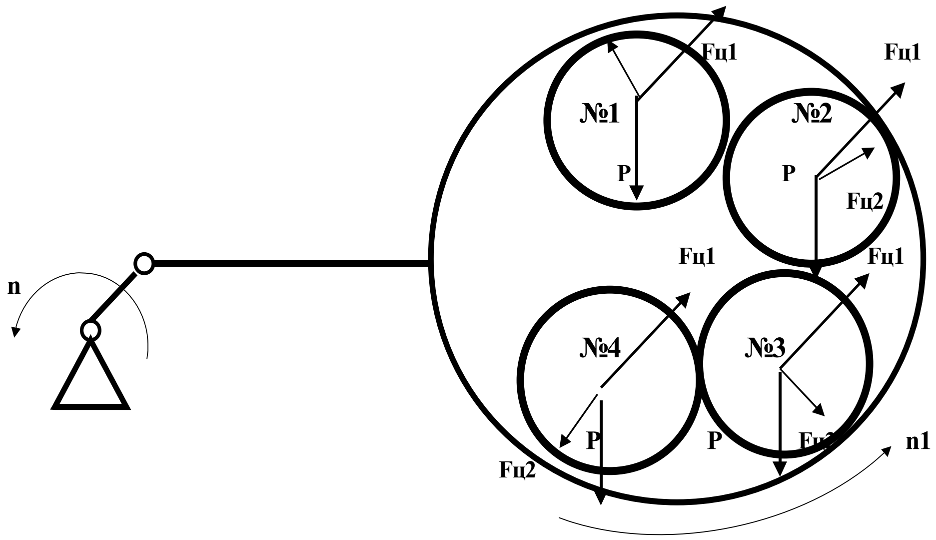


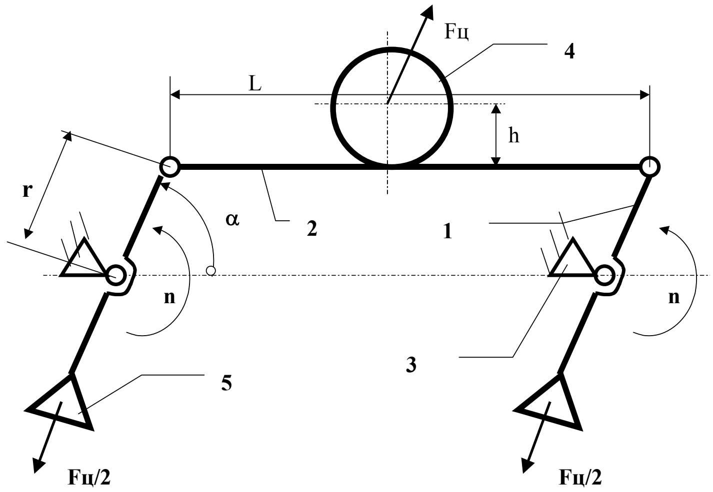
Figure 2 – Motion scheme of several grinding bodies in the grinding chamber

For the successful operation of the grinding body system, it is very important to ensure their movement with pressure against the tube walls, but taking into account the fact that $n_1 << n$, as well as the resistance of the raw materials in the grinding chamber contributes to the decrease in the value of n_1, the condition of constant clamping of the bodies to the walls of the tube is not always satisfied, especially during the passage of the upper point. In this case, it should be ensured that the upper grinding body cannot fall to the center of the tube, which instantly will absorb the entire rhythm of movement of the grinding bodies. This can be achieved by selecting geometric parameters - $D_б$, $D_т$ and the number of grinding bodies - N. From practical experiments it is seen that the optimal value of N=4, with N=3 in the grinding chamber, there is too much free space, with N=5, while ensuring that all grinding bodies are pressed against the tube wall, too much space is also released in the center of the tube. It also follows from the experiments to choose the parameters $D_б$ and $D_т$ from the following ratio $D_т/D_б = 2.6 - 2.7$.

Currently, there is a basic design of the mill, working on this principle. The scheme of this mill has a number of significant disadvantages that prevent the widespread use of mills of a similar type. These are a dynamic imbalance of the mill, a large metal capacity of the structure, its complexity and cost. The diagram of this mill is shown in figure 3. It consists of two identical cranks 1, connected by connecting rod-driver 2, which together with the rack 3 constitute the parallelogram. The rod 2 has the grinding chamber 4. Cranks 1 have counterweights 5.

To fully balance the mechanism, it is necessary that the vector sum of all the static forces applied to the mechanism (1), the sum of the twisting moments of these forces (2), the vector sum of all the dynamic

Figure 3 –
Scheme of the basic design of the mill



forces (3) and the sum of the torques of these forces (4) would be equal to zero, that is the condition would be satisfied:

$$\Sigma Pi = 0; \tag{1}$$

$$\Sigma Mi = 0; \tag{2}$$

$$\Sigma Fqi = 0; \tag{3}$$

$$\Sigma Mqi = 0. \tag{4}$$

In the above scheme, condition (4) is not always satisfied. When the condition (3) is fulfilled, the centrifugal force of the grinding chamber $F_ц$ is to be equalized by the centrifugal forces of the two counterweights, hence the force of one counterweight is $F_ц/2$. The grinding chamber 4 is installed in the center of the rod 2, the length of which is equal to L. The center of gravity of the grinding chamber 4 in this circuit is always raised to the value h relative to the rod line. This is dictated by design requirements. The condition (4) for this scheme is as follows:

$$(F_ц/2\ )\ L * \sin\alpha - F_ц\ ((L/2)* \sin\alpha + h * \cos\alpha) = 0$$

This equation will be zero only if h =0 or $\alpha = 90^0$ or 270^0.

Dynamic unbalance of the mill contributes to the appearance of the strong vibration during operation, which leads to its rapid destruction. It should also be noted that the considered scheme has an excessive connection, which also leads to the appearance of vibration, complicates the manufacture of the mill and its assembly. Cranks 1 are driven into rotation by means of a gear reducer, cranks rotate in one direction at a time. The presence of two parallel kinematic chains determines the presence of an excessive bond.

Let us consider the principle of the drive of the new mill. The engine 1 (figure 4) rotates the shaft 3 through the reduction gear 2, the cranks 4 and 7 rotate with it. The crank 4 rotates the driver 5 together with the grinding chambers 6. The crank 7, interacting with the groove 10 of the lever 9, causes the latter to perform the oscillatory motion. Lever 9 works like a link. The other end of the lever 9 also oscillates with the finger 12. The mechanism parameters are adjusted so that the axis of the finger 12 is always in line with the vertical axis of the groove 13, which in this case can only move vertically relative to the finger 12. Since the groove 13 is part of the driver 5, the driver 5, making a rotation along with the crank 4, all the time retains its parallelity with respect to the horizontal, that is, it performs a plane-parallel motion. Grinding chambers 6 also move with them.

This scheme has no excessive bonds, is dynamically balanced, does not require the use of gear wheels, is structurally simple.

Parameter	Basic version	Rocking mill
Number of bearings	10	5
Number of crankshafts	2	1
Number of gears	3	0
Number of counterweights	4	1

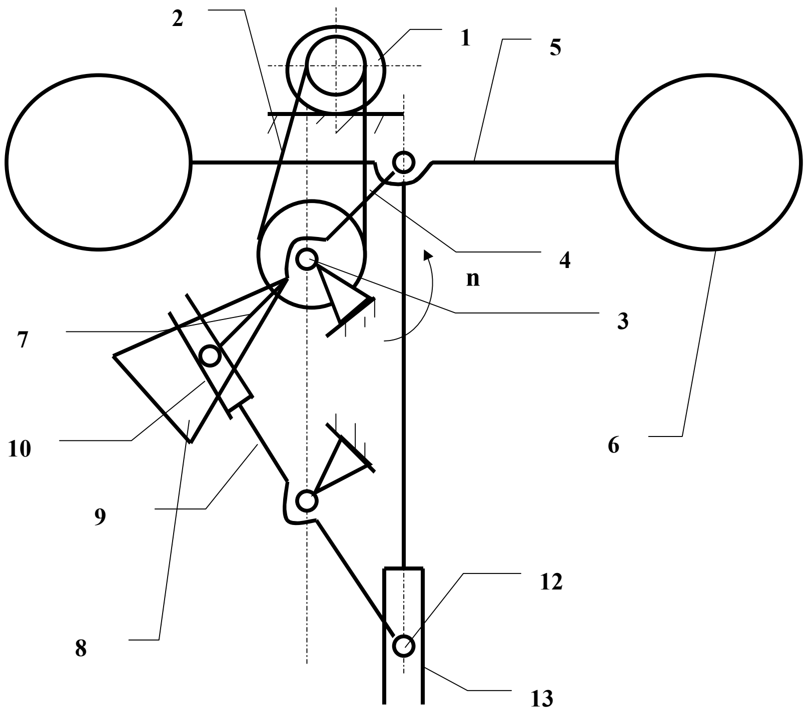


Figure 4 – Scheme of the centrifugal-rocking mill

Technical characteristics of the centrifugal-gyratory mill: productivity 300 kg/hour of ore per hour. Dimensions 1000x 900x800 mm, approximate weight 300 kg, drive power 2.2 kW, shaft speed 500 min^{-1}. The initial pieces are 20-40 mm, the finished product is 40-70 μm (main fraction). The new design of the centrifugal mill is proposed, the specific output of which is 140 kg/kW or 8 kW/ton of product (different types of raw materials were used during the test) [8]. This mill consumes three times less energy than the ball mill. The weight of the proposed mill with a capacity of 10 tons per hour will be at the level of 7-8 tons. The complexity of the structures can be said to be small since the proposed mill has 1 eccentric shaft, 5 bearings, no gears. Weight is reduced by 2 times.

The results of the work are promising for introduction at the enterprises of mining and concentrating industry of Kazakhstan and can be used in mining and processing enterprises of foreign countries.

It should be noted that there are no mills with such operating parameters, according to the open press data. Data on Russia, South Africa, the United States, and Germany were analyzed.

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ТАУ-КЕН ӨНДІРІСІНДЕ ҚОЛДАНЫЛАТЫН ЦЕНТРДЕН ТЕПКІШ ДИРМЕННІҢ КОНСТРУКЦИЯСЫ

Аннотация. Қазахстан республикасының аумағында орналасқан тау-кен өндірістерін энергияны тиімді қолданатын диірменнің жаңа типті түрімен қамтамасыз ету. Тау-кен өндірісінде қолданылатын қондырғылар арасында диірмен энергияны көп пайдаланатын құралдардың біріне жатады. Сол себепті энергияны үнемді пайдалану өзекті мәселелердің біріне жатады.

Центрленген-гирационды диірмен әртүрлі минералды шикізат көзін уатуға арналған диірмен. Бұл типті диірмендер бұрыннан белгілі және жұмыс істеу барысында жақсы нәтижелер көрсетті. Диірменнің негізгі ерекшелігі электрқуатын тиімді пайдалану болып саналады.

Жазылған жұмыста кулисті механизм негізі болатын центрленген-гирационды диірменнің конструкциясы зерттелген. Бұл диірменнің анық біраз артықшылықтары бар: конструкцияның оңайлатуы, жоғары динамикалық тұрақтылығы, энергия көзін екі есе аз пайдалануы және т.б.

Ең алғаш рет тәжірибелерді «Пайдалы казбаларды байыту Ғылыми-зерттеу институтының» полигонында жүргізілген. Ол Қазақстан Республикасының минералды ресурстарын өңдейтін ұлттық центріне енеді. Диірменнің жұмыс істеу принципі зерттеліп, цилиндрлі ұнтақтағыш камералардың параллельді жазықтық арқылы қозғалыс жасап, камералардың сыртқы диаметрі бойынша кривошиптің ұзындығына сәйкес қозғалады. Центрден тепкіш күштің мәні, салмақсыз динамикалық күштер мен моменттер, сонымен қатар күштік анализ жасалған.

Нәтижелері. Ұсынылып отырған диірменді зерттеу нәтижесінде өнімділіктің үлестік көрсеткішібір тонна өнімге 140 кг/кВт немесе 8 КВт құрайды. Осы көрсеткіштің арқасында зерттеліп отырған диірмен шарлы диірменнен 2 есе артық. Бұл сұлбада механизмдердің теориялық теңдесуі алынған. Елеулі конструктивті жетістіктер бар: бір кривошипті білік, тісті дөңгелектерді қолдануды талап етпейді, артық байланыс жоқ. Соған орай конструкциясының жеңілдеуін байқаймыз. Сонымен қатар, жөндеу жұмыстарының жоғарылағанын байқауға болады.

Ғылыми өзектілігі: центрленген-гирационды диірменнің конструкциясын зерттеп, диірменде өтетін процестерді, яғни ұнтақтау, энергосыйымдылықты, металлсыйымдылықты және диірменнің өнімділігін оңтайлы процестер қатарына енгізу.

Практикалық маңыздылығын. Эксперименталды және есептеу, сонымен қатар рационалды конструктивті және технологиялық параметрлер негізінде, диірменнің металсыйымдылық көрсеткіші жоғары емес екендігі сипатталып, диірменнің өзқұндылығының арзан болуын айтуға болады, мысалы, шарлы диірменмен салыстырғанда 3 есеге, казіргі таңда қолданылып жатқан центрленген диірмендермен салыстырғанда 1,5 есеге төмен. Сонымен қатар диірменді жөндеуге жарамдылық жұмыстары қиындықсыз жүргізіледі. Ең негізгі көрсеткіші болып – бұл энергияны ұтымды пайдалану көрсеткіші басты рөл атқарады.

Түйін сөздер: центрден тепкіш-гирационды диірмен, ұсақтау, минералды шикізат, металсыйымдылық, энергосыйымдылық, конструкция, өнімділік,уату, кривошип.

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КОНСТРУКЦИЯ ЦЕНТРОБЕЖНО-ГИРАЦИОННОЙ МЕЛЬНИЦЫ ГОРНОРУДНОГО ПРОИЗВОДСТВА

Аннотация. Обеспечить горнорудные предприятия Казахстана новым типом мельницы, имеющей пониженное потребление электроэнергии. Горнорудные мельницы являются основным потребителем электроэнергии в горнодобывающем секторе, в связи с этим задача понижения энергии очень актуальна. Центробежно-гирационные мельницы предназначены для перемола различного минерального сырья. Мельницы подобного типа известны уже достаточно давно и показали неплохие результаты в работе, одним из основных достоинств этих мельниц является пониженное потребление электроэнергии. При практических испытаниях данной схемы основным ее недостатком было выявлено высокая вероятность движения ведомого кривошипа по незапланированному (не штатному) закону движения, что приводит к поломке механизма. Даже малая неточность изготовления механизма, люфт могут привести к отставанию ведомого кривошипа от ведущего, особенно в зоне близкой к крайнему положению.

В данной работе исследуется конструкция центробежно-гирационной мельницы на базе кулисного механизма. Мельница имеет ряд преимуществ перед аналогами: упрощение конструкции, высокая динамическая устойчивость, затраты энергии уменьшены в 2 раза и т.д.

Впервые практические испытания мельниц проводились на полигоне Научно-исследовательского института обогащения полезных ископаемых Национального центра переработки минеральных ресурсов Республики Казахстан. Исследован принцип работы мельницы, который заключается в плоско-параллельном перемещении цилиндрических помольных камер – труб в плоскости перпендикулярной их оси, при котором каждая точка помольной камеры движется по окружности с радиусом равным длине кривошипа r механизма мельницы [5]. Рассчитаны центробежная сила противовесов, неуравновешенная динамические сила и моменты, проведен силовой анализ.

Результаты: Из показателей исследования видно, что предлагаемые мельницы имеют показатель удельной производительности равный 140 кг/кВт или 8 квт на тонну продукции. По этому показателю предлагаемые мельницы превосходят шаровые мельницы в 2 раза [3]. В этой схеме получена теоретическая уравновешенность механизма. Имеются существенные конструктивные достижения: имеется один кривошипный вал, нет избыточной связи, не требуется применения зубчатых колес, что значительно упростило конструкцию. Мельница имеет высокую ремонтопригодность.

Научная новизна. Новизна полученных результатов заключается в создании конструкций центробежно-гирационной мельницы, при которых обеспечивается оптимальный процесс помола, энергоемкость, металлоемкость и производительность мельницы.

Практическая значимость. На основе расчетов и экспериментальных данных, а также в определении её рациональных конструктивных и технологических параметров. Выявлено, что в процессе опытно-промышленного периода мельницы на полигоне Государственного научно-производственного объединения промышленной экологии «Казмеханобр» (Алматы), входящего в состав Национального центра по комплексной переработке минерального сырья Республики Казахстан, что мельница отличается невысоким уровнем металлоемкости, имеет невысокий уровень сложности конструкции, тем самым уменьшается стоимость мельницы по сравнению с шаровыми примерно в 3 раза, по сравнению с существующими центробежными мельницами в 1,5 раза. Испытания мельниц показали их экономичность в потреблении энергии, что является самым главным показателем.

Ключевые слова: центробежно-гирационная мельница, измельчение, минеральное сырье, металлоемкость, энергоемкость, конструкция, производительность, помол, кривошип.

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BIOCLIMATIC CONDITIONS OF CLIMATIC THERAPY ON THE COAST OF THE LAKE INDER OF THE REPUBLIC OF KAZAKHSTAN

Abstract. The article presents the results of the research of bioclimatic peculiarities on the coast of lake Inder (the Republic of Kazakhstan) on the basis of which the bioclimatic potential of this territory (2,25 points from 3,0 possible) has been estimated, and the category of its compliance for resort climatotherapy is high on condition that 60% is landscape gardening of the territory and building of a year-round climatic medical center. There have been developed some specific favourable bioclimatic features of this area (high purity of the ground atmosphere, the existence of biologically active ultra-violet solar radiation (with the wavelength of 290-315 nm) within a year, the existence of small doses of finely dispersed chlorhydric aerosol in the ground atmosphere, the increased level of natural aero ionization (till 1340 ion/cm^3) with a low coefficient of ion unipolarity (lower than 1,0), a long period with favourable conditions staying in the fresh air (280 days in a year). Bioclimatic conditions are favourable for organization year-round aero- and heliotherapies, natural aero ionization, terrainkur and recreational actions in the open air.

Key words: bioclimatic potential of the coast of lake Inder of the Republic of Kazakhstan, natural aero ionization, prospects of the organization of resort climatotherapy.

The relevance of the research is caused by the requirements of healthcare service of the Republic of Kazakhstan to develop resort medicine based on the use of natural medical resources (natural mineral waters, peloids, medical climate, recreational landscapes) as the most physiologic, highly effective, economically advantageous and available in application [1-3]. The question of construction on the coast of lake Inder (Atyrau region, Inderborsky territory) of the resort complex (RC) on the basis of usage of local natural medical factors (mineral waters, therapeutic muds, bioclimate) is being considered within the development of the sanatorium-and-health resort help to the population by Akimat of Atyrau region of the Republic of Kazakhstan.

Bioclimatic resources of the resort area are very important in the complex of natural medical resources, their naturalness, systemacity and physiology of influence. Usage of bioclimate features of the area in the treatment-and-prophylactic purposes has an advantage on medicinal therapy as climatic factors are habitual for the person, responses to them are fixed genetically, at their reasonable application there are no complications characteristic of medicinal therapy therefore they can be used for a long period of time, in courses and practically all life to temper, to train and to raise nonspecific resistance of an organism, to restore lost health, to increase life quality and duration of the period of active life [1, 4, 5].

The role of special methods of climatotherapy is especially high (air and solar baths, sleeping in the fresh air, medical terrainkur, medical swimming in the pool, health-improving rest in favorable bioclimatic conditions) at which there is a training of humoral, nervous and other mechanisms of thermal control, the vitality increases and adaptation opportunities of an organism extend. The use of climatotherapy makes synergistic positive impact on other resort treatment modalities promoting the increase in efficiency of rehabilitation treatment [6, 7]. Climatotherapy promotes the development of a number of nonspecific and specific body reactions directed to its improvement, especially at chronic or slow pathological processes. Nonspecific action of climatic factors can be presented in such sequence: thermoadaptation change; optimization of exchange processes; change of nonspecific and specific body reactivity: increase in general immunoreactivity, phagocytic leukocytes activity, decrease in sensitization of an organism; optimization of functions of organs and systems [8 7].

The experience shows that it is necessary to observe the requirements to bioclimatic conditions and influence doses of environmental factors in compliance with methodical recommendations to obtain high efficiency of climatotherapy. In this regard, the special relevance is acquired by researches of bioclimatic mode of the resort area on the basis of which the program of resort climatotherapy is carried out.

The objective of this research was to study balneological potential of landscape elements and bioclimate in the area of the planned construction of the health resort Inder and the assessment of prospects of their use for organization of various methods of climatotherapy and climatolandscape therapy.

Materials and methods. There have been used some observational materials of the following meteorological stations: the mountain (since 1999 mountain village Akkala) located in 5 km to the north of the settlement of Inderborsky settlement (the height above the sea level is 0 m, the width is 48037′09″ north latitude, the longitude 51045′30″ east longitude), from 1937 to 1943; Taypak (till 1993 Kalmykovo), located in 62 km to the north of Inderborsky settlement (the height above the sea level is 2 m, the width is $49^0$05', the longitude is $51^0$87', meteorological index is WMO 35406) from 1926 to 2017; the materials of own stationary (Inderborsky settlement) and route observations on 6 platforms different in microlandscape, located in the area of the supposed placement of HR Inder. On the stationary point, the following parameters were defined: actinometrical conditions (the intensity of straight and total solar radiation with the subsequent calculation of transparency coefficient and turbidity factor), microclimatic conditions (temperature, humidity and air pressure, an amount of precipitation - continuous registration for the electronic media). Route observations included samples of microclimatic conditions (temperature and air humidity, atmospheric pressure, speed and direction of wind, quantity and form of clouds, atmospheric phenomena), concentration of light air ions of positive and negative charge (the mobility is $k > 0{,}5$ cm^2/V s) and also the visual assessment of orography, landscape and esthetic quality and comfort of the landscape for climatolandscape therapy purposes, description of vegetation species in the area of HR Inder.

The article deals with standard technologies of climate research, special complex assessment methods of climate and landscape for medical purposes [2, 4, 9, 10-13].

Research results

Landscape features of the territory of the supposed building of the health resort near lake Inder are caused by their location in the northern suburb of Caspian Plain in the western steppe semidesert part of the Republic of Kazakhstan on the bank of brine lake Inder. The area is a poor hilly steppe plain delimited by low (to 56 m above the sea level) flat bushlike ridges and barrows of open-casts (102 units) in the north where borates were produced and lake Inder in the East. Northern and northeasten banks of the lake border Indersky mountains (the maximum height is 54 m above the sea level). In geomorphological relation, the area is located within the plateau-like upland of Indersky dome fold rising over lake Inder by 15-25 m with a slight slope to the South. Wide expansion of low depositional plains is an important factor of active manifestation of processes of natural and anthropogenic desert advancing.

The soil cover of the considered territory is presented by generally light-chestnut soils for which it is characteristic to have a small capacity of humic layers with a small amount of humus – 2-3% (slightly humic), solonchak soils and alkali soils and is used mainly for poorly intensive grazing of animals (horses, cattle and camels).

In geographical relation, the area is located in typically flat monotonous area in a steppe zone with fescue-vermuth vegetation. The vegetative cover is generally made by drimophilus: sagebrush, fescue, common thistle, sea lavender, seepweed and others, in some places there are such plats as kochia, ebeleck, eurotia, orach, and needle grass among sagebrush. In the spring there are tulips (mainly Shrenk's and Greig's tulips included in the Red Book of Kazakhstan), steppe iris and other ephemers plants and efemeroids. The territory is characterized by natural cover in original state dislocated mainly by numerous holes of ground squirrels and automobile unmade roads.

In the East of the territory of the planned HR, there is a brine deposited terminal lake of the tectonic type Inder. The area of the mirror is about 110 square kilometers, the length is about 13,5 km, the width is about 10 km, the depth is to 56 m, the shape is rounded slightly extended from the northwest to the southeast. Lake recharge is generally underground (chlorhydric springs), snow and rain. In the lake the extraction of salt is being produced, the width of the salt layer is up to 15 m. The lake bottom is marshy covered with a layer of peloids (about 4 m), the brine of the lake has a high mineralization (about 300 g/m^3). Nowadays the brine and mud on the lake banks are used for a spontaneous balneo-mud-cure.

The territory of the supposed placement of HR Inder is not subject to flooding.

In the conditions of terrain uniformity the landscape attractiveness for resort and recreational use will depend on many factors including the qualified approach to the construction of the modern complex of medical and recreational buildings, composition methods in development of space; creation of an oasis of green wood and shrubby plantings with good decorative properties, high environment-forming, phytontsid, esthetic and sanitary and hygienic functions which have the ability to microclimate correction from strong winds that are cold in the winter and hot in the summer.

Bioclimatic capacity of the area is formed under the influence of major climate factors: solar radiation, atmospheric circulation, geological substrate and ecological features of the territory. An important climatic feature of the considered territory is the abundance of sunny days (up to 60% of days in a year are clear, and in summer months - up to 80%), high duration of sunshine (about 2500 hours a year on average), big inflow of solar heat (up to 11000 mJ/m^2 a year). Within a year there are up to 40 cloudy days on average, 90% of which fall in cold season. The territory belongs to the regions with abundant of ultraviolet (UV) solar radiation, the phenomena of UV deficiency are absent (at noon in the winter UVI is 0,3-1, in the summer to 9-10).

Climatic conditions of these places in an essential measure are caused by considerable removal from the oceans, lack of high mountain barriers, a flat arrangement in the north of Caspian Depression. It causes planetary circulation over the considered territory - air masses freely move both from the west to the east, and from the north to the south. At the western (lateral) circulation pattern there are latitudinal wedges of hypertension are established or there is a shift from the west to the east of anti-cyclonic systems moving through of low pressure, sometimes with atmospheric fronts. On average at the latitudinal circulation pattern, there is a sediment supply deficit and a raised temperature background.

At ingress of the Arctic air (generally in the winter) anti-cyclonic weather is set – slightly overcast and frosty. Air masses of temperate zone soften weather a little and bring the bulk of precipitation, but as on the way they lose a significant amount of humidity, there is little precipitation here. Subtropical and tropical air masses from Central Asia reach the North of Caspian Depression mainly in warm season establishing very hot dry weather in the summer and thaw in the winter. Humid air masses and monsoons from the Indian Ocean are blocked by mountains in the south.

The wind regime in the considered territory has a pronounced annual course. In winter time east and southeast winds (under the influence of the periphery of the western spur of Siberian anti-cyclone) prevail, in summer months - winds of northern bearings, and in off-season – west-eastern transfer. The average monthly wind speed fluctuates within 3,4-5,0 m/s (maximum in February, March, minimum – August, September). In all months of a year, the most probable speed of wind is 2-5 m/s (25-27% of the total number of cases). Daily average with strong wind (≥ 15 m/s) is 30 days, with dust storms - to 20 days.

According to climatic zonation, the considered territory is included into the zone with hot long summer (144 days on average) and cold, sometimes severe winter (about 136 days), spring (about 45 days) and fall (about 40 days) are short, differ in sharp change of the weather mode. Average annual amplitude on average monthly air temperature reaches 35^0C, and magnitude is about 90^0C (sharp continental climate). Average annual air temperature is about + 8^0C, in July about + 26^0C, in January near -9^0C. On average about 190 mm of precipitation fall in a year (from October to March – 92 mm, from April to October – 96 mm), within a year precipitations are distributed rather proportionally (12-15 mm a month) with a small maximum in the spring and in the fall (18-20 mm). The driest months are June-August (the humidity is about 40% on average), and the wettest are November-January (about 80%). The cloudiest days on cloud base happen in December and January (9 days a month), and clear on total cloud cover are in July-September (about 7-9 days a month). Average annual speed of wind is quite essential - about 4,5 m/s, in the summer – about 4 m/s, in the winter – about 5 m/s. An average number of foggy days are 40 days in a year, with blizzard – 15, with thunderstorm – 19, with hail – 0,5.

Summer in the considered area (from the beginning of May to the middle of September) are mainly sunny, hot and dry - air temperature often exceeds 30^0C (more than 60 days for a warm period) and 40^0C (1-2 days in each of summer months), average monthly relative humidity of air doesn't exceed 45%, air field moisture deficiency with aqueous vapour reaches 30 hPa, with a low amount of precipitation (12-17 mm a month on average, intensity is mainly of 1-5 mm).

Winter comes in the middle of November and lasts to the beginning of March and is characterized with cold, sometimes severe weather – the average temperature of winter months is near - $7\text{-}9^0$C; more than 30 days for the cold period air temperature falls below - 20^0C, 3-5 days - below -30^0C, up to 4 days during the winter there is a thaw period (to $+5^0$C). Snow cover is quite steady (up to 100 days in a year), low (10-15 cm on average).

Autumn is short (from the middle of September to the middle of November) with prevalence of dry and rather warm weather (average monthly air temperature in September is about 17^0C, October – about 8^0C, November – near $-0{,}5^0$C).

In the **spring** (from the beginning of March to the beginning of May) air temperature quickly grows (from $-1{,}5^0$C in March, 10^0C in April to 18^0C in May), the amount of precipitation increases (to 20 mm a month), wind speed amplifies.

Table 1 shows the elements of bioclimatic capacity of the territory of the supposed placement of HR Inder (in 33 modules) where each module has a category assessment of medico-climatic conditions according to their impact on a person (in points).

Table 1 – Bioclimatic capacity of the territory of the supposed placement of the health resort on the coast of lake Inder

Bioclimatic module	Value	Category of medico-climatic conditions	Assessment in points
1	2	3	4
1. Modules of bioclimatic mode			
Duration of potentially favorable period to hold active measures in the fresh air in clothes according to the season (terrainkur, walks, sport games, etc.)	280	Favorable (slightly biotropic)	3,0
Number of days with comfortable heatfeeling (ET is than 17- 21^0 at wind-and sun protection) during air baths at noon	42	Relatively unfavorable (moderately biotropic)	2,0
Number of days with warm heatfeeling (ET is higher than 22- 24^0 at wind-and sun protection) during air baths at noon	66	Relatively unfavorable (moderately biotropic)	2,0
Number of days with hot heatfeeling (ET is higher than 24^0 at wind-and sun protection) during air baths at noon	28	Unfavorably (highly biotropic)	1,0
Average severity degree of winter according to Bodman, points	3,2	Unfavorably (highly biotropic)	1,0
Frequency of weather severity more than 2 points, %	37	Unfavorably (highly biotropic)	1,0
Index of climate continentality according to L. Gorchinsky, unit	146,2	Unfavorably (highly biotropic)	1,0
Number of days in a year with the average daily air temperature above 15^0 (duration of the summer period)	140	Favorable (slightly biotropic	3,0
Number of days in a year with the average daily air temperature above 25^0 (duration of the heat wave)	30	Unfavorably (highly biotropic	1,0
Number of days with precipitation ≥ 5 mm in a year	55	Relatively unfavorable (moderately biotropic)	2,0
Average monthly air temperature in the summer, ^{0}C	26,0	Unfavorably (highly biotropic)	1,0
Average monthly air temperature in the winter, ^{0}C	-9,0	Relatively unfavorable (moderately biotropic)	2,0
Average monthly speed of wind in the summer, m/s	4,5	Relatively unfavorable (moderately biotropic)	2,0
Average monthly speed of wind in the winter, m/s	5,0	Unfavorably (highly biotropic)	1,0
Snow cover depth in the winter	Less than 15	Unfavorably (highly biotropic)	1,0
Daily average with thunderstorm, days	19	Relatively unfavorable (moderately biotropic)	2,0
Number of foggy days	40	Favorable (slightly biotropic)	3,0

Продолжение таблицы 1

1	2	3	4
2. Mode modules of solar radiation			
Number of hours of sunshine in a year	~2500	Favorable (slightly biotropic)	3,0
Number of hours of sunshine in July	~365	Favorable (slightly biotropic)	3,0
Number of hours of sunshine in December	~85	Relatively unfavorable (moderately biotropic)	2,0
Number of sunless days in a year	~50	Relatively unfavorable (moderately biotropic)	2,0
Number of sunless days in June	~2	Favorable (slightly biotropic)	3,0
Number of sunless days in December	~10	Relatively unfavorable (moderately biotropic)	2,0
Danger level of ultraviolet radiation reaching the land surface at noon in July	9-10	Unfavorably (highly biotropic)	1,0
3. Modules of circulatory mode			
Anti-cyclonic type of atmospheric circulation, %	Более 50	Relatively unfavorable (moderately biotropic)	2,0
Degree of wind effect: number of days with a wind speed of 15 m/s and more	30	Unfavorably (highly biotropic)	1,0
Number of days with dust storms	20	Unfavorably (highly biotropic)	1,0
4. Mode modules of air humidity			
Values frequency of relative humidity that is lower than 30%, days per year	110	Unfavorably (highly biotropic)	1,0
Values frequency of relative humidity at noon that is more than 80%, days per year	80	Unfavorably (highly biotropic)	1,0
Monthly mean degree of air saturation at 1pm in July, %	30	Relatively unfavorable (moderately biotropic)	2,0
Monthly mean degree of air saturation at 1pm in January, %	81	Unfavorably (highly biotropic	1,0
Formation degree of sultriness: sultry weather frequency in the summer, %	5	Favorable (slightly biotropic)	3,0
5. Modules of air ionization			
Middle number of oxygen ions of negative (N-), ion/cm^3 (according to an autumn episode)	669	Favorable (slightly biotropic)	3
Coefficient of unipolarity of ions (CUI)	0,49	Favorable (slightly biotropic)	3,0
Integral assessment of К(ВСР) = ∑К1+……+ К33 / 33 = 62/33=1,88 point		Relatively unfavorable (moderately biotropic)	1,88

The carried-out analysis has shown that in general the weather mode in the area of the supposed placement of HR Inder is estimated as training (the integrated indicator of bioclimatic potential of K(BCP) makes 1,88 points from 3,0 possible) which corresponds to rather favorable conditions for climatotherapy organization.

It is necessary to refer the increased level of natural aero ionization to number of positive bioclimatic features of this area – 669 ion/cm^3 (maximum 1340 ion/cm^3) with low coefficient of ions unipolarity (0,49) which is substantially connected with the influence of brine lake Inder where one can find discovered salt d eposits of high quality on 110 km^2 of the surface. As the result of the atmosphere circulation there is a separation and transfer of particles of salt aerosol, fine particle fraction (1-5 micron) of which reaches deep divisions of respiratory tract and has multicomponent medical effect of extremely small doses of substance.

The salt aerosol which is present at the ground atmosphere in small doses stimulates protective mechanisms of respiratory tract, it possesses sanogenic, bronchodraining, anti-inflammatory, immuno-supportive action. The salt aerosol has an inhibiting effect on the growth and microorganisms activity which is followed by the process of their loss of pathogenic properties. Natural antimicrobial action peculiar to sodium chloride doesn't render negative effect on local protection and promotes improvement of biocenosis of respiratory tract.

The light negative air ions in the air medical environment which are present at the ground atmosphere intensify metabolism and local protection of biological tissues, favorably affect cardiovascular, endocrine systems, digestive tract, mucous membranes of respiratory system, cause adaptogenic action on central and peripheral stress-limiting systems of an organism.

The influence of negative aeroions affects a series of functions of certain organs (vegetative – organic, gas, mineral, water exchange, angenesis, activity of endocrine glands, respiration rhythm and cordial beats, blood structure etc and animal – excitability of nervous and muscular tissues), vital activity of all the organism in general (body height, sexual function, motility, reflexes) and implications of the highest nervous and mental activity [4].

The aero ionic mode is very variable, it depends on the season, an hour, meteorological and anthropogenic factors. In environmentally friendly resort areas the average concentration of the negative ions is 400-700 ion/cm^3. However, in case of the increased aerosol air pollution, high or very low air humidity the level of the negative aero ionization of the air sharply decreases, sometimes to extremal values (lower than 100-200 ion/cm^3). At favorable bioclimatic conditions and low level of aerosol impurity in the ground atmosphere the level of negative aero ions can reach 1200-2500 ion/ cm^3 [14].

Route aero ionization and microclimatic observations in the considered territory and the adjacent area were carried out on 6 platforms with various landscape conditions (table 2) – on the plateau of Indersky mountains where it is supposed to build HR Inder (observation point 1), on the bank of lake Inder (observation point 2), on the tops of the nearest open pits of borat production (observation points 3 and 5) and in their bottom next to picturesque lakes (observation points 4 and 6).

According to route researches in the area of lake Inder the concentration of light negative aero ions (N–) was higher than the level of physiological norm [13], and positive (N+) – below; KUI was in normal limits. In territorial distribution – maximum value (N–) are noted on the plateau 726 an ion/m^3 and on the

Table 2 – Natural ionization of air and microclimatic characteristics in the area of the supposed building of health resort near lake Inder

Observation points	Ionization level, ion/cm^3		CUI (N+/N–), (point)	t, ^{0}C	f, %	v, m/s
	N– (point)	N+				
1. In the area of the headstream Tuzdybulak, ~ -200 m from Lake Inder, the plateau on the NW from the lake	726 (3)	336	0,46 (3)	15,6	32	1,7-2,2
2 The bank of lake Inder, NW sector of the lake, in the area of the headstream Tolepbulak (~ 20 m from the lake face and ~ 10 m from the rock), a crust of silt mud	678 (3)	317	0,47 (3)	8,0	54	2,3-6,7
3. Near pit 99/2, the territory of the Inder mountains and pit barrows, ~ 700 m to the NNW from lake Inder	652 (3)	386	0,59 (3)	6,9	58	1,5-12,2
4. At the bottom of pit 99/2, the width is ~ 200 m, the length is ~ 400 m, near the pit lake	640 (3)	355	0,54 (3)	13,0	34	0,8-1,9
5. Near pit 98, the territory of the Inder mountains and pit barrows, ~ 1 km to the NNW from lake Inder	661 (3)	322	0,49 (3)	7,3	55	0,8-1,9
6. At the bottom of pit 98, the width is ~ 200 m, the length is ~ 400 m, near the pit lake	628 (3)	265	0,42 (3)	9,0	59	2,3-4,5
Average number	664 (3)	330	0,50 (3)			
Maximum value	1340	1090	0,59	15,6	59	12,2
Minimum value	120	120	0,42	6,9	34	0,8
Minimum allowed regulations [19]	600	400	0,4-1,0			
Интегральный модуль по уровню природной ионизации воздуха Integrated module according to the level of natural air ionization [∑(N–)+∑CUI] /n	∑(N–)/n = = 3 points		∑КУИ/n = = 3 points	Integral module [∑(N–)+∑CUI] /2 = 3 points		

Note. N+ and N– are respectively concentration of light positive and negative aero ions (ion/cm^3); KUI is the coefficient of unipolarity of ions (a ratio of concentration of positive and negative ions); t is the air temperature (^{0}C); f is relative humidity of air (%); v is wind speed (m/s); n is the quantity of series of observations.

bank of Lake Inder (N- 678 ion/m^3); the smallest, respectively, in the bottom of pits 98 and 99/2 (N– 628, 640 ion/m^3). KUI on all the sites corresponded to low aerosol air pollution (lower than 1,0) – respectively 0,42-0,59. The integrated module according to balneological scale reached maximum possible values – 3,0 points.

Complex assessment of resort and recreational capacity of the territory of the supposed building of HR Inder for medical and improving use makes 2,25 points from 3 possible (it was calculated proceeding from indicators of modular components: landscape - 1,88 point, bioclimate - 1,88 point, microclimate - 3,0 points and ecological state 2,25 points) which corresponds to the high rehabilitation potential and broad resort and recreational opportunities for the organization of special forms of climatic and landscape therapy in this territory.

The modern natural landscape doesn't perform any "Social and economic functions" and belongs to the category "not in use nowadays" [3]. Its features meet the requirements imposed in the design of constructions with climatic treatment (summer and winter aerosolaria), organization of platforms for landscape treatment, tracking terrenkur (on condition of construction of the park with wood and shrubby vegetation that occupies not less than 40-60% of the planned territory of HR Inder).

The ground atmosphere in the area of the supposed construction of HR Inder is characterized by the increased maintenance of negative aero ions (to 1340 ion/cm^3), at low (favorable) coefficient of unipolarity of ions (KUI = 0,42-0,59). Microclimatic distinctions on platforms of the territory, different in landscape, were insignificant, weather conditions were close to climatic norm for this period of the year. The integrated module of natural air ionization made 3,0 points (very high).

Solar radiation sufficiency is estimated as rather favorable (365 hours in July; 30 hours in January). During the whole year the solar range has biologically active ultra-violet solar radiation (with the wavelength of 290-315 nanometers). According to these indicators the territory of HR Inder is among rather favorable for the organization of year-round (except for the periods of strong cold and heat) heliotherapy (integrated rehabilitation potential of solar radiation reaches 2,28 points from 3,0 possible).

Atmospheric circulation to which variability meteosensitive patients especially react in this territory is for the whole year estimated by irritating influence mode (circulating potential is 1,33 points from 3 possible) which indicates the appicability of the planned meteoprophylaxis. The construction of the park with wood vegetation will promote the correction of wind mode and the improvement of microclimate in this territory.

The ecological state in the area of the supposed construction of HR Inder corresponds to features of its arrangement far from large industrial centers. The integrated indicator of air pollution is equal 2,25 points which is estimated as a low level of anthropogenic influence. The sanitary condition of the territory has to be monitored constantly and be supported by a complex of relevant activities for its improvement.

Table 3 – Perspective types of year-round climatic and landscape treatment in the territory of the supposed construction of HR Inder

Kinds of climatic and landscape treatment	Requirements to the organization of climatic and landscape treatment
Air baths at rest and in combination with physical exercises, aero chromotherapy (all the year round)	Summer and winter aerosolaria (or specially equipped climatic chambers, climatic platforms) with corrective microclimate devices, medical and bioclimatic control
General or local insolation, baths of the light solar radiation (during the warm period of year)	
Day and night sleeping in the open air (all the year round)	
Long-term rest in the fresh air in clothes according to the season (all the year round)	The equipped recreational platforms (in the summer - in a shadow of trees, in the winter – on the sunny side)
Trainings with measured (healthy) walking on terrainkur (all the year round)	The equipped avenues of terrainkur with breakdown by stations (through each 100 m) equipped with benches and arbors for rest. It is possible to use the former pits with terraced slopes and picturesque lakes at the bottom for these purposes
Aeroionophytotherapy (during the warm period of year)	Platforms with certain vegetable associations

The listed above indicators of the condition of environments correspond to resort areas with favorable gentle training mode of climate exposure, landscape and ecological state on a human body and testify to the raised potential opportunities for the organization of various forms of climatic-landscape therapy all the year round: aero therapies and heliotherapies both in the open air and in specially equipped aerosolaria; natural aeroionophytotherapy in the summer; physical trainings with walking including "Scandinavian", on health paths; nearby tourism (table 3).

Conclusion. The complex research of resort and recreational capacity of the territory of the supposed construction of resort Inder for health improving use has revealed a high rehabilitation potential (2,25 points from 3,0 possible) and broad resort and recreational opportunities for the organization of special forms of climatic treatment in this territory. The bioclimate of the territory creates rather favorable background for other resort methods of treatment. There have been found specific favorable bioclimatic features of the given area: high purity of the ground atmosphere, existence of biologically active ultraviolet solar radiation (with the wavelength of 290-315 nanometers) within a year, existence of small doses of finely-divided chlorhydric aerosol in the ground atmosphere, the increased level of natural aero ionization (to 1340 an ion/cm^3) with low coefficient of unipolarity of the ions (lower than 1,0) characterizing the ground atmosphere of the coast of lake Inder as clean with high medical and improving functions, the long period with favorable weather conditions to stay in the fresh air (280 days in a year). Bioclimatic conditions are favorable for the organization of year-round aero - and heliotherapies, natural aero ionization, terrainkur and recreational activities in the open air on condition that 60% of the gardening of the territory and the construction of a year-round climatic medical centre.

The organization of a health resort complex on the coast of lake Inder (the Republic of Kazakhstan) corresponds to the State programme of development of health care of the Republic of Kazakhstan "Densaulyk" for 2016–2019, its purpose is to strengthen health of the population for ensuring sustainable social and economic development of the country [15].

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫ ИНДЕР КӨЛІ ЖАҒАЛАУЫНЫҢ КЛИМАТПЕН ЕМДЕУДІҢ БИОКЛИМАТТЫҚ ЖАҒДАЙЫ

Аннотация. Мақалада Қазақстан Республикасы Индер көлі жағалауының биоклиматтық ерекшеліктеріне жүргізілген ізденістердің нәтижелері келтірілген, осының негізінде аймақтың биоклиматтық потенциалы (3,0 мүмкіндіктен 2,25 балл) бағаланған және жыл бойына климаттық емдеу мекемесін тұрғызып, оның 60% аймағын көгалдандырған жағдайдакурорттық климатпен емдеу мақсатындағы сәйкестік категориясы - өте жоғары. Осы жердің биоклиматтық ерекшелігінің өзіндік қолайлылығы (жербеті атмосферасының тазалығының жоғарлылығы, жыл бойына күн радиацының (толқын ұзындығы 290-315 нм) биологиялық активті ультракүлгін сәулесінің бар екендігі, жербеті атмосферасында ұсақдисперциялық тұз аэрозолдарының дозасыныңаз деңгейде кездесіп, табиғи аэроиондардың деңгейінің жоғарлығы (1340 ион/см^3 дейін) иондардың бір полюстілігі (униполярлығы) коэффициентінің төмен (1,0 төмен), қолайлы жағдайдағы таза ауада болу мерзімінің ұзақтығы (жылына 280 күн)) анықталды.Биоклиматтық жағдайы жыл бойына аэро- және күн тераппиясын, табиғи аэроиондық терренкур және ашық ауада рекрациялық іс-шаралар ұйымдастыруға қолайлы.

Тірек сөздер: Қазақстан республикасы Индер көлі жағалауының биоклиматтық потенциалы, табиғи аэроиондау, курорттыкклиматпен емдеуді ұйымдастырудың болашағы.

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БИОКЛИМАТИЧЕСКИЕ УСЛОВИЯ КЛИМАТОЛЕЧЕНИЯ НА ПОБЕРЕЖЬЕ ОЗЕРА ИНДЕР РЕСПУБЛИКИ КАЗАХСТАН

Аннотация. В статье приводятся результаты исследования биоклиматических особенностей на побережье озера Индер (Республика Казахстан), на основе которых оценен биоклиматический потенциал данной территории (2,25 балла из 3,0 возможных), и категория ее соответствия для целей курортного климатолечения – высокая при условии 60% озеленения территории и строительства круглогодичной климатолечебницы. Выявлены специфические благоприятные биоклиматические особенности данной местности (высокая чистота приземной атмосферы, наличие биологически активной ультрафиолетовой солнечной радиации (с длиной волны 290-315 нм) в течение круглого года, наличие в приземной атмосфере малых доз мелкодисперсного соляного аэрозоля, повышенный уровень природной аэроионизации (до 1340 ион/см^3) с низким коэффициентом униполярности ионов (ниже 1,0), продолжительный период с благоприятными условиями для пребывания на свежем воздухе (280 дней в году). Биоклиматические условия благоприятны для организации круглогодичной аэро- и гелиотерапии, природной аэроионизации, терренкура и рекреационных мероприятий на открытом воздухе.

Ключевые слова: биоклиматический потенциал побережья озера Индер Республики Казахстан, природная аэроионизация, перспективы организации курортного климатолечения.

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SEISMIC SIGNAL REGISTRATION WITH AN ACOUSTIC DETECTOR AT THE TIEN SHAN MOUNTAIN STATION

Abstract. The program of future development of the scientific detector complex at Tien Shan mountain cosmic ray station anticipates the creation of a system of high-sensitive microphones for registration of elastic disturbances of seismic origin in the acoustic frequency range. Synchronous operation of acoustic detector together with a widespread system of the cosmic rayparticles detectors permits to test the hypothesis on the possibility of microcrack creation in the deep seismic active regions of Earth's crustunder the influence of penetrative particles (the muons) which originateas a result of cosmic ray interaction with the atmosphere. The disturbance ofelastic oscillations which arise by the opening of microcrack propagatesas an acoustic wave within the mass of lithosphere and can be detectednear its surface as a momentary increase of acoustic noise. It is supposed that registration of such oscillations in correlation with passage moments of energetic cosmic ray particles can be a perspective earthquake forecast method in seismically active regions of the Earth. In this work, we discussthe design principles and possibilities of an acoustic detector which isbuilt on the basis of a high-sensitive microphone installed in a drilledhole, at the depth of 50 m from the surface, and is presently operating atTien Shan station. We present the results of the test acoustic signal registration which was held at the end of2017. The consideredinvestigation can be of a large importance for solving the problem of along-term earthquake forecast.

Key words: acoustic detector, cosmic rays, muon components, elastic seismic oscillations, synchronous recording.

Introduction. An actual problem of modern seismology is the long-term forecast of the level of seismic activity, in particular, of powerful earthquakes, in the seismically dangerous regions of the Earth. At present time the seismological science experiences a crisis which is connected both with the shortages of the existing theory of earthquake development and with the lack of any reliable method of earthquake forecast [1]. In fact, a multitude of methods which are applied now for prediction of the level of seismic activity such as the measurement of electric conductivity of the medium, the measurements of the deformation field and of the movement speed of different lithosphere regions, the measurements of the natural radioactivity level and the intensity of local neutron background, and the like [2, 3] are based on various physical phenomena which take place in the vicinity to the surface of the Earth's crust. Same shortages such as an extreme unreliability of the forecast and a poor reproducibility of the results gained are typical for the most part of these methods. These drawbacks are caused by the fact that the observable surface effects cannot be always unambiguously connected with an earthquake preparation in a certain region of the Earth.

Still, an open question of traditional seismology is the selection from an overwhelming information stream which comes from different seismological sensors of some distinctive signal on the approaching of a definite catastrophic earthquake with a strict forecast localization in the time and space. Usually, such a signal is lost irrecoverably against the steady background of small and non-dangerous earthquakes, and amongst the fluctuations of the large-scale geodynamics processes. Because of these obstacles, any plain signal of an earthquake preparation usually can be found only post factum.

In the late 1980s, the specialists of the P. N. Lebedev Physics Institute and the Institute of the Physics of the Earth in Russia have elaborated preliminary conception of the new perspective direction in the study of the earthquake forecast problem. Presumably, such a forecast can be based on registration of the signal from elastic waves in the acoustic frequency range which can be triggered in the depth of lithosphere under the influence of local ionization from propagation of the penetrative component of cosmic rays - the muons. Within an unstable medium like a largely stressed volume of the Earth's crust in a seismically active region any small disturbance like an elusive ionization increase can cause the momentary dissipation of elastic energy, and reveal itself as a macroscopic effect through generation of oscillations in the medium which propagate there as a sound wave [4-6].

In the case if such an approach could be realized, an effective probe of the Earth's crust with a beam of penetrative energetic muons originating from interaction of the high energy cosmic rays in atmosphere would be possible to test the inner condition of lithosphere up to the depth of 1-20 km which is close to typical formation depth of the earthquake centers. The monitoring of acoustic response on the influence of muon beam which can be made near the surface of the Earth is a unique method to reach relatively close vicinity of an earthquake center in comparison with other methods. Every separate measurement by muon monitoring is only a local one, but a set of such measurements made systematically and continuously during some period of time permit to control a large volume of the crust which depends on the sensitivity of acoustic sensors, on the level of seismic noise, and on the area of the muon detectors disposition.

One of directions in the development of the earthquake forecast methods is the analysis of temporal characteristics of the high-frequency seismic noise. In the work[7,8]it was suggested that the process of earthquake preparation causes an anomalous time behaviour of the intensity of such noises, and the role of trigger to provoke generation of elastic oscillations in acoustic frequency range can play the transient ionization increase from the passage of muons through the seismically stressed regions of lithosphere. An effective source of such muons can be the extensive air showers (EAS) – the cascades of a multitude of elementary particles which develop in the atmosphere after the hits of energetic cosmic rays which have the energy above 10^{16} eV.

Later on, the method discussed was proved quantitatively by numeric simulation of the passage of ~10-100 TeV muons through the ground which is described in the paper [9,10]. In this work concrete estimations were obtained for the muon multiplicity in the EAS with primary energy $10^{16} – 10^{18}$ eV, for the depth of muon penetration into lithosphere, and for the average number of macroscopic effects (micro-cracks) which the muons can cause within the seismically stretched crust in dependence on their energy. It was found that in a considerable part of events the creation of such micro-cracks can result in the generation of elastic sound oscillations in the acoustic frequency range of 1–2 kHz, and with an amplitude sufficient for their registration by a high-sensitive microphone near the surface of the Earth. Since the appearance of energetic muons is generally connected with extensive air shower development in the atmosphere, it was suggested in [9, 11] to use the correlation method based on the search for acoustic response signals temporally bound to the passage moments of the high-energy EAS.

A convenient experimental site to investigate the capabilities of considered method is the Tien Shan mountain cosmic ray station which, firstly, is located in mountain region above a deep lithosphere fault, and the widespread system of particle detectors of which, secondly, makes it possible to check directly the passage moments of the powerful EAS and connected energetic muons.

A preliminary search for a short-time emission of an acoustic signal by the group passage events of high energy muons has been made in a special experiment which was held at Tien Shan station in the year 2012. According to the data published in [12, 13] some transient increases of acoustic noise have been observed indeed in a short time neighbourhood (~10 s) after registration of a multiple muon event.

After completion of the complex modification of Tien Shan shower installation [14, 15] and the beginning of regular EAS studies there in 2015–2016, it is planned to continue such a type of experiment here in its advanced version, i.e. with taking into account any discrete information on the EAS (total amount of shower particles – the shower size, the type and energy of the primary cosmic ray particle, position of shower axes on the ground, and its arrival angles) which accompany the acoustic noise increase events. Accordingly, the modification program of shower installation anticipates the creation of a special system of acoustic receivers which should consist on a number of high-sensitive microphones distributed over the territory of Tien Shan station, with strict synchronization of recording process of acoustic signal with the moments of EAS passage.

At the beginning stage of this investigation program, one of such acoustic detectors has been installed in autumn 2017 and remains in continuous exploitation since that time. A microphone with a 20 mV/Pa sensitivity in acoustic frequency range, 500-10000 Hz, is placed within a hole drilled in the ground at the territory of Tien Shan station at a depth of 52 m under the surface. The distance between the hole and center of shower particles detector system is about 200 m.

A description of the microphone detector which is used now at Tien Shan mountain station for registration of the seismic noise signals, and an overview of preliminary results obtained by continuous operation of this detector during the winter season of 2017-2018 years are the subject of the present message.

Experimental equipment

The schematic of electronic equipment which is used for registration of seismic oscillations in acoustic frequency range is presented in figure 1. To obtain the necessary level of electromagnetic noise immunity, the transmission of electric signal from the microphone succeeds through a small-size transformer T1 which is connected to a long cable line made of a twisted pair of wires; both the microphone and transformer constitute a single compact construction unit which is dropped into the drilled hole. Besides, the ±3V direct current voltage for microphone powering is elaborated by a separate AC-DC power adapter which uses an independent transformer *T2* with ungrounded secondary winding. Up to the microphone this low-voltage direct current feeding comes over another twisted pair of wires. Hence, the microphone unit as a whole occurs to be isolated electrically and has not any direct contact with the grounding and external power feeding lines. This is necessary to prevent any influence on registered signal on the part of low-frequency electromagnetic interference, in particular of the 50 Hz sinusoidal noise from the power main.

Recording of acoustic signal is made indoors in a special cabin situated immediately at the top of the hole where other units of registration channels are placed: the differential amplifier and the selector of low-frequency envelope of microphone signal. The differential amplifier (the D1 element in the scheme of figure 1) is made on the basis of an integrated circuit chip of CA3130E type. This amplifier ensures the $\sim 100^x$ amplification of useful signal with simultaneous ~70 dB suppression of any co-phased interferences which may arise on the long connection line between the microphone and amplifier input. At the output of amplifier, the bipolar sinusoidal signal is formed which belongs to acoustic frequency range, $\sim 10\text{-}10^4$ Hz, and is ready for digitization with a final amplitude-to-digital conversion (ADC) unit of the data acquisition channel. The low-frequency signal selector which consists of a pair of CA3130E *(D2)* and KA1458D *(D3)* operational amplifiers permits to pick out the slow modulating envelope of the seismic acoustic signal which is digitized by the second ADC channel.

Schematic of the small ADC system with a low power consumption which has been designed especially for registration of the signals from acoustic detector is shown in figure 2. This system is located just at the top of the hole together with all other electronics of preliminary signal shaping. The basis of ADC system is a single board microcomputer Raspberry Pi B+ [16] on a Broadcom BCM2835 type ARM microcontroller with the tact frequency of 700 MHz. By the means of its in-built general purpose input/output port (GPIO) the microcontroller is connected to a pair of AD7887 type integrated ADC chips [17,18]. The latter ensures digitization of the analogue signal level which is present temporarily at their inputs with a 12-bit resolution and with conversion speed of up to $1.25 \cdot 10^5$ samples per second.

Two digital tact sequences, C (clock), and *CS* (chip select) which are necessary for ADC chips operation are elaborated at corresponding GPIO pins by the special low-level driver program which runs at the microcontroller unit. Same program accepts the binary conversion results which are set in sequential code at the *DO* pins of both ADC chips and converts them into two byte long data words. All microcontroller signals are connected to ADC pins through additional resistor dividers and through the buffer SN7404 type TTL- gates which are necessary for proper matching of their logical levels.

Permanent recording of acoustic signal data is made with a high-level program which operates at the same Raspberry Pi B+ microcomputer together with ADC system driver. Both the current level of the microphone output signal and its low-frequency envelope are registered uninterruptedly with a 2 ms temporal resolution which corresponds to the total rate of information income about 4 Mb/s. The whole

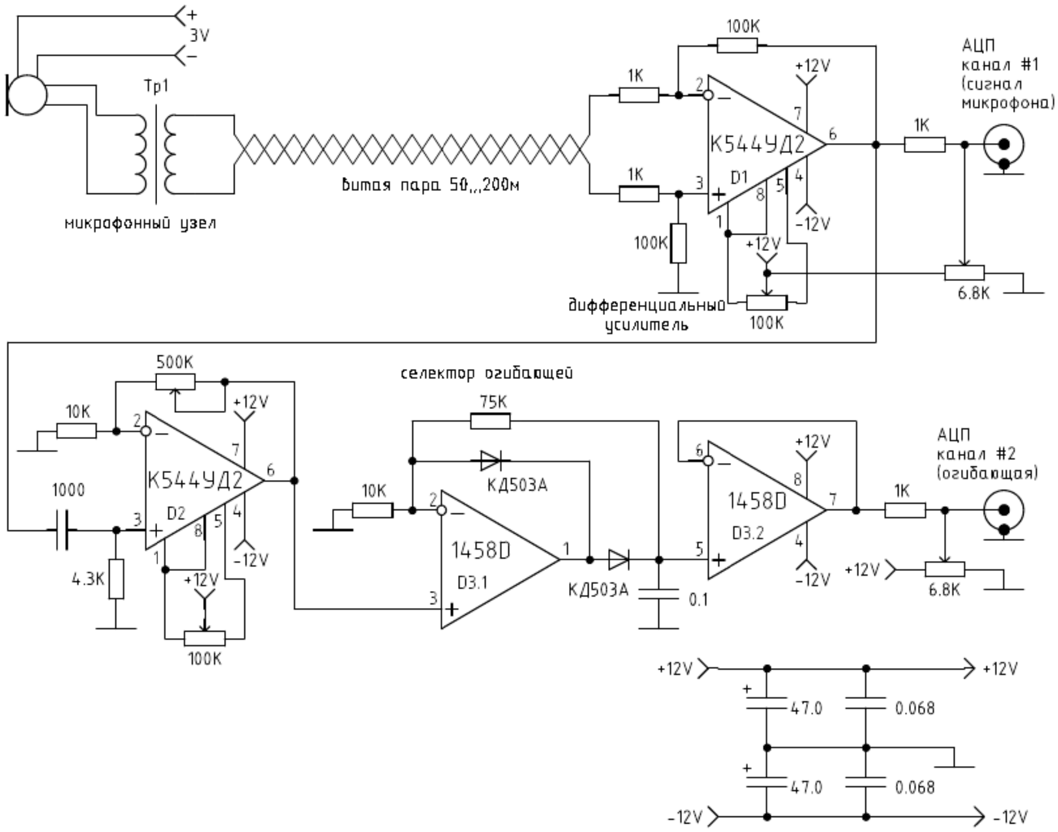

Figure 1 – Schematic of the high-sensitive microphone connection

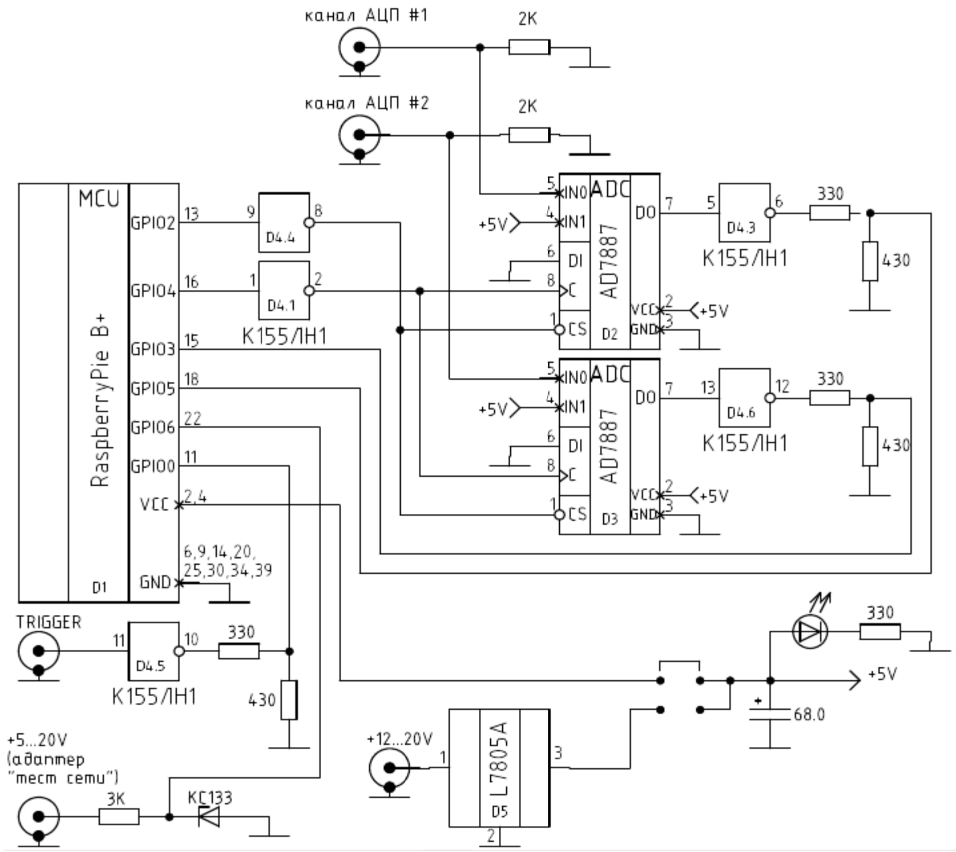

Figure 2 – Small ADC system on the basis of Raspberry Pie microcontroller

data stream of measurement information is kept completely in a compressed archive file which is created by registration program on a local hard disk connected to microcomputer through an USB interface plug.

In turn, the information kept within initial archive files is used by another high-level program to calculate periodically the mean characteristics of acoustic signal which have been observed in succeeding 1 min long averaging periods: the root-mean-square ADC codes of microphone signal and of its envelope, and minutely amounts of the events when the envelope amplitude was exceeding a number of predefined ADC code thresholds: 300, 500, and 1000. The resulting set of average characteristics comes into general database of the Tien Shan mountain station and can be seen in real time at the corresponding page of the station's web-site [19].

The results of the test detector exploitation

Test recording of the level of acoustic detector signal in accordance with the algorithm described in the previous section was initiated at Tien Shan station in November 2017, and since that time it is continuing there uninterruptedly. Since it was not known in advance any characteristic behaviour of microphone signal which should be expected in response to the events of seismic activity, during all the period of detector operation digitization of its output signal is made continuously with the time resolution of 2 ms, and the whole data set is kept completely for its further off-line operation. Some of the results gained in such postponed operation are considered in the present section.

A sample of acoustic events of the type which is most frequently met and is presumably connected with development and subsequent fast decay of micro-cracks in the seismically stretched medium is presented in figure 3. Among microphone signal records such an event manifests itself as a sharp but quickly fading increase of oscillation amplitude with typical duration of 10-20 ms, like the ones which are visible in upper graphs of figure 3. Momentary increase of the microphone signal is accompanied usually with a short-time outburst of the amplitude of its envelope, which can be seen also in the discussed figure. From a statistical point of view the reliability of these effects is beyond any doubts; hence, in the case of figure 3 the signal/noise ration is not worse than 5-7 times for the direct microphone channel, and ~30 times for envelope. The observed intensity of such a type of events does vary irregularly during the time, but usually, it remains within the limits of 1-5 events/day (for the threshold ADC code of 1000).

During the period of acoustic detector operation it was registered a noticeable seismic event – an earthquake with a magnitude of M = 4.9, and with epicenter distance about ~130 km apart from the Tien Shan station. The earthquake has occurred at the time moment of 16 November 2017, 01:42:58 UT [20].

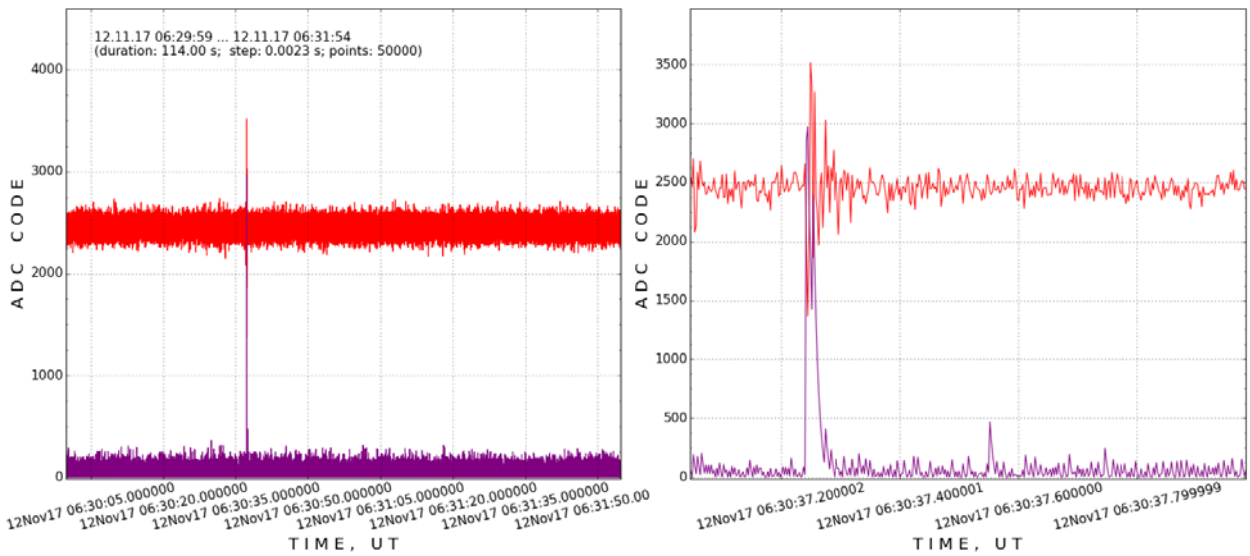

Figure 3 – Typical seismic event signal in the data records of acoustic detector.
Upper graphs in the plots correspond to the microphone signal, the lower ones – to its low-frequency envelope.
The time axes of the right plot are stretched around the moment of transient amplitude increase due to transient seismic noise.
Vertical axes are graduated in the values of the 12-bit ADC code

In the vicinity of Tien Shan station, this event was felt as a weak earthquake with local magnitude about 2. As shown in figure 4, in spite of general weakness at the observation point, the effect of this event can be seen prominently in average parameters of acoustic signal. Disturbances from the remote earthquake have influenced both the records of root-mean-square values of microphone signal, and the multiplicity of transient outbursts of the envelope amplitude.

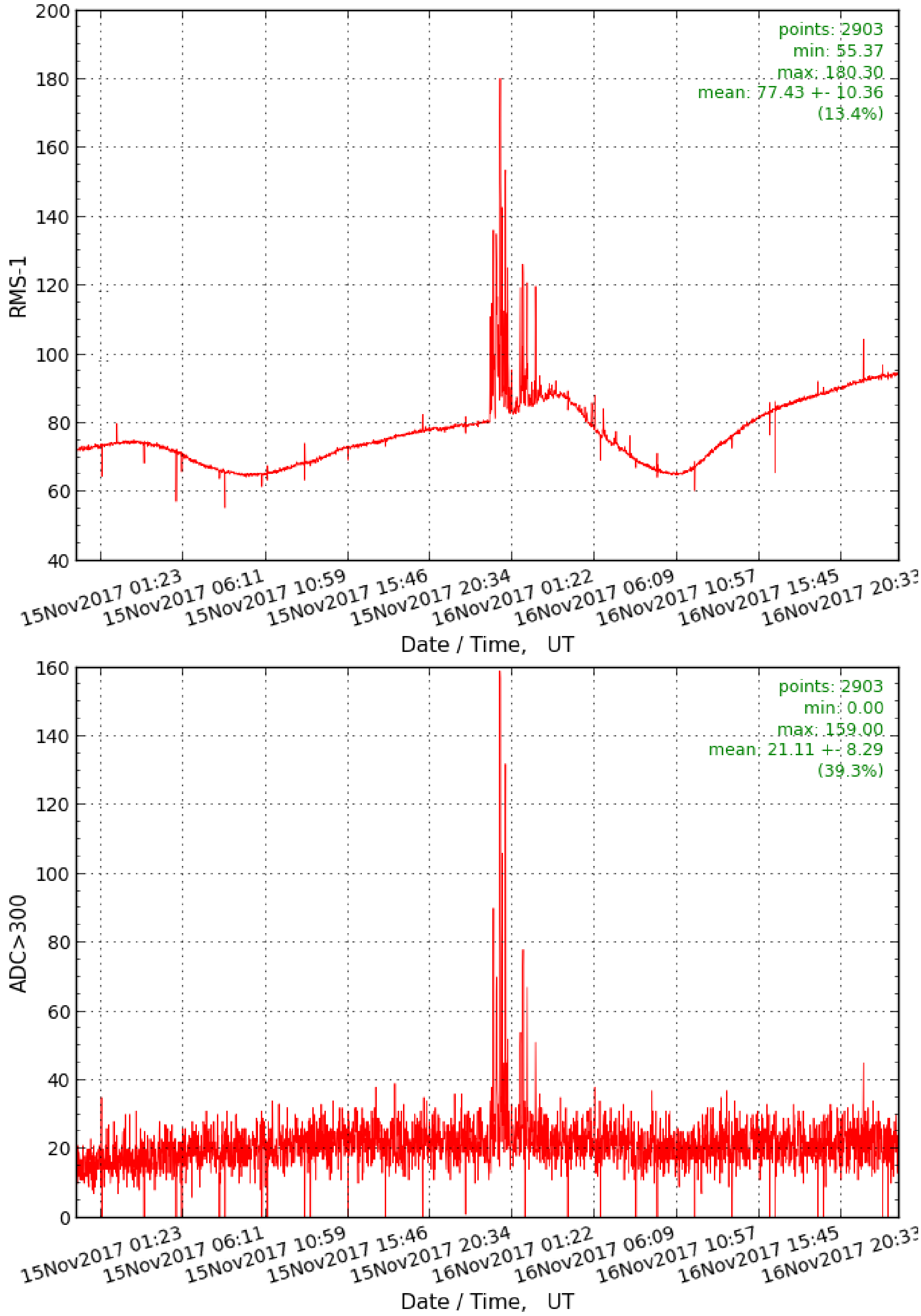

Figure 4 – Average data gained over a 2 days long period of continuous operation of acoustic detector: the minutely values of the root-mean-square ADC code in microphone channel (above), and the number, per one minute, of the events when the envelope amplitude code was exceeding the threshold of 300 (below). Time moment of 16 November 2017, 01:42:58 UT corresponds to a M = 4.9 magnitude earthquake with epicenter distance about 130 km apart from Tien Shan station

Time variation of the low-frequency envelope of acoustic signal within the temporal neighborhood of the 16 November 2017 earthquake is shown in figure 5. This plot was obtained by low-pass filtering of the original envelope record which consists of its 30-point decimation with multiple application of the moving average filter to remaining data, each time with compensation of the resulting temporal shift. The arrival moment of longitudinal seismic wave from the earthquake epicenter into the region of Tien Shan station is marked with a vertical line in the figure 5. This moment was calculated over the data of a three-component seismic station of the National Nuclear Center of Kazakhstan Republic KNDC [21]. As it is seen in the figure, just after arrival of seismic wave the acoustic detector starts to register a characteristic sequence of quasiperiodic oscillations with sum duration of 2.1 s and with the mean period of 0.55 s. This sequence can be considered as modulation result of the local seismic noises by the seismic wave in vicinity of the Tien Shan station.

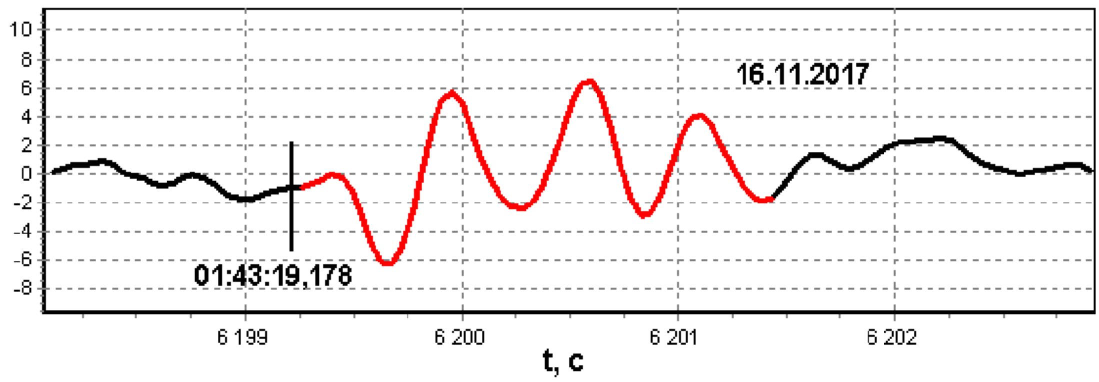

Figure 5 – An imprint of longitudinal seismic wave which has reached the Tien Shan station after the earthquake of 16 November 2017 on the record of microphone signal. Time axes is graduated in the seconds since the beginning of the day 16 November 2017, 00:00 UT

Hence, a conclusion can be made on the basis of experimental results presented in this section that registration of the acoustic detector signal which is currently on at the Tien Shan mountain station does indeed provide the necessary sensitivity level to seismic processes which take place deeply in the Earth. This result permits to consider the applicability of the described measurements technique to practical search of acoustic signals which could accompany the passage of the high-energy extensive air showers, including the intensive muon beams in the core region of the latter. Any realization of this task anticipates continuous recording of acoustic signal, together with strict registration of the shower passage moments and determination of EAS parameters accordingly to the data of the wide-spread shower particles detectors system, as well as mutual comparison of both data sets further on. The final goal of this study should be an answer to the question if some statistically significant excess of EAS events does exist which precede systematically the moments of transient increase of acoustic signal, and what are the mean characteristics of these showers (such as their size, primary energy, core distance to location point of acoustic detector and the like).

Preliminary data which have been obtained in a such type of measurements are illustrated by the figure 6. Sample events with characteristic short-time imprint of seismic effect in the records of microphone signal and of its envelope are presented here together with the data of the shower particles detector system. The latter are two-dimensional spatial distributions of the charged particles density (mostly, electrons) taken in a number of showers which have been preceding the moments of acoustic envelope outburst up to the time of 30 s, and the muonic component of which could serve as a trigger to initiate elastic oscillation deeply underground.

Making an approximation of these experimental distributions with the standard particle density distribution function of the particles cascade development theory, one can obtain a number of estimations for the basic shower parameters [8]. In particular, one can define the size of the shower, i.e. the sum amount of constituting charged particles which is connected with its primary energy and multiplicity of the muons. For the cases shown in figure 6 the EAS size is in the limits of 10^5–10^7 particles, which corresponds to the primary energy of ~ $3{\cdot}10^{14}$–10^{16} eV, and to the multiplicity of high energy muons of the order of 1-10 per a shower.

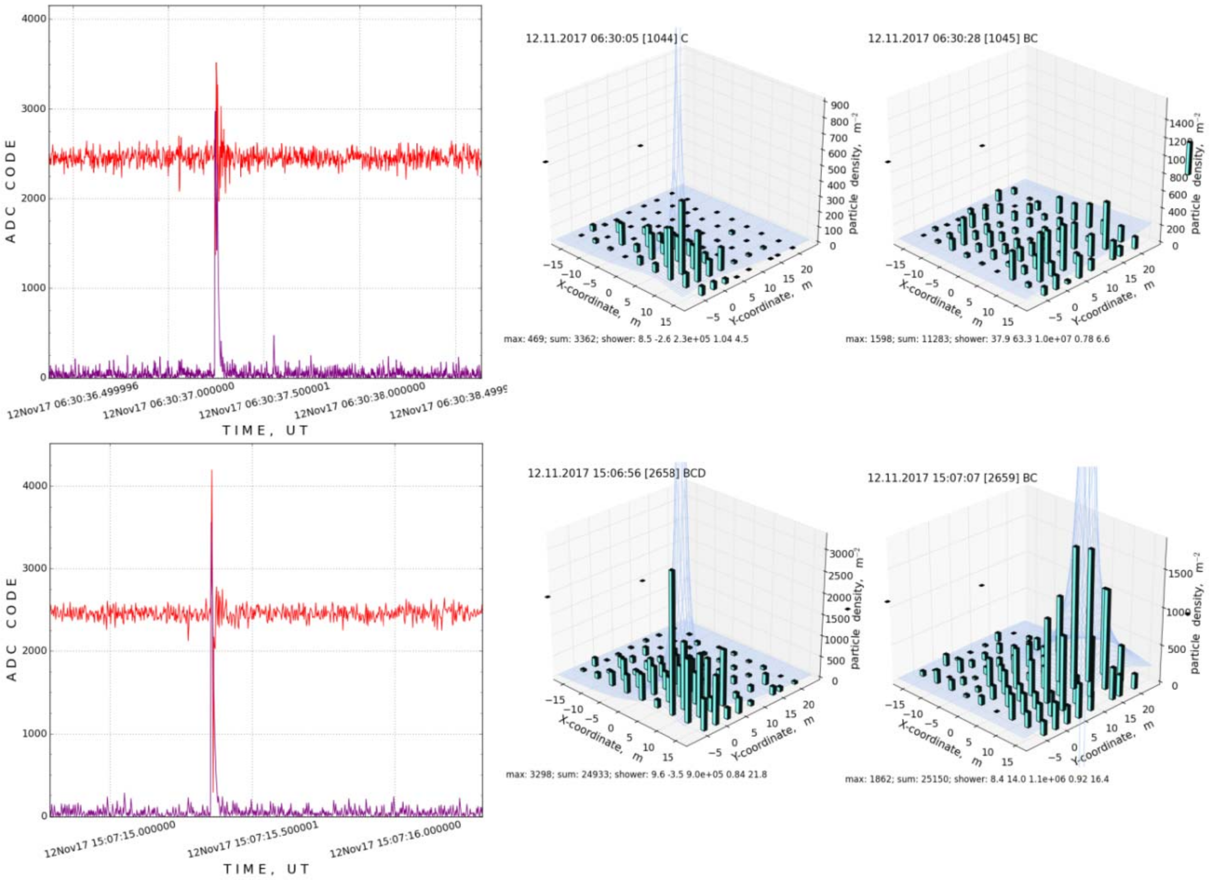

Figure 6 – Short time events with characteristic amplitude increase of acoustic signal and the two-dimensional distribution of the charged particles density amongst the shower detector system of the Tien Shan station in a number of preceding EAS (columns-original density measurements, smooth distributions-their approximation with a standard two-dimensional function of the particles cascade theory)

Conclusion. At the Tien Shan mountain cosmic ray station it is started the realization of the planned system of high-sensitive microphone detectors aimed at the search of elastic oscillations in acoustic frequency range which are connected with seismic processes in the depth of lithosphere. Up to the present time, the design of acoustic signal detector, of the necessary electronic equipment, and of the software complex have been elaborated, as well as operation technique of the incoming measurement information. According to the experience of practical exploitation of the test acoustic detector which has been taken place at the end of 2017, the detector of considered type does ensure indeed the necessary sensitivity level for registration of the signal from seismic processes. Synchronous operation of the acoustic detector system with EAS particles detector installation of the Tien Shan mountain cosmic ray station permits to check the practical applicability of proposed probing technique of seismic conditions deeply underground which is based on registration of the elastic oscillations signal originated in the seismically stretched lithosphere regions under the influence of penetrative cosmic ray particles. This study is of interest for the problem of long-term earthquake forecast.

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БИІК ТАУЛЫ ТЯНЬ-ШАНЬ СТАНЦИЯСЫНЫҢ АКУСТИКАЛЫҚ ДЕТЕКТОРЫМЕН СЕЙСМИКАЛЫҚ СИГНАЛДАРДЫ ТІРКЕУ

Аннотация. Биік таулы Тянь-Шань ғылыми станциясының құрамындағы ғылыми жабдықтарды дамыту бағдарламасы бойынша сейсмикалық серпімді тербелістерді тіркеуге арналған, сезімталдығы жоғары дыбыстық диапазондағысейсмикалық серпімдітербелістерді тіркеуге арналғанакустикалық детекторларды жобалау және станция аймағында құру жоспарланған. Акустикалық детектордың ғарыш сәулелерінің детекторларымен синхронды жұмыс істеуі сол ғарыш сәулелерінің жер атмосферасымен әсерлесуі барысында туындайтын, өтімділігі жоғары құраушыларының (мюондар) әсерімен литосфералық тереңдікте орналасқан сейсмикалық бөлшектену кеңістігіндемикро сызаттарды туғызу туралы гипотезаны тексеруге мүмкіндік береді. Сондай сызаттардың пайда болуы нәтижесінде туындайтын серпімді тербелістер жер қыртысы арқылы дыбыс толқындары түрінде таралады және жердің беттік қабатында қысқа мерзімдік акутикалық шу түрінде тіркеледі. Осы тербелістерді жоғары энергиялық ғарыштық сәулелердің өтуімен қатар тіркеу мәселесін шешу ісі сейсмикалық белсенді аймақтарда жер сілкінісін болжаудың болашағы зор тәсілдерінің қатарына қосылуы мүмкін. Мақалада сол үшін арналған және бүгінгі күні станция аумағында жұмыс істеп тұрған, жер бетінен 50 м тереңдікте скважинада орналасқан, сезімталдығы айрықша жоғары микрофон негізінде жасалған акустикалық детекторды құру принципі мен пайдалану мүмкіндігі баяндалады. Сонымен қатар, 2017 ж. соңына қарай осы жүйені тестілік тексеруден өткізу барысында қол жеткен нәтижелер де келтіріледі. Зерттеу жұмыстарының нәтижелері жер сілкінісі туралы алдын-ала ұзақ мерзімділік болжау мәселесін шешу үшін айрықша маңызды.

Түйін сөздер: акустикалық детектор, ғарыш сәулелері, мюондық құраушылар, серпімді сейсмикалық тербелістер, синхронды тіркеу.

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РЕГИСТРАЦИЯ СЕЙСМИЧЕСКИХ СИГНАЛОВ АКУСТИЧЕСКИМ ДЕТЕКТОРОМ ТЯНЬ-ШАНЬСКОЙ ВЫСОКОГОРНОЙ СТАНЦИИ

Аннотация. Программа развития комплекса научной аппаратуры Тянь-Шаньской высокогорной научной станции предусматривает разработку и размещение на ней системы чувствительных акустических детекторов для регистрации упругих колебаний сейсмического происхождения в звуковом диапазоне частот. Синхронная работа акустического детектора с расположенной на станции распределенной системой детекторов частиц позволяет проверить гипотезу об образовании микротрещин в зоне глубинных сейсмических разломов под воздействием частиц проникающей компоненты космических лучей (мюонов),которые рождаются в результате взаимодействия энергичных частиц космического происхождения с веществом земной атмосферы. Возмущение от упругих колебаний, которые генерируются при образовании таких микротрещин, распространяется в массе земной коры как звуковая волна и может регистрироваться вблизи поверхности земли в виде кратковременного всплеска акустических шумов. Предполагается, что регистрация таких колебаний в корреляции с регистрацией моментов прохождения космических лучей высокой энергии, может представлять собой перспективный метод прогноза землетрясений в сейсмически активных районах. В работе обсуждаются принцип построения и возможности действующего в настоящее время на станции детектора, который построен на основе чувствительного микрофона, установленного в пробуренной скважине, на глубине 50 м от поверхности земли Вместе с описанием акустического детектора представлены результаты измерений, которые проводились во время его тестовой эксплуатации в конце 2017 года. Результаты этих исследований имеют важное значение для решения проблемы долгосрочного прогноза землетрясений.

Ключевые слова: акустический детектор, космические лучи, мюонные компоненты, упругие сейсмические колебания, синхронная регистрация.

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MULTILAYER STRUCTURE FORMED IN DIFFUSION ZONE OF Al-Co AND Al-Ni SYSTEMS

Abstract. The Diffusion Zone (DZ) of Al-Co and Al-Ni systems using the diffusion couple method was studied. The microstructure and element composition of samples were studied in cross-sectional geometry by mean of Scanning Electron Microscopy and Electron Probe Microanalysis (SEM/EPMA) and X-rays diffraction. After isothermal treatment in the range between 1000°C and 1375°C the multilayer intermetallic structure has been formed. It was shown that the diffusion couples method demonstrates its efficiency in comparative experiments having cross-sectional geometry. Depending on the established concentration of components in DZ several layers of different phase composition have been formed. The well-known intermetallics having constant compositions were detected: Al_9Co_2, $Al_{13}Co_4$, Al_3Co, AlCo, Al_5Co_2, as well as Al_3Ni_5, Al_4Ni_3, AlNi, $AlNi_3$. New compounds having variable composition were revealed. For of Al-Co system, these four layers were detected after treatment at high temperature (1300-1375 °C): $Al_{21}Co_{79}$ (78.72 at.% Co), $Al_{44}Co_{56}$ (55.69 at.% Co), $Al_{20}Co_{80}$ (79.55 at.% Co), and $Al_{27}Co_{73}$ (73.29 at.% Co). For of Al-Ni system, the corresponding layers having clear boundaries were detected: $Al_{51}Ni_{49}$ (49.07 at.% Ni), $Al_{36}Ni_{64}$ (64.06 at.% Ni), $Al_{30}Ni_{70}$ (69.62 at.% Ni), and $Al_{32}Ni_{68}$ (67.86 at.% Ni).

Similar structural features in multilayer DZ in both systems (porosity, dendrites, and shift of intermetallics having constant composition to higher temperatures), as well as evidence of changes in local densities not only for different layers, but also within one layer, can contribute to specification of application of both systems to AM.

Keywords: diffusion couple, scanning electron microscopy, electron probe microanalysis, X-rays diffraction, diffusion zone, multilayer structure, intermetallics.

Introduction. In case of study of pattern and structure of diffusion zone (DZ) the diffusion couple method can facilitate to disclose the character of element distribution and conditions for the formation of intermetallic layers. This method is based on the close contact between two metals followed by the heat treatment at the corresponding temperature for the period of time sufficient to provide the diffusion redistribution of elements. It is expected that DZ will contain all phases in that subsequence, which is observed for them in the corresponding phase diagram at the given temperature. Therefore one can evaluate the fragments of phase diagrams through measurements of component concentration in each layer.

The concentration discontinuity is considered as the boundary line between on-phase areas in the diagrams. Adjacent phases in layers are considered ones having equilibrium with each other [1]. The DZ method can be also applied for practical purposes, e.g., to enhance the oxidation resistance of Ni-superalloys using NiAl-diffusion coatings [2]. In the most of binary systems, the mutual diffusion is accompanied by the formation of phases: solid solutions existing in the limited range of concentrations, intermetallic phases having the strictly constant composition (stoichiometric compounds, i.e., daltonides), or with variable composition (non-stoichiometric compounds, i.e., berthollides) [1]. From point of view of concentration localization of the berthollides takes the intermediate position between solid solutions and daltonides [1 Page 229, 3].

Regardless of the fact that Al-Co and Al-Ni systems are well-studied in a number of original works nevertheless new phases are still discovered for them (including the phases having variable compositions) [3-4].

The knowledge on temperature-time conditions for the creation of new intermetallic phases can be laid into the basis for updated methods of the powder intermetallics metallurgy for broad application. It should be noticed that the powder intermetallics metallurgy obtains good prospects along with rapid development of addictive manufacturing (AM) [5-7]. AM has a great potential in drastic reduction of costs in the manufacturing of parts in the aircraft industry, power plant industry, instrumentation manufacturing industry, i.e., in every branch where items having sophisticated geometry are used. In this context, the intermetallics inevitably will find their application in AM. It is very true from point of view of high prices on intermetallics; it is not appropriate to permit any substantial wastes of expensive intermetallics.

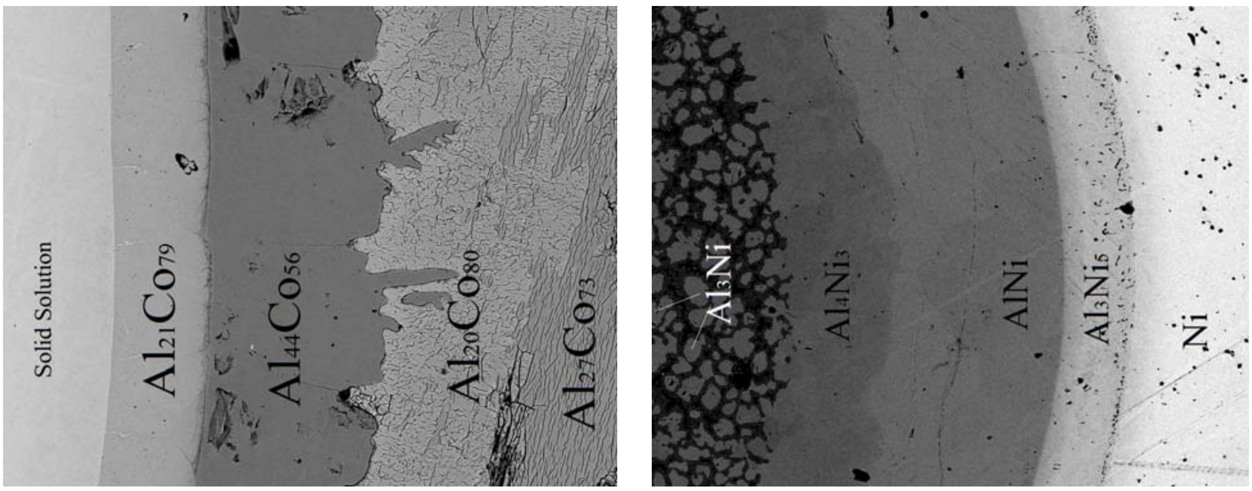
The goal of this work is to compare the formation of multilayer DZ structures formed between aluminium and cobalt as well as between aluminium and nickel.

Materials and experimental methods. The diffusion couple method has been applied to Al-Co and Al-Ni systems. Experimental details for this method are shown in [8, 9]. Samples were prepared at temperatures of isothermal treatment from 1000 °C to 1375 °C with duration from 1 to 4 hours. The initial materials were used as follows: high-grade aluminium (99,99 % Al), commercial cobalt (99,98 % Co), and nickel (99,80% Ni) in form of plates having masses up to 30 g. SEM/EPMA studies were performed on JXA-8230 (JEOL) at magnifications from ×75 to ×1,000 using the original software EPMA. Element composition of phases formed in DZ was determined by means of the spot, multipoint, and linear detection techniques using energy-dispersion spectrometry (EDS) and wave-dispersion spectrometry (WDS) demonstrated a high reproducible data obtained.

X-rays measurements were performed on a Bruker D8 Advance diffractometer operated at 40 kV voltage and 40 mA current using Cu Kα radiation (λ = 1.5406 Å). Software EVA has been used to process XRD patterns and to compute the interplanar distances. Interpretation of samples and phase searching were performed by means of the software Search/Match using the Powder Diffraction Database PDF-2.

The modern phase diagrams for Al-Co and Al-Ni systems are not final ones; they are under permanent detailing [10-13]. Therefore widely using data taken from scientific-technical handbooks [14-17] become quickly out of date. For this reason, in this work, the data references taken from PDF-2 updating database were used.

Results of study and their discussion. The cross-section pattern of DZ has the following peculiarities: DZ having two or more phases the corresponding layers (as structural fragments) have different concentration profiles. In other words, there is DZ containing several layers having different contract in the image of back-scattered electrons (figure 1).



(a) Al-Co,1350 °C, 1 h (b) Al-Ni,1300°C, 1 h

Figure 1 – Layers in DZ

In-depth sequences of phase formation (in temperature scale) in Al-Co system were reported in details in [9]. At 1350 °C all observed compounds represent were identified from a highly diluted solid solution of Al in Co to $Al_{67}Co_{33}$. The following intermetallic phases having constant composition were observed in Al-Co system: Al_9Co_2, $Al_{13}Co_4$, $CoAl_3$, $Al_{13}Co$, and AlCo [9]. However, there are observations when layers have variable compositions.

Figure 1 (a) shows microphotography of sample after treatment at 1350 °C where DZ contain four layers with clear border lines, contrast, and characteristic structure. From Cobalt side, the layers are seemed more homogenous with “smooth” boundaries whereas next layers (to Aluminium side) have more irregular boundaries with the appearance of certain dendrites. These layers were identified as compounds with variable composition: $Al_{21}Co_{79}$ (78.72 at.% Co), $Al_{44}Co_{56}$ (55.69 at.% Co), $Al_{20}Co_{80}$ (79.55 at.% Co), and $Al_{27}Co_{73}$ (73.29 at.% Co). The similar pattern was also observed after other treatments at high temperatures 1300-1375 °C. It should be noted that new similar compound for Al-Co system with non-standard formula was obtained in case of alloying of a mixture of Al powder with intermetallic Al_9Co_2 [4]. Presumably, these compounds should be referred to berthollides [18].

Similar approach was used to identify intermetallic phases having constant and variable compositions in Al-Ni system: daltonides - Al_3Ni, Al_3Ni_2, Al_3Ni_5, Al_4Ni_3, AlNi, and $AlNi_3$; berthollides – $Al_{51}Ni_{49}$ (49.07 at.% Ni), $Al_{36}Ni_{64}$ (64.06 at.% Ni), $Al_{30}Ni_{70}$ (69.62 at.% Ni), and $Al_{32}Ni_{68}$ (67.86 at.% Ni). Dendrites were also observed in Al-Ni system (see figure 1 (b)) between Al_3Ni_5 and pure nickel.

It should be noticed that common feature for both systems was the well-developed porosity in certain layers of DZ.

All observed intermetallics having constant compositions in Al-Co and Al-Ni systems after all isothermal treatments are compiled in table 1.

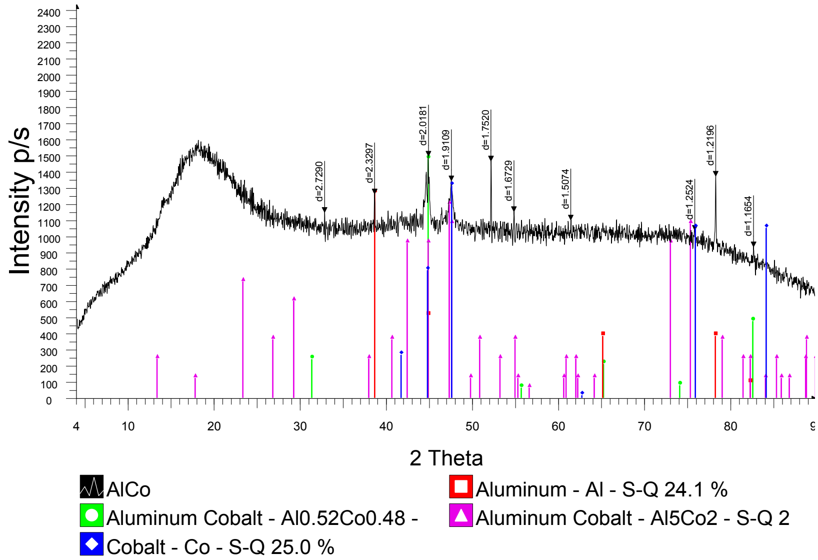
Table 1 – Intermetallics in Al-Co and Al-Ni systems

Intermetallics	Landolt-Börnstein [11-12]	Temperatures, °C	Ref.
Al_9Co_2	17.97 at.% Co	700	[17]
$Al_{13}Co_4$	23.19 at.% Co	800	[18]
Al_3Co	24.93 at.% Co	800, 900	[19]
Al_5Co_2	28.26-29.13 at.% Co *	1150,1200**, 1350**, 1375**	[20]
AlCo	50.00 at.% Co *	1150,1200, 1300, 1350, 1375	[19, 21]
Al_3Ni	25.78 at.% Ni *	1300**	[22]
Al_3Ni_2	40.00 at.% Ni *	1300	[23]
Al_4Ni_3	41.39-45.04 at.% Ni	1300**, 1350**	[24]
AlNi	50.00 at.% Ni *	1250,1350	[23]
Al_3Ni_5	63.51-68.07 at.% Ni *	1250**, 1300**, 1350**	[25]
$AlNi_3$	74.00 at.% Ni	1250,1350	[23, 26, 27]
Note. *Phase has been confirmed by X-rays measurements. **The corresponding phase diagram does not have this phase at given temperature.			

Table 1 demonstrates that experiments have resulted in all intermetallic compounds existing in the corresponding phase diagrams for Al-Co and Al-Ni systems. Some of these compounds were detected in those areas of phase diagram where they have not been determined before. It means that the diffusion couple method applied to Al-Co and Al-Ni systems has resulted to shift to higher temperatures of formation (or/and existence) for certain intermetallics in both systems. It is necessary to note that from a methodical point of view the discrepancy between experimentally EDS measurements and concentrations shown in Landolt-Börnstein database for each intermetallic compound [11, 12] does not exceed 0.5 at.%.

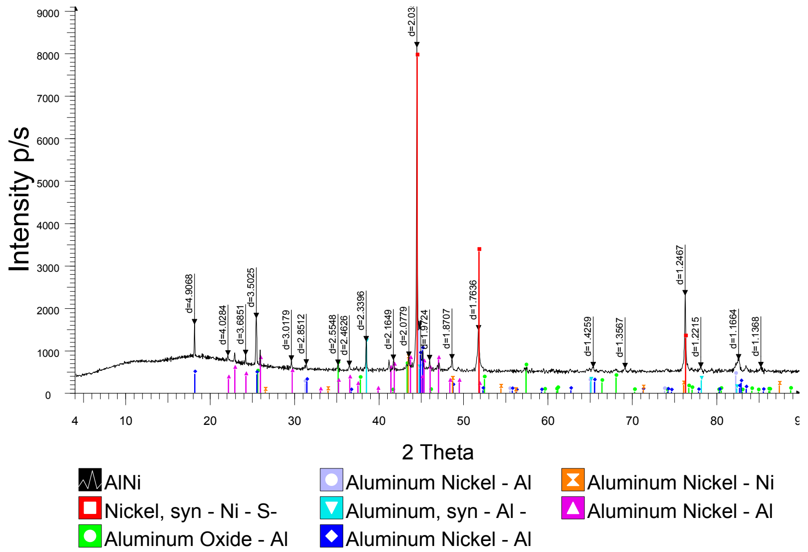
X-rays measurements confirmed the accuracy of identification of intermetallics having constant composition in DZ for both systems (figure 2).

However, some of the intermetallic layers were too small to be identified by means of X-rays pattern presumably because of its insufficient sensitivity.



Al-Co 1300 °C, 1h

Compound name	Formula
Aluminum Cobalt	Al0.52Co0.48
Cobalt	Co
Aluminum	Al
Aluminum Cobalt	Al5Co2



Al-Ni 1300 °C, 1h

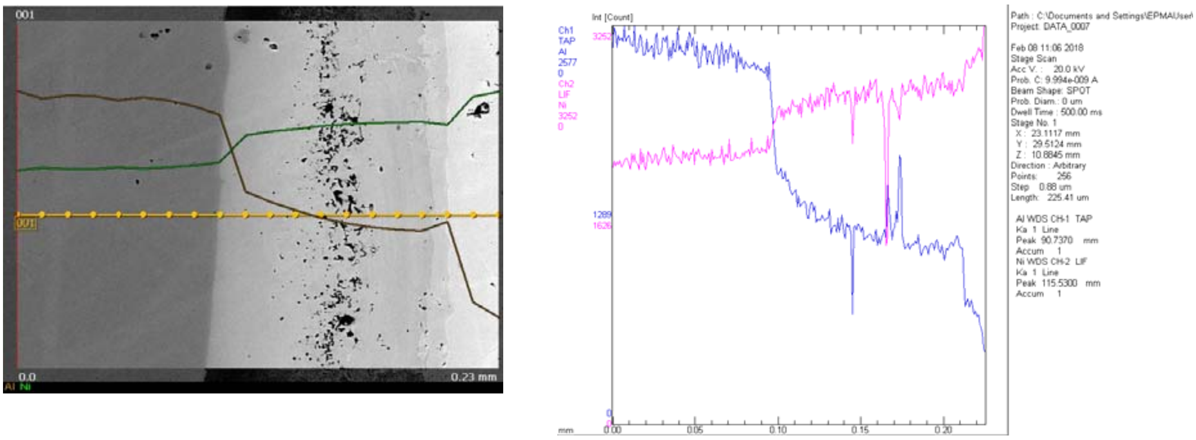
Compound name	Formula
Nickel, syn	Ni
Aluminum Nickel	Al1.1Ni0.9
Aluminum, syn	Al
Aluminum Nickel	Al3Ni2
Aluminum Nickel	Ni5Al3
Aluminum Nickel	Al3Ni

Figure 2 – Examples of X-rays patterns for Al-Co and Al-Ni systems

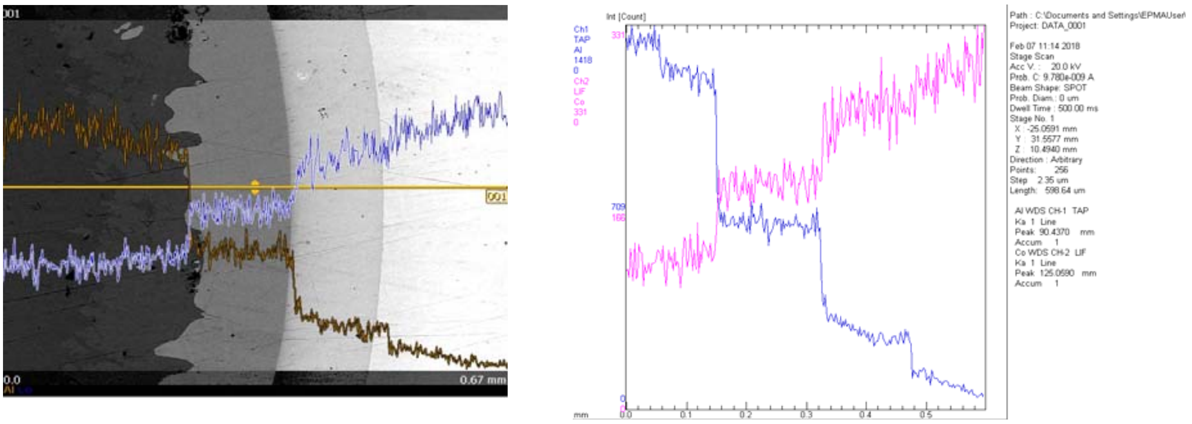
The most of samples reveal the normal element distribution in form of concentration steps on cross-sectional profiles of DZ (Figure 3 (a) and (b)). However, there are some examples of abnormal element distribution (figure 3 (c)) where one berthollide layer enriched with aluminium has two adjacent berthollide layers having lower Al concentration.

There is another important peculiarity in DZ element profiles: changes in component concentrations occur in a non-proportional manner. It is apparent that minor changes in concentration profile of Ni (or Co) correspond to more drastic changes in Al concentration profile. It is more evident when more sensitive method – WDS linear analysis – has been applied. Non-proportional changes take place not only in the area of concentration jumps (at the boundaries between layers), but also within one layer. To exclude the effect of absorption of characteristic X-rays on concentration profiles the re-measurements were performed using $K_\beta(1)$ lines of cobalt and nickel instead their regular $K_\alpha(1)$ lines. Behaviour of concentration profiles was pretty same. Smooth and non-proportional changes in concentration profiles should be associated with the ability of studied intermetallics to vary their component concentrations and local density.

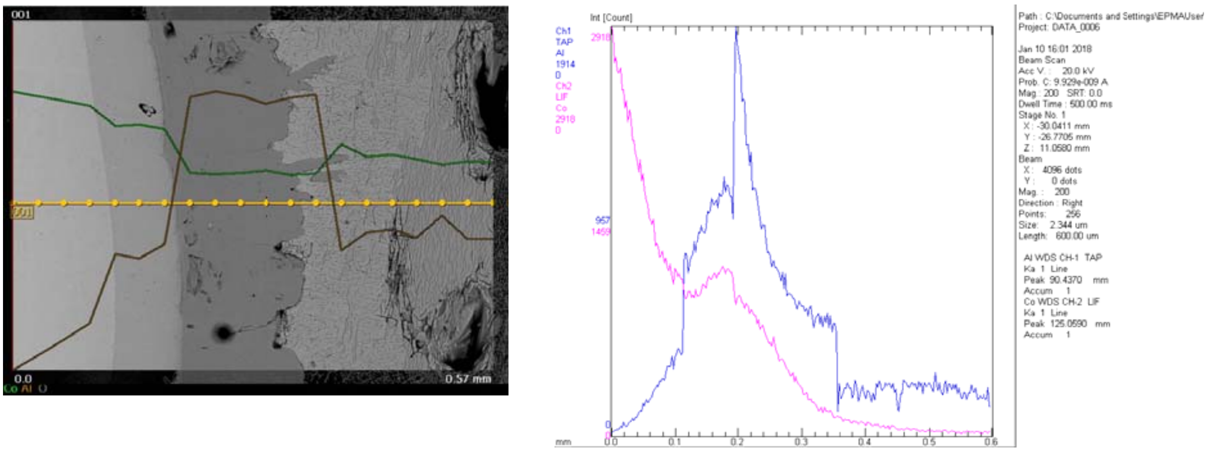
Similar features in structure of multilayer DZ in Al-Co and Al-Ni systems as well as general behaviour of their component concentration profiles could be associated with certain property (or properties) inherent to both systems. These systems are recognized as ones having omission solid solutions; therefore



(a) Al-Ni system 1250 °C, 1 h



(б) Al-Co system 1375 °C, 1 h



(в) Al-Co system 1350 °C, 1 h

Figure 3 – Element profiles in depth of DZ obtained by means of multipoint and linear EDS and WDS microanalysis

some special phenomena such as maxima in dependences of lattice parameters and density on component concentrations as well as structural defects [3 Page 232-233] can be also expected in multilayer DZ in both systems.

Conclusions. It was confirmed that diffusion couple method is efficient in comparative cross-sectional experiments on identification and characterization of phases formed in multilayer DZ in Al-Co and Al-Ni systems. Parallel with well-known intermetallic phases having constant composition new compounds having variable compositions were revealed – in fours for each system: (78.72 at.% Co),

$Al_{44}Co_{56}$ (55.69 at.% Co), $Al_{20}Co_{80}$ (79.55 at.% Co), and $Al_{27}Co_{73}$ (73.29 at.% Co); $Al_{51}Ni_{49}$ (49.07 at.% Ni), $Al_{36}Ni_{64}$ (64.06 at.% Ni), $Al_{30}Ni_{70}$ (69.62 at.% Ni), and $Al_{32}Ni_{68}$ (67.86 at.% Ni).

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Al-Co ЖӘНЕ Al-Ni ЖҮЙЕЛЕРІНІҢ ДИФФУЗИЯЛЫҚ АЙМАҒЫНЫҢ КӨП ҚАБАТТЫ ҚҰРЫЛЫМЫ

Аннотация. Жұмыста түйіспелі балқыту әдісімен Al-Co және Al-Ni жүйелерінің диффузиялық аймағы зерттелген. Микроқұрылымы және элементтік құрамы үлгілердің көлденең қимасында растрлық электрондық микроскопия және рентгеноспектралды микроталдау (РЭМ-РСМА) және де рентген дифрактометриясының (РД) көмегімен зерттелді. Изотермиялық ұзақтықтан кейін 1000-1375°С аралығында интерметаллидтердің көп қабатты құрылымы қалыптасты. Түйіскен аймақта металдардың шоғырлану белгісіне қарай фазалық құрамы әртүрлі бірнеше қабаттар құрылады. Диффузиялық аймақта құрамы тұрақты белгілі интерметаллидтердің Al_9Co_2, $Al_{13}Co_4$, Al_3Co, AlCo, Al_5Co_2, және де Al_3Ni_5, Al_4Ni_3, AlNi, $AlNi_3$. түзілуі түйіспелі балқыту әдісімен расталды. Салыстырмалы тәжірибенің көлденең қима геометриясында түйіспелі балқыту әдісінің қолайлығы көрсетілген. Ауыспалы құрамы бар жаңа қосылыстар анықталды. Al-Co жүйесінде жоғарғы температуралар аймағында 1300-1375 °С $Al_{21}Co_{79}$ (78.72 ат.% Co), $Al_{44}Co_{56}$ (55.69 ат.% Co), $Al_{20}Co_{80}$ (79.55 ат.% Co) және $Al_{27}Co_{73}$ (73,29 ат.% Co) тұратын құрамы ауыспалы төрт қосылыс анықталды. Дәл солай Al-Ni жүйесінде де нақты шекаралары мен тиісті қабаттары бар $Al_{51}Ni_{49}$ (49.07 ат. % Ni),) $Al_{36}Ni_{64}$ (64.06 ат.% Ni), $Al_{30}Ni_{70}$ (69.62 ат.% Ni), $Al_{32}Ni_{68}$ (67.86 ат.% Ni) анықталды.

Жалпы құрылымдық ерекшеліктері көп қабатты диффузиялық аймақ екі жүйені (кеуектілік, фестондар және құрамы тұрақты интерметаллидті фазалардың жоғары температураға ығысуы) сондай-ақ әр жергілікті тығыздықтың куәлікті өзгеруі түрлі қабаттардың ғана емес, бір қабаттың шегінде де аддитивті технологияның қолдануына нақты үлес қосуы мүмкін

Түйін сөздер: түйіспелі балқыту, растрлық электрондық микроскопия және рентгеноспектралды микроталдау, рентген дифрактометриясы, диффузиялық аймақ, көп қабатты құрылым, интерметаллидтер.

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МНОГОСЛОЙНАЯ СТРУКТУРА ДИФФУЗИОННОЙ ЗОНЫ СИСТЕМ Al-Co И Al-Ni

Аннотация. В работе методом диффузионных пар исследована диффузионная зона (ДЗ) систем Al-Co и Al-Ni. Микроструктура и элементный состав образцов изучены в поперечном сечении с помощью растровой электронной микроскопии, рентгеноспектрального микроанализа (РЭМ-РСМА), а также с помощью рентгеновской дифрактометрии (РД). После изотермической выдержки от 1000°С до 1375°С сформировалась многослойная структура интерметаллидов. В зависимости от установившейся концентрации компонентов в ДЗ образуются несколько слоев различного фазового состава. Установлено образование известных интерметаллидов постоянного состава в ДЗ систем, сплавленных методом диффузионных пар Al_9Co_2, $Al_{13}Co_4$, Al_3Co, AlCo, Al_5Co_2, а также Al_3Ni_5, Al_4Ni_3, AlNi, $AlNi_3$. Показано, что метод диффузионных пар эффективен в сравнительных экспериментах в геометрии поперечного сечения. Выявлены новые соединения переменного состава. В системе Al-Co в области высоких температур 1300-1375 °С выявлены четыре таких слоя: $Al_{21}Co_{79}$ (78.72 ат.% Co), $Al_{44}Co_{56}$ (55.69 ат.% Co), $Al_{20}Co_{80}$ (79.55 ат.% Co) и $Al_{27}Co_{73}$ (73,29 ат.% Co). В системе Al-Ni также обнаружены соответствующие слои с четкими границами: $Al_{51}Ni_{49}$ (49.07 ат.% Ni), $Al_{36}Ni_{64}$ (64.06 ат.% Ni), $Al_{30}Ni_{70}$ (69.62 ат.% Ni), $Al_{32}Ni_{68}$ (67.86 ат.% Ni).

Общие структурные особенности в многослойных ДЗ обеих систем (пористость, фестоны и сдвиг известных интерметаллидных фаз постоянного состава к более высоким температурам), а также свидетельства изменения локальной плотности не только для разных слоев, но и в пределах одного слоя могут внести вклад в детализацию применения этих систем в аддитивных технологиях.

Ключевые слова: диффузионная пара, растровая электронная микроскопия, рентгеноспектральный микроанализ, рентгеновская дифрактометрия, диффузионная зона, многослойная структура, интерметаллиды.

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THERMAL REGIMES OF SPONTANEOUS FIRING COAL WASHING WASTE SITES

Abstract. Spontaneous firing is a typical phenomenon at coal washing waste dumps containing argillites, siltstones, sandstones, and coal. The study of the spatial and temporal variability of the heat temperature field on the sites of spontaneous firing a topical issue for further modeling and forecasting.

At the area of the rocky dump spontaneous firingof the coal washing plant "Chervonogradska" of the JSC "Lviv Coal Company" (Ukraine), temperature measurements were performed at depths 0.5 m, 1.0 m, 1.5 m, 2.0 m, and 2.5 m along three profiles distanced 8 m, 15 m and 28 m from the edge of the dump. The measurements were taken twice at two-week intervals. The temperature measurements were carried out directly at the measuring points by a thermometer with a thermocouple and remotely in the infrared range using a FLUKE TiS40 thermal imager and a partial pyrometer "Smotrych - 4PM1".The temperature measurements were used to construct horizon maps and sections. The regularities of temperature variations in the vertical and horizontal directions were explained. The temperature gradients were calculated, and they reach 14.5 °C/m. The dependences of the temperature gradients variation on the depth and the absolute temperature values in the thickness of the heap were validated statistically. The harmfulness of water supply into the thickness of burning rock dumps leading to the intense spread of heating along the laterals was justified theoretically and confirmed experimentally.

Keywords: coal washing waste dumps, spontaneous firing, thermal field, thermal gradient.

1. Introduction. Coal mining is associated with the excavation of large volumes of rocks, water, and gas onto the surface. As a result, large areas of fertile soils are occupied by rock dumps. Each thousand tons of mining generates 110-150 m^3 of rock wastes, and 100-120 m^3 are produced at the enrichment of a thousand ton of coal [1].

The waste dumps often contain hazardous substances, and storage of the rock wastes causes a formation of the specific man-induced geochemical systems: "waste dump – soil – underground water (mining water) – surface water – soil" in the shallow horizon of the lithosphere.

Even greater amounts of pollutants are released into the environment in case of spontaneous firing of coal and coal washing stones. The issue of coal fires is typical of many countries of the world, including China, India, the USA, South Africa, Australia, France, Russia, Poland, and Ukraine [2-5].

The study of the process of coal mine dumps spontaneous firing is an actual issue of our time. The spontaneous firing of waste dumps causes environmental pollution due to the evaporation of toxic gases, formation of chemicals polluting aquifers, burnout of rock, and downwarping formation. As a result of this process, oxides of sulfur, chlorine, ammonium, hydrogen sulfide, phenols, and mercury are emitted [6, 7]. A significant proportion of these gases can cause a greenhouse effect. It is estimated that [8] coal combustion in China generates about 0.1% anthropogenic greenhouse gases.

Many scientists studied changes in the migration of chemical elements and compounds [4, 7, 9, 10], temperature conditions and kinetics of spontaneous firing of coal in laboratory conditions[11, 12], mineralogens [3, 13, 14], and relief formation [2, 4] in burning waste dumps, and their recultivation [15]. The studies of temperature features are rare; the majority were the remote measurements in the visible firing zones on the surface [8]. The authors did not find any scientific works dealing with the detailed analysis of the structure and dynamics of the fire thermal field of the waste dumps of coal washing factories. This article aims to contribute to the understanding of space and time temperatures distribution within the burning sections of the rock dumps of coal mining factories.

The researchaimis to establish the spatial and temporal variability of the temperature field of the rock dump #4 of JSC "Lviv Coal Company" as a scientific basis for the dump thermal state monitoring.

Control of the rock dumps thermal state is carried out for:

a) the timely detection of spontaneous heating zones on the existing dumps and taking measures to prevent spontaneous firing;

b) assessing the effectiveness of measures aimed at reducing the intensity of burning rock dumps;

c) obtaining initial data for the development of projects for rock dumps extinguishing or picking.

The study of the spontaneous firing processes was carried out within the dump of the coal washing factory of JSC "Lviv Coal Company."

2. Area description. In Ukraine, coal extraction is concentrated in three basins: Donetsk, Lviv-Volynsky Coal Basins, and Dnieper Brown Coal Basin. The Lviv-Volynsky Coal Basin (LVB) is located in the western part of Ukraine near the Poland-Ukraine border. Coal of the basin is mined by the underground method and enriched at the Chervonogradska enrichment plant of JSC "Lviv Coal Company".

2.1. Geological structure. The geological environment of the investigated territory is considered to be a part of the Volyn-Podolsk Plate of the Western European Platform, where the Paleo-Mesozoic-Cenozoic complex of terrigenous-carbonate and fluvio-glacial deposits of the Lviv-Volynskyi Coal Basin underlay. Coal layers are located in the rock mass of the coal formation lying in the secondary synclinal folds formed as a result of the Carpathians formation and the subduction of the East European platform for the Western European one. Coal formation of the Tournaisian, Visean, Serpukhovian stages of the Lower Carboniferous is carbonous one. The Serpukhov Stage is characterized by the primary productive carbonous stratum. *Quaternary deposits* are composed mainly of loessial (5-6 m),fluvio-glacial and alluvial rock complexes with a total thickness of 0.5 to 36 m.

The terrain in the region is mild, with the difference in elevation of 15-20 m per km in all directions.

2.2. Hydrogeology. In hydrogeological terms, the Chervonogradskyi geological and industrial area is the part of the Volyn-Podilskyi artesian basin. Here, the following parts are distinguished: a non-pressure aquifer in Quaternary deposits, and pressure, namely the Senonian aquifer complex, which serves as the main source of drinking water supply, the aquifer of the Jurassic and Carboniferous sediments, and the aquiferous complex of the Devonian deposits.

2.3. Hydrology. The research area is located within the Western Bug river basin, which flows into the river Vistula. The river flow rate is 0.2-0.6 m/s. As a result of prolonged coal mining, a significant part of the research area has suffered subsidence, resulting in frequent flooding and swamping terrain. The rivers of the study area are contaminated with organic substances, nitrogen compounds, and heavy metals [16].

2.4. Administrative affiliation of the territory. The Chervonogradska enrichment plant is located in the Lviv region in Western Ukraine, 60 km north of Lviv and 65 km east of Tomaszow Lubelski in the Lublin Voivodeship of eastern Poland.

2.5. Characteristics of the rock dump of the coal washing plant. The area of the industrial estate of the coal washing plant is 36.0 hectares. The waste dump in the area of 73.7 hectares was put into operation in 1979. The height of the central part of the dump is 60 m, the area of the base is 650 thousand m^2; perimeter on the bottom layer is 3300 m. The volume of deposited rocks is 30 million m^3; hoisting slopes are about 31°.

Solid waste of coal washing is transported by cars and poured into the rock dump, distanced by 0.2 km from the company's industrial site.

Waste coal is a mixture of mudstones, siltstones, sandstones, marl, and coal. In the waste composition, pyrite is present. The specific weight of waste is 2.6 g/cm^3.

The object of the research is the temperature field of fire banks of coal washing plants.

3. Materials and methods. Temperature measurements were carried out by remotely in the infrared range with a thermal imager, with a pyrometer, and directly in the place of contact with the rock with a special thermometer.

3.1. Remote sensing methods. The reconnaissance temperature survey of the dump surface was carried out remotely at a distance of 1.5-20 m from the surface in the infrared range of 7.5 - 14 µm using the FLUKE TiS40 thermal imager. The thermal imager has a spatial expansion of 3.9 mrad, a detector expansion of 160x120, a thermal sensitivity (NETD) ≤ 0.09 ° C at a target temperature of 30° C, a temperature range -20°C – 350°C with a maximum error of ± 2.0°C.

The temperature within the open fires was measured using a partial-measurement laser pyrometer Smotrych - 4PM1, which is characterized by a range of measured temperatures -30 – 1200°C with a maximum error of ± 1.5°C and thermal sensitivity (NETD) of ≤ 0.1°C.

At the reconnaissance stage, a survey of the surface of the working places with probes was also carried out to identify cracks, cavities, etc. Remote temperature measurements were carried out on an area of 46,600 m^2.

3.2. Contact method. On the territory of Ukraine, to control the thermal state of the rock dump, the regulatory organization [NPAOP 10.0-5.21-04] determining the general methodology and the limit values of a rock dump thermal state. According to this instruction, the temperature limit in rock dumps at a depth of 0.5 m should not exceed 45°C, but it can reach 80°C at 1.0m depth.

Temperature measurements were carried out on the leveled surface of the first tier of the dump by a stepwise temperature survey in rocks along three profiles (AA$^{|}$, CC$^{|}$, DD$^{|}$) located parallel to the edge of the dump. Temperature measurements were carried out in 2 stages: in mid-September and early October 2016 with a two-week interval. AA$^{|}$ profile laid at a distance of 7-8 m from the edge of the blade. CC$^{|}$ profile laid at a distance of 15 m and DD$^{|}$ the profile laid at a distance of 28 m from the edge of the dump. The distance between the temperature measurement points along the profiles AA$^{|}$ and CC$^{|}$ was 20 m, the distance between the temperature measurement points along the profile DD$^{|}$ was 60 m. Additionally, between the main points, the temperatures in the firing source were measured. Along the profiles AA$^{|}$ and CC$^{|}$, temperature measurements were carried out in at least 57 points.

Along the AA$^{|}$and CC$^{|}$profiles, the temperature measurements were carried out at depths of 0.5, 1.0, 1.5, 2.0, 2.5 m, and along the profile DD$^{|}$ the measurements were made at depths of 0.5 and 2.5 m. The temperature was measured at 173 points. At each point at both stages of the survey, the measurements were made three times and the average value was entered into the database.

Temperature measurements were carried out by equipment with a thermocouple (from now on thermocouple). The range of measured temperatures is from 30 to 1200°C with a maximum error of ± 2.0°C. The device is equipped with steel rods 0.5, 1.0, 1.5, 2.0, 2.5 m long. During the measurements of the temperature of the dump rocks, the air temperature varied between 19.1 and 21.5°C. In places with no obvious signs of burning, the temperature of the rocks on the surface of the dump, ranged from 22.7 to 29.0°C. The direct temperature measurements by thermocouple were made on a flat surface area of 33,300 m^2.

The primary data were merged into a database for further statistical processing. For each profile and interval of studies, the mean, median, mode, and standard quadratic deviation were calculated. All the samples that were used in the correlation analysis passed the test of the normal distribution. The significance of the Pearson's correlation coefficients was estimated using 2-tailed test of significance.

Since the number of measurement points in the profiles was different, the parameters of the temperature variation between the profiles and in time were calculated not by comparing the average temperature values, but by comparing the primary temperature values along those lines perpendicular to the edge of the dump, in which, at each stage of the study, measurements were made along three parallel edges of the profile bank.

4. Research results. *4.1. Remote temperature measurements.* According to the results of the research of the dumping masses by using the thermal imaging camera (in September), it was established that the temperature field of vaporization of the steam-air mixture does not exceed 82.8°C at a distance of 2-8 m from the edge of the slope. When examining the surface of the heap, the zones of an abnormal increase in surface temperature up to 54.5°C were detected (figure 1). The area of the heated surface of individual sections with a temperature of more than 50°C does not exceed 1.5 m^2.

The pyrometer recorded the temperatures of visible firing sites from 160.3°C to 997.4°C, with the average temperature 436.7 °C.

4.2. Immediate (contact) temperature measurements. Based on the results of the point measurement of the thermocouple temperatures, at the first stage of the research (in September 2016), we measured the rock temperatures from 35.0 °C to 98.6 °C along AA$^{|}$ profile at the section 7-8 m from the edge of the slope (table 1).

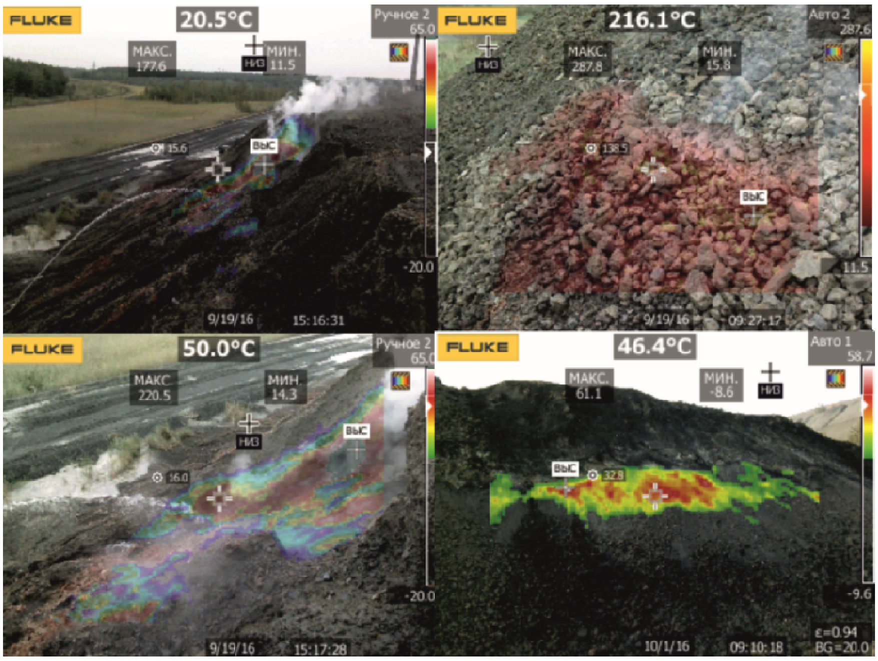

Figure 1 –The spontaneous firing sites of the coal washing waste sites (obtained by thermal imager)

Table 1 – Characteristics of the change in the average temperature of the dump rocks along the vertical and lateral (as of September 2016)

Depth, m	Min	Max	Mean	Median	Standard deviation
AA$^{|}$ profile					
0.5	35.0	80.9	55.9	55.4	11.32
1.0	42.1	85.1	65.7	67.7	10.96
1.5	46.9	86.6	70.4	72.7	10.38
2.0	50.5	92.4	72.8	75.6	10.21
2.5	50.7	98.6	77.2	77.2	10.30
CC$^{|}$ profile					
0.5	34.5	57.4	43.8	44.0	4.53
1.0	39.1	65.3	47.9	48.0	6.34
1.5	39.6	70.8	52.5	51.2	6.93
2.0	41.2	72.4	60.3	60.8	7.41
2.5	39.1	88.1	67.8	68.3	10.70
DD$^{|}$ profile					
0.5	34.8	44.4	40.9	41.5	2.92
2.5	36.2	77.2	50.8	49.0	12.3

The temperature of the rocks increases on the average with depth. The temperature at a depth of 2.5 m was higher compared to the temperature at a depth 0.5 m 1.4 times.

The rock temperature below 50°C is detected at 19 points (33%) at a depth of 0.5 m. Only 5 such points were found at a depth of 1.0 m. 2 points were detected at a depth of 1.5 m. We did not detect any points with temperatures below 50°C at depths of 2.0-2.5 m (figure 2).

One can see the vertical structure of the temperature distribution (figure 3) on the section along the slope of the rock refuse.

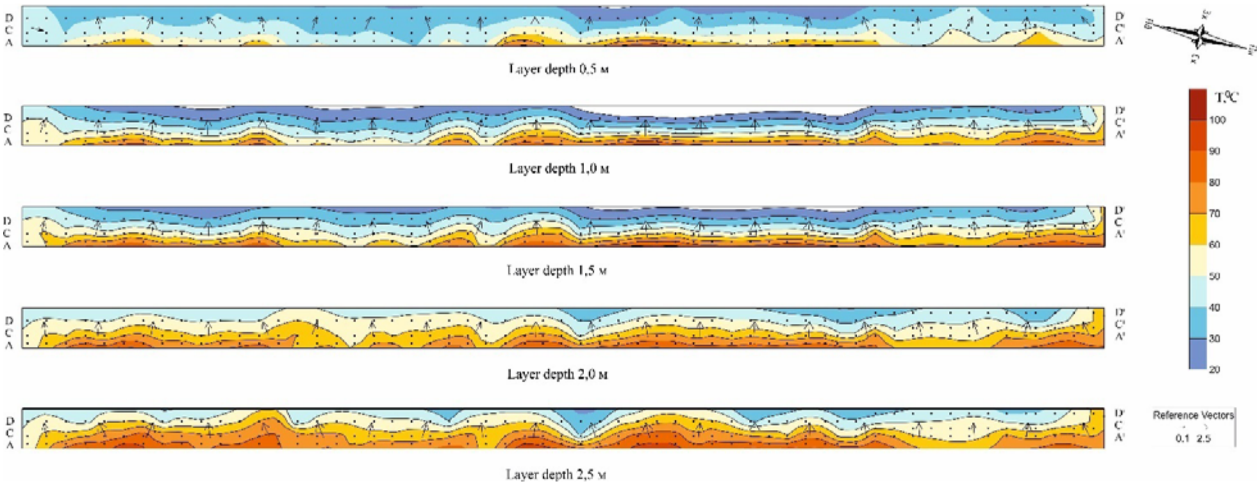

Figure 2 – The temperature field maps in the different depths (September, 2016); the color identifies the temperature, the arrows correspond to the temperature gradients

After calculating the temperature difference between the deeper layer and the overlying layer and dividing it by the distance between these layers, we obtained a temperature change characteristic with a depth similar to the geothermal gradient:

$$Grad_t = (t_1 - t_2)/\Delta l,$$

where $Grad_t$ – thermal gradient, t_1 – temperature in the deep-lying horizon, t_2 – temperature in the overlying horizon, Δl – distance between the layers.

The calculated thermal gradient is the averaged indicator of the temperature change on a specific section in a certain range of studies in a given direction (vertical or horizontal). It differs in a given direction from the traditional gradient (which is a vector directed to faster change of the temperature field). These vectors are presented on the maps and the section (see figures 2, 3). The averaged gradient has a different purpose, namely, characterizing the change in the temperature field deep down the rock dump along the vertical and deep down the terrarium along the lateral with distance from its edge. In some sections, the temperature with depth increasing or distance from the edge of the rock dump decreased, we obtained negative gradient values that are not typical of the traditional gradient.

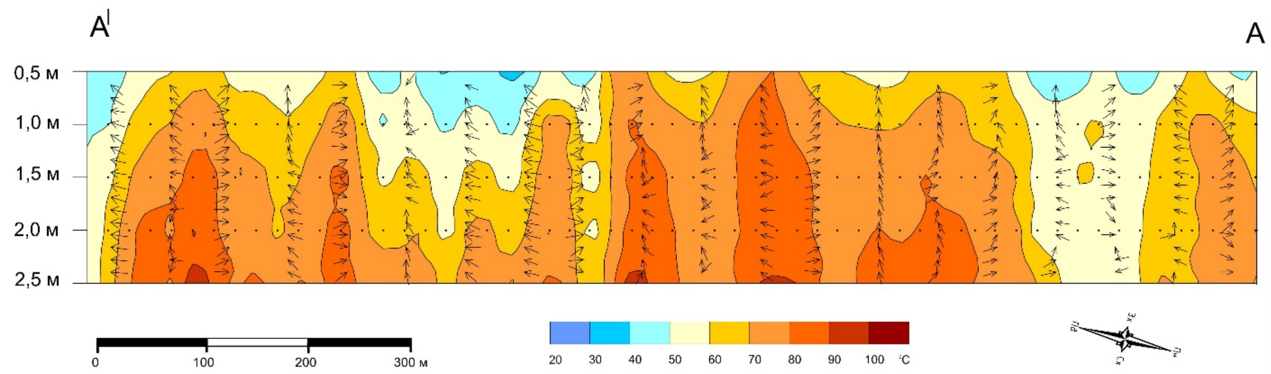

Figure 3 –The cross sectional view of the temperature field along AA| profile (September, 2016)

The value of the calculated temperature gradient with depth along the profile AA| varies from -3.0°C/m to 14.5°C/m with an average value of 2.7 °C/m. In 9% of the intervals, the coefficient is less than zero, which indicates a decrease in temperature with depth. In the depth interval 0.5-1.0 m, the average temperature change is 5.1 °C/ m, in the interval 1.0-1.5 m – 2.1 °C/m, in the interval 1.5-2.0 m – 1.4 °C/m, in the interval 2.0-2.5 m – 2.0 °C/m. That is, with depth increasing, the intensity of temperature changes decreases in general. In the intervals 0.5-1.0 m and 2.0-2.5 m, the temperature gradient tends to increase with increasing absolute values. However, these trends have not been statistically confirmed.

Along the CC$^{|}$ profile set at a distance of 15 m from the edge of the slope, the rock temperature at a depth of 0.5 m is on the average 13.9 °C lower than the temperature along the profile AA$^{|}$. Comparison of standard deviation values indicates a lower variability of the actual temperature values for the section CC$^{|}$ in comparison with the AA$^{|}$ section. The rocks along the DD$^{|}$ and CC$^{|}$profiles at a depth of 0.5 m are characterized by the lowest temperature variability. The low value of the standard deviation indicates this as well as the proximity of the mean and median. In most layers in both sections, the arithmetical mean is less than the median, which indicates a significant amount of data exceeding the arithmetical mean and the individual anomalous values of low temperatures (see table 1).

Along the CC$^{|}$ profile, the temperature gradient varies from -3.5 °C/m to 11.0 °C/m with depth increasing with an average value of 3.0 °C/m. In 7% of the intervals, the temperature decreases with depth increasing. In the depth interval 0.5-1.0 m, the average temperature change is 2.0 ° C/m, in the interval 1.0-1.5 m – 2.3 °C/m, in the interval 1.5 -2.0 m – 3.9 ° C/m, in the interval 2.0-2.5 m – 3.7 °C/ m. There is a tendency to increase the intensity of temperature changes depending on depth increasing with increasing absolute temperatures in all intervals. This trend becomes statistically confirmed in the intervals 0.5-1.0 m and 2.0-2.5 m. Therefore, it is possible to talk about a new direct relationship between the change in the intensity of temperature growth with depth increasing in comparison with the absolute values of the temperature in the indicated intervals (figure 4).

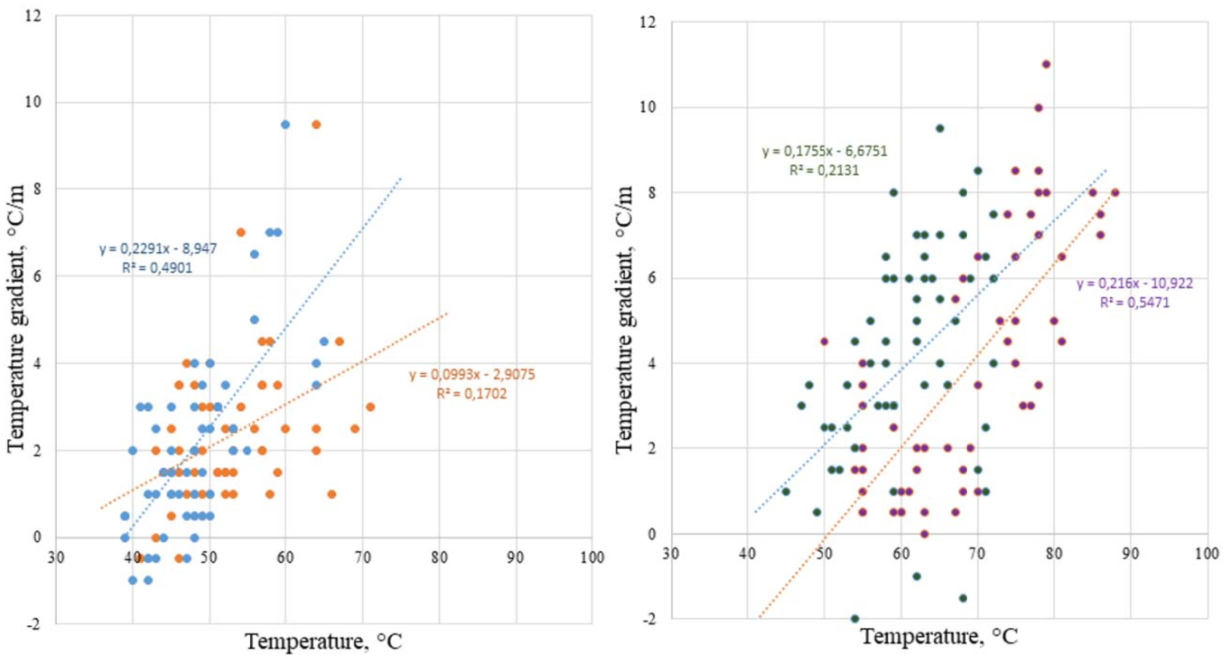

Figure 4 –The temperature gradient change with depth depending on the absolute temperature values along CC$^{|}$ profile (the color identifies the temperature gradients, the regression line and its equations blue - at depth 0.5-1.0 m, orange - at depth 1.0-1.5 m, green – at depth 1.5-2.0 m, purple – at depth 2.0-2.5 m)

The temperature naturally decreases from the profile AA$^{|}$ to profile DD$^{|}$ perpendicular to the edge of the rock dump (deep down the dump) (See table 1).

The temperature gradient horizontally at a depth of 0.5 m perpendicular to the edge of the dump was 1.7 °C/m between the profiles CC$^{|}$ and AA$^{|}$ and 0.2 °C/m between the profiles DD$^{|}$ and CC$^{|}$. That is, at the edge of the slope (profiles AA$^{|}$ and CC$^{|}$), the temperature decreased by 1.7 °C each meter deeper down the slope. The temperature decreased by 0.2 °C with further motion perpendicular to the slope of the heap. It should be noted that the temperature of rocks did not always decrease deep down the heap: on some sections (10%) with a rock temperature of up to 50 °C, an increase in temperature with the increasing of the heap depth was observed.

In the intervals of 1.0-1.5 m, 1.5 - 2.0 m, and 2.0-2.5 m between the profiles AA$^{|}$ and CC$^{|}$ the temperature decreased on the average by 2.6 °C/m, 2.5 °C/m, 1.8 °C/m, and 1.3 °C/m respectively. It means that the intensity of cooling of the dump deep down the heap in the interval 1.0-2.5 m naturally decreases.

Between the profiles CC| and DD| the temperature in the interval 2.0-2.5 m decreased by 1.1 °C on the average.

The slope of the dump was cooled with water after the first stage of the research. On average, 223 m^3 of water per m^2 of the surface of the dump was supplied per day.

After 14 days, the temperature of the rocks along the profile AA|decreased by 1.5 °C on the average. The temperature decreased by 4.9 °C at a depth of 0.5 m. At depths of 1.0-2.5 m, the temperature change varies in the range from -1.7 to +0.5 °Cin comparison with the previous stage of research. It should be noted that the maximum temperature increased to 102 °C, which we did not fix during the first stage of the study (figure 5).

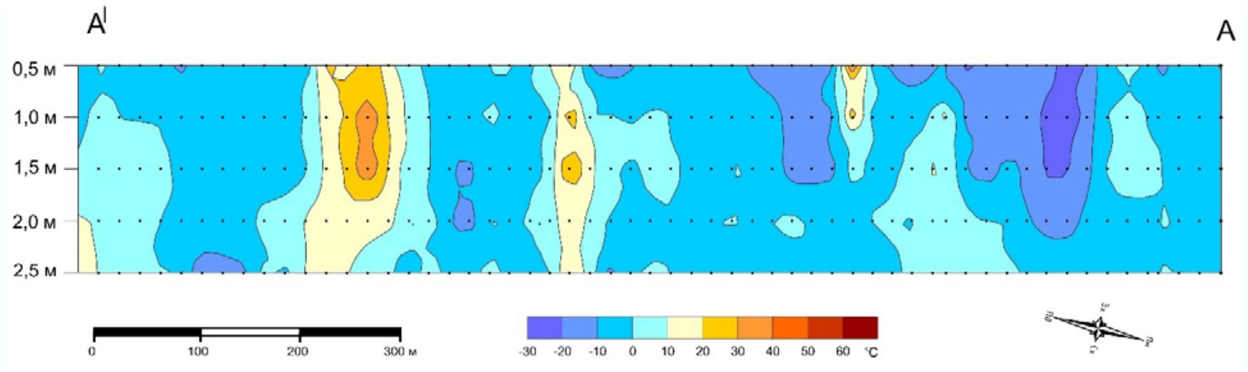

Figure 5 –The cross sectional view of the temperature field of the coal washing plant"Chervonogradska" along AA| profile (September-October, 2016)

Along the CC| profile, rock temperatures decreased by 1.5°C on the average. It increased by 2.2 °C along the DD| profile. The increase of the average temperature by 3.2 °C at a depth of 0.5 m along the DD| is especially noticeable (table 2). The latter fact may indicate an intensification of the lateral extension of the temperature field deep down the dump.

Table 2 – Characteristics of the change in the average temperatures of the dump rocks along the vertical and lateral (as of October 2016)

Depth, m	Min	Max	Mean	Median	Standard deviation
AA| profile					
0.5	28.0	102.0	50.7	51.1	14.5
1.0	36.2	101.3	64.2	64.8	14.7
1.5	38.7	99.8	69.6	71.3	14.5
2.0	42.3	99.2	73.4	75.7	12.0
2.5	51.8	100.1	76.1	76.0	10.1
CC| profile					
0.5	36.2	64.3	43.2	43.2	5.49
2.5	39.4	82.7	66.1	65.8	9.83
DD| profile					
0.5	37.8	46.2	42.1	42.1	2.78
2.5	37.4	69.8	53.8	53.2	11.1

5. Discussion of results. *5.1. Regularities of the temperature change in the body of the dump.* Based on the full-scale results of our studies, namely, on the variability of the temperature field on the laterals, it can be argued that, despite the possibility of an aoxigenic rise in temperatures in rock dumps, the main factor of the rocks firing is their contact with oxygen. This is evidenced by a breakdown in temperatures perpendicular to the edge of the dump from 1.3 to 1.7 °C/m in different horizons at an interval of 8-15 m from the edge of the dump. At a distance of 28 m from the edge of the dump, the rock temperatures at a depth of 2.5 m were 50.8 °C, which is 26.4 °C less than the temperatures fixed along the profile laid in 8 m from the edge of the dump. The source of high temperatures in the surface layers of the dump is the sources of the anomalous temperatures in the depth of the heap. The results of pairwise correlation of temperatures between different layers confirm this fact also (table 3).

Table 3 – Temperature Correlation Coefficients in Layers of Different Depths

Depths	2.5 m	2.0 m	1.5 m	1.0 m	0.5 m
AA profile					
2.5 m	1	0.93	0.87	0.74	0.69
2.0 m		1	0.96	0.83	0.73
1.5 m			1	0.93	0.84
1.0 m				1	0.89
0.5 m					1
CC profile					
2.5 m	1	0.82	0.50	0.28	0.32
2.0 m		1	0.69	0.46	0.41
1.5 m			1	0.88	0.57
1.0 m				1	0.76
0.5 m					1

It is important to note the decrease in the correlation coefficients in the deep horizons of the profile AA and partly in the profile CC with the temperature in the layer at a depth of 0.5 m, which indicates the influence of atmospheric cooling factors and possibly better convection in the surface layers. At the same time, the temperature correlation coefficient between the layers of 2.5 and 0.5 m is significant in both profiles, indicating the dominant role of firing source in the depth in the formation of the temperature field of the whole body of the heap. The decrease in the correlation coefficients of temperatures from the layers along the CC profile indicates that the temperature of the overlying horizons is influenced not only by the temperature from the lower-lying horizons, but also by the temperature that is transmitted laterally from the horizon AA. This assumption justifies the results of pairwise correlation between the temperatures measured at one depth in parallel profiles (table 4).

Table 4 – Temperature Correlation coefficients between Profiles

	AA 2.5 m	AA 2.0 m	AA 1.5 m	AA 1.0 m	AA 0.5 m
CC 2.5 m	0.57	0.49	0.45	0.37	0.40
CC 2.0 m	0.60	0.53	0.43	0.29	0.23
CC 1.5 m	0.49	0.50	0.50	0.43	0.34
CC 1.0 m	0.33	0.37	0.41	0.42	0.32
CC 0.5 m	0.39	0.37	0.44	0.46	0.46

The correlation coefficients of temperatures fixed on one horizon along parallel profiles turned out to be the highest in the deeper layers and less in the surface layers. It should be noted that close correlation links in diagonal directions, primarily between a layer of 2.5 m along the AA profile and a layer of 2.0 m along the CC profile. The obtained statistical regularities shed light on the issue of estimating the share of vertical and lateral heat displacements in the body of the rock dump.

5.2. The water effect on the spread of heat in the body of the dump. The data obtained during two stages of research experimentally confirm the harmfulness of water supply into the thickness of the firing rock dump, leading to the intensification of firing and intensive fire propagation along the laterals. It is known that liquids transfer heat better than gases. The coefficient of thermal conductivity of water at a pressure of 10^5 Pa and a temperature of 333 K (60°C) (the average temperature for the conditions of a firing dump) is $653·10^{-3}$ W/(m·deg). Under the same conditions, the thermal conductivity of atmospheric air is $29·10^{-3}$ W/(m·deg), that is, 8 times less. Under conditions of a temperature of 373 K (100 °C), the thermal conductivity of water vapor and atmospheric air is $25·10^{-3}$ W/(m·deg) and $32·10^{-3}$ W/(m·deg), respectively [18, 19]. High thermal conductivity of water is achieved due to the high water pressure in comparison with the gas. When the water changes into the water vapor, the pressure decreases sharply, and then the thermal conductivity of the water vapor decreases sharply in comparison with the liquid water.

These processes are directly related to the processes of heat transfer in the body of the rock dump under investigation. In our opinion, when water with a temperature of 50-80 °C is more dynamic in comparison with a "dry" gas, transferring heat vertically and laterally, evaporating and contributing to the development of firing sources extension.

The results of the long Ernst Beier experiment [17], which showed that the adsorption of oxygen by coal increases with air humidity increase, confirm our hypothesis. Slow oxidation of coal is accompanied by heat emission, which, of course, contributes to its spontaneous firing. Dump fire monitoring can be done using complex multiphase foam gels [20], but not water supply.

The results of our studies indicate a high variability in the parameters of the thermal field, leading to the need to create a system of constantly monitoring the temperature field of fiery heaps.

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7. Conclusions. In the case of the coal washing plant rock dumps firing, the temperature of the rocks increases with depth and decreases perpendicular to the edge of the dump. On average, the temperature at 2.5 m is 1.4 times higher compared to the temperature at a depth of 0.5 m. The temperature gradient along the profile laid in 8 m from the edge of the slope varies from -3.0 °C/m to 14.5 °C/m with an average mean of 2.7 °C/m. Along the profile laid at a distance of 15 m from the edge of the dump, the temperature gradient varies from -3.5 °C/m to 11.0 °C/m deep down the heap with an average mean of 3.0 °C/m.

The intensity of temperature changes is more significant in the surface layers and lower in the deeper ones. There is a tendency to an increase in the temperature changes intensity with an increase in its absolute values.

Perpendicular to the edge of the dump, there is a breakdown in temperatures from 1.3 to 1.7 °C/m in different horizons at an interval of 8-15 m from the edge of the dump. This fact indicates that the main factor in the rocks firing is their contact with oxygen.

The harmfulness of the water supply into the thickness of the firing rock dump leading to an intensification of the fire propagation along the laterals has been experimentally confirmed.

The obtained trends and regularities of changes in the dynamics of temperature extension along the vertical and lateral lines provide a reliable experimental basis for heat exchange processes simulation in rock dumps of coal washing plants in the firing process.

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ӨЗДІГІНЕН ЖАНУДАН ТУЫНДАҒАН КӨМІРДІ БАЙЫТУ ҚАЛДЫҚТАРЫНЫҢ ТЕРМИЯЛЫҚ РЕЖИМДЕРІ

Аннотация. Құрамында агриллиттер, алевролиттер, құмдақтар мен көмір болатын көмірді байыту қалдықтарын жинау көп жағдайда олардың өздігінен тұтануына алып келеді. Өздігінен жану аймақтарындағы температуралық өрісінің кеңістіктік және уақыттық өзгергіштігін анықтау мұндай үрдістерді ары қарай модельдеу мен болжау үшін өзекті мәселе болып табылады.

ААҚ «Львовская угольная компания» (Украина),"Червоноградская" көмір байыту фабрикасының жыныстар үйіндісінің өздігінен жану аймағында үйінді шетінен 8 м, 15 м және 28 м қашықтықта орналасқан үш профильдер бойымен 0,5 м, 1,0 м, 1,5 м, 2,0 м, 2,5 м. тереңдіктерде температуралар өлшенді. Өлшеу жұмыстары 2 апта интервалымен 2 рет жүргізілді. Температураларды өлшеу тікелей өлшеу нүктелерінде жылу сезгіш элементі бар құралдың көмегімен және қашықтықтан инфрақызыл диапазондаFLUKE TiS40 тепловизоры мен ішінара өлшейтін «Смотрич - 4ПМ1» лазерлік пирометрінің көмегімен жасалды. Температураларды нүктелік өлшеу нәтижелері бойынша карталар мен қималар тұрғызылды. Тік және көлденең бағыттарда температураладың өзгеру заңдылықтары түсіндірілді. 14,5 с/м жететін температуралар градиенттері есептелді. Температура градиенттерініңүйінді қабаттарының тереңдігі мен температуралардың абсолютті мәндеріне тәуелділігі статистикалық негізделді. Жанып тұрған жыныстық үйінді қабаттарына судың берілуі жанудың интенсивтілігінің латераль бойынша артуына себеп болатыны теориялық негізделіп, тәжрибелік түрде дәлелденді.

Түйін сөздер: көмірді байыту үйінділері, өздігінен жану, жылу өрісі, температуралық градиент.

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ТЕРМИЧЕСКИЕ РЕЖИМЫ ОТХОДОВ УГЛЕОБОГАЩЕНИЯ ВЫЗВАННЫХ САМОВОЗГОРАНИЕМ

Аннотация. Складирование отходов углеобогащения, которые содержат аргиллиты, алевролиты, песчаники и уголь в отвалы часто влечёт к их самовозгоранию. Установление пространственной и временной изменчивости температурного поля отвала на участках самовозгорания является актуальным вопросом для дальнейшего моделирования и прогнозирования таких процессов.

На участке самовозгорания породного отвала углеобогатительной фабрики "Червоноградская" ОАО «Львовская угольная компания» (Украина) выполнено замеры температур на глубинах 0,5 м, 1,0 м, 1,5 м, 2,0 м, 2,5 м вдоль трех профилей расположенных на расстоянии 8 м, 15 м и 28 м от края отвала. Измерения осуществлено дважды с интервалом 2 недели. Измерения температур осуществляли непосредственно в точках замера измерительным прибором с термопарой и дистанционно в инфракрасном диапазоне с помощью тепловизора FLUKE TiS40 и лазерного пирометра частичного измерения «Смотрич - 4ПМ1». По результатам точечных измерений температур построено карты и разрезы. Объяснены закономерности изменения температур в вертикальном и горизонтальном направлениях. Рассчитаны градиенты температур, которые достигают 14,5 С/м. Статистически обоснованно зависимости изменения градиентов температур от глубины и абсолютных значений температур в толще отвала. Теоретически обосновано и экспериментально подтверждено вредность подачи воды в толщу горящего породного отвала, которая способствует к повышению интенсивности распространения горения по латерали.

Ключевые слова: отвалы углеобогащения, самовозгорания, тепловое поле, температурный градиент.

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INVESTIGATION OF CHEMICAL COMPOSITION OF THE ARAL SEA WATER IN AUTUMN SEASONS OF 2012AND 2013

Abstract. The water level in the Aral Sea started drastically decreasing from the 1960s onward. The reduction in the volume and area of the sea has led to significant changes in the hydrological, chemical and natural biological structure of the water. Regular observations of the chemical composition of the Aral Sea stopped in the early 90s. There were practically no observations of biogenic elements and the oxygen regime of water (the so-called "first day" analyses).

In September 2012 and October 2013, a complex of hydrochemical observations, including the measurement of the content of biogenic elements, dissolved oxygen, the concentration of hydrogen sulfide and components of the carbonate equilibrium, was carried out within the framework of international expeditions. The determinations were carried out directly on the seashore in a temporary laboratory. The main purpose of the work was to determine the content of nutrients in the water of the Aral Sea and to develop methods for hydrochemical studies in conditions of increased salinity (mineralization) of water. In addition, samples were collected to determine the total mineralization of water and the content of dissolved and suspended forms of metals. It was shown that the small depth of the sea and the high intensity of the processes of vertical transport of substances allowed that seasonal changes in the chemical composition affected the entire vertical water. Deeper than 18-30 meters in water, there was hydrogen sulfide. The presence of anaerobic conditions in the deep part of the sea affected all hydrochemical parameters. Some research results are given in the article.

Key words: the Aral Sea, biogenic elements, oxygen.

Introduction. After a fairly long break, starting from 2002, the annual complex oceanographic studies of the Aral Sea was resumed by the Federal state budgetary institution of science of the IO RAS (Russia) and Khoja Akhmet Yassawi International Kazakh-Turkish University (Kazakhstan), together with the Institute of Geology and Geophysics named after Kh. M. Abdullaev (Academy of Sciences of Uzbekistan), Nukus State Pedagogical Institute named after Azhiniyaz (Uzbekistan) of Karakalpak State University named after Berdakh [1-3].

The study of the hydrochemical conditions of the reservoirs at such a stage of degradation as now the Aral Seapresents a unique opportunity for studying the catastrophic consequences of both anthropogenic impact and climate change. In this case, the Aral Sea can be considered as a unique natural laboratory as it does not sound cynical.

The correct determination of the content of biogenic elements practically excludes long-term transport of samples. The sooner the tests are performed, the more reliable the results are obtained. The permissible storage time for samples under different manuals is determined from 6 to 12 hours after the selection [3-5]. The conservation of samples naturally increases the risk of obtaining unreliable results. So, with the widespread procedure of sample freezing, it is possible to form a sparingly soluble precipitation or sorption of carbonates on the inner surface with a vial, which is especially manifested under conditions of increased mineralization. For this reason, analyses of the phosphate, nitrate, nitrite and ammonium nitrogen, as well as pH values are sometimes called "the first day analyzes". Therefore, in expeditions

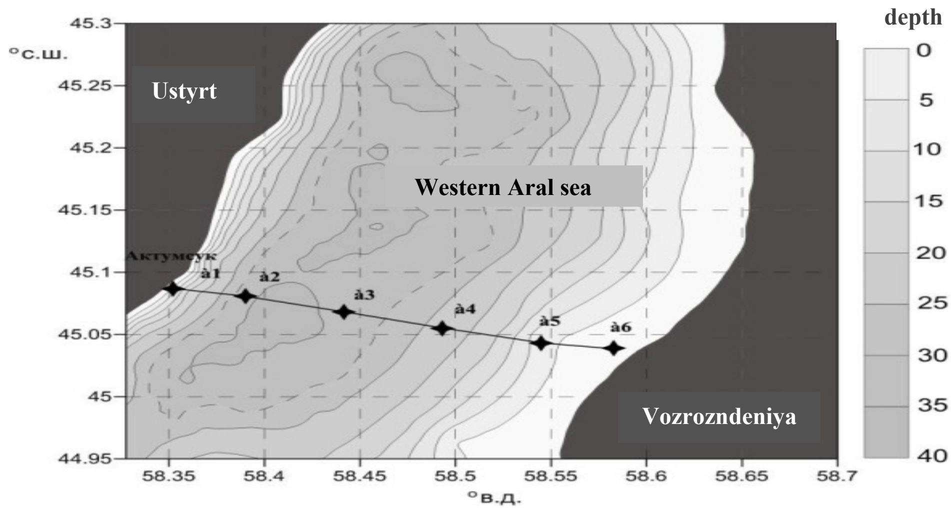

Figure 1 – Scheme of location of stations where hydro-chemical observations were carried out in 2012 and 2013

hydrochemical studies were carried out directly on the seashorein 2012 and 2013. At the meteorological station Aktumsuk Uzhydromet (figure 1), located 8 km from the modern coastline on the Ustyurt plateau, a temporary hydrochemical laboratory was deployed.

In 2012-2013, the content of biogenic elements in the water of the Aral Sea was measured and the methods of hydrochemical studies were tested in conditions of extremely high salinity (mineralization) of water. Perhapsthe complex of hydrochemical works, including the determination of dissolved oxygen, hydrogen sulfide, pH values and total alkalinity, the content of dissolved inorganic phosphorus, silicon, nitrogen in nitrate, nitrite and ammonium forms was performed on the Aral Sea shore for the first time since the beginning of the 1990s.The filtration and conservation of the samples for the subsequent determination of metals, suspended substances and general mineralization in stationary laboratories were also carried out.

Materials and methods. In 2012,selection of samples was conducted during outages at sea: 26, 27, 28 September. In 2013, it was carried out on 30, 31 October and 2 November. The sampling was conducted by a 5-liter plastic bottle of Niskinwith the help of a hand winch mounted on an inflatable boat. The selection was preceded by sounding with an STD probe (SBE19plus). On the board after selecting, the samples were fixed for oxygen, hydrogen sulfideand ammonium nitrogen. The samples were taken in plastic bottles. Considering the need for conducting methodological work, a significant number of parallel determinations were performed by the use of various methods of analysis and sample preparation. The determination of biogenic elements was carried out in filtered water. The filtration was conducted through nuclear filters with a diameter of47 mm with a pore size of 0.4 mm. The determination of hydrochemical parameters was carried out according to generally accepted methods [4-7].

With the onset of the sea level drop in the 1960s, the mineralization (the salinity) of the Aral Sea increased from about 10 to 100 g/kg or more in the western basin, while in the eastern basin, according to the data of the year 2008, the mineralization exceeded 200 g/kg [1]. Naturally, as for other hyperha-line-reservoirs, the adaptation of existing methods to the conditions of increased salinity was a serious problem [2, 8].

As mentioned above, the question of the applicability of standard methods of hydrochemical work under conditions of high mineralization and the specific ionic composition of the Aral Sea waters was one of the basic for the hydrochemical group. The simplest reliable solution to this problem in the temporary laboratory was the dilution of samples. A part of the samples with colorimetric determinations was measured, both in natural samples and with varying degrees of dilution with distilled water.

The samples were diluted in a proportion of 1:4 and 1:3, which approximated their mineralization to the ocean salinity. Each series of samples included the determination of the content of this component in distilled water in order to take into account the degree of its contamination by the component being tested. In the diluted samples, the content was calculated by the following formula:

$$C = K \cdot ((D_s - D_o) - (D_{dw} - D_o) \cdot (1 - St)) / St.$$

Where ***C*** is the concentration of the determined characteristic; $\boldsymbol{D_s}$ is the optical density of the sample with the appropriate wavelength method; ***K*** and $\boldsymbol{D_o}$are the coefficient of recalculation and blank correction for reagents, which was determined in a stationary laboratory when the method was calibrated; $\boldsymbol{D_{dw}}$ is the optical density of distilled water with reagents, which is determined simultaneously with a series of samples; ***St*** is the proportion of the Aral water in a colorimetric sample.

Results of methodical work. It was found that in the undiluted samples, methods for determining nitrite and nitrate nitrogen with a "single color reagent" and determination of phosphates by the Morphy-Riley method are not applicable. At high concentrations of phosphates and nitrite nitrogen (more than 1.5 and 0.1 μM, respectively) in undiluted samples, discoloration practically ceases.

The method for the determination of the Silicon Queen in undiluted samples gave underestimated results, in comparison with the diluted ones, by an average of 9%, but this may be due to the fact that the empirical formula for the salinity correction [4] is not sufficiently correct for such a high mineralization of water. The determination of ammonium nitrogen by the phenol-hypochloride method is applicable only for dilution of samples, at least 4 times, the dilution of the sample with distilled water should be carried out when sampling from the bathometer before fixation.

The method for determining dissolved hydrogen sulfide as well as the Winkler method for determining oxygen normally works in undiluted samples. To determine the total titrated alkalinity by the method of direct titration by Bruyevich, the dilution of the sample is not required, the procedure has no limitation on the value of salinity. But for the convenience of the analysis (too large was the natural value of total alkalinity, up to 17 mg-eq/l) and the reduction in the analysis time, we applied the dilution of samples 2-3 times immediately before the titration.

The processing of the collected samples was continued in the Institute of Oceanology Russian Academy of Science. In the laboratory conditions, the content of total dissolved nitrogen and phosphorus was determined and the weight determination of salinity (mineralization) was conducted. A reliable determination of the mineralization value is extremely important for correcting STD sounding data. The latest published data on the ion-salt composition of the Aral waters refer to 2009 [1]. To obtain reliable results on the mineralization of water, the works were carried out to determine the so-called dry residue [9-11]. A separate article will be devoted to the methodological work on determining the general mineralization of the Aral Sea waters and discussing the results of these definitions.

Results of the work

In 2012 and 2013, hydrochemical work was carried out, mainly on a section passing through the Western basin (figure 1). A significant difference was that in 2012 observations were made in the autumn period, and in 2013 later, in the conditions of transition from autumn to winter. Naturally, seasonal changes strongly affected the content of biogenic elements and other hydrochemical parameters (table 1).

Table 1 – Hydro-chemical characteristics of the surface water of the Aral Sea according to the results of the surveys in 2012 and 2013

Parameter	Average	Limits	Average	Limits
	2012		2013	
Oxygen (ml/l)	3.28	0 - 3.38	2.22	0 - 3.51
Oxygen (%)	111.3	0- 115.8	58.8	0 - 92.8
pH, NBS	8.11	8.05 - 8.16	8.11	8.01 - 8.15
Alk, mEq/L	11.260	11.109 - 11.448	11.49	11.16 - 12.78
$P\text{-}PO_4$μg-at/l	1.80	0.24 - 8.96	6.92	0.79 - 14.59
P_{total}μg-at/l	3.55	1.43 - 17.1		
$N\text{-}NO_2$μg-at/l	0.09	0 - 0.24	0.53	0.23 - 0.98
$N\text{-}NO_3$μg-at/l	6.35	1.27 - 11.34	1.26	0.00 - 2.70
$N\text{-}NH_4$μg-at/l			70.93	12.70 - 255.6
$N_{общ.}$,μg-at/l	276.6	209.1 - 424.0	516.1	317.1 - 651.7
Si - SiO_2μg-at/l	43.44	39.42 - 46.39	33.59	17.27 - 120.27
H_2S,			22.78	0.00 - 48.19

In addition to the seasonal course, a significant effect on the distribution of hydrochemical parameters was apparently also due to a change in the salinity profile observed in recent years. The smoothing of the vertical profile of mineralization caused a weakening of the stratification of waters and an increase in vertical exchange. The presence of anaerobic conditions in deep waters also has a significant effect on the hydrochemical regime. According to the literature [1], hydrogen sulfide in the deep waters of the Aral Sea was discovered in 2002, but, possibly, hydrogen sulfide contamination of water was presented even earlier, data on water chemistry between 1991 and 2002 are absent. The evidence, relating to the begin-ning of the twentieth century, about the presence of a smell of hydrogen sulfide in sediments and in the bottom layer of waterwas mentioned in the book by L. K. Blinov [12]. In the middle of the XX century, it was believed that the Aral waters were well aerated, due to vertical mixing and the development of photosynthetic processes throughout the water column [12-15].

The depth of occurrence of hydrogen sulfide from 2002 to 2010 varied from 15 to 35 m. According to the data of work [1], the highest content of hydrogen sulfide (80 mg/l) was observed in 2003. In 2012, in samples with 30 m and deeper, the smell of hydrogen sulfide was distinctly felt and oxygen was completely absent. The reason for the occurrence of hydrogen sulfide contamination, firstly, is the existence of a stable density stratification of water, and secondly, the low oxygen contents (the solubility of oxygen decreases significantly with increasing salinity) with a high content of organic matter. In 2013, the upper limit of the detection of hydrogen sulfide rose higher, up to 18 m.

Considering the distribution of hydrochemical parameters on the section passing through the western basin at about 58 ounces, it can be said that the hydrochemical composition of surface waters (up to 15-20 m) is fairly uniform across the vertical, but considerable variation in the composition of the waters was observed from the east to the west shore. In 2012, for the period of observations, the processes of production of organic substances were actively going on, the intensity of oxidative processes, on the contrary, was very weak. The relative content of oxygen in surface waters was high. The degree of saturation of water on the surface is on average above 110%. In 2013, the work, on the contrary, was at a decline in biological activity; the saturation of water with oxygen on the surface did not exceed 90%, and in some cases decreased to 60% or less. In 2013, the content of dissolved oxygen and the degree of its saturation increased, from the western to the eastern shore. An increase in the absolute and relative oxygen content of the western shore was observed in the entire upper layer (figure 2).

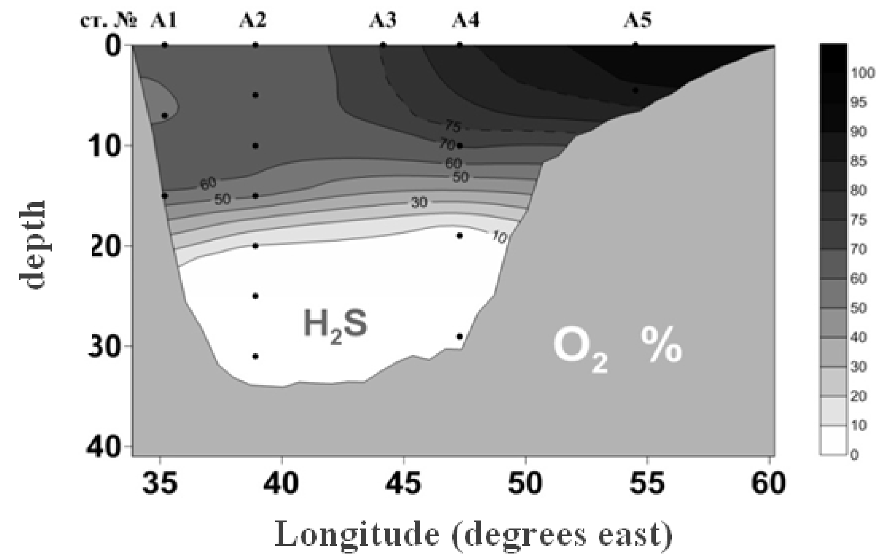

Figure2 – Distribution of the water saturation with dissolved oxygen (%) in the section on 58.5°c.min October 2013

In both 2012 and 2013,the pH value varies not so much as dissolved oxygen, but falls from the west coast to the east, although the dynamics of these quantities are usually similar. In 2012, this may be due to an increase in the surface water temperature at the eastern shore, but the entire pH change cannot be explained solely by the difference in surface water temperature at the eastern and western shores. The range of surface water temperature changes was 1.26 °C, which is equivalent to a change in the pH value by 0.01-0.02 units of NBS [16, 17].

In 2013, the surface water temperature was practically the same in the section; the changes were only 0.47°C. Perhaps the pH increase in the western coast is related to the features of the functioning of aquatic biota, in particular, photosynthetic algae. The maximum pH value in the section in 2013 was noted in the 15-20 m layer near the western shore (figure 3). Such a distribution of the pH value is quite unexpected, since in this layer the oxidative conditions change to reducing ones, which, as a rule, is accompanied by a decrease in this value. In 2013, the pH value at the surface was slightly higher than in 2012, which is associated with a seasonal decrease in water temperature.

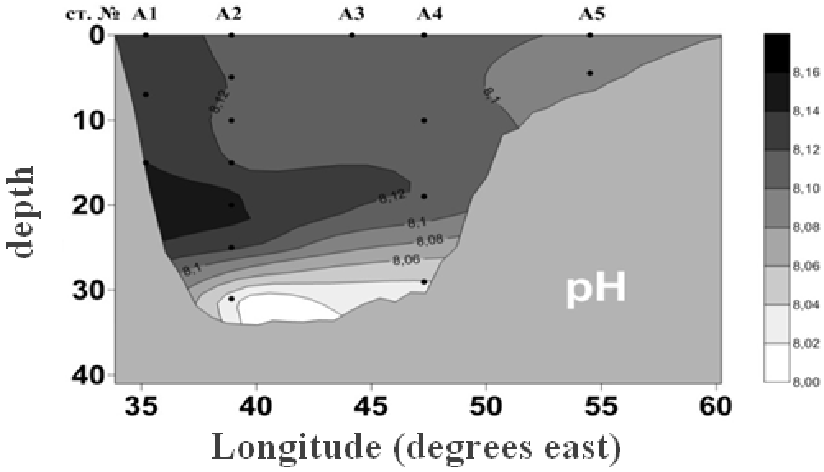

Figure 3 – Distribution of the magnitudepH(NBS) on 58.5°c.min October 2013

For the total titrated alkalinity (Alk), a weak maximum in the central part of the sea was observed on the surface. In 2013, the value of Alk on the surface increased compared to 2012 by approximately 0.10 - 0.15 mg-eq/l. This is due to an increase in salinity from 105 to 114 g/l (Table 1). With depth, an increase in Alk, especially in anaerobic waters, is observed. According to the results of both surveys, a maximum of Alk was observed in the bottom waters of the deepest station A2 (figure 4).

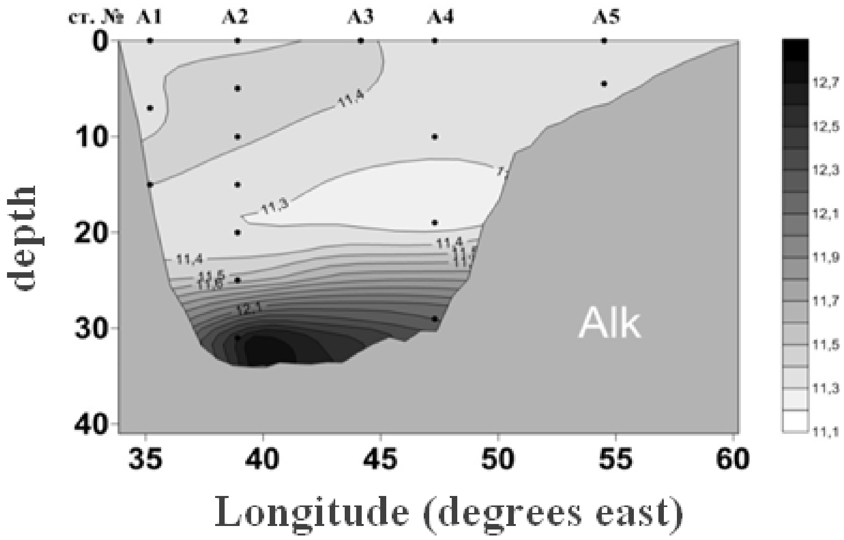

Figure 4 –Distribution of the magnitudeoftotal titrated alkalinity(mg-at/l) on 58.5°c.min October 2013

In 2012, the phosphate content in surface waters rarely exceeded 1 mg-at/l. A significant increase in surface waters once noted at station A2 in 2012 may be due to the contamination of the sample, either during the selection process or during the transportation of samples to the onshore laboratory. In deep waters, below the layer of occurrence of hydrogen sulfide, the phosphate content increased to 8.96 mg-at/l.

In 2013, there was an increase in the phosphate content throughout the profile. The most growth was in the eastern, shallow part of the section. In the bottom waters, the phosphate content in 2013 also increased to 14.59 mg-at/l (figure 5).

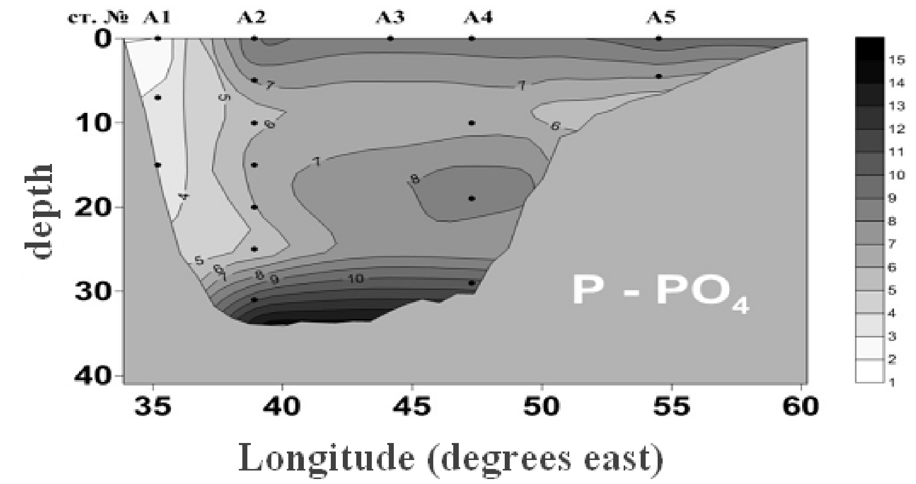

Figure 5 – Distribution of the dissolved inorganic phosphorus content(mg-at/l) on 58.5°c.min October 2013

For dissolved silicon on the surface, a small decrease in the silicon content in coastal waters can be noted in 2012, especially near the western shore. This may be due to the consumption of silicon by diatom algae, widely distributed in the sea waters [18]. The silicon content in surface waters varies little from the results of both surveys, from 21 to 26 mg-at/l. With depth, the silicon content increases, especially after the hydrogen sulfide occurrence boundary (figure 6). The maximum content of silicon reaches in the bottom waters.

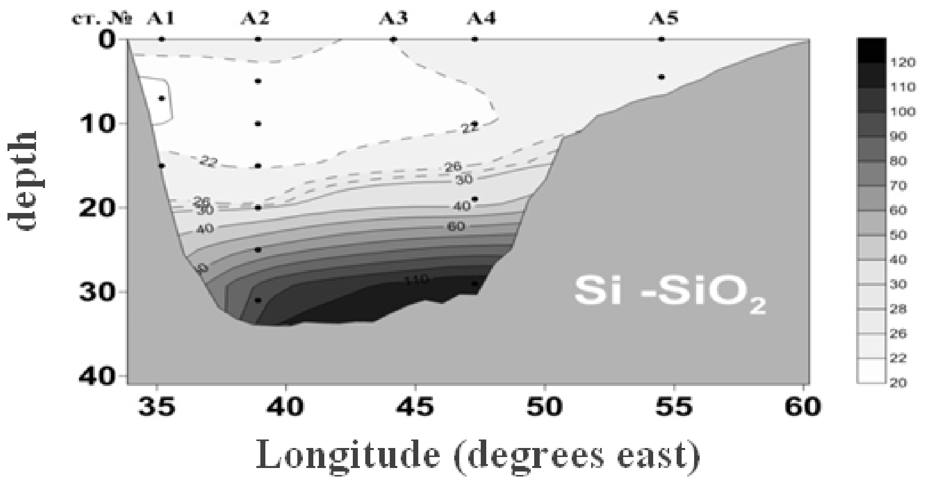

Figure 6 – Distribution of the dissolved inorganic siliconcontent(mg-at/l) 58.5°c.min October 2013

For nitrogen compounds in nitrate and nitrite forms in surface waters, a general drop in nitrate nitrogen to the eastern shore can be noted. The low content of nitrite nitrogen in 2012 indicates a weak intensity of the oxidation processes of organic substances, predominates synthesis processes that proclaim about the high saturation of water with oxygen. In 2013, on the contrary, the content of nitrite nitrogen on the surface is much higher than in 2013, and the content of nitrate nitrogen is much lower.

Taking into account the low saturation of water with oxygen, we can say that the processes of oxidation of organic substance prevailed in the upper, active layer of the water. The presence of anaerobic waters in the lower part of the profile led to the disappearance of oxidized forms of nitrogen. Because of this, a nitrate peak was formed in the 10-20 m layer, similar to what we observe in the aerobic waters of the Black Sea [19]. A considerable part of the mineral dissolved nitrogen was contained in the form of an ammonium ion (up to 255.6 mg-at/l). The total content of dissolved nitrogen reached 434 and 652 mg-at/l (in 2012 and 2013, respectively). Such a large difference in the content of total dissolved nitrogen is most likely due to the fact that the position of the bottom bathometer was determined by the contact of the end load, and the depth of selection was fixed on the block of the counter. Technically, it was difficult to keep the boat in one place, and under these conditions, a change in the depth of selection of several meters could have a strong effect on the results of the analysis.

According to the data of2013, it can be assumed that there was a "slip" of water along the western slope, caused by active cooling of the waters in the shallow part. This could be facilitated by the weakening of the stratification of waters. The descent of the waters along the slope is indicated by the bending of the is olines of the content of dissolved inorganic phosphorus and silicon, as well as the pH values (Figure. Perhaps this is due to the unusually high content of nitrate nitrogen and high pH values at the upper boundary of anaerobic waters.

Conclusions. Hydrochemical regime of the Aral Sea is characterized by sila variability in time. Seasonal changes in the chemical composition affect the entire vertical water. This contributes to the small depth of the sea and, probably, the high intensity of the processes of vertical transport of substances. But at the same time, vertical stratification of water was sufficient to preserve hydrogen sulfide contamination of the water. Despite the severe degradation of the marine ecosystem of the sea, the changes associated with the seasonal course of activity of aquatic biota remain significant. One cannot deny the existence of interannual changes associated with the continuing decline in the sea level and the penetration of waters from the eastern basin [20].

The presence of anaerobic waters in the lower part of the profile affected all hydrochemical parameters. In 2012, a sharp increase in the content of phosphorus and silicon was observed in a layer deeper than 30 m. Oxidized forms of nitrogen, on the contrary, disappeared. This led to the formation of a nitrate peak in the layer of 10-20 m. In 2013, the appearance of hydrogen sulfide was observed in the layer 18-19 m at all stations of the section. Deeper than 20 m, a significant increase in the content of dissolved phosphorus, silicon and ammonium nitrogen, the total alkalinity was observed.

An interesting and yet unexplained was the existence of a second maximum of the content of nitrate and nitrite nitrogen directly above the layer of hydrogen sulfide appearance. An increase in pH was observed in the upper part of the anaerobic layer. Perhaps this is due to the weakening of stratification and seasonal cooling of waters in coastal areas.

The smoothing of the vertical distribution profile of the mineralization of water during the transition from 2012 to 2013, naturally, caused a weakening of the stratification of waters and an increase in vertical exchange. But the hydrogen sulfide contamination of the water, in spite of this, remained, that is, even during the winter mixing of water, the bottom layer was not ventilated, despite a relatively small depth. And even a rise in the hydrogen sulfide occurrence limit was observed from 30 to 18 m. The latter, however, may be associated with a seasonal decrease in oxygen production in water.

Summarizing the results of the methodological work, it can be said that the determination of biogenic elements (phosphorus, silicon, nitrogen forms) must be preceded by filtration and dilution of samples with distilled water to salinity values comparable to the average oceanic (about 4 to 5 times). The method for determining the dissolved oxygen content (Winkler method) and the titrometric determination of hydrogen sulfide and total alkalinity is quite applicable for the Aral waters. Accuracy in these conditions is not worse than 2-3%. To clarify the magnitude of the error, additional methodological work is required.

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2012 ЖӘНЕ 2013 ЖЫЛДАРДАҒЫ КҮЗ МЕЗГІЛІНДЕГІ АРАЛ ТЕҢІЗІ СУЫНЫҢ ХИМИЯЛЫҚ ҚҰРАМЫН ЗЕРТЕУ

Аннотация. 1960 жылдың басынан бастап Арал теңізінің деңгейі түсе бастады. Теңіздің көлемі мен ауданының қысқаруы судың гидрологиялық, химиялық және әлбетте, биологиялық құрлымының айқын өзгеруіне алып келді. Арал суының химиялық құрамын тыңғылықты бақылау 90-шы жылдардың басында тоқтатылды. Судың биогенді элементтері мен оттегі режимін бақылау тәжірибе жүзінде толық доғарылды (алғашқы күннің талдамалары). 2012 жылдың қыркүйегінде және 2013 жылдың қазанында халықаралық экспедиция аясында биогенді элементтердің, ерітілген оттегінің құрамдарын, күкіртсутегі концентрациясын және карбонаттық тепе-теңдік компоненттерін өлшейтін кешенді гидрохимиялық бақылау жүргізілді. Зерттеулер теңіз жағасында уақытша лабораторияда өткізілді. Жұмыстың басты мақсаты Арал теңізі суының биогенді элементтер құрамын анықтау және судың жоғары тұздылығы (минерализация) жағдайында гидрохимиялық зерттеулер әдістерін жүргізу болып табылады. Сонымен қатар, судың жалпы минерализациясын және металдардың ерітілген және өлшенген құрамынанықтау үшін үлгілерді жинақтау жүргізілді. Теңіздің аздаған тереңдігі мен заттарды вертикалды ауыстыру процестерінің жоғары интенсивтілігі анықталды. Химиялық құрамының маусымдық өзгерістері судың барлық вертикалына әсер етті. 18-30 метр тереңдікте суда күкіртсутек анықталды. Теңіздің терең бөлігіндегі анаэробты жағдайдың болуы барлық гидрохимиялық параметрлерде айқындалды. Мақалада зерттеулер нәтижелері ұсынылады.

Түйін сөздер: Арал теңізі, биогенді элементтер, оттегі.

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ИССЛЕДОВАНИЯ ХИМИЧЕСКОГО СОСТАВА ВОД АРАЛЬСКОГО МОРЯ ОСЕНЬЮ 2012 И 2013 г.

Аннотация. С начала 1960-х годо началось падение уровня Аральского моря. Сокращение объема и площади моря привело к значительным изменениям гидрологической, химической и, естественно, биологической структуры вод. Регулярные наблюдения за химическим составом вод Арала прекратились в начале 90-х годов. Практически полностью отсутствовали наблюдения за биогенными элементами и кислородным режимом вод (так называемые анализы «первого дня»).В сентябре 2012-го и октябре 2013-го годов в рамках международных экспедициях был проведен комплекс гидрохимических наблюдений, включавший измерение содержания биогенных элементов, растворенного кислорода, концентрации сероводорода и компонентов карбонатного равновесия. Определения проводились непосредственно на берегу моря во временной лаборатории. Основной целью работ было определение содержания биогенных элементов в воде Аральского моря и отработка методов гидрохимических исследований в условиях повышенной солености (минерализации) воды. Кроме того был проведен сбор проб для определения общей минерализации вод и содержания растворенных и взвешенных форм металлов. Было показано, что небольшая глубина моря и высокая интенсивность процессов вертикального переноса вещества, делали возможным, что сезонные изменения химического состава сказывались по всей вертикали вод. Глубже 18–30 м в воде присутствовал сероводород. Наличие анаэробных условий в глубокой части моря отразилось на всех гидрохимических параметрах. В статье приводятся некоторые результаты исследований.

Ключевые слова: Аральское море, биогенные элементы, кислород.

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CONTINUOUS HYDROGENATION OF BENZENE ON PROMOTED SKELETARY NICKEL CATALYSTS

Abstract. The aim of this work is to study the physicochemical properties of skeletal nickel catalysts modified by ferroalloys, and to develop a technology for the continuous hydrogenation of benzene. A series of new samples of modified alloyed alumina-nickel catalysts for hydrogenation of benzene to cyclohexane synthesized. Their phase and granulometric compositions, the porous structure of the skeletal nickel catalysts promoted by ferroalloys are studied. Highly active stationary alloy alumina-nickel catalysts with additives as modifiers, technologies for their preparation and activation is developed. The optimal conditions for the process of continuous hydrogenation of benzene under hydrogen pressure are determined. A method developed for the preparation of cyclohexane in the presence of nickel catalysts promoted by ferroalloys, which ensures a high total yield of the desired product.

Keywords: benzol, promoted nickel catalysts, phase composition of the catalyst, porous structure, granulometric composition, cyclohexane, continuous hydrogenation.

Introduction. One of the promising areas of chemical processing of aromatic compounds, which is catalytic hydrogenation, the synthesis products of this process are in great demand in the pharmaceutical, chemical, petrochemical, medicine and other industries. Currently, the world production of caprolactam the volume of production, as well as improving the synthesis of intermediates for the production of various synthetic fibers and resins are very relevant.It is also known [1, 2] that the problem of reducing the content of aromatic hydrocarbons in motor fuels can be solved in many ways, including derivation by adsorption or extraction, and by conversion to other, less harmful compounds.An effective method of improving the operational properties of fuels, in particular gasoline, is their de-aromatization, which consists in the process of hydrogenation of aromatic hydrocarbons in the presence of catalysts. Aromatic hydrocarbons, especially polycyclic, contribute to the formation of carbon deposits in internal combustion engines, which in turn leads to an increase in the NO_2 content of the exhaust gases. In the Republic of Kazakhstan, there are practically no processes for the de-aromatization of light fractions of oil. The reason for this are, firstly, low productivity and a short service life of industrial catalysts used, and secondly, an inadequate range of industrially important contacts and technologies. Catalytic reduction of benzene shows great practical importance, since reaction products have long attracted the attention of researchers as the starting objects for the synthesis of new compounds. Cyclohexane, obtained by catalytic hydrogenation of benzene used for the production of caprolactam, adipic acid and hexamethylenediamine, i.e. is a raw material for the production of synthetic fibers, as well as various resins.Thus, cyclohexane, obtained from local raw materials, creates the opportunity of import substitution in industry, and the products obtained during its processing open up new prospects for the domestic production of synthetic fibers and resins.

A review of the principle technological schemes of hydrogenation of benzene [3-7] shows that in many cases hydrogenation is carried out in the vapor phase at temperatures of 250-325°C and a hydrogen pressure of 10.0-27.0MPa. Platinumoids also used as catalysts. Naturally, under these conditions, isomerization and cleavage products observed in the catalyst, which reduces the quality of the desired product, cyclohexane.

New methods for increasing the activity, stability and mechanical strength of nickel catalysts, adding additives of other metals into the alloy, discovered at the time of their preparation [8-11]. As a result, effective catalysts found to accelerate the hydrogenation reaction of benzene. Hydrogenation of aromatic hydrocarbons carried out in the reactor with a periodic effect at the temperature range 20-200°C and hydrogen pressure 0.1-15.0MPa.

On an industrial scale, co-precipitated copper-chromite oxide catalysts also found wide application in the production of cyclohexane [12, 13], although they are not devoid of significant disadvantages in catalytic and operational properties in hydrogenation processes. In connection with these, the researchers proposed numerous modified Ni, Cu, Co-alloy catalysts [14-18], which have not yet acquired industrial application in these industries. Therefore, it is important to improve these catalysts by modifying them, in order further improve their selectivity, operational and catalytic properties in the hydrogenation of aromatic hydrocarbons in the liquid phase.

Methods. The main reactor is a high-pressure flow column. The process is carried out at the temperature range 473-523^{0}K and hydrogen pressures at 10.0-27.0MPa. In the course of the studies, the solution of the unsaturated compound injected at a hydrogen module of 10 and the feed rate of the starting materials is 200-250 ml/h. Initial alloys were prepared according to known technology in a high-frequency melting furnace. The specificity of the preparation of the Ni-Al system is the possibility of using aluminothermy in various furnaces. The temperature of the molten aluminum adjusted to 1000^{0}C. When the exothermic reaction (aluminothermy) between nickel (ornickel oxide) and aluminum, the melt temperature increases to 1800^{0}C.During the experiments, 100 g of skeletal catalyst with linear dimensions of 3-5 mm are loaded into the column and the leaching process carried out with a solution of NaOH in the reactor. Initially, up to 10% of aluminum removed, after the catalyst rinsed for several hours with distilled water at a high water feed rate and several hours at low.

Activation of the catalyst was carried out directly in the reactor itself. In this case, a granular alloy with linear dimensions of 2-4 mm (100 g) was placed in a special glass attached to the bottom of the reactor and the leaching was carried out with a 10% aqueous solution of sodium hydroxide.

During the leaching with the help of a dosing pump NDV-1000, the reactor initially filled with distilled water, and then an alkali solution fed from the "measuring tank". The degree of aluminum removal controlled by the evolution of hydrogen, the amount of which changed by the gas counter of the GSB-400.After the calculated amount of hydrogen was isolated to the leached catalyst, water supplied from the "measuring tank" to stop the leaching process and wash the catalyst from alkali residues to pH-7. The amount of aluminum removed from the consistency was about 10-15%.

Results and discussion. In this paper, we present the results of a study of the hydrogenation of benzene to cyclohexane on promoted skeletal nickel catalysts modified with ferroalloys (ferroalloys) (ferromanganese), ferrochrome silicon (FCS), and calcium ferosilicone (CFS).

The granulometric composition of skeleton nickel catalysts with addition of FSH, FSK and ferroalloys studied. The data of microscopic and electron microscopic examination of the granulometric composition of skeleton nickel catalysts are given in table 1. All the catalysts are dominated by particles with R = 0-2 μm, which concentration reaches 75-89%. Table 1 shows that, as the amount of additives in alloys increases from 3 to 9% by weight, the concentration of particles with R = 0-2 μm in different catalysts decreases within the limits of 89-75% depending on the nature of the alloying metals. In addition, the modifying additives also increase the concentration of particles with R=2-4μm. The results of optical microscopy show that practically all the investigated skeletal nickel catalysts are enriched by 90-99% particles with R_{max} = 1-5 μm.

The results of the granulometric analysis using optical microscopy and electron microscopy confirm the enrichment of skeleton nickel catalysts with particles with R_{max} = 1 μm. Modifying metals increase the proportion of particles with a size of 0-6μm.

Table 1 – Results of microscopic and electron microscopic examination of skeleton nickel catalysts

Catalyst	Distribution of particles of % on the sizes R, microns					
	0-2	2-4	4-6	6-8	> 8	T_3
Ni (50%Al)	77	8	6	2	7	0.12
Ni–3-10% FaTi	78	8	8	4	2	0.45
Ni–3-10% FaMo	85	6	5	2	1	0.35
Ni–3-10% FaCr	83	6	6	3	1	0.36

We studied [2] the porous structure of skeletal nickel catalysts with additives of ferroalloys. Argon sorption isotherms show that the forms of hysteresis loops for the majority of modified nickel catalysts are characterized by the parallel arrangement of adsorption and desorption branches in the middle region of relative pressure and according to the de Boer classification are A type, which indicates the predominance of cylindrical pores [3].

Table 2 shows the parameters of the porous structure of skeleton nickel (50% Al) catalysts with addition of ferroalloys. It can be seen that modifying ferroalloys mainly increase S_{BET}, S_{CUM}, respectively, to 110-130.5 and 85-98 m^2/g; the volume of pores - in 1.1-1.4 times; the effective radius of the pore R_{EFF} is 1.06-1.5 times. A simultaneous increase in the specific surface area and in the pore volume with relatively high effective radii is apparently due to the dispersion of the nickel phase of the catalysts with modifying metals.

Table 2 – Parameters of the porous structure of skeleton alumino-nickel catalysts with additives of ferroalloys

Catalyst	S_{BET}*, m^2/g	S_{CUM}**, m^2/g	$\frac{S_{BET}-S_{CUM}}{S_{BET}}$, 100%	V_{of} holes, cm^3/g	R_{eff}, E***	Isotherm type
Ni (50% Al)	105	75	28.5	0.105	30	A
Ni – 3-10% FaMo	110	85	22.7	0.120	34	A
Ni – 3-10% FaTi	130.5	98	24.9	0.138	36	A
Ni – 3-10% FaCr	123.7	92	23.9	0.148	36	A
*Bayer Emmet Taylor; **cumulative; ***angstrom.						

We previously determined the structure and adsorption properties of the obtained alloys and catalysts. Further, these catalysts tested in the process of continuous hydrogenation of benzene in a column-type flow installation. During the experiments, the alloys activated by a 10% solution of sodium hydroxide. At the first leaching, 30% of aluminum removed, the catalyst saturation carried out in a stream of hydrogen for 18 hours at a process temperature of 160^0C and a pressure of 0.5MPa. The rate of benzene supply varied from 60 to 120 ml/h. An increase in the hydrogen pressure from 5 to 8MPa revealed that with increasing hydrogen pressure up to 6MPa, the degree of conversion of benzene increases, and further increase in pressure does not affect the activity of the catalyst.

Table 4 shows that stationary ferroalloy catalysts exhibit absolute cyclohexane activity and their activity is higher than that of the industrial nickel-titanium catalyst. The values of the contact loads, annealed by 30% in aluminum Ni- FaMo catalysts at 120 ° C and 10MPa, reach respectively 0.70 h-1, which is 2.3 times higher than that of industrial nickel-titanium contacts. The results of the tests showed that the Cu-Al- FaMo catalyst is 1.9 times higher in productivity, and 2.0 times higher in stability than the industrial nickel-titanium contact.

The Ni-Al-FaMo catalyst recommended for the implementation into production of the production of cyclohexane from benzene [3].

Thus, a systematic study of the activity of stationary catalysts with additives of ferroalloys in the reaction of continuous catalytic hydrogenation of benzene with a wide variation in the parameters of the process carried out.

Table 4 – Results of continuous hydrogenation of benzene in a column-type flow installation

Catalyst	T, °C	Composition of catalyst		Wh^{-1}	Relative duration of process
		cyclohexane	benzene		
Ni –Al	90-100	78-85	15-22	0.12-0.21	
	110-120	81-92	8-19	0.26-0.28	210
	130-140	87-98	-13	0.31-0.35	
Ni -Al- CFS	110-120	94-98	2-6	0.50-0.64	254
	90-100	94-97	3-6	0.42-0.63	
	110-120	96-99.8	0-4	0.53-0.70	410
	130-140	98-99.8	0-2	0.69-0.87	
Ni -Al- FSC	90-100	96-99	1-4	0.47-0.72	
Ni-Al- FaMo	90-100	96-98	4-2	0.48-0.7	420
	110-120	99-99.8	1-0.1	0.65-0.82	
	130-140	99.5-99.8	0.5-0.1	0.94-1.2	
Ni-Tiindustrial	90-100	84-96	10-16	0.40-0.44	
	40-120	84-95	5-16	0.47-0.50	202
	130-140	98-99.8	0-10	0.50-0.60	

Conclusion. A series of new samples of modified alloy alumina-nickel catalysts for hydrogenation of benzene to cyclohexane synthesized. Their phase and granulometric compositions, the porous structure of the skeletal nickel catalysts promoted by ferroalloys studied.The kinetic regularities of the hydrogenation process on modified nickel catalysts are established. Depending on the temperature and pressure of hydrogen, the optimal conditions for the realization of the technological process for the synthesis of cyclohexane are established. The promoting effects of ferroalloys (FaMo, FMo, FMnMo and FTi), on the physicochemical and adsorption properties of alloyed alumina-nickel catalysts studied.The kinetic regularities of the hydrogenation of benzene on samples of promoted catalysts established. It is experimentally determined that on the developed promoted skeletal catalysts, the rate of selective hydrogenation of benzene increased by a factor of 1.0-1.6 times, than without modifying additives. The optimal compositions of modified alloy catalysts, the conditions for their preparation, activation and hydrogenation processes in their presence identified.

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БЕНЗОЛДЫ ЫНТАЛАНДЫРЫЛҒАН ҚАҢҚАЛЫ НИКЕЛЬ ШАПШАНДАТҚЫШТА ҮЗДІКСІЗ ГИДРЛЕУ

Аннотация. Жұмыстың мақсаты темір балқымаларымен модифицирленген қаңқалы никельді шапшандатқыштардың физика-химиялық қасиеттерін зерттеу, сонымен қатар безолды осы шапшандатқыштың көмегімен үздіксіз гидрлеу технологиясын жасап шығару болып табылады. Алюмо-никельді балқыма шапшандатқыштардың модифицирленген жаңа сериялары бензолды циклогексанға дейін гидрлеу үшін синтезделген. Олардың фазалық және гранулометриялық құрамдары, темір балқымаларымен ынталандырылған қаңқалы никельді шапшандатқыштардың борқылдақ құрылымы зерттелген. Жоғары белсенділікке ие стационарлы балқымалы алюмо-никельді үстемелі шапшандатқыштар модификатор ретінде дайындау технологиясы және белсендірілуі жасалып шығарылған. Сутегі қысымы астында бензолды үздіксіз гидрлеу үрдісінің тиімді шарттары анықталған. Мақсатты өнімнің жалпы шығысын қамтамасыз ететін темір балқымаларымен ынталандырылған никельді шапшандатқыш қатысындағы циклогександы алу әдісі жасап шығарылды.

Түйін сөздер: бензол, ынталандырылған никельді шапшандатқыштар, фазалық құрам, шапшандатқышты борқылдақ құрылым, гранулометрлік құрам, циклогексан, үздіксіз гидрлеу.

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НЕПРЕРЫВНОЕ ГИДРИРОВАНИЕ БЕНЗОЛА НА ПРОМОТИРОВАННЫХ СКЕЛЕТНЫХ НИКЕЛЕВЫХ КАТАЛИЗАТОРАХ

Аннотация. Целью данной работы является исследование физико-химических свойств модифицированных ферросплавами скелетных никелевых катализаторов, а также разработка технологии непрерывного гидрирования бензола в их присутствии. Синтезированы серии новых образцов модифицированных сплавных алюмо-никелевых катализаторов для процессов гидрирования бензола до циклогексана. Исследованы их фазовый и гранулометрический составы, пористая структура разработанных промотированных ферросплавами скелетных никелевых катализаторов. Разработаны высокоактивные стационарные сплавные алюмоникелевые катализаторы с добавками в качестве модификаторов, технологии их приготовления и активации. Определены оптимальные условия осуществления процесса непрерывного гидрирования бензола под давлением водорода. Разработан способ получения циклогексана, в присутствии промотированных ферросплавами скелетных никелевых катализаторов, обеспечивающий высокий суммарный выход целевого продукта.

Ключевые слова: бензол, промотированные никелевые катализаторы, фазовый состав катализатора пористая структура, гранулометрический состав, циклогексан, непрерывное гидрирование.

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ASSESSMENT OF THE SUSTAINABILITY OF LANDSCAPES OF THE NORTH-KAZAKHSTAN REGION TO AGRICULTURAL IMPACT

Abstract. The article deals with the research of sustainability of landscapes of North Kazakhstan region under conditions of long-term agrogenic load. In this connection and basing on the developed system of indicators there was carried out the assessment of geosystems' conditions and levels of their sustainability to the influence of human agricultural activities. The assessment was made according to thirteen indicators characterizing forming factors, landscapes functional conditions and properties of their main components. Assessment methods were based on the use of different specified rates that were transferred to a relative value (points) and were ranked according to variability (sustainability) of each landscape under direct or indirect agricultural exposure. Besides, this work performs spatial analysis and typology of the regional landscapes according to the index of potential resistance to agricultural influence. It was defined that the most resistant to agricultural human activities landscapes of Northern and central parts of the region are located within forest-steppe natural zone. Low potential resistance is typical of the landscapes located in the South-East of the region within dry steppe subzone and in the landscapes of the river Yesil valley. The level of steppe zone landscapes resistance to agricultural impact is defined as relatively stable. This work provides recommendations on restoration of ecological balance and establishing of stable functioning of the landscapes.
Keywords: landscape, geosystem, sustainability, agriculture, assessment, impact.

Introduction. North Kazakhstan oblast (NKO) is one of the leading agricultural regions of Kazakhstan. The agro-industrial sector covers more than 40% of the regional gross product. Almost a quarter of the republican acreage belongs to NKO. Annually it produces 25-28% of national gross harvest of high-quality grain. The structure of the region land resources refers up to 71%, or 6988.0 thousand hectares to agricultural lands, including 4320.4 thousand hectares of arable land (data of 2017). The rate of tilled soil in the region is 50%, reaching 70% in some administrative districts [1-3].

Long-standing agricultural load on the landscapes of the region had a negative impact on their conditions. There are dehumidification and reduction of soil fertility, increase of areas with wind and water erosion, degradation of agricultural land and reduction of its environmental sustainability [4, 5].

One of the reasons for the current environmental situation is unsustainable functioning of landscapes as a result of an imbalance between their natural potential and the nature of agricultural production. Not taking into account the properties and peculiarities of geosystems, on the one hand, and permissible agricultural load on the components, on the other, may lead to its further deterioration that can adversely affect economic development and food security of the region. Under the conditions of intensive agricultural development, one of the important tasks is maintaining sustainability of geosystems on the basis of complex examination of their state and properties and peculiarities of landscape structure of the region. In this regard, urgency of the undertaken research is quite obvious.

The purpose of the study is to evaluate sustainability of NKO landscapes to agricultural impact and to determine the nature of such impact.

Materials and methods of the study. Agricultural impact is the influence of human agricultural activity that changes properties of landscape components or landscape as a whole, which can lead to non-performance of environmental or social-economic features of the landscape [6]. Accordingly, the landscape resistance to agricultural impact depends on the ability to sustain changes generated by the human agricultural activities and to recover from such impacts preserving the basic properties and functions.

At present, there is no common approach to the assessment of landscapes' sustainability to agricultural impact. Besides, the issue of defining of common assessment criteria still remains undetermined. In addition to this, the complexity of agricultural production and a large number and diversity of agricultural impacts influencing the landscapes complicate the research in this direction. By the same token, natural landscape specificity causes the complexity of analysis and assessment. This is due to the fact that landscapes are distinguished by various natural conditions and therefore different resistance to external influences. Components of landscape, in turn, are characterized by different reactions to certain effects that serve as consequences of their differences in resistance to such loads. Additionally, when one runs the analysis and assessment of landscapes sustainability to agricultural impacts, the level of landscape organization should be taken into account. It is well-known that the higher the level is, the more sustainable the landscape is to the effects of human activities [7-11].

In comparison with other types of anthropogenically modified geosystems, landscapes created by human agricultural activity are closer to the natural landscapes according to their functional and structural properties. Therefore, most studies related to assessing agrolandscapes' sustainability use approaches and methods applied for the assessment of conditions and stability of natural landscapes and ecosystems. Special attention shall be paid to a series of techniques based on study of the basic properties of landscapes and their components, which can serve as indicators of their resistance to various external influences including agricultural load [12-25].

Theoretical and methodological basis of research was found in the works of our specialists in the field of landscape study, agrolandscape study and geoecology: N.A. Solntsev, L.G. Ramenskiy, L.S. Berg, A.G. Isachenko, G.N. Vysotskiy, M.A. Glazovskaya, V.A. Kovda, B.B. Polynov, F.I. Milkov, K.V. Zvorykin, V.N. Nikolayev, V.I. Kiryushin, B.I. Kochurov, V.S. Preobrazhenskiy, I.V. Orlova, V.I. Bulatov, Z.U. Mamutov, A.I. Iorganskiy, M.B. Esimbekova and others, and in foreign studies of agriculture, landscape and agroecology made by: M. Arshad, S. Navrud, J. Iverson Nassauer, D. Chelaru and others.

As the informational background of the research we used literature, industry-specific and thematic maps, published and stock materials of industrial government organizations and agencies (Department of Land Cadastre and Technical Survey of Real Estate, Government for citizens State Corporation NCJSC in NKO, Republican Scientific-Methodical Center of Agrochemical Service RSE of the Kazakhstan Ministry of Agriculture, Department of NKO Agriculture MPUI, Department of Statistics in NKO, etc.) for the period of 2010-2016, as well as materials of summer field works in 2017.

The studies were carried out with use of complex landscape-geographical methods, such as comparative-geographical, cartographic, mathematical, statistical, extrapolation, systematic, cross-spectrum analysis, etc.

The assessment included several stages: defining the methods, indicators (criteria) and assessment parameters, preparation of evaluation scale, collecting and aggregating the necessary data, including materials of field research, evaluation according to the evaluation scale, definition of sustainability degree, and analysis of the obtained results. The final stage of the research included working out the recommendations on solving issues of agricultural environmental management, restoration of ecological balance and sustainable functioning of the landscape.

Field studies were carried out on typical for the region key areas of forest-steppe and steppe natural zones. There were 15 key areas in total. Their allocation was based on a number of factors: morphological landscape characteristics, structure of soil, agro-climatic and natural-agricultural zoning, type of agricultural use of the region territory. Study of the basic components of landscapes (relief, climate, soils, and vegetation) was carried out according to standard procedures. The field work included comprehensive landscape description of keys, soil pit testing and selected soil sampling. Chemical-analytical investigations of soil samples were carried out in certified laboratories of the branch of "National Centre of Expert Review" Republican State Enterprise on the Right of Economic Use of the Committee for Public

Health of the Ministry of National Economy of the Republic of Kazakhstan in NKO in accordance with approved methods.

In the course of our study we analyzed different approaches and criteria for the assessment of sustainability of landscapes impacted by human agricultural activity: the ratio of naturalness level, ecological-economic balance, including determining the coefficient of relative, absolute tension and natural areas protection, the coefficient of ecological stability (stabilization), the degree of actual erosional feature and potential risks of erosion, Simpson's diversity index, index of ecological balance, correlation of farmland, soil fertility, etc.

In order to assess sustainability of NKO landscapes to agricultural impacts we used the approach proposed by I. V. Orlova, modified in relation to the studied region. The substance of the approach is that the components of geosystem have different response and resistance from the point of view of agricultural impact on the geosystem. Therefore, the components shall be separately evaluated using point-based system with subsequent summation, which allows to consider each of them and construct landscapes according to their overall sustainability [9].

Hereafter you can see the figures taken as estimated parameters of sustainability of NKO geosystems to agricultural impacts (table).

Scale of assessment of sustainability of landscapes of North-Kazakhstan region to agricultural impact

N	Assessment measures	1 point	2 points	3 points	4 points	5 points
1	Hydrothermic index	≤0,40 ≤0,20	0,41-0.60 0,21-0,40	0,61-0,80 0,41-0,60	0,81-1,0 0,61-0,80	≥1,1 ≥0,81
2	Wind conditions, number of days with strong winters	more than 51	–	21-50	–	less than 20
3	Relief	undulating	gently rugged	rolling / interfuvial	flat and gently rolling	flat
4	Slope angle, degrees	≥20,1	5,1-20,0	3,1-5,0	1,1-3,0	0-1,0
5	Degree of natural drainage	drainless	0,2-1,0 slightly drained	1,1-3,0 average	3,1-10,0 good	≥10,1 very good
6	Geochemical situation	accumulative	transaccu-mulative	transit	transeluvial	eluvial
7	Soil Texture	sand	sandy soil	light loam	medium-textured loam	clay loam
8	Type of water regime	desuctive exudative	exudative	nonleaching	regularly leaching	leaching
9	Degree of hydromorphic feature	hydromorphic	–	semihydro-morphic	–	automorphic
10	Humus horizon thickness, cm	≤10,0	10,1-30,0	30,1-50,0	50,1-80,0	≥80,1
11	Humus content in the soils of 0-20 cm, %	≤2,0	2,1-4,0	4,1-6,0	6,1-9,0	≥9,1
12	Actual soil acidity, pH	strongly acid (≤4,5) or strongly alkaline (≥8,6)	acid (4,6-5,0) or alkaline (7,6-8,5)	mildly acid (5,1-5,5) or mildly alkaline (7,0-7,5)	close to neutral (5,6-6,0)	neutral 6,1-7,0
13	Cation exchange capacity, mg/eq 100 g of soil	<10	10-20	21-30	31-40	>40

Statistical calculations and processing study data and materials of field work were conducted using software of Microsoft Office, Statistica 6.0, MapInfo Professional 11, ArcGIS 10.1.

The assessment was carried out according to each indicator separately on the basis of a correlation of the actual data with the tabulated gradation. Points for each of the analyzed indicator were summed up. The highest possible score representing the highest sustainability of the landscape to agricultural impact was taken as 100%. The received sums of points were calculated relative to maximum score according to the formula [14]:

$$C = \frac{100\sum_{g=1}^{n} Cg}{Q},$$

where C means assessment of the landscape sustainability to agricultural impacts in %; Cg – points for each indicator; Q – maximum possible amount of points; g – the number of the indicator; n – number of indicators (signs).

The results of calculations were correlated with the gradation, according to which there are five levels of landscape sustainability to agricultural impact: stable (81-100%), relatively stable (61-80%), less stable (41-60%), unstable (21-40%), extremely unstable (less than 20%) [9].

Results and discussion. Spatial analysis of the obtained data allowed to reveal that within the studied region the most sustainable to agricultural impact landscapes are forest-steppe of the (typical and south outlier) natural areas (indicator of sustainability is 76-81%). This is due to the fact that here the landscape sustainability is stipulated by fairly high rate of forest cover in comparison with other territories of the region. Forests, thickets of trees and shrubs create ecological framework that supports environmentally sustainable landscapes. The forest-steppe zone is characterized by less plowed land and greater share of environment-stabilizing components of landscape. Within the zone, you can observe better drainage, favourable hydrochemical conditions and wind regime. The soils are characterized by relatively high humus content (4,1-4,4%) and thickness.

Those landscapes close to the valley of the Yesil river (55-60%) and landscapes of dry steppe subzone (53-60%) are less resistant to the effects of human agricultural activity.

The landscapes within the Yesil river valley are characterized by less favorable geochemical situation and type of water regime with hydromorphic soils. If taking into consideration humus horizon thickness they are inferior to the upland areas and are characterized by low humus content (2.3%) and weak maturity. The features of the valley determined the specific landscape structure and sustainability of its landscapes to the impacts of external factors. Gradients, division of land by temporary streams, marked steepness of the slopes especially on the right bank of the valley reduce potential resistance of landscapes to external influences including agricultural.

The dry steppe subzone has rather high level of agricultural development that adversely affects the sustainability of its landscapes. Forest and shrub vegetation makes a small part in the soil structure. Subzone is characterized by insufficiently favorable hydrothermal conditions. All the soils despite relatively high level of natural fertility (2,8-3,7%) are characterized by less favorable water-physical properties. Additionally, this subzone has widespread sodic-saline soil complexes with unfavorable physical and chemical properties. Here there is a high likelihood of soil degradation processes related to the character of wind regime with frequent days of strong winds. This determines lower landscapes' sustainability to the impacts of farm environmental management.

The steppe zone within the region is represented by two subzones: northern temperate arid and south arid. Despite many years of intensive agricultural development the landscapes of this zone are specified by relative sustainability to agricultural impacts (68-75%) due to its high natural potential in accordance with gradation. In conditions of intensive agricultural environmental management sustainable landscapes are ensured by reserves of natural soil fertility and their good water-physical properties. The humus content in soils is 4,0-4,7%. Besides, flat poorly broken relief with slight slopes, uniform morphological structure of landscapes and eluvial geochemical position help to maintain the sustainability of the landscapes.

Those landscapes that are less stable or unstable to the impacts of human agricultural activity call for special attention when organizing and conducting agricultural operations at any stages of agricultural production. The use of such landscapes for agricultural purposes should be subject to acceptable level of agrogenic load while preserving their resources and capabilities, as well as putting various restrictions on agricultural natural management.

Relatively resistant to the agricultural impact, landscapes are able to withstand current agricultural load and to ensure further development of agricultural production but only subject to the ecological balance between their maximum capabilities and agricultural load, as well as implementation of measures to maintain natural ecological potential. Here agricultural activity is associated with a lower risk of violating the balance of nature.

Conclusion. After assessing sustainability of landscapes of North-Kazakhstan oblast to agricultural impacts we revealed the following pattern: the most sustainable landscapes are in Northern and central parts of the region. The closer you move to the South, the less the landscapes sustainability to agricultural impacts is. Low potential sustainability is typical of landscapes located in the South-East of the region within the dry steppe subzone and landscapes of the Yesil river valley.

Different levels of landscapes sustainability to the influence of agricultural activities require functional zoning of the region to areas with different agricultural environmental management.

In order to maintain the landscapes sustainability to agricultural impacts we need to develop a program of rational and balanced agricultural environmental management on landscape basis and to introduce ecologization of all agricultural production processes.

The results obtained during the research can serve as informational backup for planning and implementation of programs and projects in agricultural environmental management for regional and local authorities.

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СОЛТҮСТІК ҚАЗАҚТАН ОБЛЫСЫ ЛАНДШАФТТАРЫНЫҢ АУЫЛШАРУАШЫЛЫҚ ӘСЕРІНЕ ТҰРАҚТЫЛЫҒЫН БАҒАЛАУ

Аннотация. Мақала көп жылдық агрогендік жүктеменің жағдайында Солтүстік Қазақстан облысы ландшафттарының тұрақтылығын зерттеуге арналған. Көрсеткіштердің әзірленген жүйесінің негізінде геожүйелердің жағдайы бойынша және адамның ауыл шаруашылық әрекеттерінің оларға әсер етулеріне тұрақтылықтарының деңгейіне баға берілген. Бағалау қалыптастыру факторлардың сипаттамасында, ландшафтардың жұмыс істеу шарттарында, олардың негізгі компоненттерінің қасиеттерін сипаттайтын он үш көрсеткіш бойынша жүргізілді. Бағалау әдісі ауыл шаруашылық әсерінің тікелей немесе жанама әсерінің әрқайсысының өзгермелілігін (тұрақтылығын) ескере отырып, салыстырмалы мәндерге (балл) аударылған әртүрлі есептік көрсеткіштерді пайдалануға негізделген. Ауыл шаруашылық әсерлерге тұрақтылықтың нақты көрсеткіштері бойынша аймақтың ландшафттарын типке келтіру жүзеге асырылған және кең шеңберде сараптама жасалған. Облыс аумағының солтүстік және орталық бөлігінің орманды-дала табиғи аймағында орналасқан ландшафтары адамның ауылшаруашылық қызметінің әсеріне төзімді болып табылады. Төмен әлеуетті тұрақтылық құрғақ дала подзонаның оңтүстік-шығыс аймағында орналасқан ландшафттар және Есіл өзен аңғарының ландшафттар сипатталады. Дала аймағының ландшафттарының ауыл шаруашылық әсеріне төзімділік деңгейі салыстырмалы түрде тұрақты деп белгіленген. Баяндамада экологиялық тепе-теңдікті қалпына келтіру және агрогендік табиғаттың антропогендік әсерін тигізетін геосистемалардың тұрақты жұмыс істеуін қалыптастыру бойынша ұсыныстар ұсынылған.

Түйін сөздер: ландшафт, геожүйе, тұрақтылық, ауыл шаруашылық, баға, әсер.

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ОЦЕНКА УСТОЙЧИВОСТИ ЛАНДШАФТОВ СЕВЕРО-КАЗАХСТАНСКОЙ ОБЛАСТИ К СЕЛЬСКОХОЗЯЙСТВЕННОМУ ВОЗДЕЙСТВИЮ

Аннотация. Статья посвящена исследованию устойчивости ландшафтов Северо-Казахстанской области в условиях многолетней агрогенной нагрузки. На основе разработанной системы показателей проведена оценка состояния геосистем и уровня их устойчивости к воздействию сельскохозяйственной деятельности человека. Оценка проводилась по тринадцати показателям, характеризующим факторы формирования, условия функционирования ландшафтов, свойства их основных компонентов. Методика оценки базировалась на использовании различных расчетных показателей, которые переводились в относительную величину (баллы), ранжировались с учетом изменчивости (устойчивости) каждого из них под прямым или косвенным сельскохозяйственным воздействием. Выполнен пространственный анализ и осуществлена типология ландшафтов региона по показателю потенциальной устойчивости к сельскохозяйственному воздействию. Выявлено, что наиболее устойчивы к воздействию сельскохозяйственной деятельности человека ландшафты северной и центральной части территории региона, располагающиеся в пределах лесостепной природной зоны. Невысокой потенциальной устойчивостью характеризуются ландшафты, располагающиеся на юго-востоке области в пределах сухостепной подзоны, и ландшафты долины р. Есиль. Уровень устойчивости к сельскохозяйственному воздействию ландшафтов степной зоны определен как относительно устойчивый. В работе предложены рекомендации по восстановлению экологического равновесия и формирования устойчивого функционирования геосистем, испытывающих антропогенное воздействие агрогенного характера.

Ключевые слова: ландшафт, геосистема, устойчивость, сельское хозяйство, оценка, влияние.

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THE ANALYSIS OF MODERN TECHNOLOGY AND TECHNIQUE APPLIED IN THE COMPLETION OF GEOTECHNOLOGICAL WELLS AND REMEDIAL WORKS IN THEM

Abstract. The issues related to the current state of conducting remedial works to recover geotechnological wells that are operated to mine uranium ores by the technique of underground borehole leaching are considered in the article. The essence of this method is that a chemical reagent that dissolves the ore into the liquid phase is pumped through one well (pumping/injection), and through other wells (production) the solution is lifted to the surface. The production wells tend to lose their initial productivity with the operation, and the injected ones - the injectivity due to colmatation of the working zone in well screen. The causes and types of colmatationare discussed and the analysis of existing equipment and technology for remedial works has been made. On the basis of this analysis, the promising areas for improving technology and techniques for remedial works in geotechnological wells have been identified.

Key words: well, flow rate, recovery, remedial works, well screen, colmatation, well injectivity.

Introduction. At present, the economy of the Republic of Kazakhstan mainly depends on the extraction and export of hydrocarbon raw materials, but according to many studies the world's reserves of this type of raw materials are limited and their quantity is sufficient only for the next 40-50 years.

But on the other hand, many countries, such as France, Japan, the United States, Canada and others have switched to an alternative source of energy –nuclear energy. For example, in France and Japan 80% of electricity is generated from nuclear power plants.

At the same time, Kazakhstan is very rich in ores for the nuclear industry, but today they are not consumed inside the country and the extraction of this raw material is carried out mainly for the purpose of its export. Consumption of raw materials in the nuclear industry in the future in the Republic of Kazakhstan as an alternative to hydrocarbon raw materials is beyond doubt.

25% of the world uranium reserves are concentrated in Kazakhstan, and about 70% of them are suitable for extraction by the method of underground in-situ leaching (ISL). The program for the development of the nuclear industry, approved by the Government of the Republic of Kazakhstan, envisages a sharp increase in uranium production in Kazakhstan. The solution to this task is achievable with the introduction of advanced technology and technique of exploration and production, with the replacement and improvement of the existing fleet of equipment, tools andtraining highly qualified specialists.

Currently, one of the most widely used methods for developing uranium deposits is geotechnological methods incorporating boreholes, the essence of which lies in underground in-situ leaching of uranium ores, i.e. the useful component (uranium ore) is transferred to the liquid phase by dissolving it with chemical reagents and then lifting the metal-saturated solution to the surface. For this purpose, a chemical reagent is injected through the wells drilled from the surface into the mineral deposit, capable of transferring minerals to the soluble phase and then lifting to the surface through other wells [10, 11].

This method of mining uranium minerals has one of the greatest advantages, which lies in the fact that it provides extraction without direct contact of man with ore.

However, with the operation of geotechnological wells, production wells lose their productivity over time, and the injection wells – their injectivity. These wells are subjected to remedial works after a certain period. There are thousands of such wells in the uranium deposits of Southern Kazakhstan that require cleaning.

The technology and techniqueappliedo not always provide high-quality cleaning and take up considerable time. Carrying out remedial works to restore the productivity and injectivity of wells with the least material costs and time is very urgent.

Before considering the modern technology of screen decolmatation, let us consider the causes and types of colmatation.

Colmatationof the well screens causes an increase in hydraulic frictional pressure losses when fluid is pumped into the well and, as a result, reduces the productivity of the well.

There are three types of colmatation: mechanical, chemical and biological [6].

Mechanical colmatation is observed in mesh, slotted, block filters due to the discrepancy between the perforations of screen holes in the granulometric composition of the aquifer. As a result of such colmatation, the water intake holes of the screens are wedged or overlapped by sand, clay, and therefore the specific yield is reduced by 20-30%.

The clay filtration occurring in rotary drilling using drill mudshould also be attributedto mechanical colmatation. Over time, the filter cake is densified by increasing the adsorption and molecular bonds between the clay particles, and removing it presents considerable complexity.

When installing the screen, it is necessary to tend to reduce its claying. To achieve this, it's necessary to lower the filter with the lower open end or with washing windows, place a cement plug above the screen that's further is drilled out after screen installation, to cover the screen with special compounds that are dissolved after its installation in the well. Reduction of mechanical colmatation is also facilitated by the creation around the screen of the correctly executed gravel dump.

Chemical colmatation is caused by a violation of the chemical composition of groundwater as a result of changes in hydrodynamic parameters of the filtration flow.

As the water pressure decreases, the solubility of gases (mainly CO_2) decreases, their release occurs and the carbon dioxide equilibrium is violated, according to the following reaction:

$$2HCO_3^- \rightarrow CO_3^{2-} + CO^2 \uparrow H_2O \quad (1)$$

The presence of calcium and magnesium in water leads to the formation of sparingly soluble precipitates of $CaCO_3$ and $MgCO_3$. The most intensive is the release of carbonate sediments in the filter zone. In filters having large hydraulic resistance, pressure losses increase, which leads to a more active release of CO_2 from the water and an even greater increase in the amount of carbonate precipitation.

The covering of screens and screen zones by carbonate sediments occurs mainly in wells drilled in limestones and dolomites (1.10).

The most common colmatizing deposits are ferruginous sediments, which are released during the production of groundwater containing ferrous iron. The transition of iron from ferrous to oxide and precipitation occurs when soluble oxygen is present in the water. This is also facilitated by the release of CO_2 and an increase in the pH of the water due to a violation of the carbon dioxide equilibrium:

$$Fe(HCO_3) \rightarrow Fe(OH) + 2CO_2 \quad (2)$$

The iron oxidehydrate, which has a gelatinous appearance, is deposited on the surface of the screens and in the pore space of the screen zones of the formation. The intensity of deposition of ferruginous sediments increases with the unevenproduction of water from the well, the use of an airlift or an ejector pump, which promote saturation of water with oxygen.

Violation of the chemical composition of groundwater in the producing layer can occur when interacting with the waters of other aquifers with insufficient capacity of the separating water retainer or the absence of cementation of the annular space. When mixing soft and hard waters, the concentration of carbon dioxide can increase, which causes the formation of carbonate sediments.

The covering of screens is greatly influenced by the presence in the groundwater of hydrogen sulfide H_2S. The content of HS hydrogensulfites leads to the formation of hardly soluble and impermeable sulfur deposits of iron, copper, zinc as a result of the reaction of groundwater with the filter framework material. Sulphides of metals in the form of cortical outgrowths of black color form a strong film coating on grids, wire windings, filter cages and contribute to their gradual destruction. It should be noted that sulphurous deposits are not deposited in the screen zones of the formation.

In the presence of silicic acid in iron-containing groundwater, the formation of sparingly soluble silicate deposits with an admixture of ferrous iron is observed.

Preventing the chemical colmatation when using waters with unstable chemical composition is impossible, since its cause is a violation of the natural drive of the aquifer.

To reduce the intensity of colmatation, one should not allow uneven operation of wells, do not use water lifts, during which the aerated water enters the filter zone.

In addition to precipitation, accumulation of deposits can occur as a result of corrosion of the screen itself due to the aggressiveness of underground water with the property of an electrolyte.

Electrochemical corrosion is more susceptible to screen filters, representing a steel perforated pipe, wound with a steel or copper wire mesh. These processes are greatly weakened in the manufacture of screens from plastics, the use of a screen mesh of stainless steel, the use of cords of polymeric materials instead of winding wires.

Biological colmatation is caused by the vital activity of microorganisms. The most active bacteria multiply in screens, where precipitation is formed under the influence of chemical or electrochemical processes. As a result of the life of bacteria (iron bacteria), iron hydroxide is liberated, which facilitates the transfer of ferrous oxide to insoluble oxide deposited on the working surface of the screens. The manganese bacteria present in the groundwater use the oxidation energy of the nitrous compounds and are transferred from the poorly soluble oxide compounds. Intensive biological colmatation is typical for groundwater with an oxygen content of 5 mg / l or more, which are located in the first aquifers from the surface of the earth. Bacteria are also found at great depths in zones far removed from watercourses and reservoirs.

Favorable conditions for the development of iron bacteria are found in most hydrogeological regions, therefore, in order to suppress their vital activity, it is necessary to periodically chlorinate the wells.

As a result of the analysis of a large number of literature sources, it was established [2] that the reasons for failure are (by the specific gravity of each of the following factors): filter collation - 40.9%; siltation and sanding of the well 37.77%, wear of pumping equipment - 12.52%; other reasons - 8.81%. Thus, the developed funds should be directed to the periodic decolmatation of screens and the fight against sanding and siltation of the well (together, these reasons amounted to 78%).

Therefore, depending on the type of colmatation, there are various ways of decolmatizingscreens and productive horizons. These include circulatingwellbores (through the washing window, with the help of packers and hydro-suckers, hydro- and pneumopulse, electric pulse, chemical, using explosives, etc.). The essence of these methods is described in some detail in various literary sources [1, 3, 9]. The analysis of the above-mentioned methods made it possible to determine their advantages and disadvantages. The disadvantages are:

- the complexity of the designs of technical products, which reduces their operational reliability;
- the overall dimensions of some technical devices do not always allow their descent into the screen column due to its small diameter, with which geotechnological wells are equipped;
- in carrying the chemical method of remedial works, certain safety measures are required when working with various types of chemicals, as well as the high cost of chemical reagents;
- with the electric pulse method of cleaning the screen surfaces, the disadvantages include the high cost of the equipment, observance of safety measures when working with high voltage;
- the use of explosive effect with the use of explosives in wells equipped with plastic screens can result in their destruction, the need for a special permit for blasting operations, as well as the high cost of explosives.

It should be noted here that the methods of conducting remedial works are similar to the methods of development at the stage of completion of wells.

Of greatest interest is the use of cavitated liquid for cleaning screens and the screen zone of the productive formation.

Cavitation [2, 4, 5, 7] (from Latin *cavita* - emptiness) - the process of vaporization and subsequent collapse of vapor bubbles with simultaneous condensation of vapor in the liquid flow, accompanied by noise and hydraulic shocks, the formation of cavities (cavitation bubbles, or caverns) filled with the vapor of the liquid itself. Cavitation occurs as a result of a local decrease in the pressure in the liquid, which can occur either with an increase in its velocity (hydrodynamic cavitation) or during the passage of an acoustic wave of high intensity during the half-life of rarefaction (acoustic cavitation), there are other causes of the effect. Moving with the flow into the area with a higher pressure or during the half-period of compression, the cavitation bubble collapses, while emitting a shock wave. The phenomenon of cavitation is of a local nature and arises only where there are conditions. It cannot move in the environment of origin. Cavitation destroys the surface of propellers, hydraulic turbines, acoustic radiators, shock absorber parts, hydraulic couplings, etc. Cavitation also benefits - it is used in industry, medicine, military equipment and other related fields. However, more recent studies have shown that the leading role in the formation of bubbles during cavitation is played by gases released into the emerging bubbles. These gases are always contained in the liquid, and when local pressure decreases, they begin to vigorously separate into the inside of these bubbles. Since under the influence of alternating local pressure the bubbles can contract and expand sharply, the temperature of the gas inside the vesicles varies widely, and can reach several hundred degrees in Celsius. There are computational data that the temperature inside the bubbles can reach 1500 °C. It should also be taken into account that the dissolved gases in the liquid contain more oxygen in percentage than in air, and therefore the gases in the bubbles are chemically more aggressive than the atmospheric air, resulting in the oxidation (reaction) of many normally inert materials. Cavitation is used for ultrasonic cleaning of surfaces of solids. Special devices create cavitation using sound waves in a liquid. Cavitation bubbles, collapsing, generate shock waves that destroy contaminant particles or separate them from the surface. Thus, the need for hazardous and unhealthy cleaning agents is reduced in many industrial and commercial processes where purification is required as a production step.

The number of cavitation. The cavitation flow is characterized by a dimensionless parameter (the number of cavitation) [2]:

$$K = \frac{P_0 - P_н}{\left(\frac{\rho v_0^2}{2}\right)} \quad (1)$$

where P_0 – hydrostatic pressure of the oncoming stream, Pa; $P_н$ – pressure of saturated vapor of liquid at a certain ambient temperature, Pa; ρ is the density of the medium, kg/m³; v_0 is the flow velocity at the entrance into the system, m/s.

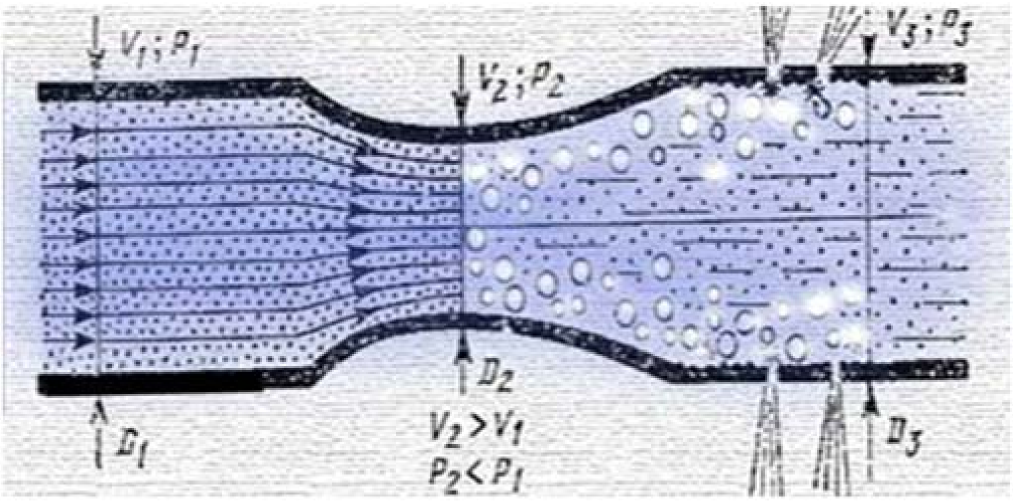

Diagram of formation of a cavitated liquid

The number of cavitation can take different values, but cavitation occurs only in the range K = 0.1-0.6. It is known that cavitation occurs when the flow reaches the boundary velocity, when the pressure in the stream becomes equal to the vapor pressure (saturated vapor). This speed corresponds to the boundary value of the criterion of cavitation.

Most often, cavitation is formed in the zone located on the pump's pressure line, in case of its narrowing i.e. the pressure of the liquid decreases after contraction (according to the Bernoulli law), since losses and kinetic energy increase. The saturated vapor pressure becomes greater than the internal pressure in the liquid with the formation of bubbles/caverns. After passing through a narrow part (it may be a slightly open gate, local constriction, etc.), the flow rate drops, the pressure increases and the bubbles of gases and vapors collapse. Moreover, the energy released in this case is very, very large, as a result of which (especially if it occurs in bubbles located on the walls) micro-hydro impacts occur that entail damage to the walls. At the same time, if you do not take measures, then the process will reach the complete destruction of the walls of the pump part. Vibration and increased noise in the pump and pipes are the first signs of cavitation.

The main weaknesses in the hydraulic systems are the places of narrowing, sudden changes in the flow velocity of the liquid (valves, cranes, latches) and impellers of pumps. They become more vulnerable when the roughness of the surface increases.

Serdyuk carried out large-scale studies on the use of cavitated liquid for decolmatation of screens and screen zones [2]. The experimental investigations carried out by the author were as follows. In the wells equipped with screens, the screenswere cleaned with a conventional uncavitated fluid and another cavitated liquid. The appearance of filters obtained after treatment in cavitation and non-cavitation modes is presented in the photo (photo).

Appearance of the cavitatedscreens after their treatment by the liquid flow in various modes:
a) uncavitated; b) cavitated

As can be seen from photo, the appearance of the screen, after its treatment in the cavity-free regime, has not changed, the thickness of the mud cake has remained the same. After treatment in cavitation mode for 15 minutes, the screen completely cleared of the mud cake. Visible in the photo, the remains of clay, in the author's opinion, are caused by contamination of the screen during its extraction.

Thus, the use of cavitated liquid for screen cleaning is a promising solution.

Conclusions. The analysis of methods and means of decolmatation of screens and aquifers, even with their positive effects, allows us to draw the following conclusions:

- the complexity of the designs of technical products, which reduces their operational reliability;
- the overall dimensions of some technical devices do not always allow their descent into the screen column due to its small diameter, with which geotechnological wells are equipped;
- in carrying the chemical method of remedial works, certain safety measures are required when working with various types of chemicals, as well as the high cost of chemical reagents;
- with the electric pulse method of cleaning the screen surfaces, the disadvantages include the high cost of the equipment, observance of safety measures when working with high voltage;
- the use of explosive effect with the use of explosives in wells equipped with plastic screens can result in their destruction, the need for a special permit for blasting operations, as well as the high cost of explosives.
- the use of cavitated liquid for screen cleaning is a promising solution and demands the improvement of the technology and technique used in conducting remedial and workover operations in geotechnological wells.

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ГЕОТЕХНОЛОГИЯЛЫҚ ҰҢҒЫЛАРДА ИГЕРУДІҢ ТЕХНОЛОГИЯСЫН, ТЕХНИКАСЫН ЖӘНЕ ЖӨНДЕУ-ҚАЛПЫНА КЕЛТІРУ ЖҰМЫСТАРЫН ЖҮРГІЗУДІ ЗАМАНАУИ ЗЕРТТЕУ

Аннотация. Мақалада уранрудаларын жер асты ұңғылық шәю әдісімен өндіретін геотехнологиялық ұңғыларды реанимациялау мақсатында жөндеу-қалпына келтіру жұмыстарын жүргізудің қазіргі жағдайының сұрақтары қарастырылған. Бұл әдістің мәні бір ұңғылардан (айдау) қабатқа руданы сұйылтатын химиялық реагент айдалады, ал басқа ұңғылардан (сору) ерітіндіні жер бетіне айдап шығарады. Пайдалану кезінде уақыт өте келе сору ұңғылары бастапқы өнімділігін жоғалтады, ал айдау ұңғылары сүзгілеу тізбегінің жұмыстық бөлігінің кольматациясы есебінен қабылдау қабілетін жоғалтады. Кольматация себептері және түрлері қарастырылды, сондай-ақ жөндеу-қалпына келтіру жұмыстарының қазіргі уақыттағы техникасы мен технологиясы сарапталды. Осы сараптаудың негізінде геотехнологиялық ұңғыларды жөндеу-қалпына келтіру жұмыстарының технологиясы мен техникасын жетілдірудің тиімді бағыттары анықталды.

Түйін сөздер: ұңғы, дебит, қалпына келтіру жұмыстары, сүзгілеу тізбегі, кольматация, қабылдау.

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АНАЛИЗ СОВРЕМЕННОЙ ТЕХНОЛОГИИ, ТЕХНИКИ ОСВОЕНИЯ И ПРОВЕДЕНИЯ РЕМОНТНО-ВОССТАНОВИТЕЛЬНЫХ РАБОТ В ГЕОТЕХНОЛОГИЧЕСКИХ СКВАЖИНАХ

Аннотация. В статье рассматриваются вопросы современного состояния проведения ремонтно-восстановительных работ с целью реанимации геотехнологических скважин, которые эксплуатируются с целью добычи урановых руд методом подземного скважинного выщелачивания. Сущность данного способа заключается в том, что через одни скважины (закачные) закачивается в пласт химический реагент, растворяющий руду в жидкую фазу, а через другие скважины (откачные) откачивают раствор на поверхность. В процессе эксплуатации со временемоткачные скважины теряют первоначальную производительность, а закачные – приемистость за счет кольматации рабочей части фильтровой колонны. Рассмотрены причины и виды кольматации, а также проведен анализ существующей техники и технологии проведения ремонтно-восстановительных работ. На основе этого анализа определены перспективные направления совершенствования технологии и техники проведения ремонтно-восстановительных работ геотехнологических скважин.

Ключевые слова: скважина, дебит, восстановление, ремонтно-восстановительные работы, фильтровая колонна, кольматация, приемистость.

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OPTIMAL STRUCTURE ESTABLISHMENT OF COMPOSITIONAL MATERIAL FOR MANUFACTURING STRENGTHENED TO BENDING MUD- FLOW PROTECTIVE CONSTRUCTIONS

Abstract. Mudflows generate human and property losses. Natural calamities are not characteristic only for a region or country it is problem of all humanity on the Earth. Mudflows phenomena are widely distributed on the Republic of Kazakhstan territory.

The constructive features of today mudflow-protective constructions in this paper are considered. There had been researches on optimal structure of the compositional material for mudflow-protective constructions. In this study, two main directions are considered in this research work: resource-saving technology and life safety problems investigation.

The purpose of the paper is raw mixture composition development for compositional material obtaining, which together diminish its cost at the strengthening characteristics keeping as well as industrial waste simultaneously utilization.

The basic practically meaningful result is the development of scientific and technological bases of production of new multi-component hydraulic binding materials for compositional material. This technology is ecologically valuable, and it is low-metal-intensive and low-energy-intensive one. The scientific value of research results lie in the new regularities of multi-component system mechanical dispersion based on different grinding principles. It lies also in revealing the new products of mechanically activated multi-component cement hydration in the presence of technogenic waste of the industries (waste of mineral wool production 1.5-2.0; slag of electric-thermal production of phosphorus 2.5-5.0; waste of slate-pipe production 1.2-1.8); as well as the development of compositions of high-strength and technological sorts of cement concretes.

Mathematical modeling of experimental works planning was carried out for compositional material structure determination for mudflow-protective constructions manufacturing with strengthening to bending at which maximal meanings are reached.

Thus, the low-clinkered floured cements developed by us based on industrial technogenic waste that meets the modern requirements. i.e. they improve physical-mechanical characteristics of the material and positively influence on ecological situation and allow decreasing the cost of final product.

Keywords: emergency situations, mudflow, reinforced compositional material, mudflow protective constructions, strength of constructions to bending.

Introduction. Mudflows regularly generate significant human and property losses. Analyzing mudflows is important to assess the risks and to delimit vulnerable areas where mitigation measures are required [1].

Natural emergencies are not specific to a single region or country; this is a problem of all humanity on planet Earth. In this regard, scientists all over the world in the field of life safety and environmental protection are working on prediction, preventive measures, possibilities of reducing the damage to a human and material.

In November 2000 a large landslide of mud and debris was triggered again and it still presents a danger to the relatively new residential houses today. At present, the village is protected against mudflows by a small rockfill dam and by the regulation of the stream bed. In rainy periods removal of mud is necessary maintain safe conditions for the village [2].

Torrential floods are the most frequent natural catastrophic events in Serbia, causing the loss of human lives and huge material damage, both in urban and rural areas. The analysis of the intra-annual distribution of maximal discharges aided in noticing that torrential floods have a seasonal character [3].

Besides of natural calamities as well human activities bad influence on environment and they are needed in new protective measures development.

Nowadays the technologies of emergency situations management in the mountain areas are developed and applied in order to safe conditions of localities organization.

The protective constructions are used more than 30-40 years. They are worn out and partly destroyed. It is necessary to develop ways of their theoretical and experimental researches as well their practical application.

The most complex objective for science in the field of engineering protection of the territories is concluded in how to forecast approaching of danger and what kind of measures to take for risk diminishing of the natural calamities. At the scientific based approach to these problems decision can safe huge material means as well to improve environment and mainly to keep life of people.

The purpose of this work is determination of constructional decision for protection from natural calamities. The maximal index of strengthening is reached at the 7 and 28 days extraction [4-6].

Scientific novelty is concluded in the following:

– experimentally optimal structure of raw mixture for reinforced compositional material obtaining to mudflow protective constructions manufacturing has been determined;

– due to mathematical planning of experiments optimal structure of raw mixture of the compositional material, which strengthening characteristics increasing such as bending and exploitation period duration have been established.

All over the world, where high mountain areas are situated have problems connected with natural calamities. Therefore, protection from mudflows, floods and other natural character emergency situations requires constructions advanced and resources saving with strengthening characteristics.

Material and methods. Nowadays many researchers are interested in out of products of the chemical productions particularly phosphorus slag the yield of which annually is increased.

Authors of this work use the following kinds of material with chemical composition in order to obtain resource-saving and energy economic new material. which answer to all exploitation question.

Portland cement of the following chemical composition, mass. %: SiO_2 – 19.45÷20.2; Al_2O_3 – 4.4 ÷4.9; Fe_2O_3 – 2.9÷4.49; CaO – 60.98÷66.0; MgO – 1.8÷3.18; R_2O – 1.80÷1.90; SO_3 – 1.85÷3.08.

Waste of slate-pipe production. Chemical composition, mass. %: SiO_2 – 20.80; $A1_2O_3$ – 3.85; Fe_2O_3 – 4.15; CaO – 50.0; MgO – 5.35; SO_3 – 1.65.

Waste of mineral wool production represent by themselves fiberglass with an average diameter 0.6 microns and length from 5 to 20 mm with module of acidity equals to 1.4. Chemicalcomposition, mass. %: SiO_2 – 45.8÷46.1; Al_2O_3 – 9.4 ÷9.84; Fe_2O_3 – 1.5÷1.63; CaO – 37.8÷39.1; MgO – 2.2÷2.22; SO_3 – 0.9÷0.93.

The applied slag of electric-thermal of phosphorus production has the following chemical composition, mass. %: SiO_2 – 40.9÷44.21; Al_2O_3 – 1.65÷2.67; Fe_2O_3 – 1.07÷2.6; CaO – 45.0÷45.92; MgO – 1.07÷3.18; SO_3 – 0.3÷0.5.

The binders are received by means of neutralization of ground till specific surface 300-350 kg/m^2 of granulated phosphoric slag with lime (lime-slag binder). cement (cement-slag) and secondary cement dust (dust-slag) magnesium chloride (salt-slag) sodium hydroxide (slag-alkaline). The content of activizators of hardening in the binder is hesitated within 2-12 % from mass of slag.

As reinforced materials are used glass Capron, basalt and steel fiber in the quantity of 2-40% on of binders. For compositional binders receiving of steel fiber segments with diameter 0.5-1.0 mm and 2-20 mm are used.

The significant effect on efficiency of concretes reinforcement with fibers fraction and coarse aggregate content influences. The number of coarse aggregate must be no more than 445-515 m^2/kg and size of its grains do not exceed 10 mm in compositional materials.

The significant influence on comfortable fit of concrete mixture and physical-mechanical characteristics reinforced concretes the diameter and correlation of length to fibers (1/d) diameter. The comfortable fit of concrete mixture with diameter diminishing and 1/d value increasing is lowered.

It is necessary to increase cement quantity for mixture comfortable fit improvement at the given water/cement correlation. For dispersed-reinforced concretes production is more effectively use steel wires with curved ends glued together in bundles. At these conditions clumping of fibers is diminished as well comfortable fit of big amount of mixture, statistic and dynamic properties of concrete is improved [7-10].

Due to the following physical-chemical methods the experimental works are carried out: x-ray phase, analytical, electron-microscopic thanks to electron-solution microscope JSM 63-90 LV, JED-2300 Analysis station Japanease firm JOEL.

It is established optimal composition and technological regime of raw mixture manufacture due to method of mathematical planning of the experiment.

– strength of construction to bend (at the 7 days extraction) kg/cm^2 ;

– strength of construction to bend (at the 28 days extraction) kg/cm^2.

The following factors are varied:

– Portlandcement. %;

– waste of mineral wool production. %;

– slag of electric-thermal of phosphorus production. %;

– waste of slate-pipe production. %.

The ranges of aggregates composition changing are brought in the table 1.

Table 1 – Table samples

Factors	X_1	X_2	X_3	X_4
Lowerlevel (1)	92.4	1.625	3.125	1.65
Upperlevel (+1)	94.8	1.875	4.375	1.50
Shoulder - (= 2) (additionalpoints)	91.20	1.50	2.50	1.20
Shoulder + (additionalpoints)	96.00	2.00	5.00	1.80
Ground level (0) (mid of plan)	93.60	1.75	3.75	1.20
Intervalofvarying (X)	2.40	0.25	1.25	0.30

Tridimensional graphics of strength dependence on bend from different factorsequaled with found optimal values at the 28 and 7 days extraction are shown on the figures from 1 to 8.

Table 2 – Plan and treatment results of the experiments for determining the optimal composition of composite materials, which gives the maximum value Y_1 – the strength of the structure in bending (with exposure time of 7 days) kg/cm^2

№ test	Internalvarieties				Yield		Inaccuracy (error)		Coefficient of mathematical model (1) in real scale	
	X_1	X_2	X_3	X_4	$Y_{experiment}$	$Y_{calculated}$	absolute	relative %		
1	2	3	4	5	6	7	8	9	10	11
1	94.80	1.63	3.13	1.35	147.400	147.5238	-0.1238	-0.0840	№	meaning
2	92.40	1.63	3.13	1.35	147.000	146.9924	0.0076	0.0052	1	473.0706
3	94.80	1.88	3.13	1.35	146.900	146.8954	0.0046	0.0031	2	3.8260
4	92.40	1.88	3.13	1.35	146.500	146.5562	-0.0562	-0.0384	3	-320.9542
5	94.80	1.63	4.38	1.35	146.600	146.7070	-0.1070	-0.0730	4	-159.0778
6	92.40	1.63	4.38	1.35	145.700	145.7068	-0.0068	-0.0046	5	-276.7881

Продолжение таблицы 2

1	2	3	4	5	6	7	8	9	10	11
7	94.80	1.88	4.38	1.35	148.500	148.5355	-0.0355	-0.0239	6	-0.0401
8	92.40	1.88	4.38	1.35	148.000	148.0259	-0.0259	-0.0175	7	23.5433
9	94.80	1.63	3.13	1.65	148.200	148.2034	-0.0034	-0.0023	8	0.9723
10	92.40	1.63	3.13	1.65	147.700	147.7437	-0.0437	-0.0296	9	-1.4522
11	94.80	1.88	3.13	1.65	147.800	147.8753	-0.0753	-0.0509	10	0.9252
12	92.40	1.88	3.13	1.65	147.850	147.7738	0.0762	0.0515	11	0.8049
13	94.80	1.63	4.38	1.65	147.500	147.5268	-0.0268	-0.0181	12	1.4044
14	92.40	1.63	4.38	1.65	147.000	147.0306	-0.0306	-0.0208	13	45.5884
15	94.80	1.88	4.38	1.65	147.000	147.0356	-0.0356	-0.0242	14	91.4725
16	92.40	1.88	4.38	1.65	147.300	147.2625	0.0375	0.0254	15	45.9248
17	96.00	1.75	3.75	1.50	147.000	146.8542	0.1458	0.0992	16	-0.2948
18	91.20	1.75	3.75	1.50	146.000	146.0346	-0.0346	-0.0237		
19	93.60	1.50	3.75	1.50	148.000	147.8949	0.1051	0.0710		
20	93.60	2.00	3.75	1.50	148.400	148.3982	0.0018	0.0012		
21	93.60	1.75	2.50	1.50	148.500	148.4494	0.0506	0.0340		
22	93.60	1.75	5.00	1.50	148.000	147.9393	0.0607	0.0410		
23	93.60	1.75	3.75	1.20	146.200	146.0841	0.1159	0.0793		
24	93.60	1.75	3.75	1.80	147.000	147.0047	-0.0047	-0.0032		
25	93.60	1.75	3.75	1.50	146.700	146.6751	0.0249	0.0170		
26	93.60	1.75	3.75	1.50	146.500	146.6751	-0.1751	-0.1195		
27	93.60	1.75	3.75	1.50	146.900	146.6751	0.2249	0.1531		
28	93.60	1.75	3.75	1.50	146.490	146.6751	-0.1851	-0.1264		
29	93.60	1.75	3.75	1.50	146.880	146.6751	0.2049	0.1395		
30	93.60	1.75	3.75	1.50	146.560	146.6751	-0.1151	-0.0785		
31	93.60	1.75	3.75	1.50	146.700	146.6751	0.0249	0.0170		
Summaryerror =							-0.22656	-0.0012		
Averagemeaningoferror =							-0.01133	-0.0001		
Meaning of criteria of $R_{quadratum}$ =							**0.9837**			

Table 3 – Plan and treatment results of the experiments for determining the optimal composition of composite materials,

which gives the maximum value Y_2 – the strength of the structure in bending (with exposure time of 28 days) kg/cm^2

№ test	Internalvarieties				Yield		Inaccuracy (error)	
	X_1	X_2	X_3		$Y_{experiment}$	$Y_{calculated}$	absolute	relative %
1	94.80	1.63	3.13	1.35	150.500	150.5855	-0.0855	-0.0568
2	92.40	1.63	3.13	1.35	151.100	151.3130	-0.2130	-0.1409
3	94.80	1.88	3.13	1.35	153.200	153.2402	-0.0402	-0.0263
4	92.40	1.88	3.13	1.35	153.000	153.2568	-0.2568	-0.1679
5	94.80	1.63	4.38	1.35	150.300	150.2816	0.0184	0.0122
6	92.40	1.63	4.38	1.35	151.000	150.9416	0.0584	0.0387
7	94.80	1.88	4.38	1.35	152.700	152.4960	0.2040	0.1336
8	92.40	1.88	4.38	1.35	152.500	152.5937	-0.0937	-0.0614
9	94.80	1.63	3.13	1.65	153.700	153.5833	0.1167	0.0759
10	92.40	1.63	3.13	1.65	153.400	153.7786	-0.3786	-0.2468
11	94.80	1.88	3.13	1.65	152.500	152.7176	-0.2176	-0.1427
12	92.40	1.88	3.13	1.65	152.300	152.2847	0.0153	0.0101
13	94.80	1.63	4.38	1.65	153.200	153.0906	0.1094	0.0714
14	92.40	1.63	4.38	1.65	153.500	153.4336	0.0664	0.0433
15	94.80	1.88	4.38	1.65	150.700	150.4816	0.2184	0.1449
16	92.40	1.88	4.38	1.65	150.300	150.3778	-0.0778	-0.0518
17	96.00	1.75	3.75	1.50	152.000	152.2313	-0.2313	-0.1522
18	91.20	1.75	3.75	1.50	153.000	152.6296	0.3704	0.2421
19	93.60	1.50	3.75	1.50	153.800	153.7217	0.0783	0.0509
20	93.60	2.00	3.75	1.50	153.800	153.7402	0.0598	0.0389
21	93.60	1.75	2.50	1.50	153.500	153.0439	0.4561	0.2971
22	93.60	1.75	5.00	1.50	151.000	151.3233	-0.3233	-0.2141
23	93.60	1.75	3.75	1.20	149.700	149.5653	0.1347	0.0900
24	93.60	1.75	3.75	1.80	151.000	150.9956	0.0044	0.0029
25	93.60	1.75	3.75	1.50	152.600	152.4847	0.1153	0.0756
26	93.60	1.75	3.75	1.50	152.420	152.4847	-0.0647	-0.0424
27	93.60	1.75	3.75	1.50	152.580	152.4847	0.0953	0.0625
28	93.60	1.75	3.75	1.50	152.300	152.4847	-0.1847	-0.1213
29	93.60	1.75	3.75	1.50	152.400	152.4847	-0.0847	-0.0556
30	93.60	1.75	3.75	1.50	152.600	152.4847	0.1153	0.0756
31	93.60	1.75	3.75	1.50	152.500	152.4847	0.0153	0.0100
Summaryerror =							-0.27902	-0.0044
Averagemeaningoferror =							-0.01395	-0.0002
Meaning of criteria of $R_{quadratum}$ =							**0.9739**	

Coefficient of mathematical model (1) in real scale	
№	meaning
1	529.6355
2	-3.5596
3	-221.3659
4	-59.1221
5	-50.3336
6	-0.0094
7	19.9401
8	-0.1927
9	-24.4914
10	1.8042
11	0.3451
12	1.4871
13	17.3555
14	-3.4337
15	22.1527
16	-0.1466

A **B**

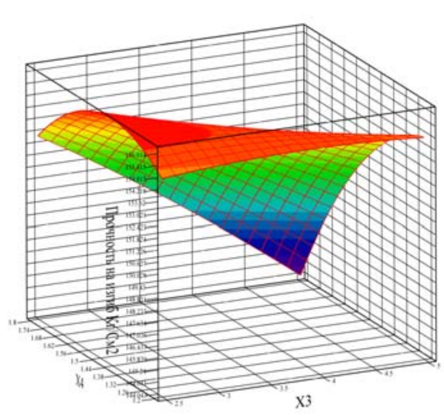


Figure 1 – Tridimensional graphic of strength dependence on bend from X_3 and X_4 at the fixed values X_1 and equaled with found optimal values (at the 28 days extraction)

C

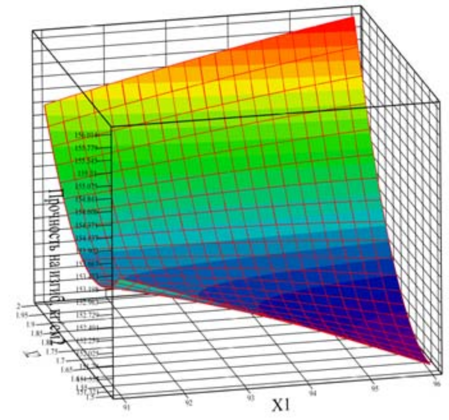


Figure 2 – Tridimensional graphic of strength dependence on bend from X_1 and X_2 at the fixed values X_3 and equaled with found optimal values (at the 28 days extraction)

D

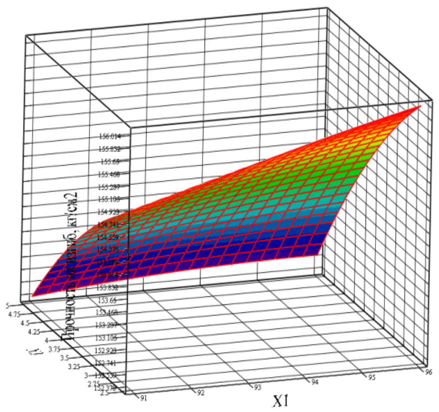


Figure 3 – Tridimensional graphic of strength dependence on bend from X_1 and X_3 at the fixed values X_2 and equaled with found optimal values (at the 28 days extraction)

E

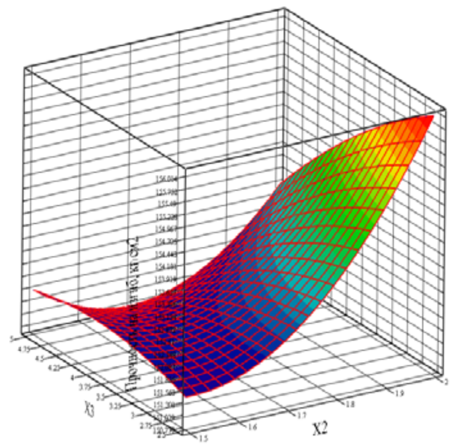


Figure 4 – Tridimensional graphic of strength dependence on bend from X_2 and X_3 at the fixed values X_1 and equaled with found optimal values (at the 28 days extraction)

F

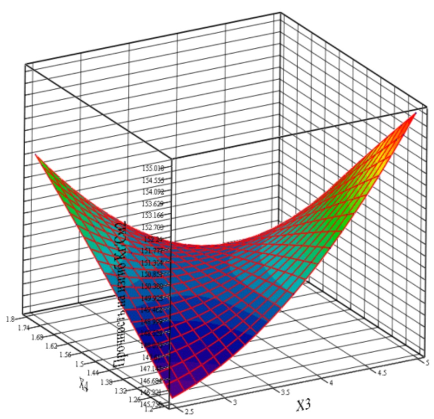


Figure 5 – Tridimensional graphic of strength dependence on bend from X_3 and X_4 at the fixed values X_1 and equaled with found optimal values (at the 7 days extraction)

G

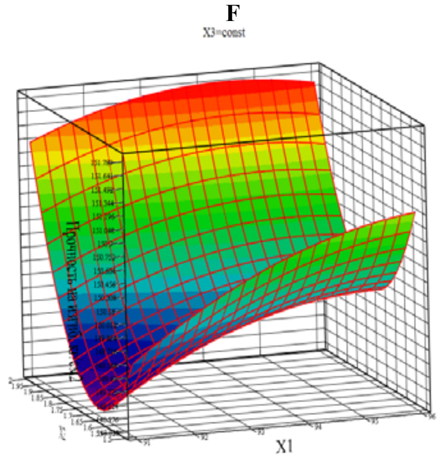
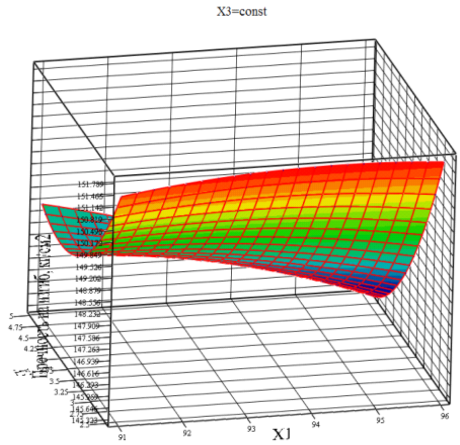
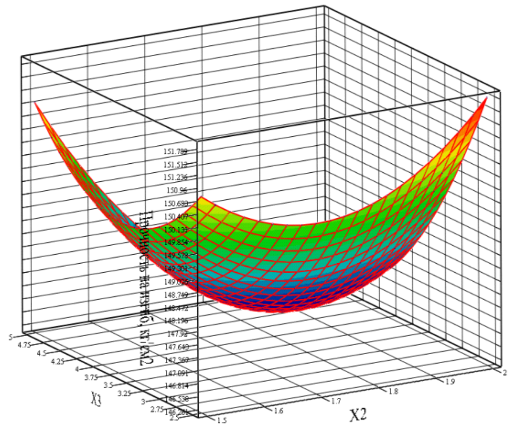


Figure 6 – Tridimensional graphic of strength dependence on bend from X_1 and X_2 at the fixed values X_3 and equaled with found optimal values (at the 7 days extraction)

H





Results and discussion. The results of optimal composition of raw mixtures searching at which is reached maximal value of strength of the construction on bend are brought in the table 4.

Table 4 – Table sample.The results of investigation

– strength of construction on bend (at the 28 days extraction) kg/cm^2				
96.0	2	2.5	1.44	**156.01**
– strength of construction on bend (at the 7 days extraction) kg/cm^2				
94.42	2	2.5	1.80	**151.79**

There were carried out testing of the compositional material on bend with different quantity of aggregates. The results of samples testing are brought in the table 5.

Table 5 – Table sample. The results of testing

Compo-tion	Appellationofaggregates, mass.%				Strength limit at the bend.	
	portlandcement	waste of mineral wool production	waste of slate-pipe production	slag of electric-thermal production of phosphorrus	7 days	28 days
Pro-totype	93.5	2.0	–	4.5	146	149
1	94.52	1.61	1.27	2.60	148	154.2
2	93.24	1.73	1.43	3.60	149	155
3	92.80	1.80	1.53	3.87	149	155.5

There are carried out experimental researches on choosing of raw mixture allowing increasing strength of mudflow protective constructions [11-14].

It is maintained optimal composition of the considered material with the limit of strength on bend in 7 days - 149 . in 28 days 155.5 .

The results of experimental data are allowed recommend optimal composition for stable mudflow protective constructions on bend having low cost in building industry.

Conclusion. The most difficult aim for science in the field of engineering protection of territories is conclude in how to forecast a danger approaching and what kind of measures to take for natural calamities risk lowering. It is possible to economy huge material facilities and improves ecology as well as keeps life of people.

In the result of periodic influence on stone-mud stream on constructions the micro-cracks are appeared. They have brought to macro-cracks and exploitation period of mudflow protective constructions is reduced. The application of Portland cement, waste of slate-pipe production, slag of electric-thermal production of phosphorus and waste of mineral wool production as reinforced fibers increase strength on bend and micro-cracks appearance is excluded. Consequently exploitation period of mudflow protection is extended.

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КОМПОЗИЦИЯЛЫҚ МАТЕРИАЛДЫ ДАЙЫНДАУ ҮШІН БЕРІКТІККЕ ИІЛГІШ СЕЛДЕН ҚОРҒАУ ҚҰРАМЫН ЖЕТІЛДІРУ

Аннотация. Сел ағындары адам және мүліктік шығындарға әкеледі. Табиғи апаттар аймақ немесе ел үшін ғана емес, бұл Жер бетінде адамзаттың проблемасы. Сел құбылыстары Қазақстан Республикасында кең тараған.

Қазіргі заманғы селден қорғау құрылыстарынның құрылымдық ерекшеліктері қаралды. Селден қорғау құрылыстарынның оңтайлы құрамының композициялық материал бойынша зерттеулер жүргізілді. Осы жұмыста екі негізгі бағыты қаралады: ресурс үнемдеушітехнологиялар және тіршілік қауіпсіздігі мәселелерінің зерттеулері.

Жұмыстың мақсаты бұл әзірлеу құрамын шикізат қоспасын алу үшін композициялық материал, бұл жиынтығында оның құнын сақтай отырып төмендетеді, беріктілік қасиетін және бір мезгілде өнеркәсіптік қалдықтарды кәдеге жарату болып табылады.

Іс жүзінде негізгі маңызды нәтижесі бұл ғылыми-техникалық негіздерін әзірлеу, өндірістің жаңа көп компонентті гидравликалық тұтқыр материалдар үшін, композициялық материалдар болып табылады. Бұл технология экологиялық бағалы, төмен-металлды және төмен-энергетикалық болып табылады. Ғылыми зерттеу құндылығының нәтижелері жаңа заңдылықтары механикалық дисперсия көпқұрамды жүйе негізделген әртүрлі принциптеріне ұсақтау болып табылады. Ол сондай-ақ анықтау, жаңа өнімдерді механо-белсендірілген көпкомпонентті гидратациялау цемент қатысуымен өндірістік техногендік қалдықтарды (минералды мақтаның өндіріс қалдықтары 1,5-2,0; электротермиялық фосфор өндірісінің шлактары 2,5-5,0; тақтата сөндіру қалдықтары 1,2-1,8); сондай-ақ әзірлеу композиция беріктігі жоғары және технологиялық сорттарының цемент бетондар.

Математикалық модельдеуді жоспарлау жөніндегі эксперименталдық жұмыстарды құрылымын айқындау композициялық материалды дайындау үшін селден қорғау құрылымдарының беріктігін жоғарылату дейін иілу кезінде ең жоғары мәні жетеді.

Осылайша, біздің тарапымыздан әзірленген төмен-клинкерлі цементтер негізінде өнеркәсіптік техногендік қалдықтардың қазіргі заманғы талаптарға сай, яғни, олар физикалық-механикалық сипаттамаларының материалды және оған оң әсеретіп, экологиялық және азайтуға мүмкіндік беріп, өзіндік құны түпкілікті жақсартады.

Түйін сөздер: төтенше жағдайлар, сел, темір-тұтқырлы композициялық материал, селден қорғау құрылыстары, иілуге берік конструкциялар.

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СОЗДАНИЕ ОПТИМАЛЬНОЙ СТРУКТУРЫ КОМПОЗИЦИОННОГО МАТЕРИАЛА ДЛЯ ИЗГОТОВЛЕНИЯ ПРОЧНЫХ НА ИЗГИБ СЕЛЕЖАЩИТНЫХ КОНСТРУКЦИИ

Аннотация. Селевые потоки приводят к людским и имущественным потерям. Стихийные бедствия характерны не только для региона или страны, это проблема всего человечества на Земле. Селевые явления широко распространены на территории Республики Казахстан.

Рассмотрены конструктивные особенности современных селезащитных сооружений. Проведены исследования по оптимальному составу композиционного материала для селезащитных сооружений. В данной работе рассматриваются два основных направления: ресурсосберегающие технологии и исследование проблем безопасности жизнедеятельности.

Целью работы является разработка состава сырьевой смеси для получения композиционного материала, что в совокупности снижает ее стоимость при сохранении упрочняющих свойств и одновременной утилизации промышленных отходов.

Основным практически значимым результатом является разработка научно-технических основ производства новых многокомпонентных гидравлических вяжущих материалов для композиционного материала. Эта технология является экологически ценной, низко-металлоемкой и низкоэнергетической. Научная ценность результатов исследований заключается в новых закономерностях механической дисперсии многокомпонентной системы, основанной на различных принципах измельчения. Она заключается также в выявлении новых продуктов механо-активированного многокомпонентного гидратации цемента в присутствии техногенных отходов производств (отходы производства минеральной ваты 1,5-2,0; шлаки электротер-

мического производства фосфора 2,5-5,0; отходы сланцевого производства 1,2-1,8); а также разработке композиций высокопрочных и технологических сортов цементных бетонов.

Проведено математическое моделирование планирования экспериментальных работ по определению структуры композиционного материала для изготовления селезащитных конструкций с упрочнением до изгиба, при котором достигаются максимальные значения.

Таким образом, разработанные нами малоклинкерные цементы на основе промышленных техногенных отходов отвечают современным требованиям. т.е. они улучшают физико-механические характеристики материала и положительно влияют на экологическую обстановку и позволяют снизить себестоимость конечного продукта.

Ключевые слова: чрезвычайные ситуации, селевой поток, армированный композиционный материал, селезащитные сооружения, прочность конструкций на изгиб.

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GEODYNAMIC MODEL AND OIL AND GAS POTENTIAL OF THE NORTH-TORGAI BASIN

Abstract. In the course of history different groups of scientists have studied the tectonic structure and evolution and consistency of mineral deposits location on the exposed territory of the Kazakhstan and along the Eastern slope of the Urals. As a consequence, the Torgai depression, which divides the East and West Kazakhstan structures was admitted to be poorly investigated, therefore, this region remains a blank spot on the geodynamic reconstruction schemes over the Kazakhstan.

A geodynamic division into districts of the territory from the Urals in the West to the Kokshetau and Ulytau upheavals in the East was carried out in the article based on the analysis of the latest geological and geophysical materials. The East-Urals anticlinorium, the Denisov's shear zone, the Valeriyanov's synclinorium, the North-Torgai depression and the Kokshetau-Ulytau upheavals zone are emphasized.

The description of each tectonic zone is provided from the plate tectonics standpoint. The structure of the North-Torgai sedimentary Basin is described in more details and, taking into account its geodynamic evolution in the Devonian and Carbonic periods, the oil and gas potential of its central part as to the Devonian and Lower Carbonic sediments is highly appreciated.

Key words: a sedimentary Basin, a volcanic arc, an allochthon, oil and gas potential, a geodynamic model.

The northern Torgai is best known for its magnetite deposits such as Kacharsky, Sokolovo-Sarbaisky, the oolitic iron ore deposits of the Lisakovsk group, the Shaimerden polymetallic deposit, and also bauxite-bearing massive reserves of Denisov-Fedorov's and Valerianov's zones. All of these deposits are in the suture zone of the Ural fold system with the North Torgai depression, in the geodynamic order they were all arranged in the suture zone of the western edge of the Kazakhstan plate with the eastern line of the Urals Ocean of Paleozoic and the East-Urals microplate.

To the East of these acclaimed ore deposits the major part of the territory is covered with the Mesozoic-Cainozoic cover of a considerable thickness, which is actually denoted as the North Torgai depression in the literature. It adjoins in the East to the Kokshetau and Ulytau upheavals and in the North merges into the West Siberian syneclise rich by gas and oil reserves.

At the course of time a notion about " The Geology of East Kazakhstan" in the geological literature has been worked out since N.G. Kassin and R.A. Borukayev, whereby "The East Kazakhstan" was understood as the territory starting the Kokshetau-Ulytau zone the whole area of Kazakhstan, the total outcrops territory of Paleozoic and more ancient formations, since the exposed areas were exactly the exploration target in seeking the solid minerals. The numerous treatises of such luminaries of Kazakhstani geology as R.A. Borukayev, I.F. Nikitin, V.N. Lyubetsky, V.Y. Koshkin, A.V. Avdeyev and et al were dedicated to the Tectonics and paleo-geodynamic reconstructions of "The East Kazakhstan".

Another group of geologists headed by L.A. Yanshin, A.A. Abdullin and others studied the Urals-Mugodzhar zone.

Among the primary treatises "The tectonic map of the Kazakh SSR and adjacent territories of the Union republics" edited by V.F. Bespalov, G.V. Garkovets, V.K. Yeremin et al, (1971) and "The tectonic map of the Paleozoic foldings region of Kazakhstan and adjacent territories (edited by A.A. Abdullin and

G.V. Zaitsev, (1976) may be designated in which the probable correlations of the largest structures along both sides of the North Torgai depression are demonstrated.

In the landmark collective treatise "The Deep structure and the mineral resources of Kazakhstan" (Alma-Ata, 2002), "The Torgai-Syrdaryan depression divides the structures of the East and West Kazakhstan is specified. The basement structure of the depression has been relatively poorly studied; therefore, this region mainly remains a blank spot in the schemes of geodynamic reconstruction over the Kazakhstan" (p. 188).

Field investigations of various mineral resources, including oil, were carried out at the exposed area of the Urals fold system in the East, and within the Kokshetau and Ulytau upheavals in the West.

The direct evidences of oil availability on the Kostanai (Borovoi) anticlinal zone at the western flank of the North-Torgai depression have been known since 1936. The attempts to find oil deposits were undertaken several times. Explorations of oil and gas drilling the small wells up to 1,500 m were carried out on a relatively regular basis in the Shcherbakov, Novonezhinsk, Lesnoi and Koskolski areas by the North Kazakhstan Territorial Geological Department in 1953-1973. The numerous indications of dispersed oil and bitumen in the Carbonic period sediments, however, showed no significant accumulations. A weak influx of heavy tarry oil was just obtained in the 119 well, and managed to gather 1.5 tons volume.

In 2012-2017 the "Energy Resources" company have carried out excessive explorations and managed to receive the oil influx in the H-I well on the Novonezhinsk area and fulfilled the seismic surveys by 2D CDP method not only in the detection area with the determined Shokai, Shakhmardan, Sagadat fault traps, but also regional lines that proved failure to deploy of the Devonian and Carbonic sediments between the Kostanai anticlinal zone and the Kokshetau massif. The same company has carried out the seismic investigations in the central part of the North-Torgai depression that allowed identifying the Devonian and Low Carbonic period ledges.

The new seismic materials along the central submerged part of the North-Torgai depression, indicating the failure to deploy of the Devonian and Carbonic sediments of more than 4,000 m thickness, unlike the Valeriyanov's zone, where they are crushed into folds, destroyed by numerous faults and broken by intrusions, are absolutely not correspond with the Hercynides development notions on this territory from the standpoint of the geosynclinal hypothesis. The fact of the North-Torgai area was referred to the Hercynides denoted on the each tectonic map published during the Soviet period and in the subsequent editions of individual scientists have retarded the oil explorations to a great extent, scientifically grounded assessment of its prospects and, as a consequence, the attraction of investors to the exploration of oil deposits.

The entire North-Torgai territory on the maps of oil and gas bearing regions of the USSR (A.N. Shardanov et al. 1983, G.Kh. Dikenshtein et al. 1984) was classified as a land with unclear prospects or of no prospects up to the beginning of the 21st century. The Central-Torgai potential oil and gas bearing area was emphasized in the treatise " The Deep Structure and the Mineral Resources of the Kazakhstan, Oil and Gas", Volume III edited by S.Z. Daukeev, B.S.Uzhkenov, A.A. Abdulin and others (2002) and in " The Intergrated research of sedimentary Basins of the Republic of Kazakhstan. The North-Torgai Basin" edited by O.A. Aksholakov and A.B. Bigarayev (2011). A scientific substantiation of oil and gas potential of the Paleozoic sediments, other than a brief description of the Paleozoic as regards the Kostanai reference profile and the individual non-deep wells is unfortunately not provided in them.

The abovementioned treatises about oil and gas geological division into districts has modeled on the study of geosynclines and platforms, and the main criteria were the stratigraphic range of the sedimentary deposits and the structural and morphological traits of the cover structure. The formation (genesis) of the Basin itself and its geodynamic conditions of evolution, which predetermined the conditions and the rate of sedimentation, probable variations in the thermal control and the influence of tectonic processes occurring in the Urals fold system, most significantly in the Valerianov's volcanic zone appearing the primary factors were not taken into account.

Such kind of failings are mostly considered and eliminated at the process of study of the Basin from the standpoint of plate tectonics theory.

The igneous and sedimentary rocks and the new seismic materials association analysis on the territory between the Urals fold system and the Kokshetau ancient massif affords to identify a number of geodynamic zones that adequately explain the regularities of as solid minerals deposition of various mineralization and the plentiful oil occurrences and provide a scientific basis for the oil and gas prospects assessment of the North-Torgai Basin. In terms of zoning of the considered territory summarizing the numerous publications on the tectonics it is expedient to single out: the East-Urals zone, terminated in the East by the Zhetigarin's regional fault; the Denisov's shear zone to the Livanov's fault; Valeryanov's zone, which forms the northern part of the regional volcanic arc and gradually turns into the Kostanai anticlinal zone, terminated from the East by the Central-Torgai fault. This anticlinal zone forms the western flank of the North-Torgai Basin; the main prospective target of new oil and gas deposits is limited in the East by the ancient Kokshetau and Ulytau upheavals (figure 1 and 2).

The East-Urals zone is represented by an allochthonous plate terminated in the East by the Zhetigarin's regional fault, well-mapped by the outcrops of the ancient strongly transformed and greatly dislocated rocks of Riphean, Vendian and Lower Paleozoic. This fault zone can be observed for several hundred kilometers and consists of several plots (?) echelon like interlocking. The allochthonous plate proceeded along this plate, which now forms the East-Urals mega-anticlinorium, in the late Paleozoic at the closing stage of the eastern line of the Urals Paleogene due to the Kazakhstani continent convergence and clashes with the East-Urals microcontinent.

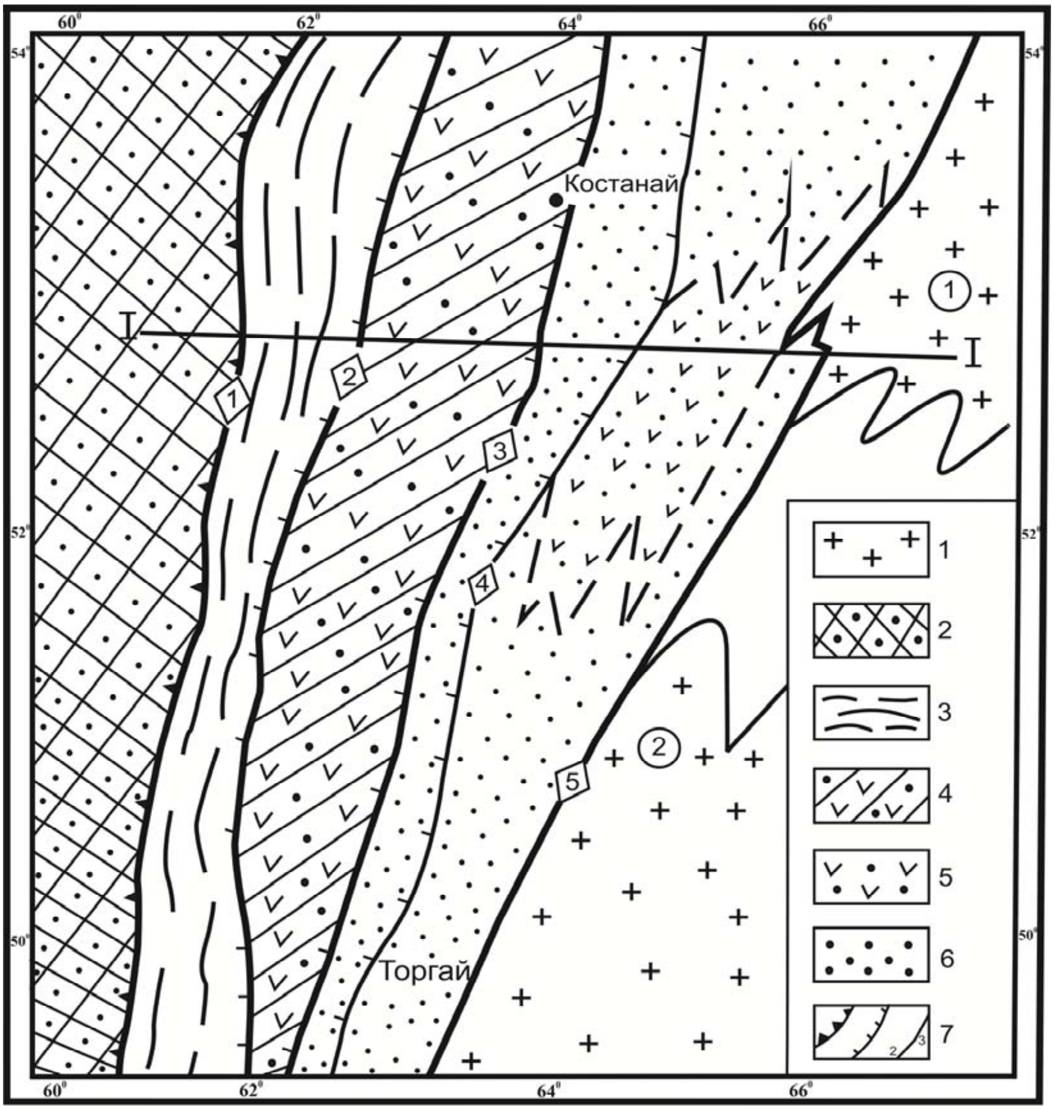

Figure 1 – The geodynamic model of the North-Torgai.

Basin structure: 1 – ancient Precambrian upheavals: 1 – Kokshetau and 2 – Ulytau; 2 – East-Urals megantiklinorium; 3 – Denisov's shear zone; 4 – Valerianov's synclinorium; 5 – Kushmurun's graben; 6 – North-Torgai depression; 7 – thrusts (1), faults (2) and regional faults (3): 1 – Zhetygara, 2 – Livanov, 3 – Apanov, 4 – Central-Torgai and 5 – Amangeldy.

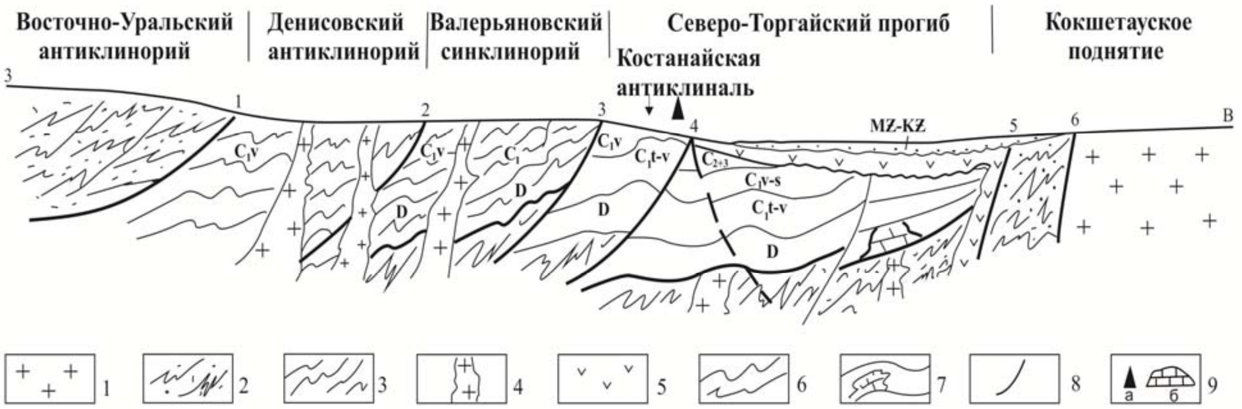

Figure 2 – Geological profile along the Ural-Kokshetau line:
1 – ancient massifs; 2 – allochthonous plate; 3 – Caledonian base; 4 – intrusions; 5 – Triassic traps; 6 – Devonian-Carbon age reefs; 7 – Mezozoic-Cainozoic cover; 8 – faults; 9 – Oil field of Novonezhinsk (a) and Ybraikhan Devonian reef (b).

The Valerianov's zone between the Zhetygara and Apanov regional faults in terms for the conventional geodynamic principle of division into districts can be considered as a part of a regional volcanic arc in the West of the Kazakhstani lithospheric paleo-plate which was formed due to the subduction of the ocean floor of the Urals Paleogene eastern line under the Kazakhstani plate.

The Valerianov's zone is a part of the regional volcanic belt is known in the literature as the Valerianov-Beltau-Kuraminsky, with a total length of more than 2,000 km, more than 1,100 km in the territory of Kazakhstan in particular. The belt formation is associated with the island-arc process in the western pericratonic margin of the Kazakhstani lithospheric plate. The main Torgai iron ore region and the Western Torgai bauxite bearing region are associated with the Valerianov's zone. The metallogenetic state of the Valerianov's zone is determined by the volcanogenic sedimentary formation of the Vize and the Serpukhov's Stage, which is represented by a terrigenous-carbonate-volcanogenic thickness, which is divided into three suites: the Sarbaian basalt-andesite ($C_{1,v}$), Sokolov's carbonate-volcanic ($C_{1,\ v2\text{-}3}$) and Kurzhunkul's Andesite ($C_{1,}$ v-s).

Similar to the Kuramin's zone in the Republic of Uzbekistan non-ferrous metals are predicted in the Valeryanov's zone: copper, lead, zinc, as well as gold. The Shaimerden zinc deposit in this zone is the first indication of the possibility to forecast the polymetallic salinity.

The sedimentary-volcanogenic formations of the Lower Carbonic Period, contorted into the structural highs of the north-south trend, complicated by discontinuous faults play the main role in the Valerianov's zone structure. They are represented by the sandstones, argillites and limestones and underlie without visible unconformity on the Famennian sediments.

The section explored in the region begins with the reddish continental sediments of the Devonian, carbon bearing thickness of the Famennian and the lower Tournaisian is above, which is overlapped by the carbonate-terrigenous thickness of the upper Tournaisian-Lower Vize. The section is completed with a huge volcanogenic-sedimentary thickness of an average Vize and the Namurian consisting of the limestones and reddish-grey color sandstones with tuffaceous material and basalt interlayers, spilites and andesite-basalts, which is the main ore-bearing suite the largest deposits of magnetite ore are confined to. The bituminous limestones were found in the Valerianov's suite at the Sarbaian deposit (figure 3).

The study of the samples from the numerous core wells and the outcrops has concluded in the content of the volcanic strata in the section decreases significantly with the distance from the Ural to the East, and the section is represented by terrigenous-carbonate rocks with the volcanic rocks inclusions and interbeds on the Kostanai (Borovoi) anticline.

The Valerianov's zone overall laminary thrust on the East is confined by the Apanov's regional fault, at the back of which the influence of tangential stresses, naturally directed from the Ural to the East is sharply faded.

Throughout the Devonian and the Early Carbonic periods the North-Torgai Basin was a passive margin of the Kazakhstani continent, facing the Urals Ocean. Starting with a late Vize, i.e. the collision of

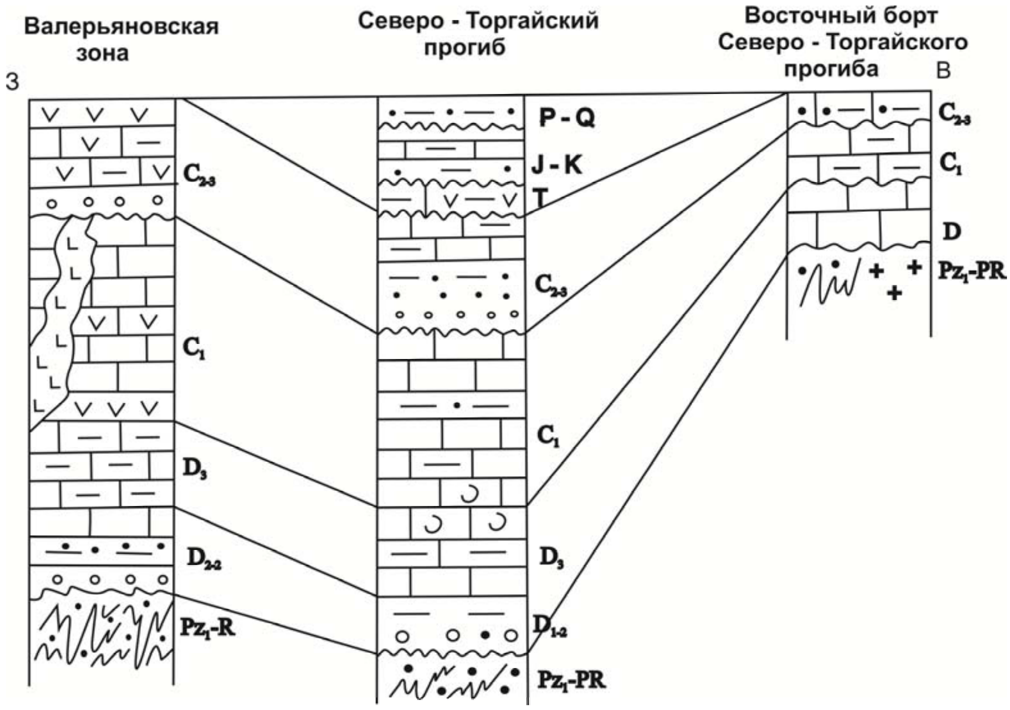

Figure 3 – Sections comparison

the Kazakhstani plate with the East-Urals micro-plate and with the East-European plate, the Valerianov's volcanic belt formed by andesites, andesite-basalts, dacites and diorites and granodiorites, breaking through them, originated behind the main island arcs of the Ural.

In the course of the Middle-Late Carbonic and Permian periods a significant shrinkage of the sea Basin size took place, foundation of the Late Paleozoic retro-arc deflections and the accumulation of terrigenous sediments with glomerations within their limits consisting of limestone pebbles and effusive of the Devonian and Lower Carbonic periods, which at the time were cropped out in the collisional orogens in the East-Urals anticlinorium, the Denisov's and Valerianov's zones of the Eastern Ural.

Following the geophysical explorations an abrupt difference of the North-Torgai depression from the Valerianov's zone is observed. The gravitational and magnetic fields have a high intensity and stretched in-line shape in the north-south trend within the Valerianov's zone. The North-Torgai depression differs by an inlaid weakly dissected shape of low intensity, both gravitational and magnetic fields (figure 4).

The structure of the North-Torgai Basin is well explored by seismology on the licensed territory of "Energy Resources" company. According to the regional latitudinal profiles, the performance of eight almost parallel reflecting horizons is evidenced by the lack of deployment of the Devonian and Carbonic formations of more than 4,000 m thickness (figure 4). Based on the geosynclines standpoint, the territory examined is within the Urals-Mongolian belt Hercynides, where the strong deployments of the Devonian and Carbonic formations are expected to be as in the Valerianov's zone. Recently accepted information confirms the accuracy of our approach to the study of the North-Torgai Basin structure from the standpoint of plate tectonics theory (3 and 4).

The reefs of the Devonian – Tournaisian age of 600-750m high as the Ybyraikhan reef have been identified on the western slope of the Aschiboy's upheaval in the central part of the Basin (figure 5). As previously mentioned, in the territory adjacent to the Kostanai anticline, several local upheavals such as Shokai, Shahmardan and Sagadat are mapped by seismology, which can serve as deformational traps for oil and gas in the Devonian and Lower Carbonic sediments (figure 5).

The Devonian deposits are cropped out on the western and eastern flanges and are uncapped by the wells in the central parts of the Torgai depression. They are represented by a sedimentary-effusive stratum consisting of the red-colored glomerations and sandstones interstratified with the persilicic effusive covers. The shale rocks, limestones and tuffites are found occasionally. The dark grey bituminous carsti-fied limestones of the Givetian age of up to 1,300 m thickness were encountered. The Upper Devonian

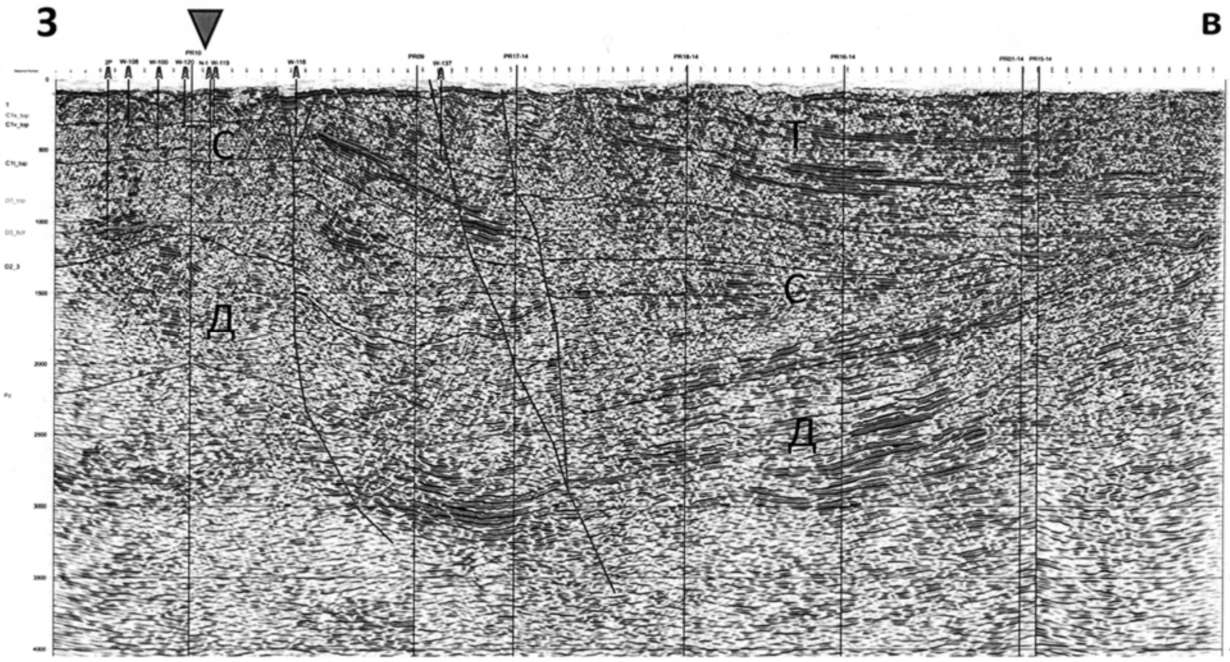

Figure 4 – Regional reflection time section through the North-Torgai Basin.
▼ Oil field of Novonezhinsk

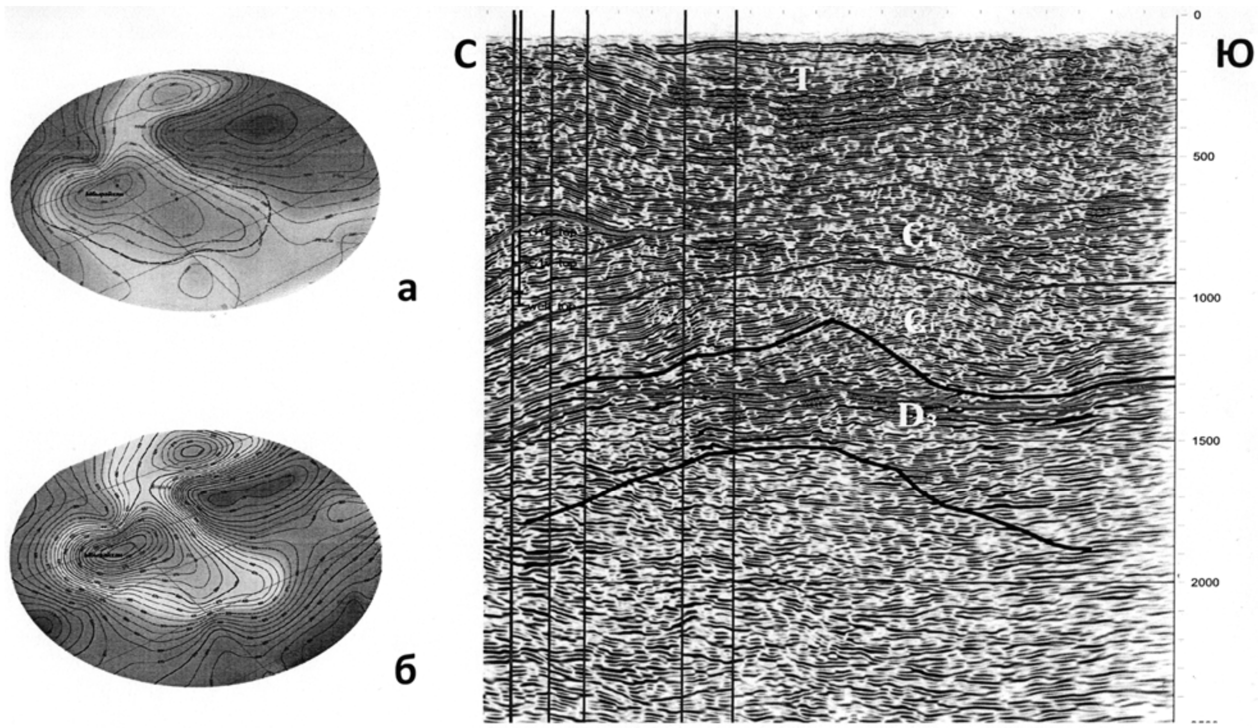

Figure 5 – Ybyraikhan reef: a – subsurface contour map along the reservoir top (reflecting R horizon),
b – Isopach map of reef complex and c – depth section with reef structures

formations as part of the Frasnian and the Famennian stages are established everywhere. The Frasnian stage is represented by the carbonate and terrigenous rocks alternation with a total thickness of 500 m. The Famennian formations in the lower part of the section are folded by the red-colored, brown glomerations, coarse-grained sandstones and clay stones, with the effusion inter-layers now and then. In the upper part of the section the grey, organogenic, cavernous-fractured limestones are predominate, where the oil shows were observed and oil influxes have been obtained in the Novonezhinsky and Shcherbakovsky stretches. Generally, the total thickness of the Devonian formations sharply increases towards the Ural, i.e. the former paleo-ocean, the content of the effusive rocks in the section increases in the same direction.

The Lower Carbonic formations are classified into three strata. The lower is of Lower Tournaisian age represented by terrigenous-carbonate sediments has a small distribution. The middle stratum of the Upper Tournaisian - Lower Vizean age in different structural-facies zones has a different composition and varies from the West to the East from the carbonate-terrigenous to terrigenous-carbonate and further to the carbonate. Numerous inclusions of liquid and inspissated oil are observed in the cracks and caverns of the limestones. The thickness of the middle strata reaches 1,000-1,200 m in the West and decreases in the East to 300-500 m.

The content of organic carbon varies from 0.1 to 2.97% per rock volume in the rocks of the Upper Devonian and the Lower Carbonic period, and, according to the results of a complex analysis, they belong to the category of oil and gas sources.

The Vize-Namur age formations are represented by the grey cavernous bituminous limestones. More recent terrigenous formations, conventionally related to the Upper Paleozoic, are distributed only in the West, mainly in the Kostanai zone and are represented by polymictic glomerations, sandstones and siltstones, effusives horizons are occasionally come across.

The main stage of tectonic deployments caused by compressive diastrophic movements is also assigned to this period, as a result of which the Denisov's zone thrust over the Valerianov's and the Valerianov's zones to Kostanai's and the systems of anticlinal folds arrangement overturned to the East and numerous faultings of the thrown up nature have occurred as a consequence. The geodynamic evolution of the Torgai depression, which was changed over time, has created depositional environment of the passive margin in the Devonian and the Early Carbonic period and then the retro-arc Basin in the Late Paleozoic.

In the central part of the North-Torgai depression the Lower Triassic formations of a considerable thickness in the Grabens unconformable embedded on the washed out surface of the Paleozoic.

The graben-synclines formations have occurred within the periods of volcanic activity alternating with the periods of aqueous sedimentation, judging by the frequent interstratifications of effusives with the sedimentary rocks. The thickness of the effusive rocks layers varies from 5-10 m to 100-160 m, and the sedimentary rocks, represented by the sandstones, conglomerates and clays, quite often enriched with the sapropelic substance, range from several meters to 60-100 m. This sedimentary-volcanogenic stratum is known as the Turinese series. The rude conglomerates layers are usually embedded in its foundation. The total thickness of the series is variable and exceeds 1,500 m in many Grabens. The central part of the North Torgai depression is covered with the low-power terrigenous sediments of the Mesozoic-Cainozoic period.

Simultaneous origin (the end of the Permian and the beginning of the Triassic) of Grabens and their confinement to the regional faults, which were the basaltic magma guides; a similar lithological composition of the filling sediments up to 3,000-4,000 m thick; the total north-south orientation is along the Ural throughout 600 km, at a line width of Grabens extension of 50-150 km allows to join them into a single East-Urals paleo-rift system. The genesis of rifts within the Torgai depression had a polycyclic nature. It took place in the Early Carbonic, Triassic and Jurassic periods. Regeneration of the rift structures is clearly observed to the South-East from Zharyk Graben formed in the Carbonic period, and Kush-Murunsky in the late Permian and Early-Middle Triassic to the Grabens of the near Ishim Group (the Late Triassic) and the Southern Torgai (Jurassic), is indissolubly connected with the activation change of the regional deep faults in the course of time. The Triassic genesis of rifts cycle was somewhat cut down in the development. The Graben of Kushmurun, perhaps, has passed the stage of deposition and, due to the change in the tectonic frameworks, specifically abrupt uplift it experienced no subsidence stage and above rift depression.

The Jurassic cycle embraced a vast territory, practically the entire central and southern part of the Torgai depression, at this the remarkable size Grabens of the Jurassic age were originated within the Grabens of the Early Carbonic and Triassic ages, that is, the second Grabens production in the same area has occurred.

The Zharyk graben-syncline is of 200 km length and 20-50 km width stretched from the southwest to the northeast, terminated by faults and executed by the Lower Carbonic sediments. The recent Kagansky and Mukyrsky graben-synclines, executed by the Jurassic sediments, occur unconformable on the Lower-Carbonic stand out within its limits.

Kushmurun, Ashibulak and Kargalytau grabens are executed by the Tournaisian series, which contains basalts and dacites in a section. The small grabens of the following generation are developed within their limits, made by Jurassic coal-terrigenous sediments. In particular, the Jurassic grabens are distinguished within the limits of the Kushmurun graben-syncline: Yeginsay, Bylkyldak, Sevastopol, Chernigov, and others.

The Koktal graben-syncline executed by the Jurassic coal-bearing formations is located between the Zharyk Carbonic and the Kushmurun Triassic Age graben-synclines. Such graben-syncline Jurassic deposits have a wide distribution within the Torgai depression.

The grabens and graben-synclines of the Jurassic system are relatively well studied in the Southern Torguy due to the discovery of oil and gas fields with the considerable reserves - Kumkol, Aryskum and others. In the northern half of the Torgai depression, the grabens have a north-east, near north-south (Urals) orientation, and in the southern, mainly, north-west (Ulutau) orientation.

On the eastern flank of the North-Torgai Basin faintly deployed continental reddish-colored are established to embed abruptly unconformable on the ancient folded base. The volcanogenic-terrigenous deposits of the Devonian upwards interchange along the section by marine terrigenous-carbonate formations of the Famennian-Early Carbonic period. The red-colored terrigenous stratum of the Upper Paleozoic terminates the section.

The geodynamic evolution of the North-Torgai Basin in the Devonian and Carbonic periods favorably contributed accumulation of the marine and coastal-marine sediments within the passive continental margins of the Kazakhstani lithospheric plate on the eastern shore of the Ural paleo-ocean. The high organic carbon content in this age rocks and numerous oil manifestations and oil inflows indicate the presence of strata generating hydrocarbons in the section of the Basin, and the thermodynamic conditions caused by the presence of magmatic and effusive processes up to the early Triassic created a favorable state for the hydrocarbons generation as well.

The tectonic processes appeared due to the Urals fold system originating and the shear stresses caused by them towards the Northern Torgai resulted in the various structural traps and fractured reservoirs formation on the strata bends. The organogenic limestones in the reef structures are essential as a reservoir and sandstones and siltstones studied by the core holes in the Kostanai zone of anticlines. The wave fields of seismic sections, reflecting the alternation of terrigenous and carbonate rocks, give grounds for assuming a broad formation in the Basin of both reservoir rocks and cap-rocks.

In the Central part of the North-Torgai Basin, where the tectonic stress from the Ural was moderate, there are probably favorable conditions for the hydrocarbon concentrations accumulation and preservation. Special conditions for the formation and preservation of oil and gas accumulations existed in the reef structures of the Devonian and Carbonic period. Altogether it provides foundation for the optimistic potential of the North-Torgai Basin as regards new significant reserves in the oil and gas fields.

The large-scale seismic investigations to identify new traps that are attractive to the investors are required to carry out with the purpose of detailed study of the Devonian-Lower Carbonic sediments structure. Drilling of prospecting wells is necessary to initiate on the sites prepared for search drilling such as Ybyraikhan, Shokay, Shakhmardan, etc. Well-aimed geological explorations will hopefully lead to open not only one or two new oil and gas fields, but new oil and gas bearing and, in the future, oil and gas extraction area in the north of our Republic.

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СОЛТҮСТІК ТОРҒАЙ БАССЕЙІНІҢ ГЕОДИНАМИКАЛЫҚ МОДЕЛІ ЖӘНЕ МҰНАЙ МЕН ГАЗ ІЗДЕУДЕГІ БОЛАШАҒЫ

Аннотация. Пайдалы қазбаларды іздеу және кен орындарын зерттеу бағытында Қазақстан жерін екіге бөлу - Шығыс Қазақстан және Батыс Қазақстан деп - геология саласында тарихи қалыптасып қалған. Бұл екі аймақты бөлетін Солтүстік Торғай ойпатын зерттеуге көп көңіл бөлінбеген.

Жаңа геологиялық және геофизикалық деректерге сүйене отырып Орал тауларынан Көкшетау-Ұлытау аймағына дейін бірнеше геодинамикалық маңызы зор тектоникалық элементтер бөлінген. Олар Шығыс Орал антиклинарий, Денисов аймағы, Валерьянов синклинарий, Солтүстік Торғай ойпаты және Көкшетау-Ұлытау белестері.

Мақалады әр тектоникалық элементтердің толық сипаттамалары белгіленген. Геодинамикалық құрылысын зерттеу нәтижесінде Солтүстік Торғай ойпатында мұнай мен газ кен орындарын іздеуге болашақ бар деген тұжырым жасалған.

Түйін сөздер: шөгінді бассейн, вулкандық дуга, аллахтон, мұнаймengаздылық, геодинамикалық модель.

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ГЕОДИНАМИЧЕСКАЯ МОДЕЛЬ И ПЕРСПЕКТИВЫ НЕФТЕГАЗОНОСНОСТИ СЕВЕРО-ТОРГАЙСКОГО БАССЕЙНА

Аннотация. Исторически сложилось так, что изучением тектонического строения и эволюции и закономерностей размещения полезных ископаемых на обнаженной части Казахстана и по восточному склону Уральских гор занимались разные группы ученных. Вследствие этого признавали, что Торгайский прогиб, разделяющий структуры Восточного и Западного Казахстана, изучен слабо, поэтому на схемах геодинамических реконструкций по Казахстану этот регион остается белым пятном.

По результатам анализа новых геологических и геофизических материалов в статье произведено геодинамическое районирование территории от Уральских гор на западе до Кокшетауского и Улытауского поднятии на востоке. Выделены Восточно-Уральский антиклинорий, Денисовская зона смятия, Валерьяновский синклинорий, Северо-Торгайский прогиб и Кокшетауско-Улытауская зона поднятий.

Даны характеристики каждой тектонической зоны с позиции тектоники плит. Более подробно описано строение Северо-Торгайского осадочного бассейна и с учетом геодинамической его эволюции в девоне и карбоне дана высокая оценка перспектив нефтегазоносности центральной его части по девонским и нижнекарбоновым отложениям.

Ключевые слова: осадочный бассейн, вулканическая дуга, аллахтон, нефтегазоносность, геодинамическая модель.

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DEVELOPMENT OF AN EXPERIMENTAL PLANT OF A NON-NOZZLE POROUS FOAM GENERATOR FOR PRODUCING WITH FOAM GENERATING AND DEFOAMING STRUCTURES

Abstract. On the basis of studies of heat-mass exchange processes by boiling of pure liquids and with the addition of surface-active agents, a new class of non-nozzle porous foam generator for producing of air (steam) and mechanical foam was developed. The results of the experiment are generalized by the criteria equations of heat-mass exchange with an accuracy of ± 20% with respect to the processes of bubbling, foam generation, pseudo-fluidization and boiling. The combined action of capillary and mass forces for capillary-porous structures of the 3x0,4 type made it possible to boost the operating mode of the foam generator by 1,5-2 times and reduce the consumption of the foam generating agent and reduce the hydraulic resistance tenfold. The nozzle-free foam generators of air mechanical foam were designed along with its case, inlet and outlet nozzles, a set of grids and sprayer. They help to conduct foam generation processes with high effectiveness under low hydro-and-gas dynamic resistance. For further enhancement of the combined processes of gas mechanical foam and collecting micro-and-ultramicroscopic dust, a dust collector along with its case, inlet and outlet nozzles, a set of grids and sprayer was proposed, which is equipped with defoaming grid porous structure, whereas foam generating and defoaming structures are installed into in case consequently as per the dusty gas movement and sludge collector. Besides, each subsequent grid of foam generating porous structure is made with the increased size of cells following the cleanable gas; e.g. made of metal cells for clearance 0,08*0,14*1, and defoaming made of grids with decreasing size of cells following the cleanable gas, e.g made of metal cells for clearance 0,4*0,14*0,08.

Key words: porous foam generator, foam generation, foaming, defoaming, heat-mass exchange, capillary-porous structures.

Study of the heat and mass exchange of boiling pure liquids in capillary porous structures, development of control methods for these processes [1] allowed to summarize trials with pure foam and dust-foam flows and study a single equation for calculation of the heat and mass exchange with an accuracy up to ±20 % [2], whereby boiling processes, bubbling, pseudofluizidation and foam generation were summarized as well.

A new class of nozzle-free foam generators and foam-dust catchers along with bubbling capillary porous grids were invented [3], as well as foam generating and defoaming structures located vertically. Due to the controlling internal characteristics of two-phase flows [4] different types of foam-dust catchers were designed [5-13]. It is possible to increase effectiveness of dust-gas catching because of controlling geometry of microchannels of porous material [6], separation of flow into wave energy and gas (steam) energy [7, 11], forming generator with the help of power (without incoming flotation) [8], design of turbulizers as foam generating and defoaming structures using a joint action of gravitation and capillary forces, pressure and vibration forces.

In accordance with the article No.358012, 1972 a method of electrostatic gas cleanup was described where electrization of settling elements was produced using a tribo effect. This effect was used earlier, though during electrization of filter elements they had a conductive layer on their surface, which reduced the electrostatic filtration component. The reviewed method describes that an effectiveness of electrostatic filters will be increased because it is recommended to implement electrization with the help of circulation of weight fine grained electrified agent in hollow settling elements.

Method of electrostatic gas cleanup as per the article No.358012, 1972 in terms of dust settling effectiveness exceeds the known methods. However, in comparison with the known methods, it has a low dust settling productivity.

Therefore, it is possible to increase the effectiveness of dust electrization in air flow by using a tribo effect. Though it requires solving a problem of dust cleanup productivity.

In addition to methods of gas cleanup from dust there is a method /article No. 247241, 1969/, where it is suggested to catch thin aerosol sprays with the help of charging aerosol spray particles when the electrostatic sprayed easily evaporating liquids are settled on them, hence a liquid vapor in a form of condensate will be re-used. Such method has an advantage over the method of dust catching by charging electrostatic sprayed water, because a mutual attraction of dust particles and drops of sprayed water leads to their adhesion and growth of particles along with charge neutralization.

A common disadvantage of electric methods is a minor size and porous structure of formed aggregation of dust particles. Under impaction, they can be easily destroyed. Low effectiveness of dust suppression process could be expected from settling of fine dust. Thus, it is required to develop a dust suppression method, which would allow significantly increase resistance to destruction of formed dust aggregation whilst processing an air dust flow by electric field with retention of high productivity of dust cleanup.

It is interesting to see the air dedusting method using porous blankets /article No. №368413, 1973/. In order to increase an effectiveness of dust catching, a dust flow goes through the parallel blankets that moist liquid. A moving air flow helps to vibrate blankets due to the irregular speeds. Dust particles located in air turbulent flow are being moisturized and coagulated. Fiber is moisturized by water supply to pipe frame where the blankets are fixed.

To achieve a required effectiveness of dust catching, it is necessary to conduct multiple test researches in various mode parameters, as well as to perform new design studies for forming an aerodynamic structure of air dust flow.

There is a dust suppression method based on enriched water steam. With a steam condensate, the area of low pressure is formed where all particles move and could be caught. The disadvantage of such method is its low effectiveness that is caused by unreasonable use of generated steam for the purposes of dust suppression. Besides, to achieve a required norm of dust content large steam resources are required, and that result in unreasonable costs for steam generation.

Similar method to the above-mentioned method is a method (article No.130461), where air dust flow is mixed with steam spray with further settling of steam-dust flow by the sprayed water.

Under such process, it is expected to obtain a low degree of dust catching. Condensate effect will be shown in unstable way, takes probabilistic nature depending on random contact of water sprayed drops with water steam molecules and will be determined by turbulence degree of air dust flow. Dust coagulation effectiveness is expected as minor in conditions of enriching air dust flow by steam. That is why water steam and sprayed water are used unreasonably, and there is increased consumption of steam and water.

When studying a movement of aerosol particles in the steam diffusion field it was evident that the aerosol particles are intensively remote from a cold surface. Aerosols with speed 1 m/s were put through the condenser of 0.5 m long and $5x10^{-3}$ m wide. Metal wall is washed by water with the temperature at condenser inlet 20°C and outlet about minus 70°C. Particle concentration was 1012 particles/m^3. Catching degree varied in large limits 75-95%. Mechanism of the dust suppression process is based on two principles: I) condensate enlargement of aerosol particles like condensation nucleus; 2) directed movement of steam particles mainly towards a cold surface.

Mechanism of the dust suppression process is very complicated, though the main acting factors could be indicated such as Stefan flow of condensed steam as a driving force of aerosol particles. Also, it is enforced by the available diffusion, thermophoretic forces and convective flows, large particles are removed from flow due to the gravitation and centrifugal forces; some particles in air steam flow are minimized because of the coagulation process.

Study of the mechanism of dust suppression in the steam diffusion field requires further development, in particular, it is related to the enhancement of the steam condensation process, steadiness of liquid film distribution, development of new devices for feeding air dust flow by the enriched steam.

Some enhancement of the dust suppression processes could be achieved by additional power sources /article No.1032197, 1983/. It is suggested to charge water steam and dispersed water oppositely, whereas water should be previously magnetized. Steam is injected to a tank with hot mass, which goes through the electric field formed at the steam nozzle outlet. Steam-air-dust flow leaving a tank is condensed at sprayed drops of electrically charged and magnetized water.

Under the weight steam consumption equal to $7x10^{-3}$ kg/f and over, a relative air dust content reaches up to 3-6% and becomes self-simulated in relation to steam consumption. The increase of process effectiveness in the described condensate system of dust suppression occurs 1.5-2 times (probably in relation to condensate system without electric charge of steam, water and magnetization of water). Also, it is unclear how it impacts upon the process of water magnetization, and what contribution of electric charge separately for steam and water is.

The reached effect is explained by the fact that when oppositely electrically charged sprays of water and steam are injected to the dust source due to electric gravity forces between steam molecules and water drops it leads to more enhanced and ordered steam condensation at water drops. At condensate surface, a larger hydrodynamic flotation occurs rather than at non-charged aerosols, which directs to drops that collects dust particles and tends to their catch by drops. Due to that, massive dust particles are settled. Capture rate of dust particles by water drops also is increased due to minimizing forces of the surface tension of electrically charged drops.

The described method of dust suppression has an additional effect on settling dust particles. However, it is achieved by huge efforts as it requires the electric charge of steam, water, water magnetization that significantly complicates a condensate system of dust suppression, and extra costs for establishing electric fields and ensuring electrical safety of manpower.

Therefore, further theoretical and experimental studies of the dust suppression processes should be aimed at new design solutions that are based on the reviewed methods using evaporator-condensing multiphase systems of dust collection and surface-active agents.

Basically, in terms of the existing types of foam generating agents we could hope for the new aerodynamic diagrams and structures, which will determine a behavior of dust suppression process, significantly increasing a cleanup degree of dust flow, and become reliable and easy to fabricate and operate and meet safety requirements whilst operating the equipment [8-13].

Figure 1 demonstrates a new class of nozzle-free foam generator with foam generating capillary porous structure.

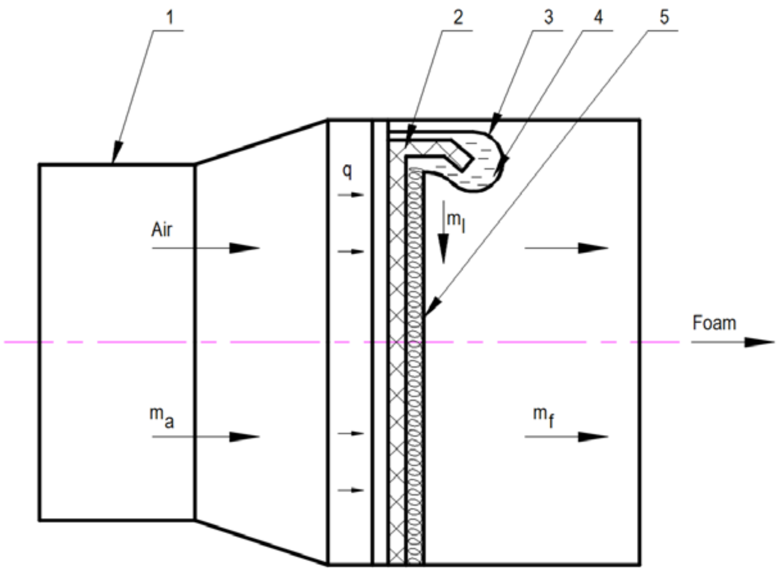

Figure 1 – Nozzle-free capillary porous foam generator of air (steam) mechanical foam:
1 – cylindrical case; 2 – capillary porous structure; 3 – spray device (feeding artery); 4 – foam generating solution;
5 – air (steam) – mechanical foam; ma, ml, ms – consumption of air (steam), liquid (foam generating solution), foam;
q – incoming (foam generating) flow energy density

Figure 2 demonstrates a test facility for research of air (steam) generation processes - mechanical foam.

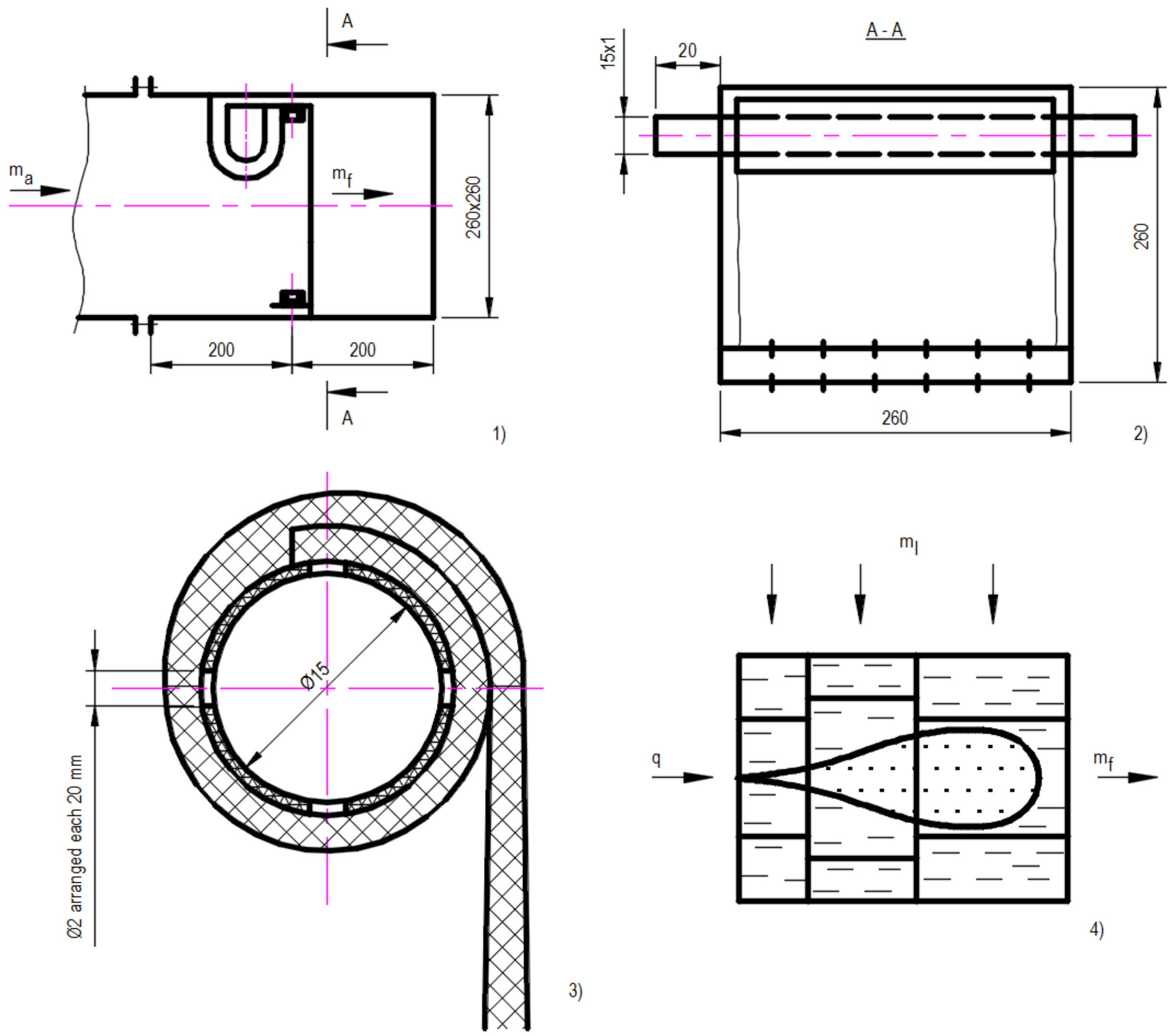

Figure 2 – Test facility for research of foam generation process:
1 – foam generator; 2 – spray device; 3 – connection of capillary porous structure; 4 – bubble dynamics in structure

The combined use of mass and capillary forces ensures the formation of uniform and stable film for distribution of the foam generation solution throughout all capillary porous structure 3x0,4 (three layers of grid where cell width in light is $0,4x10^{-3}$ m). This allows to increase operational mode of foam generator up to 1,5-2 times, reduce consumption of foam forming agent whilst retaining foam stability, dispersion and high expansion rate.

Value of hydraulic resistance will be a few times less because of nozzle unavailability rather than in foam generators GVPV-400 or PGG-4.

Research of heat-mass exchange processes by boiling of pure liquids in capillary porous structures revealed a behavior of the internal (thermal hydraulic) characteristics, generation of vapor phase, density of generation centers, discharge of drops from the structure, bubble departure diameter and frequency of bubble departure, speed of bubble growth [11, 13-16]. The different porous systems were developed applicable to heat and power units [17] and the relevant calculations were performed to verify trial data with accuracy ±20% in a form of criterial equation for bubbling, injection, suction, pseudo fluidization, foam generating [18] and focused on highly effective nozzle-free capillary porous dust-and-gas collectors with foam generating and defoaming structures [3, 6-8, 12].

Let's review a new class of nozzle-free dust-and-gas collectors. Invention called "Dust Collector" [article No.1456608, MKI E21F 5/04, 1989] refer to the different industries of national economy for highly effective gas (air) cleanup from micro-and ultramicroscopic dust (size of fractions less than $5*10^{-6}$ m and $0,25*10^{-6}$ m accordingly), for example, in fuel combustion, processing and transportation of dusty materials, removal of vent emissions.

There is a known device for collecting gases and aerosols [article No.309717, kl.V. OId 47/04, 1971], which contains inlet and gas removal nozzles, case, fiber attachment located in case, gasket and baffle, mist separator.

The disadvantage of this device is its low effectiveness for collecting micro-and ultramicroscopic dust, defined by the size of nozzle pores, that leads to a high material consumption, high hydraulic resistance as per the liquid movements and gas dynamic resistance whilst flushing gas (air).

A short duration of operations between generations due to pore plugging of fiber attachment causes a significant problem. Foam is generated outside of porous body and attacks its surface. That reduces the effectiveness of dust collection and enhancement of the mass transfer process, which increases material consumption, dimensions and weight of the device.

Gas flow penetrating a fiber attachment overcomes a high gas dynamic resistance. It is due to the excess energy and its boosting. Duration of operations between generations of such device will be low because pores in fibers tend to be blocked by dust particles. This leads to the complicated operations of the device, and minimizes its reliability.

In the suggested capillary porous structures of nozzle-free dust-and-gas collector [3, 6-8, 12] a high effectiveness for collecting micro-and ultramicroscopic dust could be explained by diffusion mechanism of dust settling in the foam flow and at the structure surface, when dust particles are under continuous influence of gas molecules, which are in the Brownian movement, whereas mobility of particles will be increased with the help of thermophoresis due to difference of temperature between skeleton of porous structure, foam flow and dust particles on the one hand, and due to diffusiophoresis caused by the gradient of concentrated components of foam flow, enforced with vapor process of foam forming solution within a porous structure and partial steam condensate of foam flow on the other hand.

High resistance and stability of liquid film in cells of grid structures is ensured with an equal injection of the sprayer liquid and allows to reduce a consumption of foam forming solution 1,5 to 2 times retaining the foam stability, dispersion and multiplicity of foam formed in foam generating structure [3, 6-8, 12].

As shown in trials [7, 12] hydraulic resistance of the grid porous structures in comparison with the fiber attachment is reduced a few times, as well as a gas dynamic resistance a few times. Since the suggested porous structures have large cell sizes in comparison with pores of the fiber attachment that tend to increase a duration of grid regeneration, and thus it simplifies operations and enhances the reliability of dust collector and its service life.

It is impossible to organize a stable process in multiphase layer with the help of fiber and filter materials similar to them (metal ceramic, sintered powders) as foam bubbles block nozzle pores and stop access of fresh portions of foam generating liquid to bubble generating pores at loads 2 to 2,5 times less than for the grid structures.

Dust collector operates in the following way as below.

Flow contaminated by dust is injected through the nozzle of dusty gas 1 into dust collector case 2 (figure 3). Gas cleanup from microscopic dust is performed in foam generating porous structure 3 of type 0,08*0,14*1. Gas mechanical foam 10 is blown by gas flow from the structure cells, supplied by foam forming solution 9, for example, 110-12, supplied by sprayer 4.

Porous structure in comparison with isotropic structure helps significantly enhance mass exchange processes flown in their volume and on the surface because of simplified growth of bubbles 8 from top of the cone to its base, that increases coagulative feature of foam. Therefore, enhancement of processes leads to higher effectiveness of catching microscopic dust due to raising rate of catching dust by foam in the volume of structure and on its surface.

Gas mechanical foam 10 will be destroyed from the surface and in the volume of defoaming porous structure 5 of type 0,4*0,14*0,08. Foam bubbles 11 start intensively burst in structure due to the growth of resistance from the cone base to its top. Microscopic dust contained in destructive gas mechanical foam under influence of gravity and pressure leaking from sprayer along the porous surface moves towards sludge collector 7.

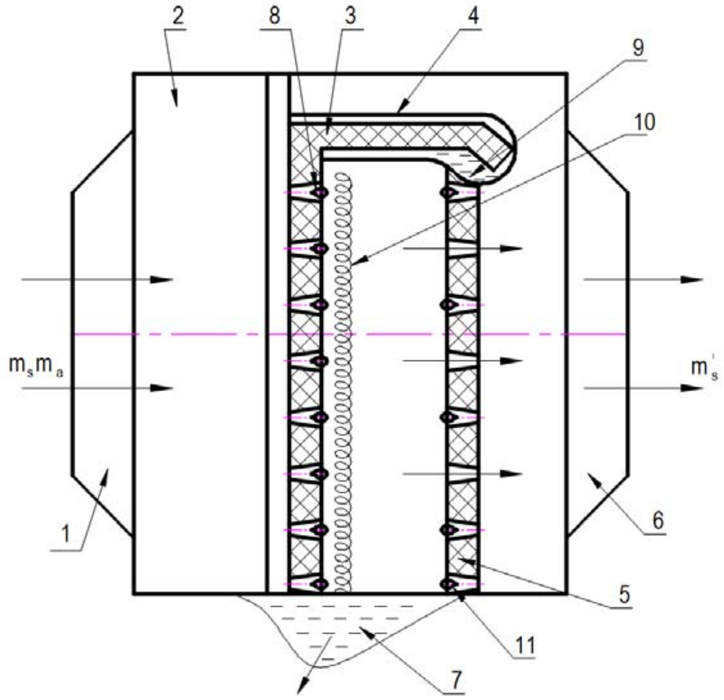

Figure 3 – Nozzle-free capillary porous dust collector with foam generating 3 and defoaming 5 structures:
1 – inlet nozzle; 2 – dust collector case; 3 – foam generating porous structure; 4 – sprayer; 5 – defoaming porous structure;
6 – outlet nozzle; 7 – sludge collector; 8 – bubble; 9 – defoaming porous structure; 10 – gas mechanical foam;
11 – foam bubbles; mf, ma, m^I_s, – consumption of foam, air (steam)

Gas will be additionally cleaned up from microscopic dust in defoaming structure where the destructive process of gas mechanical foam is significantly enhanced because grids are collected with minimized cell sizes.

This results in increasing effectiveness of collecting microscopic dust on its surface and in volume due to raising rate of catching dust and increases coagulative feature of the destructive foam flow.

Gas cleaned up from the microscopic dust is removed from the device through the outlet nozzle of clean gas 6.

Test demonstrated [8, 12] that in comparison with the filtering materials such as metal ceramic and sintered powders, consumption of form forming solution is reduced 1,5 to 2 times retaining the foam stability, dispersion and multiplicity of foam, hydraulic resistance for transportation of foam forming liquid is reduced 10 to 20 times, gas dynamic resistance 1,8 times that minimizes pump and fan (smoke exhauster) capacity, material consumption and dimensions 2 to 2,5 times, weight of device 3 to 4 times.

Time between regeneration significantly increases, as well as the effectiveness of catching microscopic dust, which could reach values up to 99,6-99,8%, thus it simplifies operations and enhances reliability of dust collector and its service life, which is proved by relevant acts of Trust Alma-AtaInzhstroi and Almaty Heat & Power Plant-2.

Cost of implementing the suggested dust collector will be saved because of reduced consumption of foam forming solution 1,5 to 2 times, minimized hydraulic resistance for transportation of foam forming liquid up to 10 to 20 times, gas dynamic resistance for pumping of dusty flow up to 1,8 times, material consumption and dimensions up to 2 to 2,5 times, weight of device 3 to 4 times. Also the device operations are getting simplified, duration between regenerations increases, and thus it enhances reliability and service life of the device, which saves capital and operational costs.

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КӨБІК ӨНДІРЕТІН ЖӘНЕ КӨБІК СӨНДІРЕТІН ҚҰРЛЫМДАРЫ БАР АУА (БУ)-МЕХАНИКАЛЫҚ КӨБІКТІҢ БҮРІККІШСІЗ КЕУЕК КӨБІК ГЕНЕРАТОРЫНЫҢ ЭКСПЕРИМЕНТТІК ҚОНДЫРҒЫСЫН ӘЗІРЛЕУ

Аннотация. Таза сұйықтықтарды қайнатумен және қабатты-белсенді заттарды қосумен жылу-салмақ алмастырғыш үдерісті зерттеу негізінде ауа(бу)-механикалық көпірікті бүріккішсіз капиллярлы-борқылдақ көпірік генераторларының жаңа класы әзірленді. Эксперимент нәтижелерін жылыну мен масса тасымалының критикалық теңдеулеріне көбік, поролон жасау, псевдоожолдау және қайнау процестеріне қатысты ±20% дәлдікпен қорытылады. Капиллярлы-бұрқылдақ құрылымдар үшін 3х0,4 түріндегі капиллярлы және салмақты бірыңғай әрекеттер көпірік генераторының жұмыс режимін 1,5-2 есе тездетуге, көпірік қалыптастырушының шығындарын қысқартуға және гидравликалық қақтығысты он есе азайтуға мүмкіндік берді. Корпус, кіру және шығу келте құбырлары, торшалар топтамасы, тозаңдатқыштан тұратын ауа-механикалық көбікке арналған бүркігішсіз көбік генераторлары әзірленді. Олар аз гидро және газдинамикалық қарсылықтарда жоғары тиімділікпен көбік өндіру процестерін жүргізуге мүмкіндік береді. Газ-механикалық көбікті өндіру мен микро және ультрамикроскопиялық тозаңды тұту бірлескен процестерін әрі қарай сәйкестендіру үшін көбік сөндіретін торкөзді кеуекті құрылыммен және қақ жинағышпен жабдықталған корпус, кіру және шығу келте құбырлары, торшалар топтамасы, тозаңдатқыштан тұратын тозаң тұтқыш ұсынылды, бұл ретте көбік өндіретін және көбік сөндіретін құрылымдар корпусқа тозаңдатылған газ қозғылысының бағытын бойлай орнатылды. Бұдан өзге, көбік өндіретін торкөзді кеуекті құрылымның кейінгі торшасы тазартылатын газдың қозғалыс бағыты бойымен ұяшықтардың ұлғаятын өлшемімен, мысалы, саңылауға ұяшықтарының өлшемі:

0,08*0,14*1 болатын метал торлардан, ал көбік сөндіретін торша - тазартылатын газдың қозғалыс бағыты бойымен ұяшықтардың кішірейетін өлшемімен, мысалы, саңылауға ұяшықтарының өлшемі: 0,4*0,14*0,08 болатын метал торлардан орындалды.

Түйін сөздер: борқылдақ көпірік генераторы, көпірік генерациясы, жылу салмақ алмастырғыш, капиллярлы-борқылдақ құрылымдар.

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РАЗРАБОТКА ЭКСПЕРИМЕНТАЛЬНОЙ УСТАНОВКИ БЕЗФОРСУНОЧНОГО ПОРИСТОГО ПЕНОГЕНЕРАТОРА ВОЗДУШНО(ПАРО)-МЕХАНИЧЕСКОЙ ПЕНЫ С ПЕНОГЕНЕРИРУЮЩИМИ И ПЕНОГАСЯЩИМИ СТРУКТУРАМИ

Аннотация. На основе исследований процессов тепло-массообмена кипением чистых, жидкостей и с добавкой поверхностно-активных веществ разработан новый класс безфорсуночных капиллярно-пористых пеногенераторов воздушно(паро)-механической пены. Результаты эксперимента обобщаются критеристыми уравнениями тепло- и массообмена с точностью ±20% применительно к процессам барботажа, пеногенерации, пвсевдоожижения и кипения. Совместное действие капиллярных и массовых сил для капиллярно-пористых структур вида 3х0,4 позволило форсировать в 1,5-2 раза режим работы пеногенератора, сократить расход пенообразователя и в десятки раз уменьшить гидравлическое сопротивление. Разработаны безфорсуночные пеногенераторы воздушно-механической пены, содержащий корпус, входной и выходной патрубки, пакет сеток, распылитель. Они позволяют проводить процессы генерации пены с высокой эффективностью при малых гидро- и газодинамических сопротивлениях. Для дальнейшей интенсификации совместных процессов генерации газомеханической пены и улавливания микро- и ультрамикроскопической пыли предложен пылеуловитель, содержащий корпус, выходной и выходной патрубки, пакет сеток, распылитель, который снабжен пеногасящей сетчатой пористой структурой, причем пеногенерирующая и пеногасящая структуры установлены в корпусе последовательно по ходу движения запыленного газа, и щламосборником. Кроме того, каждая последующая сетка пеногенерирующей сетчатой пористой структуры выполнена с увеличивающимся размером ячеек по ходу движения очищаемого газа, например, из металлических с размером ячеек на просвет: 0,08*0,14*1, а пеногасящая – из сеток с уменьшающимся размером ячеек по ходу движения очищаемого газа, например, из металлических с размером ячеек на просвет: 0,4*0,14*0,08.

Ключевые слова: пористый пеногенератор, пеногенерация, пенообразование, пеногашение, тепломассообмен, капиллярно-пористые структуры.

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EXTRACTION OF RARE-EARTH ELEMENTS FROM THE COMPOSITION OF KARATAU PHOSPHORITES

Abstract. Karatau phosphorite concentrate is a perspective and unique raw material for complex processing, which allows to obtain strontium, rare earth metal and fluorine compounds along with the main product - phosphorus fertilizers. In spite of the obvious ecological expediency of complex processing of phosphorite, actually, there is the only industrial scheme involving associated extraction of rare-earth elements, strontium and the utilization of fluorine, based on the decomposition of phosphorite with nitric acid.

This article presents the results of a study of the decomposition of the Karatau phosphorites (Kokzhon and Koksu deposits) with hydrochloric and nitric acids in a ratio of 1: 1, with an increase in temperature to 85-90 °C, for 30 minutes with vigorous stirring. The chemical composition of the products obtained was determined by titrimetric, gravimetric, photocolorimetric, potentiometric methods.

Analysis of the samples showed that the mass fraction of rare-earth elements in the concentrate obtained by extraction with nitric acid was 27%, hydrochloric acid - 36% and the extraction rate of rare-earth elements with respect to their content in phosphorite was 75%. It is possible to obtain 20-36 kg of rare-earth metal concentrate in the processing of 1 ton of phosphorite

Key words: rare earth elements, extraction, phosphorites, decomposition, concentrate.

Introduction. Rare-earth metals are one of the most scarce and demanded types of mineral raw materials, since they are used in various areas, including radio electronics, engineering, nuclear industry, chemical sector, defense industry, etc., and the global demand for them multiple exceeds the market offer [1-4, 13]. The production of rare and rare-earth metals is a promising area of industrial-innovative development of Kazakhstan aimed at creating high-tech industries.

Karatau phosphorite concentrate is a promising and unique raw material for complex processing, which allows to obtain compounds of strontium, rare earth elements and fluorine along with the main product - phosphorus fertilizers [5, 6]. In spite of the obvious ecological expediency of complex processing of phosphorite, actually, there is the only industrial scheme involving the associated extraction of rare-earth elements, strontium and utilization of fluorine, based on the decomposition of phosphorite with nitric acid [7].

The aim of this work is to develop an efficient method for extracting rare-earth elements from the Karatau phosphorites.

Methods. According to the physicochemical properties of Kokzhon, Koksu phosphorite flour (standard grinding, moisture content 0.1-0.3%) has a bulk density (t/per m^3): 1.10-1.20 on the conveyor, 1.45-1.50 when freshly poured in railway carriage, up to 1.6 after transportation by railway and 1.8-2.0 after a long-term storage in the warehouse. Dry Kokzhon, Koksu phosphorite flour is very fluid, flows like a liquid at an angle of 15-20°. Being humidified to 0.75-1.5% flour loses fluidity and is capable of caking.

The isolation of rare-earth elements from phosphate concentrate obtained by processing of phosphorites from Kokzhon and Koksu deposits has been investigated.

Prior to the beginning of the main studies, X-ray diffractometric analysis of chemical composition of the initial phosphorite has been carried out on the automatic diffractometer DRON-3 with $Cu_{K\alpha}$ radiation, β-filter. Conditions for shooting diffraction patterns: U = 35 kV; I = 20 mA; shooting θ-2θ; detector 2 gr/min. X-ray phase analysis on a semi-quantitative basis was performed on the diffraction patterns of powder samples using the method of equal weights and artificial mixtures. Quantitative ratios of crystalline phases were determined. Interpretation of the diffractograms was carried out using the ICDD file data: powder diffractometry database PDF2 (Powder Diffraction File) and diffractograms of pure minerals.

The essence of the method lies in the fact that the residual solid phase is subjected to secondary decomposition. 1 kg of the phosphate rare earth concentrates and 200 g of finely ground secondary pulp were fed to the reactor. 3.0 liters of 2N nitric acid were added to this mass. The isolation was carried out by heating in 2 N nitric acid (sample №1), in 2 N hydrochloric acid (sample №2) at solid-liquid ratio of 1: 2.5-3.5 in the presence of oxalic acid (50 wt. % excess above stoichiometry when converted to oxides of rare earth elements). The precipitate of oxalates was separated by filtration, washed with water and calcined [8-12].

1.0 ml of the liquid phase was diluted with distilled water in a volumetric flask of 100 ml. 5-10 ml aliquots were taken for chemical and physico-chemical composition analysis: for determination of total nitrogen, sodium nitrite and P_2O_5, calcium and magnesium oxide, iron, aluminum, chlorine and etc. The solid phase had been first dried at room temperature, then in an oven at a temperature of 80-850 °C and the mass fraction of moisture was determined.

Two different samples were tested (decomposition of phosphorites with 2 N nitric acid and decom-position of phosphorites with 2N hydrochloric acid). 10 ml of concentrate were poured into a 100 ml flask, then diluted with distilled water and mixed thoroughly. An aliquot of the solution obtained was analyzed by atomic emission spectroscopy on Agilent 4200 MP-AES [8].

Then it was reanalyzed by atomic-emission spectroscopy on a DFS-13 diffraction spectrograph with a grating of 500 strokes per mm and a linear dispersion of 0.4 nm/mm, manufactured in Russia. Excitation of the spectra was carried out in an electric arc at current strength 14 A, detection of spectra in the ultraviolet region 230-345 nm was carried out on PFS-03 photographic plates which are sensitive in this wavelength interval. GSO 8670-2005 (SGD-2A), GSO 3484-86 (SGXM-2) were used as reference samp-les. The research was carried out in the K. I. Satpayev Scientific Research Institute of Geological Sciences in Almaty.

Results and discussion. The Karatau phosphorite contains up to 5-7% of the rare-earth elements 70% of which are transferred to a precipitate of calcium sulfate during sulfuric acid decomposition. Along with rare-earth elements, the precipitate contains small amounts of fluoride and phosphate ions. The resulting sediment is a waste of the of mineral fertilizer production [14-20], called "phosphogypsum", and forms gigantic mountains around the plants for processing of Karatau phosphorites (Taraz city).

Table 1 – Results of semi-quantitative X-ray phase analysis of crystalline phases of the original phosphorite.

Mineral	Formula	Concentration, %
Gypsum	$Ca(SO_4)(H_2O)_2$	43.5
Quartz	SiO_2	33.8
Bassanite	$CaSO_4 \cdot 0.5H_2O$	19.8
Mica	$KAl_2(AlSi_3O_{10})(OH)_2$	2.9

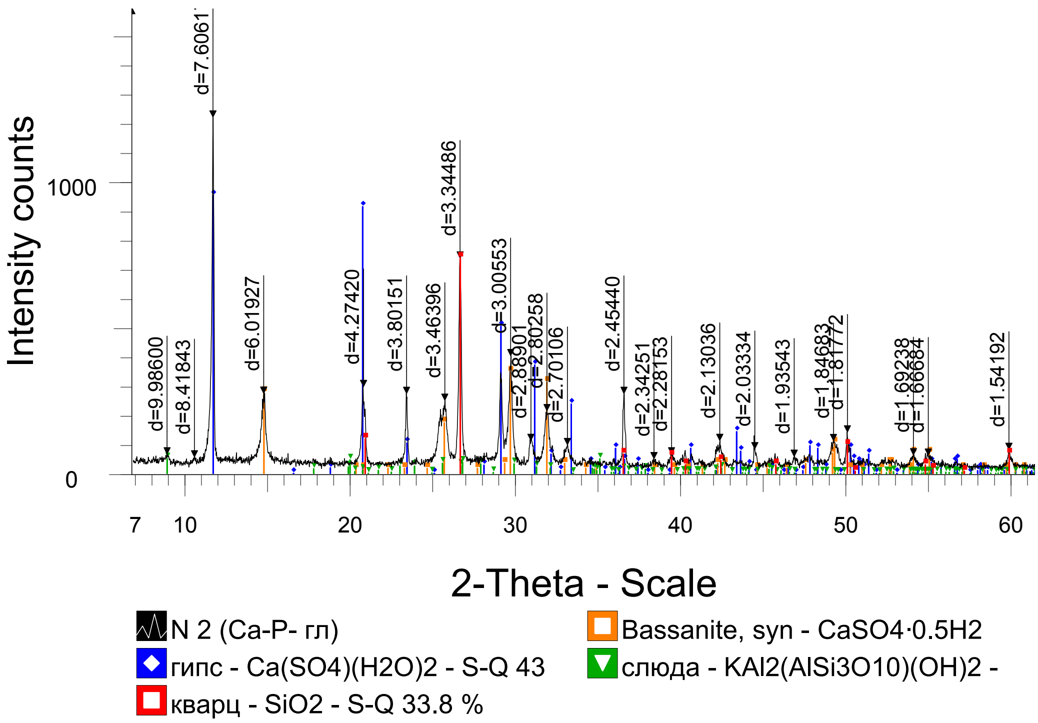

Figure 1 – Diffractogram of a sample of initial phosphorite (Ca-P-clay)

Table 2 – Determination of rare-earth element content in the Karatau phosphorite
by atomic emission spectroscopy (Agilent 4200 MP-AES)

#	Sample	Label element, nm	Concentration	Unit	SD	%, RSD
1	Sample№1. Decomposition of phosphorites 2 $nHNO_3$	Se (196,026)	0,27	Ppm	0,08	29,76
		Zn (213,857)	0,15		0,00	1,68
		Cd (228,802)	0,00		0,00	>100
		Sr (407,771)	8,19		0,03	0,42
		Ba (455,403)	1,48		0,00	0,20
		Cu (324,754)	0,06		0,00	0,48
		Ni (352,454)	0,31		0,00	0,61
		As (193,695)	0,73		0,22	29,81
		Co (340,512)	0,53		0,01	1,06
		Pb (405,781)	-0,12 mu		0,00	1,75
		Mo(379,825)	0,08		0,00	1,05
		Mn(403,076)	17,73 o		0,05	0,29
		Cr (425,433)	0,27		0,01	2,47
		Al (396,152)	13,70 o		0,79	5,78
2	Sample№2. Decomposition of phosphorites 2 nHCl	Se (196,026)	-0,28 u		0,12	43,27
		Zn (213,857)	0,25		0,00	0,83
		Cd (228,802)	0,00		0,00	>100,00
		Sr (407,771)	10,28		0,05	0,49
		Ba (455,403)	0,36		0,00	0,19
		Cu (324,754)	0,12		0,00	0,23
		Ni (352,454)	0,23		0,00	0,60
		As (193,695)	0,75		0,35	46,98
		Co (340,512)	-0,02u		0,00	5,48
		Pb (405,781)	-0,27 mv		0,01	2,24
		Mo(379,825)	0,05		0,00	4,17
		Mn(403,076)	20,44		0,03	0,14
		Cr (425,433)	0,43		0,04	9,69
		Al (396,152)	73,34 o		5,64	7,69

The data presented in the table prove that the highest efficiency in the decomposition of phosphorites with mineral acids is achieved when hydrochloric acid is used (2N HCl). For example Se - 43.27 against 29.76 with nitric acid; As -46.98 vs. 29.81; Cr - 9.69 vs. 2.47, etc.

Table 3 – Summary data on the chemical analysis of secondary concentrates of Karatau phosphorites, decomposed in nitric and hydrochloric acid

#	Content of mass fraction, %													
	Moist.	P_2O_5	Cl^-	C_2H_2	SO_4^{2-}	F^-	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	Tot. nitrogen	$NaNO_2$	NO_3^-
2 n HNO_3 (liquid phase)	–	1,9	7,92	0,0112	2,06	0,77	20,9	0,145	0,014	0,03	0,0 02	4,23	2,07	17,4
2 n HNO_3 (solid phase)	9,17	0,13	2,64	0,114	2,06	1,52	11,4	0,0207	0,014	0,02	0,06	1,29	1,93	0,02
Summary, %	–	2,03	10,52	0,1252	4,12	2,29	32,3	0,1657	0,028	0,05	0,062	5,52	4,00	17,42
2 n HNO_3 (liquid phase)	–	0,8	61,8	0,0082	2,06	0,42	23,46	0,103	0,028	0,03	0,003	1,53	2,06	–
2 n HNO_3 (solid phase)	8,28	0,5	7,92	0,152	2,26	1,615	22,83	0,014	0,014	0,01	0,06	2,23	2,08	–
Summary, %	–	1,3	69,72	0,1602	4,32	2,035	46,29	0,117	0,042	0,04	0,063	3,76	4,14	–

It can be seen (table 3) that after secondary decomposition of pulp, it still contains valuable elements, which can be used as fertilizers.

Samples of secondary concentrates of Karatau phosphorites, decomposed in nitric and hydrochloric acids, were studied by IR spectroscopic method. In figure 2, weakly pronounced bands characteristic of phosphoric acid with frequencies of 2319 cm^{-1} and medium pronounced bands characteristic of nitrate ions with frequencies of 694 cm^{-1}, 729 cm^{-1}, 879 cm^{-1} are observed.

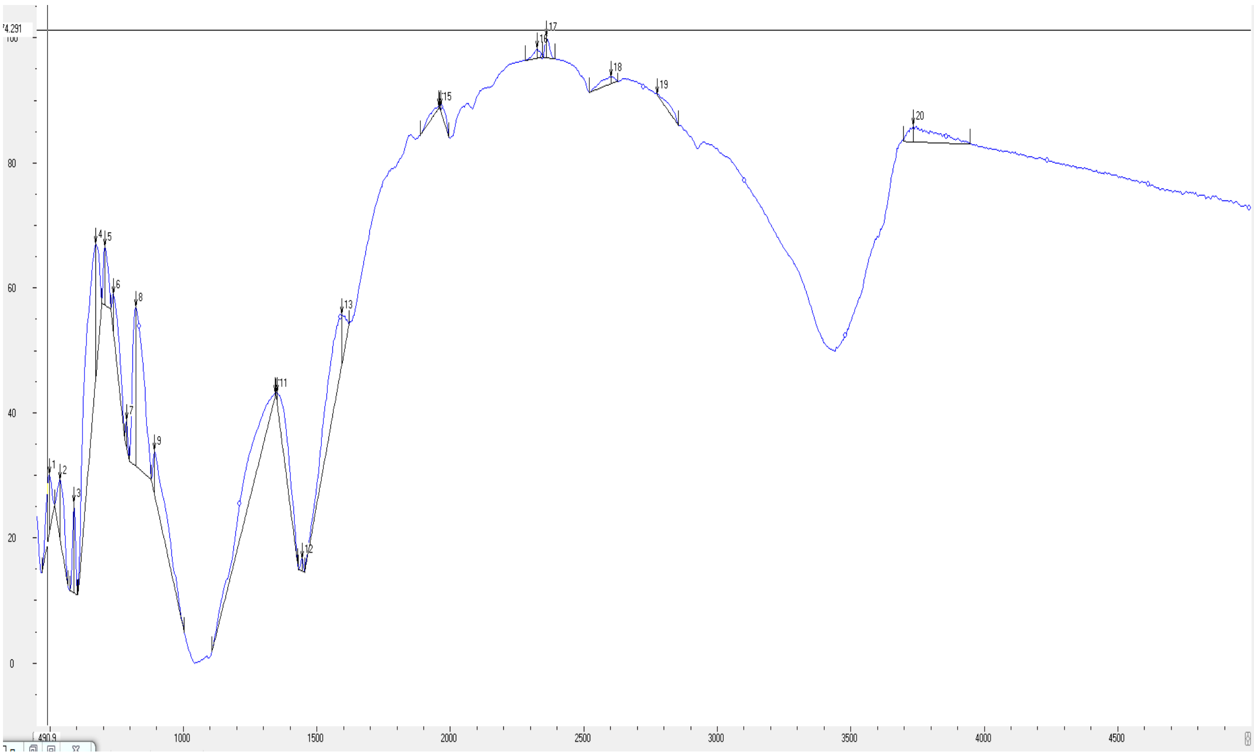

Figure 2 – IR spectra of solutions obtained by decomposition of Karatau phosphorites with nitric acid. The abscissa axis is the oscillation frequency (cm^{-1}), the ordinate – transmission (%)

The IR spectra of solutions obtained by decomposition of Karatau phosphorites with hydrochloric acid (figure 3) show medium-pronounced bands characteristic of phosphoric acid with frequencies of 2144 cm^{-1}, 2403 cm^{-1}, as well as weakly pronounced bands of 2673 cm^{-1}, corresponding to phosphoric acid.

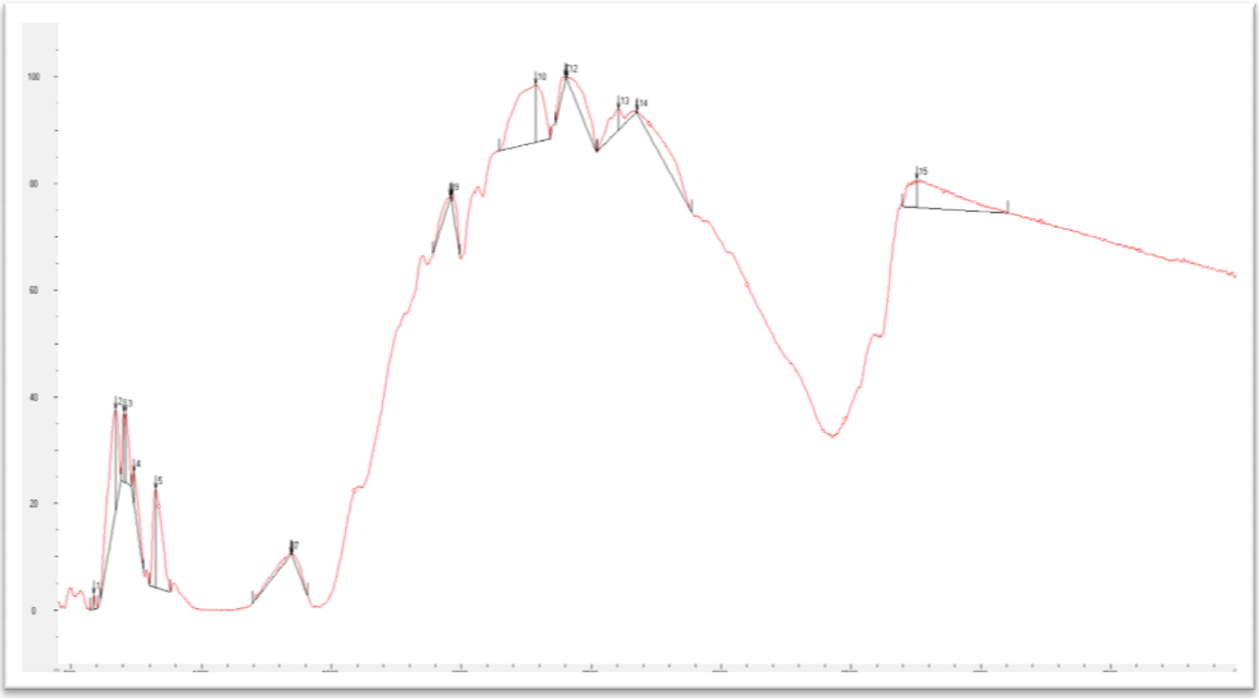

Figure 3 – IR spectra of solutions obtained by decomposition of Karatau phosphorites with hydrochloric acid.
The abscissa axis is the oscillation frequency (cm^{-1}), the ordinate axis is the transmission (%)

The results of chemical and physicochemical analysis of the liquid and solid phases of products, obtained by decomposition of Karatau phosphorites with nitric and hydrochloric acids, confirm and supplement each other and show that the main products are phosphates, nitrates and calcium chlorides. The product also contains rare-earth elements with a mass fraction of 23-36% with respect to the initial content in phosphorite.

Conclusions. The results of chemical composition study of Karatauphosphorite include rare-earth elements within Se - 23,0-29,76%, Zn - 0,5-1,68%, Sr - 0,42-2,0%, Ba - 0.20-2.8%, Cu - 0.48-3.6%, Ni - 0.61-0.75%, As - 29.81-32.0%, Co - 1.06-2,10%, Pb - 1.75-2.0%, Mo - 0.8-1.05%, Mn - 0.29-0.35%, Cr - 2.47-3.8%, Al - 5.78-7.9% Y-(yttrium) - 0.007-0.15%, Yb-(ytterbium) - 0.005-0.7%, La-(lanthanum) - 0.025-0.15%, Ce-(cerium) - 0.05-0.30%, Gd- (gadolinium) - 0.002%, Nd-(neodymium) - 0.04-0.05%, Sm-(samarium) - 0.01%, Eu-(europium) - 0.001%, Tb-(terbium) - 0.005%, Dy-(dysprosium) - 0.01%, No- (golya) - 0.001%, Er-(erbium) - 0.01%, Lu-(Lutetium) - 0.001%, Tm-(thulium) -0.0001-0.10%, Pr-(praseodymium) - 0.02%, etc.

The initial Karatauphosphorites contain 23.23% of the sum of rare-earth elements (in terms of oxides), the content of the mass fraction of% CaO, P_2O_5, and also the compounds of iron and aluminum. When processing 1 ton of phosphorite obtaining of about 20-36 kg of the sum of rare-earth element concentrate is possible. The mass fraction of rare-earth elements for decomposition with hydrochloric acid is 36%, and with nitric acid is 27%. The recovery of REE in the concentrate is ~ 75% with respect to the initial content in phosphorite.

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ҚАРАТАУ ФОСФОРИТТЕРДІҢ ҚҰРАМЫНАН СИРЕК-ЖЕР ЭЛЕМЕНТТЕРДІ БӨЛІП АЛУ

Аннотация. Қаратау фосфорит концентраты – кешенді қайта өңдеуге қажетті перспективалық және бірегей шикізат, одан фосфорлы тыңайтқыш сияқты негізгі өнімнен басқа, стронцийдың қосылыстары, сирек жер элементтерін және фторды алуға мүмкіндіктері бар. Фосфоритті кешенді қайта өңдеудің айқын экологиялық негіздемесіне қарамастан, қазіргі уақытта сирек жер элементтерін, стронцийды және фторды жолай бөліп алу үшін жалғыз өндірістік сызбасы бар, ол фосфоритті азот қышқылымен ыдыратуға негізделген.

Бұл мақалада Қаратау (Көкжон, Көксу кен орындары) фосфориттерін тұз және азот қышқылдарымен ыдыратуын ара-қатынасы 1:1, температураны 85-90^{0}С дейін жоғарылатқанда, 30 минут аралығында қарқынды түрде араластыру арқылы зерттеу нәтижелері келтірілген. Алынған өнімдердің химиялық құрамы титриметриялық, гравиметриялық, фотоколориметриялық, потенциометриялық әдістермен анықталды.

Алынған нысандардың талдауы бойынша концентраттағы сирек жер элементтерінің массалық үлесі азот қышқылымен бөліп алғанда 27%, ал тұз қышқылымен 36% құрады, сирек жер элементтерін концентраттан бөліп алу ~ 75% фосфориттің құрамындағы қатынасына қарай 1 тонна фосфоритті қайта өңдеу барысында 20-36 кг сирек жер элементтерінің концентрат сомасын алуға мүмкіндігі бар.

Түйін сөздер: сирек жер элементтері, бөліп алу, ыдырату, концентрат.

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ИЗВЛЕЧЕНИЕ РЕДКОЗЕМЕЛЬНЫХ ЭЛЕМЕНТОВ ИЗ СОСТАВА ФОСФОРИТОВ КАРАТАУ

Аннотация. Каратауский фосфоритовый концентрат – перспективное и уникальное сырье для комплексной переработки, позволяющее получить, помимо основного продукта – фосфорных удобрений, соединения стронция, редкоземельных элементов и фтора. Несмотря на явную экологическую целесообразность комплексной переработки фосфорита, в настоящее время существует единственная промышленная схема, предусматривающая попутное извлечение редкоземельных элементов, стронция и утилизацию фтора, основанная на разложении фосфорита азотной кислотой.

В данной статье представлены результаты исследования разложения фосфоритов Каратау (месторождения Кокжон и Коксу) соляной и азотной кислотами в соотношении 1:1, при повышении температуры до 85-90 °С, в течение 30 минут с интенсивным перемешиванием. Химический состав полученных продуктов определяли титриметрическим, гравиметрическим, фотоколориметрическим, потенциометрическим методами.

Анализ полученных образцов показал, что массовая доля редкоземельных элементов в концентрате при извлечении азотной кислотой составила 27%, соляной кислотой – 36%, извлечение редкоземельных элементов в концентрат ~ 75 % по отношению к содержанию в фосфорите. Существует возможность получения 20-36 кг суммы концентрата редкоземельных элементов при переработке 1 т фосфорита.

Ключевые слова: редкоземельные элементы, извлечение, фосфориты, разложение, концентрат.

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GOLD FINENESS AS INDICATOR OF PHYSICAL-CHEMICAL CONDITIONS OF MINERALIZATION AT THE KOKKIYA GOLD DEPOSIT (KYRGYZ RIDGE)

Abstract. The article describes the results of microscopic studies of ores at the Kokkiya deposit. The mineral composition of deposit's ore is determined with the identification of main, secondary and rare minerals. Fineness of gold is determined, the variability of which is determined by depth, as well as the processes of mineral formation from early associations to late ones. The fineness of native gold is accepted as a typomorphic sign by many scientists of the world and indicating the physical-chemical conditions for the formation of gold deposits. Founding rare microminerals also carry basic information about the physical-chemical conditions of ore deposition. Causal relationships between the composition of minerals and the characteristics of mineral-forming processes are revealed, which is the most important task of genetic mineralogy. It is equally important in practical terms for the development of mineralogical forecasting and evaluation criteria.

Key words: gold probability, pyrite, tellurides, gold-concentrating minerals.

Introduction. The Kokkiya deposit is located on the northern slopes of the Kyrgyz Ridge, within the Kyrgyz-TerskeiMineragenetic Zone. This zone includes six gold-ore formations in the territory of Kazakhstan: gold-quartz-vein; gold-sulphide-quartz; gold-sulphide-skarn; gold-sulphide-quartz-berezitic; gold-quartz-propylitic and gold-bearing placers.

The Kokkiya deposit is associated with the gold-quartz-propylitic formation and is confined to the rocks of the Devonian volcanic-plutonic association (andesites, rhyolites, and their lava-breccias). Their spatial distribution is controlled by tectonic dislocation and small intrusions of syenites, syenite-diorites, monzogranodiorites of the Middle Devonian intrusive complex. As a whole, it has a linear-nodal pattern. Mineralization is confined to lavas and lava-breccias of the Taldysusubvolcanic complex of rhyolite composition. These zones are overlaid with zones of hydrothermal-metasomatic alterations and veined silicification.

The Kokkiya field is divided into two sections: Kokkiya block and Yuzhnyi block, they located in one metasomatic zone. Genetically, these are the same types of ores, but are spatially separated by 2 km.

The northern part of the Kokkiya deposit is located in the zone of intensive hydrothermal alteration. Area of deposit is broken into numerous blocks by faults. Faults strike is very diverse. The distribution of gold mineralization in the deposit is immense complexity. Isolation of ore bodies within the outer homogeneous zone of quartz-sericite metasomatites is possible only by analysis of samples. Ore bodies are separate out by the cut-off grade 0.3 g/t. The shape of the bodies is linearly extended in the north-east direction. The dip of main ore zones is south-west at angles of 65-75°. The thickness of ore bodies varies from 0.5 to 60 m in the wells, in ditches from 1 to 22 m, with an average thickness of 5-6 m.

The following vertical metasomatic zoning is planned on the ore field of the Kokkiya deposit: the elevated parts of relief form secondary quartzites, and propylitized rocks bed beneath them. Sericite facies are most fully and widely manifested here. The amount of quartz and sericite is variable in the rock. Transition to monomineralic quartz rocks (monoquartzite) is observed with a decrease in the amount of sericite. As amount of sericite increases, which is typical for ore bodies, secondary quartzites transform into sericite-pyrite rocks (sericitolites). Sericite which is an essential constituent of quartzites, often partially transforms into hydromica and is associated with montmorillonite. Metasomatic and vein silicification, chloritization and carbonatizationare superposed on the sericite facies. Quartz veins contain chlorite, ferrous carbonate, dolomite, carbonate and carry polymetallic mineralization in association with gold.

Microscopic studies have allowed to separate out the following zonal facies from the periphery to the center: 1) propylitic, combining strongly chloritized, sericitized, albitized, kalishipatized, carbonatized and pyritized rocks; 2) kaolinite; 3) sericite; 4) diaspor; 5) monoquartz [1, 2].

Gold-pyrite mineralization tends to the sericite facies. The wide development of the sericite facies in the section created favorable prerequisites for manifestation of gold-silver mineralization. The monoquartz facies develops within the sericite facies, where it forms short lenses or nodular concretions. The thickness of lenses does not exceed the first meters, and the extension is not more than first tens of meters. Strong monoquartzite rocks carry an equal impregnation of pyrite and are released in the relief by positive forms.

The main gold-concentrating minerals are pyrite, quartz, sericite. Native gold is a valuable component. A number of ore minerals that determine the geochemical specificity of ore formation at the deposit are referred to minor and minor rare occurrences (table 1). Among the rare, special should be mention tellurides: gold (calaverite), bismuth (tsumoite), gold and silver (petzite).

Table 1 – Mineral composition of ores of the Kokkiya deposit

Mainminerals	Secondary and seldom met minerals	Valuableandraremicrominerals
Oreminerals		
Pyrite (somegeneration)	Chalcopyrite, Galenite, Sphalerite, Pyrrhotite, Tetrahedrite, Tennatite, Goldfieldite*, Rutil, Ilmenite, Cassiterite, Magnetite, Hematite, Molybdenite, Scheelite, Arsenopyrite, Jarosite*, Covellite, Goethite, Hydrohematite, Leucoxene	Gold, Calaverite, Tsumoite*, Petzite*, Altaite Bismuthite*, Tellurobismuthite, Native Tellurium, Mawsonite?*
Non-metallicminerals:		
Quartz Sericite	Pyrophyllite, Calcite, Chlorite, Muscovite, Barite, Kaolinite, Montmorillonite	Zircon, Monacite, Crandallite *, Hornblende, Sphene, Zunyite, Albite, K-feldspar
*Minerals established to study the technological sample of primary ore of the Kokkiya deposit.		

According to the results of microscopic studies, the most common quartz-sericite metasomatites are pyritized to a varying degree, down to sericitolites. Chlorite-quartz-sericite metasomatites are very rare. Sericitolites are most enriched with native gold among them. Visually, they are differed by the presence of spots or pyrite veinlets of light yellowish color in the mass of sericitolite, which can transform into densely impregnated pyritic ore. Spots or pyrite veinlet are thickness up to 2.5 cm. Metasomatites are silicificated in various degrees and partly carbonatized.

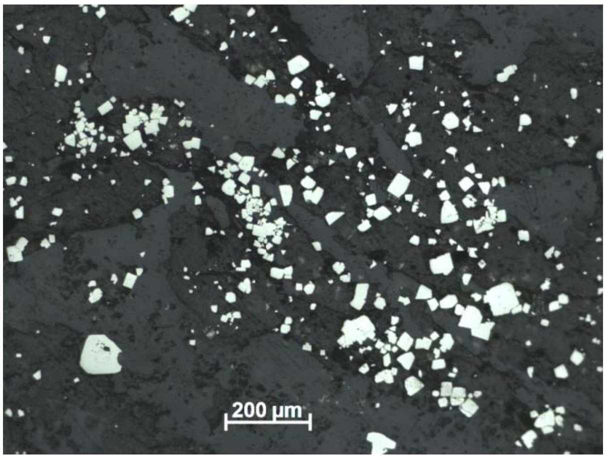
Pyrite - is the main ore mineral. It forms scattered impregnation in metasomatites, from rare to dense. It occurs in the form of nests and lenticular secretions up to 1-2 cm in size. Pyrite is represented by several generations.

Pyrite I **-** cubic form in the form of fine scattered impregnation (from 0.01 to 0.05 mm and sometimes up to 0.1 mm) in a mass of chlorite-quartz-sericite metasomatite of dark green color, confined to chlorite and sericite (figure 1/1).

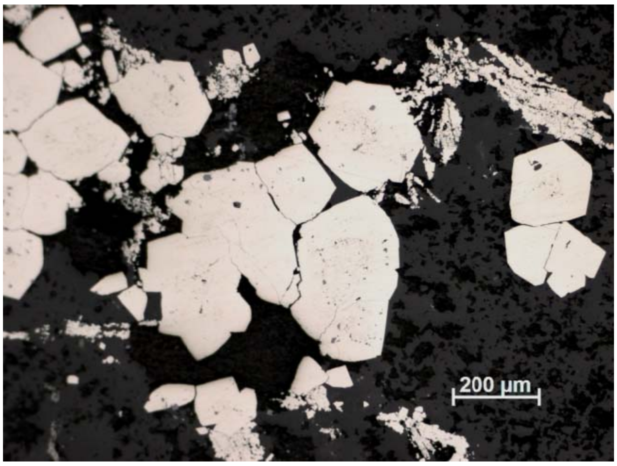
Pyrite II is sharply subordinate in quantity fine-grained, in the form of vein-like-chain formations. It is developed, apparently, along unstable marcasite and as a result of recrystallization, transforming into pentagonal dodecahedron, octahedral, and less often cubic **pyrite III** (figure 1/2).

Pyrite III is a pentagon dodecahedral, octahedral, cubic forms in the form of impregnation and intergrowths. It confines mainly to sericite, larger grains contain inclusions of rutile (figure 1/3). In pyrite III, later chalcopyrite, galena, with a size from 0.01-0.015 to 0.03 mm, develop along the cavity. Single inclusions of arsenopyrite in pyrite III and intergrowth of molybdenite with pyrite in quartz are noted. Densely impregnated pyrite III in sericitolite, intensely corroded, porous, littered with inclusions of nonmetallic, preserved pentagonal dodecahedron and cubic faces is noted. The grain size is up to 0.4 mm. In such a corroded pyrite, gold is found in close intergrowths with tellurides of gold, silver and lead.

Pyrite IV is larger (from 0.1 to 0.3 mm) in the form of intergrowths and aggregative release in the metasomatic mass. Aggregative pyrite is broken by cavities along which later sphalerite, galena and chalcopyrite develop (figure 1/3). Intergrowths and aggregate release of pyrite are up to 0.5x1.5 and 0.5x2.0 mm.



1



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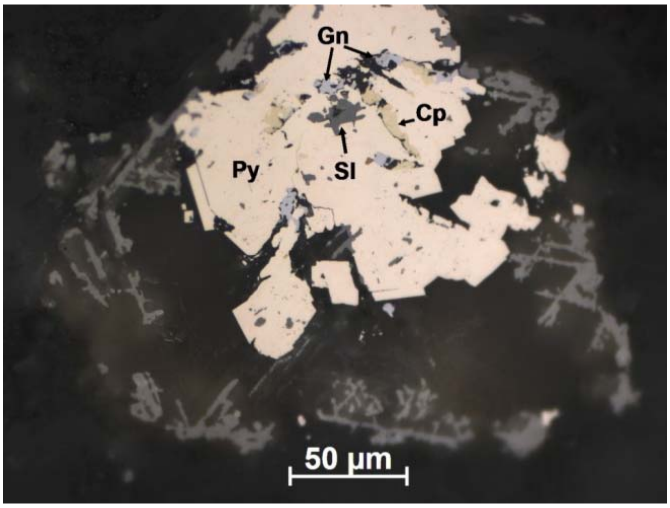

3

Figure 1 – Pyrite in several generations:
1 – Pyrite I fine-grained cubic form inchlorite and sericite. Polished section 84; 2 – Pyrite II streak-like and pyrite III pentagonal dodecahedral. Polished section 86; 3 – Pyrites IV aggregative (Py). Its grains are replaced by titanium minerals. Between the grains, it is galena (Gn), chalcopyrite (Cp) and sphalerite (Sl).Polished section 84

Fineness of native gold attracted the attention of scientists of the world since ancient times. They have considered it as a typomorphic feature due to the physical-chemical conditions of gold deposits formation. In particular, Shcherbina V.V. [3] half a century ago gave the Au/Ag relation the value of the geochemical indicator of gold and silver migratory ability and reasons for their geochemical differentiation in various geological processes. The importance of this parameter is noted in numerous works of many researchers [4, 5], as a criterium for certain conditions for the formation of specific gold ore and gold-silver deposits during their classification and formational identification. Classification of gold deposits has been proposed for six main types for the fineness of native gold. According to their estimates, for plutonogenic type, the variation range of Au fineness is 650-970‰, for porphyry - 650-1000‰, for volcanogenic - 520-870‰, for epithermal - up to 1000‰. Selected scholars consider that fineness of gold increases with increasing temperature and depth of ore formation. In particular, Petrovskaya I.V. and her co-authors state that gold in high-temperature deep deposits is high-carat, medium-deep - medium-carat, and shallow - varies in a wide range and is determined by the temperature regime, although it does not negatively affect the composition of Au pH and Eh medium. On the basis of detailed studies on the solubility of Au-Ag alloys, the other consider that fineness of gold is mainly influenced by the acidity-alkalinity of hydrothermal solutions and sulfur content in them. Only to a lesser extent depends on temperature, as well as the oxidation-reduction potential, the composition of fluids, pressure, without providing a sufficient thermodynamic justification [5, 6]. The understanding fineness of gold dependence on the physical-chemical conditions of ore formation, a significant contribution was made by experimental studies on the solubility of gold-silver alloys carried out in the last decade and the thermodynamic modeling of joint transport and deposition of Au and Ag compound in chloride, chloride-sulfide and sulfide hydrothermal solutions [7, 8]. However, basically, they concerned only systems which are in equilibrium with pyrite-pyrrhotine buffer.

Another approach based on the application of physical chemistry methods is substantiated by fundamental studies thermodynamics of mineral formation processes by geological scientists [9-11]. They are based on the results of an experimental study obtained with these thermodynamic constants and mainly on the electrochemical analysis of oxidation-reduction processes of formation, migration, and destruction of gold and silver complexes in hydrothermal solutions with different acidity-alkalinity and redox potential. Calculation of free energy and oxidative potential of noble metals various complexes allow to contour the fields of their stability in Eh-pH diagrams and to determine the evolution of hydrothermal system during the formation of gold deposits. Such studies allow considering the direction of various compounds oxidation-reduction reactions, the stability and reactivity of which is predetermined by Eh- pH of the hydrothermal system [12, 13].

The composition of minerals serves as one of the main information sources on the physical-chemical conditions of ore deposition. For that reason, the identification of cause-effect relationships between the composition of minerals and characteristics of mineral-forming processes is the most important task of genetic mineralogy. It is equally important in practical terms for the development of mineralogical forecasting-estimated criteria.

From Petrovskaya N.V. [3], temperature effect on the occurrence of Ag in the structure of crystallized gold is not decisive. There are also no reliable grounds for inferring the significance total Ag concentration in the upper parts of hydrothermal activity zone, that is, there is no direct dependence of gold alloy on the wealth of deposits with silver. In addition, a large amount of factual material is accumulated, which contradicts the well-known conclusion of Fersman A.E. on the regular purification of minerals in the late stages of ore deposition (autolysis principle). Another factor in the literature is the degree of solutions supersaturation, at which the crystallization of this mineral [14]. On the basis of typomorphic features detailed study of gold ore deposits main minerals, authors of this work concluded that between the parameters of hydrothermal solutions and the final result (composition of minerals), solutions supersaturation degree takes place, which regulates the behavior of isomorphic impurities.

Notions of low-carat and high-carat gold took root in the lexicon of mineralogical and technological descriptions, replacing the digital notations of silver content in the mineral (table 2). Sometimes the boundary of such content is determined differently by different researchers. At the same time, electrum is excluded, as a special mineral form.

Table 2 – Fineness of gold (from Petrovskaya N.V.)

Borders content	Fineness of gold, ‰
Very high-carat, almost pure	998-951
High-carat	950-900
Moderately high-carat, medium fineness	899-800
Relatively low-carat	799-700
Low-carat	699-600
Very low-carat, high-silver	<600

Fineness of native gold is in the Kokkiya deposit. In figure 2 gold is contained in the pentagonal-dodecahedral pyrite III (depth 60-61 m) chlorite-sericite quartz metasomatite. In close association with pyrite III on the deposit there are rare occurrence high-temperature molybdenite and arsenopyrite. Gold is bright yellow color, reflecting it can be attributed to high-carat gold (approximately 950‰).

Tellurides of gold, silver, lead appear in sericitolites with depth (140-143 m), which are closely associated with native gold and developed in intergranular spaces of intensely corroded pyrite III.

Gold was found in the polished section №11: 1) vein-shaped (0.01x0.05 mm) in sericite along the edge of a large corroded pyrite grain; 2) small irregular forms in sericite (0.01 mm); 3) in intergrowth with fine grains of pyrite in sericite (0.01x0.1); 4) in intergrowth with fine grains of vein-shaped pyrite and tellurides (0.01x0.1 mm); 5) in sericite - 0,005x0,025 mm; 6) in sericite intergrowth with tellurides and pyrite (8 grains of irregular shape - 0.01-0.02x0.03 mm); 7) along the edge of pyrite grain (0.01 mm); 8) 3 in the grain of pyrite (0.005-0.01 mm); 9) gold (2 grains - 0.01-0.02 mm) in intergrowth with tellurides between pyrite grains, cementing pyrite; 10) gold veins (0.01x0.1 mm) in the interval of pyrite grains in sericite; 11) 2 veins-shaped separate out of gold in sericite (0.01x0.05 mm); 12) in intergrowth with telluride and sericite in pyrite (0.01x0.02 mm); 13) veins-shaped in sericite next to pyrite grain (0.01x0.06 mm); 14) in intergrowth with pyrite and between pyrite grains (2 grains 0.01-0.005x0.01 mm). Figures 4-7 show gold and tellurides.

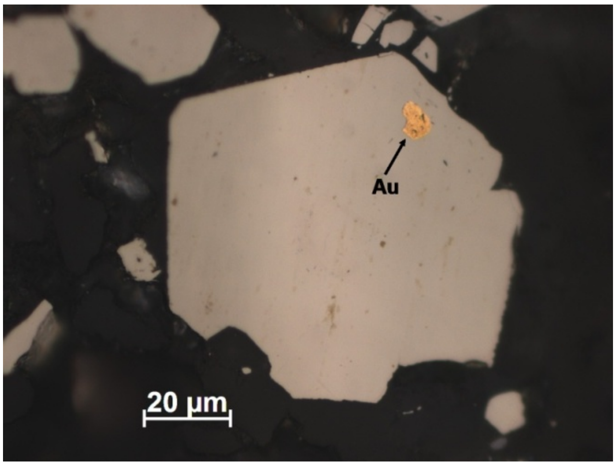

Figure 2 – Gold (Au) in the pentagonal dodecahedrongrain. Polishedsection 38

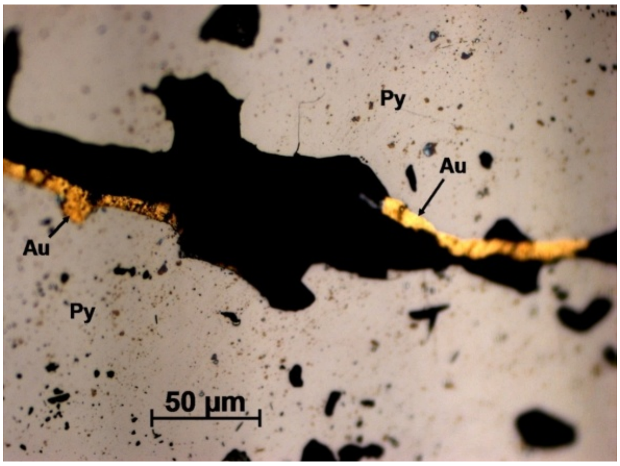

Figure 3 – Gold (Au) vein-shaped in the interval of grains of pyrite or along the edge of pyrite grains (Py) in sericitolite

Calaverite and altaite - develop between pyrite grains, veins-shaped, oval, prismatic. Occur separately in the mass metasomatite, in intergrowths with gold and pyrite, penetrate into the pyrite, corroding it. Dimensions - up to 0,04x0,07 and 0,03x0,1 mm (figures 4, 5). Minerals are confirmed analytically. In addition, altaiteis found in corroded grains and intergrowth of pyrite, sometimes in association with galena.

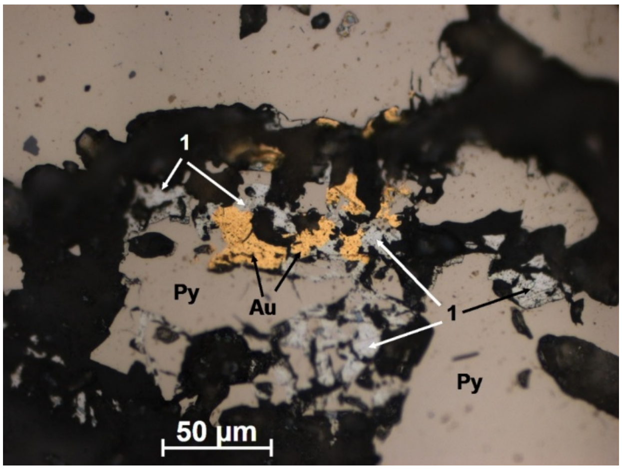

Figure 4 – Gold (Au) in intergrowth with altaite, calaverite (1) and pyrite (Py) in sericitolite. Polished section 11

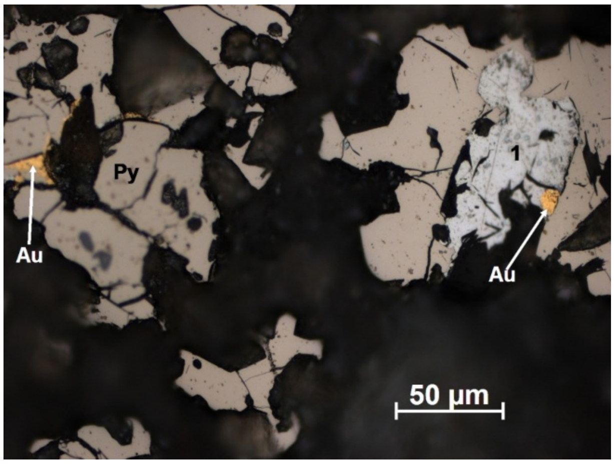

Figure 5 – Gold (Au) in conjunction with altaite (1) and pyrite (Py) in sericitolite. Polished section 11

The fineness of gold (figures 3, 6) is given in table 3 and performed by Popov Yu.V. ("Center for Studies of Mineral Raw Materials and the State of Environment" of the Southern Federal University). Scanning electron microscope Tescan Vega LMU with X-ray fluorescent microanalysis systems INCA Energy 450, INCA Wave 700 (from OXFORD Instruments Analytical). Iron is determined from the calculation results. Gold refers to the high-carat (940-944‰).

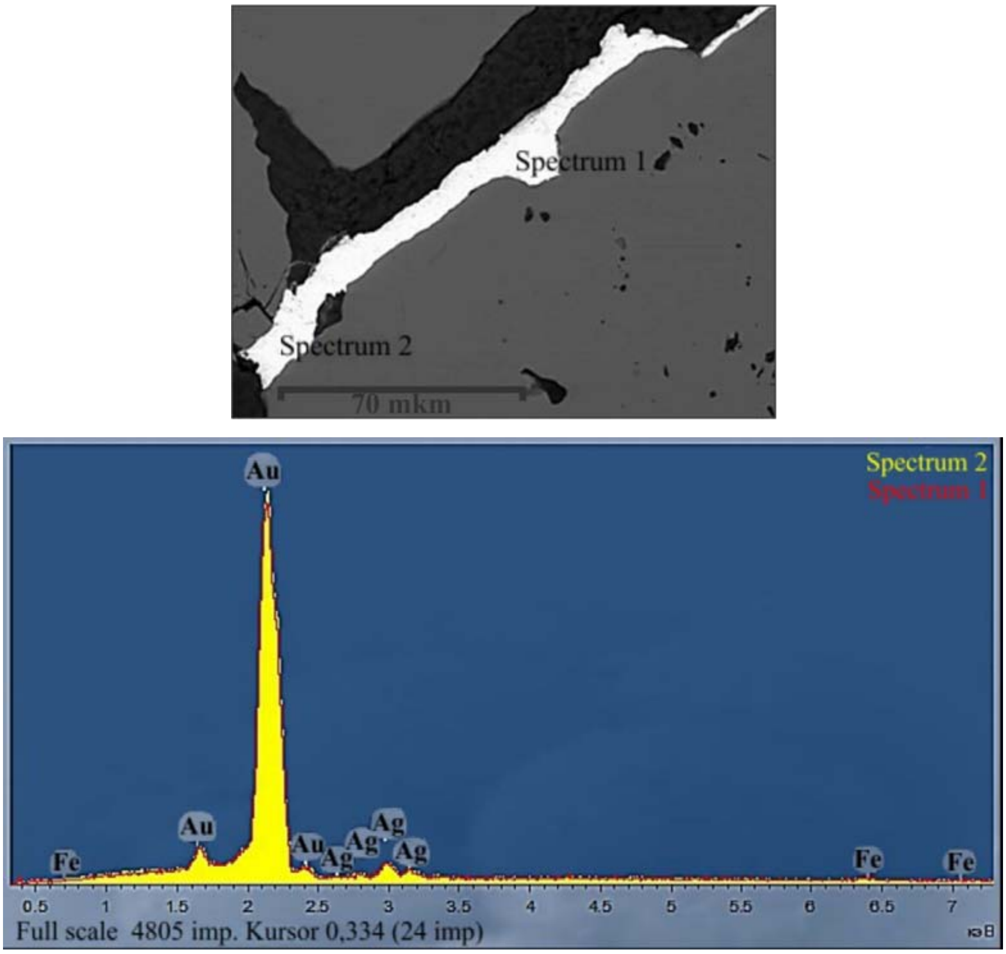

Figure 6 – Gold (Au) vein-shaped in the interval of grains of pyrite or along the edge of pyrite grains (Py) in sericitolite. Polished section 11

Table 3 – Gold composition from a scanning electron microscope (wt.%)

Polishedsection 11	Elements		Sum	Fineness of gold, ‰
	Au	Ag		
Analysis 1 – Gold (Au) vein-shaped	93,57	6,0	99,57	940
Analysis 2 - Gold in intergrowth with altaite between grains of pyrite	92,60	5,47	98,07	944

The results obtained from the microprobe according to the fineness of gold in the intergrowth with tellurides were close to those performed on a scanning electron microscope (figures 3–5, table 4). Gold refers to the high-carat and very high-carat (941 and 977‰).

Table 4 – Gold composition according to micro-X-ray spectral analysis (wt.%)

Polished section 11 – Gold in intergrowth with tellurides (altaite and calaverit) between grains of pyrite, (wt.%)				
Au	Ag	Fe	Sum	Fineness of gold, ‰
97,04	2,27	0,69	100	977
92,23	5,77	2,0	100	941
*Analysts Levin V.I. and Kotelnikov P. E. The analysis was performed on a microprobe JCXA-733 (Japan).				

Chemical composition of ore and veined minerals was studied using a scanning electron microscope "S-3700N" equipped with an energy dispersive X-ray spectrometer (EDS) with a microanalyzer in the laboratory of the Adam Mickiewicz University, Poland (figure 7).

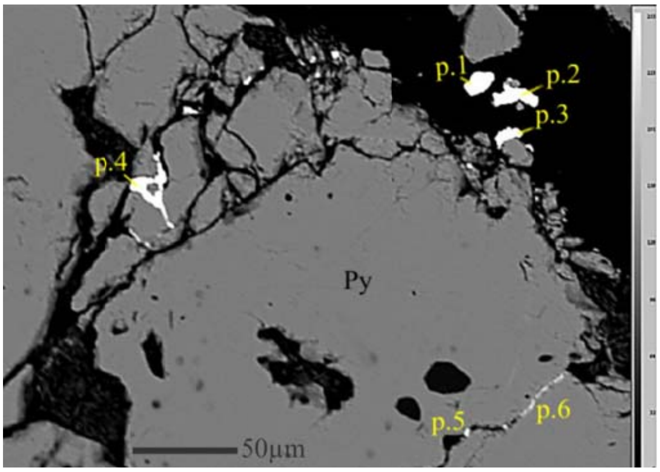

Figure 7 – Gold (Au) in the grains of pyrite (Py). Polished section 11

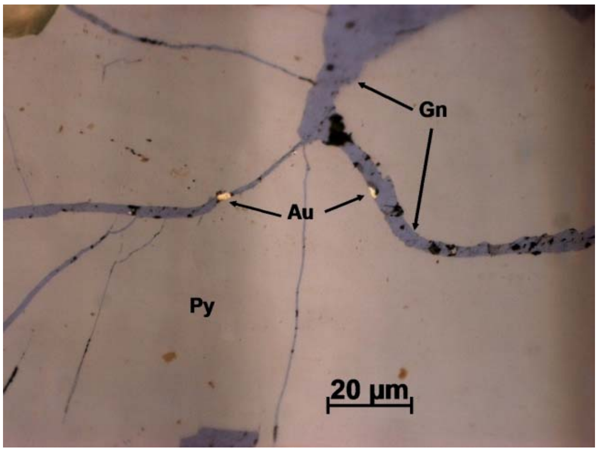

Figure 8 – Gold (Au) light yellow in galena streak (Gn). Py is pyrite. Polished section 94/2

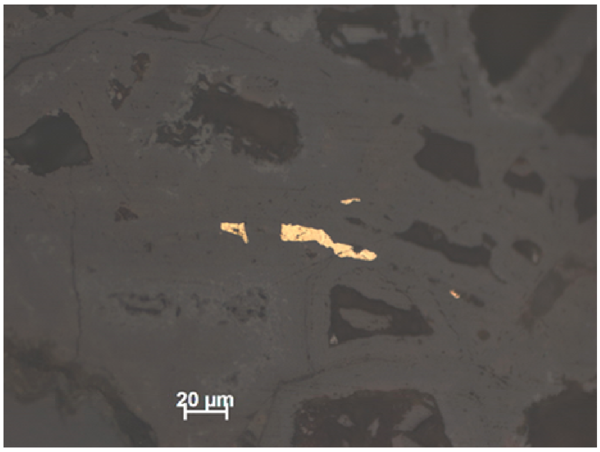

Figure 9 – Gold in iron hydroxides. Polished section 194/2

Vein-impregnated pyrite-polymetallic ore in the quartz-sericite metasomatite appearance on the deeper horizons of the deposit (175-176 m), in which gold is closely associated with galena. Galena with gold encased in it develops in the form of thin veins between grains of aggregate pyrite IV (figure 8). Gold refers to a medium, moderately-high-carat (810‰).

At shallow depths (6-8 m), finely-dispersed gold is encased in impregnated of pentagonal dodecahedral pyrite III in sericitolites is distinguished by a decrease in the fineness (table 5). Gold refers to the base and relatively low-carat (634-717‰).

Table 5 – Gold composition according to micro-X-ray spectral analysis (wt. %)

Polished section 199 – Gold in pyrite, (wt.%)			
Au	Ag	Sum	Finenessofgold, ‰
71,66	28,34	100	717
63,39	36,61	100	634
*Analysts Levin V.I. and Kotelnikov P.E. The analysis was performed on a microprobe JCXA-733 (Japan).			

Pyrite III is susceptible to oxidation at such shallow depths (6-10 m), and the gold contained in it is purified and becomes high-carat (figure 9).

Conclusions.

1. Sericitolites with impregnation of pentagonododecahedral pyrite III are the most gold-bearing minerals. Gold concentrates in both pyrite and sericite.
2. Gold associated with pentagonododecahedral pyrite III is high-carat, but with a decrease in depth (6-10 m), silver content as the main impurity element of native gold increases.
3. With depth (140-143 m) pyrite III is subjected to intense corrosion, becomes porous and native gold in close association with tellurides of gold, silver and lead penetrates into it. Gold is high-carat and very high-carat.
4. The content of silver in native gold, enclosed in late galena veins in aggregate pyrite IV, naturally increases and is characteristic of many gold deposits.
5. Native gold of high assay is found in oxidized pseudomorphs of pyrite III and in iron hydroxides.

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КӨКҚИЯ АЛТЫНРУДАЛЫ КЕНОРНЫНЫҢ (ҚЫРҒЫЗ ЖОТАСЫ) АЛТЫН СЫНАМЫ МИНЕРАЛ ЖАРАЛУДЫҢ ФИЗИКАЛЫҚ-ХИМИЯЛЫҚ ЖАҒДАЙЛАРЫНЫҢ КӨРСЕТКІШІ РЕТІНДЕ

Аннотация. Мақалада Көкқия алтын кенорнының рудаларын микроскоптық зерттеу нәтижелері сипатталған. Кенорын рудаларының минералдық құрамы, екінші дәрежелі және сирек минералдары анықталған. Алтын сынамының өзгергіштігі кенорыннның жайға су тереңдігі, сондай-ақ минерал жаралу процестерінің бастапқыдан соңғыға дейінгі сатысы бойынша анықталады. Алтын сынамын әлемнің көптеген ғалымдары алтын рудалы кенорындар жаралуының физикалық-химиялық жағдайларын анықтайтын типоморфтық белгі ретінде қабылдайды. Руда жаралудың физикалық-химиялық жағдайлары туралы негізгі ақпарат береалатын сирек минералдар да анықталған. Минералдардың құрамы мен минерал жаралу процестерінің сипаттамалары аралығындағы себептік-салдарлық байланыстар сипатталған. Бұл анықталғандар практикалық жағынан минералогиялық болжамдық-бағамдық критерийлерді әзірлеу үшін де маңызды.

Түйін сөздер: алтын сынамы, пирит, теллуридтер, алтын шоғырландырушы минералдар.

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ПРОБНОСТЬ ЗОЛОТА КАК ИНДИКАТОР ФИЗИКО-ХИМИЧЕСКИХ УСЛОВИЙ МИНЕРАЛООБРАЗОВАНИЯ НА ЗОЛОТОРУДНОМ МЕСТОРОЖДЕНИИ КОККИЯ (КЫРГЫЗСКИЙ ХРЕБЕТ)

Аннотация. В статье изложены результаты микроскопических исследований руд на месторождении Коккия. Установлен минеральный состав руд месторождения, с выявлением главных, второстепенных и редких минералов. Определена пробность золота, изменчивость которой определяется глубиной, а также процессами минералообразования от ранних ассоциаций к поздним. Пробность самородного золота принимается многими учеными мира, как типоморфный признак, указывающий на физико-химические условия образования золоторудных месторождений. Найденные редкие микроминералы также несут основную информацию о физико-химических условиях рудоотложения. Выявлены причинно-следственные связи между составом минералов и характеристиками минералообразующих процессов, что является важнейшей задачей генетической минералогии. Не менее важно это и в практическом отношении для разработки минералогических прогнозно-оценочных критериев.

Ключевые слова: пробность золота, пирит, теллуриды, золотоконцентрирующие минералы.

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TECTONIC AND TECHNOGENIC EARTHQUAKES IN CENTRAL KAZAKHSTAN

Abstract. In the article seismic events of tectonic and technogenic nature in Central Kazakhstan are considered. The characteristic of seismic monitoring of the territory of this region by the seismic network of the Institute of Geophysical Investigations of the Ministry of Energy of the Republic of Kazakhstan is given.

The new instrumental level of monitoring made it possible to obtain and study preliminary statistics on tectonic earthquakes, explosions in quarries, mines, and other technogenic events in Central Kazakhstan, as well as data on the stress-strain state of the deepest parts of the earth's crust.

A retrospective analysis of the features of the manifestation of foci of tectonic and technogenic seismicity on the platform structures of Central Kazakhstan is presented. The parameters of earthquakes in this region, the judgments about the nature of the mechanism of earthquake foci and the types of tectonic movements, maps of isoseism are constructed.

At the same time, it is shown that, in spite of tangible progress in the study of seismic events in Central Kazakhstan, some technical and methodological issues have not been developed in the long run, and work on this continues.

Key words: earthquake, focal mechanism, seismic stations, aftershock, magnitude, epicenter, isoseist.

Introduction. Central Kazakhstan has traditionally been considered aseismic, where seismic events with an intensity on the MSK-64 scale of more than 5 are not expected [1].

Based on these representations, a network of seismological stations was located in the South, South-East and East Kazakhstan, for which catalogs of earthquakes were compiled in the current regime.

According to Central Kazakhstan, earthquake catalogs were not compiled, since special seismological observations were not conducted here.

Based on these representations, the network of seismological stations was concentrated over the territories of the Northern Tien-Shan and Dzungaria, and also in part of Eastern Kazakhstan [2], for which catalogs of earthquakes were compiled in the current regime.

However, in connection with the creation of a new modern high-tech system for monitoring earthquakes and industrial explosions, the view of the seismicity of Central Kazakhstan has changed.

The use of these seismic stations, characterized by high sensitivity, made it possible to identify a number of focal zones in areas that had not previously attracted the attention of seismologists and to change the point of view on the geodynamics of this region of Kazakhstan.

All this can be considered as a leitmotif for the study of earthquake foci in Central Kazakhstan, which relevance is obvious, because in themselves they carry the potential threat to the industrial and civil facilities located nearby to these people [3].

At the same time, it should be noted that the study of natural seismicity in this region is difficult due to its low level. Approximately at the same energy level, seismic events occur regularly, generated by numerous explosions in quarries, industrial facilities and landfills.

In addition to "industrial explosions," the study of natural geodynamic and seismotectonic processes in Central Kazakhstan also complicates technogenic seismicity, sources of which arise in the Earth's crust when human engineering activities affect it, particularly in the extraction of oil and gas, extraction of ore, coal and other mineral resources, in the construction of roads, hydraulic structures, etc.

In order to identify the nature of various seismic events, special scientific research is being carried out to identify the class of sources of disturbance in the geological environment. For this purpose, various features are used - features of the wave pattern of records of earthquakes and career explosions, correlation and spectral analysis, attract independent data from space photographs, etc.

This article analyzes strong earthquakes recorded by the stations of the IGR ME RK in the territory of Central Kazakhstan and is included in seismic bulletins of national and global services. In addition, the technogenic seismicity in this region, related to the intensive development of deposits of solid minerals, is considered.

Characteristics of the system of seismic monitoring of the territory of Central and South-Eastern Kazakhstan. Over the past 20 years, Kazakhstan has created a new modern network of high-tech seismic stations integrated into the International Global Monitoring Networks.

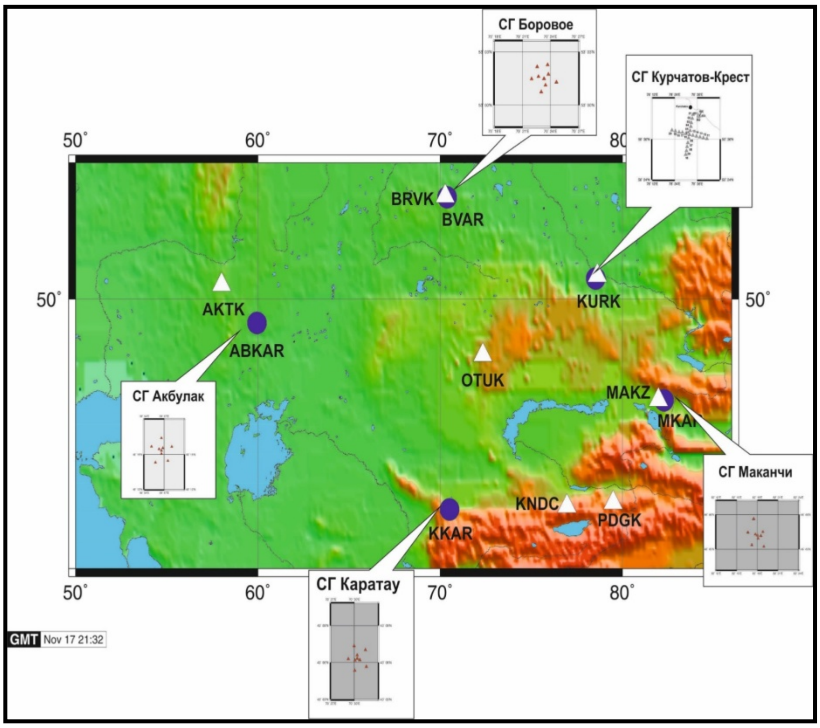

Figure 1 – Location of stations on the territory of Kazakhstan, data from which are received by KNDC.
Legend: mugs - seismic groups, triangles - three-component stations.
Separate footnotes show the configuration of seismic groups.

This system, first of all, was created to control the implementation of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in Kazakhstan, which signed the treaty in 1996 and ratified in 2001.

During the period from 1994 to 2006, a number of international agreements have built and commissioned new seismic groups and three-component stations, located mainly along the perimeter of weakly seismic territories of Kazakhstan [4, 5].

Figure 1 shows the scheme of the location of IGI ME RK stations, the data from which are received in real time by the KNDC (Kazakh National Data Center) in Almaty. Such a network allows monitoring of seismic events, both in Kazakhstan and abroad.

Information on strong earthquakes in Central Kazakhstan.

Shalginsky earthquake in 2001. Shalgin earthquake was registered by the stations of the IGI ME RK and studied by a special expedition operating in the epicentral zone.

The main parameters of the earthquake. The epicenter of the Shalgin earthquake was located on the western border of the Central Kazakhstan arch, near the intersection of the Jalair-Naiman shift with a transverse regional fault, with which epicenters of aftershocks are associated [6].

On the map of epicenters of earthquakes constructed according to the catalog of the ISC - International Seismological Center (1964-2006), epicenters of other earthquakes were not directly located near the epicenter of the Shalgin earthquake (figure 2).

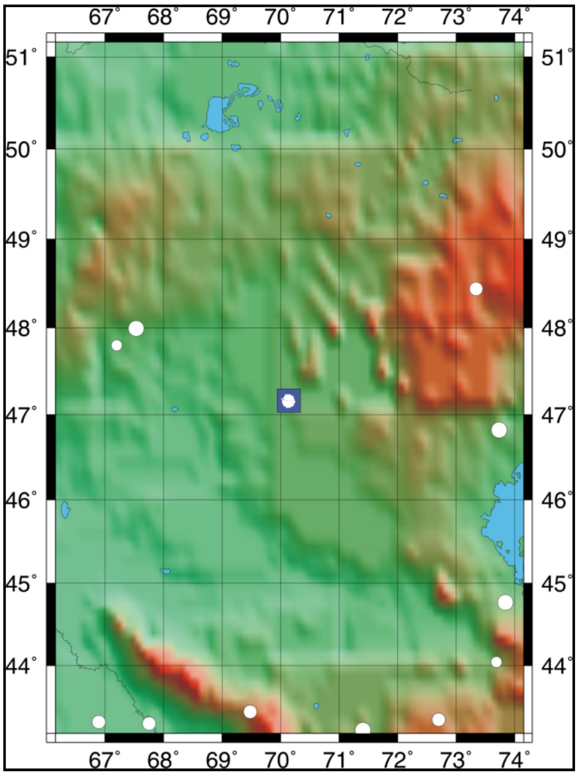

Figure 2 – Map of earthquake epicenters of Central Kazakhstan in the catalog of the International Seismic Center ISC.
The square on the map is the epicentral zone of the Shalgin earthquake.

The intensity of concussions in the epicentral region was 6 points on the MSK-64 scale.

The definitions of the hypocenter of the Shalgin earthquake for different services lie in the region with an aperture of 30 km (±15 km from the true epicenter) and, apparently, have real accuracy for this region (figure 3).

The final parameters of the main shock of this earthquake, taking into account the data of different International Centers are presented in table 1.

Macroseismic research. They were started 6 days after the main shock of the earthquake. Expedition from Almaty examined more than 10 settlements. A small number of the latter is due to the fact that the epicenter of the event is located in a sparsely populated region of Central Kazakhstan.

The closest to the epicenter is Shalginsky village - 43 km, where the earthquake was felt and observed by the majority of residents who were both inside and outside of the premises. In a number of settlements (Agadyr, Kyzyltau, Karazhal), the earthquake caused 5 point fluctuations.

As a result of macroseismic survey, the approximate position of the macroseismic epicenter can be described by the following coordinates: 47.17 ° N and 70.30 ° E (figure 3).

Based on the results of the survey, an isoseismal map of this earthquake was constructed [6], where the isoseism is clearly stretched in the northeasterly direction, consistent with a fault in the same direction orthogonal to the main northwest direction (figure 4).

According to the stereogram of the mechanism of the source for this earthquake in two variants, the following conclusions can be drawn in figure 5: 1. Shalgin earthquake is realized under conditions of compression in the northeastern direction and stretching under the sublatitudinal one. 2. In the focus, there

Legend: 1 - automatic detection (KNDC);
2 - definition by the operator (KNDC) on the data received in real time;
3 - through the network of IGI stations (KNDC); 4 - through the network of IGI stations and KNET (Kyrgyzstan).

Obn1 - urgent processing in the "Obninsk" ITC; Obn2 - the final definition of the Obninsk;
REB - definition of the International Seismological Center (IDC); NEIC - definition of the US Geological Survey.
Cross - macroseismic epicenter; an asterisk - an instrumental epicenter, non-filled circles - aftershocks of the Shalgin earthquake.

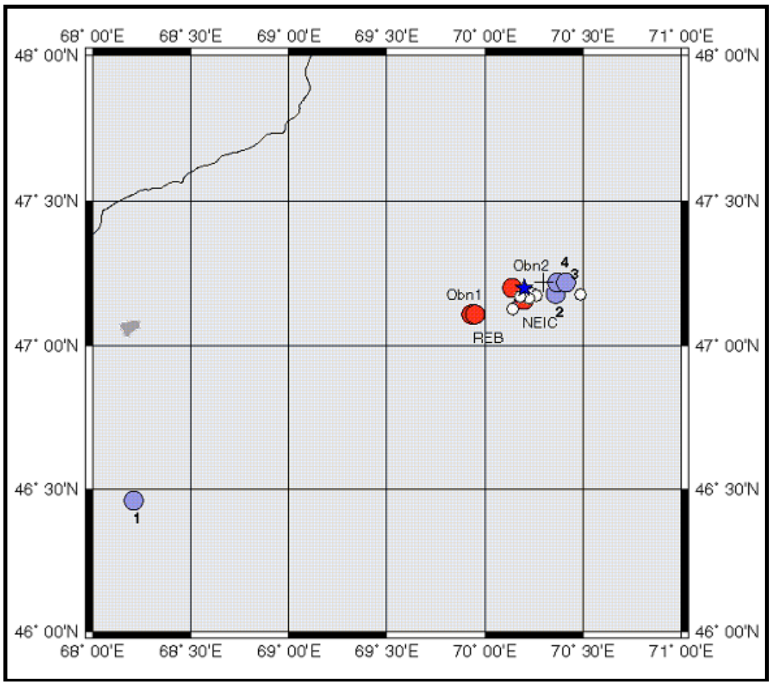

Figure 3 – Results of determining the epicenters of the main shock and aftershocks.

Table 1 – The final instrumental parameters of the Shalgin earthquake

Date	Time	Latitude, N	Longitude, E	Depth, km	M_s	MPV	K
22.08.01	15.57.57,7	47,20	70,20	19	5,0	5,4	13,2

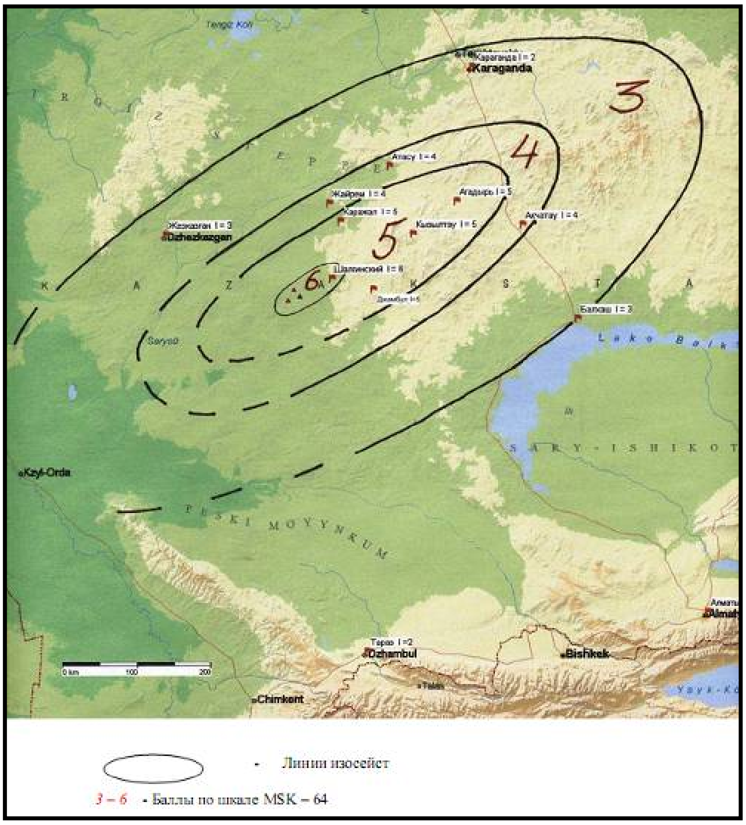

Figure 4 – Map isoseism of Shalgin earthquake on August 22, 2001 (according to A. I. Nedelkov)

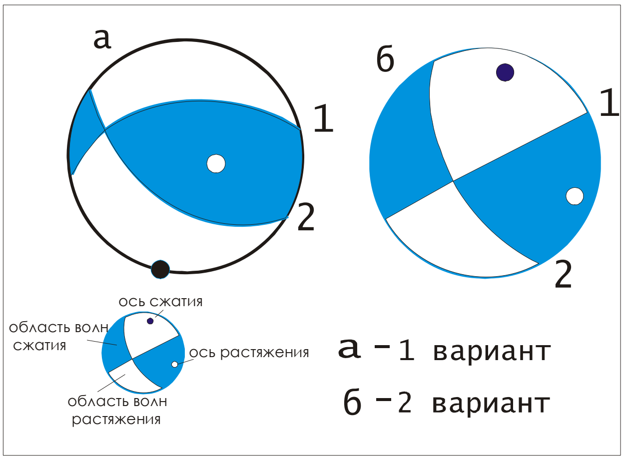

Figure 5 –
Stereograms of the mechanism of the source
of the Shalgin earthquake 22.08.01

was a displacement of the blocks in the form of a right-sided shift along the strike of the plane of the northeasterly direction, which agrees with the orientation of the fault to which the focus is confined [7].

In the epicentral area, on August 25, 2001, temporary field seismic stations were exhibited.

It was possible to register six weak aftershocks at depths of 5-15 km, the parameters of which are presented in table 2.

Table 2 – Basic parameters of aftershocks of the Shalgin earthquake

#	Date	Time, T_0	Latitude, φ°, N	Longitude, λ°, E	Depth, km	Mpva	K
1	8/22/2001	18-37-01.0	47.18	70.24	15	3.0	6.8
2	8/31/2001	05-18-21.4	47.1754	70.2631	11.5		
3	8/31/2001	22-53-59.8	47.1648	70.2264	5		
4	9/01/2001	19-53-47.6	47.1782	70.4873	15		
5	9/04/2001	22-35-56.4	47.1711	70.1780	7		
6	9/07/2001	08-53-24.8	47.1273	70.1393	10		

The strongest aftershock was recorded about three hours after the main shock. His energy class was 6.8. The rest of the aftershocks are much weaker than the first. It was not possible to determine their energy characteristics. Aftershock activation occurred along the fault plane of the northeast strike.

The Shalgin earthquake showed that the existing map of general seismic zoning does not give a complete picture of the seismic hazard in Central Kazakhstan.

On this map, a source with a development power of 6 points was not predicted, seismic generating zones with such a seismic potential were not shown. This information served as a material for recording in the new developed map the general seismic zoning of the territory of Kazakhstan.

The Karaganda earthquake on June 21, 2014.

The main parameters of the earthquake. The Karaganda earthquake was registered by all seismic stations of the IGI ME RK network. It should be noted that a strong earthquake in Central Kazakhstan with an epicenter to the north of Almaty is a rare event. Here, as well as in Northern Kazakhstan, industrial quarry explosions associated with the development of minerals are recorded.

The nearest station to the epicenter was the IGI Ortau station about 160 km away. The records were also received at Borovoye stations (432 km), Kurchatov (426 km) and other farther stations that are part of the global network of stations. Their data are automatically transmitted to international centers - the European EMSC in Paris, the American NEIC, the International Seismological Center in England ISC (figure 6).

The earthquake was processed in KNDC and in other international data centers. The solutions of different centers for determining the epicenter of earthquakes practically coincide. The coordinates of the epicenter vary within a few hundredths of a degree with a magnitude of mb = 4.8-5.2 and a depth of h = 9-20 km (table 3).

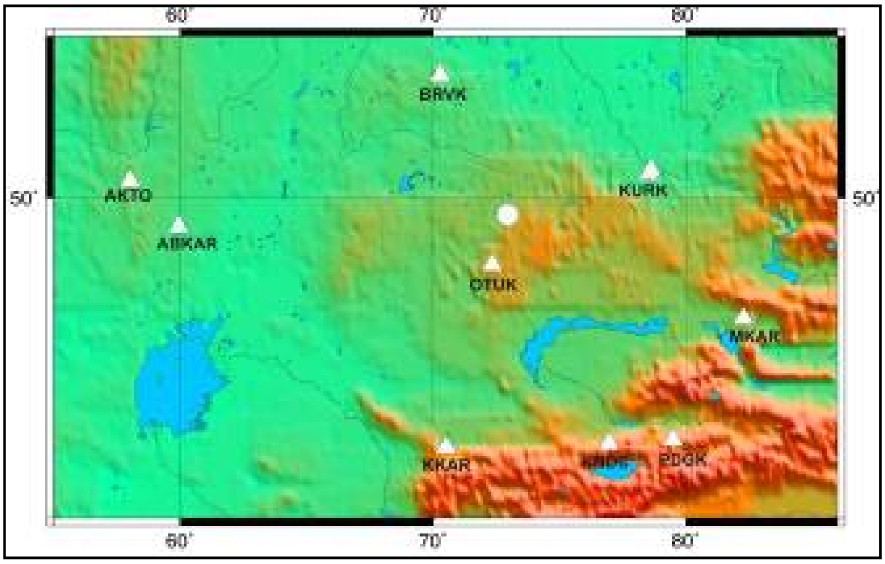

Figure 6 – Location of seismic stations IGI (triangles) relative to the epicenter of the earthquake on June 21, 2014 (circle)

Table 3 – Basic parameters of the earthquake near the city of Karaganda

Data	Latitude, N	Longitude, E	Time, t_0	mb	K	H, km
EMSC(France)	49.57	72.9	6:30:04.3	4.8		17
ГС РАН (Russia)	49,53	72,98	6:30:02.8	5.0	12	20
РК (KNDC+СОМЭ)	49,56	72,97	6:30:03.4	5.2	11,7	9

Immediately after the event, information began to be received that the Karaganda earthquake was felt in a number of settlements. The nearest to the epicenter, according to preliminary data, was Abay, located 10 km to the north-west of the epicenter. The city of Karaganda was 33 km from the epicenter with an estimated intensity of 4-5 points. The earthquake was felt in Astana with a force of 2 points.

The epicenter of the earthquake was located on the northern border of the Kazakh shield, near the southern boundary of the Karaganda coal basin. In tectonic terms, it is confined to the northern boundary of the Uspenskoye zone of the crushing of the northeastern strike with a width of up to 90 km, bounded by subparallel tectonic faults.

The question arose about the nature of this real event. Is it tectonic or man-made? Is it not associated with intensive work in the area in the coal mines?

Macroseismic survey. The epicentral territory of the earthquake was conducted in a week, from June 28 to July 3 (IGI ME RK; Velikanov AE and Uzbekov AN).

Surveys were conducted by detour of 34 settlements within a radius of just over 100 km around the epicenter of the earthquake that occurred and compiling questionnaires to establish the actual scores at the visited points on the MSK-64 seismic intensity scale. Routes of detour of settlements have coincided with the main directions of road routes diverging in different directions from the regional center of Karaganda.

For this earthquake, the focal mechanism of the source was determined from the first P-wave shifts recorded by 15 seismic stations. The reliability of the solution of the focal mechanism is indicated by the consistency of the signs, which is 100%, and also the range of the scatter of the parameters to be determined, not exceeding 10^0.

Based on the results of the earthquake source mechanism, it was realized under conditions of the submeridional orientation of the compressive stress axis and the sublatitudinal, hollow, submerging tensile stress axis. Under the conditions of a regional stress field, under the influence of which a discontinuity occurred in the focus, consistent with the dynamics and orientation of the main lineaments in the region, it can be concluded that this is a tectonic earthquake.

The type of tectonic movement in the focal zone is characterized by a horizontal shift with a small toklift component. The orientation of one of the planes is consistent with the regional fault of the north-eastern direction, marked in the scheme to the south of the epicenter [8].

Another possible plane of discontinuity agrees with the orientation of local faults that cut structures in the northwestern direction. Note that a similar type of focal mechanism is characteristic of the foci of earthquakes of the Kazakh shield (Shalginsky, Zhezkazgan and Semipalatinsk test site).

At the same time, it should be said that the possibility of provoking such an earthquake with active explosive activity in a nearby located career is not ruled out. The class of such induced earthquakes is also called natural-technogenic [8].

Summarizing the above, it is necessary to add that the seismic processes in Central Kazakhstan are continuing. Note that recently on September 20, 2017, seismic stations of the IGI ME RK recorded an earthquake that occurred at 08.44 minutes in Astana time (02:44 GMT), the epicenter of which is located 190 km east of the city of Karaganda. Coordinates of the epicenter: 50.180 degrees N, 75.700 degrees E. The magnitude mb = 3.8. The energy class is K = 8.7. The depth h = 13 km (figure 7). The elucidation of the genesis and mechanism of this earthquake is under study. The nearest town of Koyandy is 40 km away. Koyandy earthquake.

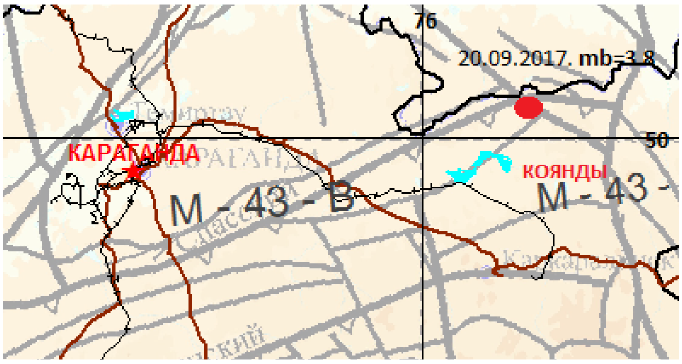

Figure 7 – Epicenter of the earthquake on September 20, 2017

Technogenic earthquakes in Central Kazakhstan. They are associated with the intensive development of deposits of solid minerals. An example of such seismic events can be considered earthquakes at the copper deposit of Zhezkazgan.

Long-term development of this field (more than 60 years) led to significant geodynamic changes in the geological environment, which were manifested by powerful technogenic earthquakes. The strongest of them, with mb = 4.8, Ms = 4.5, occurred on August 1, 1994, on the territory of the Zlatoust-Belovsky quarry, near the city of Zhezkazgan (figure 8).

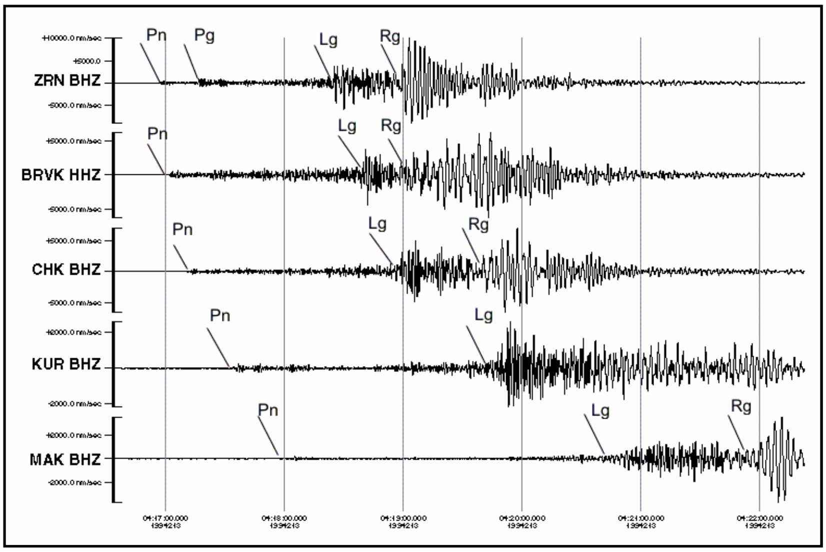

Figure 8 – Seismically records of the event 1st August, 1994.
Zhezkazgan region. t_0=4-15-39.7, φ=47.833°, λ=67.451°, mb=4.8, K=12.2. Stations of IGR. Z-component

This large-scale collapse took the lives of 6 people and caused the destruction of many operating underground excavations and buildings on the surface. The consequences of the earthquake almost led to a complete stoppage of work at one of the mines, the closure of a number of mines and the transfer of surface structures from the danger zone. Railroad tracks were destroyed, the cars were overturned [10, 11].

Figure 9 shows a diagram of the collapse of the overlaying strata with access to the surface of the day [10].

Another seismic event of technogenic nature that occurred on June 23, 1996 in the Zhezkazgan field (Ms = 3.7), was felt at considerable distances; in the village of Karazhal (epicentral distance Δ=243 км), the village of Agadyr (Δ=398 км) with an intensity of 3 points and etc.

Stations of the IGI ME RK also recorded seismic events of technogenic nature 09.09.2002 (Ms = 4.4) and 23.06.2005 (Ms = 4.0) near Zhezkazgan. Figure 10 shows the epicenters, and Table 4 shows the parameters of strong earthquakes with the energy class 9.4-12.2 occurring in this region.

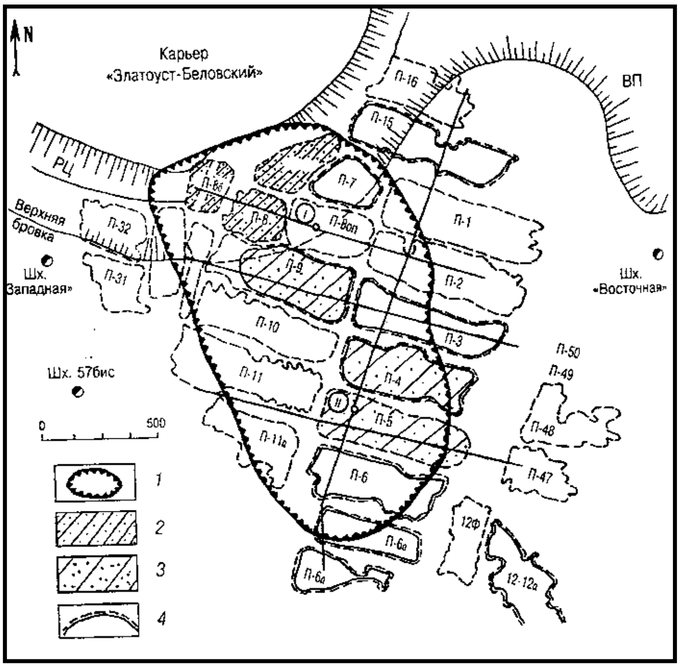

Figure 9 – Zlatoust-Belovsky quarry of the Zhezkazgan deposit.
Scheme for the implementation of the collapse process that occurred on August 1, 1994.
Legend: 1 - contour of collapse, 2-4 - panels respectively laid, partially embedded and weakened [9].

Table 4 – Parameters of technogenic seismic events near Zhezkazgan

Date	t_0	φ°,N	λ°,E	h	mpva	Ms	K
01.08.1994	04:15:39.7	47.833	67.451	0	4.8	4.5	12.2
17.07.1995	19:08:30.9	47.973	67.699	0	3.9		10.4
23.06.1996	18:28:25.8	47.8643	67.618	0	4.3		10.9
01.08.1996	00:06:04.5	47.9284	67.6856	0	4		10.4
09.09.2002	22:27:01.3	47.873	67.573	0	4.6	3.8	11.0
23.06.2005	18:00:07.6	47.9059	67.4092	0	4.1	3.5	10.4
16.01.2009	22:18:29.8	47.8672	67.4203	0	3.7		9.4
19.03.2009	19:08:46.6	47.934	67.6777	0	4.3		10.4
11.06.2009	06:05:49.9	47.8672	67.5424	0	3.9		10.3

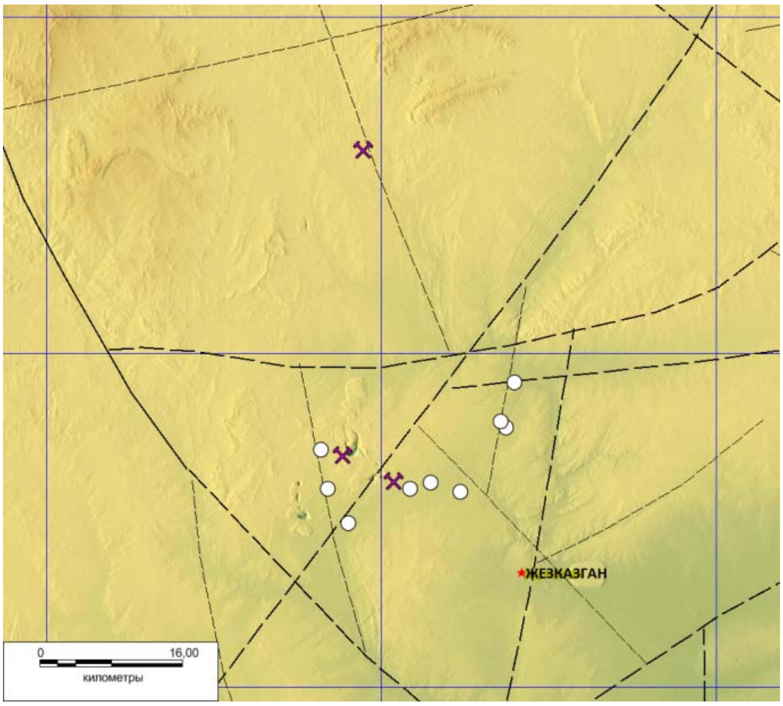

Figure 10 – Map of the location of the epicenters of seismic events in the Zhezkazgan field.
Legend: dotted line - discontinuous violations; circle - the epicenter of the event according to KNDC, crossed hammers - quarry.

In connection with the foregoing, for detailed analysis of the seismic processes taking place in Central Kazakhstan, it is not enough to attract only regional seismic stations. It is necessary to carry out special monitoring at the developed useful deposits in order to observe the patterns of preparation of strong man-made earthquakes, as well as to register the mine and mine explosions occurring here.

The **conclusion**. Based on the research:

- A new instrumental level of monitoring made it possible to obtain representative statistics on tectonic earthquakes, explosions in quarries and mines, technogenic events in Central Kazakhstan.
- The peculiarities of the manifestation of earthquake foci in platform structures are revealed and the question of the nature of seismic events in Central Kazakhstan is covered.
- It is shown that, in spite of tangible progress in the study of seismic events in Central Kazakhstan, some technical and methodological issues have still not been properly developed, and work on them continues.

For example, the generalization of all seismological data on earthquakes that have occurred, the comparison of this information with geological and tectonic data will make it possible to establish the relationship of specific foci with tectonic processes in each seismogenic zone, and also to determine the nature of the stresses acting in the region.

The identification of such links is very important for the study of previously considered aseismic regions of Central Kazakhstan.

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ОРТАЛЫҚ ҚАЗАҚСТАНДАҒЫ ТЕХНИКАЛЫҚ ЖӘНЕ ТЕХНОГЕНЦИЯЛЫҚ ЕРЕЖЕЛЕР

Аннотация. Мақалада Орталық Қазақстанда тектоникалық және техногендік сипаттағы сейсмикалық оқиғалар қарастырылған. Қазақстан Республикасы Энергетика министрлігінің Геофизикалық зерттеулер институтының сейсмикалық желісі бойынша осы аймақтың аумағын сейсмикалық бақылау сипаттамасы келтірілген.

Мониторингтің жаңа аспаптық деңгейлері Орталық Қазақстанда тектоникалық жер сілкінісі, карьерлерде, кеніштерде және басқа да техногендік оқиғалардағы жарылыстар туралы статистикалық мәліметтерді және жер қыртысының ең терең бөліктерінің стресс-күйі туралы мәліметтерді алуға мүмкіндік берді.

Орталық Қазақстанның платформалық құрылымдарында тектоникалық және техногендік сейсмикалық факторлар көріністерінің ерекшеліктерін ретроспективті талдау ұсынылды. Осы аймақтағы жер сілкінісінің параметрлері зерттелді, жер сілкінісі ошақтарының механизмі және тектоникалық ауысулардың түрлері туралы пікірлер жасалды, изосейлік карталар жасалды.

Сонымен қатар, Орталық Қазақстанда сейсмикалық оқиғаларды зерттеуде елеулі прогреске қарамастан кейбір техникалық және әдістемелік мәселелер әлі күнге дейін тиісті түрде дамымаған және олар бойынша жұмыс жалғасуда.

Түйін сөздер: жерсілкіну, фокал механизмі, сейсмичкалық станциялар, афтершок, магнитуда, эпицентр, изосейста сызығы.

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ТЕКТОНИЧЕСКИЕ И ТЕХНОГЕННЫЕ ЗЕМЛЕТРЯСЕНИЯ В ЦЕНТРАЛЬНОМ КАЗАХСТАНЕ

Аннотация. В статье рассмотрены сейсмические события тектонической и техногенной природы в Центральном Казахстане. Приводится характеристика сейсмического мониторинга территории этого региона сейсмической сетью Института Геофизических Исследований Министерства Энергетики Республики Казахстан.

Новый инструментальный уровень мониторинга дал возможность получить и изучить по Центральному Казахстану представительную статистику по тектоническим землетрясениям, взрывам в карьерах, шахтах и др. техногенным событиям, а также данные о напряженно-деформированном состоянии глубоких частей земной коры.

Представлен ретроспективный анализ особенностей проявления очагов тектонической и техногенной сейсмичности на платформенных структурах Центрального Казахстана. Изучены параметры землетрясений в этом регионе, высказаны суждения о природе механизма очагов землетрясений и типах тектонических подвижек, построены карты изосейст.

Вместе с тем, показано, что, несмотря на ощутимый прогресс в изучении сейсмических событий в Центральном Казахстане, все еще не получили должного развития некоторые вопросы технического и методического характера, работа над которыми продолжается.

Ключевые слова: землетрясения, фокальный механизм, сейсмические станции, афтершок, магнитуда, эпицентр, изосейста.

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DISSOLUTION OF STAINLESS STEEL POLARIZED BY ALTERNATING CURRENT IN HYDROCHLORIC ACID SOLUTION

Abstract. The stainless steel dissolution was shown under polarization of "steel-titanium" electrodes pair by alternating current for the first time. The effects of the main parameters of the electrolysis (current density of steel and titanium electrodes, electrolyte concentration and temperature) on the electrochemical dissolution of stainless steel in hydrochloric acidic medium were investigated. Quantitative and qualitative analyses were made on the solutions after the electrolysis had been performed. The dissolution of stainless steel in hydrochloric acidic medium by forming Fe^{2+} and Cr^{3+} ions were detected. When the current density of the steel electrode polarized by alternating current was increased up to 400 A/m^2, the current efficiency of the alloy dissolution was 45% for iron (II) ions, 12,7%, for chromium (III) ions, while the current efficiency of total steel dissolution reached 57.7%. The optimum density of the titanium electrode was determined and the current efficiency of the formation of iron (II) and chromium (III) ions in the current density of 40 kA/m^2 were 39% and 10.5% respectively, and the current efficiency of the total steel dissolution was 49.5%. The current efficiency of stainless steel electrode dissolution was shown to achieve the maximum value at 0.5 M hydrochloric acid concentration. When the temperature changed between 20-80ºC, a decrease in current efficiency was observed.

Key words: stainless steel, alternating current, hydrochloric acid, iron (II) ions, chromium (III) ions, electrolyte.

Nowadays, due to the extensive use of ferrous metallurgy products, processing their wastes, improving the waste technology, developing rational methods for their processing and making valuable inorganic compounds from these metals have gained increasing importance.

It is known that steel with a high proportion of chromium is highly resistant to corrosion in acidic medium. When the corrosion-resistant metal is added to a metal that is not resistant to corrosion, protection properties of alloy will increase. The main alloying element of the stainless steel is chromium. The pitting stability will improve while the mass fraction of chromium is 12%, the second pitting stability will increase by 17% [1]. If the mass fraction of chromium is about 40%, steel does not corrode as pure chromium [2].

The main disadvantage of chrome steel is its fragility. A small amount of nickel is added to stainless steel to eliminate this defect. Due to its high durability and corrosion resistance, nickel is used to produce resistant materials.

Nickel forms solid solutions with iron. When the temperature is decreased, the mixture of solid γ is changed to $\alpha + \gamma$. α - nickel concentration in the solid mixture is 7.5%. Nickel reduces the diffusion separation of carbon crystal lattice in iron-based alloy and prevents the carbide phase separation [3].

According to the literature data, the physical and mechanical properties of stainless steel are studied sufficiently, but its electrochemical properties are poorly studied [4-5]. In the works of G.Tatatarchenko, I.N.Shapovalova, A.L.Brodsky, studies on the corrosion properties of 12X18H10T steel in the azole-carboxylic acid were conducted in the presence of ozone [6]. It was found that oxidation of azole-carboxylic acids is an additional oxidizer of the steel and alloy dissolution. The corrosion resistance of stainless steel in the benzyl penicillin sulfoxide solution was considered in the studies of Russian scientists S.R. Tarantseva and V.S. Pakhomov [7]. According to the study, pitting corrosion resistance of stainless steel in the benzylpenicillin sulphoxide solution was detected. [8] The effect of the temperature on the current density of the alloys based on Fe-Cr-Mo, Fe-Cr-Ni, Fe-Cr-Mn-Ni was considered in the study. Corrosion resistance of stainless steel of brand 12X18H10T and 4X13 in carboxylic acid peroxide was investigated by the electrochemical and gravimetric methods. According to the study results, corrosion activity of formic acid and acetic acid is higher than that of other acids [9]. The effect of chitosan inhibitor on corrosion properties of 2205 stainless steel is considered in work [10]. The studies found that the chitosan inhibitor increased the corrosion resistance of stainless steel to a certain amount, while the corrosion properties of the stainless steel electrode in hydrochloric acidic medium in the presence of sulfur inhibitors were investigated in study [11] and its corrosion properties in the hydrochloric acidic medium were stabilized by sulfur inhibitor to a certain amount. In work [12], acidic corrosion of soft steel in the presence of Clerodendron colebrookianum walp leaves inhibitor was studied by the electrochemical impedance and the spectroscopic methods.

The physicochemical, mechanical and corrosive properties of 12X18H10T stainless steel were studied comprehensively in works [13-16].

In our previous study [17], the current efficiency of the formation of iron (II), iron (III) and chromium (III), chromium (VI) ions of stainless steel in the sulfuric acidic medium was detected to be 10%, 74% and 5,4 %, and 12% respectively.

In this work, the electrochemical dissolution of austenitic 12X18H10T stainless steel (63,83% Fe, 18,79% Cr and 9,21% Ni) was investigated in the hydrochloric acid medium. After the electrolysis, Fe^{2+} ions in the electrolyte were detected by permanganometric titration [18]. Chromium (III) ions were determined by qualitative analysis with sodium hydrophosphate and diphenylcarbazide reagents, while the quantitative amount of chromium (III) ions were found by adding ammonium sulphate and silver nitrate to Cr^{3+} ions in the electrolyte and oxidizing to Cr^{6+} ions [19]. By the qualitative and quantitative analysis, it was found that Fe^{3+} ions were not formed during the electrolysis. Due to the low nickel amount in the alloy, it was impossible to detect it in the electrolyte.

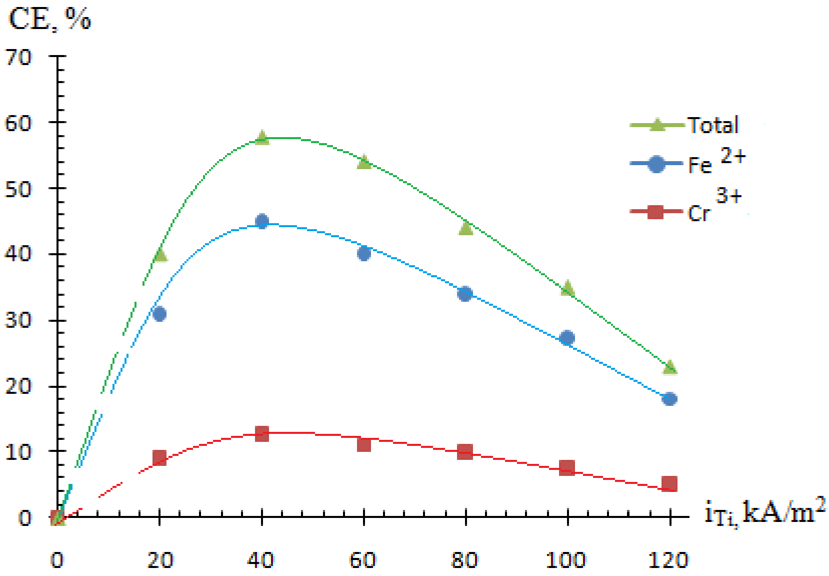
In the hydrochloric acidic solution, the dissolution of the alloy with the lowest current efficiency (CE) was defined when two steel electrodes had been polarized by alternating current (AC). Active dissolution of the alloy was observed when the stainless steel electrode was paired with the titanium electrode and polarized by the AC. In this case, the following reactions may occur on the electrode surface [20]:

$$Fe - 2e^- \leftrightarrow Fe^{2+} \qquad E^0 = -0.440\ V$$

$$Cr - 3e^- \leftrightarrow Cr^{3+} \qquad E^0 = -0.744\ V$$

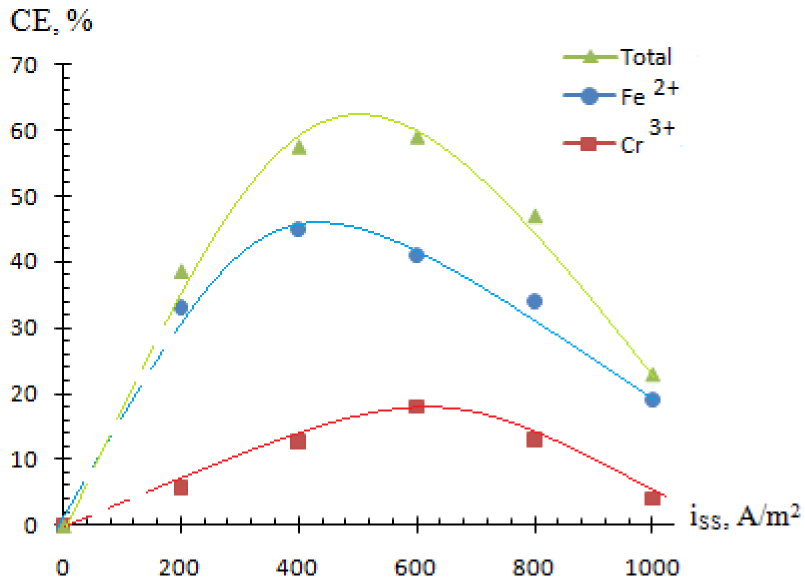
The effect of the current density in the titanium electrode on the electrochemical dissolution of the stainless steel polarized by the AC in the hydrochloric acidic medium was investigated (figure 1). When the current density in the titanium electrode was increased from 20 kA/m^2 to 40 kA/m^2, the current efficiency of the steel electrode grows, and a further increase in the current density leads to a decrease in the current efficiency. In this case, the alloy dissolution is explained by the formation of an oxide layer with "valve" properties on the surface of the titanium electrode at the anode partial period, the failure of current flow through the circuit and the discharge of hydrogen ions in the titanium electrode at the cathode partial period of the alternating current. At this time, the steel electrode exists in the anode partial period and dissolves by forming its ions. At high current density, the surface structure of the oxide shell in the titanium electrode varies, becomes loose and can be presumed to be due to the decrease of its current correction properties.

During the dissolution of the stainless steel, the effect of the current density on the steel electrode was considered (figure 2). When the current density in the stainless steel electrode increased up to 400 A/m^2, the current efficiency of its dissolution increased from 31% to 45% for iron (II) ions and 12,7% for chromium (III) ions. Further increase of the current density leads to the decrease of the current efficiency. This can be due to the increase in the rate of additional reactions by increasing the current density.



i_{SS} = 400 kA/m^2, [HCl] = 0.5M, τ = 0.5 h, ν = 50 Hz, t = 20^{0}C

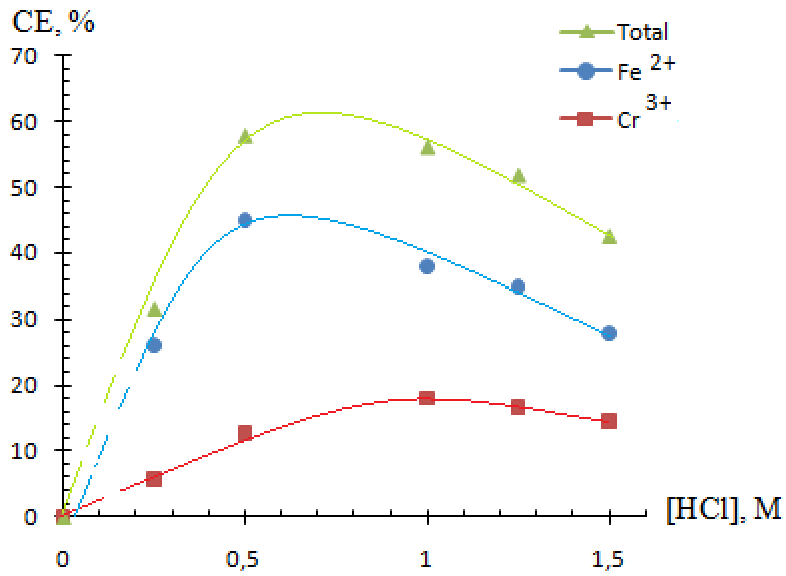
Figure 1 – Influence of the current density on current efficiency of the stainless steel electrode dissolution polarized by the alternating current in the titanium electrode



i_{Ti}=40kA/m^2, [HCl]= 0,5M, τ =0,5 h, ν=50 Hz, t=20^{0}C

Figure 2 – The effect of the current density in the stainless steel electrode on the current efficiency of the alloy dissolution

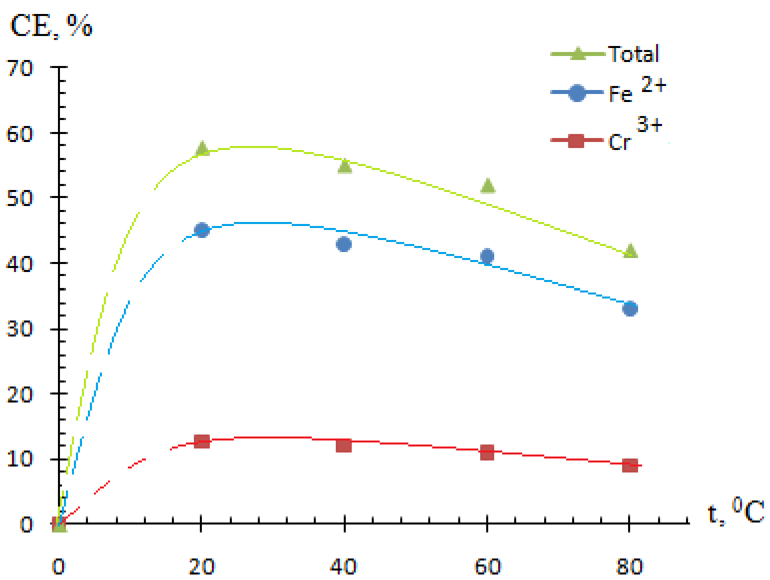
The effect of electrolyte concentration on the current efficiency of the stainless steel electrode dissolution was studied (figure 3). The current efficiency of the steel electrode increased when the concentration of the hydrochloric acidic solution increased to 0,5 M. When the acid concentration was increased up to 1,5 M, a decrease in the current efficiency of the alloy dissolution was observed. This is explained by the slower ionic motion of the electrolyte concentration and the passivation of the stainless steel electrode with chloride coating. It is also possible to assume that the adsorption is due to the formation of chlorine atoms. Low adsorbed chlorine atoms are oxidized to chloride ions in the cathode partial period.



i_{SS}=400 A/m^2, i_{Ti}=40 kA/m^2, τ =0.5 h, ν=50 Hz, t=20^{0}C

Figure 3 – The effect of the electrolyte concentration on the current efficiency of stainless steel electrode dissolution

In the hydrochloric acid solution, the effect of the solution temperature on the current efficiency of the stainless steel electrode polarized by alternating efficiency was studied (figure 4). The electrolysis was performed between 20-80^{0}C. As the solution temperature increases, it is possible to observe that the current efficiency has decreased. This anomalous phenomenon is difficult to explain.



i_{SS}=400 A/m^2, i_{Ti}=40 kA/m^2, [HCl] 0.5M, τ =0.5 h, ν=50 Hz

Figure 4 – Temperature effects on the current efficiency of the stainless steel electrodes dissolution

Thus, the effect of the current density, electrolyte concentration and dissolution temperature in the steel electrode and titanium electrode on the dissolution of the stainless steel electrode polarized by alternating current with the frequency of 50 Hz in the hydrochloric acid medium was studied for the first time and the effective conditions of the alloy dissolution were determined: i_{Ti}=40kA/м^2, i_{SS}=400 kA/м^2, [HCl]=0,5M, t=20^{0}C. In these favourable conditions, the current efficiency of iron (II) and chromium (III) ions in the hydrochloric acid solution was 45% and 18%, respectively, while the current efficiency of the alloy dissolution was 63%. Based on these studies, it is possible to process stainless steel and develop a technology separating necessary elements from them.

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АЙНЫМАЛЫ ТОҚПЕН ПОЛЯРИЗАЦИЯЛАНҒАН ТОТ БАСПАЙТЫН БОЛАТТЫҢ ТҰЗ ҚЫШҚЫЛЫ ЕРІТІНДІСІНДЕ ЕРУІ

Аннотация. «Болат-титан» электродтары жұбын айнымалы тоқпен поляризацияланған кезінде тот баспайтын болаттың еритіндігі алғаш рет көрсетілді. Тот баспайтын болаттың тұз қышқылды ортадағы электрохимиялық еруіне электролиздің негізгі параметрлерінің (болат және титан электродындағы тоқ тығыздықтарының, электролит концентрациясының және температурасының) әсерлері зерттелді. Электролиз жүргізгеннен кейінгі ерітінділерге сандық және сапалық анализдер жасалды. Тұз қышқылды ортада тот баспайтын болат Fe^{2+} және Cr^{3+} иондарын түзе еритіндігі анықталды. Айнымалы тоқпен поляризацияланған болат электродындағы тоқ тығыздығын 400 А/м^2-ге дейін жоғарылатқанда, құйманың еруінің тоқ бойынша шығымы темір (II) иондары үшін 45%, хром (III) иондары үшін 12,7%, ал жалпы болат еруінің тоқ бойынша шығымы 57,7%-ке жететіндігі көрсетілді. Титан электродындағы ток тығыздығының оңтайлы мәні анықталып, 40 кА/м^2-ге тең тоқ тығыздығында темір (II) және хром (III) иондарының түзілуінің ТШ, сәйкесінше, 39% және 10,5%, ал жалпы болат еруінің тоқ бойынша шығымы 49,5% құрайтыны анықталды. Тот баспайтын болат электродының еруінің тоқ бойынша шығымы тұз қышқылының концентрациясы 0,5 М кезінде максималды мәніне жететіндігі көрсетілді. Температура 20-80^{0}С аралығында өзгергенде, тоқ бойынша шығымның төмендеуі байқалды.

Түйін сөздер: тот баспайтын болат, айнымалы тоқ, тұз қышқылы, темір (II) иондары, хром (III) иондары, электролит.

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РАСТВОРЕНИЕ НЕРЖАВЕЮЩЕЙ СТАЛИ В РАСТВОРЕ СОЛЯНОЙ КИСЛОТЫ ПРИ ПОЛЯРИЗАЦИИ ПЕРЕМЕННЫМ ТОКОМ

Аннотация. Впервые показано, что при поляризации переменным током пары электродов “сталь-титан” происходит растворение нержавеющей стали. Изучено влияние основных параметров электролиза (плотности тока на стальном и титановом электродах, концентрации и температуры электролита) на электрохимическое растворение нержавеющей стали в растворе соляной кислоты. Растворы после электролиза подвергались качественному и количественному анализам. Установлено, что при растворении электрода из нержавеющей стали в солянокислой среде образуются ионы Fe^{2+} и Cr^{3+}. Показано, что при увеличении плотности тока на стальном электроде до 400 А/м^2 выход по току образования ионов железа (II) составляет 45%, ионов хрома (III) - 12,7%, а общий выход по току растворения стали достигает 57,7%. Установлено оптимальное значение плотности тока на титановом электроде и показано, что при плотности тока, равной 40 кА/м^2, выход по току образования ионов железа (II) и хрома (III), соответственно, достигает 39% и 10,5%, а общий выход по току растворения стали составляет 49,5%. Показано, что максимальное значение выхода по току растворения нержавеющей стали достигает при концентрации соляной кислоты 0,5 М. При изменении температуры в интервале 20-80^{0}С наблюдается уменьшение значения выхода по току.

Ключевые слова: нержавеющая сталь, переменный ток, соляная кислота, ионы железа (II), ионы хрома (III), электролит.

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NOISE RESEARCH OF TOOTH WHEEL OF THE PINION STAND OF THE RADIAL-SHIFTING BEND WITH MODIFIED TEETH (GEARS)

Abstract. A new combined method for manufacturing bars and tubes with a stable sub microcrystalline structure is proposed in the article: intensive plastic deformation by the method of radial-shear rolling with a combination of pressing. The influence of the modified teeth of the gear wheels of the radial-shear stand on the noise and vibration of its drive is investigated. At the same time, a special methodology was developed and appropriate research tools were used. To determine the noise level in tooth gears with modified teeth of the wheels, a special stand was designed and manufactured. As the object of investigation, medium-speed disc type straight-toothed pairs of medium sizes were chosen. The tests carried out on the stands were designed to find out the effect of modified wheel teeth on noise and vibration, the variation of skew, speed and load, and the effectiveness of the effect of the profile modification of the teeth of the wheels on noise and vibration when varying the gap between the teeth, speed and load. The conducted experimental studies to determine the noise levels of tooth gears with modified teeth showed that for transmissions with 7÷9 degree of use of longitudinally modified teeth on one mating wheel, a significant reduction in the load concentration and a reduction in vibration and noise of 3÷5 dB, and the use of a profile modification of the teeth along the entire height of tooth, obtained by hydro abrasive method, allowed to reduce the noise level by 4÷6 dB. If there is no load, the noise level increases with the depth of the profile modification. Under load, as the profile modification increases, the transmission noise level first decreases, then increases.

Keywords: modified teeth, gear train, contact markings (strips), modification depth, gear tooth contact, gear-meshing frequency.

Introduction. Rolling mills belong to the class of heavy energy-intensive aggregates, which are manufactured on individual projects in single copies [1, 2]. Each type of mill is characterized by its design and specific operating conditions, depending on the technology. They are low-speed, powerful crimping mills and relatively lightly loaded high-speed training and wire mills, continuous wide-band hot and cold rolling mills with a wide range of speeds along the stands, rolling mills for bars, pipes and etc.

Intensification of rolling production processes increases the load on heavy-loaded elements of mill stands, gear stands, reducers, combined reducers, etc. [3-5]. The cyclic action of powers leads to the appearance of defects in the mating elements. Gaps in gear train and bearings are one of the main reasons for increasing vibrations and the appearance of dynamic loads, leading to the destruction of parts. The primary task in the operation of mechanisms is the detection of incipient defects at early stage of occurrence using diagnostic tools.

For most mills and their stands, the impact character of the load application is typical, first of all, at the moment when the workpiece is caught by rolls [6]. This circumstance leads to the formation of significant dynamic loads, which are the reason for increasing the noise level in the rolling mill and adversely affect the durability of the equipment. The desire to increase productivity, expand the range of products and improve its quality, and increase the profit of the enterprise is associated with the intensification of the work of rolling mills. This, in turn, led to an increase in static and dynamic loads, increased wear of articulated parts and gaps, reduced longevity, the loss of production due to equipment failures due to fatigue.

The service life of most mills is estimated in tens of years [7, 8]. Maintaining the working capacity of rolling mills equipment is ensured by preventive maintenance, which is a well established, however, outdated maintenance practice. It allows you to continue the operation of rolling mills, while bearing a large cost of repairs.

Modern economic conditions lead to the need to introduce a new maintenance strategy "on the actual state". The last 10-15 years, an exceptionally great attention is paid to the determination of the technical state on the basis of vibration diagnostics of rolling equipment [9-13]. The advantages of using mills with the use of control and diagnostic systems are noted: improving the quality of products, optimizing the technological process and equipment operation, and improving the repair system oriented to the technical condition of the units. In the works [14, 15] examples of the effective and successful application of diagnostic systems are given.

Peculiarities of diagnosing and manifestations of the technical condition of the mechanical equipment of metallurgical enterprises were considered in works [9-15]. The emergence of modern stationary control systems for metallurgical equipment requires the development of new approaches to assessing the technical condition.

In our opinion, it is possible to improve the durability of individual parts of rolling mills by improving their design, for example, gear wheels of pinion stands. It is known [16] that the general indicator of the quality of the gear train is the nature and noise level. Reducing the noise level is one of the most important conditions for increasing the efficiency and reliability of high-speed, heavily loaded gears.

The main task in the production of gears with limited accuracy of their manufacture and installation is to reduce the disturbing forces in the oscillation source, i.e. reduction of its vibroactivity [17]. The use of various modifications of the wheels teeth has made it possible to largely solve the problem of reducing dynamic loads, contact stresses, increasing the smoothness of the gearing and reducing the noise level of the transmission [18]. Despite the fact that these types of modifications in gears have been used for a long time, they have not found wide application in practice in gears with increased hardness of the working surfaces of the teeth.

In the works [19-23], based on theoretical and experimental developments, methods for modifying wheel teeth with increased hardness of working surfaces have been created, and these methods are realized on cylindrical gears with an involute tooth profile. For industrial recommendations of rational parameters of wheel teeth modification, their comprehensive experimental verification on test benches and in gear mechanisms of rolling mills is necessary. In the above studies, statistical and dynamic tests of wheels with modified teeth for identifying the effect on their noise in the transmission were carried out at the stand.

To date, a sufficiently large number of studies have been performed for studying the level and nature of noise in the gear trains [20-23]. The sources of noise excitation are considered and noise transmission criteria and methods for performing air noise and vibration measurements are proposed. Frequency tables of forced oscillations, depending on the geometric parameters of the link, are given. In the study of noise, spectral analysis was used, and the comparison of the components of the noise spectrum with the calculated values of the forced oscillation frequencies made it possible to justify the method for identifying noise sources.

The most dangerous dynamically are the oscillations arising at edge contacts caused by the combined effect of manufacturing errors and the deformation of the linkage [13]. In this case, the amplitude of the oscillations is many times higher than the amplitude of the cyclic error, and the transmission operates with sharply increased noise.

The quantitative parameter of the source noise is its acoustic power [14]. A parameter that can be directly measured with instruments is sound pressure. The total noise level approximately corresponds to the value of the integral of the function of the dependence of the intensity of sound oscillations on the frequency. However, in connection with the logarithmic law of addition of noise levels, the overall noise intensity is mainly determined by the most intensive components.

In the study of the relationships between the errors of gear trains and the parameters of their noise and vibration, the last were the total, octave and one-third octave levels, or the levels obtained as a result of spectral analysis with a constant, relatively wide bandwidth [15]. With the improvement of analog analyzers and the appearance of digital analyzers that make it possible to obtain spectra of signals with a high resolution in frequency, the possibilities of special analysis have expanded substantially.

In work [10] the influence of the profile modification of the wheel teeth on the noise characteristics of the gears was verified experimentally. It is established that the profile modification of the teeth significantly changes the frequency spectrum of the noise of the gear train, reducing the level of the frequency component corresponding to the tooth frequency and its second harmonic by more than 10 dB, in addition, a certain reduction in the subharmonics of the tooth frequency was obtained.

The aim of this work was:

1. Determination of the influence of the modified wheel gears on noise and vibration, variations of a distortion, speed and load.

2. Determination of the efficiency of the influence of profile wheels gear modification on noise and vibration at variation of a gap between gears, speed and load.

Materials and experimental procedure. In this work, we propose a new combined method for the production of bars and pipes with a stable sub microcrystalline structure: intense plastic deformation by radial-displacement rolling with a combination of pressing [24].

The device for continuous pressing of rods comprises a main drive, working and gear stands, rotating in different directions of the rolls and a press-matrix. The rolls have smooth and undulating cone-shaped gripping and crimping portions, respectively, and calibrating cylindrical areas. In this case, the protrusions or valleys of the rolls having the same width and, respectively, height or depth, are made along a helical line with an angle between the tangent to the helical line and a line passing through the point of tangency along the generatrix perpendicular to the base of the roll equal to from 45^o to 60^o.

The rods are pressed in the following way. The workpiece is fed into the gap between the rolls and deformed with the protrusions and hollows of the corrugated cone-shaped sections of the rolls when the rolls rotate in one direction. Rolls, while rotating, rotate the deformable metal forwardly and squeeze it out through the opening of the press-matrix.

Rolling of the workpiece in the undulating cone-shaped sections of the rolls, with the rotation of the rolls in one direction, provides progressive and rotational motion of the workpiece in the rolling direction, efficient grinding of the structure throughout the section of the workpiece due to the development of shear deformations and reduction in the rolling force. Effective grinding of the structure ensures the production of high-quality products.

In the present work, the influence of the modified teeth gear of wheels of the pinion stand of radial-displacement rolling on the noise and vibration of the drive of this mill is investigated. At the same time, a special methodology was developed and appropriate research tools were used.

Obviously, the most reliable data on the advantages of transmissions with these or those parameters can be identified only in the process of comparative full-scale tests of these transmissions, carried out in a uniform manner on the same test equipment. In this case, the possible incompatibility of experimental results will be completely ruled out, resulting in a number of cases when comparing gears with the same parameters tested in different research organizations with different gear sizes and using different test methods and various testing equipment.

For determination of noise level in gear trains with the modified teeth of wheels the special stand with the loaded close circuit was developed and assembled.

The main design features of the stand are presented on figure 1.

The stand represents design from two parts: drive and assembly for teeth wheels noise testing.

Transmission system consists of sixteen step gearbox units 1, placed on the stand with a curbstone 2 and the 7,5 kW electric motor, located in a curbstone which are connected among themselves by V-belt transmission. The drive torque from the drive through a shaft and V-belt transmission is transferred to a driving shaft of a reducer 3.

The device for tooth wheels noise testing consists of a reducer 3, the mechanism of cogwheel testing and the mechanism of loading 4, which are installed on the stand 5. The mechanism of wheels testing is installed on the carriage and consists of two parts:static and mobile. The static part represents a support

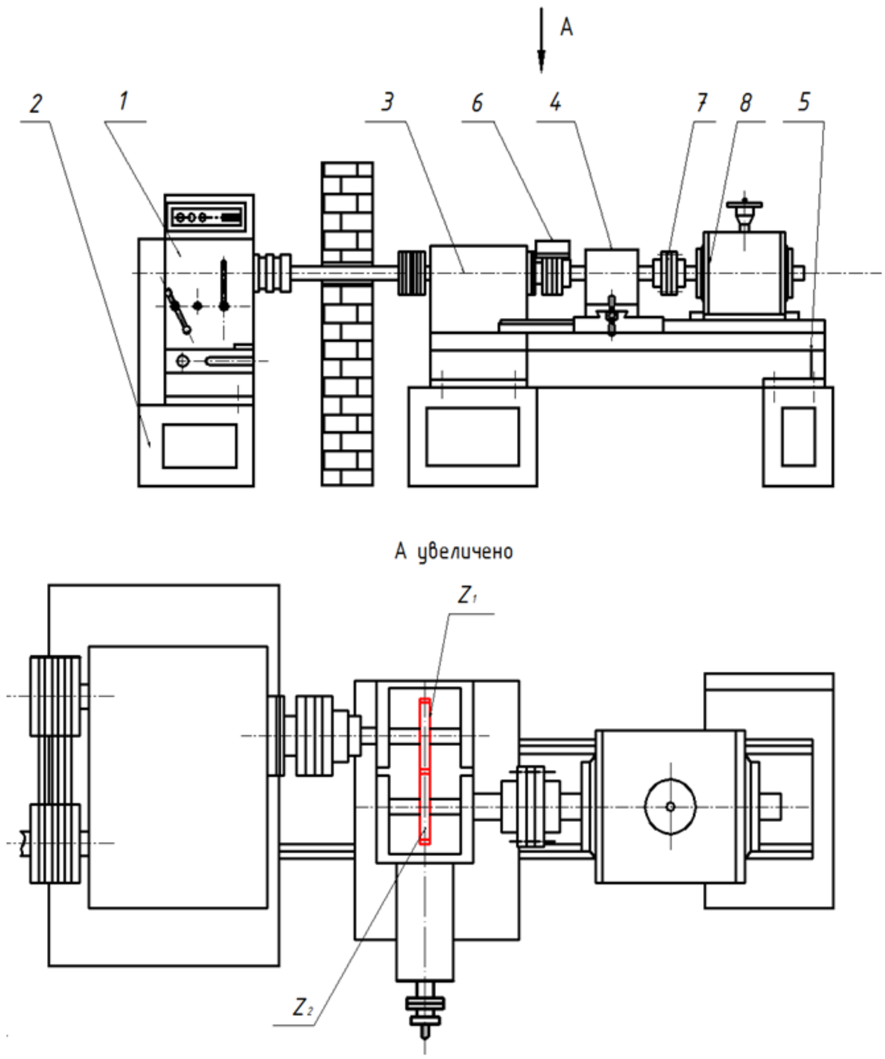


Figure 1 – General view of the stand for cogwheels noise testing

with the shaft and tested wheel, which rigidly fixed on the carriage together with a driven shaft of a reducer 3, connected by the coupling.

The second support with the shaft and the tested wheel rigidly fixed on a table of the carriage, which can move along cross guides by means of a screw pair and the handle. The electromagnetic powder brake 8, connected to a driven shaft with the coupling, creates load. Rotational speed of a driving shaft is controlled by means of the photo sensor; the frequency of reintegration is controlled by means of the electromagnetic sensor (not shown in figure 1). The torque created by a brake is evaluated according to the results of an indicator head (tarred).

At statistical tests loading of a closed boundary was carried out as follows: the driven shaft of a reducer 3 is disconnected with a driving shaft and rigidly fixed with the reducer body by means of the special device (not shown in figure 1). Loading is performed by means of the lever (figure 1b) and the screw mechanism on a dynamometer. Under the influence of the created moment cogwheels z_1, z_2 and shafts 6,7 try to turn, but as the driven shaft of a reducer 3 is connected with the body and the bedplate, this turn can happen only within backlash and elastic deformation of gearing. Teeth of wheels engage to each other and are loaded with relevant efforts. After that, the driving shaft and a driven shaft of a reducer 3 become isolated, fixed and driven shaft is disconnected with the body unloaded the lever and the lever cleans up. The report of cogwheels work cycles is performed on a turn counter.

As the object of investigation, medium-speed disc type straight-toothed pairs of medium sizes were chosen. When choosing the main parameters of gears for research, we proceed from the assumption that approximately 80% of all produced gears fit into the range of modules from 3 mm to 5 mm and diameters not exceeding 200 mm, which corresponds to the projected gears of a radial-shear mill.

Experimental cogwheels made of 40X steel are widely used in gears of mills of various designs. These wheels are manufactured to the 7th grade of accuracy by grinding (roughing and finishing) of all their surfaces after hardening.

The specification of the applied wheels is shown in table 1. The tested wheels are broken up into six groups of pair wheels. In each group, in turn, five couples of wheels with different modification of teeth. These modifications of teeth are characterized as follows:

- tested couple of wheels A. Wheels have a standard profile of tooth;
- tested couple of wheels B. Wheels have profile modification of teeth, received in the hydro abrasive way.

During experiments, tests periods were divided into two periods. An initial stage of break-in at the loadings causing tension no more than 0.6 at loadings and rotating speeds allowed during work. Conditions of break-in were chosen for all samples identical, considering that their hardness was HRC 45-50. Time of break-in for each couple was one hour that represents 46000 cycles of loading at drag torque 300 N·m. and rotating speed 800 rpm.

Table 1 – The sizes of the tested straight-toothed wheels

Characteristics of toothed wheels	1		2		3	
	Traction wheel	Driven wheel	Traction wheel	Driven wheel	Traction wheel	Driven wheel
Module (mm)	3	3	3,5	3,5	4,0	4,0
Number of teeth	59	59	56	56	51	51
Width of toothed ring (mm)	23	23	23	23	23	23
Material	steel 40X	steel 40X	steel 40X	steel 40X	steel 40X	steel 40X
Tooth hardness	45÷50	45÷50	45÷50	45÷50	45÷50	45÷50
Roughness of tooth surface, mkm	1,5÷2,0	1,5÷2,0	1,5÷2,0	1,5÷2,0	1,5÷2,0	1,5÷2,0
Accuracy of tested wheels	7-7-7B	7-7-7B	7-7-7B	7-7-7B	7-7-7B	7-7-7B

The noise measurements of the tooth gears of the transmissions were carried out in the operation modes given in table 2.

Table 2 – Load conditions

Number of rotations of traction wheel *n*, r/min	Load M, N·m
280	0, 200, 400, 600
400	0, 200, 400, 600
560	0, 200, 400, 600
800	0, 200, 400, 600

Removal and analysis of experimental results were conducted on a collected analog complex, shown in figure 2.

For measurement of noise level, the set of the acoustic equipment AK-12 was used, which included: accurate pulse noise- meter 00017 equipped with the one-inch microphone with the measuring microphone amplifier M 102 and a measuring microphone priming cap of MK102 and RG101 of model 00 003.

The microphone is installed in all cases at the same point, in 100 mm from the point corresponding to a gearing pole.

The noise of wheels was analyzed by means of the narrow-band analyzer SK4-26 with bandwidth 1/3 octaves during the gear work. Results of the spectral analysis were registered with the graph plotter N-306. For monitoring of required high-speed mode of gear, the digital frequency meter of 43-33 type was used. When required of repeated noise signals reproduction they were recorded on a DVD disk, and then it was analyzed more precisely.

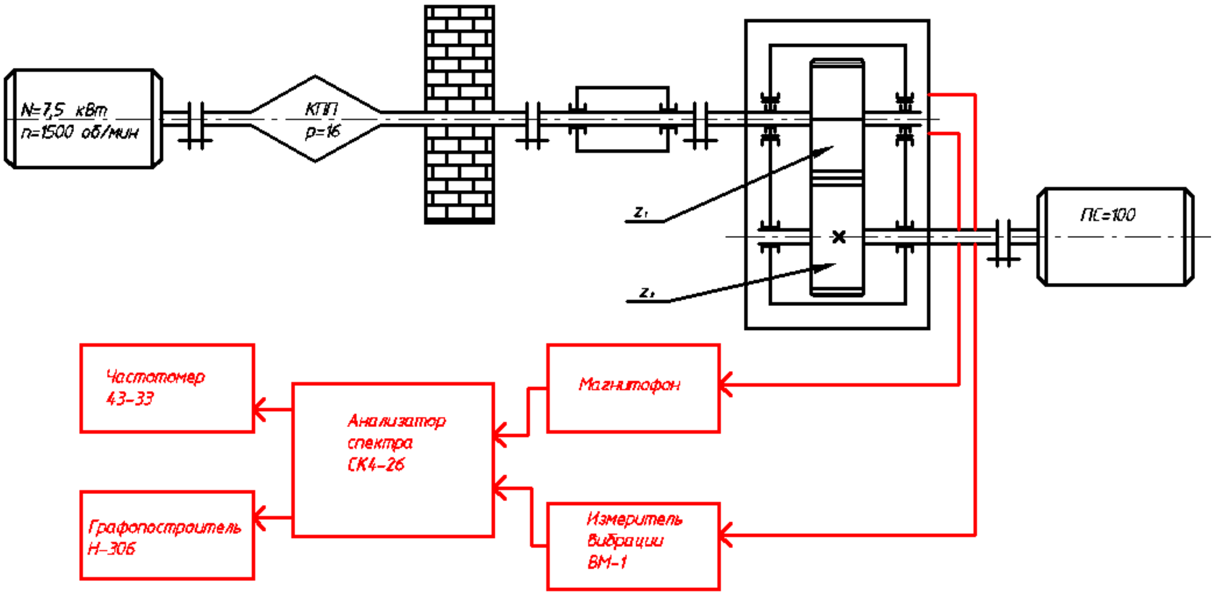


Figure 2 – Scheme of the test stand

Results and discussion

Results of measurement of a noise range for profile-modified and unmodified cogwheels are given in figure 3, the tooth frequency and its main subharmonics and harmonic as of the second order are also given. As it follows from comparison of noise ranges of the unmodified and modified cogwheels, application of profile modification, substantially reduces sound intensity level at a tooth frequency and its harmonica of the second order (to 12 dB), also reduces sound intensity level in subharmonics of tooth frequency (to 5 dB).

The results of the study of the influence of the parameters of the profile modification of the wheels teeth with high hardness of the side surfaces are given below.

A series of experiments was conducted on cogwheels which have profile modification of teeth, received in the hydro abrasive way (Tested couple B). From possible combinations of depth modification on ahead and root for gears $Z_1 = Z_2 = 57$, m = 3,5 mm, was chosen a row, providing continuous increase in depth of profile modification (table 3).

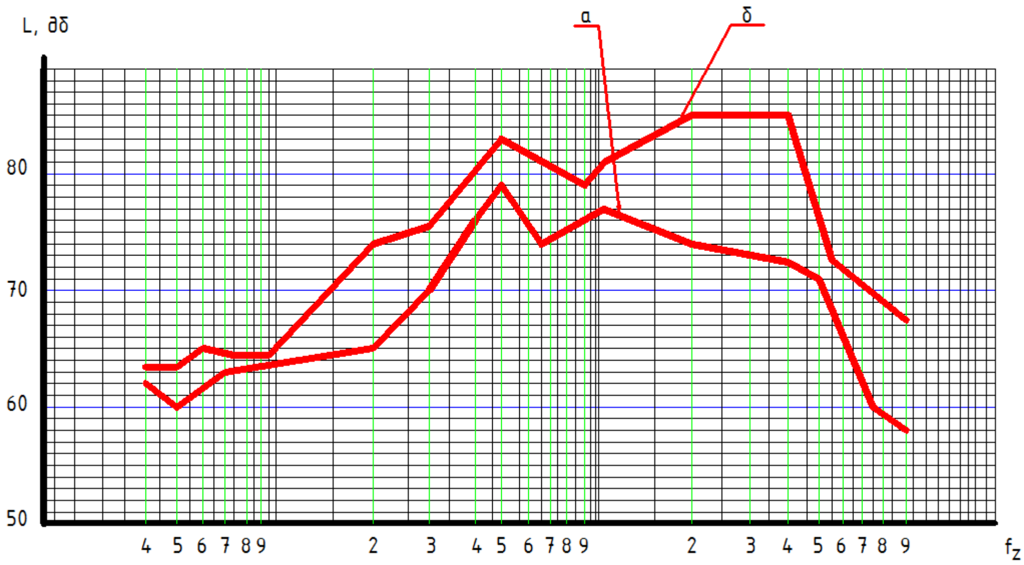


Figure 3 – Gear noise spectrum: a – Profile-modified teeths, b – Unmodified teeths

Table 3 – Depth parameters of profile modification teeth in tested cogwheels at the input and at the output of the gearing

№ of the tested couples of cogwheels	Depth of modification couples of teeth in gearing		
1	0,004	0,012	0,016
2	0,006	0,025	0,031
3	0,008	0,050	0,058
4	0,010	0,075	0,085
5	0,012	0,100	0,112

As a result of the conducted researches, the frequency characteristic of the noise of the gear train with profile-modified teeth is revealed. A characteristic frequency for transmission with a total depth of modification at the input of a pair of teeth in a mesh of 36 microns at n = 560 rpm and M = 200 N·m is shown in figure 4. At this peripheral speed, the transmission frequency was 465 Hz. This value falls into the limiting frequencies of the active band 500 Hz, which are 370 730 Hz. It can be seen from the graph shown that the intensity of sound pressure significantly (by 10 18 dB) increases in the active band corresponding to the frequency of the tooth and multiples of it (1 kHz, 2 kHz), and then decreases significantly. Due to the logarithmic law of addition of the sound pressure intensity, total transmission noise level is determined by the noise level at the mean geometric frequencies of the octave bands corresponding to the tooth frequency and multiples thereof.

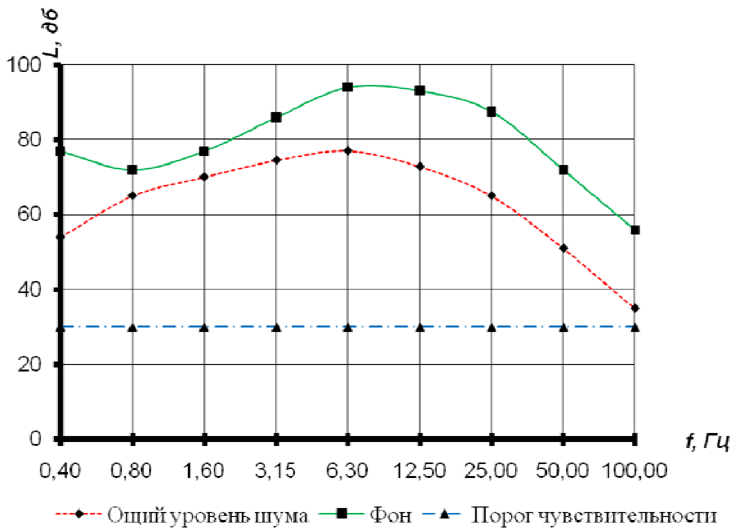
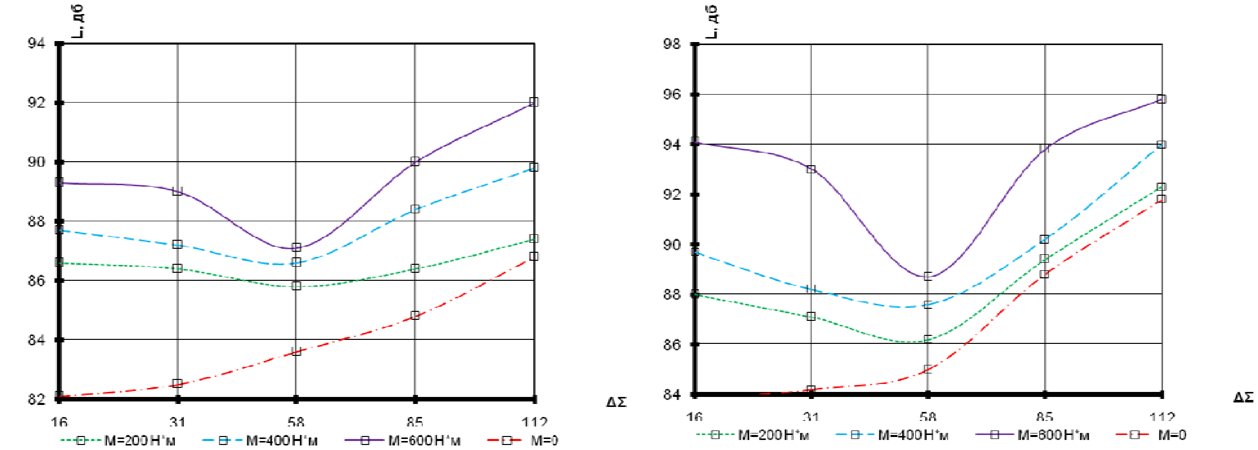


Figure 4 – The frequency characteristic of the noise tooth gear with the profile modified teeth

The characteristic of the background created by the test stand (the drive, an intermediate support, the lubrication system, a brake) in a measurement point is shown by shaped line in figure 4. Checking under the logarithmic law of addition of sound pressure intensiveness showed that additive to the noise level of the tested tooth gear from a background made no more than 0,5 dB, and it corresponds to average dispersion of an experiment by results of three-five measurements in each point

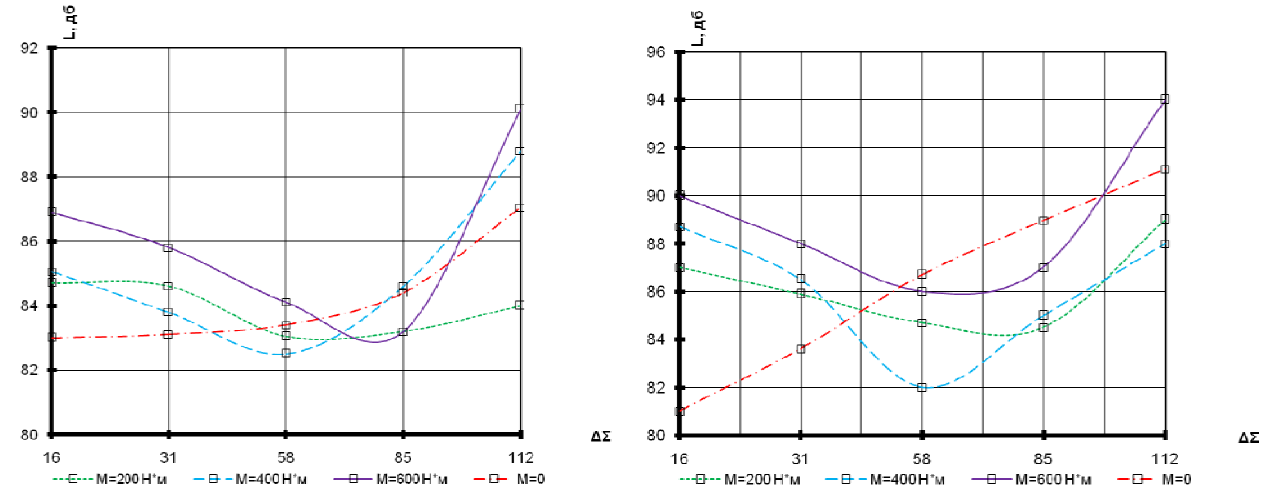
For medium geometrical octave band, center frequencies of 500 Hz, 1 kHz and 2 kHz schedules of dependence of noise level on depth of profile modification at different loadings and rotational speeds were constructed. Curves on the figures 5–7 are made after calculation of statistical characteristics of an experiment and smoothing of the function set in table in not equidistant points by method of the smallest squares.

Without loading at all rotating speeds, with increase in depth of profile modification, the noise level grows in gear. Under the loading, with increase in depth of profile modification noise level at the beginning decreases, and then increases. The general noise decrease in examinees tooth gears at different frequencies of octava strips at different stress and circumferential speeds, is given in table 4.



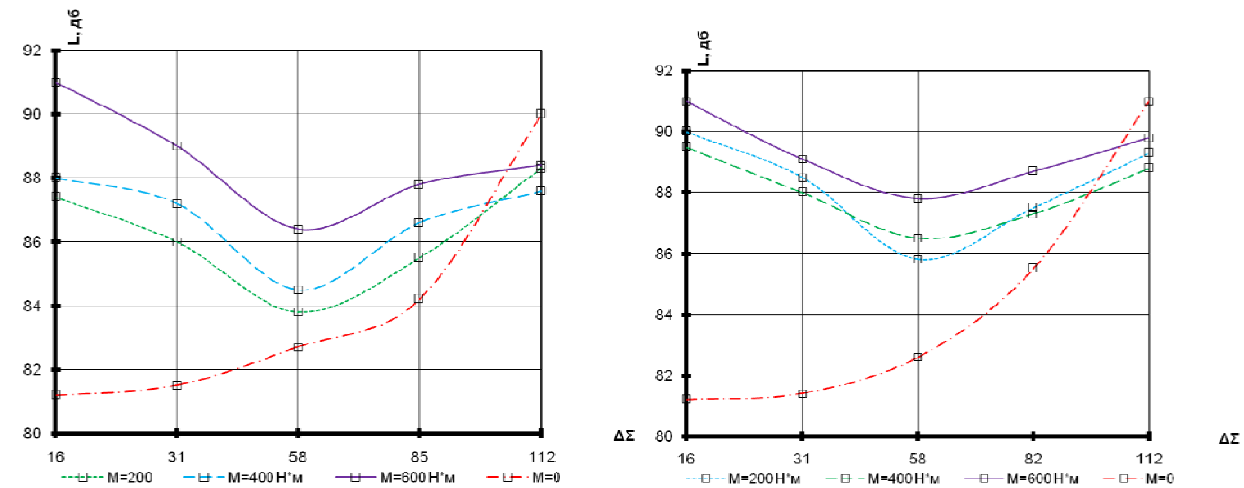
a) b)

Figure 5 – Dependence of noise level on depth of the profile modification
at n = 560 r/min, f = 500 Hz, f_{zz} = 532 gts (a) and at n = 800 r/min, f = 500 Hz, f_{zz} = 532 gts (b)



a) *b*)

Figure 6 – Dependence of noise level on depth of profile modification
at n = 560 r/min, f = 1000 Hz, f_{zz} = 532 Hz (*a*) and n = 800 r/min, f = 1000 Hz, f_{zz} = 760 Hz *(b)*



a) *b*)

Figure 7 – Dependence of noise level on depth of profile modification
at n = 560r/min, f = 2000 Hz, f_{zz} = 532 Hz (*a*) n = 800 r/min, f = 2000 Hz, f_{zz} = 760 Hz *b*)

Table 4 – The general noise decrease in tasted tooth gears

Octave band centre frequencies, Hz	Number of rotations, RPM	Stress, N·m	Average noise decrease, dB
500	560	200 400 600	1,9 1,7 3,5
	800	200 400 600	3,0 3,7 3,2
1000	560	200 400 600	3,0 2,7 2,8
	800	200 400 600	3,0 2,7 2,8
2000	560	200 400 600	3,2 2,6 2,4
	800	200 400 600	3,0 5,8 4,7

The average decrease in noise level due to the application of the full profile modification, received in the hydroabrasive way in the considered gears of 7th degrees of accuracy made 3 dB, which corresponds to decrease in intensity of noise approximately by one and a half times because of the logarithmic addition of intensiveness of noise of different sources.

Analysis of the shape and location of the contact spot on the side surface of the wheel tooth showed that with a small (insufficient) depth of the profile modification under the load, edge contact is clearly pronounced on the tooth head. At the optimum depth of the profile modification and close to it, the edge contact under load is absent; the contact patch has the correct shape.

Conclusion. Conducted researches on determination of noise levels of cogwheels with the modified teeth showed that:

1. For gears of 7÷9th extents of use on one of the interfaced wheel longwise modified teeth give a considerable decrease in stress concentration and reduction of vibration and noise of 3÷5 dB;

2. Application of profile modification teeth on all depth of tooth received in the hydroabrasive way, allowed us to reduce noise level by 4÷6 dB.

3. In the case of load absence and increase of the depth of profile modification noise level increases.

4. Under load, with increase in profile modification gear noise level decreases in the beginning, then increases.

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ТҮРЛЕНДІРІЛГЕН ТІСТЕРІ БАР РАДИАЛДЫ ЖЫЛЖЫМАЛЫ ОРНАҚТЫҢ ТІСТЕГЕРІШ ҚАПАСТАРЫНДА ТІСТІ ДОҢҒАЛАҚТАР ШУЫН ЗЕРТТЕУ

Аннотация. Мақалада тұрақты субмикрокристалды құрылымы бар шыбықтар мен құбырларды дайындаудың бірлескен жаңа әдісі ұсынылған: престеу үйлесімі бар радиалды-жылжымалы илемдеу әдісімен қарқынды пластикалық деформация. Радиалды жылжымалы орнақтың тісті дөңгелектерінің шуылға және оның дірілінің өзгеруіне әсері зерттелді. Сонымен қатар, арнайы әдіснама әзірленді және тиісті зерттеу құралдары пайдаланылды. Доңғалақтың түрлендірілген тістері бар тісті берілістердің шу деңгейін анықтау үшін арнайы стенд жобаланып, дайындалды. Зерттеу объектісі ретінде орта жылдамдықтағы дискілердің орташа өлшемді тузу тісті жұптары таңдалды. Стендте жүргізілген сынақтар шу мен дірілге, құбылу ауытқуына, жылдамдық пен жүктемеге және дөңгелектердің тістерінің профильді түрленуінің шу мен дірілге әсер ету тиімділігін анықтауға бағытталған. Түрлендірілген тістері бар тісті доңғалақтардың шуыл деңгейлерін анықтау бойынша өткізілген эксперименталдық зерттеулер көрсеткендей, бір дөңгелектегі доңғалақ бойлық түрлендірілген тістерді пайдалану дәрежесі 7÷9, жүктеме концентрациясының айтарлықтай төмендеуі және діріл мен шуылдың азаюы 3÷5 Дб және тіс биіктігіндегі тістерді профильді түрлендіру, гидроабразивті әдісімен алынған шу деңгейін 4÷6 Дб төмендетуге мүмкіндік берді. Егер жүктеме болмаса, шу деңгейі профильді түрлендіру тереңдігімен бірге артады. Жүктеме кезінде профильді түрлендіру күшейе бастағанда, берілісте шу деңгейі төмендейді, содан кейін артады.

Түйін сөздер: түрлендірілген тістер, тісті берілістер, түйіспе дағы, түрлендіру тереңдігі, тіс байланысы, тіс жиілігі.

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ИССЛЕДОВАНИЕ ШУМА ЗУБЧАТЫХ КОЛЕС ШЕСТЕРЕННОЙ КЛЕТИ РАДИАЛЬНО-СДВИГОВОГО СТАНА С МОДИФИЦИРОВАННЫМИ ЗУБЬЯМИ

Аннотация. В статье предложен новый совмещенный способ изготовления прутков и труб со стабильной субмикрокристаллической структурой: интенсивная пластическая деформация методом радиально-сдвиговой прокатки с сочетанием прессования. Исследовано влияние модифицированных зубьев колес шестереных клетей радиально-сдвигового стана на шум и вибрацию его привода. При этом разработана специальная методика и применены соответствующие средства исследования. Для определения уровня шума в зубчатых передачах с модифицированными зубьями колес был разработан и изготовлен специальный стенд. В качестве объекта исследования были выбраны среднескоростные дискового типа прямозубые пары средних размеров. Испытания, проводившиеся на стендах, имели целью выяснить влияние модифицированных зубьев колес на шум и вибрацию, варьирования перекоса, скорости и нагрузки и эффективность влияния профильной модификации зубьев колес на шум и вибрацию при варьировании зазора между зубьями, скорости и нагрузки. Проведенные экспериментальные исследования по определению уровней шума зубчатых колес с модифицированными зубьями показали, что для передач 7÷9 степени использования на одном сопрягаемом колесе продольно модифицированных зубьев дает значительное снижение концентрации нагрузки и уменьшение вибрации и шума 3÷5 дБ, и применение профильной модификации зубьев по всей высоте зуба, полученной гидроабразивным способом, позволило снизить уровень шума на 4÷6 дБ. При отсутствии нагрузки, с увеличением глубины профильной модификации уровень шума возрастает. Под нагрузкой, с увеличением профильной модификации уровень шума передачи вначале уменьшается, затем увеличивается.

Ключевые слова: модифицированные зубья, зубчатые передачи, пятна контакта, глубина модификации, контакт зубьев, зубцовая частота.

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ANALYTICAL REVIEW OF SOFTWARE FOR MULTI-AGENT SYSTEMS AND THEIR APPLICATIONS

Abstract. In this article there was conducted an analytical review of the most common modern software and implemented on their basis practical applications. There is considered the history of development of multi-agent systems (MAS). The relevance of the use of multi-agent technologies for the creation of information systems for the complex objects modeling based on various methods and algorithms is noted. There were considered the most widespread agent-oriented platforms of multi-agent systems, the comparative analysis of their characteristics and presented the development tools was carried out. The examples of modern multi-agent applications implemented with the help of these software products in industry, science and education were presented. The features of applications functioning in the production of goods and services, as well as of complex processes modeling were pointed out. Particular attention is paid to the Java Agent Development Framework (JADE), presented the structure, main functions and methodology of the multi-agent systems development. The advantages of multi-agent systems (flexibility of operation, operational interaction between agents, optimal distribution of computing resources, self-organization and multifunctionality) at creating innovative intellectual technologies based on different approaches applying and on system analysis were shown. There were analyzed the features of agent technologies and prospects of their use for the development of complex multi-user programs.

Keywords: multi-agent systems, analytical review, software.

Introduction. The development of powerful personal computers with high computing productivity and with large memory capacity, as well as the need to process large amounts of information led to the development of new intelligent technologies based on various modern approaches. Multi-agent systems (MAS), in which interacting agents are used for solving complex problems, have become widespread. Many MASs are the basis of large-scale open, decentralized systems, which consist of autonomous components with such features as reactivity, proactivity, and the ability for flexible interactions to achieve their goals [1]. Under the term reactivity of agents, there is meant the ability of agents placed in the environment to perceive this environment and to react to changes occurring in it. Proactivity is the properties of agents in order to solve problems in the environment on their own initiative. In MAS agents interact with each other, and also make independent decisions based on the implementation of certain algorithms to achieve the set goals.

Multi-agent systems have a 40-year history [2, 3]. At the end of 1990, there was a significant interest to self-organizing MAS. A lot of scientific works are devoted to the study of MAS, among which there are works by Ferber J., Schumacher M [4], Roberto A. Flores-Mendez [5], Chavez A. [6], Brooks T., Finin N. Jennings, Wooldridge M., B.I. Gorodetsky, V.B. Tarasova, V.F. Khoroshevsky and others. The most famous works are by Jacques Ferber [7], who was one of the first in France in the 90s to publish works on the MAS. In 2000-2005 there was created a working group "Self-organizing MAS" based on the European project program FP3-5 "AgentLink", which gave a powerful impulse for the researches and development in this field.

The relevance of MAS developing is determined by the need to solve complex problems that are characterized by high complexity of calculations, parameters uncertainty and functioning in real time. The main advantages of MAS are the optimal distribution of computing resources, flexibility (the system can be supplemented and modified), self-organization, self-recovery and fault tolerance, multifunctionality, etc.

The article gives an overview of the main agent-oriented platforms, their advantages and sphere of their application. There are considered the examples of modern software products application implementing a multi-agent approach to real applications in various fields of science and technology. Particular attention is paid to the multi-agent platform JADE, as to the most widespread and open system for the development of MAS. At the end, there is given a conclusion on the results of the analytical review.

Multi-agent platforms review. There is a large number of software implementing the MAS. The most famous platforms are: JADE (Java Agent Development Framework [5]), JACK Intelligent Agents [17], MadKIT (Multi-Agent Development Kit [18]), Agent Builder [23], Cougaar (Cognitive Agent Architecture [27]), Zeus (Agent Building Tool-kit) [34], MASON (Multi-Agent Simulator Of Neighborhoods [36]), etc.

Most of the presented platforms are based on the Java programming language, which allows to develop multi-agent applications on a cross-platform basis, that is, to run the final software product in various operating systems. Each platform has its own characteristics. Most multi-agent platforms have an open license and are distributed free of charge. Paid platforms (for example, Agent Builder) are closed and do not allow to change the initial code. Each software is characterized by its own tools and development models, and also has various applications.

Table 1 presents the most known multi-agent platforms and their characteristics.

Table 1 – Multi-agent platforms

#	Platform	License	Development tools
1	JADE (Java Agent Development Framework)	open (GNU Lesser General Public License)	Agent Management System, Director Facilitor, Agent Communication Channel
2	MadKIT (Multi-Agent Development Kit)	open (CEA CNRS INRIA LogicielLibre)	Agent/Group/Role model, Organization-centered Multiagent System
3	JACK Intelligent Agents	open (Proprietary software)	Belief-Desire-Intention Model, JACK Development Environment (JDE), JACK Object Modeller (JACOB), JACK Plan Language (JPL), Agent Run-time
4	Agent Builder	closed (not free of charge)	Project Control Tools, Ontology Manager, Agency Manager, Agent Manager, Agent Debugger
5	Cougaar (Cognitive Agent Architecture)	open (Cougaar Open Source License)	Blackboard, Http servlet engine, Knowledge representation system
6	Zeus (Agent Building Tool-kit)	open (free initial code)	Three layers of agents, Role Modeling
7	MASON (Multi-Agent Simulator of Neighborhoods)	open (free initial code)	2d and 3d Libraries

1. JADE (Java Agent Development Framework) [5] – a widely used software platform that is an effective tool for the development of applications based on MAS. The platform has three main modules in accordance with FIPA standards (Foundation for Intelligent Physical Agents). Agent Management System AMS controls the registration and authentication of agents, manages the life cycle of all agents within it, and also provides services of white pages (the register of existing agents). The DF (Director Facilitor) module provides yellow page services (the register of agent services registered in the AMS). The third module ACC (Agent Communication Channel) controls the communication between agents. The structural diagram of JADE is shown in figure 1.

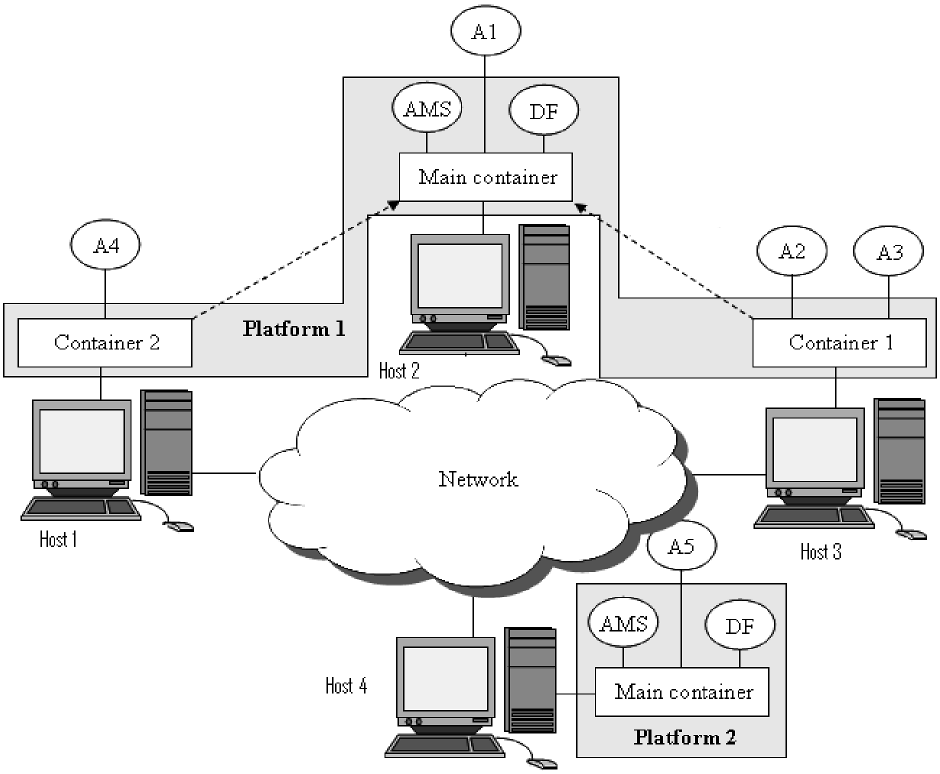

Figure 1 – Java Agent Development Framework multi-agent platform

Working with the multi-agent platform JADE there are used the standard agents Dummy Agent and Sniffer Agent, which are system controllers responsible for the operation of the main container. In order to transfer information between agents there is used a ready agent Dummy Agent, the parameters of which are specified in the additional user interface. Another ready-made tool Sniffer Agent allows to view the transmitted data between agents and to write them to the Log Manager.

Agents communicate through the ACL (Agent Communication Language) FIPA language and can communicate, regardless whether they are in the same container (for example, A2 and A3) or on different platforms (for example, A1 and A5). The communication is based on the paradigm of asynchronous messaging. The message format is built in ACL (Agent Communication Language) language, which consists of such fields as: sender, recipient, communication and content. The communication field indicates the intention to transfer information to another recipient and sends a message through the sender. The content field contains the type of processed information. In JADE the message elements can be of the primitive type (logical expression, digit, line) or of the aggregate type (user-defined structure consisting of primitive or of set of elements). Aggregate elements are usually represented as Java, XML, and bytecode classes.

Multi-agent applications based on JADE are widely used in industry, education and science. In the technology of industrial agents [9, 10] there are used the advantages of distributed computing, artificial intelligence (AI) methods and semantics in production and services spheres. In real applications, there is provided a new method of design and control based on decentralized control over distributed structures. Advantages of industrial systems based on agents are: reliability, scalability, flexibility and productivity. For example, the work [11] presents a system of information processes modeling using JADE. There is used a library that integrates in JADE and allows the proper distribution of resources. As a result of comparative tests, it was proved that in practice this modeling based on agents shows the best results.

Also, JADE is widely used in the creation of information systems in the field of education. The article [12] presents a multi-agent smart-system of distance learning (DL) for people with impaired vision (PIV). The multi-agent approach is used to optimize the functioning of the information system of DL based on intellectual, cognitive and statistical methods. In order to optimize the work of DL for PIV, the agents were distributed by containers in the JADE software environment. In work [13] there was developed a multi-agent system which is used to search and to submit training materials stored on various servers. This model is developed using JADE and the standard of metadata LOM (Learning Object Metadata), which has a hierarchical structure and provides quick access to information. The multi-agent technology improves the effectiveness of the search for educational materials. The article [14] presents a multi-agent system, which is designed to facilitate the acquisition of knowledge by older people. The advantage of the proposed approach is the possibility of using mobile devices that increase the availability of learning for dependent people. In work [15] there is considered a multi-agent model for the computer support system for collective learning. The model is aimed at identifying conflicts that have arisen in groups for improving co-education, as well as for personal training of group members. By analyzing the processes of interaction between groups, the conflicts are recognized. In order to determine the most appropriate learning strategy, the joint characteristics of students are taken into account. A similar MAS is presented in the article [16]. There is used a problem-based learning model (PBL, Problem-Based Learning) to detect passive students in a virtual DL environment. The system is designed to identify undesirable situations and to improve the learning process.

2. MADKit (Multi Agent Development Kit) [17] - is a modular and scalable multi-agent platform with open initial code written in Java and built using the AGR (Agent / Group / Role) model. The platform allows to create the distributed applications and to conduct modeling using a multi-agent paradigm. One of the key aspects of MADKit is that in comparison with conventional approaches that are mostly agent-oriented MaDKit uses the OCMAS (Organization-centered Multi- AgentSystem) approach. The main features of MaDKit are:

- the creation of intelligent agents and lifecycle control;
- the creation of an infrastructure that is used to provide communication between agents and for the structuring of multi-agent models;
- the development of distributed applications based on a set of agents.

Based on MADKit there are created the majority of multi-agent applications in the field of modeling for the industry. In work [18] there is proposed the multi-agent system IDS (Intrusion Detection System), which uses the advantages of mobile agents to improve the output of network channels. Mobile agents provide network security. In work [19] there is proposed the MAS for control and optimization the heating and ventilation processes inside the smart building. This MAS is designed to maintain a high level of comfort for residents, for minimization energy consumption and for reduction of its cost. Experimental results and their analysis confirm the effectiveness of the created MAS.

3. JACK Intelligent Agents – software complex [20] is a cross-platform environment for the creation and integration of commercial industrial systems. The complex is built on an efficient logical basis BDI (Beliefs/Desires/Intentions). In JACK there are created the agents taking into account beliefs, desires and intentions for the realization of their own goals. System packers with a high degree of encapsulation are responsible for the work of agents. Each agent is determined depending on its goals, knowledge and communication capabilities, and then autonomously performs its individual function in the environment. This approach in JACK is an effective way to create applications for dynamic and complex environments. Each agent is responsible for the implementation of its own goals, responds to events in the environment and communicates with other agents.

The key advantage of [21] JACK is an efficient cross-platform platform:

- low requirements for computing resources, designed for processing hundreds of agents working on low-level hardware;
- "transparent" communication between agents;
- the availability of a graphical tool for developing agents.

For example, the article [22] presents the dynamic planning MAS for production of MFL (Manufacturing Flow Lines) using the JACK-based Prometheus (PM) design tools. The PM methodology is used to develop a decision-making system with the possibility of dynamic restructuring. Each agent in the MAS is autonomous and has the ability to interact with other agents. The proposed decision-making system supports both static and dynamic planning.

4. Agent Builder [23] – is an integrated set of tools for creating intelligent software agents. Agent Builder consists of two main components: the toolkit and the compilation environment. The Agent Builder toolkit includes: tools for controlling the development of multi-agent software, for analyzing agent transactions, for designing and developing interrelated agents, for determining the behavior of individual agents, and tools for agents debugging and testing. The agents created with the help of Agent Builder communicate using the knowledge management language and KQML (Knowledge Query and Manipulation Language) requests and support many functions for information exchange.

Agent Builder Toolkit is designed for quick and easy creation of intelligent agents and multi-agent software on a commercial basis. It has flexible tools for organizing the projects that allow the MAS developer effectively to manage the process of creating the entire software. This toolkit contains:

- Ontology Manager, which assists the developer in analyzing the agent's problem area and in determining the structure relevant to the agent's work in this area.
- MAS Manager (Agency Manager) provides a temporary user window for viewing the operation of the entire agent system. Therefore, the developer can monitor and manage inter-agent communications, and also run a debugger to check the status of individual agents.
- Agent Manager has a tool for configuring the behavior of an individual agent. This tool includes a graphical editor for setting the initial characteristics of an agent: beliefs, commitments, intentions, opportunities and behavior. In addition, the agent manager provides the ability to plan and to train the agent.
- Agent Debugger provides the means to communicate with the executing agent, and also enables the software developer to detect system errors. Therefore, Agent Builder reduces time and development costs and simplifies the creation of high-performance, fault tolerant multi-agent applications.

There are many commercial high-performance systems [24]. The article [25] presents an intelligent factory control system that includes an industrial network, a cloud storage and dispatcher control terminals for facilities (machines, conveyors and products). These objects are classified by different types of agents, which are coordinated and controlled in the cloud space. On the basis of self-organizing MAS the work of the factory's infrastructure is coordinated through the feedback.

In the research [26] there are considered the MAS for solving the problems of production automation. There were developed the agents for the physical equipment control, which is implemented on the basis of special standards of industrial control.

5. *Cougaar (Cognitive Agent Architecture)* [27] – is a Java architecture for the creation of large-scale applications based on distributed agents. The Cougaar architecture is an open initial code that describes the class structure and basic service procedures for the creation of multi-agent applications. The Cougaar platform allows the creation of large-scale distributed systems consisting of a large number of agents. Organization of the agents work at the creation of applications is carried out using peer-to-peer groups that can effectively perform localized functions. As a result, communities are created, consisting of a set of agents.

The structure of Cougaar agents includes several integrated extended services:

- "blackboard" is intended for communication of agents among themselves;
- HTTP services (Hyper Text Transfer Protocol) for user interfaces;
- knowledge representation systems;
- coordination between the agents through the mechanisms of assignments.

With the use of Cougaar there are created applications in the field of logistics [28-30], modeling and technical objects support. The article [31] there was developed a cyber-physical system based on MAS in order to solve the problem of optimizing urban traffic. An effective mechanism is introduced in order to control the traffic taking into account the infrastructure, which allows to analyze the traffic capacity and to recognize its participants. The ontology, which acts as a knowledge base. is included in the traffic control system. The research [32] considers an adaptive MAS based on the behavior of an ant colony and a hierarchical fuzzy model. This system allows effectively to regulate the traffic in accordance with the changes in road networks in real time. The article [33] proposes an integrated approach for modeling the transport infrastructure and for optimization the traffic around the city. In order to create an extensive multi-layer transport network, there are modeled various intelligent transport agents taking into account the roads, tram and bus routes, bicycle paths, pedestrian paths. Direct interaction is provided between the mobile devices of the users and the MAS in order to send travel requests.

6. Zeus (Agent Building Tool-kit) [34] is a graphical environment for creating systems based on distributed agents. It includes tools for development, planning and visualization. Platform agents have three levels. In the first level, the agent is viewed as an autonomous object that can act according to his beliefs, resources and preferences. In the second level, the agent is defined as the organization in which the relationship between agents, protocols and other interaction mechanisms is examined. The third level serves for coordination, where each agent is viewed as an object with its own communication and control skills. In Zeus there is used the "RoleModeling" approach based on the distribution of agents by functional roles.

The main features of the Zeus Agent Toolkit are the modeling of complex processes. Applications based on the Zeus Agent Toolkit can be used to solve problems in the oil and gas industry. The work [35] presents the MAS, the agents in which successfully solve complex and distributed problems related to the production, storage, transportation and processing of petroleum products.

7. MASON (Multi-Agent Simulator of Neighborhoods) [36] - is a high-performance Java platform for multi-agent modeling of various processes, which has opportunities for graphical representation in two-dimensional and three-dimensional forms.

This platform has the following advantages:

– speed of data processing;
– small requirements for computing resources;
– possibility of integration with other applications;
– 2D and 3D visualization.

The MASON platform is used to develop practical applications for solving various tasks, for example:

– urban traffic modeling;
– surveillance of unmanned aerial vehicles, etc.

Using MASON [37] there was developed a multi-agent model of urban traffic in order to study the cars movement and to analyze its flows. Modeling predicts the occurrence of cars at intersections, taking into account the distance and speed of movement. It also takes into account the work of traffic lights, which are involved in the traffic distribution. With the help of this system, there are solved the problems of the transport optimal distribution along the roads.

In work [38] there is considered the effectiveness of the application of various algorithms for agents of observers. Observers and objects are modeled in a virtual environment (2D or 3D) in real time. There is formed a joint target surveillance environment in which customizable algorithms are implemented.

The article [39] presents researches aimed at developing an application on the basis of MAS for the mobile health application SMPHR (Self-Management mobile Personal Health Record). The system is designed for continuous care of patients with chronic diseases. The SmPHR application was developed for the mobile operating system Android 4.0.3 and implemented in accordance with standard health protocols. As a result, SmPHR can provide patients with mobile medical care and connect them to various devices via standard protocols.

Conclusion. Therefore, as a result of the conducted analytical review, there were considered the widespread agent-oriented MAS platforms and was carried out a comparative analysis of their characteristics. There were presented examples of practical multi-agent applications implemented with the help of the software in various fields of industry, science and education. Particular attention is paid to the Java Agent Development Framework (JADE), were shown the structure, main functions and methodology of the MAS development.

Advantages of MAS:

– flexibility of functioning;
– operational interaction between agents;
– optimal distribution of computing resources;
– the ability to learn and solve specific and global problems;
– autonomy, limited representation, decentralization of agents;
– self-organization;
– multifunctionality;
– reliability and resistance to failures.

The article deals with the features of agent technologies and the prospects of their use in the development of complex multi-functional applications. There were noted the actual directions of MAS, the possibility of creating and implementing mechanisms that allow agents dynamically to change the nature of interaction, and also to adjust goals, depending on changing conditions.

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МУЛЬТИАГЕНТТІК ЖҮЙЕЛЕР МЕН ОЛАРДЫҢ ҚОСЫМШАЛАРЫН ПРОГРАММАЛЫҚ ҚАМТАМАСЫЗ ЕТУІНЕ АНАЛИТИКАЛЫҚ ШОЛУ

Аннотация. Мақалада кең таралған заманауи бағдарламалық қамтамасыз ету мен оның негізінде жүзеге асатын тәжірибелік қосымшаларға талдау жүргізілді. Мультиагенттік жүйелердің (МАЖ) даму тарихы қарастырылды. Әртүрлі әдістер мен алгоритмдер негізінде күрделі объектілерді моделдеу үдерісі үшін ақпараттық жүйелерді құрудағы мультиагенттік технологияларды құрудың өзектілігі келтірілген. Мультиагенттік жүйелердің агентті-бағытталған платформалары қарастырылған, сипаттамаларына салыстырмалы талдау жасалып, оларды құру құралдары келтірілген. Өндірісте, ғылым мен білім беруде қолданысқа ие бағдарламалық өнімдердің негізінде жүзеге асқан заманауи мультиагенттік қосымшалардың мысалдары келтірілген. Тауар өндіру саласы мен қызметі, сондай-ақ күрделі үдерістерді моделдеуде пайдаланатын қосымшалар қызметінің ерекшелігі айқындалды. Java Agent Development Framework (JADE) платформасына ерекше мән беріліп, оның құрылымы, негізгі функциялары мен мультитагенттік жүйелерді құрудың әдістемесі келтірілген. Жүйелік талдау мен түрлі тәсілдерге негізделген инновациялық интеллектуалды технологияларды құруда қолданылатын мультиагенттік жүйелердің артықшылықтары (функционалдану иілгіштігі, агенттердің арасында шұғыл өзара байланыс орнату, есептеуіш қорларды оңтайлы тарату, өзара ұйымдастыру мен көп функционалдық) ұсынылған. Агенттік технологиялардың ерекшеліктері мен күрделі көп пайдаланушылық бағдарламаларды құруда қолданылу болашағы талданды.

Түйін сөздер: мультиагентті жүйелер, аналитикалық шолу, бағдарламалық қамтамасыз ету.

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АНАЛИТИЧЕСКИЙ ОБЗОР ПО ПРОГРАММНОМУ ОБЕСПЕЧЕНИЮ МУЛЬТИАГЕНТНЫХ СИСТЕМ И ИХ ПРИЛОЖЕНИЙ

Аннотация. В данной статье проведен аналитический обзор наиболее распространенного современного программного обеспечения и реализованных на их основе практических приложений. Рассмотрена история развития мультиагентных систем (МАС). Отмечена актуальность применения мультиагентных технологий при создании информационных систем для процессов моделирования сложных объектов на основе различных методов и алгоритмов. Рассмотрены наиболее распространённые агентно-ориентированные платформы мультиагентных систем, осуществлен сравнительный анализ их характеристик и приведены инструменты разработки. Представлены примеры современных мультиагентных приложений реализованных с помощью этих программных продуктов в промышленности, науке и образовании. Выделены особенности функционирования приложений в сфере производства товаров и услуг, а также моделирования сложных процессов. Особенное внимание уделено платформе Java Agent Development Framework (JADE), приведены структура, основные функции и методология разработки мультиагентных систем. Показаны достоинства мультиагентных систем (гибкость функционирования, оперативное взаимодействие между агентами, оптимальное распределение вычислительных ресурсов, самоорганизованность и многофункциональность) при создании инновационных интеллектуальных технологий, основанных на применении различных подходов и системном анализе. Проанализированы особенности агентных технологий и перспективы их использования для разработки сложных многопользовательских программ.

Ключевые слова: мультиагентные системы, аналитический обзор, программное обеспечение.

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DEVELOPMENT OF TECHNOLOGY FOR CHROMITE CONCENTRATE FROM THE SLURRY TAILINGS OF ENRICHMENT

Abstract. The exploration results of manmade residues retreatment – slurry tailings of chromite ore enrichment of Donskoi Ore Mining and Processing Plant of the Republic of Kazakhstan are performed in the article.

The technology of chromite concentrate extraction by chemical enrichment and centrifugal separator methods has been developed. The technology includes preliminary activation processes of chromite-containing tailings in sodium hydro-carbonate solution, leaching in ammonium bisulfate solution and gravity concentration in a centrifugal separator. The preliminary activation process is required to increase enrichment degree of chromite-containing tailings when leaching by means of accompanying elements removal – magnesium, silicium, ferrum. Quantitative composition of samples is changed insignificantly as a result of activation. At the same time, the phase composition of samples is changed, calcium oxides phases and ratio of magnesium-containing phases are disappearing.

Prime results through researches when choosing reagent to slurry tailings leaching have been achieved by using 30%NH_4HSO_4solution. Out of data of X-ray phase and chemical analysis, follows that when leaching slime tailings, the rock-forming minerals mainly go to solution, while chromium and chromite-containing minerals, kaolinite and amorphous silica remain in the cake-the rough concentrate.

Chromite concentrate has been received at rough concentrate treatment using centrifugal separator KNELSON consisting of chromite mineral - $(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$ with Cr_2O_3 59,2% content when ejecting Cr_2O_3 into 86,8% concentrate. Technology engineering of chromite slurry retreatment contributes to solve an environmental problem and also to increase chromite concentrate production.

Key words: slurry tailings, activation, ammonium bisulfate, centrifugal separator, and chromite concentrate.

Introduction. Processing of accumulated and newly formed manmade waste, including chromite tailings, is an actual task of the present.

The importance of solving the problem of involving in the processing of wastes of enrichment products is associated not only with ecology but also with the need to increase the production of chromium. For the period from 2005 to 2012, the world production of chromium, according to the International Chromium Development Association (ICDA), increased from about 18 million tons to 24 million tons [1].

Donskoy Ore Mining and Processing Plant is the enterprise that extracts and enriches chromium raw materials in Kazakhstan. Gravitational technology for chromium ore enrichment makes it possible to obtain a chromium concentrate from large and medium fractions. At the same time, the fine-grained tailings are practically not enriched because of the difficulty of separating complex minerals into chromium concentrates and empty rock [2, 3].

Research in Physics and Chemistry. Slurry tailings of chromite ores enrichment of the Donskoy Plant were used in the work. Chemical analysis of slurry tailings is given in table 1.

The results of X-ray diffraction analysis of slurry tailings of the Donskoy Plantare presented in table 2.

Table 1 – Chemical composition of thechromiteoreslurrytailings

Name	Content, %	Name	Content, %
Cr_2O_3	25,47	Cu	0,008
Fe_2O_3	9,1	Pb	0,05
SiO_2	21,53	As	0,025
AI_2O_3	1,51	Sb	0,23
H_2O(bound)	7,8	K	0,05
CaO	0,75	Na	0,05
MgO	29,4	P	0,008
MnO_2	0,053	C	< 0,2
S_{com}	0,1	Ag g/t	< 2,0
$S_{sulf.}$	< 0,1	Au g/t	< 0,05
Zn	0,1	Ni	0,28
Co	0,02		

Table 2 – Phase composition of the slime tailings

Name	Formula	%
Antigorite	$Mg_3Si_2O_5(OH)_4$	41,8
Aluminum-ferruginousmagnesite	$MgFeAlO_4$	29,7
MagnesiumChromite	$MgCr_2O_4$	12,5
Clinochlore	$Mg_6Si_4O_{10}(OH)_8$	5,1
CalciumIronOxide	$CaFe_2O_4$	4,8
Aluminous Iron Oxide Of Calcium	$Ca_2Fe_{1.28}Al_{0.72}O_5$	3,9
Brownmillerite	$Fe_{1.33}A_{1.67}Ca_2O_5$	1,7
AluminumCalciumSilicate	$Ca_{46}(Al_{92}Si_{100}O_{384})$	0,3
AluminumMagnesiumCalciumSilicate	$Ca_{23.20}Mg_{22.4}(Al_{92}Si_{100}O_{384})$	0,3

Mineralogical analysis of the samples was carried out using the microscope MIN-8 at 320x magnification, and using the OLYMPUS microscope at 200x, 400x magnification in transmitted light in an immersion medium and in polished sections in reflected light under an inverted Leica microscope. The photomicrographs of the samples in reflected light were made at 300x magnification using an inverted Leica microscope, in transmitted light with the help of the OLYMPUS microscope at 200x, 400x magnification using the StreamBasicR software (figure 1).

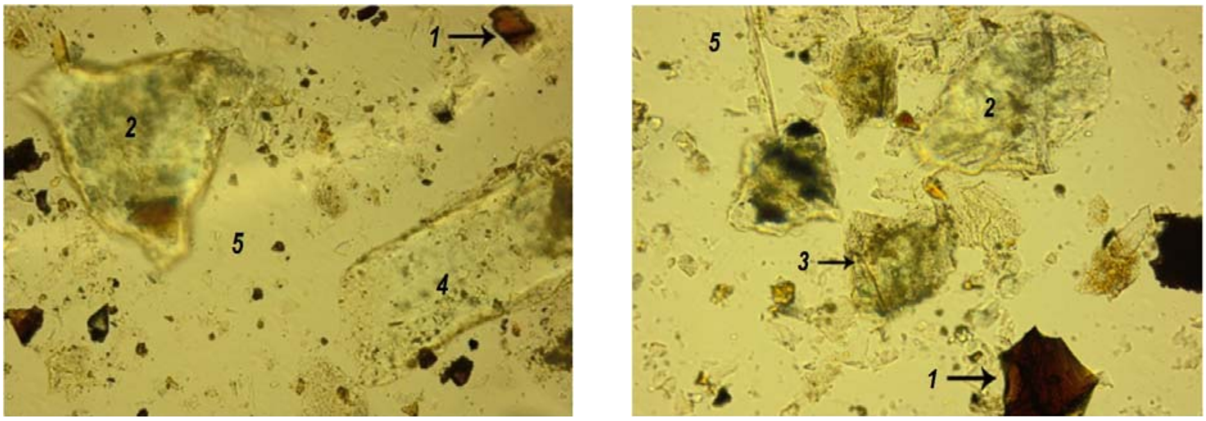

Figure 1 – Mineralogical composition of the slime tailings:
1 – shungit; 2 – spinel minerals chlorite group; 3 – aluminum-magnesium spinel; 4 – antigorite; 5 – immersion environment

The spinel of minerals of the chlorite group is represented by chamosite (Fe¸ Mg¸ Al) (Si¸ Al) 4O10 (OH) 8 - yellowish-green lamellar grains with pleochroism (pleochroism from green to light yellow).

Aluminum-magnesian spinel - Fe, Mg, Al, Cr - grains from brown to reddish brown, isotropic, fractured shell.

Antigorite Mg3Si2O5 (OH) 4 - anisotropic colorless grains with a fibrous structure. Optically biaxial negative 2V (-), with refractive index N ~ 1,550.

The thermal analysis of the tailings was carried out using a synchronous thermal analysis instrument STA 449 F3 Jupiter. Before heating, the oven space was pumped out and then purged with an inert gas. Heating of the samples was carried out at a rate of 10°C/min, in an environment of highly purified argon. The volume of incoming gas varied depending on the chemical analysis of the sample and was maintained in the range of 80-90 ml/min. Cooling was carried out to 300°Cat a speed of 15°C/min. The processing of the results obtained with the STA 449 F3 Jupiter was performed using the NETZSCHProteus software (figure 2).

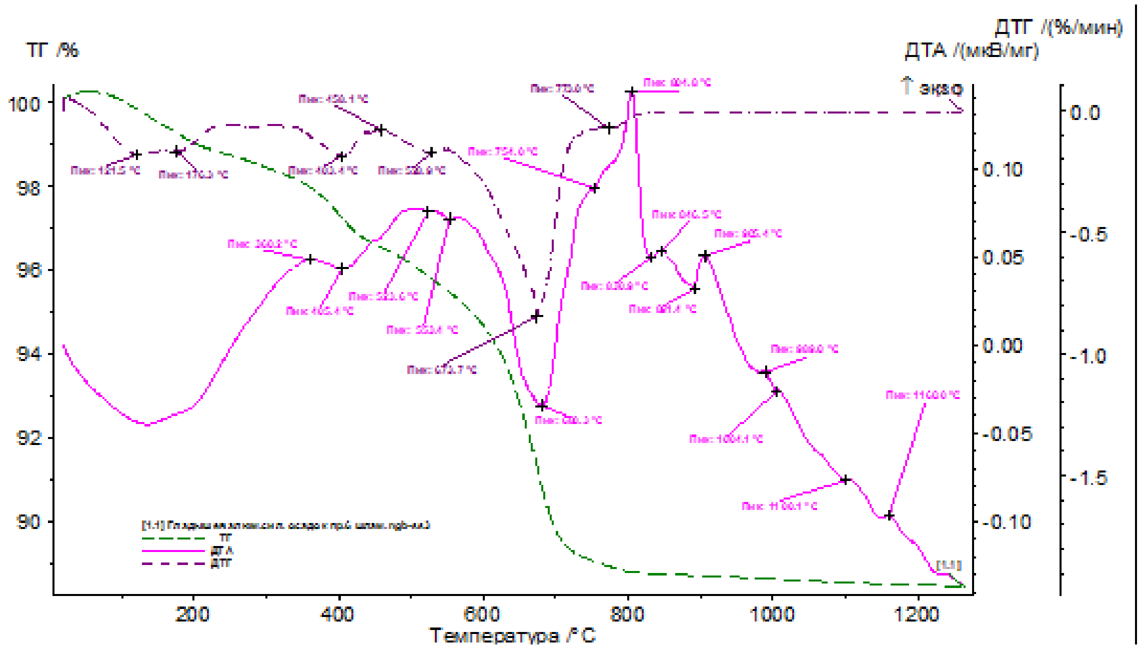

Figure 2 – Thermogram of slurrytailings

The most intense effect on the ДТА curve is endothermic, with maximum development at 680 °C accompanied by a decrease in weight of the sample. In combination with exothermic peaks at 805 °C and 1160 °C this effect may reflect the manifestation of serpentine. At680°C,the structure of the mineral breaks down with the simultaneous removal of the OH group, and the formation of new mineral phases, crystalline forsterite, and X-ray amorphous enstatite. The exothermic peak at 805°C reflects the ordering of the forsterite structure, and the peak at 1160°C shows the crystallization of X-ray amorphous enstatite. At a minimum of 403°C on the curve of DTG reflects the manifestation of dehydration of iron hydroxide, magnesium, and chromium oxyhydroxide. A weak maximum on the same curve at 458°C may show the oxidation of ferrous iron in magnetite or chromite by residual oxygen. The combination of an endothermic effect with an extremum at 680°C, an endothermic effect with an extremum at 831°C, and an exothermic effect at 847°C can be interpreted as a manifestation of some magnesian chlorite - pennin, cammererite, clinochlore. The combination of an exothermic effect with a peak at 360°C, endothermic effects with extremums at 680°C and 745°C, and an exothermic effect with a peak at 905°Capparently reflects the presence of a margarite$CaO_2Al_2O_32SiO_2H_2O$in the sample of the mineral. At 360°C, oxidation of the ferrous iron impurity takes place, at 680°C and at 745°C the removal of hydroxyl water and lattice failure occurs, at 90°C crystallization of the decomposition products proceeds.It is known [5] that heating of chlorite to temperatures exceeding the temperature of the exothermic effect leads to the formation of spinels. In [4] it is reported that after dehydration of several hydroxides, a solid solution of spinels is formed. The process is displayed on the thermogram with an exothermic effect. Based on these data, it can be assumed that exothermic effects, in addition to the processes described above, also show the formation of solid solutions of chromospinelides from thedehydration products of the phase constituents of the sample.

The results and its discussion. A technology for processing slurry tailings has been developed to produce chromite concentrate, which includes preliminary activation in sodium hydrogen carbonate solution, leaching in a solution of ammonium hydrogen sulfate and gravitational enrichment with the use of a centrifugal separator.

The preliminary activation is necessary to increase the degree of enrichment of chromite-containing tailings during leaching by the removal of the accompanying elements - magnesium, silicon, iron.

The possibility of activation of slurry tailings by treatment with sodium hydrogen carbonate solution of 120 g/dm^3 concentration at temperatures of 100-240°C, T:F = 1.0:10.0 and a duration of 90 minutes were studied.

Chemical analysis of the activated tailings showed (table 3) that, as a result of the activation, the quantitative composition of the samples changes insignificantly, except for a decrease in the calcium content. At the same time, as follows from thedata of X-ray phase analysis, the phase composition of the samples changes (Table 4), the phases containing calcium oxide are disappearing; the quantitative ratios of the magnesium-containing phases are also changing.

Table 3 – Chemical composition of the slurry tailings after the activation

Name	Cr_2O_3	MgO	SiO_2	Fe_2O_3	AI_2O_3	CaO
Initial tailings	25,47	29,4	21,53	10,4	2,97	1,95
Tailings after activation at 100°C	25,4	29,49	21,73	10,28	2,96	0,864
Tailings after activation at120°C	25,52	29,53	21,69	10,56	2,99	0,812
Tailings after activation at150°C	25,42	29,5	21,4	10,5	2,91	0,8
Tailings after activation at200°C	25,48	29,39	21,35	10,46	2,8	0,794
Tailings after activation at240°C	25,5	29,38	21,38	10,5	2,75	0,641

Table 4 – Phase composition of the tailings after activation

Name	Composition, %							
	Antigorite-8M $Mg_{3-x}(Si_2O_5)(OH)_{4-2x}$	Clinochrysotile - $Mg_3Si_2O_5(OH)_4$	Lizardite - 1M $(Mg,Fe)_3Si_2O_5(OH)_4$	Aluminum-ferruginous magnesite - $MgA1._6Fe_{1.4}O_4$	Chromite- $(Fe_{0.52}Mg_{0.48})(Cr_{0.76}AI_{0.24})_2O_4$	Clinochlore - $Mg_6Si_4O_{10}(OH)_8$	Aluminum magnesium silicate - $Ca_{23.20}Mg_{22.4}$ $(AI_{92}Si_{100}O_{384})$	Quartz SiO_2
Initial tailings	41,8	5,1	12,5	8,7	15,3	5,6	11,0	–
Tailings after activation at100°C	21,8	20,9	20,4	7,6	15,8	5,6	0,8	1,2
Tailings after activation at120°C	21,8	21,6	20,6	15,3	15,7	5,2	0,8	1,4
Tailings after activation at150°C	22,0	21,3	20,6	15,9	15,4	4,2	0,6	1,0
Tailings after activation at200°C	22,4	21,4	19,7	15,7	15,8	5,0	–	–
Tailings after activation at240°C	23,7	21,0	21,5	18,2	15,6	5,2	–	–

The analysis of thegiven data for the preliminary activation of tailings shows that practically all main changes in the phase composition are terminating at the temperature of 120°C.

After activation, the slurry tailings were processed by leaching at a temperature of 95-100°C in the regenerated solution of ammonium hydrogen sulfateNH_4HSO_4.

The carried out study in the process of leaching of slurry tailings, a solution of ammonium hydrogensulfate with a concentration of 30.0% was used. Leaching was carried out at a temperature of 95°C for 60 minutes.

For comparison,in addition to the ammonium hydrogen sulfate solution, a solution of 5% H_2SO_4 and a solution consisting of 30% NH_4HSO_4+1% H_2O_2 were used for leaching.

The obtained results of leaching are shown in table 5.

The best results were obtained using a leaching solution consisting of 30% NH_4HSO_4, in this case, the content of chromium in the cake (rough chromite concentrate) was 38.4% Cr_2O_3at cake output of 65.5% of the weight of the initial slurry tailings.

Table 5 – Cake (rough concentrate) from the leaching of slurry tailings

Name	Cr_2O_3		Fe_2O_3		MgO		SiO_2		AI_2O_3		Cake output, %
	%	Ɛ, % *	%	Ɛ, %	%	Ɛ, %	%	Ɛ, %	%	Ɛ, %	
Initial tailings	25,47	100	10,5	100	30,0	100	22,7	100	2,74	100	
Cake form leaching with 5% H_2SO_4	32,1	95,4	9,94	69,9	18,8	46,3	30,7	100	3,04	82,1	75,0
Cake form leaching with 30% NH_4HSO_4	38,4	96,8	9,25	39,9	7,08	10,7	34,0	70,0	4,56	75,0	65,5
Cake form leaching with 30% NH_4HSO_4 + 1 % H_2O_2	36,9	95,5	7,47	33,5	8,07	12,06	40,8	84,6	3,2	55,7	67,1
Ɛ, % * – extraction of the component in the cake (rough concentrate).											

For the regeneration of a solution of ammonium hydrogen sulfate, a method [6] of thermal decomposition of ammonium sulfate into hydrosulfate and ammonia according to reaction (1) is known:

$$(NH_4)_2SO_4 = NH_4HSO_4 + NH_3 . \quad (1)$$

Cakes from leaching weredispatched to enrichment using gravity separator KNELSON.

As a result of the centrifugal separation of cakes, chromite concentrates with the following content, mass% were obtained:

- from the cake after leaching in (30% NH_4HSO_4 + 1% H_2O_2) solution – 53,4 Cr_2O_3; 9,8 MgO; 19,1 SiO_2; 13,1 Fe_2O_3; 4,1 AI_2O_3; 0,14 CaO. The output of the concentrate accounted 32.4% of the weight of the initialtailings. The extraction of Cr_2O_3 into the concentrate accounted for76.2%;
- from the cake after leaching in 5% H_2SO_4solution– 42,6 Cr_2O_3; 18,7 MgO; 23,0 SiO_2; 11,0 Fe_2O_3; 3,67 AI_2O_3; 0,2 CaO. The output of the concentrate accounted 36.9% of the weight of the initialtailings. The extraction of Cr_2O_3 into the concentrate accounted for72.7%;
- from the cake after leaching in 30% NH_4HSO_4solution – 59,2 Cr_2O_3; 9,1 MgO; 12,4 SiO_2; 13,05 Fe_2O_3; 4,63 AI_2O_3; 0,21 CaO. The output of the concentrate accounted 32.9% of the weight of the initialtailings. The extraction of Cr_2O_3 into the concentrate accounted for86.8%. The material balance of cake enrichment under these conditions is given in table 6.

Table 6 – Material balance ofcakeenrichment after leaching
in a 30% NH_4HSO_4 solutionusing KNELSON centrifugal separator

Product name	Output		Content, %	Production	Extraction,%
	g	%	Cr_2O_3	Cr_2O_3	Cr_2O_3
Concentrate KNELSON	49,35	32,9	59,2	1947,68	86,8
Tailings KNELSON	100,65	67,1	4,35	291,7	13,2
Total	150	100,0		2239,38	100,0

X-ray phase analysis of cake enrichment products after leaching in 30% NH_4HSO_4 solutionis presented in tables 7, 8.

Table 7 – X-ray phase analysis of tailingsenrichment of cake after leaching in a 30% NH_4HSO_4 solution

Name	Formula	%
Kaolinite	$Al_2Si_2O_5(OH)_4$	44,9
Clinochlore	$(Mg,Fe,Al)_6(Si,Cr)_4O_{10}(OH)_8$	44,5
Chromite	$(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$	10,6

Table 8 – X-ray phase analysis of chromite concentrate

Name	Formula	%
Chromite	$(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$	100

The data of X-ray phase and chemical analysis shows that leaching of slurry tailings with a 30% NH_4HSO_4 solution of ammonium hydrogensulfate, the rock-forming minerals commonlyconvert into solution, and chromite and chromite-containing minerals, coalitol and amorphous silica remain in the cake-the rough concentrate. The amorphous silica resists the X-ray phase analysis.

When enriching the rough concentrate using the centrifugal separator KNELSON, a chromite concentrate consisting of a chromite mineral - $(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$ wasobtained.

Thus, in the process of slurry tailings enrichment, using the technology including the operations on the preliminary activation of the chromite-containing tailings in a solution of sodium hydrogen carbonate; leaching in a solution of ammonium hydrogen sulfate, and gravitational enrichment using centrifugal separator,a chromite concentrate with a 59.2% content of Cr_2O_3 was obtained with the extraction of Cr_2O_3 into a concentrate of 86.8%.

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БАЙЫТУ ҮРДІСІНІҢ ШЛАМ ҚАЛДЫҚТАРЫНАН ХРОМ КОНЦЕНТРАТЫН АЛУ ТЕХНОЛОГИЯСЫН ЖАСАУ

Аннотация. Техногенді калдықтарды – Қазақстан Республикасының Дондық тау-кен байыту комбинатының (Дондық ТКБК) хромитті кенін байытқандағы шлам қалдықтарын қайта өңдеудің зерттеу нәтижелері келтірілген.

Орталықтан тепкіш бөлгіші және химиялық байыту арқылы хром концентратын алудың технологиясы жасалынды. Бұл технология құрамында хром бар қалдықтарды гидрокарбонат натрий ерітіндісінде алдын ала белсендіруді, аммонийдің бисульфат ерітіндісінде шаймалау және орталық тепкіш бөлгішінде гравитациялық байытуды қамтиды. Алдын ала белсендіру үрдісін жүргізу – шаймалау кезінде қосымша элементтердің (магнии, кремний, темір) жойылу есебінен, құрамында хром бар қалдықтарды байыту дәрежесін жоғарлату үшін керек. Алдын ала белсендіру нәтижесінде үлгілердің құрамы сәл өзгереді. Сонымен қатар, үлгілердің фазалық құрамы өзгереді, құрамында магний бар фазалардың қатынасы, құрамында кальций оксиді бар фазалар жойылады.

Жүргізілген зерттеу жұмыстарында шлам қалдықтарын шаймалау үшін реагентті таңдағанда – 30% NH_4HSO_4 ерітіндісін қолданғанда өте жақсы нәтижелер алынды. Рентгенфазалы және химиялық талдаулар нәтижесінен шлам қалдықтарын шаймалағанда жыныстартүзегіш минералдар негізінен ерітіндіге өтеді, ал кекте – алғашқы концентратта хромит және хромитті минералдар, коалин, аморфты кремний диоксиді қалатынын көруге болады.

KNELSON ортадан тепкіш бөлгішінде алғашқы концентратты байытқанда хромит минералынан тұратын - $(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$ құрамындағы Cr_2O_3 – 59.2% - хромитті концентрат алынды. Cr_2O_3 концентрақа алынуы 86,8%.

Хром қалдықтарын өңдеу технологиясын жасау экологиялық мәселелерді шешіп қана қоймай, сонымен қатар хром концентратының шығысын арттырады.

Түйін сөздер: шлам қалдықтары, белсендіру, аммоний бисульфаты, орталық тепкіш бөлгіші, хром концентраты.

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РАЗРАБОТКА ТЕХНОЛОГИИ ПОЛУЧЕНИЯ ХРОМИТОВОГО КОНЦЕНТРАТА ИЗ ШЛАМОВЫХ ХВОСТОВ ОБОГАЩЕНИЯ

Аннотация. В статье приведены результаты исследований переработки техногенных отходов - шламовых хвостов обогащения хромитовой руды Донского горно-обогатительного комбината Республики Казахстан.

Разработана технология получения хромитового концентрата методом химического обогащения и центробежной сепарации. Технология включает операции предварительной активации хромитсодержащих шламов в растворе гидрокарбоната натрия, выщелачивание в растворе гидросульфата аммония и гравитационное обогащение на центробежном сепараторе.Проведение операции предварительной активации необходимо для повышения степени обогащения хромитсодержащих шламов при выщелачивании за счет удаления сопутствующих элементов – магния, кремния, железа. В результате активации количественный состав проб изменяется незначительно. В то же время меняется фазовый состав проб, исчезают фазы, содержащие оксид кальция, соотношения магнийсодержащих фаз.

В проведенных исследованиях при выборе реагента для выщелачивания шламовых хвостов наилучшие результаты получены при использовании раствора с 30% NH_4HSO_4. Из данных рентгенофазового и химического анализов следует, что при выщелачивании шламовых хвостов, породообразующие минералы в основном переходят в раствор, а в кеке - черновом концентрате остаются хромит и хромитсодержащие минералы, коалинит и аморфный кремнезем.

При обогащении чернового концентрата на центробежном сепараторе KNELSON получен хромитовый концентрат, состоящий из минерала хромита - $(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$ с содержанием Cr_2O_3 59,2% при извлечении Cr_2O_3 в концентрат 86,8%

Разработка технологии переработки хромитовых шламов позволит не только решать экологическую проблему, но и увеличить выпуск хромитового концентрата.

Ключевые слова: шламовые хвосты, активация, гидросульфат аммония, центробежный сепаратор, хромитовый концентрат.

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INVESTIGATION OF THE THERMAL DECOMPOSITION PROCESS OF KENDYRLIK DEPOSIT OIL SHALES

Abstract. In the article, experiments on the thermal treatment of Kendyrlik shale by its carbonization and activation were carried out. First, shale was carbonized in an inert argon medium in the temperature range 25-700 °C and then activated by water vapor at a temperature of 850-900 °C. The analysis of the elemental composition of the resulting synthetic gas showed that the highest concentration of combustible gas components (CO, H_2, CH_4) is observed at 900°C (in the absence of H_2S, low CO_2 and a small amount of liquid products - resin). Shale pyrolysis was also carried out in argon medium up to 900 °C. As a result of the analysis of the component composition of liquid products, it was found that mainly isoalkenes, alkanes and isocycloalkanes are formed. However, the elemental composition of the produced gas showed that the volume of gas and its caloric content are significantly lower in comparison with similar parameters for the gas produced during the activation of shale.
Keywords: shale, Kendyrlik, activation, carbonization, pyrolysis, gas.

Introduction. Globally, the significance of shale is its value as a source of energy, an alternative to other types of fossil fuels (for example, oil and coal) [1]. The solution to the problem of the use of oil shale, especially abroad, is mainly considered in the direction of their processing, with the production of shale resin - a substitute for oil and artificial gas (a substitute for natural gas). At the same time, the determining qualitative characteristics are: the content of organic matter and the yield of resin; calorific value (by class); the content of sulfur, rare and dispersed elements in the initial shale, semi-coking resin, gas products and ash residue; composition of the products obtained (resin, gas mixture); the ratio of the yield of the semi-coking resin to the heat of combustion (in groups) [2].

Possessing a high calorific value of combustible mass, shaleis one of the low-grade fuelsdue to the huge amount of ash. The high content of hydrogen (up to 11%) in kerogen and volatile substances (combustible mass), reaching 80%, makes it possible to utilize shale as a raw material for pyrolysis and gasification processes, as well as chemical processing for the production of various oils, motor fuels, phenols, tanning beds, combustible gas, various valuable chemical products for the chemical industry [3]. Liquid hydrocarbons (shale oil-resin), obtained by pyrolysis, are similar in composition to petroleum hydrocarbons and can be considered unconventional (shale) oil [4].

At present, considerable experience in ground processing of oil shale in off-shore retorting technology has been accumulated [5]: Galoter Process (GALOTER, Russia-Estonia), Enefit (modification of Galoter process), Kiviter (Estonia), Alberta-Taciuk Process (ATP) (Australia) , Petrosix (Brazil), ToscoII (USA), Fushun (China), Paraho Process (USA), Lurgi-Ruhrgas (Germany), Chevron STB (USA), etc. Energy efficiency of technologies is provided by technological operations optimizing physical and chemical conditions of the main process - pyrolysis process. The obtained industrial results [5, 6] showed the high efficiency of the use of oil shales.

One of the most effective shale processing technologies is the Galoter Process technology for the production of shale oil, motor fuels. This technology is mastered on a large industrial scale in Estonia (Narva). Using the potential heat of raw materials and economic efficiency, it surpasses all the technologies of thermal processing of oil shale that exist in the world today.

According to the Kazakhstan Research Institute of New Chemical Technologies and Materials, at least 25 deposits of oil shale, related to sediments of the Upper Devonian, Lower Carboniferous, Upper Paleozoic, Middle and Upper Jurassic and Paleogene, have been identified on the territory of Kazakhstan. They differ in the composition of the initial substance and in the conditions of formation, which to a large extent determined their quantitative and technological characteristics. The deposits of oil shale in Kazakhstan are extremely poorly studied [7, 8].

One of the promising and largest coal-shale basins is the Kendyrlyk basin (East Kazakhstan region), whose total reserves are estimated at 4,075 million tons, including balance reserves - 708 million tons [8,9]. It is followed by the Baykhozhinskoye (in Southern Kazakhstan) and the Priuralsky group of deposits in the west of the country [8].

The main advantage of Kendyrlyk resin is a low sulfur content, which is removed by conventional methods used in refining petroleum products. In Kendyrlyk shale, the sulfur content usually does not exceed 1%, and in many other deposits, the sulfur content in shale is 4-7%, and sometimes 9%. The total thickness of the shale horizons is more than 100 m, the thickness of the beds varies from 1 to 12 m, the calorific value is 4-15 MJ/kg, the yield of the resins is 4-20% [10, 11].

Therefore, the aim of this work is to study the processes of thermal processing of Kendyrlyk shale for the production of hydrocarbon products.

Research methods

Humidity, ash content and volatility of oil shales were determined on the Thermogravimetric Analyzer "ThermosterEltra" (according to ASTM D7582-12 "Standard Test Methods for Proximate Analysis of Coal and Coke by Macro Thermogravimetric Analysis"). The bulk density, the pH of the aqueous extract, the adsorption activity by methylorange were determined in accordance with [12, 13].

Elemental shale analysis was performed using energy dispersive X-ray spectroscopy on a SEM (Quanta 3D 200i) instrument with an attachment for energy dispersive analysis from EDAX at a resolution of: 3.0 nm at 30 kV (high vacuum mode); <12 nm at 3 kV (low vacuum mode); with an accelerating voltage from 200 V to 30 kV and with an increase from x50 to x100000. Elemental analysis is determined from Be to U. Samples were attached to a copper holder using conductive adhesive paper. Previously, a thin conducting layer of carbon was deposited on the surface of the samples in a special vacuum installation for better passage of charges. The energy of the exciting electron beam in the analysis was 15 keV, the working distance was 15 mm.

The thermal decomposition of oil shale was carried out as follows. Previously, the shale was crushed on a hammer mill (Molot-200) to a fraction of 0.1 mm and granular samples with a diameter of 0.8 cm were obtained using a tablet press (model 1000). The obtained shale samples were first subjected to heat treatment at a heating rate of 1-2 deg/min in an inert argon medium in the temperature range of 25-700 °C, and then activation of shale with water vapor within 850-900 °C. Also, the process of pyrolysis of shales in an inert argon medium in the temperature range 25-900 °C was carried out at a heating rate of 10-15 deg/min, in order to obtain mainly liquid products (resins).

The elemental composition of the gas (released in the processes of carbonization and activation) and liquid products (after distillation with the selection of hydrocarbon fractions) was determined on a Chromos GC-1000 chromatograph.

Results and discussion

TheKendyrlyk oil shale was selected as a subject for research. The results of analyzes of the technical and chemical composition of shales are presented in tables 1, 2.

Table 3 and figure 1 show the temperature dependences of the gas components obtained as a result of the carbonization and activation of the Kendyrlik shale. The formation of combustible gas components (CO, H_2, CH_4) occurs in accordance with the basic chemical reactions:

$$2H_2O \rightarrow 2H_2 + O_2 - 115\ 700\ \text{kcal} \quad (1)$$

$$C + H_2O \rightarrow CO + H_2 - 28\ 150\ \text{kcal} \quad (2)$$

$$C + CO_2 \rightarrow 2CO - 38\ 400\ \text{kcal} \quad (3)$$

$$C + 2H_2 \rightarrow CH_4 + 18\ 600\ \text{kcal} \quad (4)$$

Table 1 – Characteristics of the Kendyrlyk shale

Indicator, wt.%	Value
Total moisture, W^r_t Ash content, A^r Volatile substances outlet, V^{daf}	1-10 63-73 20-23
Element composition, wt.%	
C^{daf} H^{daf} S^d_t N^{daf} O^{daf}	76.88 9.27 0.23 1.25 12.37
Chemical composition of the mineral part, wt.%	
SiO_2 Al_2O_3 Fe_2O_3 CaO MgO K_2O+Na_2O SO_3	58.2 17.2 7.3 2.3 1.0 10.5 3.4

Table 2 – Chemical composition of Kendyrlik shales

Element	Wt. %	Atom. %
C	25.75	37.80
O	37.41	41.23
Na	0.56	0.43
Mg	0.96	0.70
Al	4.74	3.10
Si	20.05	12.59
K	1.44	0.65
Ca	5.10	2.25
Fe	3.99	1.26

Table 3 – Temperature dependence of gas components obtained from Kendyrlik shale

Temperature, °C							Gas composition, %							
							O_2	H_2	CO_2	N_2	CH_4	CO	C_2H_6	C_3H_6,C_3H_8
200	–	–	–	–	–	–	53.9	0.30	35.6	8.31	–	–	1.12	–
–	350	–	–	–	–	–	41.9	11.8	24.5	4.22	4.61	6.93	3.8	2.19
–	–	450	–	–	–	–	19.8	20.7	37.6	4.49	3.75	8.93	3.24	1.47
–	–	–	650	–	–	–	15.2	9.63	40.6	4.96	–	24.4	2.75	2.38
–	–	–	–	750	–	–	10.8	9.57	23.8	4.41	–	48.8	2.24	0.29
–	–	–	–	–	850	–	13.76	38.3	2.62	2.21	–	39.8	3.18	0.13
–	–	–	–	–	–	900	4.02	33.4	1.28	6.65	2.86	49.5	2.24	0.04

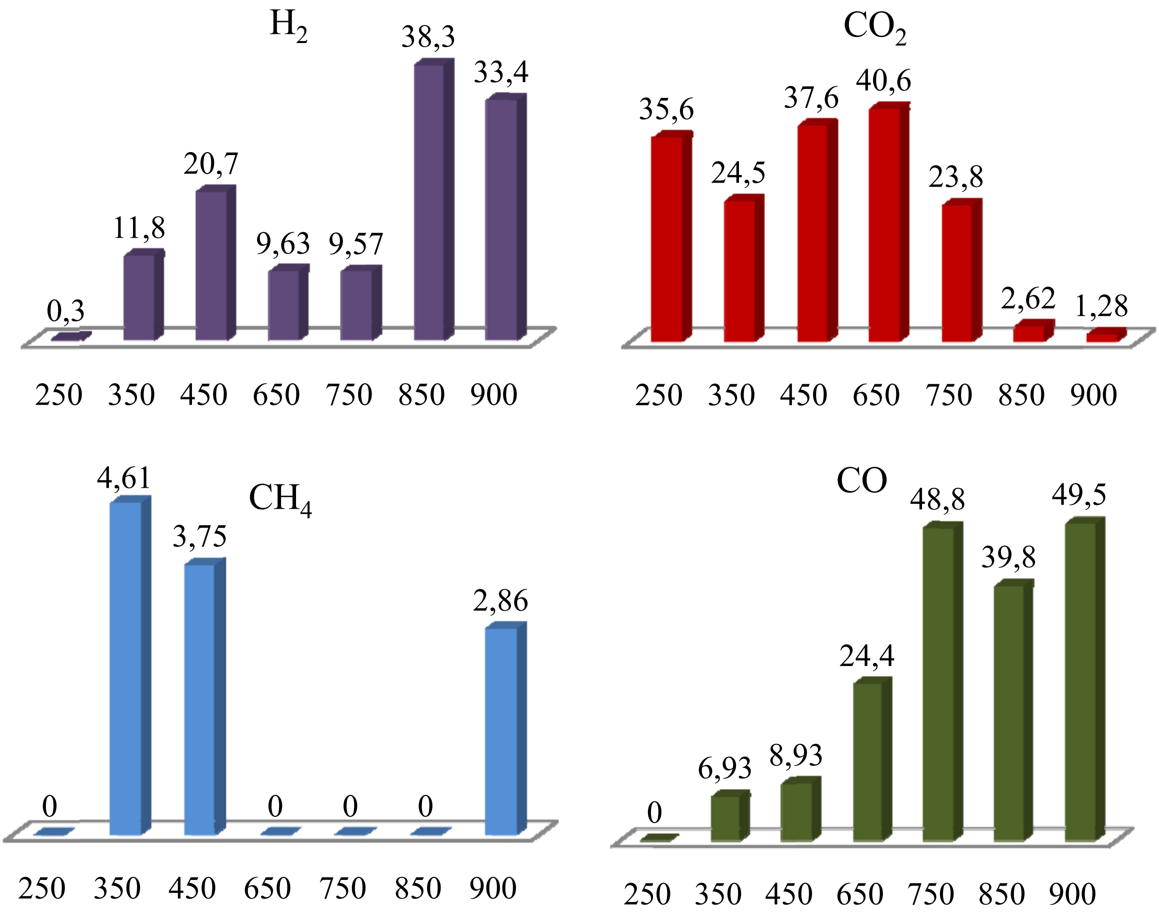

Figure 1 – Temperature dependence of gas components obtained from Kendyrlik shale

The obtained results show that the content of C_2-C_3 hydrocarbons at the whole temperature level is insignificant and is about 2-6%. In the transition from 450 °C to 650 °C, depending on the concentration of H_2 and simultaneously increases the content of CO. Beginning at a temperature of 750 °C, the CO_2 fraction decreases sharply and a significant increase in the caloric value of the gas is observed, due to an increase in CO, which is most likely to occur in accordance with the reaction (3). At a temperature of 850 °C, during the activation process, the H_2 content increases sharply (from 9.57 to 38.3%), due, apparently, to the supply of water vapor. The total fraction of the combustible gas components (CO, H_2, CH_4) in-creases and becomes greatest at the maximum shale activation temperature of 900°C. At the same time, H_2S is virtually absent during the entire process of the thermal deposition of oil shale.

The greatest oxygen content at 200-350 °C is associated with the release of pyrogenic water and oxygen-containing organic compounds, due to the decomposition of the side groups of macromolecules (since the carbon-oxygen bonds are the least stable in the thermal ratio). With further heating at 450-650 °C, oxygen is also observed in sufficient quantities (but to a lesser extent) because of the thermal decomposition reactions of the most thermostable organomineral complexes and the release of the bulk of the resin and gaseous hydrocarbons. In the temperature range 750-900 °C, decomposition of calcite and dolomite takes part in the formation of oxygen, the content of which can reach up to 50% in the mineral shale [14].

Table 4 shows the material balance of the shale activation of the Kendyrlik deposit.

Table 5 shows the elemental composition of the gas obtained as a result of the pyrolysis of the Kendyrlyk shales.

Table 4 – Material Balance of Shale Activation of the Kendyrlik deposit

#	Incoming products	Content			№	Outgoing products	Content		
		g	cm^3	%			g	cm^3	%
1	Shale	500		96.2	1	Solid residue	398.0	306.0	76.5
2	Water (saturated steam)	20	7.8	3.8	2	Generator gas	68.4	59.5	13.2
	Total	520		100	3	Liquid product (resin)	3.6	3	0.7
					4	Water	50	50	9.6
					Total		520		100

Table 5 – Gas composition of pyrolysis of shales of the Kendyrlik deposit

Temperature, °C						Gas composition, vol, %							
						O_2	H_2	CO_2	N_2	CH_4	CO	C_2H_6	C_3H_6,C_3H_8
350	–	–	–	–	–	54.0	3.08	27.5	9.40	0.00	0.15	3.48	2.31
–	400	–	–	–	–	28.2	11.0	28.1	10.7	1.41	16.6	2.75	1.16
–	–	450	–	–	–	52.5	2.32	31.7	9.3	0.01	0.12	1.93	2.07
–	–	–	720	–	–	32.7	4.77	8.75	7.15	–	44.4	1.42	0.78
–	–	–	–	820	–	61.7	6.03	4.12	5.25	0.14	22.4	0.29	0.03
–	–	–	–	–	900	59.5	9.51	1.97	4.93	–	23.9	0.15	–

As it can be seen from the data obtained, the most caloric gas (due to the content of the CO gas generally, 44%) is observed at a temperature of 720 °C, with an insignificant fraction of H_2 (≈5%), the absence of CH_4 and a small concentration of CO_2 (≈9%). A further increase in temperature to 820 °C leads to a significant decrease in the caloric value of the gas due to a significant decrease in CO (from 44.4 to 22.4%). In the course of pyrolysis, when the gas is heated to 900 °C, the C_2-C_3 (up to ≈6%) and CH_4 (up to 1.5%) gas concentrations are insignificant, the CO_2 content is significantly reduced (to ≈2%) and H_2S is practically absent.

In the process of pyrolysis of shales, the vapor-gas mixture was withdrawn to the refrigerator, where the hydrocarbon vapor condenses to form a shale resin. The liquid products obtained in this process in the temperature range 350-500 °C were distilled on a rotary evaporator (at temperatures T <55 °C and T = 55-61 °C under vacuum) with the selection of hydrocarbon fractions. Figures 2 and 3 show the chromatograms of the obtained liquid pyrolysis products of Kendyrlyksk shale.

The component composition of fractions of liquid hydrocarbons formed during pyrolysis of shale is represented by a set of C_6-C_{20} compounds (arenes, alkanes, isoalkanes, isocycloalkanes, alkenes, isoalkenes, isocycloalkenes). According to the results of the analysis (figures 2, 3), the main part of the products consists mainly of isoalkenes, alkanes andisocycloalkanes. Moreover, the hydrocarbon fractions obtained after distillation at T = 55-61 °C (under vacuum) have a much wider set of compounds than whenT <55 °C (under vacuum), mainly due to arenes, isoalkanes, isocycloalkanes.

The material balance of the pyrolysis of the Kendyrlyk oil shale is shown in table 6. The results of the data show that the amount of liquid products obtained is much larger and the volume of synthetic gas is smaller compared to similar parameters for products obtained during the activation of shale with water vapor.

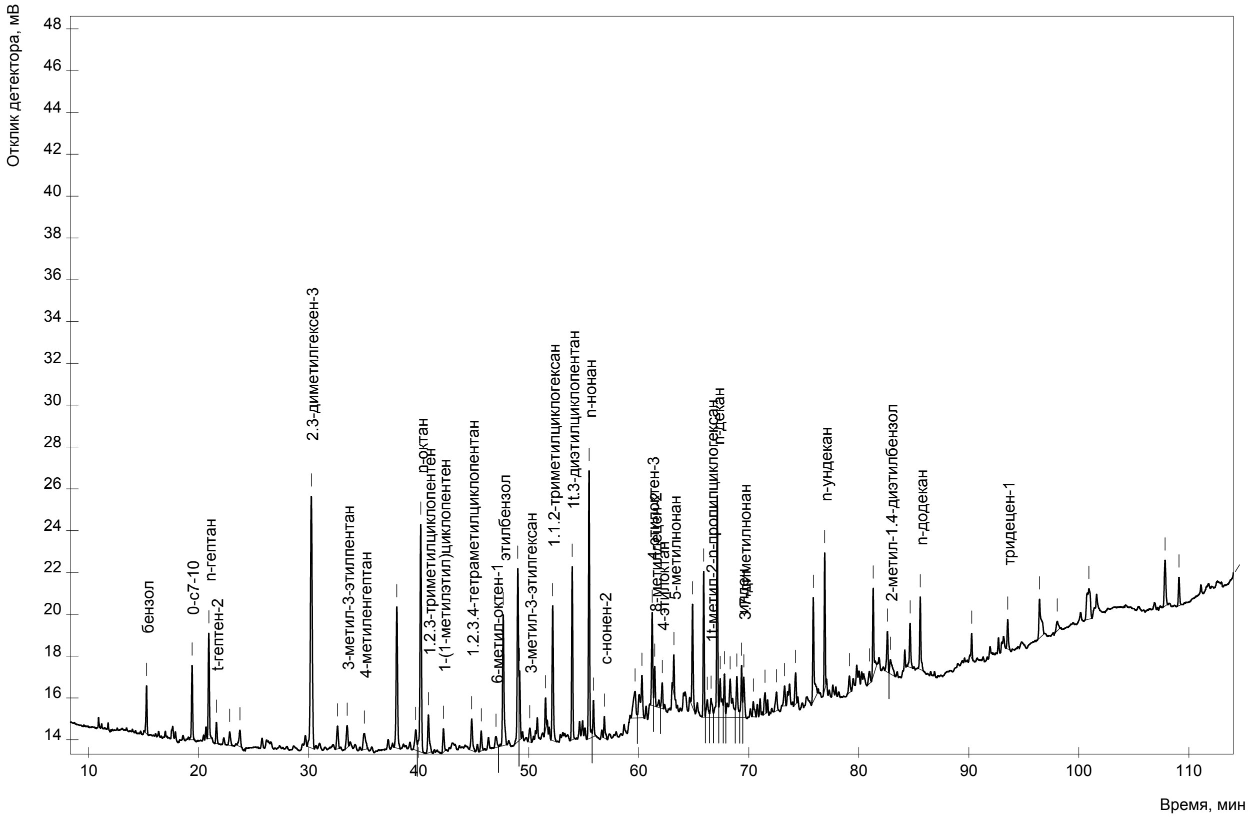

Figure 2 – Chromatogram of liquid pyrolysis products from Kendyrlyksk shale obtained by distillation at T <55 °C (under vacuum)

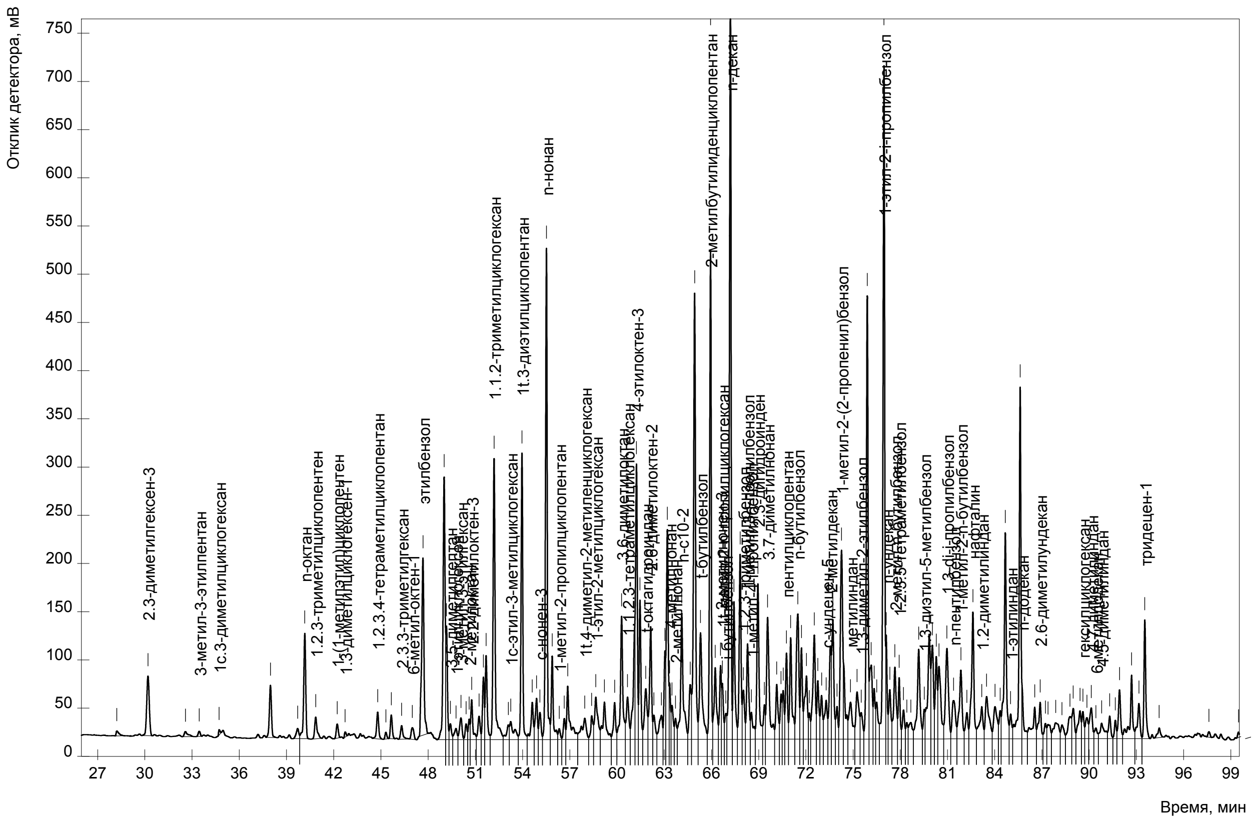

Figure 3 – Chromatogram of liquid pyrolysis products from Kendyrlyksk shale obtained by distillation at T = 55-61 °C (under vacuum)

Table 6 – Material balance of pyrolysis of Kendyrlyk shale

#	Incoming products	Content			№	Outgoing products	Content		
		g	cm^3	%			g	cm^3	%
1	Shale	500		100	1	Solid residue	409.0	371.8	81.8
	Total	500		100	2	Generator gas	40.5	35.2	8.1
					3	Liquid product (resin)	29.0	24.2	5.8
					4	Water	21.5	21.5	4.3
						Total	500		100.0

Conclusions. The experiments on the thermal decomposition of the Kendyrlyksk oil shale have shown that during the activation of the raw material with water vapor at a temperature of 900 °C a high-calorific synthetic gas with a low content of harmful and ballast substances is formed. Such gas may be suitable for use as an energy fuel (for obtaining thermal and electric energy) and as synthesis gas (CO, H_2). This gas, as well as the resin obtained as a result of pyrolysis (in argon), can be a valuable raw material for the production of motor fuels and other chemicals of chemical engineering (phenols, tannins, etc.).

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ИССЛЕДОВАНИЕ ПРОЦЕССА ТЕРМИЧЕСКОГО РАЗЛОЖЕНИЯ ГОРЮЧИХ СЛАНЦЕВ КЕНДЫРЛЫКСКОГО МЕСТОРОЖДЕНИЯ

Аннотация. В статье проведены эксперименты по термической обработке Кендырлыкского сланца путем его карбонизации и активации. Сначала проводили карбонизацию сланца в инертной среде аргона в интервале температур 25-700 °С и затем активацию сланца водяным паром при температуре 850-900 °С. Проведенный анализ элементного состава полученного синтетического газа показал, что наибольшая концентрация горючих компонентов газа (CO, H_2, CH_4) наблюдается при 900 °С (при отсутствии H_2S, низкого содержания CO_2 и малом количестве жидких продуктов − смолы). Также проводили пиролиз сланца в среде аргона до 900 °С. В результате анализа компонентного состава жидких продуктов выявлено, что образуются преимущественно изоалкены, алканы и изоциклоалканы. Однако элементный состав полученного газа показал, что объем газа и его калорийность существенно ниже по сравнению с аналогичными параметрами для газа, выделяющегося в процессе активации сланца.

Ключевые слова: сланец, Кендырлык, карбонизация, активация, пиролиз, газ.

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КЕНДІРЛІК КЕНІШІНІҢ ЖАНҒЫШ СЛАНЕЦТІҢ ТЕРМИЯЛЫҚ ЫДЫРАУ ҮРДІСІН ЗЕРТТЕУ

Аннотация. Мақалада Кендірліксланецін термиялық өңдеу нәтижелері келтірілген. Алдымен сланец аргон қатысында, инертті ортада 25-700 °С температура интервалында карбрнизацияланып, 850-900 °С температурада су буымен активация әдісімен өңделді. Түзілген синтетикалық газдың элементтік құрамын талдау нәтижесінде жанғыш газ компоненттірінің (CO, H_2, CH_4) айтарлықтай концентрациясы 900 °С байқалды (H_2S жоқ, CO_2 газы мен сұйық өнім-шайырдың аз мөлшері түзілген). Сонымен қатар аргон қатысында 900 °С-та сланецтің пиролизі жүргізілді. Түзілген сұйық өнімнің компоненттік құрамын талдау нәтижесінде негізінен изоалкендер, алкандар және изоциклоалкандар түзілгені анықталды. Алайда, түзілген газдың элементтік құрамынан анықталғандай газдың көлемі мен оның калориясы сланецті активациялау үдерісі кезінде бөлінетін газдың параметрлерімен салыстырғанда айтарлықтай төмен екені байқалды.

Түйін сөздер: тақтатас, Кендірлік, карбонизация, активация, пиролиз, газ.

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FINDING ALLOWABLE DEFORMATION OF THE ROAD ROLLER SHELL WITH VARIABLE CURVATURE

Abstract. The article examines a new mechanic and mathematical model for the conditions of the roller flexible shell of the road roller assessing its load bearing capacity, reliability and strength and making it possible, depending on the properties of the material to be compacted, to select abroad roller with the required performance of rollers before the work is started. It also reviews issues related to the acceptable transformation of the flexible shell circular surface and allowable displacementlimit while exceeding ofthe latter may lead to a failure of the road roller capability. The article is aimed at giving scientific evidence and finding feasibility of using flexible shells in the road roller design and determining their parameters that are sufficiently accurate to be used for engineering purposes. It also describes the experimental equipment used to investigate the parameters of flexible shells and presents practical effect in the form of schematics and full-scale structures, as well as an experimental roller of a road roller with a flexible steel shell. The results complement and integrate into previous studies and they are compared with analytical and elemental solutions of similar tasks from the scientific literature [7, 9, 13, 14].

Key words: Cylindrical shells, Elastic Deformation, elastic bending of a circular ring, flexible shell of roller of road roller, load bearing capacity, strength, kinematic parameters.

1. Introduction. Compulsory compaction of soil, crushed stone and asphalt in the road sector is actually the main operation to ensure their strength, stability and durability [6].

The main compacting equipment is a road roller which can be equipped with rollers of various shapes and dimensions.

Analysis of the available experimental data shows that the increase in the roller weight without adjustments in the roller diameter does not make it possible for the standard roller to adapt to the current properties of the compacted materialbecause the pressure applied to the contact area may exceed the material strength and this will lead to over-compaction and loosening of the material.

To remedy the situation and adapt to the properties of the compacted material using its optimum and compaction-friendly parameters is possible only by the application of road rollers with flexible rollers [1-3] which, given permanent static weight of the roller, allow for changing its linear pressure on the material in the area of their contact by varying the curvature radius of the roller.

The radius of flexible rollers is changed by their forced deformation along the entire perimeter and local deformation in the area of contact with the ground [1, 4, 5].

The economic significance of the problem is so high that even its partial solution will have a noticeable effect on the efficiency of road construction and their operation reliability [8, 10, 12].

2. Problem. Modern compaction equipment is marked by more advanced technologies and compaction effect that provides a change in the pressure at the supporting surface contact area due to variation in the shell curvature radius. However, given the roller weight and its pressure on the shell, an

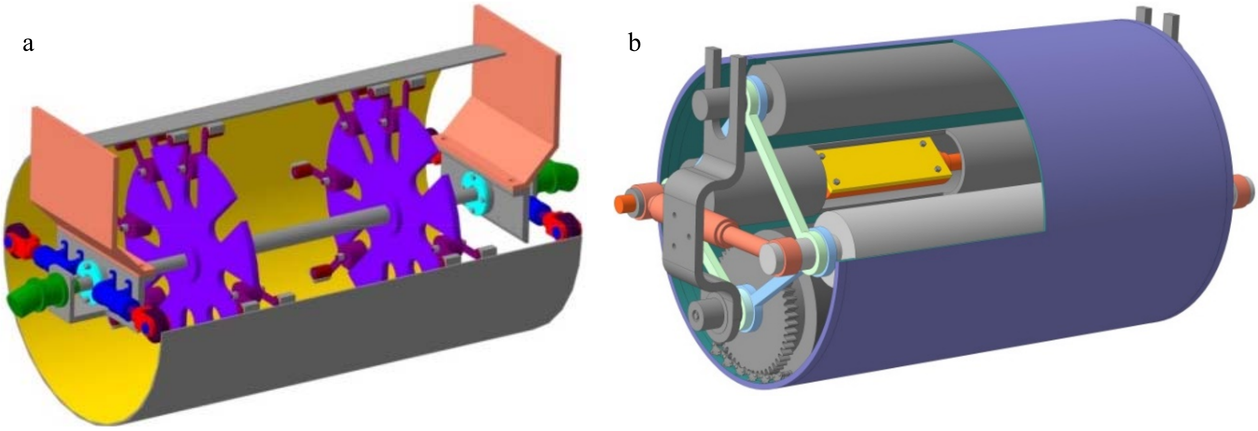

Figure 1 – Rollers of road rollers withflexible shells under provisional patents of Kazakhstan No. 18131 (a) and No. 21592 (b)

issue of the flexible shell operability, reliability and ability to recover its original shape becomes highly relevant [6].

Cylindrical shells with different thickness and made of different materials behave differently when forcibly deformed by external or internal forces. After the cylindrical shape is changed in order to achieve the desired contact area, if the allowable deformation limit is exceeded, the steel roller shell may not recover its original shape and remain flattened or stretched. Then the capability of the roller or the road roller as a whole will be completely broken, limited or terminated.

It is required to conduct a research and find scientific evidence of the allowable vertical and horizontal displacements of the roller shell after which the shell will guaranteedly retain its initial cylindrical shape. It is also needed to complete the previous studies of the roller flexible shell [6], combining them with the findings of experimental test of its stress and strain state.

3. Analytical Model. The goal of this research is to do an experimental test, complement and complete earlier analytical linear connection of displacement u, v [6] for a scale-down model of a cylindrical shell made of engineering alloy steel30ХГСА (GOST 4543-71) with modulus of elasticity E=2,11·10^5 MPa (N/mm^2), Poisson's ratio μ=0,282, yield limitσ_T=830 MPa (N/mm^2) and dimensions R=152,15 mm; B=399,3 mm; δ=1,98 mm - outside radius, width and thickness respectively, (figure1) frequently used for various operating elements of road and screening equipment [6-8, 15, 16].

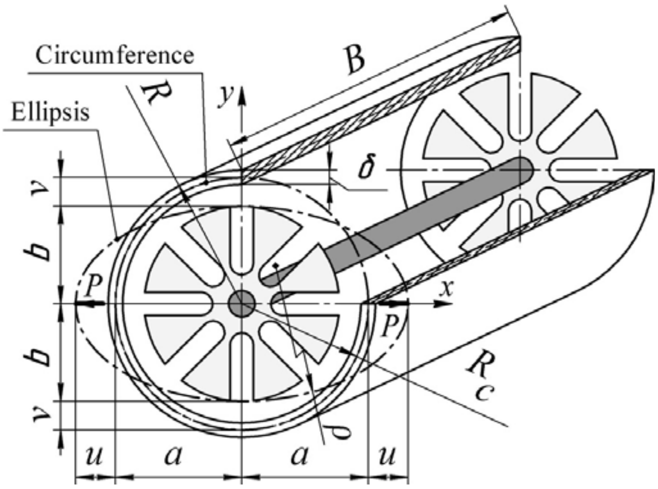

Figure 2 – Theoretical and calculation schematics of cylindrical shell

Let usintegrate the analytical model of the roller stress and strain state presented earlier [6]and the new calculated and force linear connections:

For the ellipsis curvature radius $\rho = \rho(x)$ (figure 2), upon replacing arbitrary size of bodies a, b with their allowable values $a_п$, $b_п$, the function $\rho_n = \rho_n(x)$ was obtained [6] at the highest change of the deformed shell contour expressed in terms of R_c:

$$\rho_n = \rho_n(x) = 1{,}333\mathrm{R_c}\left(1 - 0{,}2708\frac{\mathrm{x}^2}{\mathrm{R}_c^2}\right)^{3/2}, -a_п \leq \mathrm{x} \leq a_п \quad (1)$$

where,when*x=0*,

$$\rho_{max} = \rho_n(0) = 1{,}333R_c, \quad (2)$$

and when$x = \pm a_n = \pm 1{,}09537$

$$\rho_{min} = \rho_n(\pm a_n) = 0{,}7394R_c. \quad (3)$$

Functional width of flexible shellδ, should fall into the ranges

$$\delta \leq \delta_{max} = 2{,}18\ cm \quad (4)$$

When this condition is fulfilled (4), the given physical and mathematical model will be sufficiently correct with an error value allowable for engineering calculation below 5% [12, 14].

The function of internal [6] bending moment *M=M(x)*:

$$\frac{M}{H} = \frac{1}{\rho} - \frac{1}{R_c} \quad (5)$$

where H is rigidity of the shell rectangular section core [8]:

$$H = \frac{EB\delta^3}{12(1-\mu^2)} \quad (6)$$

Figure 3 – Test stand for finding allowable displacement of flexible shell and its instruments

The rule of the moment sign*M*is derived from equation (5), meaning that the parameter *H>0:* if the core curvature increases, then *M>0* and *M<0* – if it decreases. The difference change sign is also considered $1/\rho - 1/R_c$, i.e. the positive value *M>0* corresponds to $1/\rho - 1/R_c > 0$ and vice versa.

Changing the symbols $M \Rightarrow M_n$, $\rho \Rightarrow \rho_n$ and substitutingρ_n, based on (1), in the ratio (5), let us obtain a linear connection for the function of the ultimate bending moment $M_n(x)$:

$$M_n = M_n(x) = \frac{H}{R_c}\left[\frac{0{,}7502}{\left(1-0{,}2708\frac{x^2}{R_c^2}\right)^{3/2}} - 1\right] \tag{7}$$

$$-1{,}09537R_c \leq x \leq 1{,}09537R_c.$$

Figure 4 shows dimensionless modification M_n^* of epure M_n

$$M_n^* = M_n\frac{R_c}{H} = \frac{0{,}7502}{\left(1-0{,}2708\frac{x^2}{R_c^2}\right)^{3/2}} - 1 \tag{8}$$

That corresponds to analytic expression (7) subject to the symmetry of the figure 4 calculation model while to calculate the boundary coordinate y_n of the ellipsis (M_n^* epure basis) the formula$y = \pm b\sqrt{1-\frac{x^2}{a^2}}$ was used where $a = a_n$ and $b = b_n$, that means

$$y_n = \pm 0{,}9R_c\sqrt{1-\frac{x^2}{a_n^2}} \tag{9}$$

where the variable$x$is changed though the interval ±0,2 a_n:

$$x = 0;\ \pm 0{,}2\ a_n;\ \pm 0{,}4\ a_n;\ \pm 0{,}6\ a_n;\ \pm 0{,}8\ a_n; \pm a_n \tag{10}$$

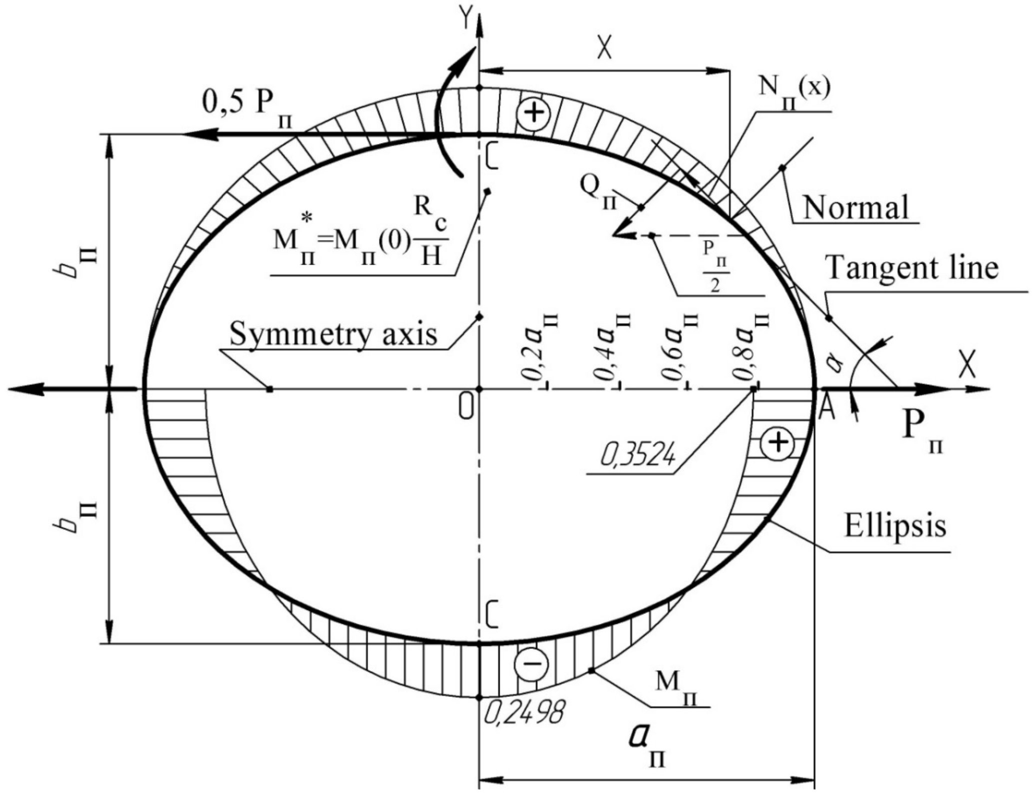

Figure 4 – E pures of internal force factor $M_П^*$ and $N_П$ adequate to the limiting boundary condition of rigidity $v_n = 0{,}1 \cdot R_c$ [6]

The figures $M_П^* = M_П^*(x)$are defined for the same points (10) of elliptical profile and given in table 1.

Table 1 – E pure M_n^* calculation values for the ultimate bending moment

x	0	0,2 a_n	0,4 a_n	0,6 a_n	0,8 a_n	a_n
yп	$\pm 0{,}9R_c$	$\pm 0{,}882R_c$	$\pm 0{,}825R_c$	$\pm 0{,}72R_c$	$\pm 0{,}54R_c$	0
M_n^*	-0,2498	-0,2372	-0,1890	-0,0416	0,1263	0,3524

Using figure 4 let us find the function of axial force$N_n = N_n(x)$ in the shell cross section

$$N_n = \frac{P_n}{2} cos\alpha \tag{11}$$

where $\alpha = \alpha(x)$ is an angle of descent to the ellipsis changing in quadrant I at a closed interval

$$0 \le \alpha \le \frac{\pi}{2} \tag{12}$$

and dependent on the argument *x* based on known differential and trigonometric ratio [7] subject to (1.37):

$$tg\alpha = \frac{dy_n}{dx} = -\frac{0{,}9R_c x}{a_n^2\sqrt{1-\frac{x^2}{a_n^2}}} \tag{13}$$

$$cos\alpha = \frac{1}{\sqrt{1+tg^2\alpha}} = \frac{1}{\sqrt{1+\frac{dy_n^2}{dx}}} \tag{14}$$

The general form of half of the epure $N_n = N_n(x)$ is shown in the same figure 4 and $N_{max} = N_n(0) = \frac{P}{2}$, when $x = 0$ and $N_{min} = N_n(a_n) = 0$ section *A*.

In accordance with the epure M_n^* (figure 4) and linear connections (6), (8), the bending moment $M_п$ in the point A at $x = \pm a_П = \pm 1{,}09537R_c$ equals to

$$M_n = M_n(\pm a_n) = 0{,}3524\frac{H}{R_c} = 0{,}05873\frac{EB\delta^2}{(1-\mu^2)(2R-\delta)} \tag{15}$$

When finding $M_n(\pm a_n)$ by the static method [16-18] as the moments of all forces summed with respect to the point A for the upper ($\sum m_A^{upper}$) right quarter of the ring, let us obtain:

$$\begin{aligned} M_n(\pm a_n) &= \sum m_A^{upper} = \frac{P_n}{2}\cdot b_n - M_n(0) = 0{,}45P_nR_c + 0{,}2498\frac{H}{R_c} = \\ &= 0{,}225P_n(2R-\delta) + 0{,}04163\frac{EB\delta^2}{(1-\mu^2)(2R-\delta)}; \end{aligned} \tag{16}$$

where $M_П(0)$ is a bending moment in the section C calculated similarly to (15) at x=0, i.e.

$$M_П(0) = -0{,}2498\frac{H}{R_c} = -0{,}04163\frac{EB\delta^3}{(1-\mu^2)(2R-\delta)}. \tag{17}$$

By making right part of the equations (16) equal tothat of (17)

$$M_n(\pm a_n) = \sum m_A^{upper}, \tag{18}$$

let us find the unknown stretching force, maximum permissible by boundary condition of rigidity P_n:

$$P_n = \frac{0{,}076\cdot EB\delta^3}{(1-\mu^2)(2R-\delta)^2}. \tag{19}$$

It is obvious that the equation (18) and the adequate load P_n determined by the above ratio (19) ensure an ellipsis-like bending of the shell. This operation and process requirement is taken into account when manufacturing flexible rollers (figure 5) of a road roller based on known inventions [4, 5] and it belongs to the basic preconditions of the calculated theoretical model.

Figure 5 – Road roller with flexible shell, Kazakhstan patent No. 18131

The essential feature of the task set in this research relates to two types of non-linearity available: ageometrical linearity resulted from large displacements*u*, v ($u \gg \delta$; $v \gg \delta$) that vastly exceeds the thickness δ of the roller cylindrical shell with an original radius of middlesurface $R_c = const$, anda constructive one resulted from a supposition about elastic bending of a circular ring [6, 7] by two mutually balanced radially stretching concentrated forces P by ellipsis equation with semi-axes a, b in the coordinate system *x0y* (figure 2) given the following correlations between the design values are maintained:

$$\delta \ll B, \frac{\delta}{\rho_{min}} \leq \frac{1}{20}; \tag{20}$$

where ρ_{min} is the lowest median radius of the shell curvature in case of an elliptical shape:

$$\rho_{min} = b^2 \cdot a^{-1} \leq R_c, \tag{21}$$

As for the assumption about the transformation of theroller circular surface to an elliptical one that relates to flexible type, a possibility of its existence is proved at any value of stretching force *P*as long as the shell is a physically linear structure [8], while the length of the arc *S* of the deformed cylinder guide is not changed when it recovers to the circumference with a radius R_c, i.e. according to the classical assumption used in the fundamental theory for calculation of flexible elastic rods: $S = 2\pi R_c = const$.

Then let usapproximate the perimeter length *S* by a complete elliptical integral $E\left(\frac{\pi}{2}, \xi\right) \equiv E\ (\xi)$ of the second sort in the form of Legendre which is reported not to be expressed through elementary functions. Reference tables [8] were compiled for its calculation depending on eccentricity or ellipsis module ξ with a large semi-axis$a \geq b$.For circumference *($a=b=R_c$)* which is a special case of the equation (2), the parameter *ξ=0,* and *E(0)=1,5708* [8].

$$S = 4a \cdot E(\xi), \tag{22}$$

$$\xi = \sqrt{1 - \frac{b^2}{a^2}}, 0 \leq \ \xi < 1 \tag{23}$$

The further mathematical modeling of the deformed state of the shell (figure 2) is based on a functional equation $\mathrm{P} = \mathrm{P}(\xi)$ adequate to a design model of pure bending [8] and the following classic preconditions [4, 6, 7, 8, 11] along with the limitations (20), (22):

– the material of the structure with an elasticity module E and Poisson's ratio$\mu$is a homogeneous, isotropic, continuous material governed by Hooke's law while the proper mass of the shell is not taken into account.

– by the ratio of geometric characteristics $\rho_{min} \gg 5\delta$, that satisfies a boundary in equation (3), the ring element of figure 2 is classified as a thin beam – cover ($B \gg 5\delta$) of low curvature with all known simplifications that arise there [11];

– classic Kirchhoff and Love's hypotheses regarding invariability of normal to the deformed middle surface of the shell and the lack of pressure from one material layer to another are complied with.

A theoretical linear connection $\mathrm{P}(\xi)$ obtained by the method [2] corresponding to the above assumptions takes the form of

$$\mathrm{P} = \mathrm{P}(\xi) = \frac{EB\delta^3}{6(1-\mu^2)R_c^2}\left(1 + \frac{a^3}{b^3} - \frac{2a}{R_c b}\right) =$$
$$= \frac{8\,E\,B\delta^3 E(\xi)}{3\,\pi^2(1-\mu^2)(2R-\delta)^2}\left\{\frac{E(\xi)\left[(1-\xi^2)\sqrt{1-\xi^2}+1\right] - \pi\,(1-\xi^2)}{(1-\xi^2)\sqrt{1-\xi^2}}\right\} \quad (24)$$

and the ellipsis semi-axes are described by the expressions:

$$a = a(\xi) = \frac{\pi R_c}{2\,E(\xi)}\ , b = b(\xi) = \frac{\pi\cdot\sqrt{1-\xi^2}}{2\,E(\xi)}\cdot R_c \quad (25)$$

Guided by (5)-(7), at the medium radius (figure-2)

$$R_c = R - \frac{\delta}{2} = 152{,}15 - \frac{1{,}98}{2} = 151{,}16\ \text{mm}. \quad (26)$$

Governed by design and process considerations [1, 21] let us introduce the rigidity condition (figure 2) $v \le 0{,}1R_c$into the calculation model and from the transcendent equation [2]

$$E\,(\xi_n) = \frac{\pi\sqrt{1-\xi_n^2}}{1{,}8} \quad (27)$$

let us find the limitary eccentricity $\xi_n = 0{,}57$ at $\pi = 3{,}1416$, and the respective boundary values $a_n = 1{,}0954R_c$, $b_n = 0{,}9\cdot R_c$, $u_n = 0{,}0954R_c$, $v_n = 0{,}1R_c$ of the functions (25) of ellipsis semi-axes and displacements where the variable ξ ranges within $0 \le \xi \le \xi_n = 0{,}57$.

$$u = u(\xi) = \left[\frac{\pi}{2\cdot E(\xi)} - 1\right]\cdot R_c, v = v(\xi) = \left[1 - \frac{\pi\cdot\sqrt{1-\xi^2}}{2\cdot E(\xi)}\right]\cdot R_c \quad (28)$$

Replacing arbitrary sizes of semi-axes a, b with their allowable values a_n, b_n – (14) in (21) let us obtain [2] $\rho_{min}^{(n)} = 0{,}7394\,R_c$. Then the secondboundary in equation(20) becomes more explicit

$$\delta \ll 0{,}05\rho_{min}^{(n)} = 0{,}03697\,R_c. \quad (29)$$

For example, at R_c*=151,16 mm*the given thickness *δ=1,98 mm* of the studied structure (figure 2)based on (29) meets the necessary condition[2] *δ=1,98 mm<δ_max=5,52 mm*by a wide margin. Thisensures a sufficient correctness and accuracy of the physical and mathematical model with an error value allowable for engineering calculation below 5% [7, 19, 20].

4. Experimental Procedure and Results. To verify the theoretical inferences and find the experimental displacement$u_э = u_э(P), v_э = v_э(P)$a special stand was designed in compliance with the applicable process requirements to experimental research on materials and structures [12, 17, 18]. The facility includes three dial gauges – an IC detector (GOST 577-68) for measuring linear displacement between

0 and 10 mm with an accuracy of 0,01 mm; and force measuring instrument - an indicator-type dynamometer DORM 0,1 (GOST 9530-60) with New tone scale (N), unit value of 1,724N.

The flexible shell for uniform distribution of the force P along the width B was fixed along its axis between the rigid cylindrical stops, movable - 5 and fixed - 8, connected with the drive and instruments. All kinematic changes in the shape of the roller flexible shell model that occur when the movable stop starts moving as the result of the tension at the rod moved by the rotating adjusting nut were recorded by the instruments and added to the table. To construct the graphs, the mean values of displacements were used deduced from 10 identical experiments carried out under identical conditions, but with a uniform rotation of the cylindrical shell with respect to rigid stops, for each experiment.

Table 2 – Theoretical and empirical data related to the finding of displacements $u\ (P),\ u_э(P),\ v(P),\ v_э(P)$ based on the known method [8]

ξ	0	0,2588	0,3420	0,3827	0,4226	0,5000	0,57
$E(\xi)$	1,5708	1,5442	1,5238	1,5116	1,4981	1,4675	1,4340
P, N	0	17,1	55,2	88,6	139,1	305,5	589,2
u, mm	0	2,60	4,66	5,93	7,33	10,64	14,42
$u_э, mm$	0	2,57	4,58	5,79	7,06	10,11	13,54
$\Delta_u, \%$	0	1,2	1,7	2,4	3,8	5,2	6,5
v, mm	0	2,65	4,75	6,03	7,51	11,04	15,12
$v_э, mm$	0	2,61	4,67	5,88	7,21	10,47	14,15
$\Delta_v, \%$	0	1,5	1,7	2,6	4,2	5,4	6,7

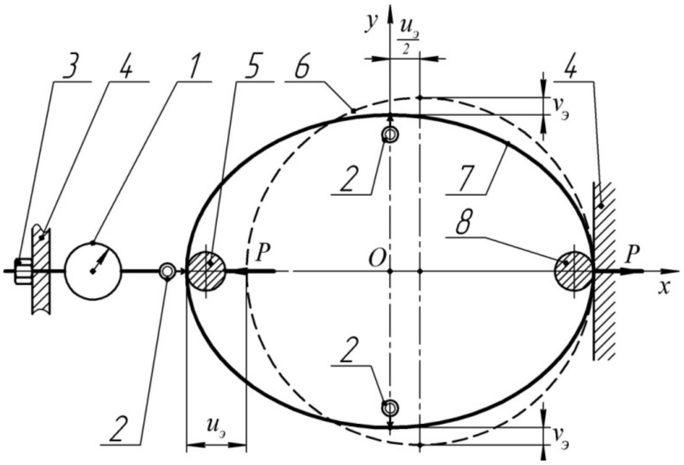

Figure 6 – Schematics of the flexible shell experimental stand (top view): 1 – indicator-type dynamometer DORM 0,1; 2 – hour indicators; 3 – adjusting nut to lock the specified load P (see the table); 4 – fixed supports; 5 – Rigidmovable 5 and fixed 8 cylindrical stops; 6 – initial round shape of the shell at P=0; 7 – elliptical profile of the shell when P>0

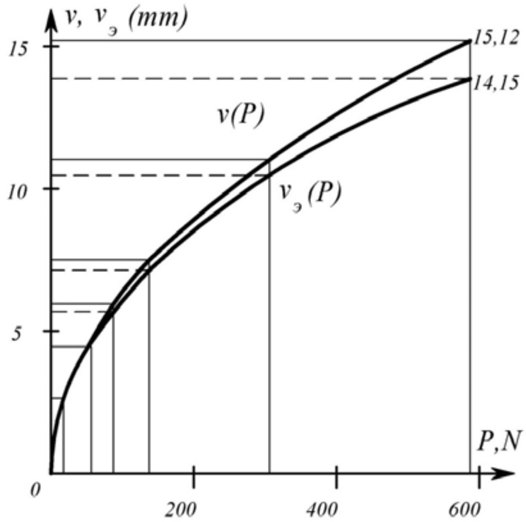

Figure 7 – External load P-dependency of the displacements$v(P), v_э(P)$

To achieve the highest accuracy and experimental integrity, the stand is designed in such a way that practically excludes the impact of the shell weight when it is positioned horizontally, as well as friction, and deformation of related parts.

The results of the theory and its experimental check are summarized in table 2 and illustrated by graphs in figures 7 and 8.

In this case the letter symbols Δ_u, Δ_v are used to indicate values that qualify the deviation between the calculation u, v and experimental $u_э$, $v_э$ kinematic parameters in per cents, depending on the external load

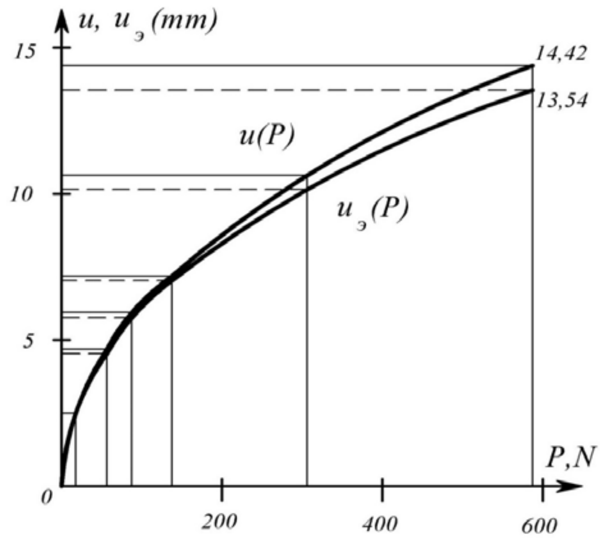

Figure 8 –
External load P-dependency
of kinematic parameters $u\ (P), u_э(P)$

P to the shell (figures 2 and 3), the values of which (in N) are set in table 1 and recorded by a dynamometer (figures 3, 6).

Conclusions.

1. The experiment findings prove the feasibility of using the road roller shell with a variable contact area made of steel 30ХГСА[3].

2. The research shows that the discrepancy between the overstated calculationu, v and experimental $u_э, v_э$ data, subject to the boundary in equation $0 \leq \xi \ \leq \xi_n$, ranged with in $\Delta_u = |u - u_э| \cdot u_э^{-1} \cdot 100\ \% \leq$ $\leq\ 6{,}5\%,\ \Delta_v = |v - v_э| \cdot v_э^{-1} \cdot 100\ \% \leq 6{,}7\ \%$. This means that the mechanical and mathematical model designed by the authors [2] to assess the strength of the variable-shape shell is a high quality and adequate model from the theoretical and calculation perspective.

3. Given the operation and process limitation $v \leq 0{,}1R_c$ is complied with, the experimental model of the steel thin-walled cylindrical shell (figure 3) was operating under the load P in an ideally elastic way, i.e. without any residual displacement when the highest normal tension σ_{max} did not exceed the yield limit σ_m of the material.

4. The experiment demonstrated that the surface of the shellhad been deformed practically on an elliptical curve. This is convincing evidence showingthe validity of using the ellipsis equation for the approximation of the shell.

5. As a result of the theoretical and practical studies of road roller flexible shells that adapt to the compactedmaterial, the optimal variation range forthe shell curvature in the contact area was determined. Exceeding of the range can lead to a loss of the roller initial shape and a failure of the ability to recover it after the load is removed.

6.The deformation and load of the roller shell let were found for different values of the curvature radius in the contact area.

7. The developed calculation algorithm for the allowable parameters of the shell deformation can be represented as an element of the base for the creation of an automated roller parameter selection system when designing different standard sizes of rollers or onboard roller system to control the reliability of the compaction parameters.

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ҚАБЫҚШАСЫНЫҢ ҚИСЫҚТЫҒЫ ӨЗГЕРІЛМЕЛІ ЖОЛ АУНАҒЫ БІЛІГІНІҢ ШЕКТІК ДЕФОРМАЦИЯЛАНУЫН АНЫҚТАУ

Аннотация. Тығыздау жұмыстарының басында, тығыздалатын материалдардың талап етілген қасиеттеріне қажет сипаттамаларға ие білікпен жабдықталған, жол аунағын таңдауға мүмкіндік беретін және оның беріктігін, сенімділігі мен тірек қабілетін бағалайтын, жол аунағының иілмелі білігі жағдайының жаңа механика-математикалық моделі қарастырылды. Мақала, жол аунақтарының құрылымында иілмелі қабықшаны қолданудың дұрыстығын және қабықшаны инженерлік жобалау мақсатында жеткілікті дәрежедегі дәлдікпен қолдануға болатын негізгі параметрлерін анықтауға және де ғылыми негіздеуге бағытталған. Қабықшасы, иілмелі болаттан жасалынған біліктен тұратын тәжірибелік жол аунағы мен сұлбалар, сонымен қатар натурдық құрылым ретінде практикалық қорытындылар келтірілген және де иілмелі қабықшаның параметрлерін зерттеуге арналған эксперименттік жабдық сипатталған. Қорытындылар ғылыми әдебиеттердегі ұқсас тапсырмалардың элементтік және аналитикалық шешімдерімен салыстырылып бұрынғы зерттеулерді біртұтас біріктіреді және толықтырады.

Түйін сөздер: цилиндрлік қабықшалар, серпімді деформация, дөңгелек сақинаның серпімді иілісі, жол аунағы білігінің иілмелі қабықшасы, тірек қабілеті, беріктік, кинематикалық параметрлері.

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ОПРЕДЕЛЕНИЕ ДОПУСТИМЫХ ДЕФОРМАЦИЙ ВАЛЬЦА ДОРОЖНОГО КАТКА С ПЕРЕМЕННОЙ КРИВИЗНОЙ ОБЕЧАЙКИ

Аннотация. Рассмотрена новая механико-математическая модель состояния гибкой обечайки вальца дорожного катка, оценивающая её несущую способность, надежность и прочность, и позволяющая, в зависимости от свойств уплотняемого материала, еще до начала работ подобрать каток с требуемыми характеристиками уплотняющих вальцов. Рассмотрены вопросы допустимой трансформации круговой поверхности гибкой обечайки вальца и пределе ее допустимых перемещений, превышение которых приведет к общему срыву работоспособности вальца дорожного катка. Статья направлена на научное обоснование и установление целесообразности использования гибких обечаек в конструкциях вальцов дорожных катков и определения их параметров, которые можно с достаточной точностью использовать в целях инженерного проектирования. Описано экспериментальное оборудование для исследования параметров гибких обечаек и приведены практические результаты в виде схем и натурной конструкции, и опытного вальца дорожного катка с гибкой стальной обечайкой. Результаты дополняют и объединяются в целое с предыдущими исследованиями и сравниваются с аналитическими и элементными решениями аналогичных задач из научной литературы.

Ключевые слова: цилиндрические оболочки, упругая деформация, упругий изгиб круглого кольца, гибкая оболочка вальца дорожного катка, несущая способность, прочность, кинематические параметры.

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APPLICATION OF SYSTEMS APPROACH TO PROGNOSTICATION OF ORE FIELDS IN LOCAL AURIFEROUS NIDALSTRUCTURES (on the example of Vera-Char - Baladzhalnidal structure in West-Kalbinsk gold-bearing area of East Kazakhstan)

Abstract. Vera-Char - Baladzhalnidal structure (NS) of the rank of the ore site is identified by the author as a promising regional research level, the estimated gold resources in it are estimated at 574,361 kg. As a result of a detailed study, to which this article is devoted, the prospective areas are localized to the rank of ore fields and deposits.

Based on the paradigm of a systemic approach to the formation of gold deposits, the Vera-Char-Baladzhal focal structure was reconstructed, regularities in the location of deposits were established in its boundaries and three promising areas for the formation of large fields were identified: the Baladzhal predicted ore field, Vera-Char forecast ore field and the Marinovsko-Kyzyltas predicted ore field. Their total area is 37.5 km^2 or 5.8% of the area of predictive research.

Keywords: prognosis researches, gold deposits, nidal structure, magmatic formation, metasomatic changes, Western – Kalbinskgold-field.

The topicality of expanding raw material base of the gold mining industry of Kazakhstan is beyond doubt. Obviously, the solution to this problem is impossible without highly effective predictive studies. This article is devoted to the results of the use of the system approach in forecasting gold deposits in the West Kalbinsky gold-bearing area in the East Kazakhstan region, one of the oldest gold mining areas in the Republic.

The West Kalbinsky gold-bearing region, located on the northwestern flank of the West Kalba-Koksentau structural zone, is extended in the north-west direction by more than 300 km and a width of 80 to 150 km. The features of its geological structure are described by previous researchers [1, etc.]. Gold ore deposits have been studied by V.A. Narseyev and others [2]; B.A. Dyachkov and others [3]; M.S. Rafailovich [4], V.A. Globa [5, 6] and other specialists. According to their ideas, they belong to gold-arsenic-carbon type (Bakyrchik, Bolshevik); gold-sulfide-quartz vein type (Zhumba, Kulujun, etc.); complex gold-quartz-beresite (Baladzhal) types.

In the territory of the described region, forecasting studies were carried out by B.A. Dyachkov, A.A. Malygin, V.V. Potylitsyn, A.P. Sitnikov and others in the 1950s-1990s. Lithologic-stratigraphic, magmatic, metamorphic, structural-tectonic, mineralogical-geochemical and geophysical factors were considered as the main factors of the localization of gold mineralization.

In 2000, [1] the forecast of different types of gold ore deposits was carried out on the basis of bulk modeling methods by the staff of authors. The advantage of these studies is the development of typical models of ore-forming systems (ROS) of gold deposits. The main components of the ROS model are the magmatic focus, caused by its development of small intrusions and ore-bearing fluids that gravitate toward the above-intrusive zone. The developed geological and geophysical model of the Bakyrchik ore field [7], is similar. According to their ideas, the connection with magmatic-ore systems is characteristic for all gold ore objects of the West Kalbinsky region.

The presentations of these authors on the uniformity of ore control structures are consistent with the data [8, 9] that the local areas of the development of endogenous mineralization are controlled by similarly imposed tectonic-magmatic structures of a focal character, which are fixed by the products of their activity - various magmatic, hydrothermal-metasomatic (including ore) formations.

Such a combination of elements of the lithosphere in the modern sense is a magmatogene-ore system possessing the properties that do not follow from the sum of the properties of its parts, and therefore its reconstruction must be based on the methodology of system analysis, the principles of which are set forth in numerous works [10, 11].

The methodology for predictive research used by the author and based on the paradigm of system analysis and described earlier [12], includes the following successive procedures: reconstruction of the magmatogene-ore system on the basis of a quantitative evaluation of the structure of its elements development using the technique of S.V. Vasilev [13], the identification of structural and statistical regularities in the placement of "reference" gold ore objects in the system and the allocation of promising areas based on the identified regularities.

At the regional level of research, as a result of which the described Vera-Char-BaladzhalNS has been singled out, small intrusions of different composition and age are considered as ore-generating factor; as "traces" of exposure through magmatic fluids - different-scale gold ore objects; as ore-supplying elements - the zones of crushing, identified by cosmogeological data. The purpose of the detailed study, the results of which are described below, is the localization of promising areas to the size of ore fields and deposits

Vera-Char - BaladzhalNS is located on the southwestern side of the West-Kalbinsk gold-bearing area (figure 1). The forecast gold resources in it are estimated at 574,361 kg. The area covering the described structure with framing and estimated at the stage of the local forecast is 673.7 km^2.

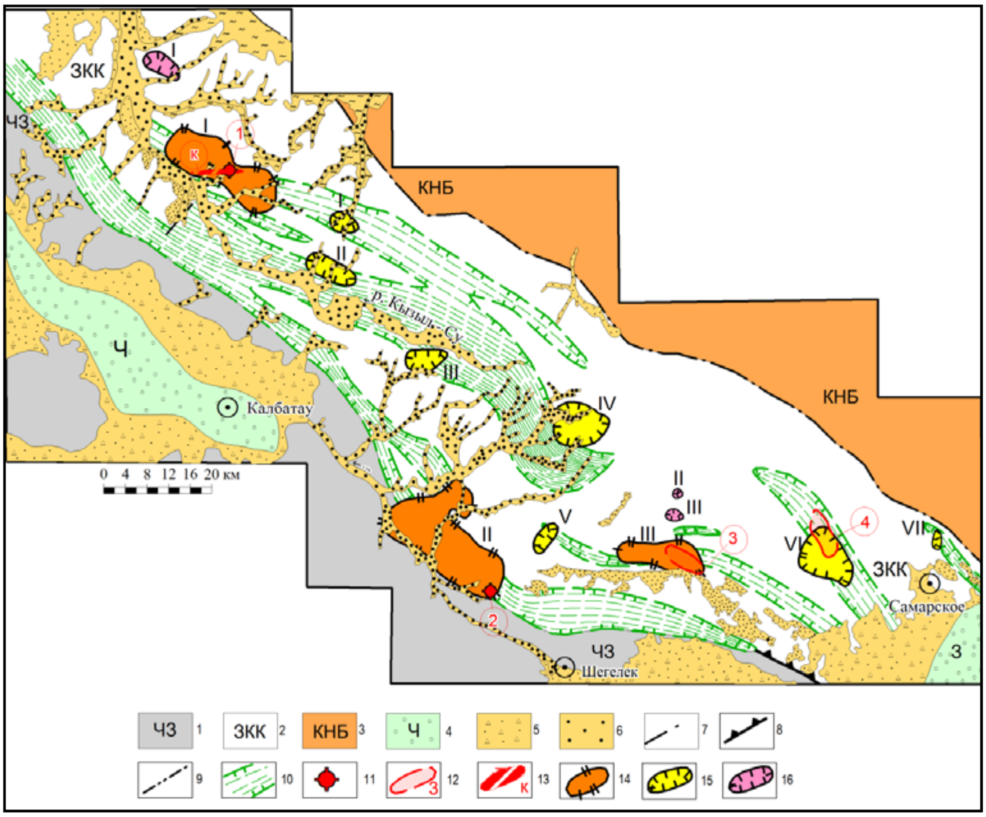

Figure 1 – The map of the location of prospective gold ore junctions on the area of the West-Kalbinsky district (a map of the forecast of gold content). Compiled by G. B. Orazbekova.

Legend: 1-3: structural zones - 1 Charsk-Zimunayskaya, 2 - West Kalba-Koksentau, 3 - Kalba-Narym-Burchumskaya; 4 - depressions of the inherited development (Ch - Charskaya, Z-Zaisanskaya); 5 - quaternary proluvial deposits of cones; 6 - neogene and quaternary deposits of valleys and intermontane depressions; 7, 8 - deep faults: 7 - Terektinsky, 8 - Charsk-Gornostaevsky; 9 - transverse fault; 10 - longitudinal crumple zones; 11 - reference gold deposits: 1 - Bakyrshik, 2 - Baladzhal; 12 - gold ore fields of reference deposits: 3 - Jumba, 4 - Kulujun; 13 - the Kyzylovskaya zone; 14 - 16: focal structures promising to find gold deposits 14 - bimodal, most promising: I - Bakyrchik, II - Vera-Char - Baladzhal, III - Jumba; 15 - unimodal, promising - I-Kanaika, II - Kazanchunchur, III - Zhanaminskaya, IV - Sentash, V - Opokoy, VI - Kulujun, VII - Lailinskaya; 16 - unimodal, least promising: I - Espinskaya, II, III - Northern Jumba.

Within its limits, the deposits of the Early Carbon are of the predominant development and the sediments of the Middle Devonian, composed of sandstones, siltstones and limestonesare developed on the southwestern flank (figure 2).

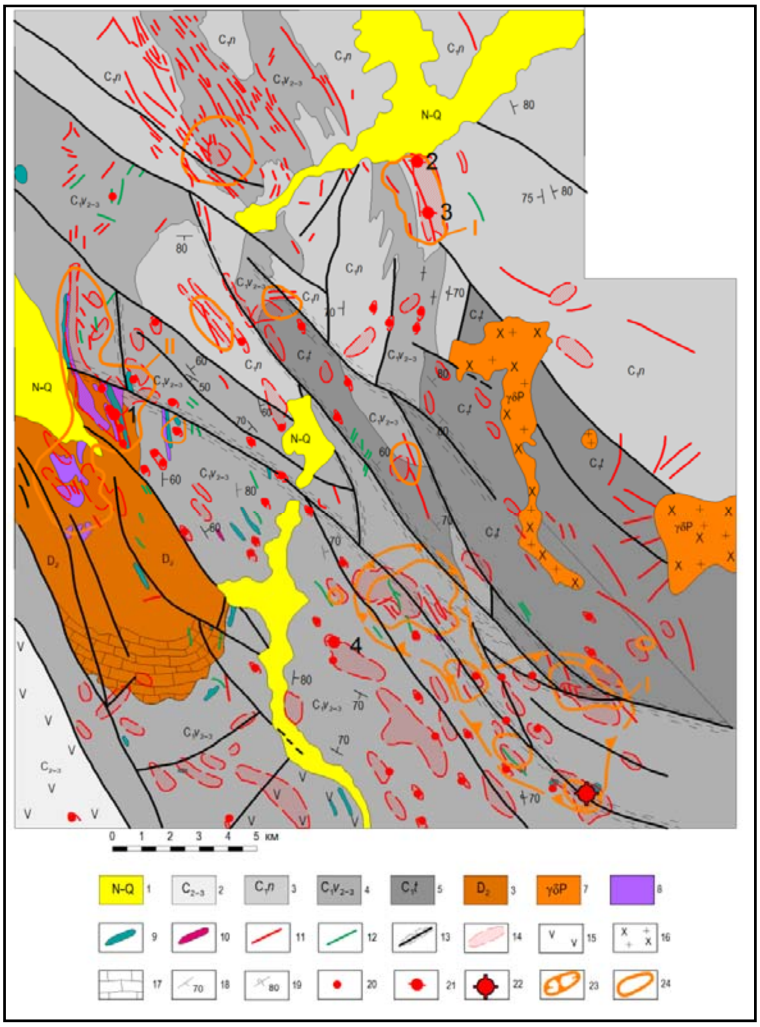

Figure 2 – Schematic geological map of Vera-Char - Baladzhal NS with elements of the forecast
(compiled using materials PGO "Vostkazgeologiya").

Legend: 1 - Neogene and Quaternary deposits are undivided; 2 - medium - upper carboniferous (andesite porphyrites, tuffs, sandstones); 3 - Lower Carboniferous, Namurian Stage (tuffites, siltstones, clay shists, sandstones); 4 - Lower Carboniferous, Visean Stage, Middle-Upper Substage (siliceous siltstones, sandstones, porphyrites, tuffs, limestones); 5 - Lower Carboniferous, Turney Stage (sandstones, tuff sandstones with interlayers of siltstones); 6 - Middle Devonian (sandstones, siltstones, limestones, schists, quartz porphyries and their tuffs); 7 - granodiorites of Permian age, post-ore; 8 - hyperbasites of conventionally early-carboniferous age (peridotites, pyroxenites, serpentinites and gabbro-diabases, 9 - small intrusions of medium and basic composition undivided, 10 - small intrusions of acidic composition undivided, 11 - dykes of acid composition, 12 - dykes of medium-basic composition, 13 - faults and near fracture zones, 14 - development zones of hydrothermal-metasomatic formations, 15 - andesites, 16 - granodiorites, 17 - limestones, 18 - inclined rocks, 19 - inverted rocks, 20 - points of gold mineralization, 21 - ash ore deposits and ore occurrences (1 - Vera-Char, 2 - Marinovskoye, 3 - Kyzyl-Tas, 4 - Jupiter), 22 - Baladzhal reference deposit, 23, 24 - predicted construction results: 23 - predicted Balazhalsky gold ore subunit, 24 - areas, promising for the identification of gold deposits (I - Marino-Kyzyltasskaya, II - Vera-Charskaya).

Intrusive formations are diverse in composition and age. The most ancient are Early Carboniferous intrusions of hyperbasites - peridotites, pyroxenites, serpentinitesand gabbro-diabases, developed on the western flank. Dyke-like and stock-shaped bodies of medium-basic composition (diabase, diabaseporphyrites, gabbro-diabase, gabbro-norites, andesite porphyrites, diorite porphyrites, quartz diorites) are not numerous. According to the views of previous researchers (O.V. Navozovand etc., 2009), their formation occurred in four stages: Early Carboniferous, Middle Carboniferous, Middle-Late Carboniferous and Permian time.

Dyke-like and stock-shaped bodies of the acid composition are formed in the late Carboniferous time. Among them are granite-porphyry, granodiorite-porphyry, syenite-porphyry, plagiogranite-porphyry, and rarely quartz porphyry. The youngest are large stock-shaped and lacollitose bodies of granodiorites of Permian age, developed on the eastern flank of the structure.

The prevalence of small intrusions and dikes in the described structure is greatest on the north-western flank and insignificant on the rest of the area. Hydrothermal-metasomatic formations are represented by quartz veins, fouling (oxidized areas of sulfidization), lystenitization and birbiritization.

Stratified deposits are crushed into strained linear folds (with incidence angles to vertical ones) of the northwestern strike in the southwestern and central parts and submeridional on the northeastern flank, and are broken by numerous faults of the general northwest orientation, the conformal strike of the Charsk-Gornostayev crumpling zone.

Within the described structure, there is a "reference" Baladzhal deposit, as well as the Vera-Char deposit and the ore occurrences of Marinovskoe and Kyzyl-Tas.

The reconstruction of the magmatogene-ore system. At the first stage of this procedure, a meaningful analysis of the initial geological data is carried out (figure 2). As can be seen, the prevalence of dykes and small intrusions is negligible, while the bodies of medium-basic and acidic composition are spatially separated, and therefore do not form a joint multiplicative structure even near the Baladzhal reference deposit. This may indicate either a low intensity of the magmatic process or an excessive generalization in the mapping of the area.

In this connection, an additive picture of their development is used to quantify the structure of dike location and small intrusions of medium-base and acidic composition related to coal-mining igneous complexes; in the analysis granitoids of Permian age do not participate, which are post-ore according to existing concepts [1]. A similar decision was made as a result of the analysis of the arrangement of quartz veins and metasomatic formations that are developed in numerous but local nodes - at the stage of reconstruction of the structure of their placement they are considered as a single factor.

The structure of the location of dikes and small intrusions of a variegated composition and of various ages is illustrated in figure 3. As can be seen, it has a nodal character, and in the placement of nodes, traces of a linear (on the north-western flank) and concentric organization are traced. This is probably due to the peculiarities of the deep structure that controls the location of magma chambers. On the south-eastern flank, the magmatic control of the linear discontinuities of the north-north-western orientation is very clearly manifested in the location of magmatic formations.

The most stable (with values of measure up to 9) the described process is manifested on the north-western flank of the OS, at the junction of linearly and concentrically oriented elements. On the remaining area, the maximum values of the measure in local nodes are predominantly 7-8, only 9 reach 9.

The distribution of gold objects in the structure of magmatic formations has a clearly expressed regularity: both the reference Balajal deposit and other potentially significant objects (Vera-Char, Marinovskoye, Kyzyl-Tas) gravitate towards local nodes of sustainable development of the magmatic process (figure 3).

The statistical regularity of the confinement of gold ore objects to certain intervals of the measure's values is not observed (table 1): the distribution of gold deposits covers the values of the measure from 2 (the Baladzhal deposit) to 8 (the Vera-Char deposit). The total area of these intervals is 235 km^2, which is 35% of the study area (673.3 km^2).

According to the author of this work, the presence of structural control of mineralization (confinement of gold ore objects to local nodes of sustainable development of magmatic process) indicates the existence of a paragenetic connection between these processes and is a structural regularity.

The structure of the distribution of hydrothermal-metasomatic formations (HMF) has a nodal character (figure 4), and the distribution of local nodes is subordinated to a multi-level hierarchical concentric organization. Two levels of structures are distinguished: the structure of the first level of the organization is developed in the northern part of the area, it is characterized by toroidal placement of nodes of sustainable development of HMFs in the external concentrator (the Marinovskoe, Kyzyltas, Vera-Char objects are connected with these nodes), the distribution of HMFnodes is controlled by linear structures in the central part. The structures of the second level are of lesser dimensions and gravitate toward the periphery of the previously described one. Within their limits, the placement of HMFnodes is also subject to linear structures.

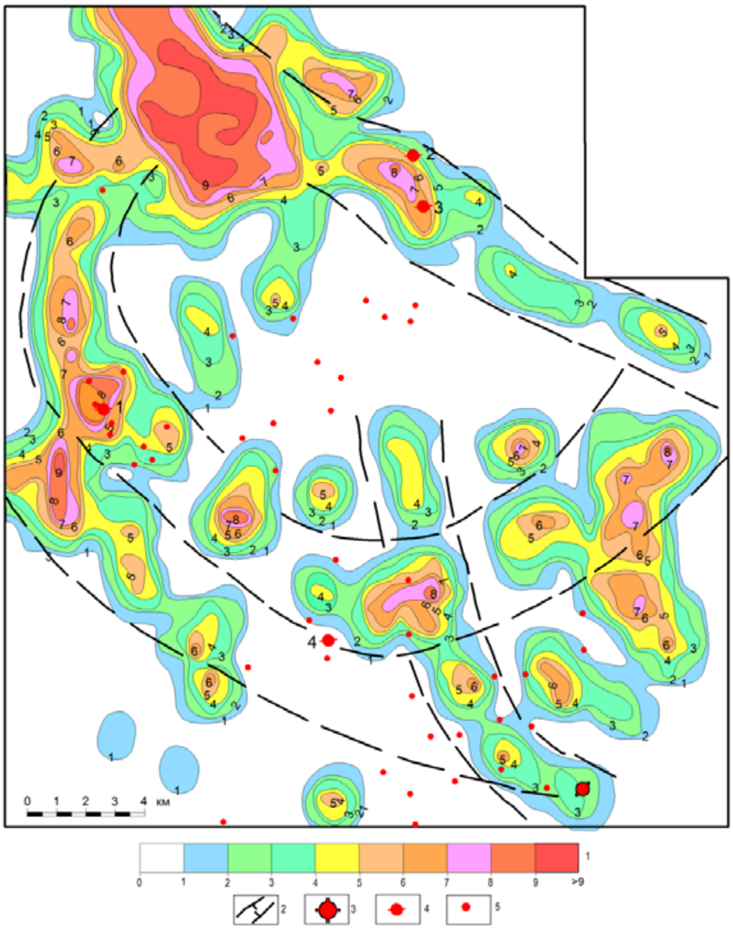

Figure 3 – The structure of the location of dykes and small intrusions of various composition in the area of Vera-Char - BaladzhalNS and the position of gold ore deposits in it (Compiled by G. B. Orazbekova).

Legend: 1 - the intervals of the stability measure of the placement of dikes and small intrusions of different composition; 2 - structural elements of the internal structure of the OS; 3 - the reference Baladzhal deposit; 4 - gold ore occurrences and deposits (1 - Vera-Char, 2 - Marinovskoe, 3 - Kyzyl-Tas, 4 - Jupiter); 5 - points of gold mineralization.

Table 1 – The distribution of values of the intervals of the stability measure for the development of dykes and small intrusions of different composition in the area of the Vera-Char - Balajal OS and the distribution of gold objects in them

Meaning of measure	Area		Position of deposits and ore manifestations					Perspective plots (area, km^2/%) from the area of the local forecast
	km^2	%	Baladzhal	Vera-Char	Marinovskoe	Kysyltas	Jupiter*	
1	64,75	20,9						
2	64,75	20,9						
33	52,5	16,9						
44	43,75	14,1						
55	28	9,04						
66	20,25	6,5						235/35
77	13,75	4,44						
88	12,25	4,11						
99	9,75	3,11						
Total	309,75	100						235/35

*The occurrence of Jupiter is located outside the range of sustainable development of dykes and small intrusions.

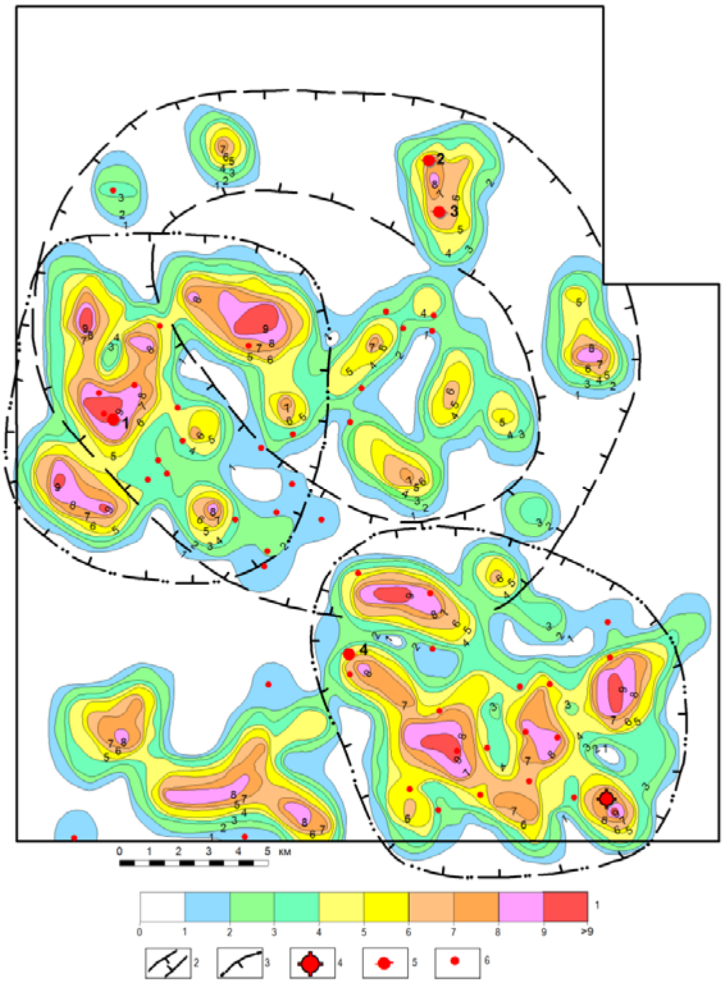

Figure 4 – The structure of the distribution of hydrothermal-metasomatic formations in the area of Vera-Char - BaladzhalNS and gold ore objects placement in it (Compiled by G. B. Orazbekova).
Legend: 1 - intervals of the stability measure of development of hydrothermal-metasomatic formations; 2, 3 - structural elements of the internal structure of the NS; 4 - the reference Balajal deposit; 5 - gold ore occurrences and deposits (1 - Vera-Char, 2 - Marinovskoe, 3 - Kyzyl-Tas, 4 - Jupiter); 6 - points of gold mineralization.

Analysis of the location of deposits in the structure of the HMFshows that they gravitate toward local nodes of the stable development of the factor located in the external concentration of the first-order structure, and the Baladzhal and Vera-Char deposits are located in local nodes located in the inner parts of structures of higher order. The outlined proposal testifies to the presence of structural regularities in the location of deposits in the structure of hydrothermal-metasomatic formations.

The statistical analysis of the location of gold ore objects in the structure of HMFs (table 2) shows that the area of their development covers intervals of values of the measure from 4 to 8 with a total area of 119.7 km^2, which is 17.8% of the area of the local forecast.

In accordance with the research paradigm, the reconstruction of the synergistic effect area was carried out by evaluating the joint sustainable development of the system elements described above: dykes and small intrusions of basic, medium and acidic (combined into a single additive element) and hydrothermal-metasomatic formations (figure 5). As can be seen, the joint manifestation of these processes is of a nodal nature, and two tendencies are clearly seen in the distribution of nodes: a focal character with the placement of nodes in the outer concentrator in the central part of the area and a linear type on the southwestern flank.

The placement of the Baladzhal reference deposit, as well as Vera-Char, Marinovskoye and Kyzyl-Tas deposits in the described structure are clearly natural: they gravitate towards the nodes of stable joint development of magmatic and hydrothermal-metasomatic processes.

Table 2 – Distribution of the intervals of the stability measure for the development of hydrothermal-metasomatic formations in the area of the Vera-Char - BaladzhalNS and the distribution of gold objects in them

Meaning of measure	Area		Position of deposits and ore manifestations					Perspective plots (area, km²/%) from the area of the local forecast
	km²	%	Baladzhal	Vera-Char	Marinovskoe	Kysyltas	Jupiter*	
1	58,25	20,37						
2	58,25	20,37						
3	43,75	15,3						
4	38,0	13,3					....	119,7/17,8
5	30,75	10,75						
6	21,25	7,43				....		
7	15,75	5,5	....		....			
8	13,95	4,88		....				
9	6,0	2,1						
Total	285,95	100						119,7/17,8

Statistical characteristics also show the presence of regularities in the location of objects relative to the described structure (table 3): all promising deposits and ore occurrences (Baladzhal, Vera-Char, Marinovskoye and Kyzyl-Tas) are concentrated in the intervals of measure from 20-30 to 70-80 with a total area of 37.5 km^2, which is 5.8% of the investigated area.

This indicates the uniqueness of the geological situation of these intervals and the possibility of their isolation as favorable for the formation of gold mineralization in this OS.

Analysis of forecasting results. The carried out researches allowed tosingle out local areas promising for the formation of gold deposits within the limits of the Vera-Bar-Baladzhal MRS (figure 2).The Baladzhal forecasted ore sub-cluster is located on the southeastern flank of the OS and covers five promising areas (figure 2), one of which is connected with the "reference" Baladzhal deposit. It is extended in the northwestern direction by 11 km and a width of 1.5 to 5 km, conformally to the Charsk-Gornostaevka crushing zone. The previous researchers pointed out (Navozov OV et al., 2009) within its limits 6 points of gold mineralization and numerous primary and secondary halos of arsenic, silver, as well as shingle haloes and placer gold, were isolated. Here, the formation of gold ore deposits is likely both in terrigenous strata (such as Zhumba, Kulujun, etc.), and in stocks and dykes.

Table 3 – The distribution of the values of intervals of the stability measure of the joint development of metasomatic formations and intrusive bodies in the area of Vera-Char - Baladzhal OS and distribution of gold ore objects in them

Interval of measure values	Area		Position of deposits and ore manifestations					Perspective plots (area, km²/%) from the area of the local forecast
	km²	%	Baladzhal	Vera-Char	Marinovskoe	Kysyltas	Jupiter*	
1-10	81,25	51,7						
10-20	37,5	23,8						
20-30	15	9,53	....		....			37,5/5,8
30-40	7,5	4,76						
40-50	8,75	5,36				....		
50-60	4,75	3,12						
70-80	1,5	0,95		....				
More 80	1,25	0,79						
Total	157,5	100						

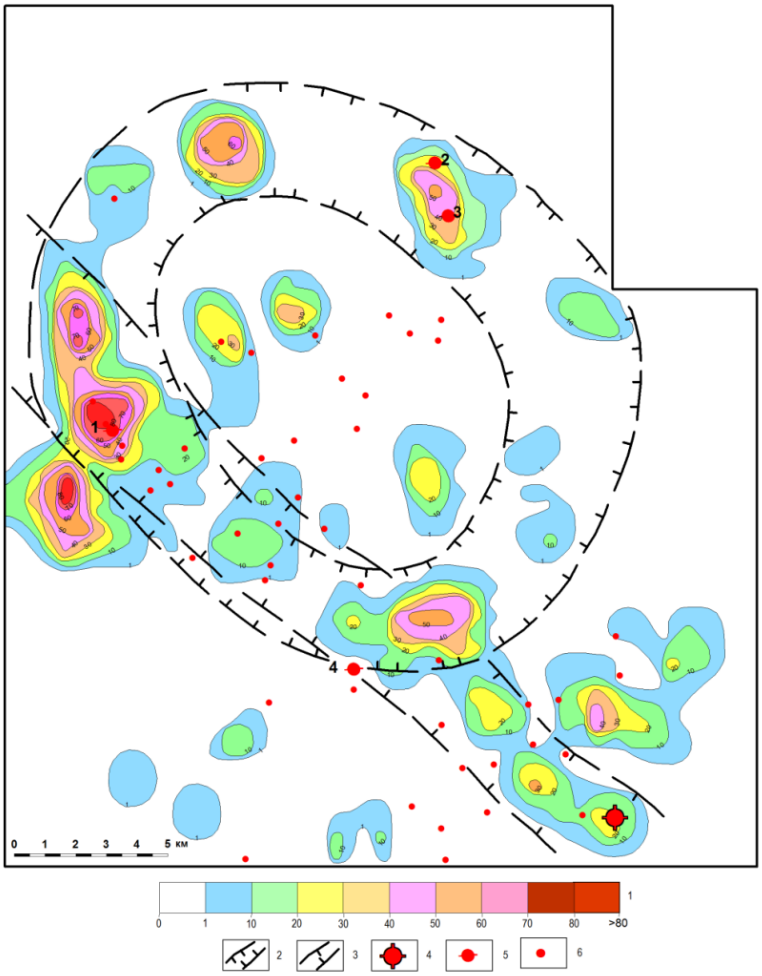

Figure 5 – The structure of the joint sustainable development of hydrothermal-metasomatic and intrusive formations in the Vera-Char-BaladzhalNS area and the position of gold ore objects in it. (Compiled by G. B. Orazbekova).

Legend: 1 - intervals of the stability measure of the joint sustainable development of hydrothermal metasomatic and intrusive formations 2,3 - structural elements of the internal structure of the NS; 4 - the reference Balajal deposit; 5 - gold ore occurrences and deposits (1 - Vera-Char, 2 - Marinovskoe, 3 - Kyzyl-Tas, 4 - Jupiter); 6 - points of gold mineralization.

No less, if not more significant, are the prospects of the Vera-Charsky predicted ore field, the northern part of which is located at the intersection of concentric and linear structurally-structuring elements of the MRS (figure 2). Within its boundaries is the well-known deposit Vera-Char, as well as a number of manifestations: Razdolny, Dmitri, Yekaterine. The previous researchers (O.V. Navozovand etc, 2009) have identified numerous points of mineralization and secondary geochemical aureoles of silver, arsenic, copper, as well as gold and arsenopyrite ingots.

The Marinovsko-Kyzyltas predicted ore field is located in the outer concentration of the OC (figure 2) and includes two gold ore occurrences - Marinovskoe and Kyzyltas. On the Marinovskoeoccurence gold-bearing bodies are brown iron minerals and secondary quartzites, penetrated by a network of quartz veins. The thickness of the zone is from 1-2 to 3-5 meters. The gold content in quartz is from 1.0 to 5 g/t, sometimes up to 20 g/t. In secondary quartzites increased concentrations of nickel, cobalt, arsenic, molybdenumwere noted. More interesting is the manifestation of Kyzyltas, where gold mineralization is associated with zones of fouled hydrothermally altered rocks bearing a rich impregnation of pyrite, less often arsenopyrite. Petrified zones can be traced at 1000-1500 m, their thickness is 5-10 meters with blowing up to 50 m, dip steep (80-90 °) with submeridional extension. The gold content in the Kyzyltas zone reaches 18.4 g/t. Gold is contained both in quartz and in altered pyritized rocks. The content from the surface to the depths of 8-10 m is 0.1-1.0 g/t (according to the galleries), in the pits 0.3-3 g/t, the highest concentrations are confined to the areas of maximum development of pyritization.

Thus, the reconstruction of the magmatic ore system of the Vera-CharkBaladzhal OS at a local level of study has made it possible to identify promising areas of ore-field rank, the total area of which is 37.5 km^2 or 5.8% of the area of predictive research.

A meaningful analysis of the results of forecasting confirms the prospects of the selected sites with the available search data.

The results of the predictive studies outlined in the article can be used to justify the direction of prospecting exploration.

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ҚОЛДАНУ ЖҮЙЕЛІ КӨЗҚАРАС БОЛЖАУ КЕЗІНДЕ КЕНДІ АЛАҢДАР, ЖЕРГІЛІКТІ АЛТЫН ОШАҚТЫ ҚҰРЫЛЫМДАРДА (мысалы, Вера-Чар - Баладжал ошақтық құрылымдар Шығыс Қазақстан облысының Батыс-Қалбақ алтынды ауданы)

Аннотация. Вера Чар - Балажал ошақтық құрылымы (OS) руда бірлігі бөлінген атағы реттегішті - AW перспективалық өңірлі конда 574.361 кг-ға дейін бағаланады болжамды ресурстары алтын зерттейді ретінде. Егжей-тегжейлі зерттеу нәтижесінде, осы баптың тақырыбы, перспективалық бағыттары кен және кенорындарына тағы орналасқан.

Вера Чарқайта алтын кен қалыптастыруға жүйелі тәсілді парадигмасынан егізделген - депозиттерді орналастыру оның алдын ала орнатылған істер заңдарына Балажал ошақты құрылымы мен кенді ірі кенорындарын қалыптастыру үшін перспективалы үш бөлінген учаскесі атағы өрістер: Балажалдын, Вера-кенболжамды Шар кенболжамды және Мариновты-Кызылтофты кенболжаған. Олардың жалпы ауданы 37,5 км^2 немесе болжамдық зерттеулер аумағының 5,8% құрайды.

Түйін сөздер: болжамды зерттеулер, алтын кенорындары, фокалды құрылымы, магматикалық білім беру, метасомалдык өзгерістер, Батыс-Қалба алтын ауданы.

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ПРИМЕНЕНИЕ СИСТЕМНОГО ПОДХОДА ПРИ ПРОГНОЗИРОВАНИИ РУДНЫХ ПОЛЕЙ В ЛОКАЛЬНЫХ ЗОЛОТОНОСНЫХ ОЧАГОВЫХ СТРУКТУРАХ
(на примере Вера-Чар - Баладжальской очаговой структуры в Западно-Калбинском золотоносном районе Восточного Казахстана)

Аннотация. Вера-Чар - Баладжальская очаговая структура (ОС) ранга рудного узла выделена автором в качестве перспективной на региональном уровне исследований, прогнозные ресурсы золота в ней оценены в 574 361 кг. В результате детального изучения, которому посвящена данная статья, перспективные площади локализованы до ранга рудных полей и месторождений.

На основе парадигмы системного подхода к формированию золоторудных месторождений произведена реконструкция Вера-Чар - Баладжальской очаговой структуры, в ее пределах установлены закономерности размещения месторождений и выделено три перспективных для формирования крупных месторождений участка ранга рудных полей: *Баладжальское прогнозное рудное поле,Вера-Чарское прогнозное рудное поле и Мариновско-Кызылтасское прогнозное рудное поле.* Их общая площадь которых составляет 37,5 км^2 или 5,8% от площади прогнозных исследований.

Ключевые слова: прогнозные исследования, золоторудные месторождения, очаговые структуры, магматические образования, метасоматические изменения, Западно-Калбинский золотоносный район.

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ON THE METHOD OF MANUFACTURE OF ORGANOMINERAL FERTILIZER BASED ON DOUBLE SUPERPHOSPHATE

Abstract. The paper considers features and advantages of using organomineral fertilizers. Large amount of weakly alkaline lignin-containing solutions being a hard-recyclable waste of cellulose production is formed as a result of the steam-explosive catalysis of herbal agricultural raw materials. The paper considers the possibility of using it as an organic component of organomineral fertilizer. Optimal parameters of the process of double superphosphate production were determined based on laboratory investigation results. The obtained product does not meet requirements of the State standard for double superphosphate, but it is similar to double superphosphate composition. We offer to conduct the process of product granulation in the presence of lignin-containing solution which is a waste of cellulose production to improve the quality, increase the assortment and the agrochemical composition of the fertilizer. Based on the research results we suggest a technological scheme of organomineral fertilizer production on a basis of double superphosphate with the use of lignin-containing solution. The obtained organomineral fertilizer has good physical qualities: it does not clump, does not cake up and does not lose its friability.

Keywords: organomineral fertilizers, delignification, lignin-containing solution, double superphosphate, wet-process phosphoric acid (WPA).

Introduction. It is known that organomineral fertilizers combine the advantages of individual organic and mineral fertilizers, strengthen and prolong the action of each of the components and simultaneously remove disadvantages of both fertilizers. The mineral part of organomineral fertilizers dissolve well in the soil solution and ensure fast assimilation by plants. Organic components have a prolonged effect and guarantee the supply of plants with nutrients for a long time. The separate application of organic and mineral fertilizers does not give such an effect. Organic and mineral parts of organomineral fertilizers interact between each other and nutrients (nitrogen, phosphorus and potassium) pass into more accessible compounds for plants. When using organomineral fertilizers, nitrogen mobility reaches 95-98%, phosphorus - 90-95%, potassium - 95%, and they are completely used by plants, while these elements are used in mineral fertilizers only by 30-35%. Therefore, the average doses of granular organomineral fertilizers are about 10 times lower compared to organic fertilizers and 2-3 times lower compared to mineral fertilizers. The ecological component is also very important in the production of organomineral fertilizers, i.e. the amount of both mineral and organic waste on the Earth will decrease. The effectiveness of the use of organomineral fertilizers has been confirmed by numerous tests, while it has been established that the content of organic matter in the soil increased on average by 16-25%. Agrochemical analysis of soil showed a significant increase of the level of macro- and microelements in the soil. The amount of nitrogen in the soil, compared with control sites, increased by an average of 2.2-2.8 times, the content of phosphorus increased by 1.3-2.0 times, potassium by 1.3-2.5 times, calcium by 1,3-1,9 times, magnesium by 1,3-1,6 times [1].

Organomineral fertilizers are characterized by high agrochemical efficiency. There are physiologically active substances in the organomineral fertilizers, which influence the growth of plants, create a loose soil structure, increase the total surface of the finished product volume. Organomineral fertilizers promote to adsorption and retention of moisture (up to 50%), as well as nutrients such as nitrogen, phosphorus, potassium, calcium, minor-nutrient elements. They have good physical qualities: they do not clump, do not cake up and do not lose their friability even when the moisture content in them is up to 50% (absolute). The use of organomineral fertilizers prevents and eliminates the possibility of elution of nutrient elements and allows to reduce significantly (by 25-50%) the norm of introducing nutrients into the soil. In addition, the use of organomineral fertilizers will allow to reduce soil salinity, provide optimal water and air regime, increase humus content in the soil, reduce the harmful effects of high doses of NPK fertilizers, pesticides, toxic chemicals and radionuclides, to increase soil fertility, crop yield, their quality value and ensure environmental safety [2].

Scientists of M. Auezov South Kazakhstan State University have developed a technology of cellulose production based on the process of steam-explosive autocatalysis of herbal agricultural raw materials, such as wheat straw and rice hulls. The developed cellulose technology is associated with the formation of large amount of weakly alkaline lignin-containing solutions. They have studied the process of explosive autocatalysis of wheat straw and rice hulls in the presence of weak alkaline solutions of cellulose production; paper or corrugated cardboard are produced from the cellulose hereafter. It has been established that the use of steam explosion of straw or rice hulls with subsequent extraction by alkaline solutions allows obtaining cellulose with better strength characteristics than that at acid delignification. Lignin is removed from these solutions; this process is called as delignification. At that, weakly alkaline lignin-containing solutions are formed, which are hard-recyclable wastes of paper production [3,4]. Further processing or recycling of these wastes is an actual production problem and an essential element of the creation of non-waste technology.

In this context, the development of the technology of organomineral fertilizer with the possibility of utilization of delignification extract is topical issue. Its use as an organic component of organomineral fertilizer based on double superphosphate can be one of such methods. To prepare an organomineral fertilizer on the basis of double superphosphate, we suggest adding the delignification extract at the granulation stage.

The proposed technology of organomineral fertilizer based on double superphosphate consists of several stages: 1) decomposition of phosphate raw materials with wet-process phosphoric acid (WPA); 2) drying the pulp; 3) granulation of the product in the presence of the lignin-containing solution; 4) drying and sifting the finished product. To determine optimal parameters of the process of obtaining organomineral fertilizer on the basis of double superphosphate, the influence of WPA norm, concentration and temperature on phosphorite decomposition degree and the additive of lignin-containing solution influence on the process conditions and the quality of the product were studied.

Materials and methods. Laboratory experiments of the decomposition of Karatau phosphorites with wet-process phosphoric acid for obtaining double superphosphate were carried out as follows. The WPA stoichiometric norm was calculated according to a simplified procedure that does not take into account the mineralogical composition of raw materials [5]. The required amount of wet-process phosphoric acid was heated up to a certain temperature and then mixed with phosphorite for 1 hour at stirring. The formed pulp was dried for 1.5 hours in a dryer at 105-110°C (to approach the temperature regime of ageing the double superphosphate in production conditions). The obtained chamber double superphosphate was analyzed for moisture content and all forms of P_2O_5 content by standard methods in accordance with GOST 20851.2-75 and GOST 20851.4-75.

Following raw materials were applied for the laboratory research: Karatau phosphorites of composition (mass %): P_2O_{5total} - 25,0; CaO - 37.04; MgO - 2.4; Fe_2O_3 - 1.18; Al_2O_3 - 0.8; insoluble residue - 21.62; F - 2.38; moisture - 0.32 and wet-process phosphoric acid produced from these raw materials; its composition (mass %): $P_2O_{5\ total}$ - 21.6; CaO - 0.57; MgO - 1.49; Fe_2O_3 - 0.99; Al_2O_3 - 0.86; F - 1.74; SO_4 - 2.22. Wet-process phosphoric acid used for the experiments was produced at the Plant of mineral fertilizers of "Kazphosphate" LLP. A complete analysis of Karatau phosphorites and WPA was conducted in the central laboratory of "Kazphosphate".

Results and discussion. To study the influence of WPA norm on the phosphorite decomposition degree the interaction process was carried out at a temperature of 70°C during 1 hour and a drying process was carried out at a temperature of 105-110°C. The WPA consumption coefficient was varied within 70-110% of the stoichiometry. The results of laboratory studies are presented in table.

Influence of WPA consumption rate on the phosphorite decomposition degree at 70 °C

#	WPA consumption rate, % of stoichiometry	Drying temperature, °C	$P_2O_{5\ total}$, %	$P_2O_{5\ free}$, %	Decomposition level, %
1	70	105-110	33,3	5,6	80,2
2	80	105-110	34,6	6,2	85,1
3	90	105-110	35,7	6,9	89,3
4	100	105-110	36,9	7,2	90,5
5	110	105-110	38,0	7,9	91,8

As can be seen from table, the phosphorite decomposition degree increases when increasing the WPA consumption rate, the content of P_2O_{5free}. also increases. In the dried samples, the P_2O_{5total} ranges as 33,3-38,0%, and P_2O_{5free} is 5.6-7.9%. At the acid norm above 90% of stoichiometry, the phosphorite decomposition degree does not increase significantly. At the norm of 110% of stoichiometry the decomposition degree is 91.8%, however, the content of free P_2O_5 is also high. Therefore, the optimal WPA norm is 90% of stoichiometry.

Under these conditions, a relatively high phosphorite decomposition degree is attained and a product with good physical properties is obtained, i.e. the prepared product can be processed further. The next step of the product treatment is granulation in the presence of the lignin-containing solution.

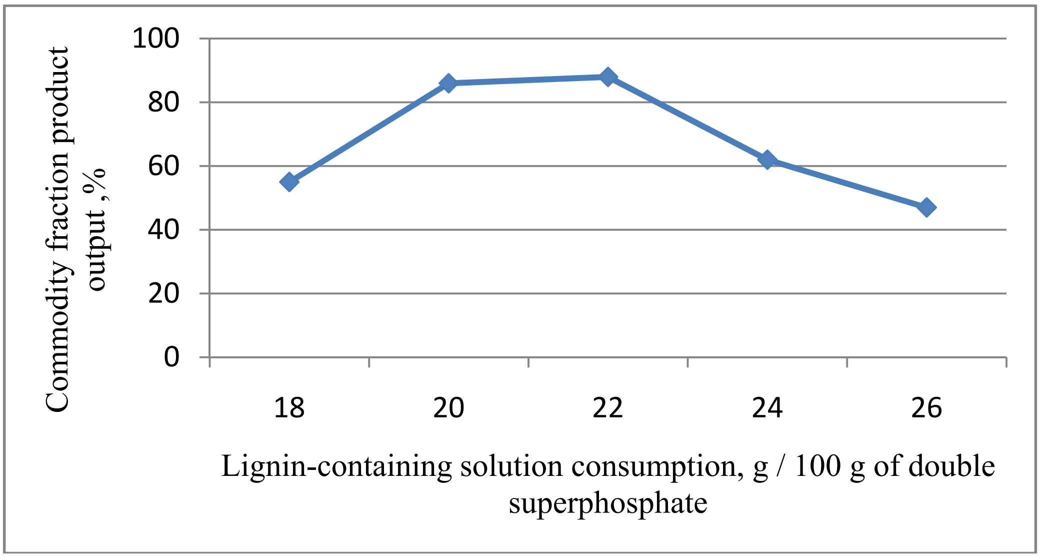
To study the effect of temperature on the phosphorite decomposition degree, decomposition temperature was varied within 40-90°C, the WPA consumption rate was 90% of the stoichiometry as an optimal value determined earlier. It is known that the phosphorite decomposition degree decreases with increasing temperature, this is explained by the nature of the change in solubility in CaO-P_2O_5-H_2O system [5]. When temperature increasing the supersaturation degree with calcium hydrophosphate increases. As a result, calcium hydrophosphate film is formed on the surface of the phosphorite grains, which leads to decomposition process deceleration. At temperature below 70°C, the phosphorite decomposition degree is somewhat higher, but the temperature of the superphosphate mass is reduced due to the relatively low ratio of the amount of heat released from the decomposition reaction to the weight of the superphosphate mass. This will increase the moisture content of the product. Evaporation of moisture takes place and the content of phosphoric acid in the liquid phase increases in the process of drying. The calcium hydrophosphate film formed on the surface of the phosphorite grains dissolves, an activity of hydrogen ions in the liquid phase increases, as a result of which the phosphorite further decomposition takes place. The results of studies showed that increasing the temperature above 70^0C causes more viscous and dense pulp formation. At a temperature of 70°C, more mobile pulp is obtained, which will easily be transported to the dryer.

Thus, optimal parameters of the process of obtaining double superphosphate were determined: WPA consumption rate is 90% of stoichiometry; the decomposition temperature is 70°C. Under these conditions, the product of the following composition was obtained, (mass %): P_2O_{5total} - 35.7; $P_2O_{5available}$ - 31.9 and P_2O_{5free} - 6.9. This product does not meet the requirements for the double superphosphate GOST, but it is similar to double superphosphate composition.

The lignin-containing solution obtained as a result of a steam explosion of rice hulls is an alkaline water extract containing 26% of lignin with pH = 12-13. After complete evaporation of this extract, the chemical composition of the obtained precipitate, determined from scanning electron microscopy, (mass %) is following: C-34.85; O-35.68; Na-0.62; Si-1.15; S-0.16; K-24.52. As can be seen from the data, the dry residue is mainly represented by carbon, oxygen, and potassium; there are sodium, sulfur and silicon in relatively small amounts.

Studying the fertilizer granulation process in the presence of lignin-containing solution has shown that the use of lignin-containing solution leads to the neutralization of free acidity forming potassium phosphates in the complex of phenylpropyl functional groups and the enrichment of the product additionally with potassium nutrient. As a result of double superphosphate preparation in laboratory conditions with the use of delignification solution at the granulation stage we have obtained the organomineral fertilizer of the composition, mass %: P_2O_{5total} – 33,8; $P_2O_{5available}$ – 32,11; P_2O_{5free} – 0; organic constituent – 5,39.

The results of investigations of lignin-containing solution additive influence on commodity fraction product output from the granulation stage are given in figure.



Dependence of commodity fraction product output on lignin-containing solution consumption

It demonstrates that optimal lignin-containing solution additive, providing maximum of commodity fraction product output, has very narrow range. Outside the range either pelletizing does not take place or spontaneous agglomeration takes place. Insignificant additive increase or decrease leads to sharp reduction of commodity fraction product output. It is explained that the additive decrease is accompanied with moisture input decrease, i.e. there is the lack of moisture for complete wetting fertilizer grain surface; at that pelletizing does not take place. And when the additive increasing the amount of moisture input increases which results in excessive growth of charge moisture content and formation of large lumps and agglomerates.

The results of laboratory testing have shown that optimal lignin-containing solution additive is 20-22 g / 100 g of powdered double superphosphate. The maximal commodity fraction product output – 86-88% is observed at this condition.

The proposed technological scheme for the production of organomineral fertilizer based on double superphosphate consists of several stages: 1) the decomposition of phosphate raw materials with WPA of P_2O_{5total} 21.6% concentration (by mass), at 90% WPA consumption rate for 1 hour at 70-90°C, while the phosphate raw material decomposing by 55-60%: 2) Drying the pulp at 105-110^{0}C. During the drying process, the decomposition of raw materials continues and the total decomposition degree of raw materials increases to 85-90%; 3) Granulation of the product in the presence of the lignin-containing solution; 4) Drying the prepared granules to the moisture content of 3-4% in warm conditions at the temperature of 60-70^{0}C.

Conclusion. Optimal parameters of the process of double superphosphate production were determined based on laboratory investigation results: decomposition of phosphate raw materials with WPA for 1 hour at 70-90°C with further decomposition during the drying process, then lignin-containing solution addition with the norm of 20-22 g / 100 g of powdered double superphosphate on the granulation stage. When using lignin-containing solution at the granulation stage of double superphosphate production we can prepare the new mineral fertilizer of improved quality. It will promote to increase product output and to increase the assortment and the agrochemical composition of the organomineral fertilizer. Simultaneously the cellulose production waste can be utilized completely. The prepared organomineral fertilizer based on double superphosphate contains P_2O_5 in easily assimilated form for plants and an organic part that is of prolonged action. The use of such a fertilizer extends the term of its effective action in the soil.

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ҚОС СУПЕРФОСАТ НЕГІЗІНДЕ ОРГАНОМИНЕРАЛДЫ ТЫҢАЙТҚЫШТЫ ДАЙЫНДАУ ӘДІСІ БОЙЫНША

Аннотация. Мақалада органоминералды тыңайтқыштардың ерекшеліктері мен артықшылықтары көрсетілген. Шөпті ауылшаруашылық шикізаттарын целлюлоза алу мақсатымен бу-жарылыс катализ арқылы өңдеу нәтижесінде көп мөлшерде әлсіз сілтілі лигнинқұрамдас ерітінділер пайда болады. Мақалада осы ерітіндіні органоминералды тыңайтқыштың органикалық құрамдас бөлігі ретінде қолдану қарастырылған. Зертханалық зерттеулер нәтижесінде қос суперфосфат алу процесінің тиімді технологиялық параметрлері анықталған. Алынған суперфосфат қос суперфосфатқа қатысты стандарт талаптарына сәйкес келмейді, бірақ құрамы бойынша қос суперфосфатқа жақын. Тыңайтқыштардың сапасын жоғарылату, ассортиментін көбейту және агрохимиялық құрамын жақсарту мақсатымен оны целлюлоза өндірісінің қалдығы – лигнинқұрамдас ерітіндінің қатысында түйіршіктеу ұсынылған. Зерттеу нәтижелері бойынша лигнинқұрамдас ерітінділерді қолдану арқылы қос суперфосфат негізінде органоминералды тыңайтқыш алудың технологиялық сызба нұсқасы ұсынылған. Алынған органоминералды тыңайтқыштың физикалық қасиеттері жақсы: жұмырланбайды, нығыздалмайды және үгілгіштігін жоғалтпайды.

Түйін сөздер: органоминералды тыңайтқыштар, дәнекерлеу, лигнинді ерітінділер, қос суперфосфат, экстракциялық фосфор қышқылы.

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ПО МЕТОДУ ИЗГОТОВЛЕНИЯ ОРГАНОМИНЕРАЛЬНОГО УДОБРЕНИЯ НА ОСНОВЕ ДВОЙНОГО СУПЕРФОСФАТА

Аннотация. В статье представлены особенности и преимущества использования органоминеральных удобрений. В результате паро-взрывного катализа травянистого сельскохозяйственного сырья с целью получения целлюлозы образуется большое количества слабощелочных лигнинсодержащих растворов, которые являются трудноутилизируемым отходом. В статье рассмотрена возможность применения его в качестве органической составляющей органоминерального удобрения. По результатам лабораторных исследований определны оптимальные параметры процесса получения двойного суперфосфата. Полученный продукт не соответствует требованиям стандарта на двойной суперфосфата, но по своему составу схож с двойным суперфосфатом. С целью улучшения качества, увеличения ассортимента и агрохимического состава удобрения предлагается процесс грануляции продукта проводит в присутствии лигнинсодержащего раствора – отхода производства целлюлозы. По результатам исследований предложена технологическая схема производства органоминерального удобрения на основе двойного суперфосфата с использованием лигнинсодержащего раствора. Полученное органоминеральное удобрение имеет хорошие физические качества: не комкуются, не слёживаются и не теряют своей рассыпчатости.

Ключевые слова: органоминеральные удобрения, делигнификация, лигнинсодержащие растворы, двойной суперфосфат, экстракционная фосфорная кислота (ЭФК).

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THE STATE AND COMPOUND OF THE PLATINOIDS AND RARE EARTH METALS WITHIN THE PICRITES SULFIDES OF THE KARA-TURGAI ASSEMBLAGE OF THE NORTHERN ULYTAU

Abstract. Violarite, siegenite, platinum telluride (moncheite), silver telluride, lead telluride (altaite), lead selenide, solid solutions of iridium group metals (Ir, Os, Ru), rare earth metals (Dy, Er, Y, Ce) have been discovered for the first time in picrites of the Kara-Turgai assemblage alongside previously known sulfides of copper, nickel and cobalt (copper pyrite, pentlandite, cobaltite, nickeline, gersdorffite). The sulfides constitute three mineral formations. The first two mineral formations form segregation "droplets", having a round and elongate elliptical shape, while the third one is represented by exudations of irregular acute-angled shapes. The platinoids in sulfides are established to exist only in the segregation droplets of the first formation, which accumulated of pyrrhotite, copper pyrite, pentlandite, violarite, and sphalerite. The sulfides of the second formation do not contain platinoids and are represented by pyrrhotite, copper pyrite, and sphalerite. The sulfides of the third formation are represented by pyrrhotite, copper pyrite, sphalerite, and pyrite. The whole of three mineral formations contain magnetite and are commonly confined to the most graded picrites horizons and apopicritic olivinites. Single sulfides inclusions were detected within the picritic diabases, represented by pentlandite, siegenite, millerite, pyrite, and galenite. Cu-Ni - ore formation (platinum group minerals [PGM]) – (rare earth elements [REE]) of Kara-Turgai ores was presumed to occur in an open magmatic system, which was favorable for accumulation of commercial bulk of sulfide.

Key words: Ulytau, copper-nickel ores, platinoids, rare earth metals.

Introduction. A diabase-picritic Kara-Turgai assemblage that is dimensionally and genetically linked with the copper and nickel sulfides [1] is long ago well-known in the west of Central Kazakhstan, in the Kara-Turgai River basin (Figure 1). The platinum group metals (PGM) [2, 3] availability in the sulfides arose the keeping interest for their study [3-13].

The copper, nickel and iron sulfide clusters are in the picrites and apopycritic serpentinites, which constitute the inclusions of three mineral formations. The first two formations constitute a segregation "droplets", of a rounded and ellipsoid-elongated shape, the third formation is irregular acute-angled shapes.

O.B. Bejseyev and his joint authors [6] have studied the mineral compound of mineralization in detail and distinguished pyrrhotite, pentlandite, copper pyrite, magnetite, nickeline, cobaltite, sperrylite, titano-magnetite, titano-ferrite and chromite in descending order. K.Sh. Dyusembayeva [8] has enlarged this ore formation with gersdorffite, covellite, bravoite, arsenic pyrite.

Currently, the platinum group metals are well-known in the sulfides of the Kara-Turgai and Akzhal occurrences, which are concentrated in the intrusive sheet compound underlying among the Proterozoic formations (figure 1). Pursuant to O.B. Bejseyev's data [6] the sulfide copper-nickel-cobalt ores of the Kara-Turgai occurrence contain Pt-5 g/t, Pd-16 g/t, whereas S.S. Chudin [7] states of the total platinoids content reaches only 10 g/t in the copper-nickel concentrate of these ores.

An extremely low Pt + Pd concentrations (up to 0.2-0.4 g/t), as to S.S. Chudin's data [7], are pointed out in apopycritic serpentinites of the Akzhal massif. The state and compound of the platinoids in sulfides were not previously established.

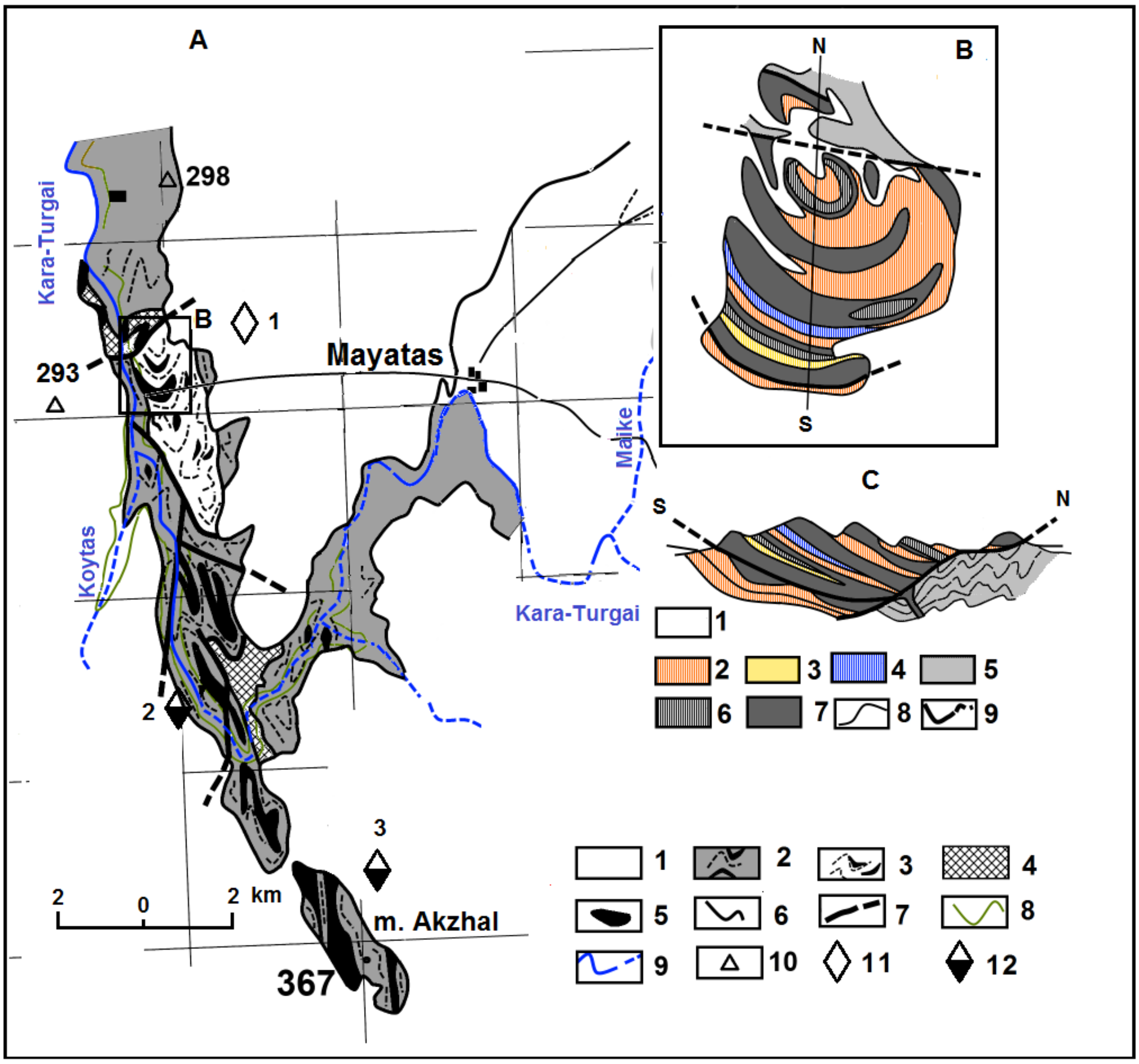

Figure 1 –

A. A geological sketch map of the middle stream area of Kara-Turgai River by I.I. Vishnevskaya and I.F. Trusova [4], S.S. Chudin [7], amended and supplemented by the authors: 1 – Cainozoic sediments; 2-3 – Karsakpai group (Mesozoic-Proterozoic): 2 – metabasalts stratum, less commonly andesites with the tributary levels of muscovite-quartzite and quartzite shales, 3 – variegated tuffs strata of quartz albitophyres and ash banded tuffs of the average compound, 4 – muscovite-albite and graphite shales, albite gneisses and micro-gneisses of the Aralbai group (PR_1ar); 5 – the Kara-Turgai diabase-picritic assemblage (PR_3k); 6 – geological boundaries; 7 – tectonic faultings; 8 – topographical contour lines; 9 – the Kara-Turgai River and its Koitas and Maike inflows; 10 – trigonometric heights. 11, 12 –genetic types of minerals; 11– magmatic group (segregation type), sulfide copper-nickel ores with platinoids and rare-earth elements (Dy, Er, Y, Ce) in the picrites, 12 – carbonatite group (fluid-magmatic type), carbonatites of quartz-carbonate-albite compound with copper sulfides and platinoids. The ore manifestations: 1 – Kara-Turgai, 2 – North Akzhal, 3 – Eastern Akzhal.

A geological sketch map of the Kara-Turgai massif (B) and the SN section (C) through the central part of the massif. The source of data is by N.P. Mikhailov, Yu.L. Semenov[1], I.I. Vishnevskaya and I.F. Trusova [4], O.B. Bejseyev [6] amended and supplemented by the authors: 1 – Cainozoic sediments; 2-4 – Karsakpai group (PR_2kr): 2 – tuffs of quartz albitophyres, 3 – banded tuffs of average compound; 4 – tuffs of main compound; 5 – graphite-albite shales of the Aralbai group (PR_1ar); 6-7 – Kara-Turgai diabasepicritic assemblage: 6 – quartz diabases, diabases, 7 - picritic diabases, picrites, apopicritic serpentinites, primary spherical, porphyraceous; 8– geological boundaries; 9 – faultings and thrusts.

Research Methods. Platinoids microinclusions within the copper and nickel sulfides from the picrites of the Kara-Turgai assemblage were studied in the mineralogy department of the IGS LLP named after K.I. Satpayev (Almaty) by means of the energy dispersive spectrometer by INCA ENERGY, OXFORD INSTRUMENTS, England, installed on an electron probe micro-analyzer Superprobe 733 by JEOL, Japan (accelerating voltage is 25 kV, probe current is 25 nA, probe diameter is 1-2 μm). When analyzing minerals as a comparison samples used the following: pure metals for the PGM; the artificial compounds (A) PO_4 for REE; $CuFeS_2$ for Fe, Cu, S; PbS for Pb, ZnS for Zn, the pure metals for the rest of metals. The analysis results rate was 100%. All the photos were taken in the back-scattered electron mode, the image contrast of which depends on the effective atomic number of the $\overline{Z}$ phase. The bigger $\overline{Z}$ is, i.e. the more heavy elements are in the phase being studied, and the lighter it is on the image.

Research Results. The sulfides of three mineral formations were thoroughly studied by us as a part of the Kara-Turgai assemblage picrites. The first is represented by the segregational globules containing: pyrrhotite, pentlandite, copper pyrite, sphalerite, magnetite. The second formation forming globules as well consists of: pyrrhotite, copper pyrite, sphalerite, magnetite. The third formation is represented by irregular shape inclusions, containing: pyrrhotite, copper pyrite, sphalerite, pyrite, magnetite.

The globules of the first formation included platinum telluride (moncheite), silver telluride, lead telluride, lead selenide, polymetallic solid solutions of platinum group metals (Ir, Os, Ru), rare earth metals (Dy, Er, Y, Ce) were discovered for the first time along with the previously known copper and nickel sulfides (pentlandite and copper pyrite). The microinclusions of silver telluride, platinoids and the rare earth elements were not discovered in the sulfides globules of the second formation. The sulfides of the third formation, such as pyrrhotite, copper pyrite and sphalerite do not contain inclusions of platinum group minerals detected in the back scattered electron mode (compound) and the rare earth elements, and just very small inclusions containing Ce and Os were found in the $FeOS_2$ phase.

Segregation Group Minerals.

The first mineral formation. The ore-forming sulfides of the first picrites formation are represented by pyrrhotite, pentlandite, violarite, copper pyrite, sphalerite.

Pyrrhotite (FeS) has a fine sulfur excess. Chemically it is close to the troilite formula in theory (see table 1). The states of the solid solutions decay are clearly observed in the pyrrhotite (figure 2 (B)). It contains microinclusions of platinum telluride ($PtTe_2$), silver telluride (Ag_2Te), altaite (PbTe). When arsenic occurs in pyrrhotite (As to 3.44%) at performing an analysis of the small heavy microinclusions in pyrrhotite, then Os (up to 29.77%), Ir (up to 6.89%), Ru (up to 15.27%) is certainly found, and also a high content of Y (11.41%). Once arsenic concentration increases (up to 10.83%), then Ir content grows (up to 16.41%), and Pt (> 4.62%) appears, as well as Te admixture (> 0.62%). It makes consider dealing with the polymetallic solid solutions of platinoids.

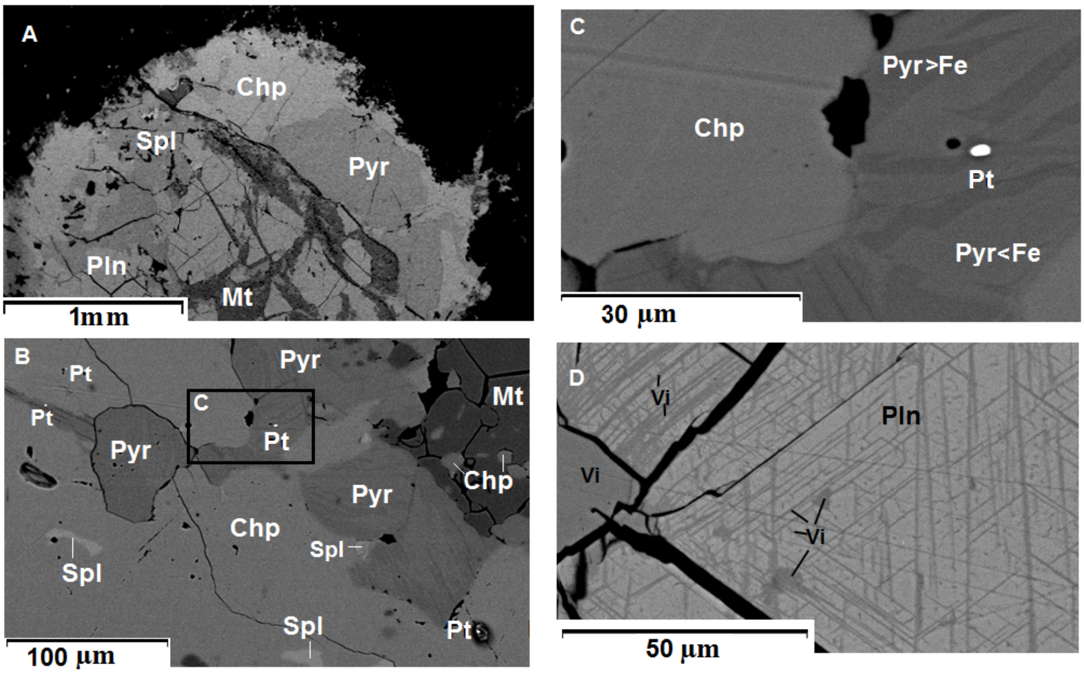

Figure 2 – Back-scattered electron image of the parts of polished sections made from ore samples containing pyrrhotite (Pyr), copper pyrite (Chp), pentlandite (Pln) violarite (Vi), sphalerite (Spl), magnetite (Mt) with the platinum (Pt) microinclusions. Figures A, B show a structure of a sulfide drop and the minerals interaction. Figure C demonstrates the nature of copper pyrite ratio to pyrrhotite (with the solid solution decay structure), and Figure D shows the slaty structure of the pentlandite-violarite decay

The pyrrhotite crystals form a two-phase area (figure 2 (C)), where the lighter areas are represented by a phase of greater Fe_2O_3 (61.85%, see Table 1, 9-12) content than in the dark phase.

Pentlandite ($(Fe,Ni)_9S_8$) contains cobalt (1.04-1.31%) admixture and is specified by sulfur deficiency, and the lack of cobalt leads to a sulfur excess. The pentlandite is undersaturated by sulfur, as a rule, contains platinum telluride ($PtTe_2$) microinclusions with Pd, Bi admixtures and contains Rh (1.99%), Ir (1.84%) extremely rarely. There are also sometimes Dy (1.65%), Er (1.6%), and Y (0.08%) admixtures. The slaty structure of the solid solutions decay is established in the pentlandite (Fig. 2 (D)), where the dark decay phase is depleted in Fe (<26.11%). Chemically this phase is similar to violarite (table 1).

Violarite ($(Fe,Ni)_3S_4$) pseudomorphic in pentlandite is less common. It similar to pentlandite has a lack of sulfur. Violarite contains rare small microinclusions providing Er up to 1.76% and Os up to 15.43% in the analysis, which indicates the availability of an independent mineral state of osmium.

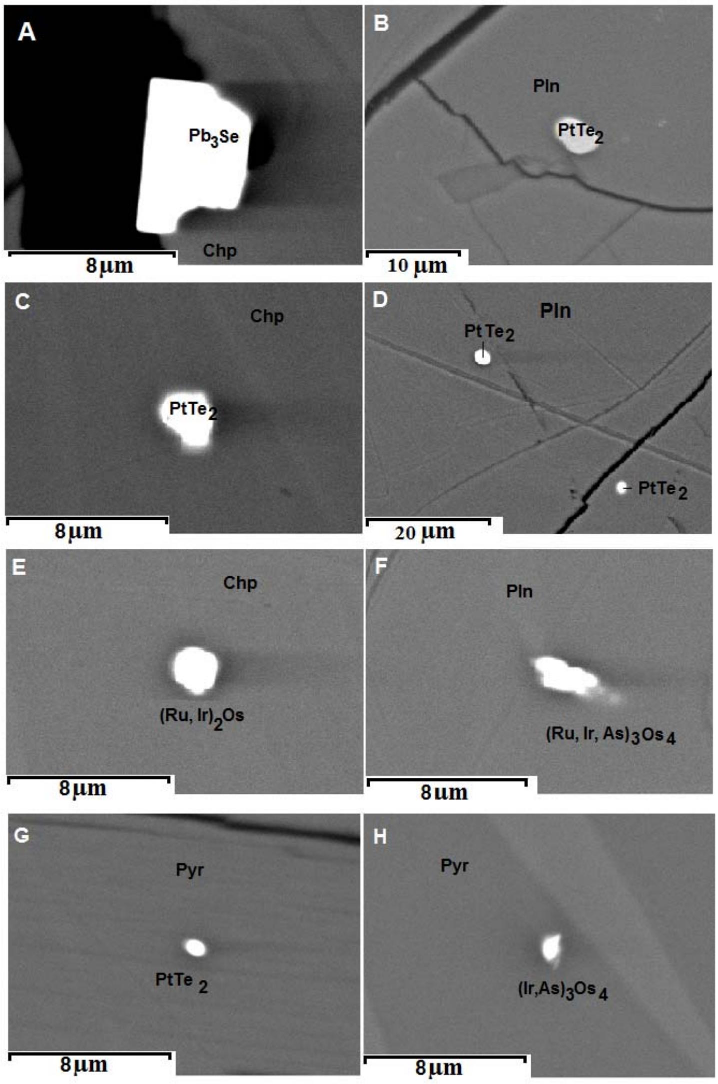

Figure 3 – Back-scattered electron image of the parts of polished sections made from ore samples containing pentlandite, copper pyrite with the platinoids and platinum telluride II ($PtTe_2$) microinclusions

Copper pyrite ($CuFeS_2$) displays a constant sulfur excess (see Table 1). Platinum telluride ($PtTe_2$) with Pd, Bi admixtures; silver telluride (Ag_2Te); altaite (PbTe) microinclusions are rarely contained, but lead selenide (PbSe) is predominant, and Os (11.31%), Ir (1.60%) and Rh 11.17%) form polymetallic solid solutions. Ce (11.27%) and F inclusions which, apparently, jointly form a CeF_3 phase appear in the copper pyrite exceedingly rare.

Table 1 – The sulfides compound of the first mineral formation with the magnetite, together with PGM, REE picrites of the Kara-Turgai assemblage (wt. %, 100% total)

Sr. No	Mineral	S	Fe	Cu	Co	Ni	Zn	Pb	Er	Os	Te
The first ore mineral formation with magnetite, together with PGM, REE.											
1	Cooper pyrite	36.61	30.00	33.39							
2	Cooper pyrite	36.44	30.19	33.37							
3	Cooper pyrite	36.46	29.97	33.57							
4	Cooper pyrite	33.50	30.05	33.45							
5	Cooper pyrite	37.28	29.43	33.19	0.10						
6	Cooper pyrite	34.99	30.52	34.50							
7	Cooper pyrite	35.53	30.04	34.43							
8	Cooper pyrite	35.39	30.44	34.17							
9*	Cooper pyrite	35.23	28.89	32.43							3.44
10	Sphalerite	35.09	9.05	1.02			54.83				
11	Sphalerite	34.98	8.88	0.32			55.82				
12	Sphalerite	35.29	10.31	0.80			53.60				
13	Sphalerite	35.12	9.41	0.71			54.75				
14	Sphalerite	33.65	10.19	0.54		1.17	54.45				
15	Sphalerite	33.83	9.44	1.19		0.16	55.38				
16*	Pyrrhotite	41.20	49.35	0.59		0.50				8.36	
17	Pyrrhotite	38.15	61.85								
18	Pyrrhotite	38.16	61.84								
19	Pyrrhotite	38.15	61.85								
20	Pyrrhotite	38.15	61.85								
21	Pyrrhotite	40.37	59.63								
22	Pyrrhotite	40.29	59.71								
23	Pyrrhotite	40.52	59.48								
24	Pyrrhotite	40.39	59.61								
25	Pyrrhotite	38.93	61.07								
26	Pyrrhotite	38.82	61.18								
27*	Pyrrhotite	39,73	59.03							1.24	
28*	Pyrrhotite	33.50	52.60								4.74
29*	Pyrrhotite	31.54	61.98								6.47
30	Pentlandite	35.04	33.24		1.18	30.54					
31	Pentlandite	35.28	33.56		1.04	30.13					
32	Pentlandite	35.75	32.78		1.31	30.16					
33	Pentlandite	35.28	33.56		1.04	30.13					
34	Pentlandite	35.75	31.78		1.31	30.16					
35	Pentlandite	34.01	32.82			31.60			1.57		
36	Pentlandite	34.00	33.60			31.55			0.85		
37	Pentlandite	34.13	33.54			31.46			0.88		
38	Pentlandite	34.37	33.55			30.55			1.24		
39	Pentlandite	33.91	33.59			30.90			1.60		
40	Violarite	40.66	24.81			32.86			1.68		
41	Violarite	40.27	26.11			31.86			1.76		
42	Violarite	40.70	22.95			35.19			1.16		
43*	Violarite	39.84	25.49			31.36			1.42	15.43	
44	Violarite	41.58	24.20			34.22					
*The analysis point contains a small inclusion.											

Crystallo-chemical formulas.

1. $Cu_{0.999}Fe_{1.011}S_{2.149}$;
2. $Cu_{0.996}Fe_{1.014}S_{2.133}$;
3. $Cu_{0.992}Fe_{1.008}S_{2.136}$;
4. $Cu_{0.989}Fe_{1.011}S_{2.08}$;
5. $Cu_{0.99}Fe_{1.0}S_{2.21}$;
6. $Cu_{1.0}Fe_{1.01}S_{2.0}$;
7. $Cu_{1.0}Fe_{1.01}S_{2.04}$;
8. $Cu_{1.0}Fe_{1.01}S_{2.04}$;
9. $Cu_{0.97}Fe_{0.98}Te_{0.05}S_{1.99}$;
10. $Zn_{0.838}Fe_{0.161}S_{1.030}$;
11. $Zn_{0.843}Fe_{0.157}S_{1.080}$;
12. $Zn_{0.816}Fe_{0.184}S_{1.096}$;
13. $Zn_{0.832}Fe_{0.167}S_{1.089}$;
15. $Fe_{1.00}S_{1.075}$;
16. $Fe_{1.00}S_{1.075}$;
17. $Fe_{1.00}S_{1.075}$;
18. $Fe_{1.00}S_{1.075}$;
19. $Fe_{1.00}S_{1.179}$;
20. $Fe_{1.00}S_{1.175}$;
21. $Fe_{1.00}S_{1.187}$;
22. $Fe_{1.0}S_{1.18}$;
23. $Fe_{0.91}S_{1.09}$;
24. $Fe_{0.92}S_{1.08}$;
25. $Fe_{0.95}S_{1.05}$;
26. $Fe_{0.95}S_{1.05}$;
27. $Fe_{0.99}S_{1.16}$;
28. $Fe_{0.96}Te_{0.04}S_{1.07}$;
29. $Fe_{0.95}Te_{0.05}S_{0.85}$;
30. $(Fe_{4.72}Ni_{4.12}Co_{0.16})_{\sum 9.0}S_{8,66}$;
31. $(Fe_{4.78}Ni_{4.08}Co_{0.14})_{\sum 9.0}S_{8.75}$;
32. $(Fe_{4.70}Ni_{4.12}Co_{0.18})_{\sum 9.0}S_{8.94}$;
33. $(Fe_{4.78}Ni_{4.08}Co_{0.14})_{\sum 9.0}S_{8.75}$;
34. $(Fe_{4.63}Ni_{4.19}Co_{0.18})_{\sum 9.0}S_{9.08}$;
35. $(Fe_{4.66}Ni_{4.27}Er_{0.07})_{\sum 9.0}S_{8.04}$;
36. $(Fe_{4.73}Ni_{4.23}Er_{0.04})_{\sum 9.0}S_{8.34}$;
37. $(Fe_{4.73}Ni_{4.23}Er_{0.04})_{\sum 9.0}S_{8.39}$;
38. $(Fe_{4.79}Ni_{4.15}Er_{0.06})_{\sum 9.0}S_{8.55}$;
39. $(Fe_{4.76}Ni_{4.17}Er_{0.07})_{\sum 9.0}S_{8.37}$;
40. $(Fe_{1.33}Ni_{1.37}Er_{0.03})_{\sum 3.03}S_{3.79}$;
41. $(Fe_{1.39}Ni_{1.61}Er_{0.03})_{\sum 3.03}S_{3.73}$;
42. $(Fe_{1.39}Ni_{1.61}Er_{0.03})_{\sum 3.03}S_{3.73}$;
43. $Fe_{1.38}Ni_{1.62}Er_{0.03})_{\sum 3.03}S_{3.76}$;
44. $(Fe_{1.28}Ni_{1.72})_{\sum 3.0}S_3$

Sphalerite (ZnS) is a relatively uncommon mineral that is oversaturated with sulfur and contains up to 10.31% Fe and Cu up to 1.02% (see table 1). Chemically, it matches marmatite $((Zn_{0.84},Fe_{0.16})_{\sum 1.00}S_{1.08})$. A high level of Fe and S excess is presumably determined by a pyrrhotite in formation as a product of solid solution decay. Considering the iron entering into the sphalerite structure greatly increases the total system storage, then the iron amount in the solid solution decreases at a high pressure, and consequently, as the pressure releases, the iron amount in the sphalerite structure increases.

The mineral of oxides group. Magnetite (Fe_3O_4), combined with the first formation sulfides, contains (wt.%): Fe (73.92 -74.66). A fine grain is detected in, which produced Os (6.44), Ru (2.01), and Rh (0.22) in the general review. A Y (2.15) admixture is also detected in this grain. These data indicate a solid solution of platinoids and yttrium is established.

Precious and rare minerals microinclusions in the first formation sulfides are represented both as the intermetallic compounds (intermetallides) that form independent round, ellipsoidal, less irregular shapes of exudations of not more than 3 μm diameter (figure 3), and in the form of tellurides, selenides and arsenides .

The most common is **platinum telluride** with Pd, Bi admixtures, which chemically is close to the stoichiometric formula of **moncheite $PtTe_2$** (see table 2, No. 1-3). **Silver telluride** generates a perfectly rounded grain (figure 3). Chemical compositions of the inclusions in copper pyrite correspond to **Ag_2Te** (see table 2, No. 4). Occasional **altaite (PbTe)** inclusions in pyrrhotite and copper pyrite (see table 3)

The **(Ru, Ir) Os** entity was found in the pentlandite (see table 3), its empirical formula can be represented as $(Ru_{0.61}Ir_{017}As_{0.08})_{\sum 0.86}Os_{1.14}$ with the chemical compound (wt%) (without matrix elements): Os (29.77), Ru (8.60), Ir (4.39), As (0.87).

A grain of no more than 1.0 μm was detected in copper pyrite (see Table 3), which contains (wt. %): Ru (11.17), Os (11.31), Ir (1.60), Bi (0.11) along with iron, copper and sulfur in the analysis. The empirical formula of such a high-temperature solid solution can be represented as $(Ir_{0.153}Ru_{01.841})_{\sum 2.004}Os_{0.996}$, which perfectly corresponds to the osmiridium **$(Ru, Ir)_2Os$** formula. Also an ellipsoidal grain of up to

Table 2 – Microinclusions analysis in the sulfides of the first picrites formation of the Kara-Turgai assemblage (wt. %) without matrix elements

Sr.No.	Mineral	Pt	Pd	Rh	Ru	Te	Bi	Ag	Pb	Se	∑
1	$PtTe_2$(pln)	35.66	2.37	1.27		47.94	7.99				95.23
2	$PtTe_2$ (pln)	32.03	1.65	1.99		42.66	8.83				87.16
3	$PtTe_2$(chp)	32.73	2.10		0.02	42.48	8.58				85.91
4	Ag_2Te (chp)					30.89		51.46			82.35
5	PbSe(chp)								62.38	20.41	82.79
6	Pb_3Se (chp)								83.51	11.01	94.52

Crystallo-chemical formulas.

1. $(Pt_{0.89}Pd_{0.11}Rh_{0.06})_{\sum 1.06}(Te_{1.77}Bi_{0.18})_{\sum 1.95}$;
2. $(Pt_{0.86}Pd_{0.08}Rh_{0.10})_{\sum 1.04}(Te_{1.74}Bi_{0.22})_{\sum 1.96}$;
3. $(Pt_{0.84}Pd_{0.10})_{\sum 0.94}(Te_{1.873}Bi_{0.191})_{\sum 2.06}$;
4. $Ag_{2.02}Te_{0.98}$;
5. $Pb_{0.54}Se_{0.46}$;
6. $Pb_{2.97}Se_{1.03}$.

Table 3 – The chemical compound of the mineral phases in the sulfides of the picrites first formation of the Kara-Turgai assemblage (wt. %, amount 100%)

Mineral	pyr	pyr	pyr	pyr	pyr	pyr	pyr	pyr	pyr	pyr
Sr.No. of element	1	2	3	4	5	6	7	8	9	10
S	34.32	39.35	33.66	32.12	36.62	37.89	36.54	33.50	31.54	39.10
Fe	19.70	49.34	39.95	35.39	37.71	43.59	51.55	52.60	61.98	50.20
Cu						0.54				
Ni	1.71									
Co										
As	2.15	3.44	7.49	10.83	1.29	0.99				3.06
Os	15.43	0.99			14.03	12.20				1.09
Ir		6.89	14.21	16.41	2.15					6.55
Ru	15.27		0,21		6.25	4.51				
Pt			4.24	4.62	1.94					
Ag							7.89	9.16		
Te			0.24	0.62			4.01	4.74	6.47	
Bi										
Y	11.41									
Pb						0.28				

Table 3. Extension 1

Mineral	pyr	pyr	chp	chp	chp	chp	chp	chp	chp	chp
Sr.No. of element	11	12	13	14	15	16	17	18	19	20
S	27.79	23.42	26.24	22.55	19.63	14.38	15.55	31.22	30.00	31.22
Fe	40.97	31.06	27.85	18.59	15.24	12.10	8.87	25.89	24.65	25.89
Cu			14.91	12.90	13.96	11.39	2.78	28.16	25.99	28.16
Pt		18.05							9.08	
Pd		0.95							1.05	
Ag			1.43			39.32		9.73		9.73
Te	10.14	21.12	11.30			22.81		5.01	9.23	5.01
Bi		5.41								
Pb	21.09		18.27	45.96	44.96		72.16			6.08
Se					2.03		0.64			
O					4.17					

Table 3. Extension 2

Mineral	chp	chp	chp	pln	pln	pln	gm
Sr.No. of element	22	23	24	25	26	27	28
S	37.16	22.62	17.66	31.65	33.33	30.18	
Fe	19.59	19.41	13.13	13.78	30.31	27.14	19.45
Cu	18.83	7.01	7.03				
Ni			4.15	10.93	28.53	24.01	
Co					0.61	0.72	
As				0.87			
Os	11.31			29.77			
Ir	1.60			4.39	1.84		
Ru	11.17			8.60			
Pt					2.23	7.17	25.50
Te						7.48	25.71
Bi	0.11					3.30	10.93
Dy					1.62		
Pb		47.84	45.30		1.52		
Ce							
Se		1.87	3.44				
Zn		1.25					
Si			0.95				
Mg			0.57				1.21

Table 3. Extension 3

Mineral	chp	chp	mg	chp	mg	mg	
Sr.No. of element	29	30	31	32	33	34	35
S	22.55	19,63	4,38	23.52	9,62	3.27	13,71
Fe	18.59	15,24	53,35	18.99	33,72	53.74	16,18
Cu	12.90	13.96		20.26			
As			1,59				
Os			6,44				
Ir			1,74				
Ru			2,01				
Rh			0.22				
Y			2,15				
Pb	45.96	44.96			22.43	11.53	53.61
Ce				11.27			
Se		2.03			3.14	1.25	6.82
Si				2.05	4.13	2.81	
Mg				3,72	2.33	2.27	
Al				0,68			
F				0.55			
O			28,11	18,96	24.64	25.13	9,68

3 μm is found in copper pyrite, which has a complex chemical compound (wt. %): Pt (11.87), Pd (1.11), Te (13.69), Mo (10.42), Bi (3.42), Ag (0.71). Supposing molybdenum is not associated with copper pyrite, then, in terms of 8 units, the crystallo-chemical formula $(Pt_{1.624}Bi_{0.437})_{2.061}(Te_{2.864}Ag_{0.176})_{\sum 3.04}Mo_{2.9}$ is obtained, the formula of this solid solution is perfectly represented as - $\mathbf{(Pt,Bi)_2\ (Te,Ag)_3\ Mo_3}$

Arsenides. High-temperature metals of the **IPGM** (Ir, Os, Ru) platinum group and As generate platinoid arsenides, which are found in pyrrhotite and less often in iron sulfide (see Table 3). They all are represented by extremely fine grains of irregular shape (figure 3), which makes it difficult to obtain an authentic grains consistence, since when analyzing characteristic X-ray radiation is recorded not only from the elements composing inclusion but also from the matrix elements.

If the iron and sulfur amount is subtracted out of these analyses, the two types of entities may be conditionally distinguished. The first entity with the chemical compound (wt. %): As (3.44), Ir (6.89), Os (1.09) in terms of 100% recalculation has the following empirical formula: $(Ir_{0.85}Os_{0.13)\sum 0.98}As_{1.02}$, then its formula perfectly corresponds to arsenide of iridium **(Os, Ir) As**. The second entity (wt. %): As (10.83), Ir (16.41), Pt (4.62), Te (0.62) in terms of 100% recalculation has the following empirical formula $(Ir_{0.68}Pt_{0.18)\sum 0.86}(Te_{0.04}As_{1.1})_{\sum 1.14}$, which corresponds to the ultimate formula **(Ir, Pt) As**.

Lead selenide (II) (PbSe) is enclosed in copper pyrite (see table 2, No. 5). Also, the Pb_3Se phase was detected (see table 2, No. 6), which forms rectangular crystal of a regular shape, 8 × 4 μm (figure 3). It has straight-line boundaries with iron sulfide, while copper pyrite absorbs it, which indicates the lead selenide phase appeared earlier than copper pyrite.

Altaite (PbTe) is extremely rare. It forms isometric microinclusions in pyrrhotite and copper pyrite grains (see table 3).

The second mineral formation. Chemically, the sulfides of the second formation (pyrrhotite, copper pyrite, sphalerite) has no difference from those of the first formation (see table 4), but pentlandite is absent nevertheless. **A moncheite** is found in none of the sulfides (pyrrhotite, copper pyrite and sphalerite) of this formation, which is widely present in the sulfides of the first formation.

Copper pyrite is compositionally close to the stoichiometric formula ($\mathbf{CuFeS_2}$). In **pyrrhotite** (figure 4 (B)), the structure of the solid solutions decay is clearly observed, where the pyrrhotite's light part corresponds to the theoretical formula of troilite (**FeS**) by composition, and the pyrrhotite's dark part is oversaturated with sulfur ($FeS_{1.13}$). **Sphalerite** by chemical compound is close to the theoretical formula of marmatite $((Zn_{0.8},Fe_{0.2})_{\sum 1.0}S_{1.0})$. When Fe (17.97%) significance grows, the Cu (9.03%) concentration increases and its crystallo-chemical formula modifies $((Zn_{0.6}Fe_{0.3}Cu_{0.1})_{\sum 1.00}S_{1.00})$.

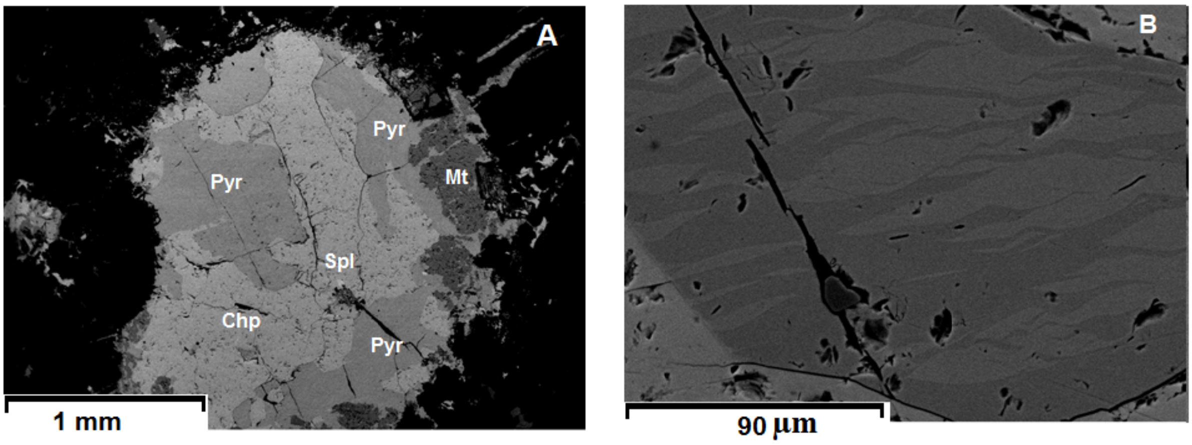

Figure 4 – Back-scattered electron image of the parts of polished sections made from sulfides of the picrites second formation of the Kara-Turgai assemblage. A. The figure shows the nature of sulfides interrelations with the silicate minerals. Figure B demonstrates the structure of the pyrrhotite solid solutions decay

Group of oxides mineral. Magnetite (Fe_3O_4), combined with the second sulfides formation, contains Fe (72.06 -72.36%), which is lower than in those of the first formation.

Table 4 – The minerals compound of the second picrites formation of the Kara-Turgai assemblage (wt. %)

Sr. No	Mineral	S	Fe	Cu	Zn	O
1	Copper pyrite	35.64	30.47	33.88		
2	Copper pyrite	35.35	30.45	34.21		
3	Copper pyrite	35.33	29.98	34.69		
4	Sphalerite	33.59	11.69	1.55	53.17	
5	Sphalerite	33.64	17.94	9.03	39.40	
6	Pyrrhotite	37.62	62.38			
7	Pyrrhotite	37.02	62.98			
8	Pyrrhotite	36.87	63.13			
9	Pyrrhotite	39.42	60.58			
10	Pyrrhotite	39.34	60.66			
11	Pyrrhotite	39.24	60.76			
12	Magnetite		72.06			27.94
13	Magnetite		72.36			27.64
14	Magnetite		72.18			27.82

Crystallo-chemical formulas.
1. $Cu_{0.99}Fe_{1.01}S_{2.06}$;
2. $Cu_{0.99}Fe_{1.01}S_{2.04}$;
3. $Cu_{1.01}Fe_{0.99}S_{2.04}$;
4. $(Zn_{0.78}Fe_{0.20}Cu_{0.02})_{\sum 1.0}S_{1.00}$;
5. $(Zn_{0.57}Fe_{0.31}Cu_{0.15})_{\sum 1.03}S_{1.00}$;
6. $Fe_{0.98}S_{1.02}$;
7. $Fe_{0.99}S_{1.01}$;
8. $Fe_{0.99}S_{1.01}$;
9. $Fe_{0.94}S_{1.06}$;
10. $Fe_{0.94}S_{1.06}$;
11. $Fe_{0.94}S_{1.06}$

The third mineral formation. The sulfides of the third formation are represented by pyrrhotite, copper pyrite, pyrite, sphalerite, which differ from those of the first and second formations by chemical compound (see table 5) and have a number of structural and texture features. The pentlandite is not peculiar to this formation, however, pyrite and the $FeOS_2$ phase occurs. The availability of lead selenide and magnetite, as well as Os solid solution and the Ce admixture are the conspicuity factor that aggregates them with the minerals of the segregation category.

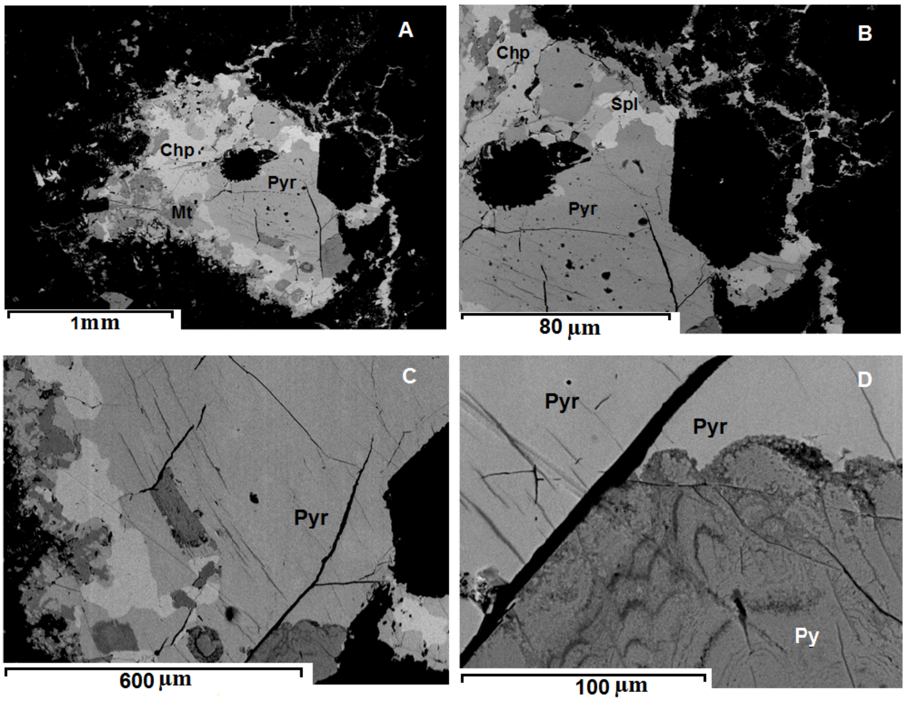

Figure 5 – Back-scattered electron image of the parts of polished sections made from sulfides of the third picrites formation of the Kara-Turgai assemblage. The figure demonstrates the nature of interrelations between sulfides and silicate minerals. The substitution feature of pyrrhotite by a mineral with the typical undulated colloidal gel texture is displayed in figures C, D.

Table 5 – The minerals compound of the third picrites formation of the Kara-Turgai assemblage (wt. %)

Sr.No	Mineral	S	Fe	Cu	Zn	Ni	Ce	Os	Si	O
1	Pyrrhotite	39.59	60.41							
2	Pyrrhotite	39.49	60.51							
3	Pyrrhotite	39.56	60.44							
4	Pyrrhotite	39.19	60.81							
5	$FeOS_2$	41.79	47.08						0.69	10.44
6	$FeOS_2$	41.87	47.64						0.76	9.73
7	$FeOS_2$	42.36	47.96						0.67	9.01
8	$FeOS_2$ spectrum	42.73	47.36			0.12			0.11	9.68
9	$FeOS_2$	37.96	46.67				1.08		0.43	13.86
10*	$FeOS_2$	36.99	46.44					0.92	0.40	15.25
11	$FeOS_2$	40.18	48.26						0.72	10.85
12	$Fe_2O_3S_1$	17.38	54.97						0.48	27.17
13	Пирит	51.95	48.05							
14	Copper pyrite	35,25	30.18	34.57						
15	Copper pyrite	35.48	30.50	34.02						
16	Copper pyrite	35.38	30.55	34.06						
17	Copper pyrite	35.33	30.68	33.99						
18	Sphalerite	34.16	9.61		56.23					
19	Sphalerite	34.10	9.72		56.19					
20	Sphalerite	34.42	9.47		56.11					
21	Sphalerite	34.36	9.53		56.11					
22	Magnetite		72.62							27.38
23	Magnetite		71.47							28.11
24	Magnetite		72.56							27.44
25	Magnetite		72.45							27.55
26	Magnetite		72.23							27.77
27	Magnetite		72.61							27.39

*The analysis point contains a small inclusion.

Crystallo-chemical formulas.

1. $Fe_{0.94}S_{1.06}$;
2. $Fe_{0.94}S_{1.06}$;
3. $Fe_{0.94}S_{1.06}$;
4. $Fe_{0.94}S_{1.06}$;
5. $Fe_{1.17}O_{0.90}S_{1.80}$;
6. $(Fe_{1.16}O_{0.84})_{\sum 2.0}S_{1.80}$;
7. $(Fe_{1.17}O_{0.77})_{\sum 1.94}S_{1.80}$;
8. $(Fe_{1.16}O_{0.83})_{\sum 1.99}S_{1.83}$;
9. $(Fe_{1.23}O_{1.28})_{\sum 2.52}S_{1.75}$;
10. $(Fe_{1.25}O_{1.43})_{\sum 2.68}S_{1.73}$;
11. $(Fe_{1.21}O_{0.95})_{\sum 2.16}S_{1.75}$;
12. $Fe_{1.91}O_{3.30}$ $S_{1.05}$;
13. $Fe_{1.04}S_{1.96}$;
14. $CuFeS_{2.02}$;
15. $Cu_{0.99}Fe_{1.01}S_{2.05}$;
16. $Cu_{0.99}Fe_{1.01}S_{2.04}$;
17. $Cu_{0.99}Fe_{1.01}S_{2.03}$;
18. $(Zn_{0.81}Fe_{0.16})_{\sum 0.97}S_{1.00}$;
19. $(Zn_{0.81}Fe_{0.16})_{\sum 0.97}S_{1.00}$;
20. $(Zn_{0.80}Fe_{0.16})_{\sum 0.96}S_{1.00}$;
21. $(Zn_{0.80}Fe_{0.16})_{\sum 0.96}S_{1.00}$;
22. $Fe_{2.99}O_{4.01}$;
23. $Fe_{2.92}O_{4.08}$;
24. $Fe_{2.99}O_{4.01}$;
25. $Fe_{2.98}O_{4.02}$;
26. $Fe_{2.96}O_{4.04}$;
27. $Fe_{2.99}O_{4.01}$.

The deficiency of solid-solution decay structures, which is typical for the first-formation platinum-containing pyrrhotite (figures 2 and 3) is a peculiarity of, for example, **pyrrhotite** ($FeS_{1.1}$) (figure 5 (C)). **Copper pyrite** is close to the stoichiometric formula by consistency and does not have a sulfur excess ($CuFeS_2$) with respect to platinum-containing copper pyrite. **Sphalerite** $(Zn_{0.81}Fe_{0.16})_{\sum 0.97}S$ does not contain Cu, which is typical for the sphalerite of the first formation too (see table 5). One of the peculiarities of this formation is the **pyrite** (FeS_2) and formations with a colloidal-gel texture. The presence of Ce (1.08%) as part of this formation does not except its accomplishment due to pyrrhotite, in the process of oxidation of the latter, the $FeOS_2$ phase originates. Its ultimate formula in the Hille system, per total number of atoms equal to 4, can be introduced as $FeOS_2$ with 11.77% O, 41.07% Fe and 47.16% S. Magnetite and copper pyrite contain lead selenide inclusions (PbSe) (see table 2).

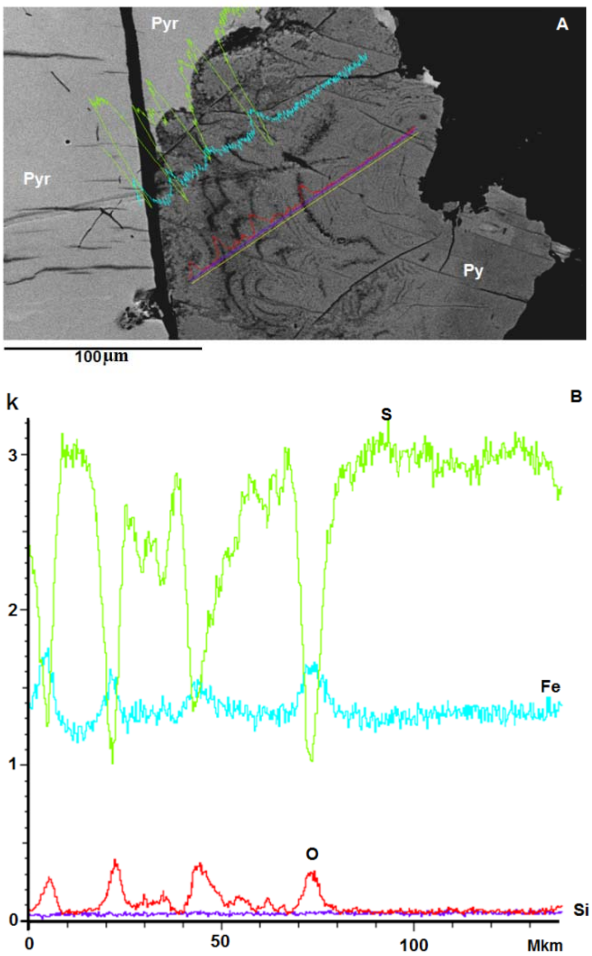

Figure 6 – A – An image of the colloidal-gel texture of pyrite (white iron pyrite) with overlaid log of concentration curves of the separate elements along the white line.
B – Independent logging of the concentration curves

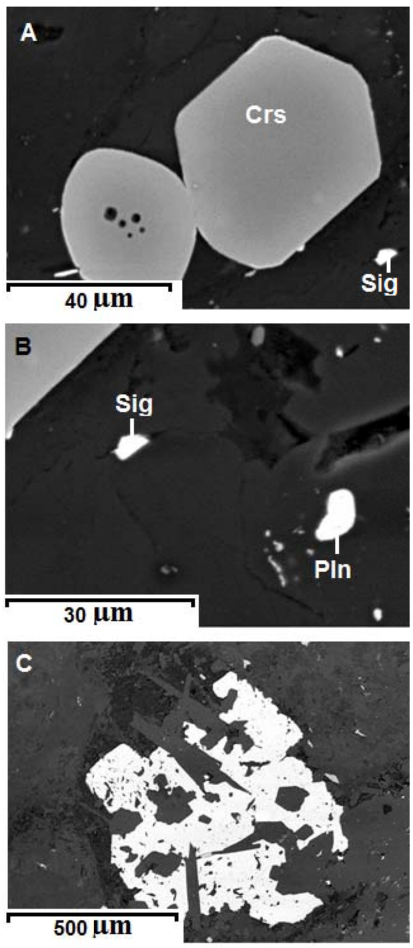

Figure 7 – Back-scattered electron image of the parts of polished sections made of picrite diabase containing chromium spinel (Crs), siegenite (Sig), pentlandite (Pln), pyrite (Py)

Oxides Category Mineral. Magnetite (Fe_3O_4), connected with the third sulfides formation, contains Fe (<72.62%), which is lower than in the first magnetite formation.

The single inclusions of sulfides in picritic diabases are represented by sulfide category minerals: pentlandite, pyrite, siegenite (newly discovered mineral), millerite, galenite.

Pentlandite (Fe, Ni)$_9$S$_8$) generates fine, rare grains in the bulk (figure 7 (B)). Chemically, it is close to the stoichiometric formula of pentlandite (see Table 6). It is supersaturated with S (38.23%), does not contain Co, and is poorly enriched by Cr (0.16%) with respect to the picrites pentlandite.

Siegenite ($(Co,Ni)_3S_4$) generates fine grains totally in the rock (figure 6 (A)). It is composed of iron admixture (5.01-7.91%, see table 6), and a constant excess of sulfur is in the siegenite formula and nickel prevails over cobalt.

Millerite (NiS) occurs in the clinopyroxene interstices, where the small crystals form. Iron in its compound was found as an admixture (see table 6).

Galenite (PbS) is available in the form of fine grains in formation with millerite. Fe and Ni admixtures in its compound, the Pb content reaches 83.18%, and S is up to 12.37%.

Pyrite (**FeS_2**) contains S = 56.31% and Fe = 43.69%.

Oxides Category Minerals. Titanium-hematite and mangano-titano-ferrite form the solid solutions decay, and **chromium spinel** – grains of isometric shape.

Table 6 – The sulfides compound of picritic diabases of the Kara-Turgai assemblage (wt. %)

Sr. No	Mineral	**S**	**Fe**	**Co**	**Ni**	Cr	Pb	Total
1	Pentlandite	36.36	33.05		30.59			100.0
2	Pentlandite	38.23	33.87		27.75	0.15		100.0
3	Siegenite	44.29	5.01	9.72	40.47	0.51		100.0
4	Pyrite	56.31	43.69					100.0
5	Siegenite	44.51	7.91	15.25	32.33			100.0
6	Siegenite	44.32	7.97	15.60	32.11			100..0
7	Siegenite	45.30	10.79	12.53	31.38			100.0
8	Millerite	37.58	1.83		60.58			100.0
9	Millerite	37.89	1.70		60.41			100.0
10	Millerite	37.89	1.70		60.41			100.0
11	Galenite	12.37	1.68		2.77		83.18	100.0

Crystallo-chemical formulas.

1. $(Fe_{4.786}Ni_{4.214})_{\sum 9.0}S_{9.171}$;
2. $(Fe_{5.045}Ni_{3.933}Cr_{0.022})_{\sum 9.0}S_{9.920}$;
3. $(Ni_{2.168}Co_{0.519}Fe_{0.281}Cr_{0.093})_{\sum 3.062}S_{4.345}$;
4. $Fe_{0.924}S_{2.076}$;
5. $(Ni_{1.737}Co_{0.816}Fe_{0.447})_{\sum 3.0}S_{4.378}$;
6. $(Ni_{1.719}Co_{0.832}Fe_{0.449})_{\sum 3.0}S_{4.345}$;
7. $(Ni_{1.705}Co_{0.679}Fe_{0.616})_{\sum 3.0}S_{4.507}$;
8. $(Ni_{0.97}Fe_{0.03})_{\sum 1.0}S_{1.1}$;
9. $(Ni_{0.97}Fe_{0.03})_{\sum 1.0}S_{1.11}$;
10. $(Ni_{0.97}Fe_{0.03})_{\sum 1.0}S_{1.11}$.

Results and discussion. The siegenite, platinum telluride (moncheite), silver telluride, lead telluride (altaite), lead selenide, solid solutions of metals of the iridium group (Ir, Os, Ru), rare-earth elements (Dy, Er, Y, Ce) are established to be discovered for the first time in the picrites of Kara-Turgai assemblage alongside with the previously known sulfides (pyrrhotite, pentlandite, and copper pyrite) consequently of our investigations. The sulfides constitute three mineral formations. The first two constitute segregation "droplets", of a rounded and elliptical-elongated shape, and the third mineral formation is irregularly sharply angular (figure 8). The platinoids in copper and nickel sulfides are established to appear only in the first-formation segregation droplets, which are composed of pyrrhotite, copper pyrite, pentlandite, sphalerite. The sulfides of the second formation do not contain platinoids and are represented by pyrrhotite, copper pyrite, sphalerite. The sulfides of the third formation are represented by pyrrhotite, copper pyrite, sphalerite, pyrite. Each formation of minerals contains magnetite and as a rule is confined to the most differentiated picrites horizons and apopycritic olivinites. The consistency in the platinoids distribution as a part of the segregation sulfides revealed by us provides explanation to the fact of ore impoverishment has occurred [7].

The picrite sulfides globules of the Kara-Turgai assemblage do not have perfectly even boundaries, as well as the metasomatic halo (figure 8), which is typical for the most sulfide globules of copper-nickel ores of ultrabasite-basitic intrusive assemblages [14]. The flexuous boundary, as the frequent penetration of sulfides into the silicate groundmass, indicates that the process of globules formation was accompanied by simultaneous compression. The traditional globules design which is typical for intrusive assemblages, where the lower part is formed of pyrrhotite, the upper one – copper pyrite, and pentlandite is in the mid is not established either.

The sulfide globules of the Kara-Turgai type are the most similar with the sulfide globules in the picrites of the Norilsk-Talnakh type, where copper pyrite is above, pyrrhotite and pentlandite are in the bottom, and magnetite is located along the edge of the sulfide droplets in the picritic horizon ores. [15]. Although, globules of the first formation have a significant difference regarding magnetite distribution, as a rule, it is located in the central parts of the ore platinum-containing globules (figure 8.1A), whereas the magnetite of the second formation of the Kara-Turgai type is located at the edges of sulfide droplets (figure 8.2A).

The rare grains of the $FeOS_2$ phase with a colloidal-gel structure is one of the peculiarities of the third mineral formation, which formed as a result of pyrrhotite and oxygen interaction, which was accompanied by a decrease in sulfur rate, an increase in oxygen and iron oxide generation that forms a dark fines in the front of moving waves (figure 8.3C). This can serve as an evidence of such a mineralogical formation generation under hypabyssal factors, where an essential role is assigned to oxidative processes.

The set of minerals of sulphide droplets is generally identical to the segregation ores; except, some differences in their compound. Say, the ores pyrrhotite of the Kara-Turgai type do not contain nickel and cobalt, which is typical for the ores pyrrhotite of Norilsk-Talnakh type. If the latter ore have palladium,

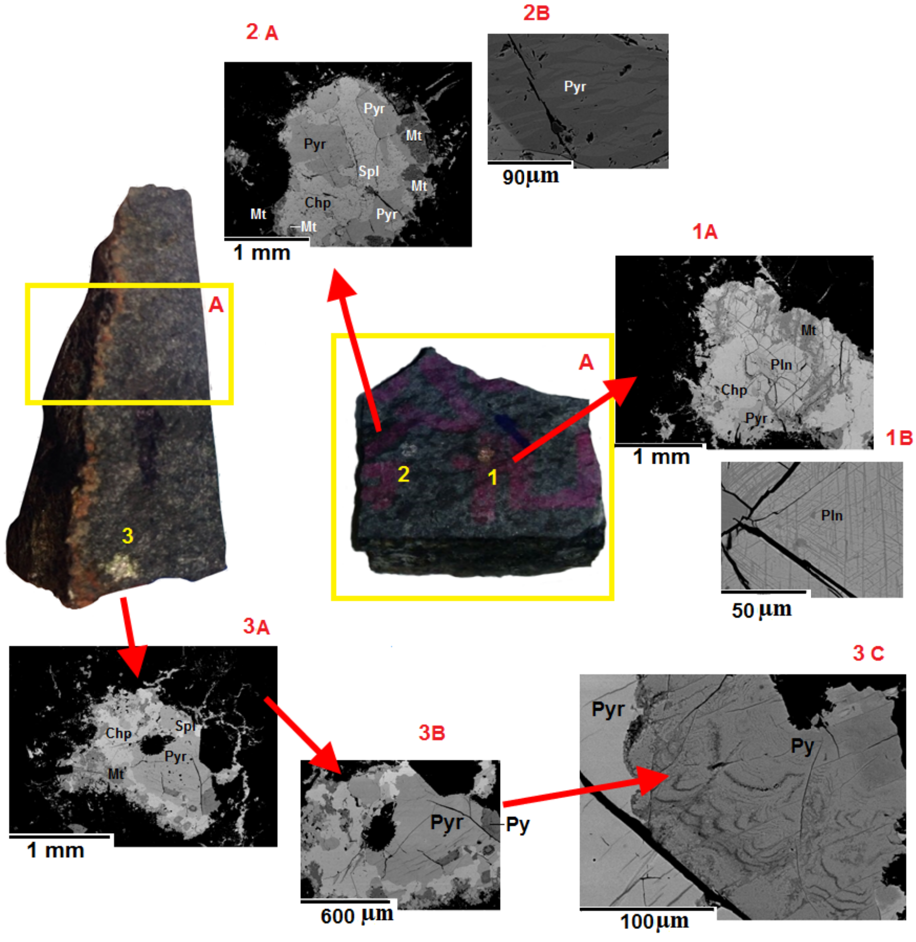

Figure 8 – Background about sulfides compound and aging of the Kara-Turgai assemblage.
See "Results and Discussion" for clarification

sperrylite, gold, silver and selenium, then the picrite ores of the Kara-Turai type have no sperrylite, palladium and selenium are extremely rare, yet rare-earth elements are widely represented. Platinum telluride in the Kara-Turgai type ores is found in all main ore minerals (pentlandite, copper pyrite and pyrrhotite) of the first formation, however gold has not been detected, but a lot of silver telluride. One of the specifics of the Kara-Turgai type ores are lead selenide, arsenides of the iridium group and a high rate of rare-earth elements of the yttrium subclass (Y, Dy).

The siegenite and millerite were first discovered being a part of picritic diabase, along with pentlandite, pyrite and galenite which were not previously described in the rocks of the Kara-Turgai assemblage. The pentlandite is peculiar to be oversaturated with S, does not contain Co, and is poorly enriched by Cr with respect to the pentlandite of Kara-Turai picrits.

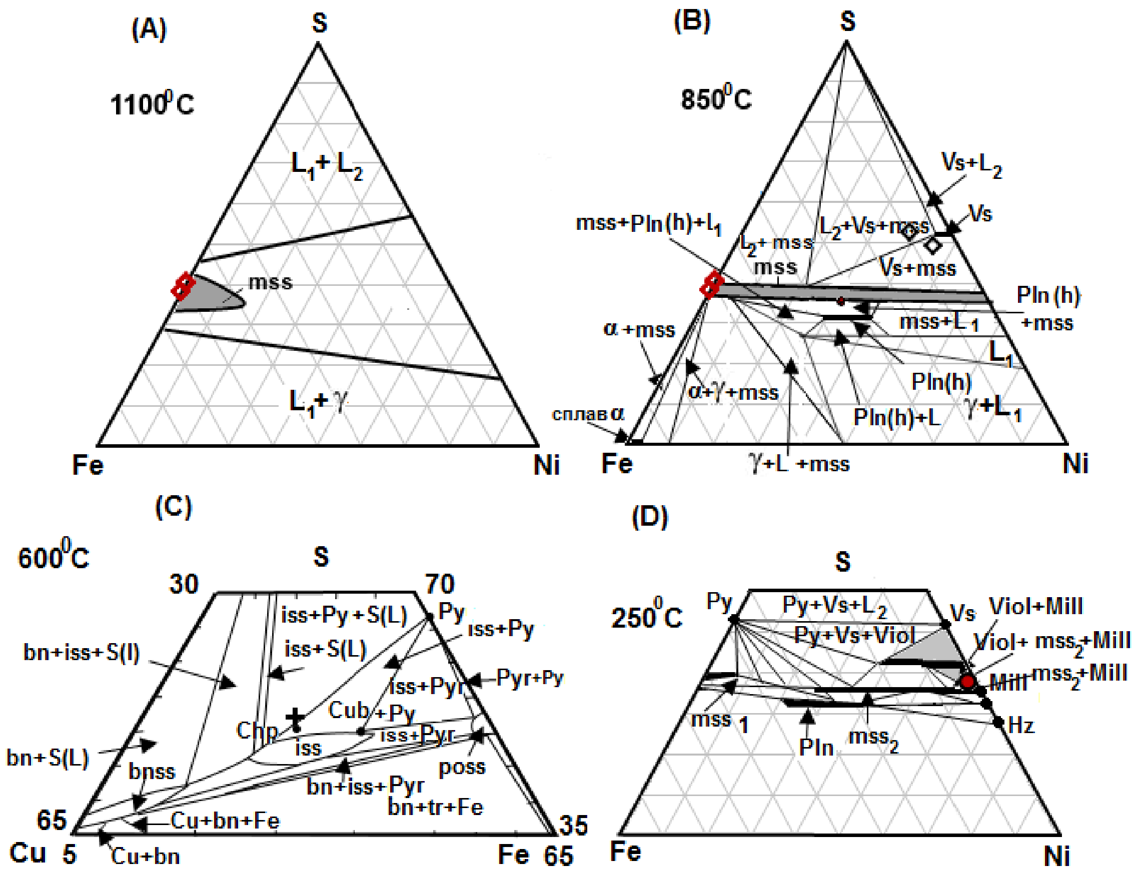

Figure 9 – Isothermal sections of Fe-Ni-S condensed systems [16] at 1000^{0}C (A), 850^{0}C (B), 250^{0}C (D) and Cu-Fe-S [17] at 600^{0}C (C) for pyrrhotite (red colored rhomb), pentlandite (black circle), copper pyrite (black cross), siegenite (black colored rhomb) and millerite (red spot) from picrites and picrite-diabases of the Kara-Turgai assemblage; mss – monosulfide solid solution; iss – intermediate solid solution; copper pyrite (Chp); pentlandite (Pln); vaseat (Vs); pyrrhotite (Pyr); pyrite (Py); violarite (Viol); millerite (Mill); the liquid (L)

The representative points of pentlandite in the Fe-Ni-S system (figure 9 (A, B)), proposed by A. Naldrett [16] are located below the barrier S-enriched isolating phase, from the phases plentiful with metals, and attracted to the monosulfide solid solution (mss) field. The pyrrhotite in this system is located on the Fe-S side, apart from that its representative points lie within mss barrier, IPGM, $PtTe_2$ and Ag_2Te minerals availability in pyrrhotite, and in pentlandite may be probably explained by. In the Cu-Fe-S system (figure 9 (C)), copper pyrite is located in the iss + Py + S (L) field, taking into account the sulfur excess, which, apparently, conforms to the freezing temperature decrease in copper pyrite.

Considering the sequence of mineral phases separation and isothermal sections analysis of the Fe-Ni-S condensed system [16], the genesis of the sulfide copper-nickel mineralization of the Kara-Turgai type seems to subordinate to the following scheme.

In view of the present temperature version and the mss formation, Fe $_{(1-x)}$S (troilite) may be assumed to appear at 1190^{0}C, on the Fe-S line, which spreads to the inner part of the system at the 1100^{0}C, forming the mss field (figure 9 (A)). At this stage mss is enriched in Fe and depleted of Ni in relation to the liquid it is in balance with as suggested by A. Naldrett [16]. Afterwards, mss, formed from a fractionated liquid in the proceeding process of fractional freezing, according to D. Ibel and A. Naldrett [18], becomes enriched by Ni. By A. Sugaki and A. Kitakatse view [19] as a result of the reaction between mss and the liquid, a high-temperature polymorphic pentlandite is formed at 865^{0}C (Figure 9 (B)). Following the A.A. Fedorov and A.V. Sinyakov materials [20], siegenite was instead of vaseat (Ni3 ± xS2) in our system it can be assumed, then the temperature descended below 806^{0}C in the magmatic chamber. The liquid equals to mss at 850^{0}C may be inferred to be enriched with Cu, but depleted by Ni with regard to mss taking into account the compound of the studied sulfides and accept the conclusions of J. Craig and G. Kullerud [21]. Considering the isothermal sections of the Cu-Fe-S system (Fig. 9 (C)), then the intermediate solid solution (iss) is submitted to be separated from the Cu-containing mss. Iss is presumably dissolved into copper pyrite-pyrrhotite mineral phases with the temperature decrease (up to 400^{0}C or less). The millerite in the Fe-Ni-S system (figure 9 (D)) allows us to assume, in accordance with J. Craig [22], that mss was divided into mss$_1$ and mss$_2$+ millerite phases at 250° C. This also corresponds with the K. Misra and M. Fleet conclusions [23] that millerite and, unidentified Heazlewoodite mineral, are sustained at low temperatures.

Conclusions. The abovementioned states that the mineral inclusions formation of copper-nickel ores containing platinum-mineral mineralization was proceeded with a temperature decrease, which varied from 1200^{0}C to 100-135^{0}C. Apparently, such a rapid temperature decrease of the magmatic liquid has contributed to the minerals retention of the platinum group and rare earth elements during its fractionation and could proceed under hypabyssal conditions. Titano-haematite in picrites fairly corresponds with this assumption. Titano-haematite is known to be formed at a high oxidation potential of oxygen, which is a direct evidence of the rocks formation containing it under hypabyssal conditions. This is justified by iron in the sphalerite, since an increase in the amount of iron in the sphalerite structure occurs when the pressure decreases; as well as the altaite formed in the conditions of the hydrothermal mid-temperature mineral formation process as a late mineral. The lead selenide and altaite availability, as well as a high content of lead in other sulfides, indicates that igneous, including ore processes occurred in the continental crust. The rare-earth elements Ce, Dy, Er, Y discovered by us, in the sulfides compound, against the platinoids, substantially increase the industrial interest in the potential ores of the picrite-diabase of Kara-Turgai assemblage. The platinoids and rare earth elements within the segregation droplets only, represented by pyrrhotite, copper pyrite, pentlandite and sphalerite, allows conducting technological testing of Kara-Turgai type ores more properly.

The above facts totally indicate the ore formation of Cu-Ni- (PGM) - (REE) ores of the Kara-Turgai type occurred within the open magmatic system. Recent studies [24] have demonstrated that open magmatic systems are favorable for the concentration of a large number of sulfides. Additionally was specified [24] sulfur input from enclosing rocks is not required for the Cu-Ni- (PGM) - (REE) ores formation in open magmatic systems. This also inspires that large masses of Cu-Ni- (PGE) - (REE) ores can be placed in the benthic and root zones of the picrite-diabase of the Kara-Turgai assemblage.

The rocks formation of the Kara-Turgai assemblage is apparently associated with repeated impulses of the magma chamber against compression processes during the formation of the Rodinia supercontinent should be specially emphasized [25].

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СОТҮСТІК ҰЛЫТАУДЫҢ ҚАРАТОРҒАЙ КЕШЕНІНІҢ ПИКРИТ СУЛЬФИДЫНДАҒЫ СИРЕК КЕЗДЕСЕТІН ЭЛЕМЕНТТЕРДІҢ ЖӘНЕ ПЛАТИНОИДТАРДЫҢ ҚҰРАМЫ ЖӘНЕ ФОРМАСЫ

Аннотация. Біздің зерттеулер нәтижесінде қараторғай кешенінің пикритында ертеден белгілі мыс сульфиді, никель, кобальт (халькопипит, пентландит, кобальтитникелин, герсдорфит) басқа алғаш рет виоларит, сфалерит, зигенит, платина теллуриті (мочеит), күміс теллуриді, қорғасын теллуриді (алтаит), қорғасын селениді, ирид тобының металлдарының қатты ерітінділері (Ir, Os, Ru), сирек кездесетін элементтер (Dy, Er, Y, Ce). Сульфидтер үш минералды ассоциация құрайды. Бірінші екі ассоциация домалақ және эллипсті созылған формасы бар ликвациялық «тамшы» құрайды, үшіншісі минеарлды ассоциация – дұрыс емес өткірбұрышты формалы шығыстар. Нақытланған, егер перротин, халькопирит, пентландит, виоларит және сфалиттер құралған бірінші ассоциацияның ликвациялық тамшыларында ғана сульфидтің құрамында платиноидтар болады. Екінші ассоциация сульфидтары құрамында платиноидтар жоқ, олар пирротин, халькопирит, сфалеритпен ұсынылған. Үшінші ассоциация сульфиттері пирротин, халькопирит, сфалерит және пиритпен ұсынылған. Барлық минералогиялық ассоциациялар құрамында магнетит бар, олар еределі түрде пикриттер және апопикритті оливиниттер горизонттарына түсталған. Пикритті диабаз құрамында сульфидтердің кірістері анықталған: пентладит, зигенит, миллерит, пирит, галенит.Cu- Ni- (платина топтарының минералдары (ПТМ)) – (сирек кездесетін элементтері СКЭ) қараторғай кен түрінің, сульфидтардың өндірістік массаларының шоғырлануынына қолайлы, ашық магматикалық жүйе шегінде пайда болуы нақтыланған.

Түйін сөздері: Ұлытау, мыс-никельді кеніштер, платиноидтар, сирек кездесетін элементтер.

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СОСТАВЫ И ФОРМЫ НАХОЖДЕНИЯ ПЛАТИНОИДОВ И РЕДКОЗЕМЕЛЬНЫХ ЭЛЕМЕНТОВ В СУЛЬФИДАХ ПИКРИТОВ КАРАТУРГАЙСКОГО КОМПЛЕКСА СЕВЕРНОГО УЛЫТАУ

Аннотация. В результате наших исследований, наряду с ранее известными сульфидами меди, никеля и кобальта (халькопиритом, пентландитом, кобальтином, никелином, герсдорфитом), в пикритах каратургайского комплекса были впервые обнаружены виоларит, зигенит, теллурид платины (мончеит), теллурид серебра, теллурид свинца (алтаит), селенид свинца, твердые растворы металлов иридиевой группы (Ir, Os, Ru), редкоземельные элементы (Dy, Er, Y, Ce). Сульфиды формируют три минеральных ассоциации. Первые две образуют ликвационные «капли», имеющие округлую и эллипсовидно-удлинённую форму, а третья минеральная ассоциация – выделения неправильных остроугольных форм. Установлено, что платиноиды в сульфидах присутствуют только в ликвационных каплях первой ассоциации, которые сложены пирротином, халькопиритом, пентландитом, виоларитом и сфалеритом. Сульфиды второй ассоциации не содержат платиноидов и представлены пирротином, халькопиритом, сфалеритом. Сульфиды третьей ассоциации представлены пирротином, халькопиритом, сфалеритом, пиритом. Все три минералогические ассоциации содержат магнетит и, как правило, приурочены к наиболее дифференцированным горизонтам пикритов и апопикритовых оливинитов. В составе пикритовых диабазов обнаружены единичные включения сульфидов: пентландит, зигенит, миллерит, пирит, галенит. Постулируется, что рудообразование Cu-Ni-(минералов платиновой группы [МПГ]) – (редкоземельных элементов [РЗЭ]) руд каратургайского типа происходило в пределах открытой магматической системы, благоприятной для накопления промышленных масс сульфидов.

Ключевые слова: Улытау, медно-никелевые руды, платиноиды, редкоземельные элементы.

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FORECASTING OF PERSPECTIVE OBJECTS USING GEOPHYSICAL DATA ON THE PALEOZOIC COMPLEX OF WESTERN KAZAKHSTAN

Abstract. Clarification of the internal structure and the deep structure of the Paleozoic deposits of Western Kazakhstan, due to the emergence of new geophysical technologies to identify large promising search objects, acquire topical significance. New data on the south-eastern and eastern margins of the Pre-Caspian basin indicate the possibility of isolating large Paleozoic uplifts at the level of the Upper Devonian and Lower Carboniferous (there flecting horizon P_3). Large uplifts has of a supposedly structure are the massive character and tend to gravitate toward the inner side of the hollow. Inthesouth-east, there are the Guryev-Kulsarin zone and the Matken-Bikjalsky step while in the east of the basin there are the Borzher-Akzhar zone and the Shubarkuduk-Koskol step. The selection of objects of this category is associated with the features of the distribution of magnetic field anomalies, which are located in the contour of the region of its elevated values. In these conditions, an additional factor in matter of optimal delineation of objects of this type is the application of innovative technologies for processing and interpreting of the 2D and 3D seismic data. The substantiation of the forecast of development in the context of major uplifts in the relatively deep parts of the basin is given, in the long term, the important priority tasks of the exploration phase will be to bring the surveys in line with the geological exploration stage and adapt the strategy to the conditions of deep-lying promising zones and objects.

Key words: Paleozoic complex, Pre-Caspian basin, geophysical seismic survey, geological exploration, local features, eastern and south-eastern framing of the basin, sedimentation, oil and gas forecast, structure reflecting the horizon.

The hydrocarbon market of Western Kazakhstan is characterized by the presence of a large number of deposits with a significant period of operation. In these conditions, in order to maintain the planned level of production, it needs to expand prospecting surveys to prepare new large objects in the Paleozoic sediments in the forefront, which is associated with increased depths of occurrence (6.5–8.0 km). The replenishment of the resource base at the expense of large subsalt Paleozoic structures is now becoming important for the entire Pre-Caspian region (Mangyshlak Basin and the Pre-Caspian Basin). This is most relevant, first of all, in the south-eastern and eastern marginal sides of the Caspian basin, according to which new data have obtained in a number of publications recent years [1, 2].

On the side zones of the Pre-Caspian basin, large Paleozoic objects lie on more accessible depths for drilling, about 4.5–5.5 km (figure 1). Mostly are significant hydrocarbon deposits are confined to zones of predominantly carbonate sedimentation, forming high-amplitude structures as platforms and structures, such as Tengiz, Astrakhan, Karachaganak, Kashagan, Korolevskoe (figure 2). The large hydrocarbon deposits in the section of the eastern side (Zhanazhol, Kozhasai, Alibekmola, etc.) are confined to carbonate deposits of a somewhat different formational appearance, in which reservoirs for hydrocarbons of predominantly bedded massive type were developed and formed (figure 3).

The new data on the mode of occurrence of Paleozoic objects have been obtained along the south-eastern and eastern parts of the Pre-Caspian Basin since last few years. As the positive results of drilling shows, along with the adjacent areas (Urikhtau, Alibekmola, Saztobinskaya group), large perspective objects can also be associated with the near-submerged (more "internal") areas of the sedimentation basin (Southeast Tasim, East Akzhar, Kuzbak, Biikzhal, South-West Ulkentobe, Yesekzhal, etc.). Similarly, data on the possible productivity of local uplifts in the Paleozoic were also obtained from the south-western border of the Pre-Caspian basin (Kobyakovskaya, Alga).

Figure 1 – East and South-eastern sides of the Pre-Caspian basin.
Tectonic scheme of the Paleozoic complex (according to Akchulakov U. A. et.al, 2012).

1. Geological structures of the I order: A – Pre-Caspian Basin, B – Ustyurt-Bozashi, C – Ural folded system; 2. Isohypses along the Paleozoic roof, km; 3. Contours of geological blocks and marginal zones of the Pre-Caspian basin: I – South-East, II – East, III – Central); 4. Elements of the II order: Eastern side (uplifts zones: 1 – Temir, 2 – Zhanazhol-Tortkol, 3 – Shubar-kuduk-Koskol steps, 4 – Borzher-Akzhar, 5 – Baiganinskaya, 6 – Yegendy-Sarykumak, deflections, 7 – Ostansuk, 8 – Teresken). Southeast side (steps: 9 – Guryev-Kulsary, 10 – Matken-Biikjal, 11 – Namaztakyr, 12 – Karaton-Tengiz uplifts zones, 13 – South Emba uplift). 5. Lower order structures: East side (shafts: a – Kenkiyak-Akkuduk, b – Alibekmola, c – Zhanazhol-Sinelnikov, d – Urikhtau-Kozhasai, e – Tuzkum). The south-eastern side (zones: f – Kulsary, g – Arman-Elemes, h – Saryniyaz uplift, shafts: i – Kumsheti, j – Saztobe, k – Sholkara-Ravnina, l – Tortay, m – Urtatau-Sarybulak). 6. Faults; 7. Hydrocarbon fields.

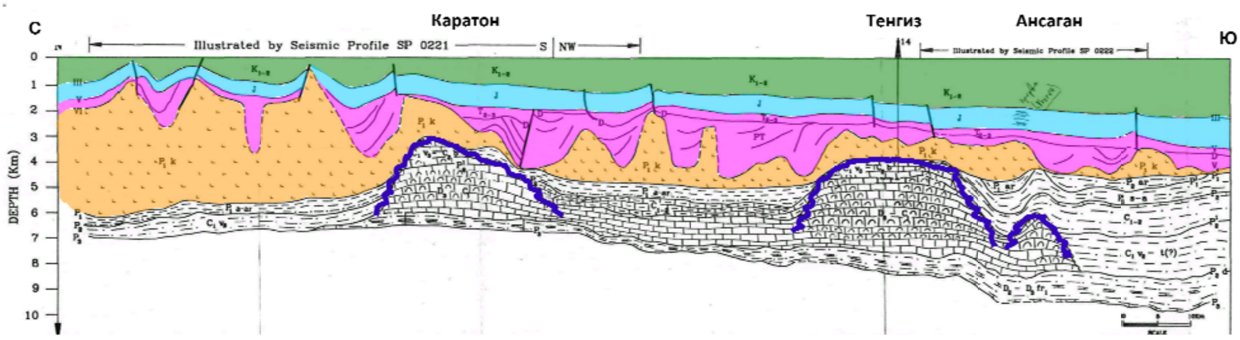

Figure 2 – South-east of the Pre-Caspian basin. Karaton-Tengiz carbonate platform

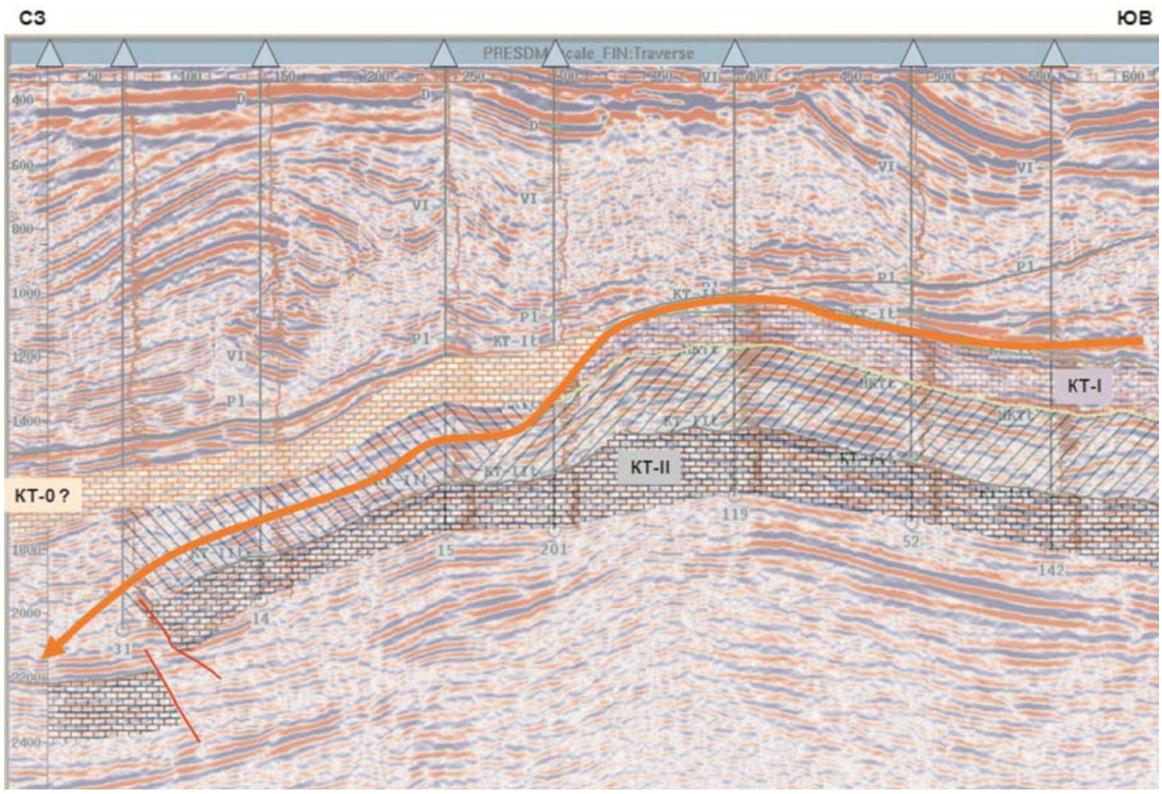

Figure 3 – Eastern side of the Pre-Caspian basin. Principal
Seismic-geological section and characteristics of carbonate strata KT-II and KT-I

Seismic structures and drilling data of a few wells indicate the connection of probable zones of oil and gas accumulation with large local objects as uplifts of the structural and consedimentary development. Major uplifts in the Paleozoic are formed under conditions of extending far to the central deep-water part of the basin of the continental slope. The range of the continental slope is determined by the character and features of the anomalous magnetic field. Thus, the region of development of anomalies with a high value of the magnetic field is associated with a giant "geomagnetic step", a convex side faces to the southeast. Taking into account possible differences in the composition of the crust and basement, which are characterized by the corresponding behavior of the main magneto-active boundary in the section of the sedimentary cover, this region presumably indicates a relatively elevated position (up to 8.0 km) and the occurrence of the pre-Devonian complex and Devonian strata.

According to [2, 4], suggestion of an alternative option in determining the structural-tectonic and spatial confinement and the position of the continental slope, preference is given to the influence of sedimentation processes and the formation of the Astrakhan-Aktobe system of basement highs or the South Pre-Caspian arch.

A new view of the authors regarding the zones of development of the major Paleozoic uplifts, along with marginal part (traditional in this respect according to the estimates of previous years), is associated with the more submerged and deeply submerged adjacent areas of the sedimentation basin with the occurrence top mark of the Paleozoic sequence of about 7.0-8.0 km. At the same time, the authors assume that the priority perspective objects allocated in the internal more submerged areas of the Pre-Caspian basin are characterized mainly by the terrigenous and carbonate-terrigenous composition of the section with low, minimal or no hydrogen sulphide and elemental sulphur in the reservoir fluids [3]. It should also be noted that on the one hand, the forecasting of the oil-and-gascontent at large depths is associated with difficulties in the technical implementation of well wiring and, significant economic costs. On the other hand, the survey of Paleozoic deposits, lying at elevated depths, including in relatively more submerged basin areas, predetermines the most favourable conditions for occurrence, taking into account the possible scale and commercial characteristics of the hydrocarbon deposits, the ever increasing role as a reliable fluid insulator of the Kungurian salt formation.

The substantiated favourable prerequisites and opportunities for allocating large potential oil and gas bearing sites in the marginal and relatively submerged areas of the Pre-Caspian basin are significantly broaden, involving (along with technical support for drilling at elevated depths) methods of modern processing of seismic data and complexation technology with other types of geophysical surveys (gravity prospecting, electrical prospecting, magnetic prospecting, new methods of geophysical well logging). These new methods provide a more reasonable interpretation of geological and geophysical data with respect to the forecast of prospective horizons in great depths.

The main reliable information on the geological structure of deep-lying Paleozoic horizons is extracted from field seismic data. Among the field seismic method, in addition to the high-tech ground-based methods of 3D-CDP method, it should be noted the well-seismic survey of the VSP, MA-VSP (multi-azimuth and multi-level VSP), which give a more detailed seismic image in the wellbore space and below the bottom, drilled into Paleozoic deposits of single prospecting wells. Unfortunately, the solution of urgent survey problems of deep-lying Paleozoic horizons is restrained by the discrepancy between the parameters of field seismic observation systems [5].

In these conditions, the use of modern technologies for in-depth processing of existing 2D/3D seismic data obtained with relatively low density and limited observation base is becoming important. The quality of the zones seismic images with fragmentary and sporadic tracking of reflecting suprasalt and subsalt horizons is significantly improved in the sections and cubes obtained by the Multifocusing method (MF) and pre-stack depth migration technologies based on improved MF seismograms (figure 4) [5]. In this

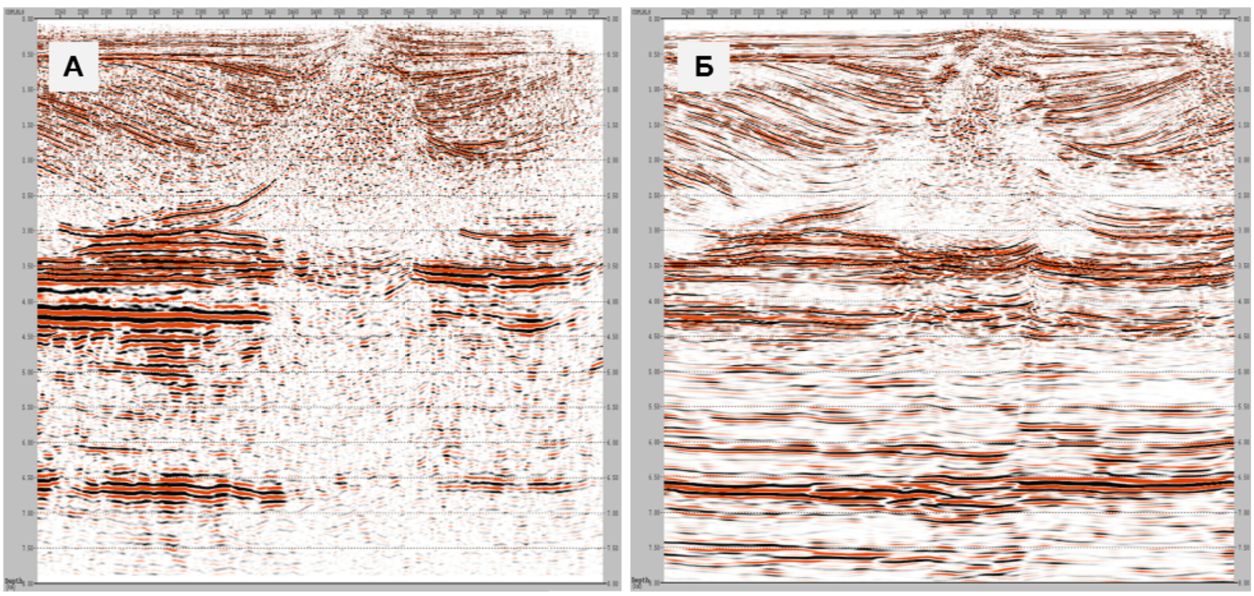

Figure 4 – Comparison of deep cubes:
a) PSDM standard processing, b) Multifocusing + PostSDM technique (example of a deposit on the Caspian Basin's eastern side)

case, the MF method provides the isolation of groups of energetically weak reflecting horizons which can be associated with large uplifts within the Devonian and Carboniferous sediments, as the earlier isolated Urikhtau uplift on the eastern edge of the Pre-Caspian basin. At the same time, the detail of the contours of these uplifts or objects of non-structural type provides additional opportunities for expanding the zone of exploratory surveys due to new local objects which have a probable development along the periphery or within the known Paleozoic uplifts (large in terms of area and thickness). The outline of the large Paleozoic structure of Urikhtau made it possible to identify and justify the prospects of the new Eastern Urikhtau and Northern Urikhtau objects, which are situated in plan between the earlier relatively well surveyed uplifts of Urikhtau and Zhanazhol, Urikhtau and Kozhasai, respectively (figure 1).

In the example of Alibekmola area it is shown that detailed work made it possible to identify a prospective deposit's part in the north of the structure (deposit has elongated structural configuration along the Paleozoic complex (figure 5). In fact, the Alibekmola uplift has a “squeezed” nature of the structure and contours in the plan. Thus, earlier in practice due to the lack of sufficient qualitative data on the structure of the uplift, part of the territory of the potential trap was “cut off” and remained out of sight of prospectors. The results of new seismic methods increase the detail of the geological structure study of the section as a whole and the productive strata, which allow us to more fully account for zones with additional reserves of industrial categories, which was demonstrated in recent years in assessing new prospects for Alibekmola uplift's oil- and-gaspotential.

Thus, on the basis of a comprehensive interpretation of regional 2D profiles and new 3D-CDP method seismic data on a number of large Paleozoic structures had been made significant adjustments and models of the internal structure. As a result, in the south in the interfluve of the Ural-Volga (Novobogatinsk, Sarayshik), in the south-east (Kyzylkuduk, Buyrgyn, Kirykmergen-Munayly North), in the east (Urikhtau) and in the north-east (Shirak, Koblandy) of the Pre-Caspian Basin the new data at organization of prospecting surveys allow to count on a favorable scenario and the possibility of detecting large-scale hydrocarbon deposits [1, 3]. At a number of sites in recent years, these forecasts on the oil-and-gas potential of the Paleozoic strata at depths of 5.5–7.5 km have been confirmed (Tasim Southeast, Ansagan, Urikhtau, Koblandy, Kobyakovskaya, Alga).

It should be specially noted that thanks to the cooperation efforts of several companies' to implement targeted programs in the areas and deposits of the eastern side of the Pre-Caspian basin, a number of unique technologies have been introduced that make it possible to significantly improve the quality of the forecast of the internal structure and oil-and-gas content of complex subsalt Paleozoic objects. The provision of auxiliary services and first of all seismic surveys in various modifications is a great accompaniment for great depths wells drilling. As an important factor it should be taken into account the well-developed infrastructure (proximity of pipelines and transport highways, objects of oil and gas real consumers) and the adequacy of qualified personnel in the region.

In the northern part of the Alibekmola area (the eastern side of the Pre-Caspian Basin), a number of wells did not provide tributaries corresponding to the project level. In this regard, in 2010-2012 JSC NC “KazMunaiGas” with the companies Schlumberger and Azimut for the first time in the CIS realized complex ground and borehole surveys in the region of the arrangement of 3 deep wells by the technology of multi-azimuth MA-VSP, AK (of increased penetration depth), 2D-MOGT (on 6 radial profiles). These surveys made it possible to explain the causes and more clearly delineating the zones of fracturing and loss of productionrate, to study the regularities in the distribution of reservoirs and the inter-carbonate thickness and the oil saturation of the KT-I and KT-II carbonate reservoirs sections, to survey the deep intervals of the Paleozoic section below the bottom-hole mark (figure 5).

On the Kozhasai deposit it also were obtained unique results on increasing the information content and resolution of the seismic signal using the latest software technologies on 3D survey materials [5]. By the way, the uniqueness of MF technology is visible not only in the expressiveness of the reflections from the roof of the salt dome and the adjacent Permian-Triassicsediments, but also in the subsalt complex including the dome zone. Usually these are mute areas due to the variety of disturbances in this zone. The diffractive MF method makes it possible to obtain, in addition to the expressiveness of the wave pattern, a clear correlation between the amplitudes of the diffraction anomalies directly with the hydrocarbons production rate in wells. It opens up new opportunities for the application of this technology in the developed fields for the forecast of production rates and monitoring the design parameters in subsequent development.

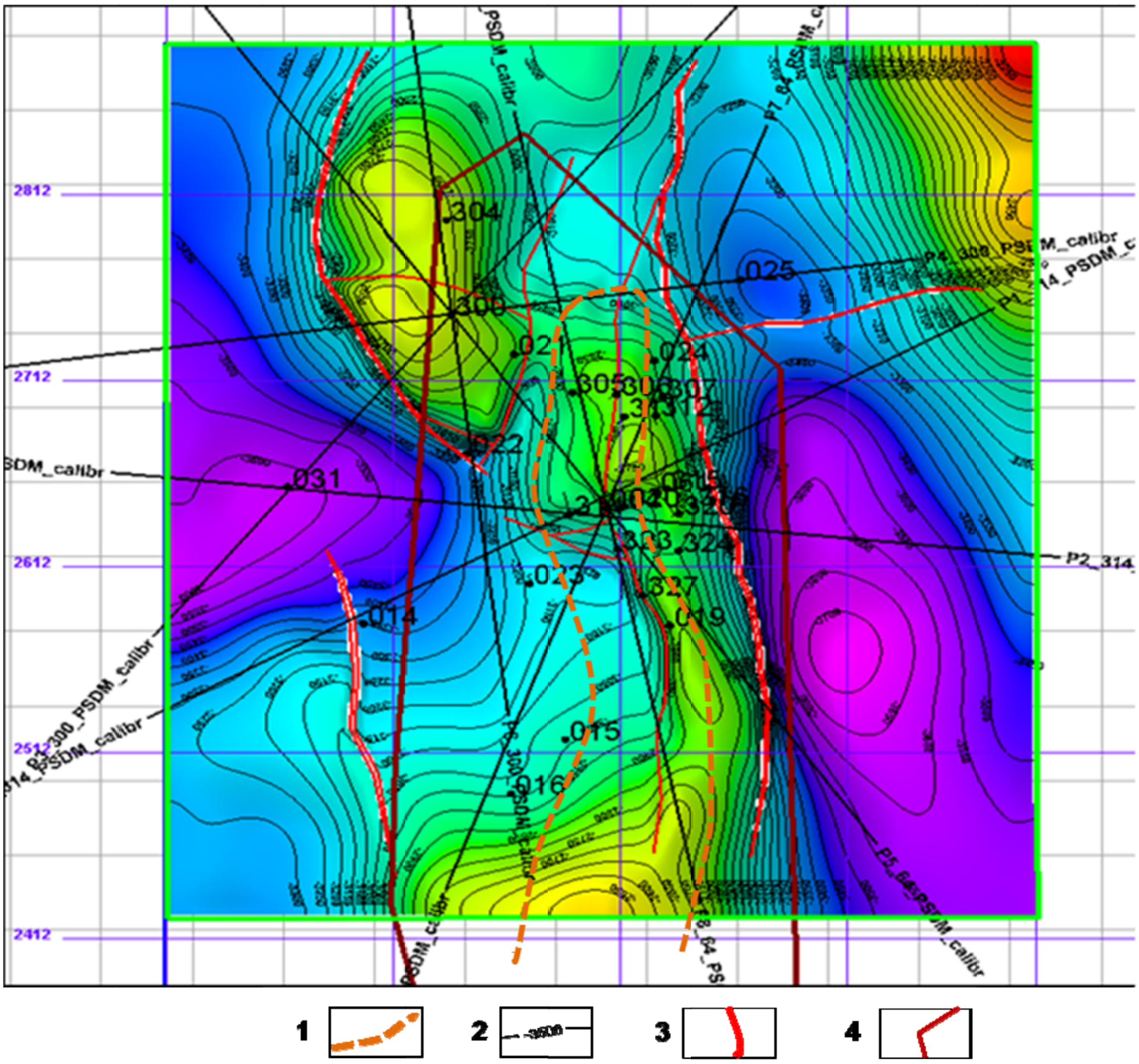

Figure 5 – Alibekmola area. Structural diagram of the roof KT-II of the unit
(according to the data of JSC NC "KazMunaiGas", 2011)

1. Zone of increased density of rock sfractures; 2. Isohyps on the roof CT-IIof the unit; 3. Tectonic faults; 4. Contours of the contract territory.

Based on the analysis of new data and results, the application of the latest technologies (in terms of "advanced" seismic survey methods) within the prospective areas and uplifts of the Zhanazhol-Tortkol zone is proposed. With this in mind, local facilities and areas on the eastern board in the future can be represented to an extent as landfills for the application of advanced methods and the latest seismic survey technologies in the rest of the prospective territory of the Pre-Caspian Basin.

In this regard, in the south-eastern adjacent zone the exploratory interest from the point of view of the ability to detect large deposits of reserves on the basis of the experience gained in the application of new technologies, is primarily acquired by the internal submerged areas of the sedimentation basin. The main part of the south-east relatively submerged territory is represented by the Matken-Biikzhal tectonic step (figure 1). On the roof of the subsalt Paleozoic (RH P_1), this step stands out in the depth interval of 3.4-5.6 km. Estimating the degree of perspective of this step should be noted that its exploratory maturity in comparison with its south-east areas is somewhat lower.

To the north-west of the Matken-Biikjal step is associated with the Namaztakyr step. On the further farther north along the Paleozoic roof it is recorded a weak regional upward movement in the direction of the Guriev-Kulsary regional step (figure 1). Nearly all the major in recent years discovered Paleozoic uplifts are associated with these regional elements of the second order, in which the Upper Devonian-Lower Carboniferous part of the section is emphasized in evaluating the prospects.

It should be noted detail some features of this type of objects' structure. Local objects (uplifts) within the considered territory generally differ in large sizes, high amplitude and, presumably, to a greater extent, the consedimental nature of development (figure 6). The authors tend to attribute the allocated part of the south-eastern edging to the region of the continental slope of the paleo-basin. Throughout its entirety, the conditions for the formation of deposits contributed to the formation of large local structures - uplifts along the Devonian and Lower Carboniferous (Kyzylkuduk, Buyrgyn, Kuzbak, Tasym Southeast, Esek-zhal, Kyrykmergen - Munayly North, Ulkentobe Southwest, etc.). By analogy with this, on the eastern side in the advanced part of the sedimentation basin the forecast of major structural uplifts is associated with the Shubarkuduk-Koskol zone (Shilikty) and the Borzher-Akzhar step (Akzhar Eastern-Kursay).

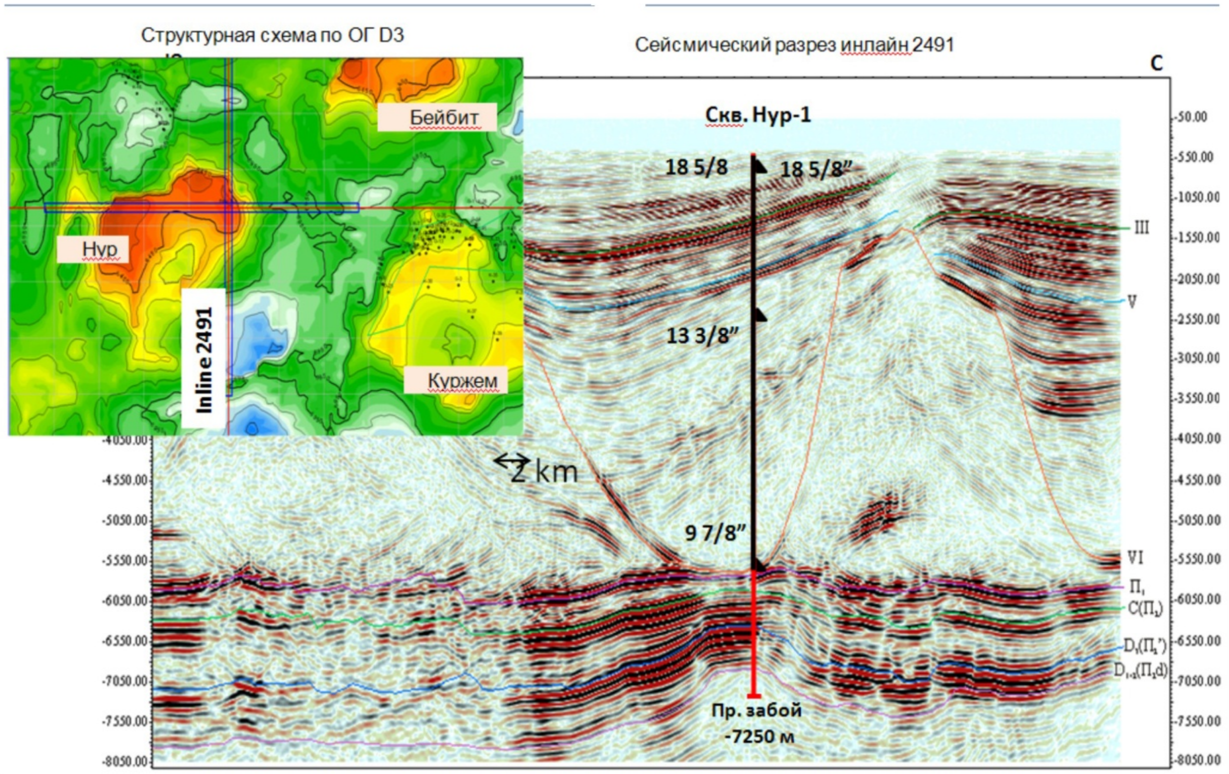

Figure 6 – Guryev-Kulsary tectonic step. Kuzbak uplift
(according to the data of LLP "Samek International", 2013)

The analysis of the spread features of magnetic field anomalies shows the general characteristics of the structure and composition of the pre-Devonian complex and Devonian deposits in the section of these large elements of the second order. The isolation of the Matken-Biikzhal step is seenin the analysis and tracing the lithic-facies conditions of the Lower Permian sedimentation step (Assel-Sakmar). On this development fragment the step was characterized by a more intensive sedimentation. The deposition of sediments in North-west of the Namaztakyr and Guryevo-Kulsarinskiy zones in the Assel-Sakmar period was weakened or intermittent. At the regional level the Matken-Вшikzhal step continues alongside to the north-easterly direction and on the east side the Borzher-Akzhar step is its structural continuation (figu-re 1). In the direction to the south-west the Matken-Biikzhal and Namaztakyr steps are structurally "resting" on the Karaton shaft (Karaton-Tengiz uplift zones). This transition is fixed by changing the "calm" occurrence and the structural plan to a more contrasting character. And in the direction to the Karaton-Tengiz uplift zone the territory has a sharp hypsometric rise.

To the south-east the main large structural elements in the zone of more active folded and faulted tectonics are the Elemes-Arman uplifts zone, Kumshet shaft (-3.7-4.8 km). To the south it is stacked out a series of contrastingly distinct long anticlines, structural shafts (Sholkara-Ravninniy, Tortaisky and Saztobinskiy shafts) defining simultaneously the isohypes thickening band along the subsalt reflecting surfaces, which directly marks the "transition" in the south-east to the South Emba Paleozoic uplift (figure 1).

Taking into account the found structural and lithic-facies differentiation of the concerned territory as well as new drilling data obtained from the relatively advanced interior part of the south-east of the Pre-Caspian Basin, below it will be mentioned important features of the structure of the Paleozoic stratum and its oil-and-gas potential.

– The Paleozoic section has a distinct three-membered structure, up-section are terrigenous lower carbon (C_1v_{1-2}-s), carbonate-terrigenous deposits of the Middle Carboniferous-Upper-Moscow-Moscow age (C_1v-C_2m) and the terrigenous fragment of the Lower Permian (P_1as-s).

– In a relatively advanced part of the basin in a number of well sinareas of Ulkentobein South-West,Karashungyl, Matken, Esekzal the oil inflows were previously obtained in Middle Carboniferous sediments (C_1v_3-C_2m). These inflows often had a pulsating character. In the areas of Biikzhal and Tortay the hydrocarbons inflows were also obtained in the Lower Carboniferous sediments.

– In South-east in the strip of relatively elevated bedding of the Paleozoic roof (Elemes-Arman zone, Kumshetinskiy, Sholkara-Ravninniy and Tortay shafts), the oil-and-gas potential in the Paleozoic complex is more closely related to the Lower Permian terrigenous deposits of the detrital cone and Paleontological flows (P_1ar), and also the sulfate-terrigenous unit of the Philippine horizon (P_1k). In the end, despite the lack of a “perfect”exploration methodology, in the early stage of study in the Carboniferous two small depositswith limited reservoir (Ravninniy, Tortay) of the subsalt complex in the south-east were discovered.

– The deposits and oil-and-gas show are confined to certain stratigraphic intervals of the section (Matken-Biikzhal step), which accordingly determines some common regional patterns in the spatial location of hydrocarbon deposits.

– The structural plan of local uplifts generally at the level of seismic horizons P_{21}, P_2, P_1has an inherited character without significant fluctuations in the thicknesses of seismic complex itiesen closed between the reflecting boundaries. In given depths for a seismic signal (no more than 4.4–5.0 km) previously general reference points for prospecting survey were set, which were adjusted depending on several factors (i.e. the quality of structural formations, the foundation state of the more prepared structures and etc.). As a consequence, the seismic pattern of the lower Terrigenous complex lying below the boundary of P_{21} remained as not completely clear.

– The picture of the structural plan representation for the lower part of the subsalt section (Devonian - Lower Carboniferous) has noticeably improved. According to the results of research in recent years (by JSC Kazakhstankaspiyshelf in 2005-2006, LLP OilGeoconsulting in 2007-2008), the reflecting horizon P_3 (bottom of the Upper Devonian?) corresponds to this interval of the section. A rather differentiated character of the structural plan and a relatively more contrasting character of the reflection on the structural basis of local upliftsare noted in a number of regions.

In contrast, the pattern of the structural plan and local uplifts along the lower subsalt seismic horizons in the section is more seen in the northern and north-eastern parts of the Matken-Biikjal step. The Kulsary uplifts zone corresponding to the southern part of the Guryev-Kulsary regional step (U. A. Akchulakov et.al, 2012) [1] is stacked out. Uplifts within mentioned structural zone are characterized in general by large sizes, significant amplitude and contrast development, especially at the level of horizon P_3. The main features of local objects in this regard are the buried character and the gradual smoothing of their development upwards along the section. In the relief of the reflecting boundary P_1 they are fixed less contrast. An important factor in forecasting the prospects on large uplifts in the intra-basin part of the territory is their association with inter-dome zones in the plan, which was confirmed by the results of the area seismic interpretation of the Kyrykmergen-Munayly North and Kuzbak major uplifts and points to a fairly high level of assumptions’objectivity (Eskozha, Voronov, 2008) [4]. At the same time, the contrasting character of the structure along the lower Devonian-Lower Carboniferous interval of the section is quite typical, and the “lock” of the structure is occurred at the level of the reflecting horizon P_3 (figure 6).

In assessing and substantiating the high prospects of large structural uplifts in the Devonian Carbon, along with the tectonic criterion, the role of the litho-facies criterion is also dominant. Deep-lying local structural objects were formed in a condition of predominantly terrigenous and carbonate-terrigenous sedimentation. High values of filtration and capacitance properties were provided by the occurrence of fracture tectonics and the development of fracturing processes, the activity of paleo-channel systems and deep-sea detrital cones, which cause the lenticular character of the traps in some places, as well as paleoflows. The positive results and nature of hydrocarbon occurrence on Ulkentobe South-West, Esekzhal, Karashungyl, Matken, Biikzhal uplifts confirm these conclusions and assumptions.

In this, the role and new capabilities of seismic methods of data processing and interpretation are significant, allowing to substantiate and consider the identified large Paleozoic uplifts on a higher qualitative level. In practical terms, the possibilities of new methods have been successfully tested in the preparation and justification of the typical Paleozoic uplifts of Kuzbak (Nur-Kurzhem-Beybit), Kyzylkuduk, Buyrgyn, Kyrykmergen-Munayly North etc.

Conclusions.

1. The conditions of formation and sedimentation in the Paleozoic complex of the internal, relatively submerged part in the Pre-Caspian basin’s south-east (Matken-Biikjal, Namaztakyr, Guryev-Kulsary zone) and east (Borzher-Akzhar and Yegendy-Sarykumak steps, Shubarkuduk-Koskol zone) contributethe formation of major uplifts which have massive consediment ativenature of development. The new technologies of seismic processing and interpretation give expectation significantly improving the survey degree of the Paleozoic deposits deep-lying complex and the forecasting of perspective local structures and objects.

2. For an optimal survey of deep horizons structure in the Paleozoic scientific research institutes should develop and implement with oil companies a clear phasing of geological exploration and a strategy for adapting to the conditions of deep-lying persperctive zones of technological seismic methods, both at the stage of field research and at the stage of processing primary data.

3. A detailed comprehensive analysis of geological and geophysical data should be the basis for improving the technology of prospecting and improving the efficiency of oil exploration in Western Kazakhstan as a whole.

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ГЕОФИЗИКАЛЫҚ ДЕРЕКТЕР БОЙЫНША БАТЫС ҚАЗАҚСТАННЫҢ ПАЛЕОЗОЙЛЫҚ КЕШЕНІНДЕ ПЕРСПЕКТИКАЛЫҚ ОБЪЕКТІЛЕРДІ БОЛЖАУ

Аннотация. Ірі перспективалық іздестіру объектілерін анықтаудың жаңа геологиялық-геофизикалық деректері мен технологияларының пайда болуына байланысты палеозой шөгінділерінің ішкі құрылысы мен терең құрылымын нақтылаудың өзекті маңызы бар. Каспий маңындағы бассейнді оңтүстік-шығыс және шығыс жиектеуі бойынша жаңа деректер үстіңгі девон және астыңғы карбон (ПЗ көкжиегін көрсететін) деңгейінде ірі палеозойлық көтеруді бөлудің мүмкіндіктері туралы куәландырады. Ірі көтерілулер құрылымдық жаппай сипатта жиектеудің ішкі тереңдетілген бөлігіне заңды түрде болжалды тартылады. Оңтүстік-шығыста – бұл Гурьев-Құлсары аймағы және Мәткен-Биікжал деңгейі, бассейннің шығысында - Боржер-Ақжар аймағы және Шұбарқұдық-Қоскөл деңгейі. Осындай санаттағы объектілерді бөлу магнитті өрістің ауытқуларын бөлу ерекшеліктерімен байланыстырылады, бұл тұрғыда оның жоғарылатылған мәндері облыстың сызығында бар. Бұл жағдайда, осындай түрдегі объектілердің оңтайлы кескіндеу мәселелеріндегі қосымша фактор 2Д және 3Д (МФ, дифракциялық МФ, көп азимуталды ВСП және енудің жоғарылатылған тереңдігінің АК) сейсмикалық деректерін өңдеу және түсіндірудің инновациялық технологияларын қолдану болып табылады. Бассейн жиектеуінің тереңдетілген бөліктеріне қатысті ірі көтерілулер бөлінісінде даму болжамының негіздемесі беріледі, келешекте іздестіру кезеңінің маңызды басым міндеттері тереңде жатқан перспективалық аймақтар мен объектілердің шарттарына іздеу стратегиясын бейімдеу және геологиялық барлау жұмыстарының кезеңділігіне сәйкес зерттеулерді келтіру болып табылады.

Түйін сөздер: ұңғыма, палеозойлық кешен, Каспий маңындағы бассейн, геофизикалық сейсмикалық зерттеулер, геологиялық барлау жұмыстарды, жергілікті объекті, бассейнді шығыс және оңтүстік-шығыс жиектеу, шөгінді жиналуы, мұнайгаздылық болжамы, құрылым, деңгейжиегін көрсетуші және т.б.

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ПРОГНОЗИРОВАНИЕ ПЕРСПЕКТИВНЫХ ОБЪЕКТОВ В ПАЛЕОЗОЙСКОМ КОМПЛЕКСЕ ЗАПАДНОГО КАЗАХСТАНА ПО ГЕОФИЗИЧЕСКИМ ДАННЫМ

Аннотация. Уточнение внутреннего строения и глубинной структуры палеозойских отложений, в связи с появлением новых геолого-геофизических данных и технологий выявления крупных перспективных поисковых объектов приобретают актуальное значение. Новые данные по юго-восточному и восточному обрамлению Прикаспийского бассейна свидетельствуют о возможностях выделения крупных палеозойских поднятий на уровне верхнего девона и нижнего карбона (отражающий горизонт $П_3$). Крупные поднятия предположительно, структурного массивного характера закономерно тяготеют к глубинной внутренней части обрамления. На юго-востоке – это Гурьевско-Кульсаринская зона и Маткен-Биикжальская ступень, на востоке бассейна – Боржер-Акжарская зона и Шубаркудук-Коскольская ступень. Выделение объектов такой категории увязывается с особенностями распределения аномалий магнитного поля, которые в плане располагаются в контуре области его повышенных значений. В этих условиях, дополнительным фактором в вопросах оптимального оконтуривания объектов данного типа, является применение инновационных технологий обработки и интерпретации сейсмических данных 2Д и 3Д (МФ, дифракционный МФ, многоазимутальное ВСП и АК повышенной глубины проникновения). Дается обоснование прогноза развития в разрезе крупных поднятий в относительно глубинных частях обрамлений бассейна, в перспективе важными приоритетными задачами поискового этапа будут являться приведение исследований в соответствии с этапностью геолого-разведочных работ и адаптации стратегии поисков к условиям глубоко залегающих перспективных зон и объектов.

Ключевые слова: скважина, палеозойский комплекс, Прикаспийский бассейн, геофизические сейсмические исследования, геологоразведочные работы, локальный объект, восточное и юго-восточное обрамление бассейна, осадконакопление, прогноз нефтегазоносности, структура, отражающий горизонт и др.

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CHARACTERISTICS OF MELTS FROM HIGH-TEMPERATURE TESTS OF LOWER QUARTENARY LOAMS AND TECHNOGENIC COAL ASH FROM BORALDAY TPP AS THE BASIS FOR THE PRODUCTION OF LIGHT CONCRETE FILLERS

Abstract. The study describes of the material composition, technological properties of light concrete fillers (aggregates) from Lower Quaternary loam and coal ash waste from TPP. Huge amount of ash (many hundreds of millions tons) has accumulated on the territory of Kazakhstan, which is a waste product of coal power industry. Organization of light concrete fillers production from waste would allow manufacturing various building structures on their basis.

Old and new ash burials from Boralday area contains up to 90% siliceous formations (mullite and quartz), which is characterized as a durable, fireproof and chemically stable substances. These natural formations are durableas part of the construction material. Due to the peculiarities of the mineral content of the formations under consideration, with negligible impurities of calcium and magnesium carbonates, they can be used directly as a filler of concrete. And with the additional firing of this ash, the lightness, heat and soundproofness of the concrete product will be added to the abovementioned qualities.

When calcining loam, some of its components (montmorillonite, muscovite, and chlorite) together with non-melted quartz particles form a homogeneous aggregate. Minerals such as calcite, dolomite and gypsum degenerated into calcium and magnesium oxides during dissociation, which eventually allowed to reduce the viscosity of the melt. The main aggregates of the melt (~ 50%) in the obtained firing product were powder granules of siliceous constituents of loam.

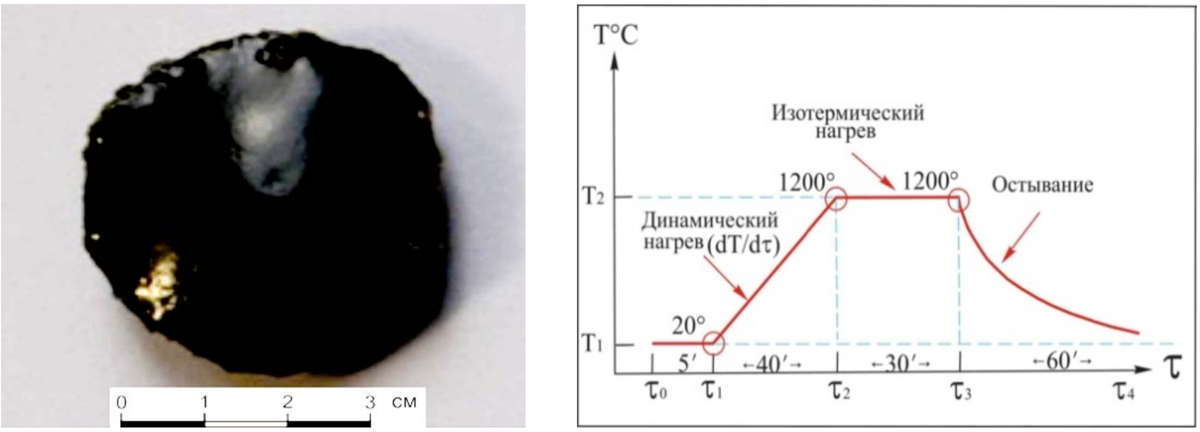
Thus, the product obtained at this stage of the study can already be used in the production of heat-resistant and mechanically strong flake aggregates of light concrete aggregates.

Keywords: keramzit, charge, loess-like loam, coal ash, thermal, X-ray phase and microprobe analyzes, melting of batch of high-temperature furnace.

Keramzit (expanded clay) has a reputation of a material with good insulating and strength properties. Keramzit is a porous rounded granule, which is obtained from raw materials by their firing and melting. A structure made of keramzit is durable and has a light weight and keramzit itself is a thermal insulator with excellent parameters. Traditionally, clays are used as a raw material for the production of expanded clay. Such Lower Quaternary loess like loams are widely developed in the foothills of the Zailisky Alatau, where their reserves are enormous.

On the territory of Kazakhstan, a huge amount of ash has accumulated (many hundreds of millions of tons) representing a waste of coal energy. The organization of industrial production of lightweight aggregates from such wastes would allow them to make various building structures on their basis. In this regard, the possibility of using as has a raw material for keramzit from industrial wastes of Boralday TPP was considered. For this, samples were selected and subsequently studied by laboratory methods [1, 2] in accordance with existing GOSTs [3, 4]. Subsequently, the samples were subjected to high-temperature tests in the chamber furnace LHT 04/16 (Nabertherm) with a dynamic temperature increase from 50 to

1200 °C and further to a temperature of 1300 °C. The temperature rise was controlled by the set time, after which the thermal installation automatically switched to the next heating mode at T° → constant. The process of the furnace thermal exposure to a sample was completed by free cooling of the system. The graphic scheme of high-temperature heating of samples in a chamber furnace is shown in figure 1 (Ungurtas vil.). On the y-axis, symbols T_1 and T_2 designate the initial temperature of the furnace and the temperature at which the heating regime changes,respectively. On the abscissa axis, ϑ_0, ϑ_1, ϑ_2, ϑ_3, and ϑ_4 time of thermal testing of stone material is shown. The work of the thermal installation is carried out according to the following scheme: 1) heating under conditions of dynamic temperature rise; 2) isothermal regime (thermal effect); 3) free cooling of the charge. After the test, the firing products were visually examined under a microscope. The evaluation was carried out for its suitability as a finished product or light concrete filler and for direct casting of heat-resistant, chemically stable, electrical insulating and heat-resistant products.



a b

Figure 1 – Photo illustration (a) of the product of firing (clay, the upper horizon, Ungurtas);
b – diagram of high-temperature heating of samples in a chamber furnace – 1200°C (5',40', 30')

The production requirements are based on the correspondence of the physical and chemical properties of each of the listed types of raw materials and is determined, first of all, by its elemental composition, structural features and accompanying mineral impurities. For this, melting of the initial material was carried out in various temperature regimes to select the optimal melting temperature of the charge [5, 6]. Another important requirement for the properties of raw materials is its thermochemical susceptibility to the firing process, which determines the homogenization of the resulting melt and the crystallization sequence of the substrate obtained [6-8].

Loams melt at a temperature of 1200° C and crystallization of the molten substrate proceeds during its cooling. The scheme of thermal effect on loam and ash is acceptable for the production of technical products with specified physical properties. As a result of loam heating in the indicated firing regime a firm to the touch product was obtained of a dark brown color with a light matte shade of the surface part of the ingot. At the same time, this substance retained all the three-dimensional outlines of the charge (dome shape) left on it during the preparation of the powder sample for a programmed thermal test. This characteristic of the new transformed substance was formed as a result of a combination of circumstances related to the thermal properties of the components of the test sample and were caused by the conditions of the combined heating of this object from 20 to 1200° C (figure 1).

When calcining the loam, minerals such as montmorillonite (6.7%), muscovite (7.2%) and chlorite (3.8%) allowed non-melted quartz particles to consolidate into a homogeneous aggregate. Whereas calcite, dolomite, and gypsum degenerated into calcium and magnesium oxides in the process of dissociation, which eventually reduced the viscosity of the melt. The main aggregates of the melt (~ 50%) in the obtained firing product were powder granules of siliceous constituents of loam. Thus, the product obtained at this stage of the study can already be used in the production of heat-resistant and mechanically strong flake aggregates of light concrete fillers.

The temperature-chronological scheme of the thermal test of the stone material shown in figure 1 further will be presented as follows: T°C ($\Delta\vartheta_1$, $\Delta\vartheta_2$, $\Delta\vartheta_3$). Based on the example of this sample, the first number means the upper temperature limit of the test and the values in parentheses correspond to the waiting time of the experiment, its dynamic heating, and the stage of isothermal calcination of the sample.

When calcining the loam in the mode indicated in figure 2, the material was obtained with appearance and physical properties very similar to the product of calcination of the previous sample. This fact is explained by the relationship between the composition of these rocks and the similarity of conditions for their calcination. These two samples contain almost the same set of minerals with close proportions of their quantity. In their compositions, the proportion of thermally active and thermally inert components is also observed. Direct confirmation of this is the proximity of the percentage content in these samples, both clay-carbonate and anhydrous siliceous formations. And finally, when calcining these samples, 12.3 and 11.9% of the mass are lost (in the form of H_2O, OH and CO_2 emissions), which indicates a proximity of the amount of thermally active mineral inclusions in them.

Figure 2 – Photo illustration of the product of firing clay loam (lower the horizon, the village of Ungurtas).
The temperature-temporal parameters of firing stone material in a high temperature heating to 1200°C (5', 40', 30')

The loess like loam north of the Boralday town repeats all the stages of the formation of the ceramic product that occurred during the firing of loam during the calcination at 1200 °C (5', 40', 30'). In all samples, as the burning temperature increased several stages of dehydration of clay inclusions and the processes of thermal dissociation of carbonate constituents of tested samples were observed. Dehydration of the system was provided by two types of hydrate emissions: removal of interlayer water (H2O) in the range from 60 to 215 °C and yield of hydroxyls (OH) from tetrahedral grids of clay minerals (220-830 °C). The dissociation of carbonate inclusions ($CaCO_3$ and CaMg $(CO_3)_2$) was studied by dynamically heating them on a thermal installation called derivatograph Q1500D.The thermal destruction of these impurities was carried out in the range of ~ 400-800 °C, in which the decomposition product (CO_2) indicated the degree of its belonging to dolomite and calcite and at the same time informed about quantitative content of these carbonates in the rock. Thus, the results of thermal analysis showed that the chemical decomposition of the thermally active components of the sample started at 40 °C is completely completed in the vicinity of 830 °C.As a result of this, in the substrate for calcination of clays, carbonates and gypsum in this temperature range centers are already formed in which the first points of melting are formed. These include melting of silicon-oxygen compounds, which are the products of thermochemical destruction of layered silicates. The process proceeds without significant participation of quartz, albite, and orthoclase present in the samples, since melting temperatures of these silicates are much higher than a sintering temperature of carbonate-argillaceous inclusions of the loams in question.

As results of a differential thermal analysis (DTA) showed, complete sintering of these objects with dynamic heating from 20 to 1000 °C did not occur, which is due to the high gradient dTº/dt = 10 deg/min, i.e. insufficient storage time of the charge in the high temperature range. In a special test of loam in the high-temperature installation, according to the scheme shown in Fig. 2 (1200 °C (5', 40', 30'), an alloy (from the carbonate-argillaceous part of the charge) was obtained, which unified in its mass unmelted chips of quartz, albite, and orthoclase (figure 3). The substance crystallized from such a melt has a number of advantages to construction products: it is environmentally friendly, durable, fire-resistant and chemically inert. Produced in this way product can be used as a casting material for the production of litter plates, facing coatings, and flake aggregates of concrete widely used in the construction of buildings and special structures. A combination of the three main factors is required in the production of such material: a certain composition of the raw materials, an upper limit of the calcination temperature, and holding time of the charge during its heating. All these factors were taken into account in our experiments in the process of selecting a test object as well as in selecting the temperature-chronological (Tº and t') parameters for the dynamic and isothermal high-temperature (1200 °C) heating of the charge.

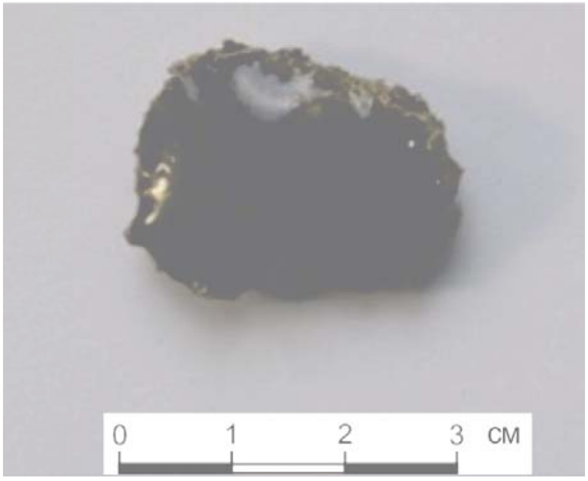


Figure 3 – Зhoto illustration of the product of firing clay loam (Boraldai); temperature-temporal parameters of firing stone material in a high temperature heating to 1200°C (5', 40', 30')

Loams north of Uzun-Agachvillage and the quarry of Boralday TPP have a polymineral composition of which 55% are not subjected to any phase transformations in the investigated temperature range and 45% decompose within 60-820 °C with a release into the atmosphere of 12.3% (of the sample mass) of volatile compounds: H_2O, OH and CO_2.Due to the low content of fine montmorillonite in the system (respectively 6.7, 4.6, and 6.2%), the probability of forming a large amount of refractory mullite, cristobalite (by roasting), is also low. But this is the only problem for low-temperature production (up to 1000 °C) of these clays, to obtain a material with qualities comparable to those of burnt bricks. With proper additions to these montmorillonite loams and a slight increase in the firing temperature, these formations will provide raw materials for the technology of manufacturing a fireproof, chemically inert, and mechanically strong concrete filler. In particular, these loams serve as a promising material for the production of expanded clay and thermal insulation materials. From a series of high-temperature tests performed with heating of these complexes, a group of products with qualities corresponding to the physical properties of expanded clay was identified. The choice of these qualities in crystallized melts was carried out taking into account the energy saving factors of furnace heating and the expression of the production cycle. The most acceptable calcination temperature of most samples was 1200 °C and time of isothermal roasting (without taking into account a preheating of the charge and its cooling) for different samples was 20-30 minutes.

The sample firing product (old storage ash, Boralday TPP) is presented as a hard, porous substance with a yellowish tinge of the surface on which dotted, sparsely populated dark specks of quartz and micro cracks with sizes from 2 to 4 mm are seen (figure 4). Heat treatment (20-1000°C) of the studied ash did not cause a significant reduction in the initial mass of the charge. The main stages of weight loss of the sample are in the temperature range of 20-800 °C, where the system loses up to 7.3% of its mass as a gaseous substance. Within these temperatures, the analytical balance of the derivatograph records all the steps of removing volatile components of the ash (in the form of moisture and carbon monoxide).

Figure 4 – Photo illustration (4) the product of annealing of the sample (the remains of an old storage pit Boraldai TPP); thermal-temporal parameters of firing stone material in a high temperature heating to 1200°C (5', 40', 30')

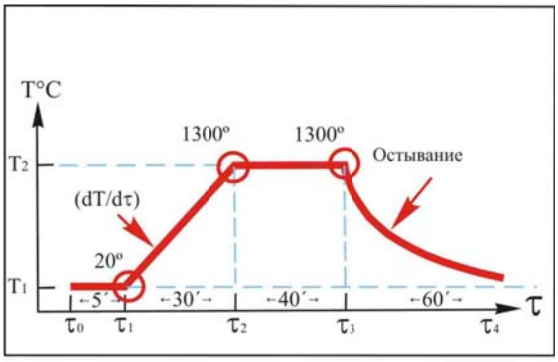
However, when the sample was heated in the range of 20-1200 °C, the weight loss was ~ 9%, i.e. in the range of 1000-1200 °C, the investigated charge loses another ~ 1.5% of its weight. This difference is due to the release of organic carbon monoxide (CO_{OR}) and carbonate CO_2 into the atmosphere. The reaction is due to thermal depressurization of microscopic silicon capsules included in the ash composition. Formation of these capsules and its contents was carried out even while burning fuel in the ovens of TPP. This way, in the process of combustion of coal, part of the organic and carbonate inclusions can appear in the spaces of these hermetic cells, whose shells at some point served as an obstacle for ingress of oxygen.

To determine the dependence of the change in the quality of the roasting product on changing the upper limit of the heating temperature from 1200 °C to 1300 °C, while maintaining the other earlier used heating parameters, this ash was tested at 1300 °C (5, 30', 40'), see figure 5.

Figure 5 – Photo illustration (5) of the product of calcination of ash of a new storage (Boraldai TPP); thermal-temporal parameters of firing stone material in a high temperature heat of 1300°C (5', 30', 40')

The coal ash of current dumps when heated at 1300 °C (5', 30', 40') forms a ceramic mass according to the external appearance of the previous firing of the ash obtained under the same temperature-chronological conditions of calcination. The sintered batch of the object under consideration is also presented in the form of a microporous formation, but with a few dark specks with diameters ranging from 0.5 to 2 mm. Most of the surface is dotted with micro-craters formed as a result of bursting of bubbles in the process of gas inclusions coming out of them. The resulting product does not contain cracks and is a consolidated mass with a more dim shade of the surface than was observed in the example of the abovementioned sample.

Based on results of X-ray tests, the mineral composition of the investigated charge mainly consists of mullite (68%) and quartz (22.4%) (figure 6). The new heating mode could not significantly change the ratio of these minerals and their aggregate state in the firing product. This is due to the insufficiency of the upper temperature limit (1300 °C) achieved in the experiment, which is below the melting point of mullite (1810-1530 °C) and quartz (1713-1728°C).The same should be attributed to the calcium and magnesium oxides obtained as a result of the decomposition present in the calcite and dolomite sample. However, CaO and MgO reduce viscosity of the liquid phase, the source of which can be one of the components of the studied ash, orthoclase. The feldspar is melted within (1130-1450 °C). Consequently, the development of ceramic formation in a system based on mullite and quartz as well as with the participation of calcium and magnesium oxides is performed as a result of melting of orthoclase, further crystallization of which ensures the consolidation of particles of the named minerals.



a b

Figure 6 – (a) photo illustration the product of annealing of a sample of ash's old warehouse (Boraldai TPP); (b) – scheme for high-temperature ash heating in a chamber furnace - 1300 °C (5', 30', 40')

To reveal new qualities of expanded clay from old storage ash when changing the upper limit of the heating temperature from 1200 to 1300 °C a test was also conducted in the 1300 °C (5', 30', 40 ') mode, figure 6.Thermal treatment of this object in the new temperature range slightly increased its weight loss (~ 10%) and did not change the appearance of the sintered sample. Due to this, the resulting ceramic formation has the same hardness and micro porosity as the product made with the first firing process. Dark specks of crystalline origin are clearly traced on the surface of this formation. A distinctive feature of the new calcination product in relation to the external appearance of the compared material serves grayish-matt color of its surface. The yellowish-almond color of the formation was preceded by this color shade of the sintered charge at 1300 °C obtained in the heating mode of 1200 °C (5 ', 40', 30 ').

Thus, as a result of the given high-temperature modes of heating of the specified ash, highly porous materials with a special hardness, heat and noise insulating properties were obtained, characterized as chemically inert and fire-resistant substances. The procedure for obtaining materials with similar quality from the same ash in different heating regimes can later be used in large-scale production of construction products to find an acceptable technical and economic balance between the required quality of the products produced and the cost of energy resources for manufacturing them. Since this formation includes up to 50% of mullite ($Al_2(Al_{2.8}Si_{1.2})O_{9.6}$), 41% of quartz, and 9% of oxides (aluminum, calcium and iron) which do not have chemically active properties, environmental safety can be added to the abovementioned advantages of burnt material (figure 6). All these qualities of obtained products fully meet the technological requirements of light concrete fillers, which can be used in the construction of residential, administrative, and industrial buildings as well as for the construction of technical structures for various purposes.

The ashes of the old and new burials from the Boraldai area contain up to 90% of siliceous formations (mullite and quartz) characterized as strong, fire-resistant, and chemically inert substances. As part of a building material, these natural formations are durable. Due to the peculiarities of the mineral content of the formations under consideration with negligible impurities of calcium and magnesium carbonates

(2.3 and 2.1%, respectively), they can be used directly as a concrete aggregate. And with the additional of firing of this ash, the lightness, heat, and sound proofness of the concrete product will be added to the abovementioned qualities.

The use of industrial waste from Boralday TPP as raw material for the production of expanded clay has a number of undeniable advantages over other types of natural material, namely the aggregate state of ash, low cost of energy, waste utilization, the solution of the environmental storage problem, and other benefits associated with the proximity of the heat-power center to a large metropolis. To obtain a test sample of quality expanded clay from said ash, isothermal heating of the charge at 1300 °C is required for 40 minutes (without taking into account the time of the furnace temperature rise and its cooling). Interest in this ash from the position of using it as raw material in the production of concrete filler is enormous in connection with the solution of environmental problems of recycling industrial waste and with an improvement of the quality of products and lowering of the cost of raw materials too.

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ЖЕҢІЛ БЕТОН ТОЛТЫРҒЫШТАР ӨНДІРІСТІҢ НЕГІЗІ РЕТІНДЕ ҚОЛДАНЫЛАТЫН ЖОҒАРЫ ТЕМПЕРАТУРАЛЫ СЫНАУЛАРДАН ӨТКЕН ТӨМЕНГІ ТӨРТТІК САЗДАҚТАРДЫҢ ЖӘНЕ БОРАЛДАЙ ЖЫЛУ ЭЛЕКТРОСТАНЦИЯНЫҢ ТЕХНОГЕНДІК КӨМІР КҮЛДЕРІНІҢ БАЛҚЫМАЛАРЫНЫҢ СИППАТАМАСЫ

Аннотация. Төменгі төрттік саздақтардан және жылулық электростансаның қалдықтардың көмір күлдерінен жасалған жеңіл бетон толтырғыштардың заттық құрамының, технологиялық қасиеттердің зерттеу мәселері қаралған. Қазақстан аймағында көмір энергетика қалдықтары түрінде көп мөлшері күлдер (жүздеген миллион тонна) қорланған. Өнеркәсіптік жеңіл бетон толтырғыш өндірісі ұйымдастыруы осы қалдықтар негізінде әртүрлі құрылыс құрылмалар дайындап шығаруға жағдай тұғызады.

Боралдай алаңындағы ескі және жаңа жерлеу күлдері 90% дейін кремний құрастырулар (муллит және кварц) жасайды және беріктік, отқатөзімділік, химиялық тұрақты зат ретінде сиппаталады. Құрылыс материалдары құрамында осы табиғи құрастырулар шыдаммерзімді болып саналады. Минералды мөлшері өзгешілігі себебінен қаралған құрастырулар өте аз кальций және магний карбонаттар түрінде зиянды қоспалар құрайды, оларды тікелей бетон толтырғыш ретінде колдануға болады. Қосымша күйдіру осы күлддің жоғарыда ескерілген қасиеттеріне тағы бірнеше қосылады – бетон бұйымдардың жеңілдігі, жылу және дыбыс жұтатын оқшаламасы.

Саздақты күйдіргенде құрамбөліктердің жартысы (монтмориллонит, мусковит және хлорит) балқылмаған кварц бөлшектерімен бірге біртектілік жентек құрайды. Кальцит, доломит, және гипс минералдары диссоциация арқылы магний және кальций окидтерге айналады, соңында балқыманын тұтқырлығын төмендетеді. Ең басты балқыманың толтырғышы (~50%) күйдіру арқылы алынған бұйымы кремнезем құраушы саздақтардың ұнтақтық түйіршіктері болған.

Осы зерттеу кезеңінде алынған бұйым өндірісте термиялық төзімді және механикалық берікті жеңіл бетон толтырғыш қабыршақты агрегат шығару үшін қолдану мүмкін.

Түйін сөздер: керамзит, шихта, лесс тарызды саздақтар, көмір күлі, термиялық, рентгенфаздық, микрозондық талдауы, жоғары температуралы пеште шихта балқытуы.

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ХАРАКТЕРИСТИКА РАСПЛАВОВ ВЫСОКОТЕМПЕРАТУРНЫХ ИСПЫТАНИЙ НИЖНЕЧЕТВЕРТИЧНЫХ СУГЛИНКОВ И ТЕХНОГЕННОЙ УГОЛЬНОЙ ЗОЛЫ БОРАЛДАЙСКОЙ ТЭЦ, КАК ОСНОВА ДЛЯ ПРОИЗВОДСТВА ЛЕГКИХ ЗАПОЛНИТЕЛЕЙ БЕТОНОВ

Аннотация. Рассматриваются вопросы изучения вещественного состава, технологических свойств легких заполнителей для бетонов из нижнечетвертичных суглинков и угольной золы – отходов ТЭЦ. На территории Казахстана накопилось огромное количество золы (многие сотни миллионов тонн), представляющие собой отходы угольной энергетики. Организация промышленного производства легких заполнителей из таких отходов позволила бы на их основе изготавливать различные строительные конструкции.

Золы старого и нового захоронения из площади Боралдай содержат в себе до 90% кремнистых образований (муллит и кварц), характеризующихся, как прочные, огнеупорные и химически устойчивые вещества. В составе строительного материала эти природные образования являются долговечными. В силу особенностей минерального содержания рассматриваемых образований с ничтожно малыми примесями в них карбонатов кальция и магния, они могут быть использованы непосредственно в качестве заполнителя бетона. А при дополнительном обжиге этой золы к вышеупомянутым качествам добавятся – легкость, тепло- и звуконепроницаемость бетонного изделия.

При обжиге суглинка, часть его компонентов (монтмориллонит, мусковит и хлорит), совместно с нерасплавившимися частицами кварца образуют однородный агрегат. Такие минералы, как кальцит, доломит и гипс, в процессе диссоциации, переродились в оксиды кальция и магния, что в итоге позволило снизить вязкость расплава. Главными заполнителями расплава (~50%) в полученном продукте обжига явились порошковые гранулы кремнеземистых составляющих суглинка.

Таким образом, полученный продукт на данном этапе исследования уже может быть использован при производстве термостойких и механически прочных чешуйчатых агрегатов легких заполнителей бетона.

Ключевые слова: керамзит, шихта, лессовидные суглинки, угольная зола, термический, рентгенофазовый и микрозондовый анализы, плавление шихты в высокотемпературной печи.

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APPROXIMATE EQUATION PLATE OSCILLATION FOR TRANSVERSE DISPLACEMENT OF POINTS OF THE MEDIAN PLANE

Abstract. The materials used in building structures have elastic and viscoelastic properties, are anisotropic, multilayer and other mechanical characteristics. Two-dimensional elements are components of many structures. Construction of general and approximate equations of oscillations of a various kind of plane elements is an actual problem in the development of theoretical bases of calculation of building designs and construction in general. These problems include the objectives of improved models of non-stationary nature of the structures and their elements, the materials of which are difficult mechanical, rheological properties inherent to various building designs under the influence of various external factors.

Keywords: plate, oscillation, mixed points, dynamic motion, approximate equation, three-dimensional problem, stress.

Let limitless in terms of plate thickness $2h_1$ is below the surface of a semi-infinite medium at depth $(h_0 - h_1)$. Put the plane XY in the median plane of the plate at $z = 0$. Axis OZ to the right towards the outer surface of the outer layer. Denote the layer parameters index" 1", the upper layer $[-\infty < (x, y) < \infty;$ $h_1 \le z \le (h_0 - h_1)]$ by the index" 2", and the lower half-space $[-\infty < (x, y) < \infty; -h_1 \le z \le 0]$ - index" 3".

We assume that the materials of the upper layer of the plate and the grounds are homogeneous, isotropic, show the viscous properties.

We introduce the potentials of $\Phi^{(l)}$ and $\Psi^{(l)}$ transverse and longitudinal waves well-known formulas

$$\vec{u}^{(l)} = grad\Phi^{(l)} + rot\vec{\Psi}^{(l)}, \tag{1}$$

where $\vec{u}^{(l)}$ – the displacement vector points in the layer of the plate and the foundation.

In potentials $\Phi^{(l)}$ and $\Psi^{(l)}$ equations of motion of a layer of the plate and the foundation will take the form of:

$$N_l\left(\Delta\Phi^{(l)}\right) = \rho_l \frac{\partial^2\Phi^{(l)}}{\partial t^2} \qquad M_l\left(\Delta\vec{\Psi}^{(l)}\right) = \rho_l \frac{\partial^2\Psi^{(l)}}{\partial t^2}, \tag{2}$$

where the operator N_l is equal to:

$$N_l = L_l + 2M_l,$$

Δ – three-dimensional Laplace operator; $\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ L_l, M_l – viscoelastic operators.

The Helmholtz theorem, in the absence of internal sources of the vector potential $\vec{\Psi}$ of transverse waves must satisfy the condition:

$$div\vec{\Psi}^{(l)} = 0 \tag{3}$$

a closing equation for finding four unknown potentials $\Phi^{(l)}, \Psi_1^{(l)}, \Psi_2^{(l)}, \Psi_3^{(l)}$.

Displacement, u, v, w deformation ε_{ij} and strains in Cartesian coordinates through the potentials Φ and $\vec{\Psi}$ the longitudinal and transverse waves are determined by the well-known formulas.

In [1] it is shown that the boundary value problem vibrations of the plate under the surface are reduced to the integro-differential equations (2) with boundary and initial conditions: on the outer surface $(z = h_0)$

$$\sigma_{zz}^{(2)} = f_z^{(2)}(x, y, t);\ \sigma_{jz}^{(2)} = f_{zj}^{(2)}(x, y, t); \tag{4}$$

on the contact boundary between the upper layer – plate $(z = h_1)$

$$\sigma_{zz}^{(1)} = \sigma_{zz}^{(2)};\ \sigma_{jz}^{(1)} = 0;\ \sigma_{jz}^{(2)} = 0;\ w^{(1)} = w^{(2)} \tag{5}$$

on the boundary of the plate - foundation $(z = -h_1)$

$$\sigma_{zz}^{(1)} = \sigma_{zz}^{(3)} + f_{3z}^{(3)}(x, y, t);$$

$$\sigma_{jz}^{(1)} = 0;\ \sigma_{ij}^{(3)} + f_{jz}^{(3)}(x, y, t) = 0;$$

$$w^{(1)} = w^{(3)} + f_0^{(3)}(x, y, t) \qquad (j = x, y) \tag{6}$$

Furthermore, there should be conditions decay at infinity, i.e. at $z \to -\infty$

$$\Phi^{(3)} = 0;\ \Psi_1^{(3)} = \Psi_2^{(3)} = \Psi_3^{(3)} = 0. \tag{7}$$

The initial conditions are zero, i.e.

$$\Phi^{(l)} = \frac{\partial \Phi^{(l)}}{\partial t} = \frac{\partial \vec{\Psi}_j^{(l)}}{\partial t} = \vec{\Psi} = 0 \tag{8}$$

$$\left(l = \overline{1,3}\right), \qquad t = 0 \quad (j = 1,2,3).$$

The task of the vibrations of the plate in a differentiable environment is reduced to the study of equation (2) satisfying the boundary (4), (5), (6) and initial conditions (8).

In the study of oscillations of plate's accurate three-dimensional problem is replaced by simpler, two-dimensional points of median plane of the plate, which imposes limitations on the external conditions. These restrictions are that external forces cannot be high frequency.

The above problem is solved with the use of Fourier *X* and *Y* Laplace at *t*.

In the work [1] found the General solution of the formulated three-dimensional tasks for zero initial conditions and the General expressions for the displacement and strain.

$$u^{(l)} = \sum_{n=0}^{\infty} \left\{ \left[\left(\lambda_2^{(n)} + C_1 Q_{1n} \frac{\partial^2}{\partial x^2} \right) U^{(l)} + C_1 Q_{1n} \frac{\partial}{\partial x} \left(\frac{\partial V^{(l)}}{\partial y} + W^{(l)} \right) \right] \times \right.$$

$$\left. \times \frac{z^{2n}}{(2n)!} \right\} + \sum_{n=0}^{\infty} \left\{ \left[\left(\lambda_2^{(n)} - D_1 Q_{1n} \frac{\partial^2}{\partial x^2} \right) U_1^{(l)} - D_1 Q_{1n} \frac{\partial}{\partial x} \times \left(\frac{\partial V_1^{(l)}}{\partial y} + \lambda_2^{(1)} W_1^{(l)} \right) \right] \frac{z^{2n+1}}{(2n+1)!} \right\};$$

$$v^{(l)}=\sum_{n=0}^{\infty}\left\{\left[\left(\lambda_2^{(n)}+C_1Q_{1n}\frac{\partial^2}{\partial y^2}\right)V^{(l)}+C_1Q_{1n}\frac{\partial}{\partial y}\left(\frac{\partial U^{(l)}}{\partial x}+W^{(l)}\right)\right]\times\right.$$

$$\left.\times\frac{z^{2n}}{(2n)!}\right\}+\sum_{n=0}^{\infty}\left\{\left[\left(\lambda_2^{(n)}-D_1Q_{1n}\frac{\partial^2}{\partial y^2}\right)V_1^{(l)}-D_1Q_{1n}\frac{\partial}{\partial y}\times\right.\right.$$

$$\left.\left.\times\left(\frac{\partial U_1^{(l)}}{\partial x}+\lambda_2^{(1)}W_1^{(l)}\right)\right]\frac{z^{2n+1}}{(2n+1)!}\right\}; \qquad (9)$$

$$w^{(l)}=\sum_{n=0}^{\infty}\left\{\left[\left(\lambda_2^{(n)}+C_1Q_{1n}\lambda_1^{(1)}\right)W^{(l)}+C_1Q_{1n}\lambda_1^{(1)}\left(\frac{\partial U^{(l)}}{\partial x}+\frac{\partial V^{(l)}}{\partial y}\right)\right]\times\right.$$

$$\left.\times\frac{z^{2n+1}}{(2n+1)!}\right\}+\sum_{n=0}^{\infty}\left\{\left[\left(\lambda_2^{(n)}-D_1Q_{1n}\lambda_2^{(1)}\right)W_1^{(l)}-D_1Q_{1n}\times\left(\frac{\partial U_1^{(l)}}{\partial x}+\frac{\partial V_1^{(l)}}{\partial y}\right)\right]\frac{z^{2n}}{(2n)!}\right\};$$

$C_1=1-\dfrac{N_1}{M_1};\ Q_{1n}=\sum_{m=0}^{n-1}\lambda_1^{(n-m-1)}\cdot\lambda_2^{(m)};\ D_1=1-\dfrac{M_1}{N_1}$ where operators $\lambda_1^{(1)}$ and $\lambda_2^{(1)}$ are equal

$$\lambda_1^{(1)}=\left[\rho_1N_1^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\Delta\right];\quad \lambda_2^{(1)}=\left[\rho_1M_1^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\Delta\right];\quad \Delta=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2} \qquad (10)$$

$$\sigma_{xx}^{(l)}=M_1\left[\sum_{n=0}^{\infty}\left\{\left[(1-C_1)\lambda_2^{(n)}+C_1Q_{1n}\left(\lambda_2^{(1)}-2\lambda_2^{(1)}+\frac{\partial^2}{\partial x^2}-\frac{\partial^2}{\partial y^2}\right)\right]\right.\right.$$

$$\times\frac{\partial U^{(l)}}{\partial x}+\left[C_1Q_{1n}\left(\lambda_2^{(1)}-2\lambda_2^{(1)}+\frac{\partial^2}{\partial x^2}-\frac{\partial^2}{\partial y^2}\right)-(1+C_1)\lambda_2^{(n)}\right]\times$$

$$\times\left(\frac{\partial V^{(l)}}{\partial y}+W^{(l)}\right)\left.\right\}\frac{z^{2n}}{(2n)!}+\sum_{n=0}^{\infty}\left\{\left[2D_1Q_{1n}\left(\lambda_2^{(1)}+\frac{\partial^2}{\partial y^2}\right)+(1+\alpha D_1)\lambda_1^{(n)}\right]\times\right.$$

$$\left.\left.\times\frac{\partial U^{(l)}}{\partial x}+\left[(1+\alpha D_1)\lambda_1^{(n)}-2D_1Q_{1n}\frac{\partial^2}{\partial x^2}\right]\left(\frac{\partial V_1^{(l)}}{\partial y}+\lambda_2^{(1)}W_1^{(l)}\right)\right\}\frac{z^{2n+1}}{(2n+1)!}\right];$$

$$\sigma_{yy}^{(l)}=M_1\left[\sum_{n=0}^{\infty}\left\{\left[(1+C_1)\lambda_2^{(n)}+C_1Q_{1n}\left(\lambda_2^{(1)}-2\lambda_2^{(1)}-\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\right]\right.\right.$$

$$\times\frac{\partial V^{(l)}}{\partial y}+\left[C_1Q_{1n}\left(\lambda_2^{(1)}-2\lambda_1^{(1)}-\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)-(1+C_1)\lambda_2^{(n)}\right]\times$$

$$\times\left(\frac{\partial V^{(l)}}{\partial x}+W^{(l)}\right)\left.\right\}\frac{z^{2n}}{(2n)!}+\sum_{n=0}^{\infty}\left\{\left[1+2D_1\left(\lambda_1^{(n)}\right)+2D_1Q_{1n}\left(\lambda_2^{(n)}+\frac{\partial^2}{\partial x^2}\right)\right]\times\right.$$

$$\left.\left.\times\frac{\partial V_1^{(l)}}{\partial y}+\left[(1+D_1)\lambda_1^{(n)}-2D_1Q_{1n}\frac{\partial^2}{\partial y^2}\right]\left(\frac{\partial U_1^{(l)}}{\partial x}+\lambda_2^{(1)}W_1^{(l)}\right)\right\}\frac{z^{2n+1}}{(2n+1)!}\right];$$

$$\sigma_{zz}^{(l)} = M_1\left[\sum_{n=0}^{\infty}\left\{\left[C_1Q_{1n}\left(\lambda_2^{(1)}-\Delta\right)-\left(1+C_1\right)\lambda_2^{(n)}\right]\left(\frac{\partial U^{(l)}}{\partial x}+\frac{\partial V^{(l)}}{\partial y}\right)+\right.\right.$$

$$\left.+\left[\left(1+C_1\right)\lambda_2^{(n)}+C_1Q_{1n}\left(\lambda_2^{(1)}-\Delta\right)\right]W^{(1)}\right\}\frac{z^{2n}}{(2n)!}+\sum_{n=0}^{\infty}\left\{-\left[2D_1Q_{1n}\lambda_2^{(1)}+\lambda_1^{(n)}\right]\times\right.$$

$$\left.\left.\times\left(\frac{\partial U_1^{(l)}}{\partial x}+\frac{\partial V_1^{(l)}}{\partial y}\right)+\lambda_2^{(1)}\left[\lambda_1^{(n)}+2D_1Q_{1n}\Delta\right]W_1^{(1)}\right\}\frac{z^{2n+1}}{(2n+1)!}\right];$$

$$\sigma_{xy}^{(l)} = M_1\left[\sum_{n=0}^{\infty}\left\{\left[2C_1Q_{1n}\frac{\partial^2}{\partial x^2}+\lambda_2^{(n)}\right]\frac{\partial V^{(1)}}{\partial y}+\left[\lambda_2^{(n)}+2C_1Q_{1n}\frac{\partial^2 W^{(1)}}{\partial x\partial y}\right\}\times\right.\right.$$

$$\times\frac{z^{2n}}{(2n)!}+\sum_{n=0}^{\infty}\left\{\left[\lambda_1^{(n)}+D_1Q_{1n}\left(\lambda_2^{(1)}-\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\right]\frac{\partial U_1^{(l)}}{\partial y}+\right.$$

$$\left.\left.+\left[D_1Q_{1n}\left(\lambda_2^{(1)}-\frac{\partial^2}{\partial x^2}-\frac{\partial^2}{\partial y^2}\right)+\lambda_1^{(n)}\right]\frac{\partial V_1^{(l)}}{\partial x}-2D_1Q_{1n}\lambda_2^{(1)}\frac{\partial^2 W_1^{(1)}}{\partial x\partial y}\right\}\times\frac{z^{2n+1}}{(2n+1)!}\right];$$

$$\sigma_{xz}^{(1)} = M_1\left[\sum_{n=0}^{\infty}\left\{\left[C_1\left[2\lambda_1^{(1)}Q_{1n}+\lambda_2^{(n)}\right]\frac{\partial^2 V^{(1)}}{\partial x\partial y}+\left[2C_1Q_{1n}\lambda_1^{(1)}\frac{\partial^2}{\partial x^2}+\right.\right.\right.\right.$$

$$\left.\left.+\lambda_2^{(n)}\left[\left(1-C_1\right)\lambda_1^{(1)}-C_1\frac{\partial^2}{\partial y^2}\right)\right]V^{(1)}+\left[\left(1+C_2\right)\lambda_2^{(n)}+2C_1Q_{1n}\lambda_1^{(1)}\right]\frac{\partial W^{(1)}}{\partial x}\right\}\times$$

$$\left.\times\frac{z^{2n+1}}{(2n+1)!}\right]+\sum_{n=0}^{\infty}\left\{\left[\left(\lambda_2^{(1)}-\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)D_1Q_{1n}+\lambda_1^{(n)}\right]V_1^{(1)}-\right.$$

$$\left.-2D_1Q_{1n}\frac{\partial^2 V_1}{\partial x\partial y}-\left[D_1Q_{1n}(\lambda_2^{(1)}-\Delta)-\lambda_1^{(n)}\right]\frac{\partial W_1^{(1)}}{\partial x}\right\}\frac{z^{2n}}{(2n)!}$$

$$\sigma_{yz}^{(1)} = M_1\left[\sum_{n=0}^{\infty}\left\{\left[C_1\left[2\lambda_1^{(1)}Q_{1n}+\lambda_2^{(n)}\right]\frac{\partial^2 U^{(1)}}{\partial x\partial y}+\left[2C_1Q_{1n}\lambda_1^{(1)}\frac{\partial^2}{\partial y^2}+\right.\right.\right.\right.$$

$$\left.\left.+\lambda_2^{(n)}\left[\left(1-C_1\right)\lambda_1^{(1)}-C_1\frac{\partial^2}{\partial x^2}\right)\right]V^{(1)}+\left[2C_1Q_{1n}\lambda_1^{(1)}+\left(1+C_2\right)\lambda_2^{(n)}\right]\frac{\partial W^{(1)}}{\partial x}\right\}\times$$

$$\left.\times\frac{z^{2n+1}}{(2n+1)!}\right]+\sum_{n=0}^{\infty}\left\{\left[\left(\lambda_2^{(1)}-\frac{\partial^2}{\partial x^2}-\frac{\partial^2}{\partial y^2}\right)D_1Q_{1n}+\lambda_1^{(n)}\right]V_1^{(1)}-\right.$$

$$\left.-2D_1Q_{1n}\frac{\partial^2 V_1}{\partial x\partial y}-\left[D_1Q_{1n}(\lambda_2^{(1)}-\Delta)-\lambda_1^{(n)}\right]\frac{\partial W_1^{(1)}}{\partial y}\right\}\frac{z^{2n}}{(2n)!}, \qquad (11)$$

where unknown $U^{(1)}, V^{(1)}, W_1^{(1)}$ are the tangent and normal displacements of the points in the plane $z=0$ and points of median plane of the plate, $U_1^{(1)}, V_1^{(1)}, W^{(1)}$ - value of derivatives Z transverse displacement or values type of deformation ($W^{(1)}$-deformation at $Z=0$).

Operators $\lambda_1^{(2)}, \lambda_2^{(1)}$ are two-dimensional integro-differential describing the propagation of longitudinal and transverse waves in a plane $z=0$.

For finding the unknown $U^{(1)}, V^{(1)}, W_1^{(1)}\, U_1^{(1)}, V_1^{(1)}, W^{(1)}$ we have boundary conditions (4)–(6).

Using the formulas (9) and (11) of strains and displacements substituting these expressions into the boundary conditions (4) - (6) equations are obtained for determining the unknown functions that are general solutions of the considered problem and describing oscillations of a three-dimensional environment.

For the study of oscillations of rectangular plates in terms of the need to formulate boundary problems.

Under the boundary tasks fluctuations limited plate in the plan, which is under the surface, means the conclusion of the equation of oscillations of plates; the formulation of boundary conditions on the edges of the plate and the initial conditions for the functions.

As a general equations of oscillations of plates obtained by the author [1] contain derivatives of any order of the coordinates x, y and time t, stacked on the structure and therefore are not suitable for solving applied tasks and of engineering calculations.

For this purpose it is necessary to formulate approximate boundary value problems of oscillation.

In [2-5] is obtained approximate equation of transverse vibrations of the plate for transverse shift $W_1^{(1)}$ points of median plane of the plate in the shape of

$$A_1\left(\frac{\partial^2 W_1^{(1)}}{\partial t^2}\right)+A_2\left(\frac{\partial^4 W_1^{(1)}}{\partial t^4}\right)+A_3\left(\Delta\frac{\partial^2 W_1^{(1)}}{\partial t^2}\right)+A_4\left(\Delta^3 W_1^{(1)}\right)+P\left(W_1^{(1)}\right)=\Phi(x,y,t), \tag{12}$$

where $A_j, P, \Phi(x,y,t)$ are equal to

$$A_1=\rho_1 M^{-1}h_1+\rho_2 N_2^{-1}(h_0-h_1);$$

$$A_2=\rho_1^2 M_1^{-1}\left(N_1^{-1}+3M_1^{-1}\right)\frac{h_1^3}{6}+\rho_2 N_2^{-1}\left[\rho_2 N_2^{-1}\frac{(h_0-h_1)^3}{6}-\rho_1 N_1^{-1}\frac{h_1^2(h_0-h_1)}{2}\right];$$

$$A_3=\left[\left(3-4M_2N_2^{-1}\right)\frac{(h_0-h_1)^3}{6}-\left(2M_1N_1^{-1}\right)\frac{h_1^2(h_0-h_1)}{2}\right]\rho_2 N_2^{-1}-2\rho_1\left(3M_1^{-1}-2N_1^{-1}\right)\frac{h_1^3}{3}$$

$$A_4=4\left(1-M_1N_1^{-1}\right)\frac{h_1^3}{3}-4\left(1-M_2N_2^{-1}\right)\left(M_2N_2^{-1}\right)\frac{(h_0-h_1)^3}{6}$$

$$P=\frac{S}{2}\rho_1 M_1\left\{\frac{\partial}{\partial t}+\frac{h_1^2}{2}\left[\rho_1\left(M_1^{-1}+3N_1^{-1}\right)\left(\frac{\partial^3}{\partial t^3}\right)-4\left(\frac{\partial}{\partial t}\right)\Delta\right]+2\left(M_1N_1^{-1}\right)\left(\rho_2N_2^{-1}\right)\left(\frac{\partial^3}{\partial t^3}\right)h_1(h_0-h_1)\right\};$$

$$\Phi(x,y,t)=\left[1-\left(3-2M_1N_1^{-1}\right)\frac{h_1^2}{2}\Delta+\left(\rho_1M_1^{-1}\right)\left(\frac{\partial^2}{\partial t^2}\right)\frac{h_1^2}{2}\left\{F_3+M_2^{-1}f_z^{(3)}\left[\left(M_1N_1^{-1}\right)\left(\rho_2N_2^{-1}\right)\left(\frac{\partial^3}{\partial t^3}\right)(h_0-h_1)h_1\right]\right.\right. \tag{13}$$

Reaction of the basis of P, is determined by the formula (13) includes both the velocity of the points transverse displacement of the plane $z=0$ and the odd derivatives time.

Thus, the law of resistance $P\left(W_1^{(1)}\right)$ (13) explicitly contains the parameters of the plate, foundation and topcoat.

Despite the fact that the equation (12) is approximate, it is quite difficult. In the operators (13) contains all the parameters and operators characterizing the mechanical and rheological properties of the materials of plates - and the base layers and their thicknesses.

We derive the boundary conditions on the edges of a rectangular plate. For simplicity, consider a flat edge $x=const$, the boundary conditions for easy record of the conditions for $x=const$, and for an arbitrary curved edge of the known formulas through the boundary conditions at $x=const$, $y=const$.

Boundary conditions will display on the theory of thick platform or plates.

Based on the boundary conditions on a surface of a plate $z = h$ or $z = -h$ we obtain the dependence of the quantities $u_1^{(1)}, V_1^{(1)}$, from transverse shift $W_1^{(1)}$.

$$u_1^{(1)} = -\frac{\partial W_1^{(1)}}{\partial x}; \qquad V_1^{(1)} = -\frac{\partial W_1^{(1)}}{\partial y}. \tag{14}$$

Rigid fixation of the edge $x = const$. As it is known from the theory of thick plates are two types of such fastening

$$u_1^{(1)} = v_1^{(1)} = w_1^{(1)} = 0 \tag{15}$$

or

$$u_1^{(1)} = w_1^{(1)} = \sigma_{xy}^{(1)} = 0 \tag{16}$$

hinge-supported edge $x = const$.

For this fix also two ways of fastening.

$$v_1^{(1)} = w_1^{(1)} = \sigma_{xx}^{(1)} = 0 \tag{17}$$

or

$$w_1^{(1)} = \sigma_{xx}^{(1)} = \sigma_{xy}^{(1)} = 0 \tag{18}$$

Edge, free from strain.

For the free edge stringent conditions are

$$\sigma_{xx}^{(1)} = \sigma_{xz}^{(1)} = \sigma_{xy}^{(1)} = 0. \tag{19}$$

Rigid and hinged fixations are quite simple, and using the approximate formulas (13) and the dependence (15), we obtain for the transverse displacement of the boundary conditions:

For rigid fixation

$$W_1^{(1)} = \frac{\partial W_1^{(1)}}{\partial x} = 0. \tag{20}$$

For hinged fixation

$$W_1^{(1)} = \frac{\partial^2 W_1^{(1)}}{\partial x^2} = 0. \tag{21}$$

For the edge, which is free from strain, in the formula of- σ_{xx} take the first additive component $|\ z$, and for $\sigma_{xz}^{(1)}$ the first two, as the first identical equation is zero due to conditions (15)

It is obtained

$$(2 + 3D_1)\frac{\partial^2 W_1^{(1)}}{\partial x^2} + (1 + D_1)\left[2\frac{\partial^2 W_1^{(1)}}{\partial y^2} - \rho M^{-1}\left(\frac{\partial^2 W_1^{(1)}}{\partial t^2}\right)\right] = 0$$

$$\frac{\partial}{\partial x}\left[2\Delta W_1^{(1)} - \rho M^{-1}\left(\frac{\partial^2 W_1^{(1)}}{\partial t^2}\right)\right] = 0 \tag{22}$$

excluding $\frac{\partial^2 W_1^{(1)}}{\partial t^2}$ in the second condition (22) from the first, we obtain

$$(2 + 3D_1)\frac{\partial^2 W_1^{(1)}}{\partial x^2} + (1 + D_1)\frac{\partial^2 W_1^{(1)}}{\partial y^2} - \rho(1 + D_1)M^{-1}\left(\frac{\partial^2 W_1^{(1)}}{\partial t^2}\right) = 0$$

$$\frac{\partial^3 W_1^{(1)}}{\partial x^3} = 0. \tag{23}$$

The third of the conditions (19) gives $\frac{\partial^3 W_1^{(1)}}{\partial x} = F(t)$, i.e. in the first approximation $\frac{\partial W_1^{(1)}}{\partial x}$ does not depend on y, and decide upon a solution to a particular problem.

The first additive component in (23) differs from the classical and the second matches. The first condition (23) takes into account the deformability of the edge over time and d'Alembert principle similar to the dynamics of a material point.

General initial conditions for the plate as a three-dimensional body are of the form:

$$u^{(1)} = v^{(1)} = w^{(1)} = 0; \qquad \frac{\partial u^{(1)}}{\partial t} = \frac{\partial v^{(1)}}{\partial t} = \frac{\partial w^{(1)}}{\partial t} = 0; \quad (t = 0). \tag{24}$$

Using dependency (14) for movements have

$$u^{(1)} = -\frac{\partial W_1^{(1)}}{\partial x} z + D_1 \frac{\partial}{\partial x} \Delta W_1^{(1)} \frac{z^3}{6};$$

$$v^{(1)} = -\frac{\partial W_1^{(1)}}{\partial y} z + D_1 \frac{\partial}{\partial y} \Delta W_1^{(1)} \frac{z^3}{6}; \tag{25}$$

$$w^{(1)} = W_1^{(1)} + \left[(2D_1 - 1)\Delta W_1^{(1)} + (1 - D_1)\rho M^{-1} \frac{\partial^2 W_1^{(1)}}{\partial t^2} \right] \frac{z^2}{2}$$

In the beginning let us consider the initial conditions from (24) for the movement. Then from the expressions (25) we get

$$\frac{\partial W_1^{(1)}}{\partial x} = 0; \qquad \frac{\partial}{\partial x} \Delta W_1^{(1)} = 0;$$

$$\frac{\partial W_1^{(1)}}{\partial y} = 0; \qquad \frac{\partial}{\partial y} \Delta W_1^{(1)} = 0 \;; \tag{26}$$

$$W_1^{(1)} = 0; \qquad \frac{\partial^2 W_1^{(1)}}{\partial t^2} = 0. \tag{27}$$

Differentiating the expression (25) and by using the second three initial conditions (24), we similarly obtain

$$\frac{\partial W_1^{(1)}}{\partial t} = \frac{\partial^3 W_1^{(1)}}{\partial t^3} = 0 \;. \tag{28}$$

Initial conditions (26) and (27) provide the necessary number of initial conditions for transverse shift $W_1^{(1)}$ meets with the hyperbolic equation of fourth order in the coordinates and time.

In conclusion, it should be noted that the evaluation and conclusion initial and boundary conditions for the plate under the surface completely coincides with similar initial boundary conditions for a free plate, obtained in the works [1].

Thus, in the formulation of boundary value problems boundary conditions do not depend on the presence of the upper layer and lower foundation.

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КӨЛБЕУ ЫҒЫСУЛАР ЖАҒДАЙЫНДАҒЫ ЖАЗЫҚТЫҚТЫҢ ОРТАСЫНДА ОРНАЛАСҚАН НҮКТЕЛЕР ҮШІН ПЛАСТИНА ТЕРБЕЛІСІНІҢ ЖУЫҚ ТЕҢДЕУІ

Аннотация. Мақалада сыртқы әсерлер кезінде иілгіш және тұтқыр иілгіш пластиналардың динамикалық қозғалысын анықтау дірілдерін математикалық теория тұрғысынан түсіндіруге талпынған. Осы көзқарасқа негізделген физикалық бейсызықтық материалдар теңдеулеріне жақындатылған, бастапқы ауыстыру мен кернеулерді ескерген және ескерусіз тұтқыр иілгіш пластиналардың бойлық және көлденең дірілдерінің нақты теңдеулері шығарылған. Нақты теңдеулер негізінде сол немесе олардан кейінгі дәлдік дәрежесі бар кейбір жуықтау теңдеулері талданған және олар үшін шекаралық есептер құрастырылған.

Түйін сөздер: пластинка, тербеліс, аралас нүктелер, динамикалық қозғалыс, жуық теңдеу, үш өлшемді есеп, кернеу.

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ПРИБЛИЖЕННОЕ КОЛЕБАНИЕ ПЛАСТИНЫ УРАВНЕНИЯ ДЛЯ ПОПЕРЕЧНОГО СМЕЩЕНИЯ ТОЧЕК СРЕДИННОЙ ПЛОСКОСТИ

Аннотация. В настоящей работе предпринята попытка изложения математической теории колебаний упругой или вязкоупругой пластинки для изучения динамического их поведения при нестационарных внешних воздействиях. На основе такого подхода выведены точные уравнения продольных и поперечных колебаний вязкоупругих пластин с учетом и без учета начальных смещений и напряжений, приближенные уравнения физической нелинейности материала. На основе точных уравнений проанализированы некоторые вытекающие из них приближенные уравнения с той или иной

Ключевые слова: пластина, колебание, смешанные точки, динамическая движение, приближенные уравнение, трехмерная задача, напрянение.

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BIOCLIMATIC CONDITIONS OF CLIMATIC THERAPY ON THE COAST OF THE LAKE INDER OF THE REPUBLIC OF KAZAKHSTAN

Abstract. The article presents the results of the research of bioclimatic peculiarities on the coast of lake Inder (the Republic of Kazakhstan) on the basis of which the bioclimatic potential of this territory (2,25 points from 3,0 possible) has been estimated, and the category of its compliance for resort climatotherapy is high on condition that 60% is landscape gardening of the territory and building of a year-round climatic medical center. There have been developed some specific favourable bioclimatic features of this area (high purity of the ground atmosphere, the existence of biologically active ultra-violet solar radiation (with the wavelength of 290-315 nm) within a year, the existence of small doses of finely dispersed chlorhydric aerosol in the ground atmosphere, the increased level of natural aero ionization (till 1340 ion/cm^3) with a low coefficient of ion unipolarity (lower than 1,0), a long period with favourable conditions staying in the fresh air (280 days in a year). Bioclimatic conditions are favourable for organization year-round aero- and heliotherapies, natural aero ionization, terrainkur and recreational actions in the open air.

Key words: bioclimatic potential of the coast of lake Inder of the Republic of Kazakhstan, natural aero ionization, prospects of the organization of resort climatotherapy.

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БИОКЛИМАТИЧЕСКИЕ УСЛОВИЯ КЛИМАТОЛЕЧЕНИЯ НА ПОБЕРЕЖЬЕ ОЗЕРА ИНДЕР РЕСПУБЛИКИ КАЗАХСТАН

Аннотация. В статье приводятся результаты исследования биоклиматических особенностей на побережье озера Индер (Республика Казахстан), на основе которых оценен биоклиматический потенциал данной территории (2,25 балла из 3,0 возможных), и категория ее соответствия для целей курортного климатолечения – высокая при условии 60% озеленения территории и строительства круглогодичной климатолечебницы. Выявлены специфические благоприятные биоклиматические особенности данной местности (высокая чистота приземной атмосферы, наличие биологически активной ультрафиолетовой солнечной радиации (с длиной волны 290-315 нм) в течение круглого года, наличие в приземной атмосфере малых доз мелкодисперсного соляного аэрозоля, повышенный уровень природной аэроионизации (до 1340 ион/см^3) с низким коэффициентом униполярности ионов (ниже 1,0), продолжительный период с благоприятными условиями для пребывания на свежем воздухе (280 дней в году). Биоклиматические условия благоприятны для организации круглогодичной аэро- и гелиотерапии, природной аэроионизации, терренкура и рекреационных мероприятий на открытом воздухе.

Ключевые слова: биоклиматический потенциал побережья озера Индер Республики Казахстан, природная аэроионизация, перспективы организации курортного климатолечения.

Актуальность исследования обусловлена запросами здравоохранения Республики Казахстан на развитие курортной медицины, основанной на использовании природных лечебных ресурсов (природные минеральные воды, пелоиды, лечебный климат, рекреационные ландшафты) как наиболее физиологичных, высокоэффективных, экономически выгодных и доступных в применении [1-3]. В рамках развития санаторно-курортной помощи населению Акиматом Атырауской области Республики Казахстан исследуется вопрос о строительстве на побережье озера Индер (Атырауская область, Индерборский район) лечебно-курортного комплекса (ЛКК) на основе использования местных природных лечебных факторов (минеральные воды, лечебные грязи, биоклимат).

В комплексе природных лечебных ресурсов важное место принадлежит биоклиматическим ресурсам курортной местности, которым свойственна естественность, системность и физиологичность воздействия. Использование особенностей биоклимата местности в лечебно-профилактических целях имеет преимущество перед лекарственной терапией, так как климатические факторы привычны для человека, ответные реакции на них закреплены генетически, при их обоснованном применении обычно не бывает осложнений, характерных для лекарственной терапии, поэтому их можно использовать длительно, курсами и практически всю жизнь для закаливания, тренирования и повышения неспецифической резистентности организма, восстановления утраченного здоровья, увеличения качества жизни и продолжительности периода активной жизни [1, 4, 5].

Особенно велика роль специальных методов климатотерапии (воздушные и солнечные ванны, сон на свежем воздухе, лечебный терренкур, лечебное плавание в бассейне, оздоровительный отдых в благоприятных биоклиматических условиях), при которых происходит тренировка гуморальных, нервных и других механизмов терморегуляции, возрастает жизненный тонус и расширяются адаптационные возможности организма. Использование климатотерапии оказывает синергичное позитивное воздействие на другие курортные методы терапии, способствуя повышению эффективности восстановительного лечения [6, 7]. Климатотерапия способствует развертыванию ряда неспецифических и специфических реакций организма, направленных на его оздоровление, особенно при хронических или вялотекущих патологических процессах. Неспецифическое действие климатических факторов можно представить в такой последовательности: изменение термоадаптации; оптимизация обменных процессов; изменение неспецифической и специфической реактивности организма: повышение общей иммунореактивности, фагоцитарной активности лейкоцитов, снижение сенсибилизации организма; оптимизация функций органов и систем [8 **7**].

Опыт показывает, что для получения высокой эффективности климатолечения необходимо соблюдение требований к биоклиматическим условиям и доз воздействия факторов внешней среды в соответствии методическими рекомендациями. В этой связи особую актуальность приобретают исследования биоклиматического режима курортной местности, на основе которых строится программа курортного климатолечения.

Целью данного исследования явилось изучение курортологического потенциала элементов ландшафта и биоклимата в районе планируемого строительства лечебно-курортного комплекса Индер и оценка перспектив их использования для организации различных методов климатолечения и климатоландшафтотерапии.

Материалы и методы. Использованы материалы наблюдений следующих метеорологических станций: Горы (с 1999 г. аул Аккала), расположенной в 5 км севернее поселка Индерборский, (высота над уровнем моря 0 м, широта $48^0 37'09''$ с.ш., долгота $51^0 45'30''$ в.д.), за период с 1937 по 1943 гг.; Тайпак (до 1993 года Калмыково), расположенной в 62 км севернее пос. Индерборский (высота над уровнем моря 2 м, широта $49^0 05'$, долгота $51^0 87'$, синоптический индекс WMO 35406) за период с 1926 по 2017 годы; материалы собственных стационарных (в пос. Индерборский) и маршрутных наблюдений на 6 различных по микроландшафту площадках, расположенных в районе предполагаемого размещения ЛКК Индер. На стационарном пункте определялись следующие параметры: актинометрические условия (интенсивность прямой и суммарной солнечной радиации с последующим расчетом коэффициента прозрачности и фактора мутности), микроклиматические условия (температура, влажность и давление воздуха, количество осадков – непрерывная регистрация на электронный носитель). Маршрутные наблюдения включали замеры микроклиматических условий (температура и влажность воздуха, атмосферное давление, скорость и направление ветра, количество и форма облаков, атмосферные явления), концентрации легких аэроионов положительного и отрицательного заряда (подвижностью К > 0,5 $см^2/В·с$), а также визуальную оценку орографии, пейзажно-эстетического качества и комфортности ландшафта для целей климатоландшафтотерапии, определение пород растительности в районе ЛКК Индер.

В работе использованы общепринятые технологии исследования климата, специальные комплексные методы оценки климата и ландшафта для медицинских целей [2, 4, 9, 10-13].

Результаты исследования

Ландшафтные особенности территории предполагаемого строительства лечебно-курортного комплекса в районе озера Индер обусловлены их месторасположением на северной окраине Прикаспийской низменности в западной степной полупустынной части Республики Казахстан на берегу соленого озера Индер. Местность представляет собой слабо всхолмленную равнину, ограниченную с севера невысокими (до 56 м над ур. м.) пологими кустообразными грядами и отвалами карьеров (102 ед.), в которых добывались бораты, с востока – озером Индер. Северные и северо-восточные берега озера окаймляют Индерские горы (максимальная высота 54 м над ур. м.). В геоморфологическом отношении район расположен в пределах платообразной возвышенности Индерского купола, поднимающегося над озером Индер на 15-25 м со слабым уклоном к югу. Широкое распространение низменных аккумулятивных равнин – важный фактор активного проявления процессов природно-антропогенного опустынивания.

Почвенный покров рассматриваемой территории представлен в основном светло-каштановыми почвами, для которых характерна небольшая мощность гумусовых горизонтов с малым содержанием гумуса – 2-3% (слабогумусированная), а также солончаками и солонцами и используется преимущественно для слабо интенсивного выпаса животных (лошади, крупный рогатый скот и верблюды).

В географическом отношении местность расположена в типично равнинной монотонной области в зоне степи с типчаково-полынной растительностью. Растительный покров в основном составляют галофилы: полынь, типчак, солянки, кермеки, сведы и др. в некоторых местах среди полыни встречаются кохия, эбелек, терескен, лебеда, ковыль. Весной цветут тюльпаны (преимущественно тюльпаны Шренка и Грейга, занесенные в Красную книгу Казахстана), степной касатик и другие эфемеры и эфемероиды. Территория характеризуется естественным покровом в первозданном виде, нарушенным в основном многочисленными норами сусликов и автомобильными грунтовыми дорогами.

С востока к территории планируемого ЛКК примыкает соленое самосадочное бессточное озеро тектонического типа Индер. Площадь зеркала составляет около 110 квадратных километров, длина – около 13,5 км, ширина – около 10 км, глубина – до 56 м, форма округлая, слегка вытянутая с северо-запада на юго-восток. Питание озера в основном подземное (соляные ключи), а также снеговое и дождевое. В озере ведётся добыча соли, толщина солевого слоя – до 15 м. Дно озера топкое, покрытое слоем лечебной грязи (около 4 м), рапа озера имеет высокую минерализацию (около 300 $г/м^3$). В настоящее время рапа и грязь на берегах озера используются для стихийного бальнеогрязелечения.

Территория предполагаемого размещения ЛКК Индер не подвержена подтоплению.

В условиях монотонности рельефа привлекательность ландшафта для целей курортно-рекреационного использования будет зависеть от многих факторов, в том числе, от квалифицированного подхода к строительству современного комплекса лечебно-рекреационных сооружений, композиционных приемов в освоении пространства; создания оазиса зеленых древесно-кустарниковых насаждений с хорошими декоративными свойствами, высокими средоформирующими, фитонцидными, эстетическими и санитарно-гигиеническими функциями, обладающими способностью к коррекции микроклимата от сильных ветров, холодных зимой и жарких летом.

Биоклиматический потенциал местности формируется под воздействием основных климатообразующих факторов: солнечной радиации, атмосферной циркуляции, подстилающей поверхности и экологических особенностей территории. Важной особенностью климата рассматриваемой территории является обилие солнечных дней (до 60% дней в году бывают ясными, а в летние месяцы – до 80%), высокая продолжительность солнечного сияния (в среднем около 2500 часов в год), большой приток солнечного тепла (за год до 11000 МДж/м^2). В течение года бывает в среднем до 40 пасмурных дней, 90% которых приходится на холодное время года. Территория относится к регионам с избыточным поступлением ультрафиолетовой (УФ) солнечной радиации, явления УФ дефицита отсутствуют (в полдень зимой UVI 0,3-1, летом до 9-10).

Климатические условия этих мест в существенной мере обусловлены значительным удалением от океанов, отсутствием высоких горных преград, равнинным расположением на севере Прикаспийской низменности. Это обуславливает планетарную циркуляцию над рассматриваемой территорией – воздушные массы беспрепятственно перемещаются как с запада на восток, так и с севера на юг. При западном (широтном) типе циркуляции устанавливаются широтные полосы повышенного давления или происходит смещение с запада на восток антициклональных систем, перемещающихся с ложбинами низкого давления, иногда с атмосферными фронтами. В среднем при широтном типе циркуляции отмечаются дефицит осадков и повышенный температурный фон.

При вторжении арктического воздуха (в основном зимой) устанавливается антициклональная погода – малооблачная и морозная. Воздушные массы умеренных широт несколько смягчают погоду и приносят основную часть осадков, но так как по пути они теряют значительное количество влаги, осадков здесь выпадает мало. Субтропические и тропические воздушные массы из Центральной Азии достигают севера Прикаспийской низменности преимущественно в теплое время года, устанавливая очень жаркую сухую погоду летом и оттепели зимой. Влажные воздушные массы и муссоны с Индийского океана преграждаются горами на юге.

Режим ветра на рассматриваемой территории имеет ярко выраженный годовой ход. В зимнее время преобладают восточные и юго-восточные ветра (под влиянием периферии западного отрога сибирского антициклона), в летние месяцы – ветра северных румбов, а в межсезонье – западно-восточный перенос. Средняя месячная скорость ветра колеблется в пределах 3,4-5,0 м/с (максимум в феврале, марте, минимум – август, сентябрь). Во все месяцы года наиболее вероятная скорость ветра 2-5 м/с (25-27% от общего числа случаев). Среднее число дней с сильным ветром (≥15 м/с) – 30, с пыльными бурями – до 20 дней.

По климатическому районированию рассматриваемая территория входит в зону с жарким продолжительным летом (в среднем 144 дня) и холодной, иногда суровой зимой (около 136 дней), весна (около 45 дней) и осень (около 40 дней) короткие, отличаются резкой сменой погодного режима. Средняя годовая амплитуда по средней месячной температуре воздуха достигает 35^{0}С, а по абсолютным значениям – около 90^{0}С (климат резко континентальный). Средняя годовая температура воздуха составляет около +8^{0}С, в июле около +26^{0}С, в январе около -9^{0}С. В среднем за год выпадает около 190 мм осадков (с октября по март – 92 мм, с апреля по октябрь – 96 мм), в течение года осадки распределены относительно равномерно (12-15 мм в месяц) с небольшим максимумом весной и осенью (18-20 мм). Самыми сухими месяцами являются июнь-август (влажность в среднем составляет около 40%), а самыми влажными – ноябрь-январь (около 80%). Наиболее часто пасмурные дни по нижней облачности бывают в декабре и январе (по 9 дней в месяц), а ясные по общей облачности – в июле-сентябре (около 7-9 дней в месяц). Средняя годовая скорость ветра довольно существенна - около 4,5 м/с, летом – около 4 м/с, зимой – около 5 м/с. Среднее за год число дней с туманом – 40, с метелью – 15, с грозой – 19, с градом – 0,5.

Лето в рассматриваемом районе (с начала мая до середины сентября) преимущественно солнечное, жаркое и засушливое - температура воздуха часто превышает 30^{0}С (более 60 дней за теплый период) и 40^{0}С (1-2 дня в каждый из летних месяцев), средняя месячная относительная влажность воздуха не превышает 45%, недостаток насыщения воздуха водяными парами достигает 30 гПа, с низким количеством осадков (в среднем 12-17 мм в месяц, интенсивностью преимущественно 1-5 мм).

Зима наступает в середине ноября и длится до начала марта и характеризуется холодной, иногда суровой погодой – средняя температура зимних месяцев составляет около – 7-9^{0}С;

более 30 дней за холодный период температура воздуха опускается ниже -20^{0}С, 3-5 дней - ниже -30^{0}С, до 4 дней за зиму отмечаются оттепели до +5^{0}С. Снежный покров довольно устойчив (до 100 дней в году), невысокий (в среднем 10-15 см).

Осень короткая (с середины сентября до середины ноября) с преобладанием сухой и относительно теплой погоды (средняя месячная температура воздуха в сентябре около 17^{0}С, октябре – около 8^{0}С, ноябре – около -0,5^{0}С).

Весной (с начала марта до начала мая) температура воздуха быстро растет (с -1,5^{0}С в марте, 10^{0}С в апреле до 18^{0}С в мае), увеличивается количество осадков (до 20 мм в месяц), усиливается скорость ветра.

В таблице 1 представлены элементы биоклиматического потенциала территории предполагаемого размещения ЛКК Индер (по 33 модулям), в которой для каждого модуля приведена оценка категории медико-климатических условий по характеру их воздействия на человека (в баллах).

Таблица 1 – Биоклиматический потенциал территории предполагаемого размещения лечебно-курортного комплекса на побережье озера Индер

Биоклиматические модули	Величина	Категория медико-климатических условий	Оценка в баллах
1. Модули биоклиматического режима			
1	2	3	4
Продолжительность потенциально благоприятного периода для проведения активных мероприятий на свежем воздухе в одежде по сезону (терренкур, прогулки, спортигры и др.)	280	Щадящие	3,0
Число дней с комфортным теплоощущением (ЭТ 17-21^0 при ветро- и солнцезащите) при воздушных ваннах в полдень	42	Тренирующие	2,0
Число дней с теплым теплоощущением (ЭТ выше 22-24^0 при ветро- и солнцезащите) при воздушных ваннах в полдень	66	Тренирующие	2,0
Число дней с жарким теплоощущением (ЭТ выше 24^0 при ветро- и солнцезащите) при воздушных ваннах в полдень	28	Раздражающие	1,0
Средняя степень суровости зимы по Бодману, баллы	3,2	Раздражающие	1,0
Повторяемость суровости погоды более 2-х баллов,%	37	Раздражающие	1,0
Индекс континентальности климата по Л. Горчинскому, ед	146,2	Раздражающие	1,0
Число дней в году со средней суточной температурой воздуха выше 15^0 (продолжительность летнего периода)	140	Щадящие	3,0
Число дней в году со средней суточной температурой воздуха выше 25^0 (продолжительность жаркого периода)	30	Раздражающие	1,0
Число дней с осадками ≥ 5 мм за год	55	Тренирующие	2,0
Ср. месячная температура воздуха летом, ^{0}С	26,0	Раздражающие	1,0
Ср. месячная температура воздуха зимой, ^{0}С	-9,0	Тренирующие	2,0
Ср. месячная скорость ветра летом, м/с	4,5	Тренирующие	2,0
Ср. месячная скорость ветра зимой, м/с	5,0	Раздражающие	1,0
Высота снежного покрова зимой	Менее15	Раздражающие	1,0
Среднее число дней с грозой, дни	19	Тренирующие	2,0
Число дней с туманом	40	Щадящие	3,0
2. Модули режима солнечной радиации:			
Число часов солнечного сияния за год	~2500	Щадящие	3,0
Число часов солнечного сияния за июль	~365	Щадящие	3,0
Число часов солнечного сияния за декабрь	~85	Тренирующие	2,0
Число дней без солнца за год	~50	Тренирующие	2,0
Число дней без Солнца за июнь	~2	Щадящая	3,0
Число дней без Солнца за декабрь	~10	Тренирующие	2,0

Продолжение таблицы 1

1	2	3	4
Уровень опасности ультрафиолетовой радиации, достигаемой земной поверхности в полдень в июле	9-10	Раздражающие	1,0
3. Модули циркуляционного режима:			
Антициклональный тип атмосферной циркуляции, %	Более 50	Тренирующие	2,0
Степень ветровой нагрузки: число дней со скоростью ветра 15 м/с и более	30	Раздражающие	1,0
Число дней с пыльными бурями	20	Раздражающие	1,0
4. Модули режима влажности воздуха:			
Повторяемость значений относительной влажности ниже 30%, дни за год	110	Раздражающие	1,0
Повторяемость значений относительной влажности в полдень выше 80%, дни за год	80	Раздражающие	1,0
Средняя месячная относительная влажность воздуха в 13 часов в июле, %	30	Тренирующие	2,0
Средняя месячная относительная влажность воздуха в 13 часов в январе, %	81	Раздражающие	1,0
Степень формирования духоты: повторяемость погод с явлениями погодной «духоты» летом %	5	Щадящие	3,0
5. Модули ионизации воздуха			
Среднее число легких ионов кислорода отрицательных (N^-), ион/см^3 (по данным осеннего эпизода)	669	Щадящие	3,0
Коэффициент униполярности ионов (КУИ)	0,49	Щадящие	3,0
Комплексная оценка К(БКП) = $\sum K_1+_{......}+K_{33}$ / 33 = 62/33=1,88 балла		Тренирующие	1,88

Проведенный анализ показал, что в целом погодный режим в районе предполагаемого размещения ЛКК Индер оценивается как тренирующий (интегральный показатель биоклиматического потенциала К(БКП) составляет 1,88 балла из 3,0 возможных), что соответствует относительно благоприятным условиям для организации климатотерапии.

К числу позитивных биоклиматических особенностей данной местности следует отнести повышенный уровень природной аэроионизации – 669 ион/см^3 (максимум 1340 ион/см^3) с низким коэффициентом униполярности ионов (0,49), что в значительной степени связано с влиянием соленого озера Индер, на 110 км^2 поверхности которого расположены открытые залежи соли высокого качества. В результате циркуляции атмосферы происходит отрыв и перенос частиц солевого аэрозоля, респирабельная фракция (1-5 мкм) которого достигает глубоких отделов дыхательных путей, оказывая многокомпонентное лечебное действие чрезвычайно малых доз вещества.

Присутствующий в приземной атмосфере в малых дозах солевой аэрозоль стимулирует защитные механизмы дыхательных путей, он обладает саногенным, бронходренирующим, противовоспалительным, иммунокоррегирующим действием. Солевой аэрозоль оказывает ингибирующий эффект на рост и жизнедеятельность микроорганизмов, сопровождающийся процессом потери ими патогенных свойств. Свойственное хлориду натрия естественное противомикробное действие не оказывает отрицательного эффекта на местную защиту и способствует улучшению биоценоза дыхательного тракта.

Присутствующие в приземной атмосфере легкие отрицательные аэроионы в воздушной лечебной среде активизируют метаболизм и местную защиту биологических тканей, благоприятно действуют на сердечно-сосудистую, эндокринную системы, желудочно-кишечный тракт, слизистые оболочки дыхательной системы, вызывают адаптогенное действие на центральные и периферические стресс-лимитирующие системы организма.

Влияние отрицательных аэроионов сказывается на ряде функций отдельных органов (вегетационных – органический, газовый, минеральный, водный обмен, регенерация тканей, деятельность эндокринных желез, ритм дыхания и сердечных биений, состав крови и пр. и анимальных – возбудимость нервной и мышечной тканей), на жизнедеятельности всего организма в целом (рост, половая функция, моторика, рефлексы) и на проявлениях высшей нервной и психической деятельности [4].

Аэроионный режим – величина весьма переменная, зависящая от времени года, часа суток, метеорологических и антропогенных факторов. В экологически чистых курортных зонах средняя концентрация отрицательных ионов составляет в среднем 400-700 ион/см^3. Однако при повышенном аэрозольном загрязнении атмосферы, высокой или очень низкой влажности воздуха уровень отрицательной аэроионизации воздуха резко снижается, иногда до экстремальных значений (ниже 100-200 ион/см^3). При благоприятных биоклиматических условиях и низком уровне аэрозольных примесей в приземной атмосфере уровень отрицательных аэроионов может достигать 1200-2500 ион/см^3 [14].

Маршрутные аэроионизационные и микроклиматические наблюдения на рассматриваемой территории и прилегающей местности проводились на 6-и площадках с различными ландшафтными условиями (таблица 2) – на плато Индерских гор, на котором предполагается расположить ЛКК Индер (пункт наблюдений 1), на берегу озера Индер (п. 2), на вершинах ближайших открытых карьеров добычи боратов (пп. 3 и 5) и на их дне у живописных озер (пп. 4 и 6).

Таблица 2 – Природная ионизация воздуха и микроклиматические характеристики в районе предполагаемого строительства лечебно-курортного комплекса в районе озера Индер

Пункты наблюдений	Уровень ионизации, ион/см^3		КУИ (N^+/N^-), (балл)	t, ^{0}C	f, %	v, м/с
	N^- (балл)	N^+				
1. В районе ист. Туздыбулак, ~-200 м от оз. Индер, плато на СЗ от озера	726 (3)	336	0,46 (3)	15,6	32	1,7-2,2
2. Берег озера Индер, СЗ сектор озера, в районе ист. Толепбулак (~20 м от зеркала озера и ~10 м от скалы), наст иловой грязи	678 (3)	317	0,47 (3)	8,0	54	2,3-6,7
3. У карьера 99/2, территория Индерских гор и отвалов карьеров, ~ 700 м на ССЗ от озера Индер,	652 (3)	386	0,59 (3)	6,9	58	1,5-12,2
4. На дне карьера 99/2, ширина ~ 200 м, длина ~ 400 м, рядом с карьерным озером	640 (3)	355	0,54 (3)	13,0	34	0,8-1,9
5. У карьера 98, территория Индерских гор и отвалов карьеров, ~ 1 км на ССЗ от озера Индер,	661 (3)	322	0,49 (3)	7,3	55	0,8-1,9
6. На дне карьера 98, ширина ~ 200 м, длина ~ 400 м, рядом с карьерным озером	628 (3)	265	0,42 (3)	9,0	59	2,3-4,5
Средние значения	664 (3)	330	0,50 (3)			
Максимальные значения	1340	1090	0,59	15,6	59	12,2
Минимальные значения	120	120	0,42	6,9	34	0,8
Минимально допустимые нормы по [19]	600	400	0,4-1,0			
Интегральный модуль по уровню природной ионизации воздуха [∑(N^-)+∑КУИ] /n	∑(N^-)/n = = 3 балла		∑КУИ/n = = 3 балла	Интегральный модуль [∑(N^-)+∑КУИ] /2 = 3 балла		

Примечание. N^+ и N^- – соответственно концентрация легких положительных и отрицательных аэроионов (ион/см^3); КУИ – коэффициент униполярности ионов (соотношение концентраций положительных и отрицательных ионов); t – температура воздуха (^{0}C); f – относительная влажность воздуха (%); v – скорость ветра (м/с); n – количество серий наблюдений.

По данным маршрутных исследований районе озера Индер концентрации легких отрицательных аэроионов в (N^-) находилась выше уровня физиологической нормы [13], а положительных (N^+) – ниже; КУИ находился в пределах нормы. В территориальном распределении - наибольшие величины (N^-) отмечены на плато 726 ион/м^3 и на берегу оз. Индер (N^- 678 ион/м^3); наименьшие, соответственно, на дне карьеров 98 и 99/2 (N^- 628, 640 ион/м^3). КУИ на всех участках соответствовал низкому аэрозольному загрязнению воздуха (ниже 1,0) – соответственно 0,42-0,59. Интегральный модуль по курортологической шкале достигал максимально возможных значений – 3,0 балла.

Комплексная оценка курортно-рекреационного потенциала территории предполагаемого строительства ЛКК Индер для целей лечебно-оздоровительного использования составляет 2,25 балла из 3-х возможных (рассчитывалась исходя из показателей модульных компонентов: ландшафта - 1,88 балла, биоклимата 1,88 балла, микроклимата - 3,0 балла и экологического состояния 2,25 балла), что соответствует высокому реабилитационному потенциалу и широким курортно-рекреационным возможностям для организации на данной территории специальных форм климатолечения и ландшафтотерапии.

Современный природный ландшафт не выполняет никаких «Социально-экономических функций» и относится к категории «не используемых в настоящее время» [3]. Его особенности отвечают требованиям, предъявляемым при проектировании климатолечебных сооружений (летний и зимний аэросолярии), организации площадок для ландшафтолечения, прокладки маршрутов терренкура (при условии возведения парка с древесно-кустарниковой растительностью, занимающего не менее 40-60% планируемой территории ЛКК Индер).

Приземная атмосфера в районе предполагаемого строительства ЛКК Индер характеризуется повышенным содержанием отрицательных аэроионов (до 1340 ион/см^3), при низком (благоприятном) коэффициенте униполярности ионов (КУИ = 0,42-0,59). Микроклиматические различия на разных по ландшафту площадках территории были незначительными, погодные условия - близкими к климатической норме для этого периода года. Интегральный модуль природной ионизации воздуха составил 3,0 баллов (очень высокий).

Обеспеченность солнечной радиацией оценивается как относительно благоприятная (365 часов в июле; 30 часов в январе). В течение всего года в солнечном спектре присутствует биологически активная ультрафиолетовая солнечная радиация (с длиной волны 290-315 нм). По этим показателям территория ЛКК Индер относится к числу относительно благоприятных для организации круглогодичной (за исключением периодов сильного холода и жары) гелиотерапии (интегральный реабилитационный потенциал солнечной радиации достигает 2,28 балла из 3,0 возможных).

Атмосферная циркуляция, на изменчивость которой особенно реагируют метеочувствительные больные, на данной территории в целом за год оценивается раздражающим режимом воздействия (циркуляционный потенциал – 1,33 балла из 3-х возможных), что указывает на необходимость проведения плановой метеопрофилактики. Возведение парка с древесной растительностью будет способствовать коррекции ветрового режима и улучшению микроклимата на данной территории.

Экологическое состояние в районе предполагаемого строительства ЛКК Индер соответствует особенностям его расположения вдали от крупных промышленных центров. Интегральный показатель загрязнения атмосферы равен 2,25 балла, что оценивается как низкий уровень антропогенного воздействия. Санитарное состояние территории должно постоянно мониторироваться и поддерживаться комплексом соответствующих мероприятий по благоустройству.

Перечисленные выше показатели состояния природных сред соответствуют курортным районам с благоприятным щадящее-тренирующим режимом воздействия климата, ландшафта и экологического состояния на организм человека и свидетельствуют о повышенных потенциальных возможностях для организации различных форм климато-ландшафтотерапии круглогодично: аэротерапии и гелиотерапии как на открытом воздухе, так и в специально оборудованных аэросоляриях; природной аэроионофитотерапии летом; физических тренировок ходьбой, в том числе и «скандинавской», по маршрутам терренкура; ближнего туризма (таблица 3).

Заключение. Комплексное исследование курортно-рекреационного потенциала территории предполагаемого строительства лечебно-курортного комплекса Индер для целей лечебно-оздоровительного использования выявило высокий реабилитационный потенциал (2,25 балла из 3,0 возможных) и широкие курортно-рекреационные возможности для организации на данной территории специальных форм климатолечения. Биоклимат территории создает относительно благоприятный фон для других курортных методов лечения. Выявлены специфические благоприятные биоклиматические особенности данной местности: высокая чистота приземной атмосферы, наличие биологически активной ультрафиолетовой солнечной радиации (с длиной волны 290-315 нм) в течение круглого года, наличие в приземной атмосфере малых доз мелкодисперсного

Таблица 3 – Перспективные виды круглогодичного климатолечения и ландшафтолечения на территории предполагаемого строительства ЛКК Индер

Виды климатолечения и ландшафтолечения	Требования к организации климатолечения и ландшафтолечения
Воздушные ванны в покое и в сочетании с физическими упражнениями, аэрохромотерапией (круглогодично)	Летний и зимний аэросолярии (или специально оборудованные климатопалаты, климатоплощадки) с коррегирующими микроклимат устройствами, медицинский и биоклиматический контроль
Общие или местные солнечные ванны, ванны ослабленной солнечной радиации (в теплый период года)	
Дневной и ночной сон на открытом воздухе (круглогодично)	
Длительный отдых на свежем воздухе в одежде по сезону (круглогодично)	Обустроенные рекреационные площадки (летом в тени деревьев, зимой – на солнечной стороне)
Тренировки дозированной (оздоровительной) ходьбой по маршрутам терренкура (круглогодично)	Обустроенные аллеи терренкура с разбивкой по станциям (через каждые 100 м), оснащенные лавочками и беседками для отдыха. Можно использовать для этих целей бывшие карьеры с террассированными склонами и живописными озерами на дне.
Аэроионофитотерапия (в теплый период года)	Площадки с определенными растительными ассоциациями

соляного аэрозоля, повышенный уровень природной аэроионизации (до 1340 ион/см^3) с низким коэффициентом униполярности ионов (ниже 1,0), характеризующих приземную атмосферу побережья озера Индер как чистую с высокими лечебно-оздоровительными функциями, продолжительный период с благоприятными погодными условиями для пребывания на свежем воздухе (280 дней в году). Биоклиматические условия благоприятны для организации круглогодичной аэро- и гелиотерапии, природной аэроионизации, терренкура и рекреационных мероприятий на открытом воздухе при условии 60% озеленения территории и строительства круглогодичной климатолечебницы.

Организация на побережье озера Индер (Республика Казахстан) лечебно-курортного комплекса соответствует Государственной программе развития здравоохранения Республики Казахстан «Денсаулық» на 2016–2019 годы, целью которой является укрепление здоровья населения для обеспечения устойчивого социально-экономического развития страны [15].

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫ ИНДЕР КӨЛІ ЖАҒАЛАУЫНЫҢ КЛИМАТПЕН ЕМДЕУДІҢ БИОКЛИМАТТЫҚ ЖАҒДАЙЫ

Аннотация. Мақалада Қазақстан Республикасы Индер көлі жағалауының биоклиматтық ерекшеліктеріне жүргізілген ізденістердің нәтижелері келтірілген, осының негізінде аймақтың биоклиматтық потенциалы (3,0 мүмкіндіктен 2,25 балл) бағаланған және жыл бойына климаттық емдеу мекемесін тұрғызып, оның 60% аймағын көгалдандырған жағдайдакурорттық климатпен емдеу мақсатындағы сәйкестік категориясы - өте жоғары. Осы жердің биоклиматтық ерекшелігінің өзіндік қолайлылығы (жербеті атмосферасының тазалығының жоғарлылығы, жыл бойына күн радиацының (толқын ұзындығы 290-315 нм) биологиялық активті ультракүлгін сәулесінің бар екендігі, жербеті атмосферасында ұсақдисперциялық тұз аэрозолдарының дозасыныңаз деңгейде кездесіп, табиғи аэроиондардың деңгейінің жоғарлығы (1340 ион/см^3 дейін) иондардың бір полюстілігі (униполярлығы) коэффициентінің төмен (1,0 төмен), қолайлы жағдайдағы таза ауада болу мерзімінің ұзақтығы (жылына 280 күн)) анықталды.Биоклиматтық жағдайы жыл бойына аэро- және күн тераппиясын, табиғи аэроиондық терренкур және ашық ауада рекрациялық іс-шаралар ұйымдастыруға қолайлы.

Тірек сөздер: Қазақстан республикасы Индер көлі жағалауының биоклиматтық потенциалы, табиғи аэроиондау, курорттыққлиматпен емдеуді ұйымдастырудың болашағы.

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ASSESSMENT OF THE SUSTAINABILITY OF LANDSCAPES OF THE NORTH-KAZAKHSTAN REGION TO AGRICULTURAL IMPACT

Abstract. The article deals with the research of sustainability of landscapes of North Kazakhstan region under conditions of long-term agrogenic load. In this connection and basing on the developed system of indicators there was carried out the assessment of geosystems' conditions and levels of their sustainability to the influence of human agricultural activities. The assessment was made according to thirteen indicators characterizing forming factors, landscapes functional conditions and properties of their main components. Assessment methods were based on the use of different specified rates that were transferred to a relative value (points) and were ranked according to variability (sustainability) of each landscape under direct or indirect agricultural exposure. Besides, this work performs spatial analysis and typology of the regional landscapes according to the index of potential resistance to agricultural influence. It was defined that the most resistant to agricultural human activities landscapes of Northern and central parts of the region are located within forest-steppe natural zone. Low potential resistance is typical of the landscapes located in the South-East of the region within dry steppe subzone and in the landscapes of the river Yesil valley. The level of steppe zone landscapes resistance to agricultural impact is defined as relatively stable. This work provides recommendations on restoration of ecological balance and establishing of stable functioning of the landscapes.

Keywords: landscape, geosystem, sustainability, agriculture, assessment, impact.

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ОЦЕНКА УСТОЙЧИВОСТИ ЛАНДШАФТОВ СЕВЕРО-КАЗАХСТАНСКОЙ ОБЛАСТИ К СЕЛЬСКОХОЗЯЙСТВЕННОМУ ВОЗДЕЙСТВИЮ

Аннотация. Статья посвящена исследованию устойчивости ландшафтов Северо-Казахстанской области в условиях многолетней агрогенной нагрузки. На основе разработанной системы показателей проведена оценка состояния геосистем и уровня их устойчивости к воздействию сельскохозяйственной деятельности человека. Оценка проводилась по тринадцати показателям, характеризующим факторы формирования, условия функционирования ландшафтов, свойства их основных компонентов. Методика оценки базировалась на использовании различных расчетных показателей, которые переводились в относительную величину (баллы), ранжировались с учетом изменчивости (устойчивости) каждого из них под прямым или косвенным сельскохозяйственным воздействием. Выполнен пространственный анализ и осуществлена типология ландшафтов региона по показателю потенциальной устойчивости к сельскохозяйственному воздействию. Выявлено, что наиболее устойчивы к воздействию сельскохозяйственной деятельности человека ландшафты северной и центральной части территории региона, располагающиеся в пределах лесостепной природной зоны. Невысокой потенциальной устойчивостью характеризуются ландшафты, располагающиеся на юго-востоке области в пределах сухостепной подзоны, и ландшафты долины р. Есиль. Уровень устойчивости к сельскохозяйственному воздействию ландшафтов степной зоны определен как относительно устойчивый. В работе предложены рекомендации по восстановлению экологического равновесия и формирования устойчивого функционирования геосистем, испытывающих антропогенное воздействие агрогенного характера.

Ключевые слова: ландшафт, геосистема, устойчивость, сельское хозяйство, оценка, влияние.

Введение. Северо-Казахстанская область (СКО) является одним из ведущих аграрных регионов Республики Казахстан. На долю агропромышленного комплекса приходится более 40% регионального валового продукта. Почти четверть посевных площадей республики располагается в пределах СКО. Ежегодно здесь производится 25-28% республиканского валового сбора высококачественного зерна. В структуре земельного фонда региона доля земель сельскохозяйственного назначения составляет 71%, или 6988,0 тыс. га, из них пашня – 4320,4 тыс. га (на 2017 г.). Показатель распаханности в среднем по области составляет 50%, достигая в ряде административных районов 70% [1-3].

Многолетняя сельскохозяйственная нагрузка на ландшафты региона негативно отразилась на их состоянии. В области наблюдается дегумификация и сокращение плодородия почвенного покрова, расширение площадей, охваченных процессами ветровой и водной эрозией, деградация сельскохозяйственных угодий, снижение их экологической устойчивости [4, 5].

Одной из причин сложившейся экологической ситуации является неустойчивое функционирование ландшафтов в результате нарушения баланса между их природным потенциалом и характером сельскохозяйственного производства. Отсутствие учета свойств и особенностей геосистем с одной стороны и допустимой сельскохозяйственной нагрузки на их компоненты с другой может привести к ее дальнейшему обострению, что, негативно отразиться на экономическом развитии региона и продовольственной безопасности. В условиях интенсивного сельскохозяйственного освоения важной задачей является сохранение устойчивости геосистем на основе комплексного изучения их состояния и свойств, особенностей ландшафтной структуры региона. В связи с этим актуальность предпринятых исследований является очевидным.

Цель исследования заключается в оценке устойчивости ландшафтов СКО к сельскохозяйственному воздействию и определении характера этого воздействия.

Материалы и методы исследования. Под сельскохозяйственным воздействием понимается влияние сельскохозяйственной деятельности людей, вызывающее изменения свойств компонентов ландшафта или ландшафта в целом, которые могут привести к нарушению выполнения ландшафтом заданных ему экологических или социально-экономических функций [6]. Соответственно устойчивость ландшафта к сельскохозяйственному воздействию определяется способностью выдерживать изменения, создаваемые сельскохозяйственной деятельностью человека, а также восстанавливаться после этих воздействий, сохраняя свои основные свойства и функции.

В настоящее время пока отсутствует общепринятый подход к оценке устойчивости ландшафтов к сельскохозяйственному воздействию. Остается неразработанным и вопрос, связанный с определением единых критериев проведения оценки. Затрудняет осуществление исследований в данном направлении сложность самого сельскохозяйственного производства, большое количество и разнообразие действующих на ландшафты сельскохозяйственных воздействий. Кроме того сложность анализа и оценки вызывает природная специфика ландшафтов, которая обусловлена тем, что ландшафты отличаются различными природными условиями и, следовательно, разной устойчивостью к внешним воздействиям. Составляющие компоненты ландшафта в свою очередь характеризуются разной реакцией на те или иные воздействия, что является следствием их различий в устойчивости к этим нагрузкам. Кроме того при выполнении анализа и оценки устойчивости ландшафтов к сельскохозяйственному воздействию следует учитывать уровень их ландшафтной организации. Известно, чем выше этот уровень, тем более устойчива геосистема к воздействию хозяйственной деятельности человека [7-11].

По сравнению с другими видами антропогенно-модифицированных геосистем, ландшафты, формирующиеся в результате сельскохозяйственной деятельности человека, по своим функциональным и структурным свойствам наиболее близки к природным. Поэтому в большинстве исследований, связанных с определением устойчивости агроландшафтов, используются подходы и методы, применяемые в оценке состояния и устойчивости естественных ландшафтов и экосистем. Особого внимания заслуживает ряд методик, основанных на изучении основных свойств ландшафтов и их компонентов, которые могут служить индикаторами их устойчивости к различным внешним воздействиям, в том числе сельскохозяйственным нагрузкам [12-25].

Теоретико-методологической основой исследования послужили работы отечественных ученых в области ландшафтоведения, агроладшафтоведения, геоэкологии: Н.А. Солнцева, Л.Г. Раменского, Л.С. Берга, А.Г. Исаченко, Г.Н. Высоцкого, М.А. Глазовской, В.А. Ковда, Б.Б. Полынова, Ф.И. Милькова, К.В. Зворыкина, В.Н. Николаева, В.И. Кирюшина, Б.И. Кочурова, В.С. Преображенского, И.В. Орловой, В.И. Булатова, Ж.У. Мамутова, А. И. Иорганского, М.Б. Есимбекова и др., а также зарубежные исследования вопросов сельского хозяйства и ландшафта, агроэкологии: M. Arshad, S. Navrud, J. Iverson Nassauer, D. Chelaru и др.

В качестве исходной информационной базы исследования привлечены литературные источники, отраслевые и тематические карты, опубликованные и фондовые материалы отраслевых государственных организаций и учреждений (Департамент земельного кадастра и технического обследования недвижимости НАО «Государственная корпорация «Правительство для граждан» по СКО, РГУ «Республиканский научно-методический центр агрохимической службы» МСХ РК, КГУ «Управление сельского хозяйства СКО», Департамент статистики СКО и др.) за период 2010-2016 гг., а также материалы летних полевых работ 2017 г.

Исследования проводились с использованием комплекса ландшафтно-географических методов, сравнительно-географического, картографического, математического, статистического, экстраполяции, системного и сопряженного анализа и др.

Проведение оценки включало несколько этапов: определение методики, показателей (критериев) и параметров оценки, составление оценочной шкалы, сбор и статистическая обработка необходимых данных, в том числе материалов полевых исследований, проведение оценки согласно оценочной шкале, определение категории устойчивости, анализ полученных результатов. Завершающий этап исследований включал разработку рекомендаций для решения проблем сельскохозяйственного природопользования, восстановлению экологического равновесия и формированию устойчивого функционирования ландшафтов.

Полевые исследования осуществлялись на типичных для региона ключевых участках лесостепной и степной природных зон. Всего было определено 15 ключевых участков, размещение которых осуществлялось с учетом ряда факторов: ландшафтно-морфологических особенностей, структуры почвенного покрова, агроклиматического и природно-земледельческого районирование, характера сельскохозяйственного использования территории региона. Изучение основных компонентов ландшафтов (рельефа, климата, почв, растительного покрова) осуществлялось по стандартным методикам. В ходе полевых работ проведено комплексное ландшафтное описание ключей, заложены почвенные шурфы, отобраны образцы почв. Химико-аналитические исследования почвенных образцов проводились в сертифицированных лабораториях Филиала РГП на ПХВ «Национальный центр экспертизы» Комитета общественного здоровья Министерства здравоохранения РК по СКО в соответствии с утвержденными методиками.

В процессе работы нами были проанализированы различные подходы и критерии оценки устойчивости ландшафтов, испытывающих воздействие сельскохозяйственной деятельности человека: коэффициент уровня естественности, эколого-хозяйственный баланс, включающий определение коэффициента относительной, абсолютной напряженности и естественной защищенности территории, коэффициент экологической стабильности (стабилизации), степень фактической эродированности территории и потенциальной опасности проявления эрозионных процессов, индекс разнообразия Симпсона, индекс экологической сбалансированности, соотношение угодий, почвенное плодородие и т.д.

Для проведения оценки устойчивости ландшафтов СКО к сельскохозяйственному воздействию нами использовался подход, предложенный И.В. Орловой, модифицированный применительно к исследуемому региону. Суть данного подхода заключается в том, что, с точки зрения сельскохозяйственного воздействия на геосистемы, составляющие их компоненты отличаются разной реакцией и устойчивостью. Поэтому компоненты должны оцениваться отдельно по балльной системе с последующим суммированием, что позволяет учитывать каждый из них и группировать ландшафты по степени их общей устойчивости [9].

Ниже приведены показатели, принятые в качестве оценочных параметров устойчивости геосистем СКО к сельскохозяйственному воздействию (таблица).

Шкала оценки устойчивости ландшафтов Северо-Казахстанской области к сельскохозяйственному воздействию

№ п/п	Показатели оценки	1 балл	2 балла	3 балла	4 балла	5 баллов
1	Гидротермический коэффициент ГТК/КУ	≤0,40 ≤0,20	0,41-0,60 0,21-0,40	0,61-0,80 0,41-0,60	0,81-1,0 0,61-0,80	≥1,1 ≥0,81
2	Ветровой режим, количество дней с сильными ветрами	более 51	–	21-50	–	менее 20
3	Характер рельефа	холмистый	холмисто-увалистый	полого-холмистый	ровный и слабоволнистый	плоский
4	Крутизна склона, градусы	≥20,1	5,1-20,0	3,1-5,0	1,1-3,0	0-1,0
5	Степень естественной дренированности	бессточная	0,2-1,0 слабо дренированная	1,1-3,0 средняя	3,1-10,0 хорошая	≥10,1 очень хорошая
6	Геохимическое положение	аккумулятивное	трансаккумулятивное	транзитное	трансэллювиальное	элювиальное
7	Механический состав почв	песок	супесь	легкий суглинок	средний суглинок	тяжелый суглинок, глина
8	Тип водного режима	десуктивно-выпотной	выпотной	непромывной	периодически промывной	промывной
9	Степень гидроморфности почв	гидроморфные	–	полугидроморфные	–	автоморфные
10	Мощность гумусового горизонта, см	≤10,0	10,1-30,0	30,1-50,0	50,1-80,0	≥80,1
11	Содержание гумуса в слое 0-20 см, %	≤2,0	2,1-4,0	4,1-6,0	6,1-9,0	≥9,1
12	Кислотность почвенного раствора, pH	сильнокислая (≤4,5) или сильнощелочная (≥8,6)	кислая (4,6-5,0) или щелочная (7,6-8,5)	слабокислая (5,1-5,5) или слабощелочная (7,0-7,5)	близкая к нейтральной (5,6-6,0)	нейтральная 6,1-7,0
13	Емкость катионного поглощения (обмена), мг/экв на 100 г почвы	<10	10-20	21-30	31-40	>40

Статистические расчеты и обработка полученных в ходе исследования данных и материалов полевых работ проводились с использованием программного пакета Microsoft Office, Statistica 6.0, MapInfo Professional 11, ArcGIS 10.1.

Оценка выполнялась по каждому показателю отдельно на основе соотнесения полученных фактических данных с предложенной в таблице градацией. Баллы по каждому анализируемому показателю суммировались. Максимально возможный балл, характеризующий наибольшую устойчивость ландшафта к сельскохозяйственному воздействию, принимался за 100%. Полученные суммы баллов пересчитывались относительно максимального показателя по формуле [14]:

$$C = \frac{100\sum_{g=1}^{n} Cg}{Q},$$

где C – оценка устойчивости ландшафта к сельскохозяйственному воздействию, в %; Cg – балл по каждому показателю; Q – максимально возможная сумма баллов; g – порядковый номер показателя; n – количество показателей (признаков).

Результаты расчетов соотносились с градацией, согласно которой выделяются пять уровней устойчивости ландшафтов к сельскохозяйственному воздействию: устойчивые (81–100%), относительно устойчивые (61–80%), малоустойчивые (41–60%), неустойчивые (21-40%), весьма неустойчивые (менее 20%) [9].

Результаты и их обсуждения. Пространственный анализ полученных данных позволил выявить, что в пределах исследуемого региона наиболее устойчивыми к сельскохозяйственному воздействию являются ландшафты лесостепной (типичной и южной колочной) природной зоны (показатель оценки устойчивости 76-81%). Это обусловлено тем, что здесь стабилизации ландшафтов способствует достаточно высокий показатель лесистости относительно других территорий области. Лесные участки, заросли древесно-кустарниковой растительности создают экологический каркас, который способствует поддержанию экологической устойчивости ландшафтов. Лесостепная зона характеризуется меньшей распаханностью, большей долей средостабилизирующих компонентов ландшафта. В пределах зоны отмечается лучшая дренированность, благоприятные гидрохимические условия и ветровой режим. Почвы характеризуются относительно высоким содержанием гумуса (4,1-4,4%) и мощностью.

Менее устойчивы к воздействию сельскохозяйственной деятельности человека ландшафты, относящиеся к долине р. Есиль (55-60%), и ландшафты сухостепной подзоны (53-60%).

Ландшафты в пределах долины р. Есиль, характеризуются менее благоприятным геохимическим положением и типом водного режима, отличаются гидроморфностью почв. По мощности гумусового горизонта они уступают плакорным территориям и характеризуются низким содержанием гумуса (2,3%), слабой сформированностью. Особенности устройства долины определили специфику ландшафтной структуры и характер устойчивости ее ландшафтов к воздействиям внешних факторов. Наличие уклонов, расчлененность руслами временных водотоков, заметная крутизна склонов, особенно в правобережной части долины, снижают потенциальную устойчивость ее ландшафтов к внешним воздействиям, в том числе сельскохозяйственным.

Сухостепная подзона отличается достаточно высоким уровнем сельскохозяйственной освоенности, что негативно отражается на устойчивости ее ландшафтов. В структуре земель леса и древесно-кустарниковая растительность составляют незначительную долю. Подзона характеризуется недостаточно благоприятными гидротермическими условия. Почвы, несмотря на достаточно высокий уровень естественного плодородия (2,8-3,7%), характеризуются менее благоприятными водно-физическими свойствами. Кроме того в этой подзоне получили широкое распространение солонцово-солончаковые почвенные комплексы, отличающиеся неблагоприятными физико-химическими свойствами. Здесь сохраняется высокая вероятность развития процессов деградации почв, связанная с характером ветрового режима, частой повторяемостью дней с сильными ветрами. В условиях сельскохозяйственного природопользования это определяет меньшую устойчивость ландшафтов к воздействиям.

Степная зона в пределах области представлена двумя подзонами: северной умеренно-засушливой и южной засушливой. Ландшафты данной зоны, несмотря на многолетнее активное сельскохозяйственное освоение, благодаря высокому природному потенциалу в соответствии с градацией характеризуются относительной устойчивостью к сельскохозяйственному воздействию (68-75%). В условиях интенсивного сельскохозяйственного природопользования устойчивость ландшафтов обеспечивается резервам естественного плодородия почв, их хорошими водно-физическими свойствами. Содержание гумуса в почвах составляет 4,0-4,7%. Кроме того ровный слаборасчлененный рельеф с незначительными уклонами, однородная морфологическая структура ландшафтов, элювиальное геохимическое положение способствует поддержанию их устойчивости.

Ландшафты, малоустойчивые и неустойчивые к воздействию сельскохозяйственной деятельности человека, требуют особого внимания при организации и проведении сельскохозяйственных работ на всех этапах сельскохозяйственного производства. Использование таких ландшафтов в сельскохозяйственных целях должно осуществляться при соблюдении допустимого уровня агрогенной нагрузки на них в режиме сохранения их ресурсов и потенциала, а также ввода различных ограничений сельскохозяйственного природопользования.

Относительно устойчивые к сельскохозяйственному воздействию ландшафты способны выдержать современную сельскохозяйственную нагрузку и обеспечить дальнейшее развитие сельскохозяйственного производства, но при соблюдении экологического баланса между их предельными возможностями и оказываемой нагрузкой на них, а также осуществления мероприятий по поддержанию природно-экологического потенциала. Сельскохозяйственная деятельность здесь сопряжена с меньшим риском нарушения природного равновесия.

Выводы. В результате проведенной оценки устойчивости ландшафтов Северо-Казахстанской области к сельскохозяйственному воздействию выявлена следующая закономерность: наиболее устойчивы ландшафты северной и центральной частей региона. По мере продвижения на юг устойчивость ландшафтов к сельскохозяйственному воздействию понижается. Невысокой потенциальной устойчивостью характеризуются ландшафты, располагающиеся на юго-востоке области в пределах сухостепной подзоны, и ландшафты долины р. Есиль.

Разный уровень устойчивости ландшафтов к воздействию на них сельскохозяйственной деятельности человека требует осуществления функционального зонирования территории региона на районы с различными режимами сельскохозяйственного природопользования.

Для поддержания устойчивости ландшафтов к сельскохозяйственным воздействиям необходима разработка программы рационального и сбалансированного сельскохозяйственного природопользования на ландшафтной основе, осуществление экологизации всех процессов сельскохозяйственного производства.

Полученные в ходе исследования результаты могут послужить областным и местным органам управления в качестве информационной основы для планирования и реализации программ и проектов сельскохозяйственного природопользования.

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СОЛТҮСТІК ҚАЗАҚТАН ОБЛЫСЫ ЛАНДШАФТТАРЫНЫҢ АУЫЛШАРУАШЫЛЫҚ ӘСЕРІНЕ ТҰРАҚТЫЛЫҒЫН БАҒАЛАУ

Аннотация. Мақала көп жылдық агрогендік жүктеменің жағдайында Солтүстік Қазақстан облысы ландшафттарының тұрақтылығын зерттеуге арналған. Көрсеткіштердің әзірленген жүйесінің негізінде геожүйелердің жағдайы бойынша және адамның ауыл шаруашылық әрекеттерінің оларға әсер етулеріне тұрақтылықтарының деңгейіне баға берілген. Бағалау қалыптастыру факторлардың сипаттамасында, ландшафтардың жұмыс істеу шарттарында, олардың негізгі компоненттерінің қасиеттерін сипаттайтын он үш көрсеткіш бойынша жүргізілді. Бағалау әдісі ауыл шаруашылық әсерінің тікелей немесе жанама әсерінің әрқайсысының өзгермелілігін (тұрақтылығын) ескере отырып, салыстырмалы мәндерге (балл) аударылған әртүрлі есептік көрсеткіштерді пайдалануға негізделген. Ауыл шаруашылық әсерлерге тұрақтылықтың нақты көрсеткіштері бойынша аймақтың ландшафттарын типке келтіру жүзеге асырылған және кең шеңберде сараптама жасалған. Облыс аумағының солтүстік және орталық бөлігінің орманды-дала табиғи аймағында орналасқан ландшафтары адамның ауылшаруашылық қызметінің әсеріне төзімді болып табылады. Төмен әлеуетті тұрақтылық құрғақ дала подзонаның оңтүстік-шығыс аймағында орналасқан ландшафттар және Есіл өзен аңғарының ландшафттар сипатталады. Дала аймағының ландшафттарының ауыл шаруашылық әсеріне төзімділік деңгейі салыстырмалы түрде тұрақты деп белгіленген. Баяндамада экологиялық тепе-теңдікті қалпына келтіру және агрогендік табиғаттың антропогендік әсерін тигізетін геосистемалардың тұрақты жұмыс істеуін қалыптастыру бойынша ұсыныстар ұсынылған.

Түйін сөздер: ландшафт, геожүйе, тұрақтылық, ауыл шаруашылық, баға, әсер.

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THE ANALYSIS OF MODERN TECHNOLOGY AND TECHNIQUE APPLIED IN THE COMPLETION OF GEOTECHNOLOGICAL WELLS AND REMEDIAL WORKS IN THEM

Abstract. The issues related to the current state of conducting remedial works to recover geotechnological wells that are operated to mine uranium ores by the technique of underground borehole leaching are considered in the article. The essence of this method is that a chemical reagent that dissolves the ore into the liquid phase is pumped through one well (pumping/injection), and through other wells (production) the solution is lifted to the surface. The production wells tend to lose their initial productivity with the operation, and the injected ones - the injectivity due to colmatation of the working zone in well screen. The causes and types of colmatationare discussed and the analysis of existing equipment and technology for remedial works has been made. On the basis of this analysis, the promising areas for improving technology and techniques for remedial works in geotechnological wells have been identified.

Key words: well, flow rate, recovery, remedial works, well screen, colmatation, well injectivity.

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АНАЛИЗ СОВРЕМЕННОЙ ТЕХНОЛОГИИ, ТЕХНИКИ ОСВОЕНИЯ И ПРОВЕДЕНИЯ РЕМОНТНО-ВОССТАНОВИТЕЛЬНЫХ РАБОТ В ГЕОТЕХНОЛОГИЧЕСКИХ СКВАЖИНАХ

Аннотация. В статье рассматриваются вопросы современного состояния проведения ремонтно-восстановительных работ с целью реанимации геотехнологических скважин, которые эксплуатируются с целью добычи урановых руд методом подземного скважинного выщелачивания. Сущность данного способа заключается в том, что через одни скважины (закачные) закачивается в пласт химический реагент, растворяющий руду в жидкую фазу, а через другие скважины (откачные) откачивают раствор на поверхность. В процессе эксплуатации со временемоткачные скважины теряют первоначальную производительность, а закачные – приемистость за счет кольматации рабочей части фильтровой колонны. Рассмотрены причины и виды кольматации, а также проведен анализ существующей техники и технологии проведения ремонтно-восстановительных работ. На основе этого анализа определены перспективные направления совершенствования технологии и техники проведения ремонтно-восстановительных работ геотехнологических скважин.

Ключевые слова: скважина, дебит, восстановление, ремонтно-восстановительные работы, фильтровая колонна, кольматация, приемистость.

Введение. В настоящее время экономика республики Казахстан в основном зависит от добычи и экспорта углеводородного сырья, но по данным многих исследований мировые запасы этого вида сырья ограничены и их количество достаточно только на ближайшие 40-50 лет.

Но с другой стороны многие страны, такие как Франция, Япония, США, Канада и др. перешли на альтернативный источник энергии – использование атомной энергии. Так например, во Франции и Японии 80 % электроэнергии получают от атомных электростанций.

В то же время Казахстан очень богат рудами для атомной промышленности, но на сегодняшний день внутри страны они не используются и добыча этого сырья осуществляется в основном с целью его экспорта. Потребление сырья в атомной промышленности в будущем в республике Казахстан не вызывает сомнений, как альтернатива углеводородному сырью.

В казахстанских недрах сосредоточено 25% мировых запасов урана, причем около 70% из них пригодны для добычи методом подземного скважинного выщелачивания. Программой развития атомной промышленности, утвержденной Правительством РК намечено резкое увеличение добычи урана в Казахстане. Решение этой задачи возможно с внедрением передовой технологии и техники разведки и добычи, с заменой и совершенствованием существующего парка оборудования, инструмента, подготовки высококвалифицированных специалистов.

В настоящее время одним из широко распространенных способов разработки урановых месторождений являются геотехнологические методы с использованием буровых скважин, сущность которых заключается в подземном выщелачивании урановых руд, т.е. полезный компонент (урановая руда) переводится в жидкую фазу путем его растворения химическими реагентами и затем подъему насыщенного металлом раствора на поверхность. С этой целью через скважины, пробуренные с поверхности, в пласт полезного ископаемого нагнетается химический реагент, способный переводить минералы полезного ископаемого в растворимую фазу и затем через другие скважины осуществляется подъем на поверхность [10, 11].

Данный способ добычи урановых полезных ископаемых имеет один из больших достоинств, заключающийся в том, что он обеспечивает добычу без непосредственного контакта человека с рудой.

Однако, при эксплуатации геотехнологических скважин со временем откачные скважины теряют проектную производительность, а закачные скважины – приемистость. Эти скважины через определенный промежуток подвергаются проведению ремонтно-восстановительных работ. Таких скважин, которые требуют чистки, на урановых месторождениях Южного Казахстана тысячи.

Применяемая технология и техника не всегда обеспечивают качественную чистку и занимают значительное время.Проведение ремонтно-восстановительных работ с целью восстановления проектного дебита и приемистости скважин с наименьшими материальными затратами и времени является очень актуальным.

Прежде чем рассматривать современную технологию декольматации фильтров рассмотрим причины и виды кольматации.

Кольматация фильтров вызывает увеличение гидравлических сопротивлений при пропуске жидкости в скважину и, как следствие, снижает производительность скважины.

Различают три вида кольматации: механическую, химическую и билологическую [6].

Механическая кольматация наблюдается в сетчатых, щелевых, блочных фильтрах вследствие несоответствия проходных отверстий фильтрующих поврехностей гранулометрическому составу водоносного пласта. В результате такой кольматации водоприемные отверстия фильтров заклиниваются или перекрываются песком, глиной, в связи с чем удельный дебит снижается на 20-30%.

К механической кольматации следует также отнести глинизацию фильтра при вращательном бурении с промывкой глинистым раствором. С течением времени глинистая корка на фильтре уплотняется за счет усиления адсорбционных и молекулярных связей между глинистыми частицами, и ее удаление представляет значительную сложность.

При установке фильтра необходимо стремиться к уменьшению его глинизации. Для этого следует опускать фильтр с нижним открытым концом или с промывочными окнами, устанавливать выше фильтра цементный мост, разбуриваемый после утановки фильтра, покрывать фильтр специальными составами, растворяемыми после его установки в скважине. Снижению механической кольматации способствует также создание вокруг фильтра правильно выполненной гравийной обсыпки .

Химическая кольматация обусловлена нарушением химического состава подземных вод в результате изменения гидродинамических параметров фильтрационного потока.

При уменьшении давления воды в ней уменьшается растворимость газов (в основном СО2), происходит их выделение и нарушается углекислотное равновесие, в соответствии со следующей реакцией:

$$2HCO_3^- \rightarrow CO_3^{2-} + CO^2 \uparrow H_2O \quad (1)$$

Присутствие в воде катионов кальция и магния приводит к образованию трудно растворимых осадков CaCO3 и MgCO3. Наиболее интенсивно происходит выделение карбонатных осадков в зоне фильтров. В фильтрах, имеющих большие гидравлические сопротивления, возрастают потери давления, что приводит к более активному выделению из воды СО2 и еще большему увеличению количества карбонатных осадков.

Зарастание фильтров и прифильтровых зон карбонатными отложениями происходит в основном в скважинах, заложенных в известняках и доломитах (1, 10).

Наиболее распростроненными кольматирующими отложениями являются железистые осадки, которые выделяются при заборе подземных вод, содержащих закисное железо. Переход железа из закисного в окисное и выпадение в осадок происходит при наличии в воде растворимого кислорода. Этому также способствует выделение СО2 и повышение рН воды вследствие нарушения углекислотного равновесия:

$$Fe(HCO_3)_3 \rightarrow Fe(OH)_3 + 2CO_2 \quad (2)$$

Гидрат окиси железа, имеющий студнеобразный вид, отлагается на поверхности фильтров и в поровом пространстве прифильтровых зон пласта. Интенсивность выпадения железистых осадков возрастает при неравномерной откачке воды из скважины, использовании эрлифта или эжекторного насоса, способствующих насыщению воды кислородом.

Нарушение химическоого состава подземных вод эксплатируемого пласта может произойти при взаимодействии с водами других водоносных горизонтов при недостаточной мощности разделяющего водоупора или отсутствии цементации затрубного пространства. При смешивании мягких и жестких вод может увеличиться концентрация углекислоты, что вызывает образование карбонатных осадков.

На зарастание фильтров большое влияние оказывает наличие в подземных водах сероводорода H_2S Содержание гидросульфитов HS приводит к образованию труднорастворимых и непроницаемых сернистых отложений железа, меди, цинка в результате реакции подземных вод с материалом каркаса фильтра. Сульфиды металлов в виде корковидных наростов черного цвета образуют прочное пленочное покрытие на сетках, проволочных обмотках, каркасах фильтров и способствует их постепенному разрушению. Следует отметить, что сернистые отложения не откладываются в прифильтровых зонах пласта.

При наличии в железосодержащих подземных водах кремнекислоты наблюдаются образование труднорастворимых силикатных отложений с примесью закисного железа. Предотвратить химическую кольматацию при использовании вод с неустойчивым химическим составом невозможно, так как ее причиной является нарушение естественного режима водоносного пласта.

Для уменьшения интенсивности кольматации следует не допускать неравномерного режима эксплуатации скважин, не использовать водоподъемники, при работе которых происходит поступление аэрированных вод в зону фильтров.

Помимо выпадения осадков накопление отложений может происходить в результате коррозии самого фильтра вследствие агрессивности подземной воды, обладающей свойством электролита.

Электрохимической коррозии в большей степени подвержены сетчатые фильтры, представляющие стальную перфорированную трубу, обмотанную стальной или медной сеткой. Эти процессы значительно ослабляются при изготовлении фильтров из пластмасс, использовании фильтрующей сетки из нержавеющей стали, применение вместо обмоточной проволоки шнуров из полимерных материалов.

Биологическая кольматация обусловлена жизнедеятельностью микроорганизмов. Наиболее активно бактерии размножаются у фильтров, где откладываются осадки, образовавшиеся под действием химических или электрохимических процессов. В результате жизнедеятельности бактерий (железобактерий) выделяется гидрат окиси железа, что способствует переводу закиси железа в нерастворимую окись, осаждающуюся на рабочей поверхности фильтров. Присутствующие в подземных водах марганцевые бактерии используют энергию окисления закисных соединений и переводят из в малорастворимые окисные соединения. Интенсивная биологическая кольматация характерна для подземных вод с содержанием кислорода 5 мг/л и более, находящихся в первых от поверхности земли водоносных горизонтах. Бактерии обнаруживаются также на больших глубинах в зонах, значительно удаленных от водотоков и водоемов.

Благоприятные условия для развития железобактерий имеются в большинстве гидрогелогических районах, поэтому для подавления их жизнедеятельности необходимо периодически проводить хлорирование скважин.

В результате анализа большого числа литературных источников установлено [2], что причинами выхода из строя является (по удельному весу каждого нижеприведенного фактора): кольматаж фильтров – 40,9%; заиливание и пескование скважины 37,77% , износ насосного оборудования – 12,52%; прочие причины – 8,81%. Таким образом, разрабатываемые средства должны быть направлены на периодические декольматации фильтров и борьбу с пескованием и заиливанием скважины (вместе эти причины составили 78%).

Таким образом, в зависимости от вида кольматации существуют различные способы декольматации фильтров и продуктивного горизонта. К ним относятся промывка скважин (поинтервальная, через промывочное окно, с помощью пакеров и гидроершей, гидро- и пневмоимпульсные, электроимпульсные, химические, с использованием взрывчатых веществ и т.п.). Сущность этих способов довольно подробно изложена в различных литературных источниках [1, 3, 9]. Анализ вышеперечисленных способов позволил определить их достоинства и недостатки. К недостаткам следует отнести:

- сложность конструкций технических изделий, что снижает их эксплуатационную надежность;
- габаритные размеры некоторых технических средств не всегда позволяют их спуск в фильтровую колонну из-за малого ее диаметра, которой оборудуются геотехнологические скважины;
- при химическом способе проведения РВР требуется соблюдение определенных мер безопасности при работе с различными видами химикатов, а также дороговизна химических реагентов;
- при электроимпульсном способе очистки поверхностей фильтров к недостаткам относятся дороговизна оборудования, соблюдение мер безопасности при работе с высоким напряжением;
- использование взрывного эффекта с применением взрывчатых веществ в скважинах, оборудованных пластмассовыми фильтрами, чревато их разрушением, необходимость специального разрешения на проведение взрывных работ, а также дороговизна ВВ.

Здесь необходимо отметить, что способы проведения РВР аналогичны со способами освоения на стадии заканчивания скважин.

Наибольший интерес вызывает использование кавитированной жидкости для очистки фильтров и прифильтровой зоны продуктивного пласта.

Кавита́ция [2, 4, 5, 7] (от лат. *cavita* – пустота) – процесс парообразования и последующего схлопывания пузырьков пара с одновременным конденсированием пара в потоке жидкости, сопровождающийся шумом и гидравлическими ударами, образование в жидкости полостей (кавитационных пузырьков, или каверн), заполненных паром самой жидкости. Кавитация возникает в результате местного понижения давления в жидкости, которое может происходить либо при увеличении её скорости(гидродинамическая кавитация), либо при прохождении акустической волны большой интенсивности во время полупериода разрежения (акустическая кавитация), существуют и другие причины возникновения эффекта. Перемещаясь с потоком в область с более высоким давлением или во время полупериода сжатия, кавитационный пузырёк схлопывается, излучая при этом ударную волну. Явление кавитации носит локальный характер и возникает только там, где есть условия. Перемещаться в среде возникновения не может. Кавитация разрушает поверхность гребных винтов, гидротурбин, акустических излучателей, деталей амортизаторов, гидромуфт и др. Кавитация также приносит пользу – её применяют в промышленности, медицине, военной технике и других смежных областях. Однако более поздние исследования показали, что ведущую роль в образовании пузырьков при кавитации играют газы, выделяющиеся внутрь образовывающихся пузырьков. Эти газы всегда содержатся в жидкости, и при местном снижении давления начинают интенсивно выделяться внутрь указанных пузырьков. Поскольку под воздействием переменного местного давления жидкости пузырьки могут резко сжиматься и расширяться, то температура газа внутри пузырьков колеблется в широких пределах, и может достигать нескольких сот градусов по Цельсию. Имеются расчётные данные, что температура внутри пузырьков может достигать 1500 °С. Следует также учитывать, что в растворённых в жидкости газах содержится больше кислорода в процентном отношении, чем в воздухе, и поэтому газы в пузырьках при кавитации химически более агрессивны, чем атмосферный воздух – вызывают в итоге окисление (вступление в реакцию) многих обычно инертных материалов. Кавитация используется при ультразвуковой очистке поверхностей твёрдых тел. Специальные устройства создают кавитацию, используя звуковые волны в жидкости. Кавитационные пузыри, схлопываясь, порождают ударные волны, которые разрушают частицы загрязнений или отделяют их от поверхности. Таким образом, снижается потребность в опасных и вредных для здоровья чистящих веществах во многих промышленных и коммерческих процессах, где требуется очистка как этап производства.

Число кавитации. Кавитационное течение характеризуют безразмерным параметром (числом кавитации) [2]:

$$K = \frac{P_0 - P_н}{\left(\frac{\rho v_0^2}{2}\right)} \quad (1)$$

где P_0 – гидростатическое давление набегающего потока, Па; $P_н$ – давление насыщенных паров жидкости при определенной температуре окружающей среды, Па; ρ – плотность среды, кг/м³; v_o – скорость потока на входе в систему, м/с.

Число кавитации может принимать различные значения, но кавитация возникает только в диапазоне К = 0,1–0,6. Известно, что кавитация возникает при достижении потоком граничной скорости, когда давление в потоке становится равным давлению парообразования (насыщенных паров). Этой скорости соответствует граничное значение критерия кавитации.

Чаще всего кавитация образуется в зоне, расположенной на напорной магистрали насоса, в случае её сужения. Т.е. давление жидкости после сужения падает (согласно закону Бернулли), так как увеличиваются потери и кинетическая энергия. Давление насыщенных паров становится больше внутреннего давления в жидкости с образованием пузырьков/каверн. После прохождения узкой части (это может быть приоткрытый затвор, местное сужение и т.п.) скорость потока падает,

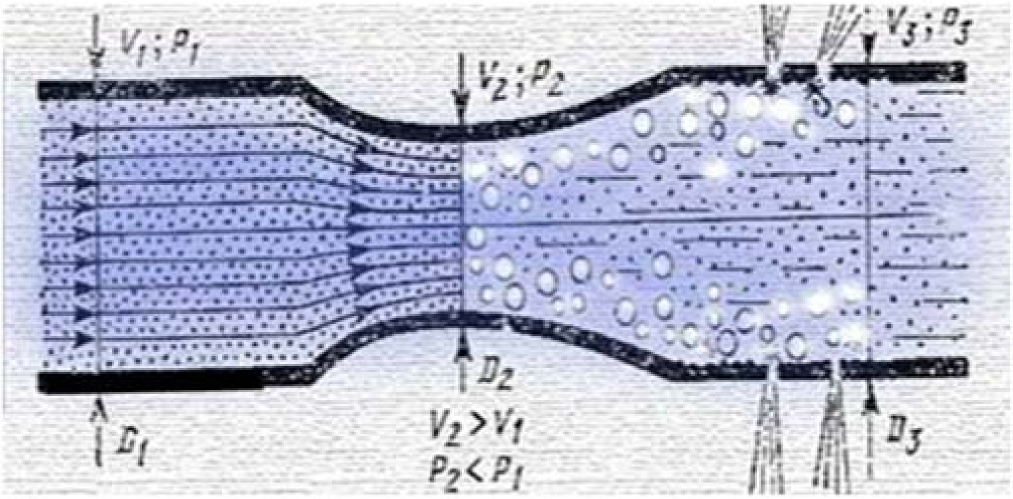
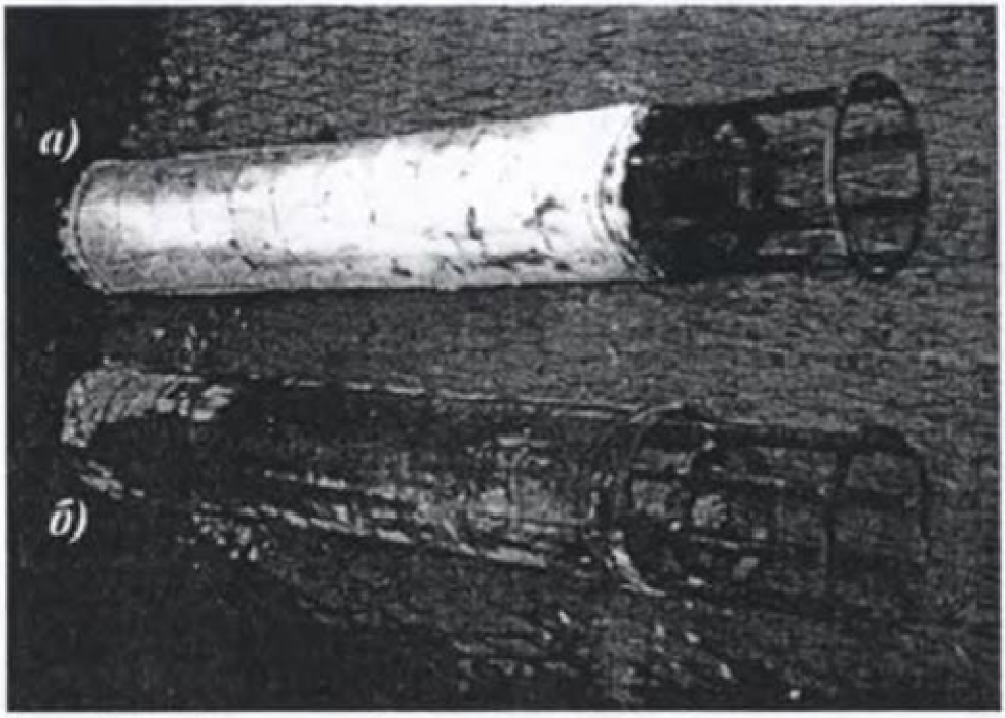


Схема образования кавитированной жидкости давление возрастает и пузырьки газов и паров схлопываются. Причём энергия, высвобождаемая при этом, весьма и весьма велика, в результате чего (особенно если это происходит в пузырьках, находящихся на стенках) происходят микро-гидроудары, влекущие за собой повреждения стенок. При этом, если не принять мер, то процесс дойдёт и до полного разрушения стенок насосной части. Вибрация и повышенный шум в насосе и трубах-первейшие признаки кавитации.

Основные слабые места в гидросистемах – места сужения, резкого изменения скорости потока жидкости (клапаны, краны, задвижки) и рабочие колёса насосов. Более уязвимыми они становятся при увеличении шероховатости поверхности.

Большие исследования по использованию кавитированной жидкости для декольматации фильтров и прифильтровых зон проведены Н. И. Сердюк [2]. Экспериментальные исследования, проведенные автором, заключались в следующем. В скважинах, оборудованных фильтрами, проводилась чистка фильтров обычной некавитированной жидкостью и в другой кавитированной жидкостью. Внешний вид фильтров, полученных после обработки в кавитационном и бескавитацинных режимах, представлен на фотографии (фото).



Внешний вид закольматированных фильтров после их обработки потоком жидкости на различных режимах: а) бескавитационный; б) кавитационный.

Как видно из фото внешний вид фильтра, после его обработки в бескавитационнм режиме, не изменился, толщина глинистой корки осталась прежней. После обработки в кавитационном режиме в течение 15 минут фильтр полностью очистился от глинистой корки. Видимые на фотографии остатки глины, по мнению автора, вызваны загрязнением фильтра во время его извлечения.

Таким образом, использование кавитированной жидкости для очистки фильтров является перспективным направлением.

Выводы. Проведенный анализ методов и средств декольматации фильтров и водоносных пластов даже при их положительных эффектах позволяет сделать следующие выводы:

- сложность конструкций технических изделий, что снижает их эксплуатационную надежность;
- габаритные размеры некоторых технических средств не всегда позволяют их спуск в фильтровую колонну из-за малого ее диаметра, которой оборудуются геотехнологические скважины;
- при химическом способе проведения РВР требуется соблюдение определенных мер безопасности при работе с различными видами химикатов, а также дороговизна химических реагентов;

- при электроимпульсном способе очистки поверхностей фильтров к недостаткам относятся дороговизна оборудования, соблюдение мер безопасности при работе с высоким напряжением;

- использование взрывного эффекта с применением взрывчатых веществ в скважинах, оборудованных пластмассовыми фильтрами, чревато их разрушением, необходимость специального разрешения на проведение взрывных работ, а также дороговизна;

- использование кавитированной жидкости для очистки фильтров является перспективным направлением и требует совершенствования технологии и техники проведения РВР в геотехнологических скважинах.

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ГЕОТЕХНОЛОГИЯЛЫҚ ҰҢҒЫЛАРДА ИГЕРУДІҢ ТЕХНОЛОГИЯСЫН, ТЕХНИКАСЫН ЖӘНЕ ЖӨНДЕУ-ҚАЛПЫНА КЕЛТІРУ ЖҰМЫСТАРЫН ЖҮРГІЗУДІ ЗАМАНАУИ ЗЕРТТЕУ

Аннотация. Мақалада уранрудаларын жер асты ұңғылық шәю әдісімен өндіретін геотехнологиялық ұңғыларды реанимациялау мақсатында жөндеу-қалпына келтіру жұмыстарын жүргізудің қазіргі жағдайының сұрақтары қарастырылған. Бұл әдістің мәні бір ұңғылардан (айдау) қабатқа руданы сұйылтатын химиялық реагент айдалады, ал басқа ұңғылардан (сору) ерітіндіні жер бетіне айдап шығарады. Пайдалану кезінде уақыт өте келе сору ұңғылары бастапқы өнімділігін жоғалтады, ал айдау ұңғылары сүзгілеу тізбегінің жұмыстық бөлігінің кольматациясы есебінен қабылдау қабілетін жоғалтады. Кольматация себептері және түрлері қарастырылды, сондай-ақ жөндеу-қалпына келтіру жұмыстарының қазіргі уақыттағы техникасы мен технологиясы сарапталды. Осы сараптаудың негізінде геотехнологиялық ұңғыларды жөндеу-қалпына келтіру жұмыстарының технологиясы мен техникасын жетілдірудің тиімді бағыттары анықталды.

Түйін сөздер: ұңғы, дебит, қалпына келтіру жұмыстары, сүзгілеу тізбегі, кольматация, қабылдау.

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GEODYNAMIC MODEL AND OIL AND GAS POTENTIAL OF THE NORTH-TORGAI BASIN

Abstract. In the course of history different groups of scientists have studied the tectonic structure and evolution and consistency of mineral deposits location on the exposed territory of the Kazakhstan and along the Eastern slope of the Urals. As a consequence, the Torgai depression, which divides the East and West Kazakhstan structures was admitted to be poorly investigated, therefore, this region remains a blank spot on the geodynamic reconstruction schemes over the Kazakhstan.

A geodynamic division into districts of the territory from the Urals in the West to the Kokshetau and Ulytau upheavals in the East was carried out in the article based on the analysis of the latest geological and geophysical materials. The East-Urals anticlinorium, the Denisov's shear zone, the Valeriyanov's synclinorium, the North-Torgai depression and the Kokshetau-Ulytau upheavals zone are emphasized.

The description of each tectonic zone is provided from the plate tectonics standpoint. The structure of the North-Torgai sedimentary Basin is described in more details and, taking into account its geodynamic evolution in the Devonian and Carbonic periods, the oil and gas potential of its central part as to the Devonian and Lower Carbonic sediments is highly appreciated.

Key words: a sedimentary Basin, a volcanic arc, an allochthon, oil and gas potential, a geodynamic model.

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ГЕОДИНАМИЧЕСКАЯ МОДЕЛЬ И ПЕРСПЕКТИВЫ НЕФТЕГАЗОНОСНОСТИ СЕВЕРО-ТОРГАЙСКОГО БАССЕЙНА

Аннотация. Исторически сложилось так, что изучением тектонического строения и эволюции и закономерностей размещения полезных ископаемых на обнаженной части Казахстана и по восточному склону Уральских гор занимались разные группы ученных. Вследствие этого признавали, что Торгайский прогиб, разделяющий структуры Восточного и Западного Казахстана, изучен слабо, поэтому на схемах геодинамических реконструкций по Казахстану этот регион остается белым пятном.

По результатам анализа новых геологических и геофизических материалов в статье произведено геодинамическое районирование территории от Уральских гор на западе до Кокшетауского и Улытауского поднятии на востоке. Выделены Восточно-Уральский антиклинорий, Денисовская зона смятия, Валерьяновский синклинорий, Северо-Торгайский прогиб и Кокшетауско-Улытауская зона поднятий.

Даны характеристики каждой тектонической зоны с позиции тектоники плит. Более подробно описано строение Северо-Торгайского осадочного бассейна и с учетом геодинамической его эволюции в девоне и карбоне дана высокая оценка перспектив нефтегазоносности центральной его части по девонским и нижнекарбоновым отложениям.

Ключевые слова: осадочный бассейн, вулканическая дуга, аллахтон, нефтегазоносность, геодинамическая модель.

Северный Торгайславится своими магнетитовыми месторождениями как Качарское, Соколово-Сарбайское, месторождениями оолитовых железных руд Лисаковской группы, полиметаллическим месторождением Шаймерден, также крупными по запасам бокситоносными зонами Денисовско-Федоровской и Валерьяновской. Все эти месторождения находятся в зоне сочленения Уральской складчатой системы с Северо-Торгайским прогибом, в геодинамическом режиме все они формировались в зоне сочленения западной окраины Казахстанской плиты с восточней ветвью Уральского палеозойского океана и Восточно-Уральской микроплитой.

Восточнее этих известных рудных месторождении большая часть территории покрыта значительной мощности мезокайнозойским чехлом, который в литературе обозначен собственно Северо-Торгайским прогибом. На востоке он граничит с Кокшетауским и Улытауским поднятиями и на севере переходит в Западно-Сибиркуюсинеклизу, богатую запасами газа и нефти.

Исторически со времен Н.Г.Кассина и Р.А.Борукаева в геологической литературе сложилось понятие о «Геологии Восточного Казахстана», при этом под понятием «Восточный Казахстан» подразумевалась территория начиная на западе от Кокшетау-Улытауской зоны вся площадь Казахстана, вся территория обнажений палеозойских и более древних отложений, поскольку именно обнаженные участки были предметом изучения на поиски твердых полезных ископаемых. Тектонике и палеогеодинамическим реконструкциям «Восточного Казахстана» посвеещены многочисленные труды таких корифеев геологии Казахстана как Р.А.Борукаева, И.Ф.Никитина, В.Н.Любецского, В.Я.Кошкина, А.В.Авдеева и др.

Урало-Мугоджарской зоной занималась другая группа геологов во главе с Л.А.Яншиным, А.А.Абдуллиным и др.

В числе первых работ, где показаны возможные соотношения крупнейших структур по обе стороны от Северо-Торгайского прогиба можно назвать «Тектоническую карту Казахской ССР и прилегающих территории союзных республик» под редакцией В.Ф.Беспалова, Г.В.Гарьковца, В.К.Еремина и др, (1971) и «Тектоническую карту области палеозойских складчатостей Казахстана и сопредельных территорий (под редакцией А.А.Абдуллина и Г.В.Зайцева, (1976).

В капитальном коллегиальном труде «Глубинное строение и минеральные ресурсы Казахстана» (Алма-Ата, 2002) отмечается, что «Торгайско-Сырдарьинский прогиб разделяет структуры Восточного и Западного Казахстана. Строение фундамента прогиба изучено относительно слабо, поэтому на схемах геодинамических реконструкций по Казахстану этот регион в большей части остается белым пятном» (стр. 188).

Полевые работы на различные виды полезных ископаемых, в том числе на нефть велись в обнаженной части на востоке Уральской складчатой системы, а на западе в пределах Кокшетауского и Улытауского поднятия.

На Костанайской (Боровской) антиклинальной зоне на западном борту Северо-Торгайского прогиба прямые признаки нефти известны с 1936 года. Попытки по поискам месторождений нефти предпринимались несколько раз. Относительно системные поисковые работы на нефть и газ проводились Северо-Казахстанским территориальным геологическим управлением в 1953-1973 годах на площадях Щербаковская, Новонежинская, Лесная и Коскольская с бурением мелких скважин до 1 500 м. Несмотря на многочисленные признаки капельно-жидкой нефти и битума в отложениях карбона существенных скоплениий не было найдено. Лишь в скважине 119 был получен слабый приток тяжелой смолистой нефти, которую удалось собрать в объеме 1,5 тонны.

Более целенаправленные поисковые работы были проведены в 2012–2017 годах компанией «Энергоресурсы», которой удалось получить приток нефти в скважине Н-I на Новонежинской площади и которая провела сейсмические исследования 2Д МОГТ не только в районе обнаружения, где выявлены структурные ловушки Шокай, Шахмардан, Сагадат, но и региональные профили, которые доказали недислоцированность девонских и карбоновых отложений между Костанайской антиклинальной зоной и Кокшетауским массивом. Эта же компания провела сейсмические исследования в центральной части Северо-Торгайского прогиба, где выявлены рифы девонского и нижнекарбонового возраста.

Новые сейсмические материалы по центральной погруженной части Северо-Торгайского прогиба, свидетельствующие о недислоцированности девонских и карбоновых отложений мощностью более 4000 м, в отличие от Валерьяновской зоны, где они смяты в складки, разрушены многочисленными разломами и прорваны интрузиями, никак не согласуются с представлениями о развитии на этой территории герцинид с позиции геосинклинальной гипотезы. Отнесение Северо-Торгайской зоны к герцинидам на всех тектонических картах, изданных в период Советского Союза и в последующих изданиях отдельных ученых, в значительной мере тормозило проведение целенаправленных поисков на нефть, научно-обоснованной оценки его перспектив и, следовательно, привлечение инвесторов на поиски нефтяных месторождений.

До начала XXI века на картах нефтегазоносных областей СССР (А.Н.Шарданов и др. 1983, Г.Х.Дикенштейн и др. 1984) вся территория Северного Торгая относилась к категории земель с неясными перспективами или бесперспективных. В работе «Глубинное строение и минеральные ресурсы Казахстана, Нефть и Газ», том IIIпод редакцией С.Ж.Даукеева, Б.С.Ужкенова, А.А.Абдулина и др. (2002 г.)и в работе «Комплексное исследование осадочных бассейнов Республики Казахстан Северо-Торгайский бассейн» под редакцией О.А.Акшолакова и А.Б.Бигараева (2011 г.) выделен Центрально-Торгайский перспективно-нефтегазоносный район. К сожалению, научного обоснования возможной нефтегазоносности палеозойских отложений, кроме как краткой характеристики палеозоя по Костанайскому опорному профилю и единичным не глубоким скважинам, в них не приведено.

В основу нефтегазогеологического районирования выше упомянутых работ было положен учение о геосинклиналях и платформах и главными критериями были стратиграфический диапазон осадочных отложений и структурные и морфологические особенности строения чехла. Основные факторы, как формирование (генезис) самого бассейна и его геодинамические условия эволюции, которые предопределяли условия и скорость седиментации, возможные изменения теплового режима и влияние тектонических процессов, происходивших в Уральской складчатой системе, особенно в Валерьяновской вулканической зоне, не учитывались.

Эти недостатки в значительной мере учитываются и устраняются при подходе к изучению бассейна с позиции теории тектоники плит.

Анализ ассоциации магматических и осадочных пород и новых сейсмических материалов на территории между Уральской складчатой системой и Кокшетауским древним массивом позволяет выделить ряд геодинамических зон, которые удовлетворительно объясняют закономерности размещения как месторождении твердых полезных ископаемых различной минерализации, так и обильных нефтепроявлений и дает научную основу оценки перспектив нефтегазоносности Северо-Торгайского бассейна. Обобщая многочисленные публикации по тектонике рассматриваемой территории в региональномплане целесообразно выделить: Восточно-Уральскую зону, ограниченную с востока Жетыгаринским региональным разломом; Денисовеную зону смятия до Ливановского разлома; Валерьяновскую зону, составляющую северную часть региональной вулканической дуги и постепенно переходящую в Костанайскую антиклинальную зону, ограниченную с востока Центрально-Торгайским разломом. Эта антиклинальная зона составляет западный борт Северо-Торгайского бассейна, основного объекта перспективного для поисков новых месторождений нефти и газа, ограниченного на востоке древними поднятиями Кокшетауским и Улытауским (рисунки 1 и 2).

Восточно-Уральская зона представлена аллохтонной пластиной ограниченной на востоке Жетыгаринским региональным разломом, хорошо картируемым по выходам древних сильно метаморфизованных и сильно дислоцированных пород рифея, венда и нижнего палеозоя. Эта зона разлома прослеживается на несколько сот километров и состоит из нескольких участков (?) кулисообразно заходящих друг за друга. По ней происходило продвижение аллохтонной пластины, составляющей ныне Восточно-Уральский мегантиклинорий, в позднем палеозое в этап закрытия восточной ветви Уральского палеокена вследствие сближения и столкновений Казахстанского континента с Восточно-Уральским микроконтинентом.

Валерьяновская зона между региональными разломами Жетыгаринским и Апановским по классическому геодинамическому принципу районирования может рассматриваться как часть региональной вулканической дуги на западе Казахстанской литосферной палеоплиты образованной вследствие субдукции океанического дна восточной ветви Уральского палеокена под Казахстанскую плиту.

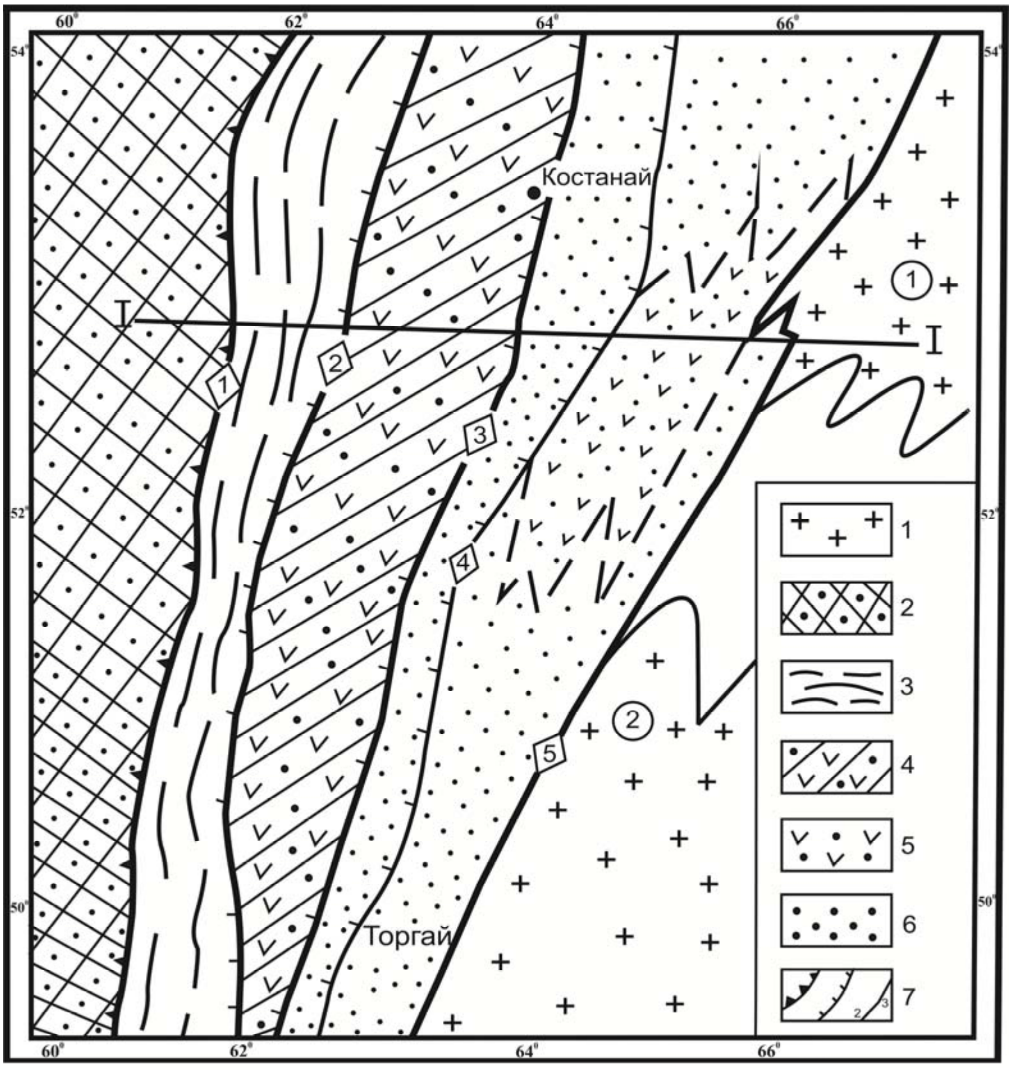

Рисунок 1 – Геодинамическая модель строения Северо-Торгайского бассейна:

1 – древние докембрийские поднятия: 1 – Кокшетауское и 2 – Улытауское; 2 – Восточно-Уральский мегантиклинорий; 3 – Денисовная зона смятия; 4 – Валерьяновский синклинорий; 5 – Кушмурунский грабен; 6 – Северо-Торгайский прогиб; 7 – надвиги (1), взбросы (2) и региональные разломы (3): 1 – Жетыгаринский, 2 – Ливановский, 3 – Апановский, 4 – Центрально-Торгайский и 5 – Амангельдинский

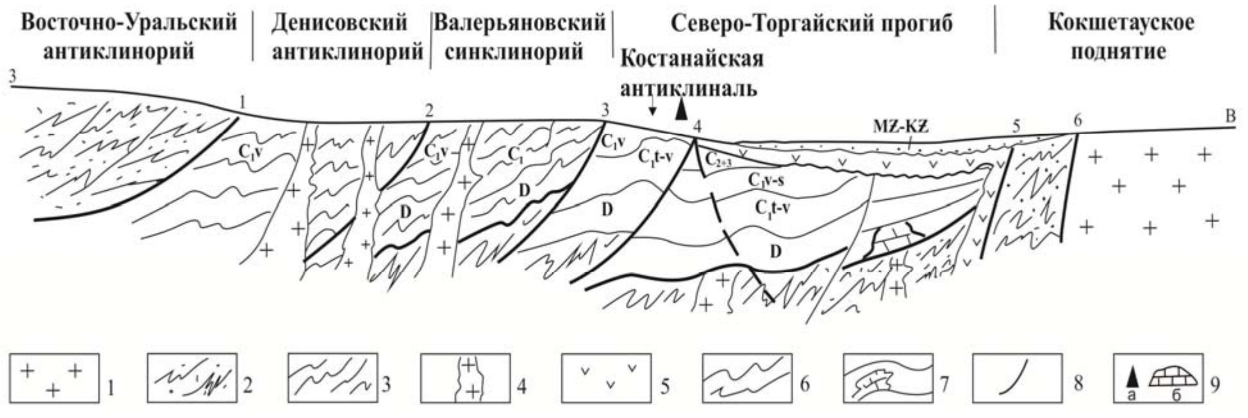

Рисунок 2 – Геологический профиль по линии Урал-Кокшетау:

1 – древние массивы; 2 – аллахтонная пластина; 3 – каледонское основание; 4 – интрузии; 5 – траппы триаса; 6 – рифы девон-карбонового возраста; 7 – мезокайнозойский чехол; 8 – разломы; 9 – Новонежинское нефтяное месторождение (а) и девонский риф Ыбрайхан (б)

Валерьяновская зона является частью регионального вулканического пояса известного в литературе как Валерьяновско-Бельтау-Кураминский, общей протяженностью более 2000 км, в том числе на территории Казахстана более 1 100 км. Формирование пояса связано с островодужным процессом в западном перикратонном обрамлении Казахстанской литосферной плиты. С Валерьяновской зоной ассоциируется главный железорудный регион Торгая и Западно-Торгайский бокситоносный район. Меллогенетический статус Валерьяновской зоны определяется вулканогенно-осадочной формацией визе и серпуховского яруса, представленной терригенно-карбонатно-вулканогенной толщей, которая расчленяется на три свиты: сарбайскую существенно базальт-андезитовую ($C_{1,v}$), соколовскую карбонатно-вулканогенную ($C_{1,\ v2\text{-}3}$) и куржункульскую андезитовую ($C_{1,}$ v-s).

По аналогии с Кураминской зоной в Узбекстане в Валерьяновской зоне прогнозируют цветные металлы: медь. свинец, цинк, а так жезолото. Месторождение цинка Шаймерден в этой зоне является первым признаком возможности прогноза полиметаллической минерализации.

Основную роль в строении Валерьяновской зоны играют осадочно-вулканогенные образования нижнего карбона, смятые в брахиантиклинальные складки субмеридионального простирания осложненные разрывными нарушениями. Представлены они песчаниками, аргиллитами и известняками и залегают без видимого несогласия на фаменских отложениях.

Изученный в регионе разрез начинается с красноцветных континентальных осадков девона, выше залегает карбонатная толща фамена и нижнего турне, которая перекрывается карбонатно-терригенной толщей верхнего турне-нижнего визе. Завершается разрез мощной вулканогенно – осадочной толщей среднего визе и намюра, состоящей из известняков и песчаников красноватосерого цвета с туфовым материалом и прослоями базальтов, спилитов и андезита-базальтов, являющейся основной рудоносной свитой к которой приурочены крупнейшие месторождения магнетитовых руд. В валерьяновской свите на Сарбайском месторождении встречены битуминозные известняки (рисунок 3).

По результатам изучения образцов из многочисленных структурных скважин и по обнажениям можно заключить, что по мере удаления от Урала на восток содержание вулканических толщ в разрезе значительно уменьшается и на Костанайской (Боровской) антиклинали разрез представлен терригенно-карбонатными породами с включениями и прослоями вулканогенных.

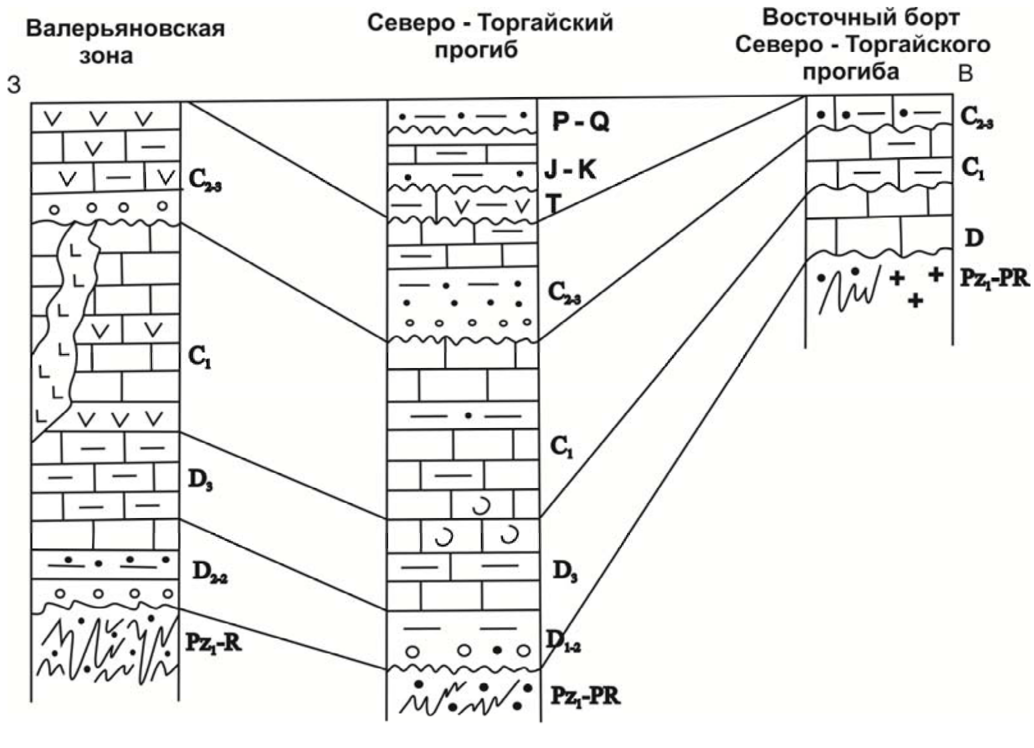

Рисунок 3 – Сопоставление разрезов

Валерьяновская зона в целом, чешуйчато надвинутая на восток, ограничивается Апановским региональным разломом, за которым резко затухает влияние тангенциальных напряжений, направленных, естественно, с Урала на восток.

Северо-Торгайский бассейн в течение девона и раннего карбона представлял собой пассивную континентальную окраину Казахстанского континента, обращенную в сторону Уральского океана. Начиная с позднего визе, т.е. начиная со столкновения Казахстанской плиты с Восточно-Уральской микроплитой и с Восточно-Европейской плитой, за главными островными дугами Урала образовался Валерьяновский вулканический пояс, сложенный андезитами, андезит-базальтами, дацитами и прорывающими их диоритами и гранодиоритами.

В течение среднего-позднего карбона и перми происходило значительное сокращение площади морского бассейна, заложение средне-позднепалеозойских задуговых прогибов и накопление в их пределах терригенных осадков с конгломератами, состоящими из галек известняков и эффузивов девона и нижнего карбона, которые в то время обнажались в коллизионных орогенах в Восточно-Уральском антиклинории, Денисовской и Валерьяновской зонах восточного Урала.

Наблюдается резкое отличие Северо-Торгайского прогиба от Валерьяновской зоны по материалам геофизических исследований. В пределах Валерьяновской зоны гравитационное и магнитное поля имеют высокую интенсивность и линейно вытянутую в субмеридинональном направлении форму. Северо-Торгайский прогиб отличается мозаичиной слабо расчленной формой низкой интенсивности как гравитационного, так и магнитного полей (рисунок 4).

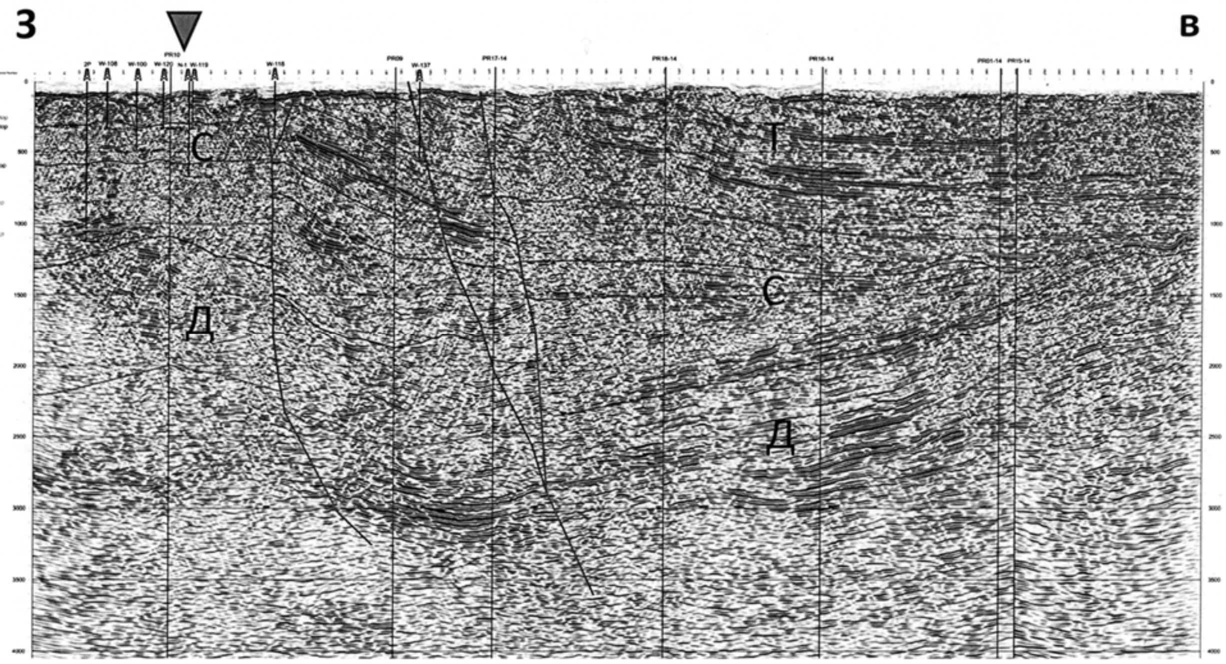

Рисунок 4 – Региональный временной разрез через Северо-Торгайский бассейн.
▼ Новонежинское нефтянное месторождение

Строение Северо-Торгайского бассейна на лицензионной территории компании «Энергоресурсы» достаточно хорошо изучено сейсмикой. По региональным широтным профилям поведение восьми почти паралельных отражающих горизонтов свидетельствует от отсутствии дислоцированности девонских и карбоновых отложений толщиного более 4000 м (рисунок 4). С позиции концепции геосинклиналей рассматриваемая территория находится в пределах герцинид Урало-Монгольского пояса, где следовало бы ожидать сильную дислоцированность девонских и карбоновых отложений как в Валеровановской зоне. Полученная новая информация служить подтверждением корректности нашего подхода к изучению строения Северо-Торгайского бассейна с позиции теории тектоники плит (3 и 4).

На западном склоне Ащибойского поднятия в центральной части бассейна выявлены рифы девон – турнейского возраста высокою 600-750 метров как риф Ыбфрайхан (рисунок 5). Как отмечалось выше, в примыкающей к Костанайской антиклинали территории сейсмикой картировано несколько локальных поднятии как Шокай, Шахмардан и Сагадат, которые могу служить структурными ловушками для нефти и газа в девонских и нижнекарбоновых отложениях (рисунок 5).

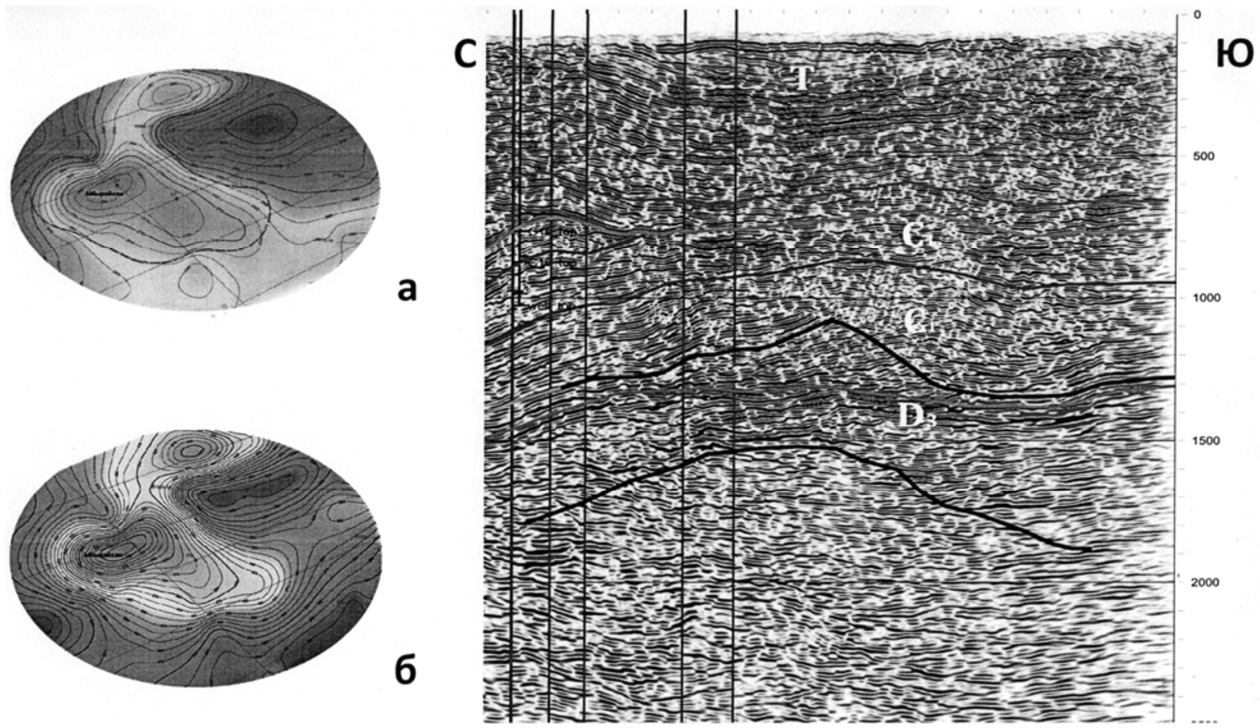

Рисунок 5 – Риф Ыбырайхан: а – структурная карта по кровле резервуара (отражающий горизонт R);
б – карта изопахит рифового комплекса и в-глубинный разрез с рифовыми постройками

Девонские отложения обнажены на западном и восточном бортах и вскрыты скважинами в центральных частях Торгайского прогиба. Представлены они осадочно-эффузивной толщей, состоящей из красно-цветных конгломератов и песчаников, перемежающихся с покровами кислых эффузивов. Местами встречаются глинистые сланцы, известняки и туффиты. Встречены темно-серые битуминозные закарстованные известняки живетского возраста мощностью до 1300 м. Верхнедевонские отложения в составе франского и фаменского ярусов установлены повсеместно. Франский ярус представлен переслаиванием карбонатных и терригенных пород общей толщиной 500 м. Фаменские образования в нижней части разреза сложены красноцветными, коричневыми конгломератами, грубозернистыми песчаниками и аргиллитами, иногда с пропластками эффузивов. В верхней части разреза преобладают известняки серые, органогенные, кавернозно-трещиноватые , в которых наблюдались нефтепроявления и получены притоки нефти на площадях Новонежинская и Щербаковская. В целом общая толщина девонских отложений резко возрастает в сторону Урала, т.е. бывшего палеоокеана, в этом же направлении увеличивается содержание эффузивных пород в разрезе.

Нижнекаменноугольные отложения подразделяют на три толщи. Нижняя нижнетурнейского возраста, представленная терригенно-карбо-натными осадками, имеет небольшое распространение. Средняя толща верхнетурнейско-нижневизейского возраста в различных структурно-фациальных зонах имеет различный состав и меняется с запада на восток от карбонатно-терригенного к терригенно-карбонатному и далее карбонатному. В трещинах и кавернах известняков наблюдаются многочисленные включения жидкой и загустевшей нефти. Толщина средней толщи достигает на западе 1000-1200 м и уменьшается на востоке до 300-500 м.

В породах верхнего девона и нижнего карбона содержание Сорг изменяется от 0,1 до 2,97% на объем породы и они по результатам комплексного анализа относятся к категории нефтегазоматеринских.

Отложения визе-намюрского возраста представлены серыми кавернозными битуминозными известняками. Более молодые терригенные образования, условно относимые к верхнему палеозою, распространены только на западе, в основном в Костанайской зоне и представлены они полимиктовыми конгломератами, песчаниками и алевролитами, изредка встречаются горизонты эффузивов.

К этому периоду приурачивается также основной этап тектонических дислокаций, вызванных сжимающими тектоническими движениями, в результате чего происходило надвигание Денисовской зоны на Ва-лерьяновскую, Валерьяновской зоны на Костанайскую и формирование опрокинутых на восток систем антиклинальных складок и многочисленных нарушений взбросового характера. Геодинамическая эволюция Торгайского прогиба, изменившаяся во времени, создавала в девоне и раннем карбоне условия осадконакопления пассивной окраины и затем задугового бассейна в позднем палеозое.

В центральной части Севера-Торгайского прогиба несогласно на размытой поверхности полеозоя залегают нижнетриасовые отложения значительной толщины в грабенах.

Судя по многократным переслаиваниям эффузивов с осадочными породами, формирование грабен-синклиналей происходило в условиях чередования периодов вулканической деятельности с периодами осадочной седиментации. Толщина пластов эффузивных пород изменяется от 5-10 м до 100-160 м, а осадочных пород, представленных песчаниками, конгломератами и глинами, нередко обогащенных сапропелевым веществом, от нескольких метров до 60-100 м. Эта осадочно-вулканогенная толща известна как туринская серия. В её основании обычно залегают пласты грубых конгломератов. Общая толщина серии изменчива и во многих грабенах превышает 1500 м. Центральная часть Северо-Торгайского прогиба покрыта маломощными терригенными отложениями мезокайнозоя.

Одновременность зарождения (конец перми и начало триаса) грабенов и их приуроченность к региональным разломам, которые явились проводниками базальтовой магмы, сходный литологический состав заполняющих осадков толщиною до 3000-4000 м, общая меридиональная, параллельно Уралу, ориентировка на протяжении 600 км при ширине полосы развития грабенов 50-150 км позволяет объединить их в единую Восточно-Уральскую палеорифтовую систему. Рифтогенез в пределах Торгайского прогиба имел полициклический характер. Он имел место в раннем карбоне, триасе и юре. Отчетливо прослеживается омоложение рифтогенных структур к юго-востоку от Жарыкского грабена, сформировавшегося в карбоне, и Куш-мурунского в конце перми и раннем-среднем триасе до грабенов Приишимской группы (поздний триас) и Южного Торгая (юра), неразрывно связанное с изменением активизации региональных глубинных разломов во времени. Триасовый цикл рифтогенеза оказался несколько урезанным по развитию. Кушмурунский грабен, например, прошел стадию заложения и, в связи с изменением тектонической обстановки, а именно резкого воздымания, он не испытывал стадию проседания и образования надрифтовой депрессии,

Юрский цикл охватил обширную территорию, практически всю центральную и южную часть Торгайского прогиба, причем в пределах грабенов раннекаменноугольного и триасового возраста образовались значительных размеров грабены юрского возраста, то есть имела место вторая генерация грабенов на одной и той же площади.

Жарыкская грабен-синклиналь размерами 200 км в длину и 20-50 км в ширину вытянута с юго-запада на северо-восток, ограничена сбросами и выполнена нижнекаменноугольными отложениями. В её пределах выделяются молодые грабен-синклинали-Каганская и Мукырская, выполненные юрскими отложениями, залегающими несогласно на нижнекаменноугольных.

Кушмурунский, Ашибулакский и Каргалытауский грабены выполнены туринской серией, содержащей в разрезе базальты и дациты. В их пределах развиты мелкие грабены следующей генерации, выполненные юрскими угленосно-терригенными отложениями. В частности, в пределах Кушмурунской грабен-синклинали выделяются юрские грабены: Эгинсайский, Былкылдакский, Севастопольский, Черниговский и др.

Между Жарыкской каменноугольного возраста и Кушмурунской триасового возраста грабен-синклиналями находится Коктальская грабен-синклиналь, выполненная юрскими угленосными образованиями. Подобные грабен-синклинали юрского заложения имеют широкое распространение в пределах Торгайского прогиба.

Грабены и грабен-синклинали юрской системы относительно хорошо изучены в Южном Тургае благодаря открытию месторождений нефти и газа со значительными запасами – Кумкольского, Арыскумского и других. В северной половине Торгайского прогиба грабены имеют северо-восточную, субмеридиональную (уральскую) ориентировку, а в южной, главным образом, северо-западную (улутаускую).

На восточном борту Северо-Торгайского бассейна установлено, что на древнем складчатом основании резко несогласно залегают слабо дислоцированные континентальные красноцветные. Вулканогенно-терригенные отложения девона, сменяющиеся вверх по разрезу морскими терригенно-карбонатными образованиями фамена-раннего карбона. Завершается разрез красноцветной терригенной толщей верхнего палеозоя.

Геодинамическая эволюция Северо-Торгайского бассейна в девоне и карбоне благоприятствовала накопленного морских и прибрежно-морских осадков в условиях пассивной континентальной окраины Казахстанской литосферной плиты на восточном берегу Уральского палеокеана. Высокое содержание Сорг в породах этого возраста и многочисленные нефтепроявление и притоки нефти свидетельствуют о присутствии в разрезе бассейна толщ спсобных генерировать углеводороды, а термодинамические условия, вызванное присутствием магматических и эффузивных процессов вплоть до раннего триаса, так же создавали благоприятный режим для генерации углеводородов.

Тектонические процессы происходившие в связи с возникловение Уральской складчатой системы и вызванные ими тангенциальные напряжения, направленные в сторону Северного Торгая, привели к образованного различных типов структурных ловушек и трещиноватых коллекторов на изгибах пластов. Особые место как коллектора занимают ограногенные известняки в рифовых постройках и песчаники и алевролиты изученные по структурным скважинам в Костанайской зоне антиклиналей Волновое поля на сейсмических разрезах, отражающие чередование терригенных и карбонатных пород, дают основание предполагают широкое развития в бассейна как пород – коллекторов, так и пород-покрышек.

В Центральной части Северо-Торгайского бассейна, где тектоническое напряжение со стороны Урала проявлялось умеренно, вероятно, существуют благоприятные условия для акку-муляции и консервации скоплений углеводородов. Особые условия для образования и сохранности скоплений нефти и газа существовали в рифовых постройках девонского и карбонового возраста. Все это дает основание к оптимистическому заключению о высокой перспективности Северо-Торгайского бассейна на поиски новых со значительными запасами месторождений нефти и газа.

С целью детального изучения строения девон-нижнекарбоновых отложений необходимо провести широкомасштабные сейсмические исследования для выявления новых ловушек инвестиционно привлекательных для инвесторов. На подготовленных для поискового бурения объектах как Ыбырайхан, Шокай, Шахмардан и др. следует начать бурение поисковых скважин. Целенаправленные геолого-разведочные работы надеемся приведут к открытно не только одного-двух новых месторождений нефти и газа, но и новой нефтегазоносной и в перспективе нефтегазодобывающей области на севере нашей Республики.

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СОЛТҮСТІК ТОРҒАЙ БАССЕЙІНІНІҢ ГЕОДИНАМИКАЛЫҚ МОДЕЛІ ЖӘНЕ МҰНАЙ МЕН ГАЗ ІЗДЕУДЕГІ БОЛАШАҒЫ

Аннотация. Пайдалы қазбаларды іздеу және кен орындарын зерттеу бағытында Қазақстан жерін екіге бөлу - Шығыс Қазақстан және Батыс Қазақстан деп - геология саласында тарихи қалыптасып қалған. Бұл екі аймақты бөлетін Солтүстік Торғай ойпатын зерттеуге көп көңіл бөлінбеген.

Жаңа геологиялық және геофизикалық деректерге сүйене отырып Орал тауларынан Көкшетау-Ұлытау аймағына дейін бірнеше геодинамикалық маңызы зор тектоникалық элементтер бөлінген. Олар Шығыс Орал антиклинарий, Денисов аймағы, Валерьянов синклинарий, Солтүстік Торғай ойпаты және Көкшетау-Ұлытау белестері.

Мақалады әр тектоникалық элементтердің толық сипаттамалары белгіленген. Геодинамикалық құрылысын зерттеу нәтижесінде Солтүстік Торғай ойпатында мұнай мен газ кен орындарын іздеуге болашақ бар деген тұжырым жасалған.

Түйін сөздер: шөгінді бассейн, вулкандық дуга, аллахтон, мұнайменгаздылық, геодинамикалық модель.

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DEVELOPMENT OF AN EXPERIMENTAL PLANT OF A NON-NOZZLE POROUS FOAM GENERATOR FOR PRODUCING WITH FOAM GENERATING AND DEFOAMING STRUCTURES

Abstract. On the basis of studies of heat-mass exchange processes by boiling of pure liquids and with the addition of surface-active agents, a new class of non-nozzle porous foam generator for producing of air (steam) and mechanical foam was developed. The results of the experiment are generalized by the criteria equations of heat-mass exchange with an accuracy of ± 20% with respect to the processes of bubbling, foam generation, pseudo-fluidization and boiling. The combined action of capillary and mass forces for capillary-porous structures of the 3x0,4 type made it possible to boost the operating mode of the foam generator by 1,5-2 times and reduce the consumption of the foam generating agent and reduce the hydraulic resistance tenfold. The nozzle-free foam generators of air mechanical foam were designed along with its case, inlet and outlet nozzles, a set of grids and sprayer. They help to conduct foam generation processes with high effectiveness under low hydro-and-gas dynamic resistance. For further enhancement of the combined processes of gas mechanical foam and collecting micro-and-ultramicroscopic dust, a dust collector along with its case, inlet and outlet nozzles, a set of grids and sprayer was proposed, which is equipped with defoaming grid porous structure, whereas foam generating and defoaming structures are installed into in case consequently as per the dusty gas movement and sludge collector. Besides, each subsequent grid of foam generating porous structure is made with the increased size of cells following the cleanable gas; e.g. made of metal cells for clearance 0,08*0,14*1, and defoaming made of grids with decreasing size of cells following the cleanable gas, e.g made of metal cells for clearance 0,4*0,14*0,08.

Key words: porous foam generator, foam generation, foaming, defoaming, heat-mass exchange, capillary-porous structures.

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РАЗРАБОТКА ЭКСПЕРИМЕНТАЛЬНОЙ УСТАНОВКИ БЕЗФОРСУНОЧНОГО ПОРИСТОГО ПЕНОГЕНЕРАТОРА ВОЗДУШНО(ПАРО)-МЕХАНИЧЕСКОЙ ПЕНЫ С ПЕНОГЕНЕРИРУЮЩИМИ И ПЕНОГАСЯЩИМИ СТРУКТУРАМИ

Аннотация. На основе исследований процессов тепло-массообмена кипением чистых, жидкостей и с добавкой поверхностно-активных веществ разработан новый класс безфорсуночных капиллярно-пористых пеногенераторов воздушно(паро)-механической пены. Результаты эксперимента обобщаются критеристыми уравнениями тепло- и массообмена с точностью ±20% применительно к процессам барботажа, пеногенерации, пвсевдоожижения и кипения. Совместное действие капиллярных и массовых сил для капиллярно-пористых структур вида 3x0,4 позволило форсировать в 1,5-2 раза режим работы пеногенератора, сократить расход пенообразователя и в десятки раз уменьшить гидравлическое сопротивление. Разработаны безфорсуночные пеногенераторы воздушно-механической пены, содержащий корпус, входной и выходной патрубки, пакет сеток, распылитель. Они позволяют проводить процессы генерации пены с высокой эффективностью при малых гидро- и газодинамических сопротивлениях. Для дальнейшей интенсификации совместных процессов генерации газомеханической пены и улавливания микро- и ультрамикроскопической пыли предложен пылеуловитель, содержащий корпус, выходной и выходной патрубки, пакет сеток, распылитель, который снабжен пеногасящей сетчатой пористой структурой, причем пеногенерирующая и пеногасящая структуры установлены в корпусе последовательно по ходу движения запыленного газа, и щламосборником. Кроме того, каждая последующая сетка пеногенерирующей сетчатой пористой структуры выполнена с увеличивающимся размером ячеек по ходу движения очищаемого газа, например, из металлических с размером ячеек на просвет: 0,08*0,14*1, а пеногасящая – из сеток с уменьшающимся размером ячеек по ходу движения очищаемого газа, например, из металлических с размером ячеек на просвет: 0,4*0,14*0,08.

Ключевые слова: пористый пеногенератор, пеногенерация, пенообразование, пеногашение, тепломассообмен, капиллярно-пористые структуры.

Исследование процессов тепломассообмена при кипении чистых жидкостей в капиллярно-пористых структурах, разработка способов управления этими процессами [1] позволило обобщить эксперименты с чистыми пенными и запылёнными пенными потоками и изучить единое уравнение для расчета теплообмена и масообмена с точностью ±20 % [2], причем обобщались процессы кипения, барботажа, псевдоожижения и пеногенерации.

На основе таких исследований разработан новый класс безфорсуночных пеногенераторов и пенопылегазоуловителей с барботажными капиллярно-пористыми решетками [3], так и с пеногенерирующими и пеногасящими структурами, ориентированными вертикально. За счет управления внутренними характеристиками двухфазных потоков [4] сконструированы различные устройства пено-пылеулавливания [5-13]. Стало возможно повысить эффективность пылегазоулавливания за счет управления геометрией микроканалов пористого материала [6], разделение потока на энергию волны и энергию газов (паров) [7, 11], создание генератора пены путем подвода электроэнергии (без набегающего потока) [8], разработки турбулизаторов в виде пеногенерирующих и пеногасящих пористых структур, использующих совместное действие гравитационных и капиллярных сил, сил давления и вибрации.

В а. с. №358012, 1972 описан способ электростатической очистки газов, где электризацию осадительных элементов производят, использую трибоэффект. Данный эффект использовали и ранее, однако при электризации фильтрующих элементов на них образовывался проводящий слой, который снижал электростатическую составляющую фильтрации. В рассматриваемом способе будет повышена эффективность электростатических фильтров, поскольку электризацию предлагается осуществить путем циркуляции взвешенного, тонкодисперсного электризующего агента в полых осадительных элементах.

Способ электростатической очистки газов /а.с. 358012, 1972/ по эффективности пылеосаждения превосходит известные способы, однако в отличие от них он имеет низкую производительность пылеосаждения.

Таким образом, используя трибоэффект можно увеличить эффективность электризации пыли в воздушном потоке, однако необходимо решить задачу по увеличению производительности пылеочистки.

Дополнением к способам очистки газов от пыли является способ /а.с. 247241, 1969/, в котором предлагается улавливать тонкие аэрозоли путем зарядки частиц аэрозоля при осаждении на них электростатически распыляемой легко испаряющейся жидкости, причем пар жидкости конденсируют для повторного использования. Такой способ имеет преимущество над способом пылеулавливания зарядкой частиц электростатически распыленной водой, так как при взаимном притяжении частиц пыли и капелек распыленной воды, происходит их слипание, укрупнение частиц с нейтрализацией зарядов.

Общим недостатком электрических способов является незначительный размер и рыхлая структура образующихся конгломератов пылевых частиц. При соударении они могут легко разрушаться. Особенно низкую эффективность процесса пылеподавления следует ожидать при осаждении мелкодисперсной пыли. Следовательно, необходимо разработать способ осаждения пыли, который бы позволил существенно повысить прочность и устойчивость разрушению образующихся пылевых конгломератов при обработке воздушного запыленного потока электрическим полем при сохранении высокой производительности пылеочистки.

Интересен способ обеспыливания воздуха с применением пористых полотен /а.с. №368413, 1973/. Для повышения эффективности улавливания пыли запыленной поток пропускают между параллельно расположенными полотнами, которые смачивают жидкость. Движущийся поток воздуха приводит полотна в колебательные движения из-за неоднородности профиля скоростей. Частички пыли, находясь в турбулентном потоке воздуха, увлажняются, подвергаясь столкновениям и коагулируются. Увлажнение ткани осуществляется путем подачи воды к трубчатой раме, на которой закреплены полотна.

Для достижения необходимой эффективности пылеулавливания потребуется проведение многочисленных экспериментальных исследований при различных режимных параметрах, а также новые конструктивные разработки для формирования аэродинамической структуры запыленного воздушного потока.

Известен способ пылеподавления, основанный на использовании насыщенного водяного пара. При конденсации пара возникает область пониженного давления, в которую устремляются пылинки, и могут быть уловлены. К недостаткам данного способа можно отнести его низкую эффективность, обусловленную нерациональным использованием генерируемого пара в целях пылеподавления. К тому же, для достижения требуемых норм запыленности, необходимы большие расходы пара, а, следовательно, неоправданные затраты на выработку пара.

Близким к описанному способу можно считать способ (а.с. №130461), где производится смешение пылевоздушного потока со струей пара с последующим осаждением паропылевого потока распыленной водой.

При такой организации процесса также следует ожидать низкую степень пылеулавливания. Конденсационный эффект будет проявляться нестабильно, носить вероятностный характер, зависящий от случайных столкновений распыленных капелек воды с молекулами водяного пара и будет определяться степенью турбулентности пылевоздушного потока. При насыщении пылевоздушного потока паром эффективность коагуляции пыли следует ожидать незначительной. Поэтому водяной пар и распыленная вода используется нерационально, имеются повышенные расходы пара и воды.

При изучении движения аэрозольных частиц в поле диффузии пара показано, что аэрозольные частицы особенно интенсивно удаляются вблизи холодной поверхности. Аэрозоли со скоростью I м/с пропускали через конденсатор длиной 0,5 м и шириной $5x10^{-3}$ м. Металлическая стенка омывалась водой с температурой на входе в конденсатор 20°С и на выходе из него около минус 70°С. Концентрация частиц составляла 1012 частиц/м^3. Степень улавливания колебалась в больших пределах (75-95%). Механизм процессов пылеулавливания объяснен двумя положениями: I) конденсационным укрупнением аэрозольных частиц как на ядрах конденсации; 2) направленным движением молекул пара преимущественно к холодной поверхности.

Механизм процесса осаждения пыли очень сложный, хотя можно указать основные действующие факторы: движущей силой аэрозольных частиц является стефановский поток конденсирующегося пара, к тому же она усиливается наличием диффузионных, термофоретических сил и конвективных потоков, крупные частицы удаляются из потока за счет гравитационных и центробежных сил; некоторое число частиц в паровоздушном потоке уменьшается за счет процесса коагуляции.

Исследование механизма процесса пылеулавливания в поле диффузии пара требует дальнейшего развития, особенно это относится к интенсификации процессов конденсации пара, равномерности распределения жидкостной пленки, разработке новых устройств питания пылевого воздушного потока насыщенным паром.

Некоторая интенсификация процессов пылеулавливания может быть достигнута за счет наложения дополнительных источников энергии /а.с. №1032197, 1983/. Предлагается водяной пар и диспергированную воду заряжать разноименно, причем воду необходимо предварительно омагнитить. В бункер с горной массой по ходу ее движения подается пар, который проходит через электрическое поле, сформированное на выходе из парового сопла. Паропылевоздушный поток, покидая бункер, конденсируется на распыленных форсункой каплях электрически заряженной, предварительно омагниченной воды.

При весовом расходе пара, равном $7x10^{-3}$ кг/с и более, относительная запыленность воздуха достигает 3-6% и становится автомодельной относительно расхода пара. Увеличение эффективности процесса в описанной конденсационной системе пылеподавления происходит в 1,5-2 раза (видимо, по отношению к конденсационной системе без электрической зарядки пара, воды и омагничивания воды). Также неясно, как влияет процесс омагничивания воды, и какой вклад электрической зарядки отдельно для пара и воды.

Полученный эффект объяснен тем, что при подаче в очаг пыли разноименно электрозаряженных аэрозолей пара и воды из-за электрических сил притяжения между молекулами пара и каплями воды происходит более интенсивная и упорядоченная конденсация пара на каплях воды. У поверхности конденсации возникает большее, чем при незаряженных аэрозолях, гидродинамическое течение запыленной среды, направленное к каплям, которое притягивает пылинки и способствует их захвату каплями, за счет чего происходит коллективное осаждение пылинок. Коэффициент захвата частичек пыли каплями воды также возрастает за счет уменьшения сил поверхностного натяжения электрозаряженных капель.

Описанный способ пылеподавления имеет дополнительный эффект по осаждению пылевых частиц, однако достигается это большой ценой: необходима электрическая зарядка пара, воды, омагничивание воды, что серьезно усложняет схему конденсирующей системы пылеподавления, требует дополнительных затрат на создание электрических полей и на обеспечение условий электробезопасности работающих.

Таким образом, дальнейшие теоретические и экспериментальные исследования процессов пылеулавливания должны быть направлены на создание новых конструктивных решений, в основе которых могут быть положены рассмотренные способы с применением испарительно-конденсационных многофазных систем пылеулавливания и поверхностно-активных веществ.

Главным образом, при существующих типах пенообразующих веществ, возлагаются надежды на новые аэрогазодинамические схемы и конструкции, которые будут определять протекание процесса пылеосаждения, существенно увеличивая степень очистки запыленного потока, явятся надежными, простыми в изготовлении и эксплуатации, удовлетворяющие требованиям техники безопасности при эксплуатации оборудования [8-13].

На рисунке 1 представлен новый класс безфорсуночного пеногенератора с пеногенерирующей капиллярно-пористой структурой 2. Экспериментальная установка по исследованию процессов генерации воздуха (паро)-механической пены показана на рисунке 2.

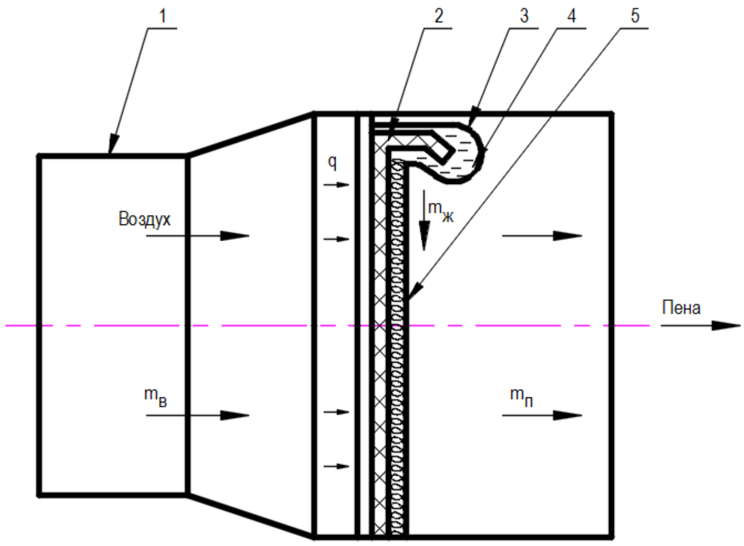

Рисунок 1 – Безфорсуночный капиллярно-пористый пеногенератор воздушно(паро)-механической пены: 1 – цилиндрический корпус; 2 – капиллярно-пористая структура; 3 – распылитель (питающая артерия); 4 – пенообразающий раствор; 5 – воздушно (паро) – механическая пена; $m_в$, $m_ж$, $m_п$ – расходы воздуха (пара), жидкости (пенообразующего раствора), пены; q – плотность энергии набегающего (пенообразующего) потока

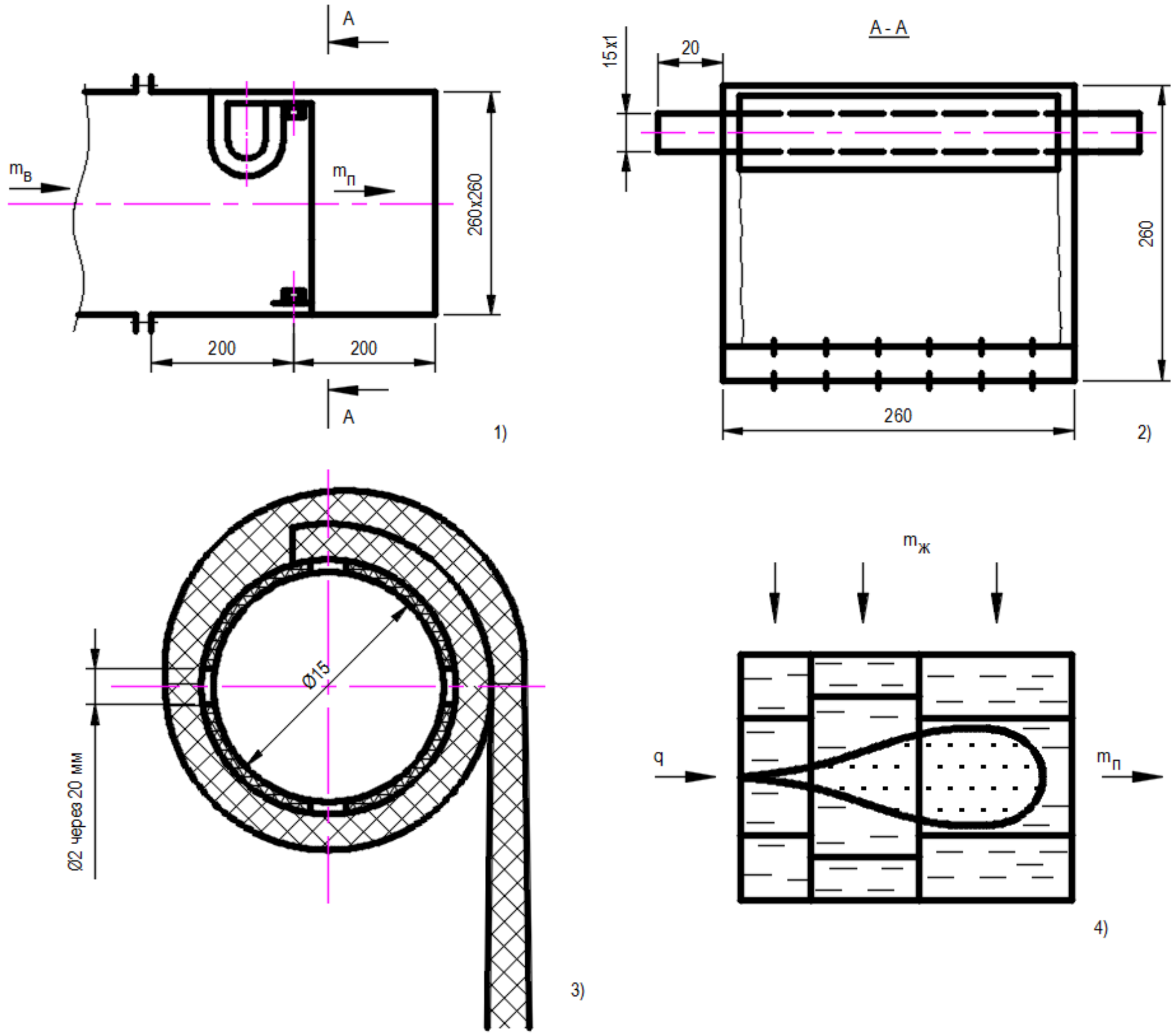

Рисунок 2 – Экспериментальная установка по исследованию процессов генерации пены:
1 – пеногенератор; 2 – распылитель; 3 – соединение капиллярно-пористой структуры; 4 – динамика пузыря в структуре

Комбинированное использование массовых и капиллярных сил обеспечивает создание равномерного и устойчивого распределения пленки пенообразующего раствора по всей капиллярно-пористой структуре вида 3х0,4 (три слоя сетки с шириной ячейки в свету $0,4x10^{-3}$ м). это позволяет форсировать в 1,5-2 раза режим работы пеногенератора, сократить расход пенооборазователя при сохранении стойкости, дисперсности и высокократности пены.

Величина гидравлического сопротивления будет в десятки раз меньше (нет форсунки), чем в пеногенераторах ГВПВ-400 или ПГГ-4.

Исследование процессов тепломассообмена кипением чистых жидкостей в капиллярно-пористых структурах выявило поведение внутренних (термогидравлических) характеристик (зарождение паровой фазы, плотность центров генерации, выброс капель из структуры, отрывной диаметр и частота отрыва пузырей, скорость роста пузырей [11, 13-16]. Были разработаны различные пористые системы применительно к тепловым энергетическим установкам [17] и с целью их расчета обработаны экспериментальные данные с точностью ±20% в виде критериального уравнения для барботажа, вдува, отсоса, псевдоожижения, пеногенерации [18] и сконструированы высокоэффективные безфорсуночные капиллярно-пористые пылегазоуловители с пеногенерирующими и пеногасящими структурами [3, 6-8, 12].

Рассмотрим характерный аппарат из нового класса безфорсуночных пылегазоуловителей. Изобретение авторов «Пылеуловитель» [а.с. №1456608, МКИ E21F 5/04, 1989] относится к различным областям народного хозяйства для высокоэффективной очистки газа (воздуха) от микро-и ультрамикроскопической пыли (фракций размером менее $5*10^{-6}$ м и $0,25*10^{-6}$ м соответственно), например, при сжигании топлива, переработке и транспортировке пылящих материалов, при удалении вентиляционных выбросов.

Известен пенный аппарат для улавливания газов и аэрозолей [а.с.№309717, кл.В. OId 47/04, 1971], содержащий патрубки ввода и удаления газа, корпус, волокнистую насадку, расположенную в корпусе, прокладку-перегородку, каплеотбойник.

Недостатком устройства является низкая эффективность улавливания микро- и ультрамикроскопической пыли, определяемая размерами пор насадки, что в свою очередь создает высокую материалоемкость, большие гидравлические сопротивления по движению жидкости и газодинамические сопротивления при прокачке газа (воздуха).

Небольшая продолжительность работы между регенерациями за счет забивания пор волокнистой насадки является серьезной проблемой. Пена образуется вне пористого тела и набрасывается на его поверхность. Это снижает эффективность улавливания пыли и интенсивность процессов массопереноса, что приводит к росту материалоёмкости, габаритов и массы аппарата.

Поток газа, проходя через волокнистую насадку, преодолевает большое газодинамическое сопротивление. Это связано с перерасходом энергии на его прокачку. Продолжительность работы между регенерациями такого аппарата будет невысокой, поскольку поры в волокнах начнут забиваться пылинками. Все это усложняет эксплуатацию аппарата и уменьшает его надежность.

В предлагаемых капиллярно-пористых структурах безфорсуночного пылегазоуловителя [3, 6-8, 12] высокую эффективность улавливания микро- и ультрамикроскопической пыли можно объяснить диффузионным механизмом осаждения пыли в пенном потоке в объеме и на поверхности структуры, когда пылинки испытывают непрерывное воздействие молекул газа, находящегося в броуновском движении, причем подвижность частиц будет увеличена путем термофореза, возникающего за счет разности температур между скелетом пористой структуры, пенного потока и частицами пыли, и за счет диффузиофореза, вызванного градиентом концентрации компонентов пенного потока, усиленным процессами испарения пенообразующего раствора в объеме пористой структуры и частичной конденсаций пара пенного потока.

Высокая устойчивость и стабильность пленки жидкости в ячейках сетчатых структур обеспечивается равномерным подводом жидкости распылителя и позволяет в 1,5÷2 раза уменьшить расход пенообразующего раствора при сохранении стойкости, дисперсности и высокократности пены, получаемой в пеногенерирующей структуре [3, 6-8, 12].]

Как показывают опыты [7, 12] гидравлическое сопротивление сетчатых пористых структур по сравнению с волокнистой насадкой уменьшится в десятки раз, а газодинамическое – в несколько раз. За счет того, что предлагаемые пористые структуры имеют большие размеры ячеек по сравнению с порами волокнистой насадки, существенно увеличится период между регенерациями сеток, а значит, упрощается эксплуатация и повышается надежность работы пылеуловителя и срок службы.

Организовать устойчивый процесс в многофазном слое с помощью волокнистых и им подобным фильтрующим материалам (металлокерамические, спеченные порошки) не удается, так как пузыри пены закупоривают поры насадки, прекращаю поступление свежих порций пенообразующей жидкости к пузырегенерирующим порам при нагрузках в (2…2,5) раза меньших, чем для сетчатых структур.

Работает пылеуловитель следующим образом.

Загрязненный пылью поток вводится через патрубок подвода запыленного газа 1 в корпус пылеуловителя 2 (рисунок 3). Очистка газа от микроскопической пыли производится в пеногенерирующей пористой структуре 3 вида 0,08*0,14*1. Газомеханическая пена 10 выдувается газовым потоком из ячеек структуры, снабжаемой пенообразующим раствором 9, например, ПО-12, подаваемым из распылителя 4.

Пористая структура по сравнению с изотропной структурой позволяет существенно интенсифицировать массообменные процессы, протекающие в ее объеме и на поверхности за счет облегченного роста пузырей 8 от вершины конуса к его основанию, что повышает коагулирующую способность пены. Следовательно, интенсификация процессов приводит к росту эффективности улавливания микроскопической пыли за счет повышения коэффициента захвата пыли пеной в объеме структуры и на ее поверхности.

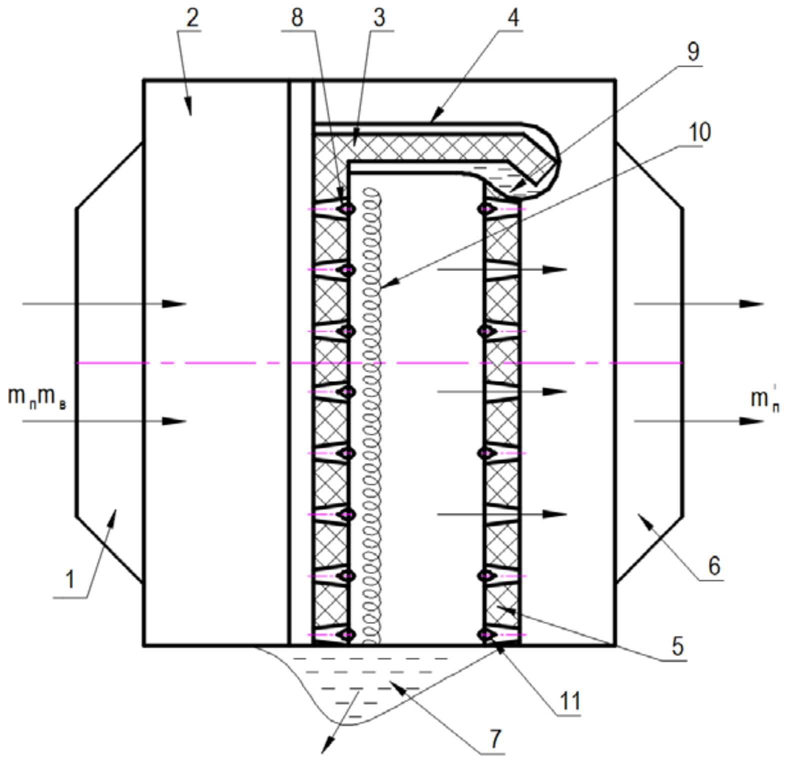

Рисунок 3 – Безфорсуночный капиллярно-пористый пылегазоуловитель с пеногенерирующими 3 и пеногасящими 5 структурами: 1 – входной патрубок; 2 – корпус пылеуловителя; 3 – пеногенерирующая пористая структура; 4 – распылитель; 5 – пеногасящая пористая структура; 6 – выходной патрубок; 7 – шламосборник; 8 – пузырь; 9 – пеногасящая пористая структура; 10 – газомеханическая пена; 11 – пузыри пены; $m_п$, $m_в$, $m^I_п$, – расходы пены, воздуха (пара)

Газомеханическая пена 10 будет разрушаться от поверхности и в объеме пеногасящей пористой структуры 5 вида 0,4*0,14*0,08. Пузыри пены 11 начнут интенсивно схлопываться в структуре за счет роста сопротивления от основания конуса структуры к его вершине. Микроскопическая пыль, содержащаяся в разрушаемой газомеханической пене, под действием гравитационных сил и сил давления, стекающего из распылителя по поверхности пористой структуры устремится в шламосборник 7.

Газ будет дополнительно очищаться от микроскопической пыли в пеногасящей структуре, где существенно интенсифицируется процесс разрушения газомеханической пены за счет того, что сетки набраны с уменьшающимся размером ячеек.

Это способствует повышению эффективности улавливания микроскопической пыли на ее поверхности и в объеме, за счет чего увеличивается коэффициент захвата пыли и коагулирующая способность разрушаемого пенного потока.

Газ, очищенный от микроскопической пыли, удаляется из аппарата через патрубок отвода очищенного газа 6.

Опыты показали [8, 12], что по сравнению с фильтрующими материалами, такими как металлокерамика и спеченные порошки, расход пенообразующего раствора сокращается в (1,5…2) раза при сохранении стойкости, дисперсности и высокократности пены, гидравлическое сопротивление по транспорту пенообразующей жидкости уменьшается в (10…20) раз, газодинамическое сопротивление – в 1,8 раза, что уменьшает мощность насоса и вентилятора (дымососа), материалоемкость и габариты – в (2…2,5) раза, массу установки – в (3…4) раза.

Существенно повышается период между регенерациями и эффективность улавливания микроскопической пыли, которая может достигать значений (99,6…99,8) %, упрощается условия эксплуатации, возрастает надежность пылеуловителя и срок его службы, что подтверждается актами треста «Алма-Атаинжстрой» и Алма-Атинской ТЭЦ-2.

Экономический эффект от внедрения предложенного пылеуловителя будет иметь место за счет сокращения расхода пенообразующего раствора в 1,5÷2 раза, уменьшения гидравлического сопротивления по транспорту пенообразователя в (10÷20) раз, газодинамического сопротивления по прокачке запыленного потока – в 1,8 раза, материалоемкости и габаритов – в 2÷2,5 раза, массы установки в 3÷4 раза. Также упростятся условия эксплуатации аппарата, повысится период работы между регенерациями, а значит, возрастет его надежность и срок службы, что снизит капитальные и эксплуатационные затраты.

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КӨБІК ӨНДІРЕТІН ЖӘНЕ КӨБІК СӨНДІРЕТІН ҚҰРЛЫМДАРЫ БАР АУА (БУ)-МЕХАНИКАЛЫҚ КӨБІКТІҢ БҮРІККІШСІЗ КЕУЕК КӨБІК ГЕНЕРАТОРЫНЫҢ ЭКСПЕРИМЕНТТІК ҚОНДЫРҒЫСЫН ӘЗІРЛЕУ

Аннотация. Таза сұйықтықтарды қайнатумен және қабатты-белсенді заттарды қосумен жылу-салмақ алмастырғыш үдерісті зерттеу негізінде ауа(бу)-механикалық көпірікті бүріккішсіз капиллярлы-борқылдақ көпірік генераторларының жаңа класы әзірленді. Эксперимент нәтижелерін жылыну мен масса тасымалының критикалық теңдеулеріне көбік, поролон жасау, псевдоожолдау және қайнау процестеріне қатысты ±20% дәлдікпен қорытылады. Капиллярлы-бұрқылдақ құрылымдар үшін 3х0,4 түріндегі капиллярлы және салмақты бірыңғай әрекеттер көпірік генераторының жұмыс режимін 1,5-2 есе тездетуге, көпірік қалыптастырушының шығындарын қысқартуға және гидравликалық қақтығысты он есе азайтуға мүмкіндік берді. Корпус, кіру және шығу келте құбырлары, торшалар топтамасы, тозаңдатқыштан тұратын ауа-механикалық көбікке арналған бүркігішсіз көбік генераторлары әзірленді. Олар аз гидро және газдинамикалық қарсылықтарда жоғары тиімділікпен көбік өндіру процестерін жүргізуге мүмкіндік береді. Газ-механикалық көбікті өндіру мен микро және ультрамикроскопиялық тозаңды тұту бірлескен процестерін әрі қарай сәйкестендіру үшін көбік сөндіретін торкөзді кеуекті құрылыммен және қақ жинағышпен жабдықталған корпус, кіру және шығу келте құбырлары, торшалар топтамасы, тозаңдатқыштан тұратын тозаң тұтқыш ұсынылды, бұл ретте көбік өндіретін және көбік сөндіретін құрылымдар корпусқа тозаңдатылған газ қозғылысының бағытын бойлай орнатылды. Бұдан өзге, көбік өндіретін торкөзді кеуекті құрылымның кейінгі торшасы тазартылатын газдың қозғалыс бағыты бойымен ұяшықтардың ұлғаятын өлшемімен, мысалы, саңылауға ұяшықтарының өлшемі: 0,08*0,14*1 болатын метал торлардан, ал көбік сөндіретін торша - тазартылатын газдың қозғалыс бағыты бойымен ұяшықтардың кішірейетін өлшемімен, мысалы, саңылауға ұяшықтарының өлшемі: 0,4*0,14*0,08 болатын метал торлардан орындалды.

Түйін сөздер: борқылдақ көпірік генераторы, көпірік генерациясы, жылу салмақ алмастырғыш, капиллярлы-борқылдақ құрылымдар.

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EXTRACTION OF RARE-EARTH ELEMENTS FROM THE COMPOSITION OF KARATAU PHOSPHORITES

Abstract. Karatau phosphorite concentrate is a perspective and unique raw material for complex processing, which allows to obtain strontium, rare earth metal and fluorine compounds along with the main product - phosphorus fertilizers. In spite of the obvious ecological expediency of complex processing of phosphorite, actually, there is the only industrial scheme involving associated extraction of rare-earth elements, strontium and the utilization of fluorine, based on the decomposition of phosphorite with nitric acid.

This article presents the results of a study of the decomposition of the Karatau phosphorites (Kokzhon and Koksu deposits) with hydrochloric and nitric acids in a ratio of 1: 1, with an increase in temperature to 85-90 °C, for 30 minutes with vigorous stirring. The chemical composition of the products obtained was determined by titrimetric, gravimetric, photocolorimetric, potentiometric methods.

Analysis of the samples showed that the mass fraction of rare-earth elements in the concentrate obtained by extraction with nitric acid was 27%, hydrochloric acid - 36% and the extraction rate of rare-earth elements with respect to their content in phosphorite was 75%. It is possible to obtain 20-36 kg of rare-earth metal concentrate in the processing of 1 ton of phosphorite

Key words: rare earth elements, extraction, phosphorites, decomposition, concentrate.

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ИЗВЛЕЧЕНИЕ РЕДКОЗЕМЕЛЬНЫХ ЭЛЕМЕНТОВ ИЗ СОСТАВА ФОСФОРИТОВ КАРАТАУ

Аннотация. Каратауский фосфоритовый концентрат – перспективное и уникальное сырье для комплексной переработки, позволяющее получить, помимо основного продукта – фосфорных удобрений, соединения стронция, редкоземельных элементов и фтора. Несмотря на явную экологическую целесообразность комплексной переработки фосфорита, в настоящее время существует единственная промышленная схема, предусматривающая попутное извлечение редкоземельных элементов, стронция и утилизацию фтора, основанная на разложении фосфорита азотной кислотой.

В данной статье представлены результаты исследования разложения фосфоритов Каратау (месторождения Кокжон и Коксу) соляной и азотной кислотами в соотношении 1:1, при повышении температуры до 85-90 °С, в течение 30 минут с интенсивным перемешиванием. Химический состав полученных продуктов определяли титриметрическим, гравиметрическим, фотоколориметрическим, потенциометрическим методами.

Анализ полученных образцов показал, что массовая доля редкоземельных элементов в концентрате при извлечении азотной кислотой составила 27%, соляной кислотой – 36%, извлечение редкоземельных элементов в концентрат ~ 75 % по отношению к содержанию в фосфорите. Существует возможность получения 20-36 кг суммы концентрата редкоземельных элементов при переработке 1 т фосфорита.

Ключевые слова: редкоземельные элементы, извлечение, фосфориты, разложение, концентрат.

Введение. Редкоземельные металлы являются одним из наиболее дефицитных и востребованных видов минерального сырья, поскольку используются в различных областях, в том числе в радиоэлектронике, машиностроении, атомной отрасли, химическом секторе, оборонной промышленности и т.д., и глобальный спрос на них многократно превышает предложение [1-4, 13]. Для Казахстана производство редких и редкоземельных металлов является перспективным направлением индустриально-инновационного развития, направленного на создание в стране высокотехнологичных производств высокого передела.

Каратауский фосфоритовый концентрат – перспективное и уникальное сырье для комплексной переработки, позволяющее получить, помимо основного продукта – фосфорных удобрений, соединения стронция, редкоземельных элементов и фтора [5, 6]. Несмотря на явную экологическую целесообразность комплексной переработки фосфорита, в настоящее время существует единственная промышленная схема, предусматривающая попутное извлечение редкоземельных элементов, стронция и утилизацию фтора, основанная на разложении фосфорита азотной кислотой [7].

Цель данной работы – разработка эффективного способа извлечения редкоземельных элементов из состава фосфоритов Каратау.

Методика проведения эксперимента. По физико-химическим свойствам фосфоритная мука месторождений Кокжон, Коксу стандартного помола при влажности 0,1-0,3% имеет объемный вес (в т/м^3): на ленте транспортера 1,1-1,2, свеженасыпанная в вагоны 1,45-1,5 после транспортирования по железной дороге до 1,6 после длительного хранения на складе 1,8-2,0%. Сухая фосфоритная мука Кокжон, Коксу очень подвижна, растекается подобно жидкости, ссыпаясь под углом 15-20^0. Увлажненная до 0,75-1,5% мука теряет текучесть и способна слеживаться.

Было исследовано выделение редкоземельных элементов из фосфоритного концентрата, полученного при переработке фосфоритов Каратау, месторождений Кокжон и Коксу.

До начала основных исследований был проведен рентгенодифрактометрический анализ химического состава исходного фосфорита на автоматизированном дифрактометре ДРОН-3 с $Cu_{K\alpha}$ – излучением, β-фильтр. Условия съемки дифрактограмм: U=35 кВ; I=20 мА; съемка θ-2θ; детектор 2 град/мин. Рентгенофазовый анализ на полуколичественной основе выполнен по дифрактограммам порошковых проб с применением метода равных навесок и искусственных смесей. Определялись количественные соотношения кристаллических фаз. Интерпретация дифрактограмм проводилась с использованием данных картотеки ICDD: база порошковых дифрактометрических данных PDF2 (PowderDiffractionFile2) и дифрактограмм чистых от примесей минералов.

Сущность способа заключается в том, что остаточную твердую фазу подвергают вторичному разложению. Взвешиваютфосфатный редкоземельный концентратмассой1 кг, 200 г мелко измельченнойвторичной пульпы, затем подают в реактор. В эту массу добавляют 3,0 литра 2 н азотной кислоты. Выделение ведут при нагревании для пробы №1 в 2 н азотной кислоте, для пробы № 2 в 2 н соляной кислоте при соотношении Т:Ж - 1: 2,5-3,5 в присутствии щавелевой кислоты, которая необходима в количестве 50 мас. % сверх стехиометрии при пересчете на оксиды редкоземельных элементов, осадок оксалатов отделяют фильтрованием, промывают водой и прокаливают [8-12].

Далее берут мерную колбу объемом 100 мл, приливают 1,0 мл жидкой фазы и разбавляют дистиллированной воде. Из этого раствора берут 5-10 мл аликвоты для химического и физико-химического анализа состава, определение общего азота, нитрита натрия и P_2O_5, оксида кальция и магния, железа, алюминия, хлора и т.д. Твердую фазу сушат сначала при комнатной температуре, затем в сушильном шкафе при температуре 80-85^{0}С и определяют массовую долю влаги.

Были испытаны 2 разные пробы (разложение фосфоритов 2н азотной кислотой и разложение фосфоритов 2н соляной кислотой). В колбу объемом 100 мл приливают 10 мл концентрата, разбавляют дистиллированной водой, хорошо перемешивают. Из этого раствора набирают аликвоту и исследует атомно-эмиссионным спектроскопическим методом на приборе Agilent 4200 MP-AES [8].

Повторно анализируют атомно-эмиссионным спектроскопическим методом на дифракционном спектрографе ДФС-13 с дифракционной решеткой 500 штрихов на мм и линейной дисперсией 0,4 нм/мм, производство – Россия. Возбуждение спектров проводилось в дуге электрического тока силой 14, регистрация спектров в ультрафиолетовой области от 230 нм до 345 нм осуществлялась на фотопластинки ПФС-03, чувствительные в этом интервале длин волн. В качестве образцов сравнения использовались ГСО 8670-2005 (СГД-2А), ГСО 3484-86 (СГХМ-2). Исследования проводили в научно–исследовательском институте геологических наук им. К. И. Сатпаева в г. Алматы.

Результаты исследований. В фосфорите Каратау содержится до 5-7% редкоземельных элементов, которые при сернокислотном вскрытии на 70% переходят в осадок сульфата кальция. Кроме редкоземельных элементов осадок содержит небольшие количества фторид- и фосфат-ионов. Полученный осадок, это – отход производства минеральных удобрений [14-20], носящий название "фосфогипс", образует целые горы вокруг заводов по переработке фосфоритов Каратау (в г. Таразе).

Таблица 1 – Результаты полуколичественного рентгенофазового анализа кристаллических фаз исходного фосфорита

Минерал	Формула	Концентрация, %
Гипс	$Ca(SO_4)(H_2O)_2$	43.5
Кварц	SiO_2	33.8
Бассанит	$CaSO_4{\cdot}0.5H_2O$	19.8
Слюда	$KAl_2(AlSi_3O_{10})(OH)_2$	2.9

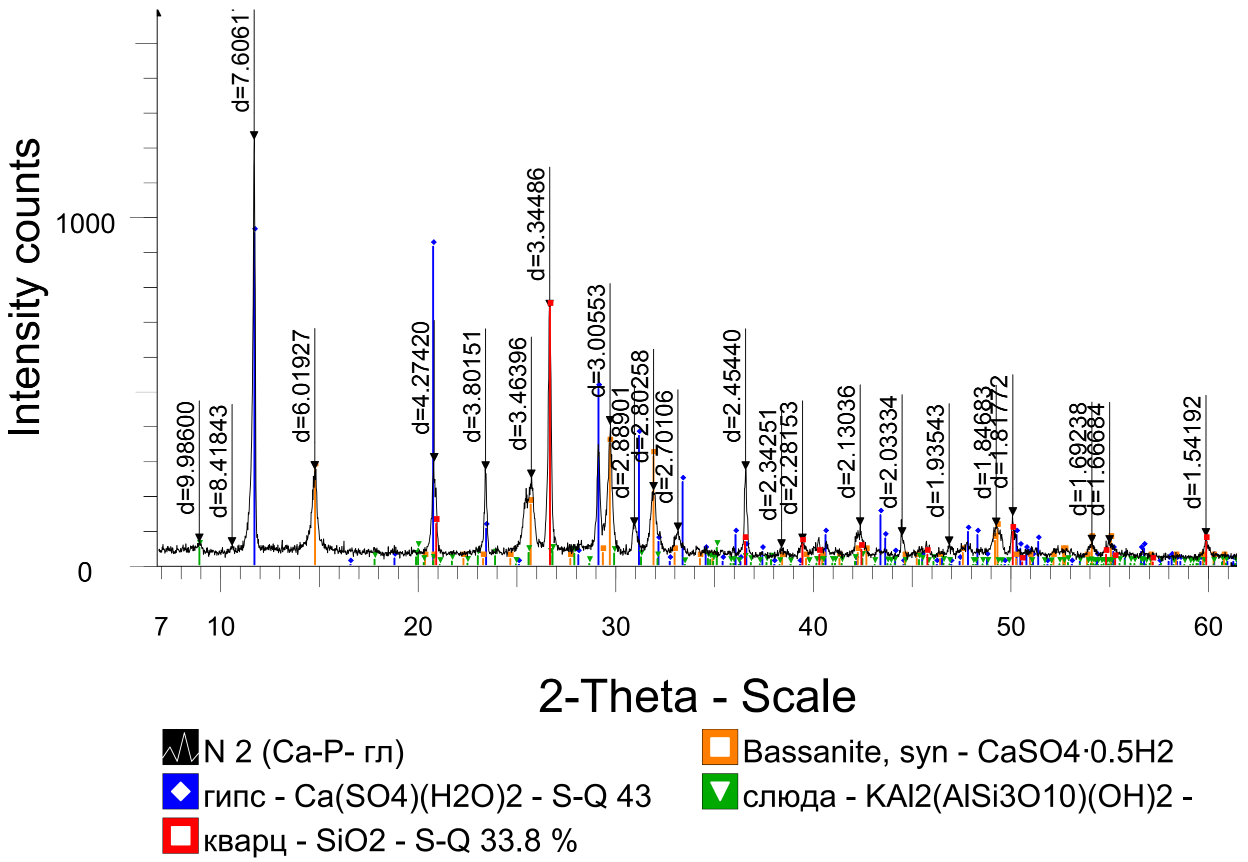

Рисунок 1 –Дифрактограммаобразца исходного фосфорита (Са – Р – гл)

Таблица 2 – Определение содержания редкоземельных элементов в составе фосфоритов Каратау методом атомно-эмиссионной спектроскопии на приборе Agilent 4200 MP-AES

№ н/п	Наименование пробы	Метка элемента, нм	Концентрация	Единица измерения	SD	%, RSD
1	Проба №1. Разложение фосфоритов 2н HNO_3	Se (196,026)	0,27	Ppm	0,08	29,76
		Zn (213,857)	0,15		0,00	1,68
		Cd (228,802)	0,00		0,00	>100
		Sr (407,771)	8,19		0,03	0,42
		Ba (455,403)	1,48		0,00	0,20
		Cu (324,754)	0,06		0,00	0,48
		Ni (352,454)	0,31		0,00	0,61
		As (193,695)	0,73		0,22	29,81
		Co (340,512)	0,53		0,01	1,06
		Pb (405,781)	-0,12 mu		0,00	1,75
		Mo(379,825)	0,08		0,00	1,05
		Mn(403,076)	17,73 o		0,05	0,29
		Cr (425,433)	0,27		0,01	2,47
		Al (396,152)	13,70 o		0,79	5,78
2	Проба №2. Разложение фосфоритов 2н HCl	Se (196,026)	-0,28 u		0,12	43,27
		Zn (213,857)	0,25		0,00	0,83
		Cd (228,802)	0,00		0,00	>100,00
		Sr (407,771)	10,28		0,05	0,49
		Ba (455,403)	0,36		0,00	0,19
		Cu (324,754)	0,12		0,00	0,23
		Ni (352,454)	0,23		0,00	0,60
		As (193,695)	0,75		0,35	46,98
		Co (340,512)	-0,02u		0,00	5,48
		Pb (405,781)	-0,27 mv		0,01	2,24
		Mo(379,825)	0,05		0,00	4,17
		Mn(403,076)	20,44		0,03	0,14
		Cr (425,433)	0,43		0,04	9,69
		Al (396,152)	73,34 o		5,64	7,69

Из таблицы видно, что при разложении фосфоритов минеральными кислотами, эффективно вскрывает соляная кислота (2н HCl). По содержанию элементов, например Se - 43,27 против 29,76; As - 46,98 против 29,81; Cr - 9,69 против 2,47 и т.д.

Из таблицы 3 видно, что при вторичном разложении пульпы остаются ценные элементы, которые могут быть использованы в качестве удобрений.

ИК-спектроскопическим методом были исследованы пробы вторичных концентратов фосфоритов Каратау, разложенных в азотной и соляной кислоте. На рисунке 2 наблюдаются слабо выраженные полосы, характерные для фосфорной кислоты с частотами 2319 $см^{-1}$, средне выраженные полосы, характерные для нитрат-ионов с частотами 694 $см^{-1}$, 729 $см^{-1}$, 879 $см^{-1}$.

На ИК-спектрах растворов, полученных разложеннием фосфоритов Каратау соляной кислотой (рисунок 3), наблюдаются средне выраженные полосы, характерные для фосфорной кислоты с частотами 2144 $см^{-1}$, 2403 $см^{-1}$, а также слабо выраженные полосы 2673 $см^{-1}$, соответствующие фосфорной кислоте.

Таблица 3 – Сводные данные по химическому анализу вторичных концентратов фосфоритов Каратау, разложенных в азотной и соляной кислоте

№ п/п	Содержание массовой доли, %													
	Вла-ги	P_2O_5	Cl^-	C_2H_2	SO_4^{2-}	F^-	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	Общ азот	$NaNO_2$	NO_3^- ион
2 н HNO_3 (жидкая фаза)	–	1,9	7,92	0,0112	2,06	0,77	20,9	0,145	0,014	0,03	0,002	4,23	2,07	17,4
2 н HNO_3 (твердая фаза)	9,17	0,13	2,64	0,114	2,06	1,52	11,4	0,0207	0,014	0,02	0,06	1,29	1,93	0,02
Суммарный выход, %	–	2,03	10,52	0,1252	4,12	2,29	32,3	0,1657	0,028	0,05	0,062	5,52	4,00	17,42
2 н HCl (жидкая фаза)	–	0,8	61,8	0,0082	2,06	0,42	23,46	0,103	0,028	0,03	0,003	1,53	2,06	–
2 н HCl (твердая фаза)	8,28	0,5	7,92	0,152	2,26	1,615	22,83	0,014	0,014	0,01	0,06	2,23	2,08	–
Суммарный выход,%	–	1,3	69,72	0,1602	4,32	2,035	46,29	0,117	0,042	0,04	0,063	3,76	4,14	–

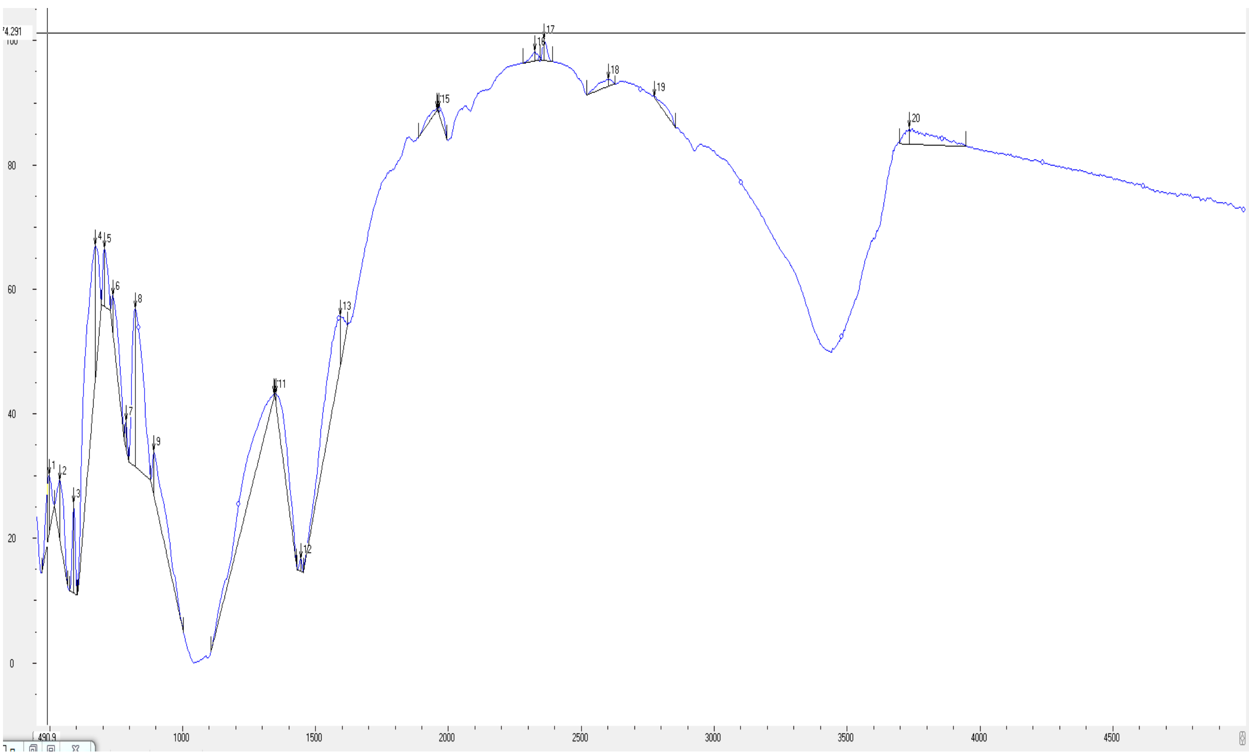

Рисунок 2 – ИК-спектры растворов, полученных разложением фосфоритов Каратау азотной кислотой. Ось абсцисс – частота колебаний (см$^{-1}$), ось ординат – пропускание (%)

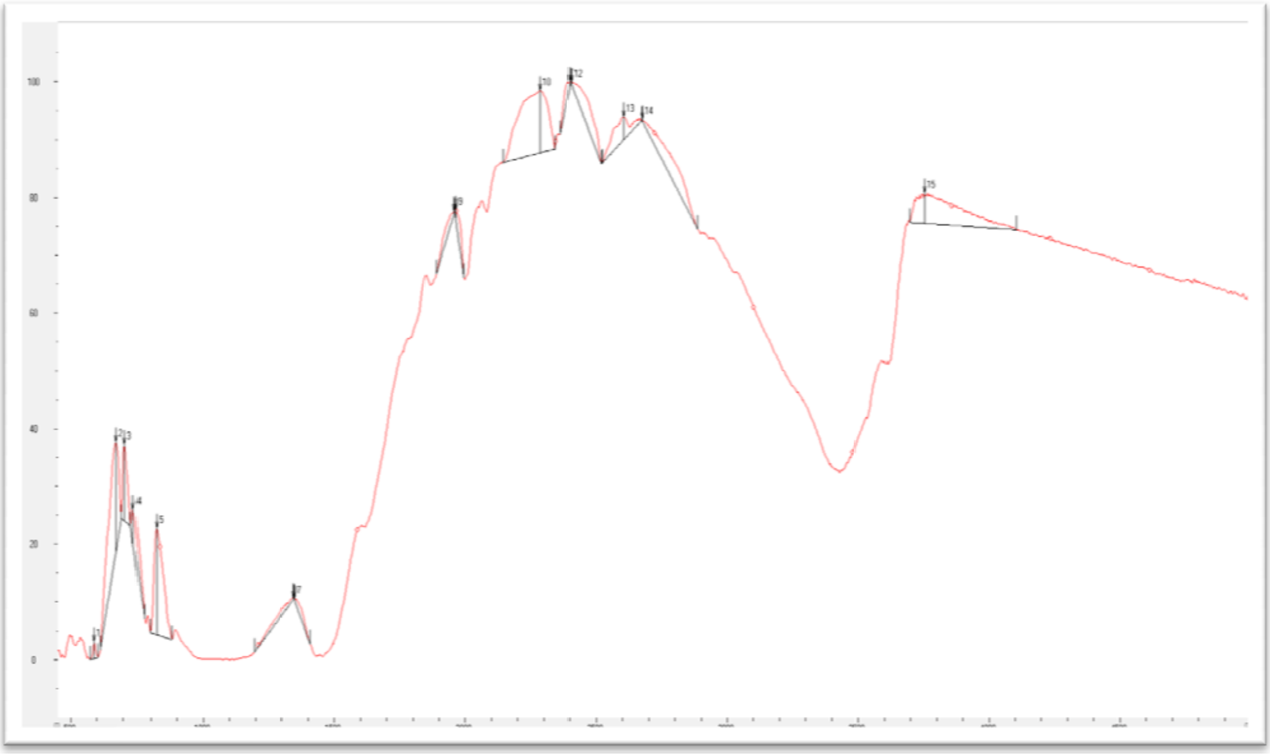

Рисунок 3 – ИК-спектры растворов, полученных разложением фосфоритов Каратау соляной кислотой. Ось абсцисс – частота колебаний (см$^{-1}$), ось ординат – пропускание (%)

Результаты химического и физико-химического анализа жидкой и твердой фазы продуктов, полученных разложением фосфоритов Каратау азотной и соляной кислотами, подтверждают и дополняют друг друга и показывают, что основным продуктом являются фосфаты, нитраты и хлориды кальция. В составе продукта также имеются редкоземельные элементы с массовой долей 23-36% по отношению к исходному содержанию в фосфорите.

Выводы. Результаты исследования химического состава показали, что в составе фосфоритов Каратау имеются редкоземельные элементы в пределах Se - 23,0-29,76%, Zn - 0,5-1,68%, Sr - 0,42-2,0%, Ba - 0,20-2,8%, Cu - 0,48-3,6%, Ni - 0,61-0,75%, As - 29,81-32,0%, Co - 1,06-2,10%, Pb - 1,75-2,0%, Mo - 0,8-1,05%, Mn - 0,29-0,35%, Cr - 2,47-3,8%, Al - 5,78-7,9% Y-(иттрий) - 0,007-0,15%, Yb-(иттербий) - 0,005-0,7%, La-(лантан) - 0,025-0,15%, Ce-(церий) - 0,05-0,30%, Gd-(галолиний) - 0,002%, Nd-(неодим) - 0,04-0,05%, Sm-(самарий) - 0,01%, Eu-(европий) - 0,001%, Tb-(тербий) - 0,005%, Dy-(диспрозий) - 0,01%, Ho-(гольий) - 0,001%, Er-(эрбий) - 0,01%, Lu-(лютеций) - 0,001%, Tm-(тулий) - 0,0001-0,10%, Pr-(празеодим) - 0,02% идр.

Исходные фосфориты Каратау содержат 23,23 % суммы РЗЭ (в пересчете на оксиды) содержание массовой доли % CaO, P_2O_5, а также соединения железа и алюминия. При переработке 1 т фосфорита можно получить около 20-36 кг суммы концентрата редкоземельных элементов. Содержание массовой доли редкоземельных элементов при вскрытии соляной кислотой - 36%, азотной кислотой - 27%. Извлечение РЗЭ в концентрат ~ 75 % по отношению к содержанию в фосфорите.

Источник финансирования исследования. Инициативный проект «Исследование и разработка технологии улавливания аммиака и переработки фосфогипса в производстве аммофоса с получением концентрата редкоземельных элементов» кафедры «Химия и химическая технология».

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ҚАРАТАУ ФОСФОРИТТЕРДІҢ ҚҰРАМЫНАН СИРЕК-ЖЕР ЭЛЕМЕНТТЕРДІ БӨЛІП АЛУ

Аннотация. Қаратау фосфорит концентраты – кешенді қайта өңдеуге қажетті перспективалық және бірегей шикізат, одан фосфорлы тыңайтқыш сияқты негізгі өнімнен басқа, стронцийдың қосылыстары, сирек жер элементтерін және фторды алуға мүмкіндіктері бар. Фосфоритті кешенді қайта өңдеудің айқын экологиялық негіздемесіне қарамастан, қазіргі уақытта сирек жер элементтерін, стронцийды және фторды жолай бөліп алу үшін жалғыз өндірістік сызбасы бар, ол фосфоритті азот қышқылымен ыдыратуға негізделген.

Бұл мақалада Қаратау (Көкжон, Көксу кен орындары) фосфориттерін тұз және азот қышқылдарымен ыдыратуын ара-қатынасы 1:1, температураны 85-90^{0}С дейін жоғарылатқанда, 30 минут аралығында қарқынды түрде араластыру арқылы зерттеу нәтижелері келтірілген. Алынған өнімдердің химиялық құрамы титриметриялық, гравиметриялық, фотоколориметриялық, потенциометриялық әдістермен анықталды.

Алынған нысандардың талдауы бойынша концентраттағы сирек жер элементтерінің массалық үлесі азот қышқылымен бөліп алғанда 27%, ал тұз қышқылымен 36% құрады, сирек жер элементтерін концентраттан бөліп алу ~ 75% фосфориттің құрамындағы қатынасына қарай 1 тонна фосфоритті қайта өңдеу барысында 20-36 кг сирек жер элементтерінің концентрат сомасын алуға мүмкіндігі бар.

Түйін сөздер: сирек жер элементтері, бөліп алу, ыдырату, концентрат.

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GOLD FINENESS AS INDICATOR OF PHYSICAL-CHEMICAL CONDITIONS OF MINERALIZATION AT THE KOKKIYA GOLD DEPOSIT (KYRGYZ RIDGE)

Abstract. The article describes the results of microscopic studies of ores at the Kokkiya deposit. The mineral composition of deposit's ore is determined with the identification of main, secondary and rare minerals. Fineness of gold is determined, the variability of which is determined by depth, as well as the processes of mineral formation from early associations to late ones. The fineness of native gold is accepted as a typomorphic sign by many scientists of the world and indicating the physical-chemical conditions for the formation of gold deposits. Founding rare microminerals also carry basic information about the physical-chemical conditions of ore deposition. Causal relationships between the composition of minerals and the characteristics of mineral-forming processes are revealed, which is the most important task of genetic mineralogy. It is equally important in practical terms for the development of mineralogical forecasting and evaluation criteria.

Key words: gold probability, pyrite, tellurides, gold-concentrating minerals.

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ПРОБНОСТЬ ЗОЛОТА КАК ИНДИКАТОР ФИЗИКО-ХИМИЧЕСКИХ УСЛОВИЙ МИНЕРАЛООБРАЗОВАНИЯ НА ЗОЛОТОРУДНОМ МЕСТОРОЖДЕНИИ КОККИЯ (КЫРГЫЗСКИЙ ХРЕБЕТ)

Аннотация. В статье изложены результаты микроскопических исследований руд на месторождении Коккия. Установлен минеральный состав руд месторождения, с выявлением главных, второстепенных и редких минералов. Определена пробность золота, изменчивость которой определяется глубиной, а также процессами минералообразования от ранних ассоциаций к поздним. Пробность самородного золота принимается многими учеными мира, как типоморфный признак, указывающий на физико-химические условия образования золоторудных месторождений. Найденные редкие микроминералы также несут основную информацию о физико-химических условиях рудоотложения. Выявлены причинно-следственные связи между составом минералов и характеристиками минералообразующих процессов, что является важнейшей задачей генетической минералогии. Не менее важно это и в практическом отношении для разработки минералогических прогнозно-оценочных критериев.

Ключевые слова: пробность золота, пирит, теллуриды, золотоконцентрирующие минералы.

Введение. Месторождение Коккия расположено на северных склонах Киргизского хребта, в пределах Киргизско-Терскейской минерагенической зоны. На территории Республики Казахстан, эта зона включает 6 золоторудных формаций: золото-кварцево-жильная; золото-сульфидно-кварцевая; золото-сульфидно-скарновая; золото-сульфидно-кварц-березитовая; золото-кварц-пропилитовая и золотоносных россыпей.

Месторождение Коккия связано с золото-кварц-пропилитовой формацией и приурочено к породам девонской вулкано-плутонической ассоциации (андезиты, риолиты, и их лавобрекчии). Пространственное размещение их контролируется тектоническими нарушениями и малыми интрузиями сиенитов, сиено-диоритов, монцогранодиоритовсредне-девонского интрузивного комплекса, и, в целом, носит линейно-узловой рисунок. Оруденение приурочено к лавам и лавобрекчиям риолитового состава талдысуского субвулканического комплекса. На эти породы наложены зоны гидротермально-метасоматических изменений и прожилково-жильного окварцевания.

Месторождение Коккия делится на два участка: участок Коккия и участок Южный, расположенные в одной метасоматической зоне. Генетически это руды одного типа, но пространственно разнесены на 2 км.

Северная часть месторождения Коккия располагается в зоне интенсивного гидротермального изменения. Разрывные нарушения разбивают площадь месторождения на многочисленные блоки. Простирание разломов самое разнообразное. Распределение золотой минерализации на месторождении крайне сложное. Выделение рудных тел в пределах внешне однообразной зоны кварц-серицитовых метасоматитов возможно только по результатам анализа проб. Рудные тела выделены по бортовому содержанию 0,3 г/т. Форма тел - линейно-вытянутая в северно-восточном направлении. Падение основных рудных зон - юго-западное под углами 65-75°. Мощность рудных тел в скважинах изменяется от 0,5 до 60 м, в канавах от 1 до 22 м при средней мощности – 5-6 м.

На рудном поле месторождения Коккия намечается следующая вертикальная метасоматическая зональность: возвышенные части рельефа слагают вторичные кварциты, а под ними залегают пропилитизированные породы. Здесь же наиболее полно и широко проявлена серицитовая фация. Количество кварца и серицита в породе изменчиво. С уменьшением количества серицита наблюдается переход в мономинеральные кварцевые породы (монокварциты). С увеличением количества серицита, что обычно характерно для рудных тел, вторичные кварциты переходят в серицит-пиритовые породы (серицитолиты). Серицит, представляющий существенную составную часть кварцитов, нередко частично переходит в гидрослюду и ассоциирует с монтмориллонитом. На серицитовую фацию накладываются метасоматическое и прожилковое окварцевание, хлоритизация и карбонатизация. Кварцевые прожилки содержат хлорит, железистый карбонат, доломит, карбонат и несут полиметаллическую минерализацию в ассоциации с золотом.

Микроскопические исследования позволили выделить следующие зональные фации от периферии к центру: 1) пропилитовая, объединяющая сильно хлоритизированные, серицитизированные, альбитизированные, калишпатизированные, карбонатизированные и пиритизированные породы; 2) каолинитовая; 3) серицитовая; 4) диаспоровая; 5) монокварцевая [1, 2].

Золото-пиритовая минерализация тяготеет к серицитовой фации. Широкое развитие на участке серицитовой фации создало благоприятные предпосылки для проявления золото-серебряной минерализации. Монокварцевая фация развивается внутри серицитовой фации, где образует короткие линзы или желвакообразные стяжения. Мощность линз не превышает первых метров, а протяженность – первых десятков метров. Прочные монокварцитовые породы несут равномерную вкрапленность пирита и выделяются в рельефе положительными формами.

Главные золотоконцентрирующие минералы: пирит, кварц, серицит. Ценным компонентом является самородное золото. К числувторостепенных редко встречающихся относится целый ряд рудных минералов, определяющих геохимическую специфику рудообразования на месторождении (таблица 1). В числе редких особенно следует отметить теллуриды: золота (калаверит), висмута (цумоит), золота и серебра (петцит).

По результатам микроскопических исследований наиболее распространены кварц-серицитовые метасоматиты в различной степени пиритизированные, вплоть до серицитолитов. Значительно редки хлорит-кварц-серицитовые метасоматиты. Среди них серицитолиты наиболее обогащены самородным золотом. Визуально они отличаются присутствием пятен или прожилков

Таблица 1 – Минеральный состав руд месторождения Коккия

Главные	Второстепенные и редко встречающиеся минералы	Ценные и редкие микроминералы
Рудные		
Пирит (несколько генераций)	Халькопирит, Галенит, Сфалерит, Пирротин, Тетраэдрит, Теннатит, Голдфилдит*, Рутил, Ильменит, Касситерит, Магнетит, Гематит, Молибденит, Шеелит Арсенопирит, Ярозит* Ковеллин, Гетит, Гидрогематит, Лейкоксен	Золото Калаверит Цумоит* Петцит* Алтаит Висмутин* Теллуровисмутин Теллур самородный Моусонит? *
Нерудные минералы		
Кварц Серицит	Пирофиллит Кальцит Хлорит Мусковит Барит Каолинит Монтмориллонит	Циркон Монацит Крандаллит* Роговая обманка Сфен Цуниит Альбит Калишпат
*Минералы, установленные при исследовании технологической пробы первичной руды месторождения Коккия.		

пирита светло-желтоватого цвета в массе серицитолита, которые могут переходить в густовкрапленную колчеданную руду. Пятна или прожилки пирита мощностью до 2,5 см. Метасоматиты в различной степени прокварцованы, местами карбонатизирваны.

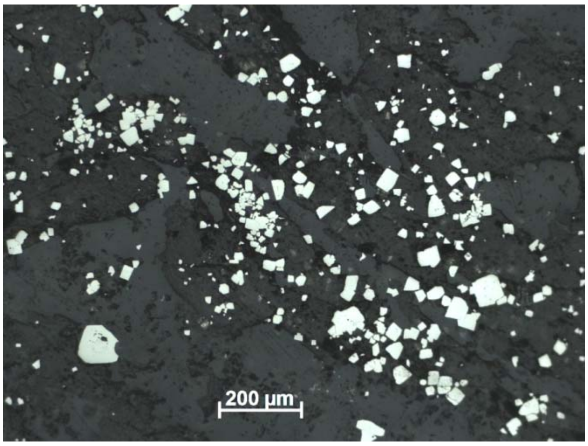
Пирит – главный рудный минерал. Он образует рассеянную вкрапленность в метасоматитах, от редкой до густой. Встречается в виде гнезд и линзовидных выделений размером до 1-2 см. Пирит представлен несколькими генерациями.

Пирит I **–** кубической формы в виде мелкой рассеянной вкрапленности (от 0,01 до 0,05 мм и иногда до 0,1 мм) в массе хлорит-кварц-серицитового метасоматита темно-зеленоватого цвета, приурочен к хлориту и серициту (рисунок 1/1).

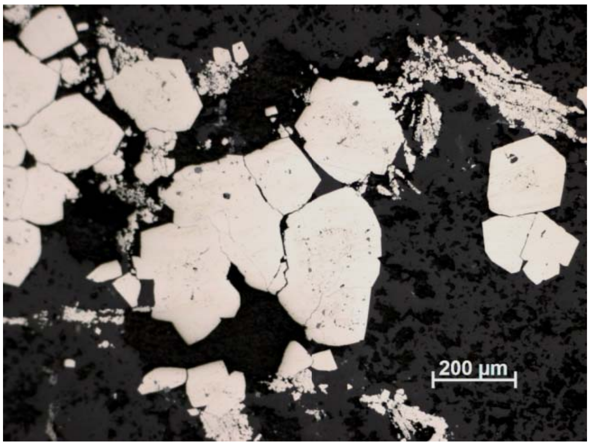
Пирит II – в резко подчиненном количестве, мелкозернистый, в виде прожилковидно-цепочечных образований, развитый по-видимому по неустойчивому марказиту и в результате перекристаллизации переходящий в пентагондодекаэдрический, октаэдрический и реже кубический ***пирит III*** (рисунок 1/2).

Пирит III – пентгондодекаэдрической, октаэдрической, кубической форм в виде вкрапленности и сростков, приурочен преимущественно к серициту, более крупные зерна содержат включения рутила (рисунок 1/3). В пирите III по трещинкам развиваются более поздние халькопирит, галенит, размером от 0,01-0,015 до 0,03 мм. Отмечаются единичные включения арсенопирита в пирите III и сростки молибденита с пиритом в кварце. Отмечается густовкрапленный Пирит III в серицитолите, интенсивно корродированый, пористый, засорен включениями нерудных, по сохранившимся граням пентагондодекаэдрический и кубический. Размер зерен до 0,4 мм. В таком корродированном пирите золото находится в тесных срастаниях с теллуридами золота, серебра и свинца.

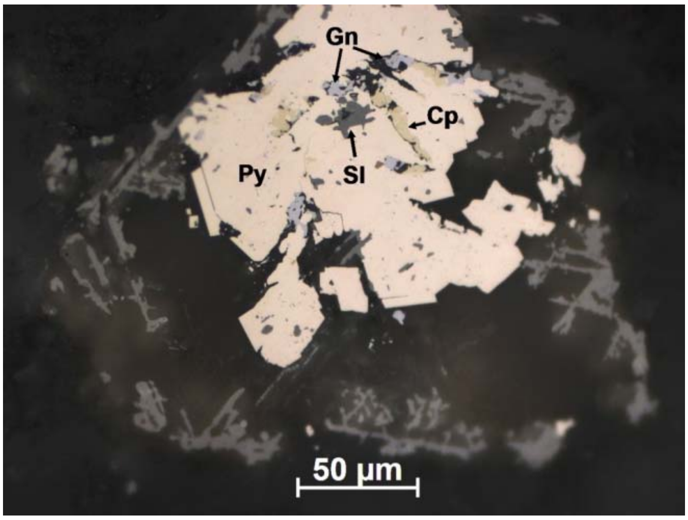
Пирит IV **–** более крупный (от 0,1 до 0,3 мм) в виде сростков иагрегативных выделений в массе метасоматита. Агрегативный пирит разбит трещинками, по которым развиваются более поздние сфалерит, галенит и халькопирит (рисунок 1/3). Сростки и агрегативные выделения пирита размером до 0,5х1,5 и 0,5х2,0 мм.



1



2



3

Рисунок 1 – Пирит в различных генерациях:
1 – Пирит I мелкозернистый кубической формы в хлорите и серицие. Аншлиф 84;
2 – Пирит II прожилковидный и Пирит III пентагондодекаэдрический. Аншлиф 86; 3 – IV агрегативный (Py).
Зерна его замещаются минералами титана. Между зерен его галенит (Gn), халькопирит (Cp) и сфалерит (Sl). Аншлиф 84

Пробность самородного золота издавна привлекала внимание ведущих ученых мира, рассматривающих её как типоморфный признак, обусловленный физико-химическими условиями образования золоторудных месторождений. В частности, В.В. Щербина [3] ещё полвека назад придавала отношению Au/Ag значение геохимического индикатора миграционной способности золота и серебра и причин их геохимической дифференциации в различных геологических процессах. Важность этого параметра, как критерия определенных условий формирования конкретных золоторудных и золото-серебряных месторождений при их классификации и формационной идентификации отмечается в многочисленных работах многих исследователей [4, 5]. Так для пробности самородного золота предложена классификация золоторудных месторождений по шести основным типам. По их оценкам для плутоногенного типа диапазон вариации пробности Au составляет 650–970‰, для порфирового – 650–1000‰, для вулканогенного – 520–870‰, для эпитермального – до 1000‰. Ряд ученых считают, что пробность золота возрастает с увеличением температуры и глубины рудообразования. В частности, И.В. Петровская с соавторами констатирует, что золото в высоко-температурных глубинных месторождениях высокопробное, средне-глубинных – среднепробное, а малоглубинных – изменяется в широком диапазоне и определяется температурным режимом, хотя она и не отрицает существенного влияния на состав Au pH и Eh среды. Другие напротив, на основе детальных исследований по растворимости Au-Ag сплавов считают, что на пробность золота влияют, в основном, кислотность-щелочность гидротермальных растворов и содержание в них серы и лишь в меньшей степени она зависит от температуры, а также окислительно-восстановительный потенциал, состав гидротерм, давление, не приводя при этом достаточного термодинамического обоснования [5, 6]. Существенный вклад в понимание зависимости пробности золота от физико-химических условий рудообразования внесли осуществленные в последнее десятилетие экспериментальные исследования по растворимости золото-серебряных сплавов и проведенное на их основе термодинамическое моделирование совместного переноса и отложения соединений Au и Ag в хлоридных, хлоридно-сульфидных и сульфидных гидротермальных растворах [7, 8]. Но, в основном, они касались лишь систем, равновесных с пирит-пирротиновым буфером.

Иной подход, основывающейся на применении методов физической химии, обоснован фундаментальными исследованиями термодинамики процессов минералообразования корифеев советской и зарубежной геологической науки [9-11]. Они базируются на результатах экспериментального изучения, полученных при этом термодинамических константах и, главным образом, на электрохимическом анализе окислительно-восстановительных процессов образования, миграции и разрушения комплексов золота и серебра в различных по кислотности-щелочности и редокс-потенциалу гидротермальных растворов. Расчет свободной энергии и окислительного потенциала различных комплексов благородных металлов позволяет оконтурить поля их устойчивости на диаграммах Eh – pH и определить ход эволюции гидротермальной системы при формировании золоторудных месторождений. Такие исследования позволяют рассматривать направленность окислительно-восстановительных реакций различных соединений, устойчивость и реакционная способность которых предопределяется Eh – pH гидротермальной системы [12, 13].

Состав минералов служит одним из главных источников информации о физико-химических условиях рудоотложения, поэтому выявление причинно-следственных связей между составом минералов и характеристиками минералообразующих процессов является важнейшей задачей генетической минералогии. Не менее важно это и в практическом отношении для разработки минералогических прогнозно-оценочных критериев.

По данным Н.В. Петровской [3] влияние температуры на вхождение Ag в структуру кристаллизовавшегося золота не является определяющей. Нет также достоверных оснований для вывода о значении общей концентрации Ag в верхних частях зоны гидротермальной деятельности, то есть не наблюдается прямая зависимость пробы золота от богатства месторождений серебром. Кроме того накоплен большой фактический материал, которые противоречит известным выводом А.Е. Ферсмана о закономерном очищении минералов на поздних стадиях рудоотложения (принцип автолизии). В литературе приводится еще один фактор - степень пересыщения растворов, при которой идет кристаллизация данного минерала [14]. Авторы этой работы на основании детального изучения типоморфных особенностей основных минералов золоторудных месторождений пришли к выводу, что между параметрами гидротермальных растворов и конечным результатом (состав минералов) имеет место степень пересыщения растворов, которая регулирует поведение изоморфных примесей.

В лексиконе минералогических и технологических описаний прижились понятия низкопробное и высокопробное золото, заменяющие цифровые обозначения содержаний серебра в минерале (таблица 2). Иногда граница таких содержаний определяется разными исследователями неодинаково. При этом исключен электрум, как особый минеральный вид.

Таблица 2 – Пробность золота (по Н.В. Петровской)

Границы содержаний	Пробность, ‰
Весьма высокопробное, почти чистое	998-951
Высокопробное	950-900
Умеренно высокопробное, средней пробы	899-800
Относительно низкопробное	799-700
Низкопробное	699-600
Весьма низкопробное, высокосеребристое	< 600

Пробность самородного золота на месторождении Коккия. На рисунке 2 золото заключено в пентагондодекаэдрическом пирите III (глубина 60-61 м) хлорит-серицит кварцевого метасоматита. В тесной ассоциации с пиритом III встречены редко встречающиеся на месторождении высокотемпературные молибденит и арсенопирит. Золото ярко-желтого цвета, по отражательной способности его можно отнести к высокопробному золоту (примерно 950‰).

С глубиной (140-143 м) в серицитолитах появляются теллуриды золота, серебра, свинца, находящиеся в тесной ассоциации с золотом самородным и развивающиеся в межзерновых пространствах интенсивно корродированного пирита III.

В аншлифе 11 найдены золотинки: 1) прожилковидной формы (0,01х0,05мм) в сериц　ите по краю крупного корродированного зерна пирита; 2) мелкие неправильной формы в сериците (0,01 мм); 3) в срастании с мелкими зернами пирита в сериците (0,01х0,1); 4) в срастании с мелкими зернами пирита и теллуридами прожилковидной формы (0,01х0,1 мм); 5) в сериците – 0,005х0,025 мм; 6) в срастании с теллуридами и пиритом в сериците (8 зерен неправильной формы – 0,01-0,02х0,03 мм); 7) по краю зерна пирита (0,01 мм); 8) 3 в зерне пирита (0,005-0.01 мм); 9) золото (2 зерна - 0,01-0,02 мм) в срастании с теллуридами между зерен пирита, цементируя пирит; 10) прожилок золота (0,01х0,1 мм) в промежутке зерен пирита в сериците; 11) 2 прожилковидных выделения золота в сериците (0,01х0,05 мм); 12) в срастании с теллуридом и серицитом в пирите (0,01х0,02 мм); 13) прожилковидный в сериците рядом с зерном пирита (0,01х0,06 мм); 14) в срастании с пиритом и между зерен пирита (2 зерна 0,01-0,005х0.01 мм). На рисунках 2-5 показаны золото и теллуриды.

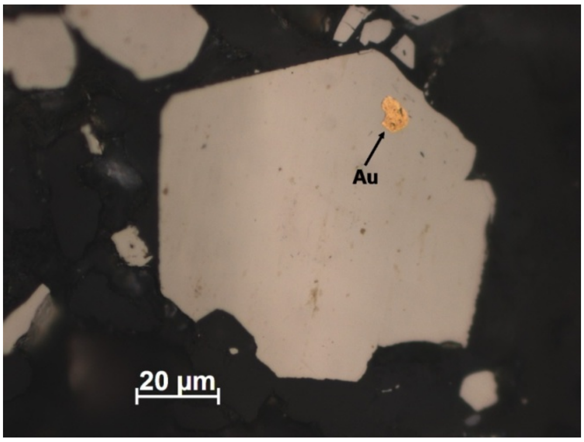


Рисунок 2 – Золото (Au) в зерне пентагондодекаэдра. Аншлиф 38

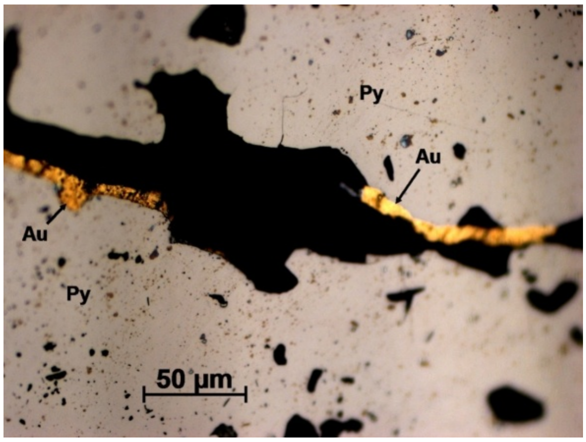


Рисунок 3 – Золото (Au) прожилковидной формы в промежутке зерен пирита или по краю пиритовых зерен (Py) в серицитолите. Аншлиф 11

Калаверит и алтаит – развиваются между зерен пирита, прожилковидной, овальной, призматической формы. Встречаются обособленно в массе метасоматита, в сростках с золотом и пиритом, проникают в пирит, корродируя его. Размеры – до 0,04х0,07 и 0,03х0,1 мм (рисунки 4, 5). Минералы подтверждены аналитически. Кроме того, алтаит встречается в корродированных зернах и сростках пирита, иногда в ассоциации с галенитом.

Пробность золота (рисунки 3, 6) приведена в таблице 3 и выполнена Поповым Ю.В. («Центр исследований минерального сырья и состояния окружающей среды» Южного федерального университета). Растровый электронный микроскоп TescanVegaLMU с системами рентгенофлуоресцентного микроанализа INCAEnergy 450, INCAWave 700 (фирмы OXFORDInstruments Analytical). Железо исключено из результатов расчета. Золото относится к высокопробному (940-944‰).

Результаты, полученные на микрозонде по пробности золота в срастании с теллуридами оказались близкими к выполненным на растровом электронном микроскопе (рисунки 3–5, таблица 4). Золото относится к высокопробному и весьма высокопробному (941 и 977‰).

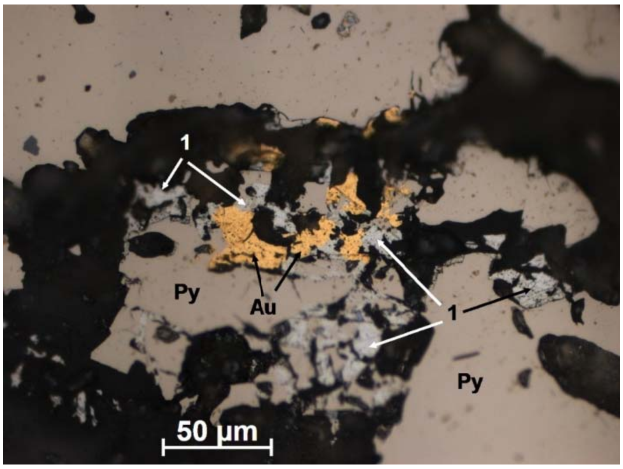


Рисунок 4 – Золото (Au) в срастании с алтаитом, калаверитом (1) и пиритом (Py) в серицитолите. Аншлиф 11

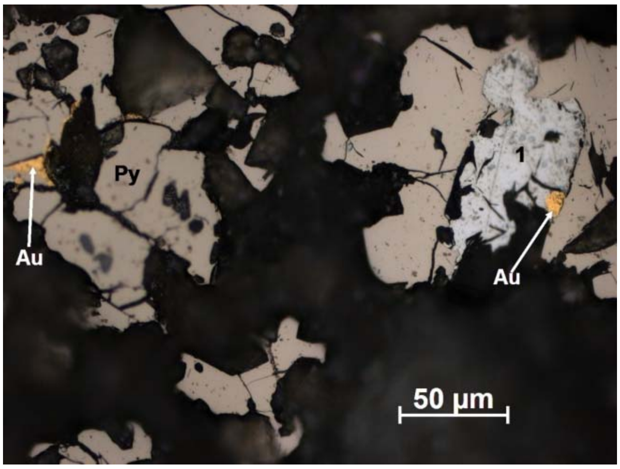
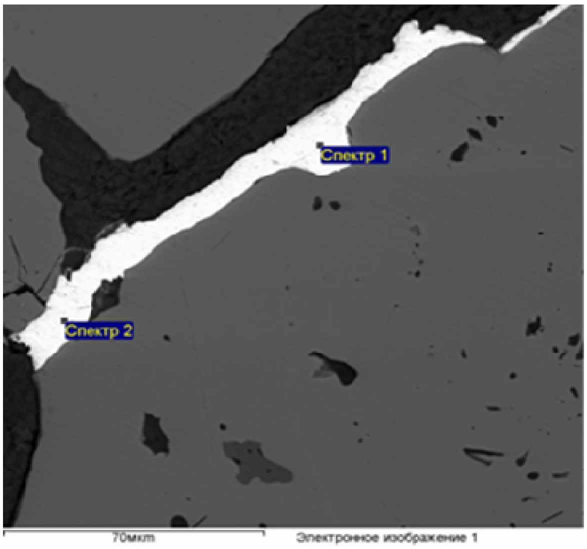


Рисунок 5 – Золото (Au) в срастании с алтаитом (1) и пиритом (Py) в серицитолите. Аншлиф 11



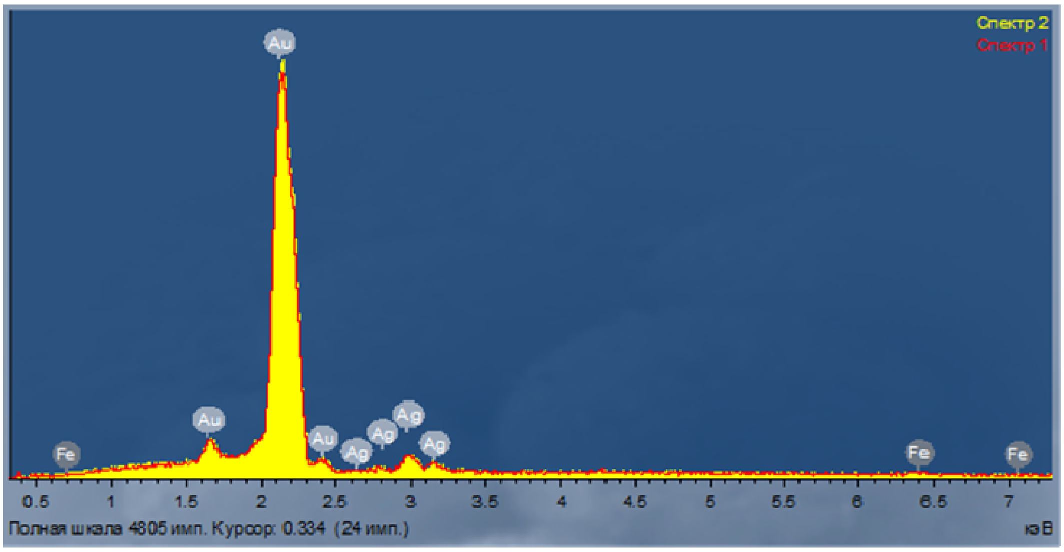


Рисунок 6 – Золото (Au) прожилковидной формы в промежутке зерен пирита или по краю пиритовых зерен (Py) в серицитолите. Аншлиф 11

Таблица 3 – Состав золота по данным растрового электронного микроскопа (вес. %)

Аншлиф 11	Элементы		Сумма	Пробность, ‰
	Au	Ag		
Анализ 1 – Золото прожилковидной формы	93,57	6,0	99,57	940
Анализ 2 – Золото в срастании с алтаитом между зерен пирита	92,60	5,47	98,07	944

Таблица 4 – Состав золота по данным микрорентгеноспектрального анализа (вес. %)

Аншлиф 11 – Золото в срастании с теллуридами (алтаит и калаверит) между зерен пирита, (вес. %)				
Au	Ag	Fe	Сумма	Пробность, ‰
97,04	2,27	0,69	100	977
92,23	5,77	2,0	100	941
*Аналитики В.И. Левин и П.Е Котельников. Анализ выполнен на микрозонде JCXA-733 (Япония).				

Химический состав рудных и жильных минералов изучен при помощи сканирующего электронного микроскопа «S-3700N» оснащенного энергодисперсионным рентгеновским спектрометром (EDS) с микроанализатором в лаборатории Университета имени Адама Мицкевича, Польша (рисунок 7).

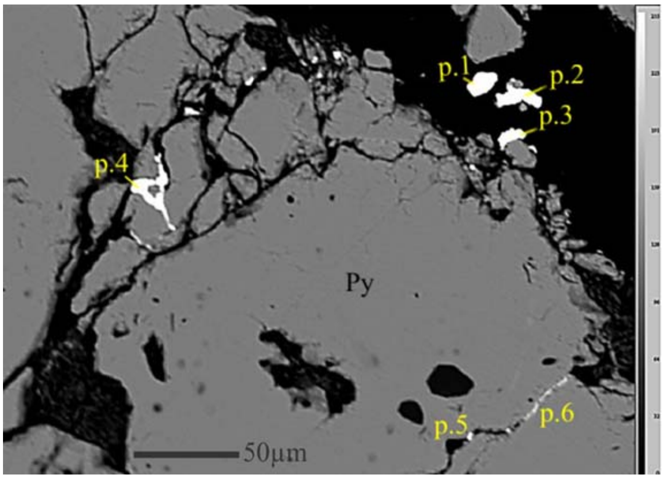


Рисунок 7 – Золото в зернах пирита. Аншлиф 11

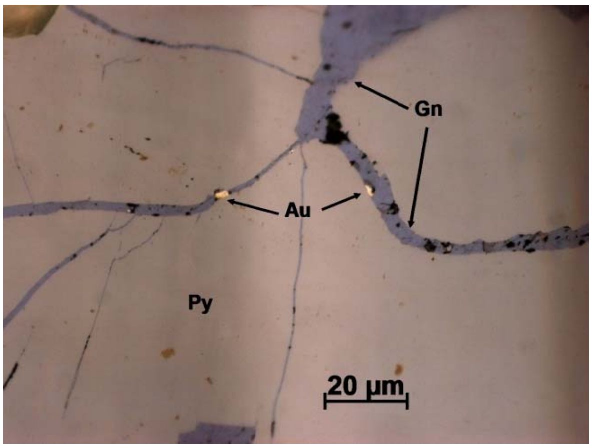


Рисунок 8 – Золото (Au) светло-желтое в галенитовом прожилке (Gn). Py – пирит

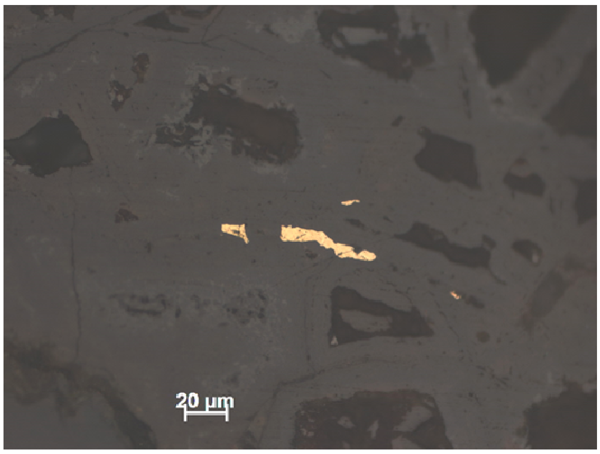


Рисунок 9 – Золото в гидроксидах железа. Аншлиф 194/2

На более глубоких горизонтах месторождения (175-176 м) отмечается появление прожилково-вкрапленной колчеданно-полиметаллической руды в кварц-серицитовом метасоматите, в котором золото тесно ассоциирует с галенитом. Галенит с заключенным в нем золотом развивается в виде тонких прожилков между зерен агрегативного пирита IV (рисунок 8). Золото относится к умеренновысокопробному, среднему (810‰).

На малых глубинах (6-8 м) тонкодисперсное золото, заключенное во вкрапленниках пентагондодекаэдрического пирита IIIв серицитолитах, отличается понижением пробности (таблица 5). Золото относится к низкопробному и относительно низкопробному (634-717‰).

Таблица 5 – Состав золота по данным микрорентгеноспектрального анализа (вес. %)

Аншлиф 199 – Золото в пирите, (вес. %)			
Au	Ag	Сумма	Пробность золота, ‰
71,66	28,34	100	717
63,39	36,61	100	634
*Аналитики В.И. Левин и П.Е Котельников. Анализ выполнен на микрозонде JCXA-733.			

Пирит III на таких малых глубинах (6-10 м) подвержен окислению, а золото, заключенное в нем очищается и становится высокопробным (рисунок 9).

Выводы.

1. Серицитолиты с вкрапленностью пентагондодекаэдрического пирита III являются наиболее золотоносными. Золото концентрируется как в пирите, так и в серните.
2. Золото, связанное с пентагондодекаэдрическим пиритом III высокопробное, однако с уменьшением глубины (6-10 м) содержание серебра, как основного примесного элемента самородного золота увеличивается.
3. С глубиной (140-143 м) пирит III подвергается интенсивному корродированию, становится пористым и самородное золото в тесной ассоциации с теллуридами золота, серебра и свинца проникает в него. Золото высокопробное и весьма высокопробное.
4. Содержание серебра в самородном золоте, заключенном в поздних галенитовых прожилках в агрегативном пирите IV закономерно увеличивается и является характерным для многих золоторудных месторождений.
5. Самородное золото высокой пробы находится в окисленных псевдоморфозах пирита III и в гидроксидах железа.

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КӨКҚИЯ АЛТЫНРУДАЛЫ КЕНОРНЫНЫҢ (ҚЫРҒЫЗ ЖОТАСЫ) АЛТЫН СЫНАМЫ МИНЕРАЛ ЖАРАЛУДЫҢ ФИЗИКАЛЫҚ-ХИМИЯЛЫҚ ЖАҒДАЙЛАРЫНЫҢ КӨРСЕТКІШІ РЕТІНДЕ

Аннотация. Мақалада Көкқия алтын кенорнының рудаларын микроскоптық зерттеу нәтижелері сипатталған. Кенорын рудаларының минералдық құрамы, екінші дәрежелі және сирек минералдары анықталған. Алтын сынамының өзгергіштігі кенорыннның жайға су тереңдігі, сондай-ақ минерал жаралу процестерінің бастапқыдан соңғыға дейінгі сатысы бойынша анықталады. Алтын сынамын әлемнің көптеген ғалымдары алтын рудалы кенорындар жаралуының физикалық-химиялық жағдайларын анықтайтын типоморфтық белгі ретінде қабылдайды. Руда жаралудың физикалық-химиялық жағдайлары туралы негізгі ақпарат береалатын сирек минералдар да анықталған. Минералдардың құрамы мен минерал жаралу процестерінің сипаттамалары аралығындағы себептік-салдарлық байланыстар сипатталған. Бұл анықталғандар практикалық жағынан минералогиялық болжамдық-бағамдық критерийлерді әзірлеу үшін де маңызды.

Түйін сөздер: алтын сынамы, пирит, теллуридтер, алтын шоғырландырушы минералдар.

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TECTONIC AND TECHNOGENIC EARTHQUAKES IN CENTRAL KAZAKHSTAN

Abstract. In the article seismic events of tectonic and technogenic nature in Central Kazakhstan are considered. The characteristic of seismic monitoring of the territory of this region by the seismic network of the Institute of Geophysical Investigations of the Ministry of Energy of the Republic of Kazakhstan is given.

The new instrumental level of monitoring made it possible to obtain and study preliminary statistics on tectonic earthquakes, explosions in quarries, mines, and other technogenic events in Central Kazakhstan, as well as data on the stress-strain state of the deepest parts of the earth's crust.

A retrospective analysis of the features of the manifestation of foci of tectonic and technogenic seismicity on the platform structures of Central Kazakhstan is presented. The parameters of earthquakes in this region, the judgments about the nature of the mechanism of earthquake foci and the types of tectonic movements, maps of isoseism are constructed.

At the same time, it is shown that, in spite of tangible progress in the study of seismic events in Central Kazakhstan, some technical and methodological issues have not been developed in the long run, and work on this continues.

Key words: earthquake, focal mechanism, seismic stations, aftershock, magnitude, epicenter, isoseist.

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ТЕКТОНИЧЕСКИЕ И ТЕХНОГЕННЫЕ ЗЕМЛЕТРЯСЕНИЯ В ЦЕНТРАЛЬНОМ КАЗАХСТАНЕ

Аннотация. В статье рассмотрены сейсмические события тектонической и техногенной природы в Центральном Казахстане. Приводится характеристика сейсмического мониторинга территории этого региона сейсмической сетью Института Геофизических Исследований Министерства Энергетики Республики Казахстан.

Новый инструментальный уровень мониторинга дал возможность получить и изучить по Центральному Казахстану представительную статистику по тектоническим землетрясениям, взрывам в карьерах, шахтах и др. техногенным событиям, а также данные о напряженно-деформированном состоянии глубоких частей земной коры.

Представлен ретроспективный анализ особенностей проявления очагов тектонической и техногенной сейсмичности на платформенных структурах Центрального Казахстана. Изучены параметры землетрясений в этом регионе, высказаны суждения о природе механизма очагов землетрясений и типах тектонических подвижек, построены карты изосейст.

Вместе с тем, показано, что, несмотря на ощутимый прогресс в изучении сейсмических событий в Центральном Казахстане, все еще не получили должного развития некоторые вопросы технического и методического характера, работа над которыми продолжается.

Ключевые слова: землетрясения, фокальный механизм, сейсмические станции, афтершок, магнитуда, эпицентр, изосейста.

Введение. Центральный Казахстан традиционно считался асейсмичным, где не ожидаются сейсмические события с интенсивностью по шкале MSK-64 более 5.

Исходя из этих представлений сеть сейсмологических станций, была размещена в Южном, Юго-Восточном и Восточном Казахстане, по которым составлялись в текущем режиме каталоги землетрясений.

По Центральному Казахстану каталоги землетрясений не составлялись, поскольку специальные сейсмологические наблюдения здесь не проводились.

Однако в связи с созданием новой современной высокотехнологичной системы наблюдений за землетрясениями и промышленными взрывами взгляд на сейсмичность Центрального Казахстана изменился.

Применение этих сейсмических станции, отличающиеся высокой чувствительностью, позволило выявить ряд очаговых зон в районах, ранее не привлекавших внимание сейсмологов и изменить точку зрения на геодинамику этого региона Казахстана.

Все это можно рассматривать как лейтмотив для изучения очагов землетрясений в Центральном Казахстане, актуальность которого очевидна, поскольку сами по себе они несут в себе потенциальную угрозу расположенным рядом промышленным и гражданским объектам, проживающему в этих районах населению [3].

Вместе с тем, необходимо отметить, что изучение природной сейсмичности в этом регионе затруднено из-за её низкого уровня. Примерно на таком же энергетическом уровне здесь регулярно возникают сейсмические события, генерируемые многочисленными взрывами на карьерах, промышленных объектах и полигонах.

Помимо «промышленных взрывов» изучение природных геодинамических и сейсмотектонических процессов в Центральном Казахстане осложняет также техногенная сейсмичность, источники которой возникают в земной коре при воздействии на нее инженерной деятельности человека, в частности, при добыче нефти и газа, извлечении руды, угля и других минеральных ресурсов, при строительстве дорог, гидротехнических сооружений и т.д.

В целях идентификации природы различных сейсмических событий проводятся специальные научные исследования, направленные на распознавание класса источников возмущения геологической среды. Для этого используются самые разные признаки - особенности волновой картины записей землетрясений и карьерных взрывов, корреляционный и спектральный анализы, привлекают независимые данные космофотоснимки и др.

В настоящей статье анализируются сильные землетрясения, зарегистрированные станциями ИГИ МЭ РК на территории Центрального Казахстана и включенные в сейсмические бюллетени национальной и глобальных служб. Кроме того, рассмотрена техногенная сейсмичность в этом регионе, связанная с интенсивной разработкой месторождений твердых полезных ископаемых.

Характеристика системы сейсмического мониторинга территории Центрального и Юго-Восточного Казахстана. За последние 20 лет в Казахстане создана новая современная сеть высокотехнологичных сейсмических станций, интегрированных в Международные глобальные сети мониторинга.

Эта система, в первую очередь, создавалась для обеспечения контроля за выполнением Договора о всеобъемлющем запрещении ядерных испытаний (ДВЗЯИ) в Казахстане, подписавшего этот договор в 1996 г. и ратифицировавшего в 2001 г.

В течение 1994–2006 гг. по ряду международных соглашений построены и введены в строй новые сейсмические группы и трехкомпонентные станции, расположенные в основном по периметру слабо сейсмичных территорий Казахстана [4, 5].

На рисунке 1 показана схема расположения станций ИГИ РК МЭ, данные с которых в режиме реального времени поступают в Центр данных KNDC (Kazakh National Data Center) в г. Алматы. Такая сеть позволяет вести мониторинг сейсмических событий, как на территории Казахстана, так и за его пределами.

Сведения о сильных землетрясениях в Центральном Казахстане.

Шалгинское землетрясение 2001 г. Шалгинское землетрясение было зарегистрировано станциями ИГИ РК и изучено специальной экспедицией, работавшей в эпицентральной зоне.

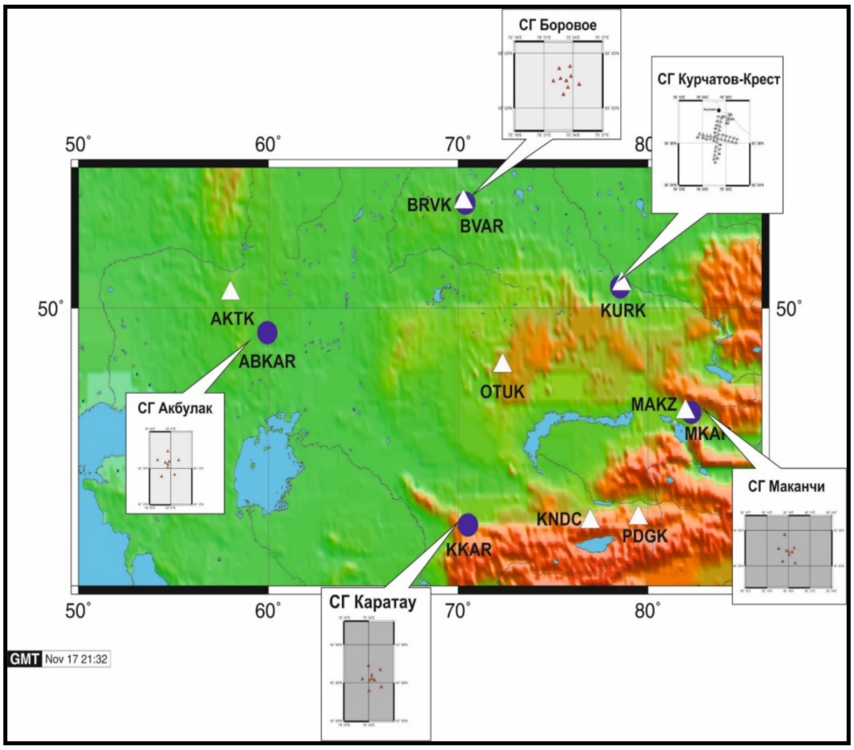

Рисунок 1 – Расположение станций на территории Казахстана, данные с которых поступают в KNDC
Условные обозначения: кружки – сейсмические группы, треугольники – трехкомпонентные станции.
В отдельных сносках показана конфигурация сейсмических групп.

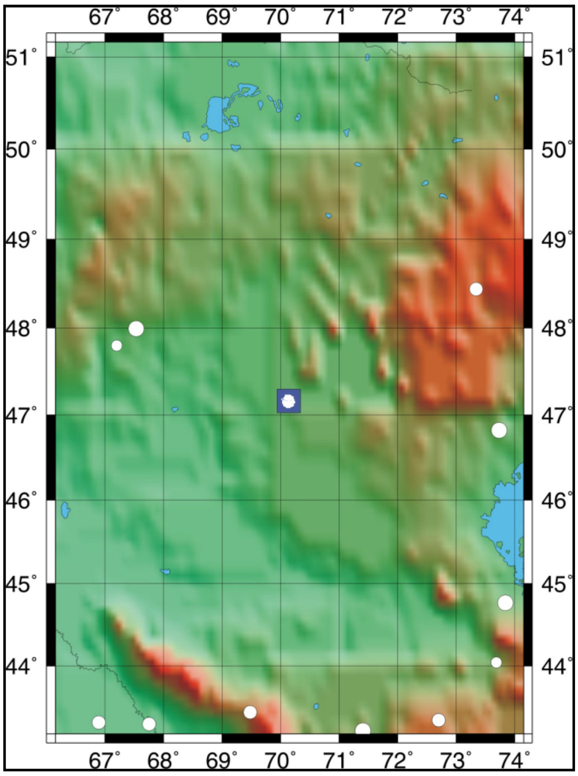

Рисунок 2 – Карта эпицентров землетрясений Центрального Казахстана по каталогу
Международного сейсмологического центра ISC.
Квадрат на карте – эпицентральная зона Шалгинского землетрясения.

Основные параметры землетрясения. Эпицентр Шалгинского землетрясения располагался на западной границе Центрально-Казахстанского свода, вблизи пересечения Жалаир-Найманского сдвига с поперечным региональным разломом, с которым связаны и эпицентры афтершоков [6].

На карте эпицентров землетрясений, построенной по каталогу ISC - Международного Сейсмологического Центра (1964-2006 гг.), непосредственно вблизи эпицентра Шалгинского землетрясения не отмечено эпицентров других землетрясений (рисунок 2).

Интенсивность сотрясений в эпицентральной области составило 6 баллов по шкале MSK-64.

Определения гипоцентра Шалгинского землетрясения по разным службам лежат в области с апертурой 30 км (±15 км от истинного эпицентра) и, по-видимому, обладают реальной точностью для этого района (рисунок 3).

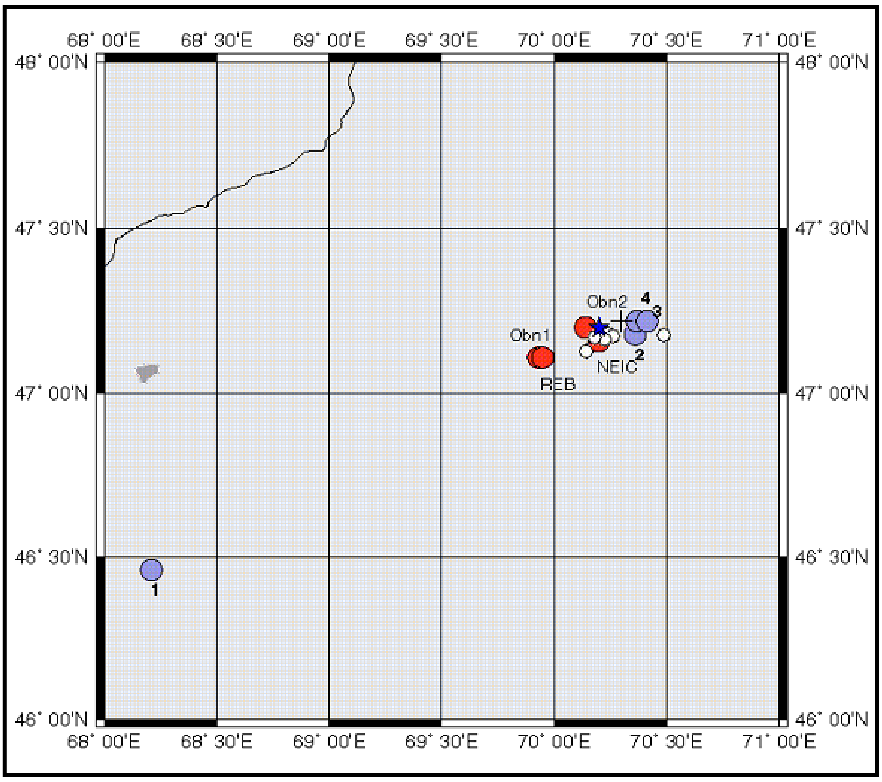

Рисунок 3 – Результаты определения эпицентров главного толчка и афтершоков.
Условные обозначения: 1 – автоматическое определение (KNDC); 2 – определение оператором (KNDC) по данным, поступившим в реальном времени; 3 – по сети станций ИГИ (KNDC); 4 – по сети станций ИГИ и KNET (Кыргызстан). Obn1 – срочная обработка в ИСЦ «Обнинск»; Obn2 – окончательное определение ИСЦ «Обнинск»; REB – определение Международного сейсмологического Центра (IDC); NEIC – определение Геологической службы США.
Крестик – макросейсмический эпицентр; звездочка – инструментальный эпицентр,
незалитые кружки – афтершоки Шалгинского землетрясения.

Окончательные параметры главного толчка этого землетрясения с учетом данных разных Международных Центров представлены в таблице 1.

Таблица 1 – Окончательные инструментальные параметры Шалгинского землетрясения

Дата	Время в очаге	Широта, N	Долгота, E	Глубина, км	M_s	MPV	K
22.08.01	15.57.57,7	47,20	70,20	19	5,0	5,4	13,2

Макросейсмические исследования. Были начаты спустя 6 суток после основного толчка землетрясения. Экспедицией из г. Алматы обследовано более 10 населенных пунктов. Небольшое количество последних объясняется тем, что эпицентр события находится в малонаселенном районе Центрального Казахстана.

Наиболее близко к эпицентру расположен поселок Шалгинский – 43 км, где землетрясение ощутили и наблюдали большинство жителей, находившихся как в помещениях, так и вне их. В ряде населенных пунктов (Агадырь, Кызылтау, Каражал) землетрясение вызвало 5 балльные колебания.

В результате макросейсмического обследования примерное положение макросейсмического эпицентра может быть описано следующими координатами: 47.17° северной широты и 70.30° восточной долготы (рисунок 3).

По результатам обследования была построена карта изосейст этого землетрясения [6], на которой наблюдается четкая вытянутость изосейст в северо-восточном направлении, согласующимся с ориентированным в том же направлением разломом, ортогональным к разломам главного северо-западного направления в регионе (рисунок 4).

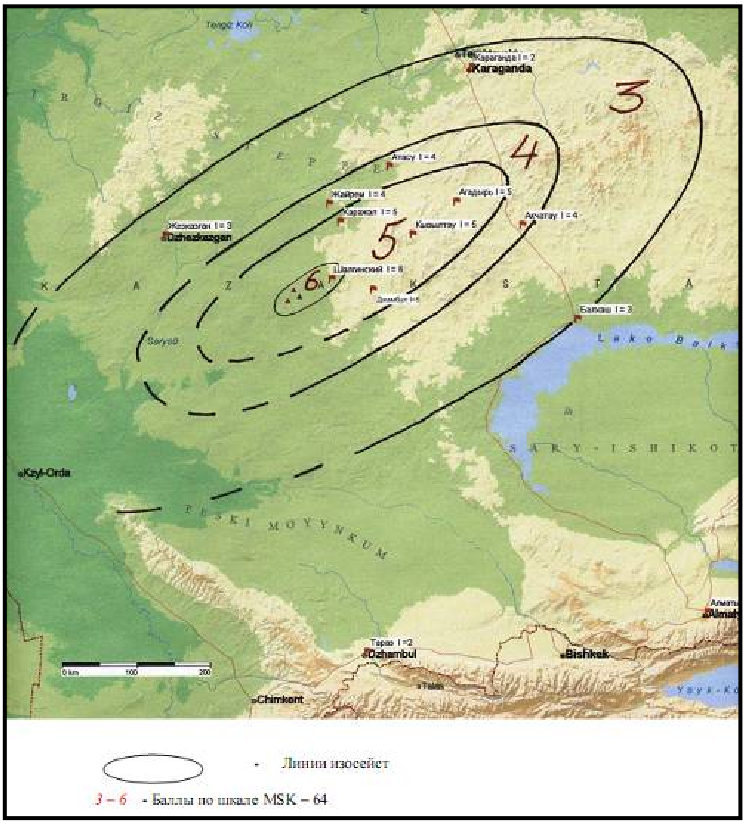

Рисунок 4 – Карта изосейст Шалгинского землетрясения 22.08.2001 г. (по А. И. Неделкову)

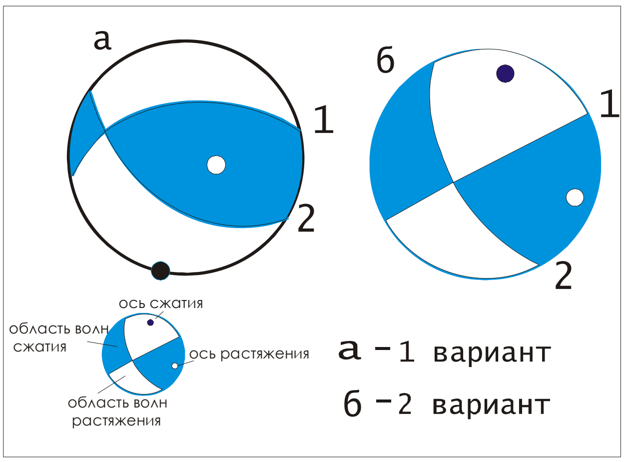

Рисунок 5 – Стереограммы механизма очага Шалгинского землетрясения 22.08.01

По стереограмме механизма очага для этого землетрясения в двух вариантах на рисунке 5 можно сделать следующие выводы: 1. Шалгинское землетрясение реализовано в условиях сжатия в северо-восточном направлении и растяжения субширотном. 2. В очаге произошло смещение блоков в виде правостороннего сдвига по простиранию плоскости северо-восточного направления, что согласуется с ориентацией разлома, к которому приурочен очаг[7].

В эпицентральной области с 25.08.2001 г. были выставлены временные полевые сейсмические станции. Удалось зарегистрировать шесть слабых афтершоков на глубинах 5-15 км, параметры которых представлены в таблице 2.

Таблица 2 – Основные параметры афтершоков Шалгинского землетрясения

№ п/п	Дата	Время в очаге, T_0	Широта, φ°, N	Долгота, λ°, E	Глубина, км	Mpva	K
1	8/22/2001	18-37-01.0	47.18	70.24	15	3.0	6.8
2	8/31/2001	05-18-21.4	47.1754	70.2631	11.5		
3	8/31/2001	22-53-59.8	47.1648	70.2264	5		
4	9/01/2001	19-53-47.6	47.1782	70.4873	15		
5	9/04/2001	22-35-56.4	47.1711	70.1780	7		
6	9/07/2001	08-53-24.8	47.1273	70.1393	10		

Самый сильный афтершок был зарегистрирован примерно через три часа после основного толчка. Его энергетический класс составил 6,8. Остальные афтершоки намного слабее первого. Определить их энергетические характеристики не удалось. Афтершоковая активизация происходила вдоль плоскости разлома северо-восточного простирания.

Шалгинское землетрясение показало, что существующая карта общего сейсмического районирования не дает полной картины о сейсмической опасности в Центральном Казахстане.

По этой карте не был предсказан очаг с силой проявления 6 баллов, не были показаны сейсмогенерирующие зоны с таким сейсмопотенциалом. Эта информация послужила материалом для учета в новой разрабатываемой карте общего сейсмического районирования территории Казахстана.

Карагандинское землетрясение 21 июня 2014 года.

Основные параметры землетрясения. Карагандинское землетрясение зарегистрировано всеми сейсмическими станции сети ИГИ РК. Надо отметить, что сильное землетрясение в Центральном Казахстане с эпицентром на север от г.Алматы – событие редкое. Здесь, также как и в Северном Казахстане регистрируются промышленные карьерные взрывы, связанные с разработкой полезных ископаемых.

Наиболее близкая к эпицентру станция ИГИ Ортау находилась на расстоянии примерно 160 км. Записи получены также на станциях Боровое (432 км), Курчатов (426 км) и других более далеких станциях, которые входят в мировые глобальные сети станций. Их данные автоматически передаются в международные центры – Европейский EMSC в Париже, в Американский NEIC, в Международный сейсмологический центр в Англии ISC (рисунок 6).

Землетрясение было обработано в KNDC и в других международных центрах данных. Решения разных центров по определению эпицентра землетрясений практически совпадают. Координаты эпицентра варьируют в пределах сотых долей градуса с магнитудой mb=4.8–5.2 и глубиной h=9-20 км (таблица 3).

Сразу же после события стали поступать сведения о том, что Карагандинское землетрясение ощущалось в ряде населенных пунктов. Наиболее близким к эпицентру по предварительным данным оказался г. Абай, расположенный в 10 км на северо-запад от эпицентра. Город Караганда находился в 33 км от эпицентра с расчетной интенсивностью 4-5 баллов. Землетрясение ощущалось в г. Астана с силой 2 балла.

Эпицентр землетрясения был расположен на северной границе Казахского щита, вблизи южной границы карагандинского каменноугольного бассейна. В тектоническом плане он приурочен к северной границе Успенской зоны смятия северо-восточного простирания шириной до 90 км, ограниченной субпараллельными тектоническими разломами.

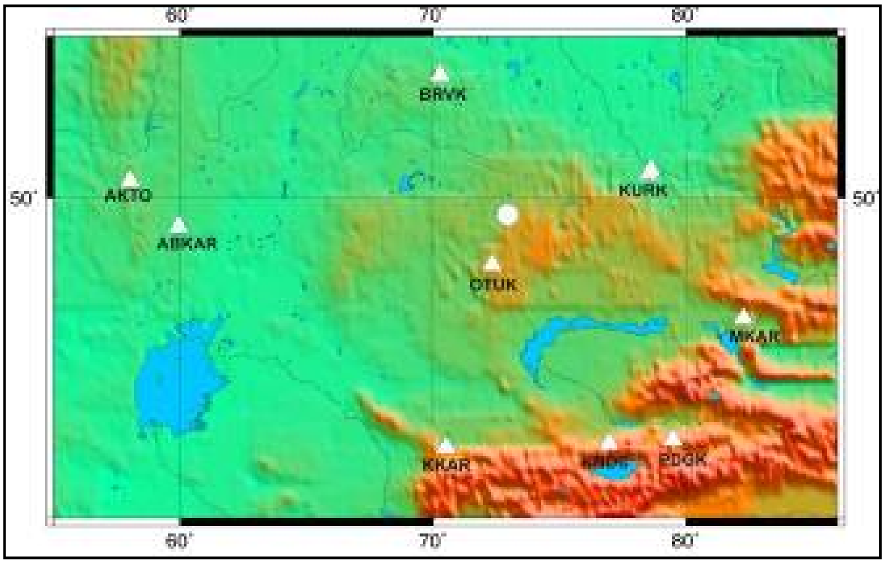

Рисунок 6 – Расположение сейсмических станций ИГИ (треугольники) относительно эпицентра землетрясения 21 июня 2014 года (кружок)

Таблица 3 – Основные параметры землетрясения близ г. Караганды

Источник	Широта, с.ш.	Долгота, в.д.	to, ч/м/с	mb	K	H, км
EMSC (Франция)	49.57	72.9	6:30:04.3	4.8		17
ГС РАН (Россия)	49,53	72,98	6:30:02.8	5.0	12	20
РК (KNDC+СОМЭ)	49,56	72,97	6:30:03.4	5.2	11,7	9

Встал вопрос о природе этого реального события. Является оно тектоническим или техногенным? Не связано ли оно с интенсивными в этом районе работами на угольных шахтах?

Макросейсмические обследования. Эпицентральной территории землетрясения проведено через неделю, с 28 июня по 3 июля (ИГИ РК; Великанов А. Е. и Узбеков А. Н.).

Обследования были проведено путём объезда 34 населённых пунктов на территории радиусом чуть больше 100 км вокруг эпицентра произошедшего землетрясения и составления анкетированных опросов для установления фактической балльности в посещённых пунктах по шкале сейсмической интенсивности MSK-64. Маршруты объезда населённых пунктов совпали с основными направлениями автодорожных трасс, расходящихся в различных направлениях от областного центра г. Караганды.

Для этого землетрясения был определен фокальный механизм очага по первым смещениям P-волн, зарегистрированным 15 сейсмическими станциями. О надежности решения фокального механизма свидетельствует согласованность знаков, составляющая 100%, а также область разброса определяемых параметров, не превышающая 10^0.

По результатам решения механизма очага землетрясение, оно было реализовано в условиях субмеридиональной ориентации оси напряжения сжатия и субширотной, полого погружающейся оси напряжения растяжения. В условиях регионального поля напряжения, под действием которого в очаге произошел разрыв, согласующийся с динамикой и ориентацией главных линеаментов района региона, можно сделать вывод, что это тектоническое землетрясение.

Тип тектонической подвижки в очаговой зоне характеризуется горизонтальным сдвигом с небольшой взбросовой составляющей. Ориентация одной из плоскостей согласуется с региональным разломом северо-восточного направления, отмеченного на схеме к югу от эпицентра [8].

Другая возможная плоскость разрыва согласуется с ориентацией локальных разломов, секущих структуры в северо-западном направлении. Отметим, что подобный тип механизма очага является характерным для очагов землетрясений Казахского щита (Шалгинского, Жезказганских и Семипалатинского полигона).

В то же время, следует сказать, что не исключена возможность провоцирования такого землетрясения активной взрывной деятельностью в рядом расположенном карьере. Класс таких индуцированных землетрясений еще называют природно-техногенным [8].

Резюмируя вышеизложенное, необходимо добавить, что сейсмические процессы в Центральном Казахстане продолжается. Отметим, что недавно 20 сентября 2017 года сейсмическими станциями ИГИ РК было зарегистрировано землетрясение, которое произошло в 08 часов 44 минуты по времени Астаны (в 02 часа 44 минуты по Гринвичу), эпицентр которого расположен на расстоянии 190 км к востоку от г. Караганда. Координаты эпицентра: 50.18^0 градуса с.ш., 75.70^0 градуса в.д. Магнитуда mb=3.8. Энергетический класс K=8,7. Глубина h = 13 км (рисунок 7). Выяснение генезиса и механизма этого землетрясения находится в стадии изучения. Ближайший населённый пункт Коянды в 40 км. Кояндыская землетрясение.

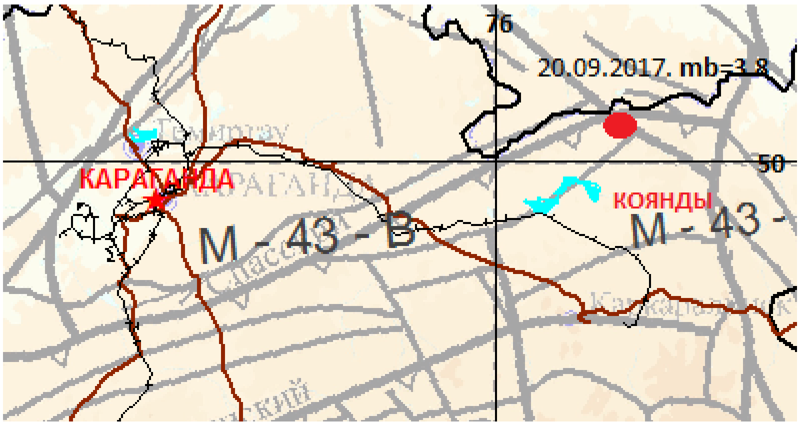

Рисунок 7 – Эпицентр землетрясения 20 сентября 2017 г.

Техногенные землетрясения в Центральном Казахстане. Связаны с интенсивной разработкой месторождений твердых полезных ископаемых. Примером таких сейсмических событий может рассматриваться землетрясения на месторождении меди Жезказган.

Длительная разработка данного месторождения (более 60 лет) привела к существенным геодинамическим изменениям в геологической среде, которые проявились мощными техногенными землетрясениями. Самое сильное из них, с mb=4.8, Ms=4.5, произошло 1 августа 1994 г. на территории карьера Златоуст-Беловский, вблизи г. Жезказган (рисунок 8).

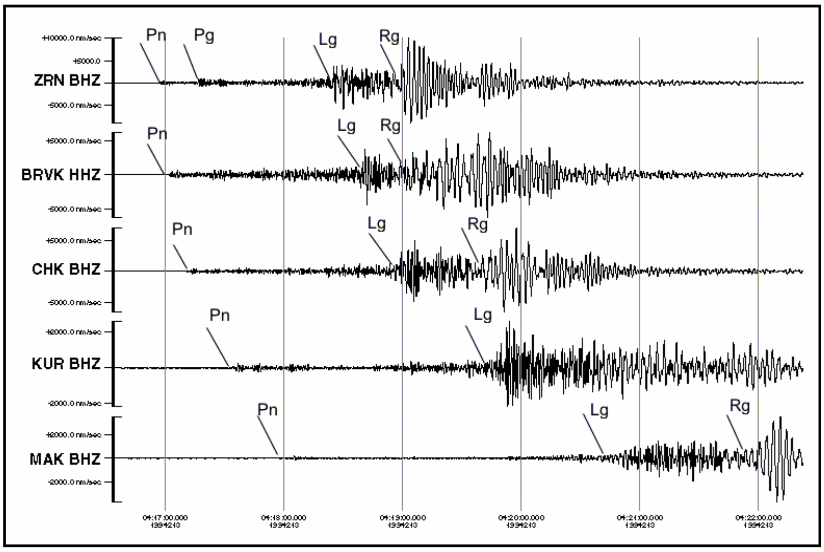

Рисунок 8 – Сейсмические записи события 1 августа 1994 г. Район Жезказгана.
t_0=04-15-39.7, φ=47.833°, λ=67.451°, mb=4.8, K=12.2. Станции ИГИ. Z-компонента

Это крупномасштабное обрушение унесло жизнь 6 человек и вызвало разрушение множества действующих подземных выработок и зданий на поверхности. Последствия землетрясения практически привели к полной остановке работ на одном из рудников, закрытию ряда шахт и переносу поверхностных строений из опасной зоны. Были искорежены рельсовые пути, опрокинуты вагоны [10, 11].

На рисунке 9 приведена схема обрушения налегающей толщи с выходом на дневную поверхность [10].

Другое сейсмическое событие техногенной природы, произошедшее 23.06.1996 г. в районе Жезказганского месторождения (M_s=3.7), ощущалось ощущалось на значительных расстояниях; в поселке Каражал (эпицентральное расстояние Δ=243 км), поселке Агадырь (Δ=398 км) с интенсивностью 3 балла и т.п.

Станциями ИГИ РК зарегистрированы также сейсмические события техногенной природы 09.09.2002 (Ms=4.4) и 23.06.2005 (Ms=4.0) вблизи г. Жезказган. На рисунке 10 показаны эпицентры, а в таблице 4 приведены параметры сильных землетрясений с энергетическим классом 9.4-12.2 произошедших в этом районе.

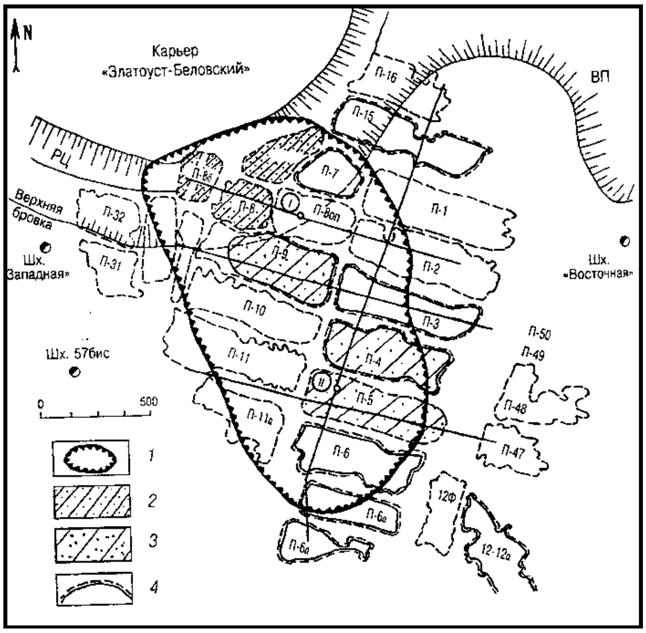

Рисунок 9 – Карьер Златоуст-Беловский Жезказганского месторождения.
Схема реализации процесса обрушения, произошедшего 1 августа 1994 г.
Условные обозначения: 1 – контур обрушения,
2-4 – панели соответственно заложенные, частично заложенные и ослабленные [9]

Таблица 4 – Параметры техногенных сейсмических событий вблизи г. Жезказган

Дата	t_0	φ°,N	λ°,E	h	mpva	Ms	K
01.08.1994	04:15:39.7	47.833	67.451	0	4.8	4.5	12.2
17.07.1995	19:08:30.9	47.973	67.699	0	3.9		10.4
23.06.1996	18:28:25.8	47.8643	67.618	0	4.3		10.9
01.08.1996	00:06:04.5	47.9284	67.6856	0	4		10.4
09.09.2002	22:27:01.3	47.873	67.573	0	4.6	3.8	11.0
23.06.2005	18:00:07.6	47.9059	67.4092	0	4.1	3.5	10.4
16.01.2009	22:18:29.8	47.8672	67.4203	0	3.7		9.4
19.03.2009	19:08:46.6	47.934	67.6777	0	4.3		10.4
11.06.2009	06:05:49.9	47.8672	67.5424	0	3.9		10.3

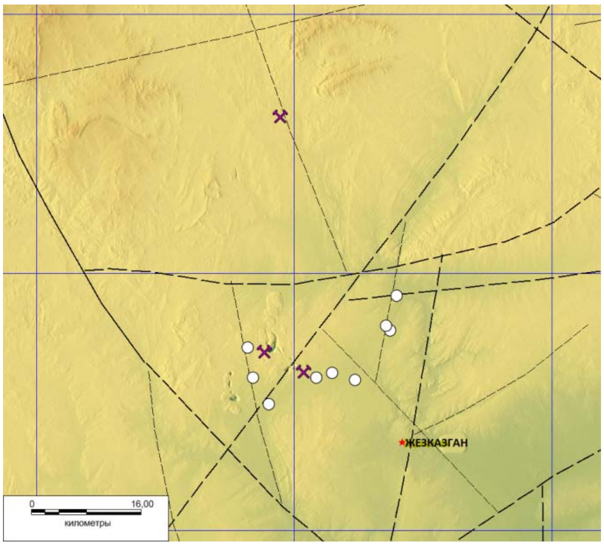

Рисунок 10 – Карта расположения эпицентров сейсмических событий в районе Жезказганского месторождения.
Условные обозначения: пунктирная линия - разрывные нарушения;
кружок - эпицентр события по данным KNDC, скрещенные молоты - карьер.

В связи с вышеизложенным, для детального анализа происходящих в Центральном Казахстане сейсмических процессов недостаточно привлечение только региональных сейсмических станций. Необходимо проводить специальный мониторинг на разрабатываемых месторождениях полезных, чтобы заметить закономерности подготовки сильных техногенных землетрясений, а также регистрировать происходящие здесь карьерные и шахтные взрывы.

Заключение. На основании проведенных исследований:

– Новый инструментальный уровень мониторинга дал возможность получить представительную статистику по тектоническим землетрясениям, взрывам на карьерах и в шахтах, техногенным событиям в Центральном Казахстана.

– Выявлены особенности проявления очагов землетрясений в платформенных структурах и освещен вопрос о природе сейсмических событий в Центральном Казахстане.

– Показано, что, несмотря на ощутимый прогресс в изучении сейсмических событий в Центральном Казахстане, все еще не получили должного развития некоторые вопросы технического и методического характера, работа над которыми продолжается.

К примеру, обобщение всех сейсмологических данных по произошедшим землетрясениям, сопоставление этой информации с геологическими и тектоническими данными позволит установить связь конкретных очагов с тектоническими процессами в каждой сейсмогенерирующей зоне, а также определить характер действующих в регионе напряжений.

Выявление таких связей очень важно для исследования считавшихся ранее асейсмичных районов Центрального Казахстана.

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ОРТАЛЫҚ ҚАЗАҚСТАНДАҒЫ ТЕХНИКАЛЫҚ ЖӘНЕ ТЕХНОГЕНЦИЯЛЫҚ ЕРЕЖЕЛЕР

Аннотация. Мақалада Орталық Қазақстанда тектоникалық және техногендік сипаттағы сейсмикалық оқиғалар қарастырылған. Қазақстан Республикасы Энергетика министрлігінің Геофизикалық зерттеулер институтының сейсмикалық желісі бойынша осы аймақтың аумағын сейсмикалық бақылау сипаттамасы келтірілген.

Мониторингтің жаңа аспаптық деңгейлері Орталық Қазақстанда тектоникалық жер сілкінісі, карьерлерде, кеніштерде және басқа да техногендік оқиғалардағы жарылыстар туралы статистикалық мәліметтерді және жер қыртысының ең терең бөліктерінің стресс-күйі туралы мәліметтерді алуға мүмкіндік берді.

Орталық Қазақстанның платформалық құрылымдарында тектоникалық және техногендік сейсмикалық факторлар көріністерінің ерекшеліктерін ретроспективті талдау ұсынылды. Осы аймақтағы жер сілкінісінің параметрлері зерттелді, жер сілкінісі ошақтарының механизмі және тектоникалық ауысулардың түрлері туралы пікірлер жасалды, изосейлік карталар жасалды.

Сонымен қатар, Орталық Қазақстанда сейсмикалық оқиғаларды зерттеуде елеулі прогреске қарамастан кейбір техникалық және әдістемелік мәселелер әлі күнге дейін тиісті түрде дамымаған және олар бойынша жұмыс жалғасуда.

Түйін сөздер: жерсілкіну, фокал механизмі, сейсмичкалық станциялар, афтершок, магнитуда, эпицентр, изосейста сызығы.

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APPLICATION OF SYSTEMS APPROACH TO PROGNOSTICATION OF ORE FIELDS IN LOCAL AURIFEROUS NIDALSTRUCTURES (on the example of Vera-Char - Baladzhalnidal structure in West-Kalbinsk gold-bearing area of East Kazakhstan)

Abstract. Vera-Char - Baladzhalnidal structure (NS) of the rank of the ore site is identified by the author as a promising regional research level, the estimated gold resources in it are estimated at 574,361 kg. As a result of a detailed study, to which this article is devoted, the prospective areas are localized to the rank of ore fields and deposits.

Based on the paradigm of a systemic approach to the formation of gold deposits, the Vera-Char-Baladzhal focal structure was reconstructed, regularities in the location of deposits were established in its boundaries and three promising areas for the formation of large fields were identified: the Baladzhal predicted ore field, Vera-Char forecast ore field and the Marinovsko-Kyzyltas predicted ore field. Their total area is 37.5 km^2 or 5.8% of the area of predictive research.

Keywords: prognosis researches, gold deposits, nidal structure, magmatic formation, metasomatic changes, Western – Kalbinskgold-field.

УДК 553.411

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ПРИМЕНЕНИЕ СИСТЕМНОГО ПОДХОДА ПРИ ПРОГНОЗИРОВАНИИ РУДНЫХ ПОЛЕЙ В ЛОКАЛЬНЫХ ЗОЛОТОНОСНЫХ ОЧАГОВЫХ СТРУКТУРАХ (на примере Вера-Чар - Баладжальской очаговой структуры в Западно-Калбинском золотоносном районе Восточного Казахстана)

Аннотация. Вера-Чар - Баладжальская очаговая структура (ОС) ранга рудного узла выделена автором в качестве перспективной на региональном уровне исследований, прогнозные ресурсы золота в ней оценены в 574 361 кг. В результате детального изучения, которому посвящена данная статья, перспективные площади локализованы до ранга рудных полей и месторождений.

На основе парадигмы системного подхода к формированию золоторудных месторождений произведена реконструкция Вера-Чар - Баладжальской очаговой структуры, в ее пределах установлены закономерности размещения месторождений и выделено три перспективных для формирования крупных месторождений участка ранга рудных полей: *Баладжальское прогнозное рудное поле,Вера-Чарское прогнозное рудное поле и Мариновско-Кызылтасское прогнозное рудное поле.* Их общая площадь которых составляет 37,5 км^2 или 5,8% от площади прогнозных исследований.

Ключевые слова: прогнозные исследования, золоторудные месторождения, очаговые структуры, магматические образования, метасоматические изменения, Западно-Калбинский золотоносный район.

Актуальность расширения сырьевой базы золотодобывающей промышленности Казахстана не вызывает сомнения. Очевидно, что решение этой задачи невозможно без высокоэффективных прогнозных исследований. Данная статья посвящена результатам использования системного подхода при прогнозировании золоторудных месторождений на территории Западно-Калбинского золотоносного района в Восточно-Казахстанской области – одного из старейших районов золотодобычи в Республике.

Западно-Калбинский золотоносный район, расположенный на северо-западном фланге Западно-Калба-Коксентауской структурной зоны, вытянут в северо-западном направлении более чем на 300 км при ширине от 80 до 150 км. Особенности его геологического строения описаны предшествующими исследователями [1 и др.]. Золоторудные месторождения изучены В.А. Нарсеевым и др. [2]; Дьячковым Б.А. и др. [3]; М.С. Рафаиловичем [4], В.А. Глобой [5, 6] и другими специалистами. По их представлениям, они принадлежат золото-мышьяково-углеродистому (Бакырчик, Большевик); золото-сульфидному-кварцево жильному (Жумба, Кулуджун и др.); комплексному золото-кварц -березитовому (Баладжал) типам.

На территории описываемого района прогнозные исследования в 1950 – 90 годах выполнены Б.А. Дьячковым, А.А. Малыгиным, В.В. Потылицыным, А.П. Ситниковым и другими. В качестве основных факторов локализации золотого оруденения рассматривались литолого-стратиграфические, магматические, метаморфические, структурно-тектонические, минералого-геохимические и геофизические.

В 2000 году коллективом авторов [1] прогноз разнотипных золоторудных месторождений был выполнен на основе методов объемного моделирования. Достоинством этих исследований является разработка типовых моделей рудообразующих систем (РОС) золоторудных месторождений. Основными составляющими модели РОС являются магматический очаг, обусловленные его развитием малые интрузии и рудоносные флюиды, тяготеющие к надинтрузивной зоне. Аналогична геолого-геофизическая модель Бакырчикского рудного поля, разработанная [7]. По их представлениям, связь с магматогенно-рудными системами характерна для всех золоторудных объектов Западно-Калбинского района.

Представления этих авторов об однотипности рудоконтролирующих структур согласуются с данными [8, 9] о том, что локальные площади развития эндогенного оруденения контролируются однотипными по своей природе наложенными тектоно-магматическими структурами очагового характера, которые фиксируются продуктами их деятельности - разнофациальными магматическими, гидротермально-метасоматическими (в том числе рудными) образованиями. Подобное сочетание элементов литосферы в современном понимании - магматогенно-рудная система, обладающая свойствами, не вытекающими из суммы свойств ее частей, в связи с чем ее реконструкция должна проводиться на основе методологии системного анализа, принципы которого изложены в многочисленных работах [10, 11].

Использованная автором методика прогнозных исследований, опирающаяся на парадигму системного анализа и описанная ранее [12], включает следующие последовательные процедуры: реконструкция магматогенно-рудной системы на основе количественной оценки структуры развития ее элементов с использованием методики С.В. Васильева [13], выявление структурных и статистических закономерностей размещения "эталонных" золоторудных объектов в системе и выделение перспективных площадей на основе выявленных закономерностей.

На региональном уровне исследований, в результате которых выделена описываемая Вера-Чар - Баладжальская ОС, в качестве рудогенерирующего фактора рассмотрены малые интрузии разного состава и возраста; в качестве "следов" воздействия сквозьмагматических флюидов - разномасштабные золоторудные объекты; в качестве рудоподводящих элементов - зоны смятия, выделенные по космогеологическим данным. Цель детального изучения, результаты которого изложены ниже, локализация перспективных площадей до размеров рудных полей и месторождений

Вера-Чар - Баладжальская ОС расположена в юго-западном борту Западно-Калбинского золотоносного района (рисунок 1). Прогнозные ресурсы золота в ней оценены в 574 361 кг. Площадь, охватывающая описываемую структуру с обрамлением и оцениваемая на стадии локального прогноза - 673,7 км^2.

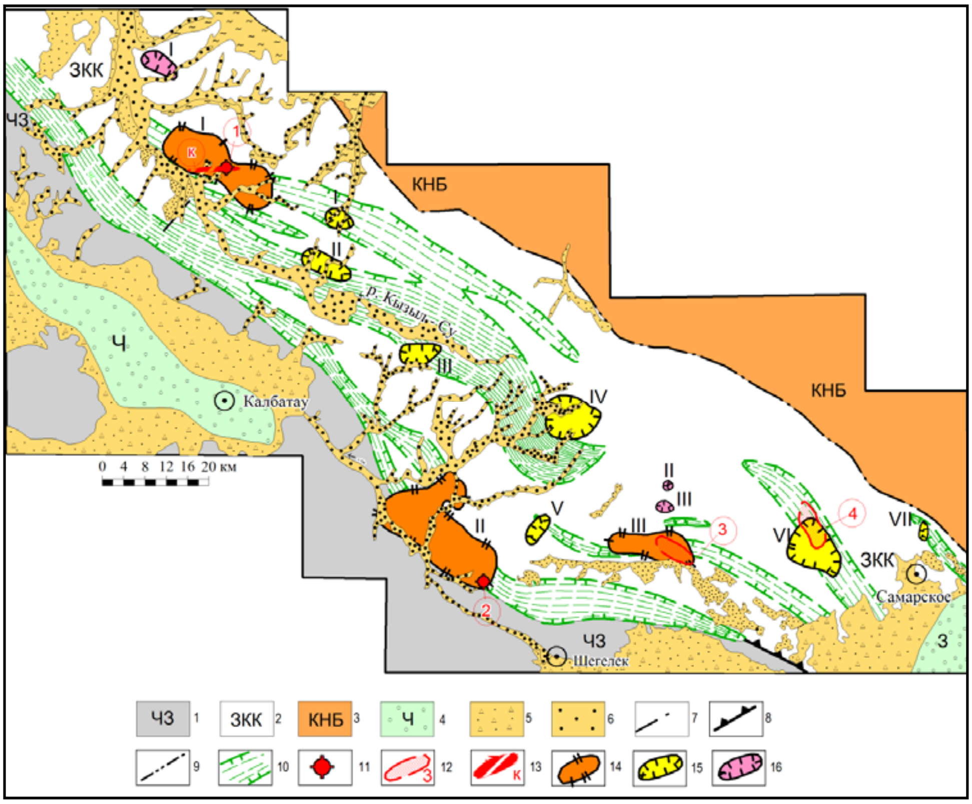

Рисунок 1 – Карта размещения перспективных золоторудных узлов на площади Западно-Калбинского района (карта прогноза золотоносности). Составила Г. Б. Оразбекова.

Условные обозначения: 1-3: структурные зоны - 1- Чарско-Зимунайская, 2 - Западно-Калба-Коксентауская, 3 - Калба-Нарым-Бурчумская; 4 - впадины унаследованного развития (Ч- Чарская, З - Зайсанская); 5 - четвертичные пролювиальные отложения конусов выноса; 6 - неогеновые и четвертичные отложения долин и внутригорных впадин; 7, 8 - глубинные разломы: 7 - Теректинский, 8 - Чарско-Горностаевский; 9 - поперечный разлом; 10 - продольные зоны смятия; 11 - эталонные золоторудные месторождения: 1 - Бакыршик, 2 - Баладжал; 12 - золоторудные поля эталонных месторождений: 3 - Джумба, 4 - Кулуджун; 13 - Кызыловская зона; 14 - 16: очаговые структуры, перспективные на поиски золоторудных месторождений 14 - бимодальные, наиболее перспективные: I - Бакырчикская, II - Вера-Чар - Баладжальская, III - Джумбинская; 15 - одномодальные, перспективные - I- Канайка, II - Казанчункур, III - Жанаминская, IV - Сенташская, V - Опокой, VI - Кулуджунская, VII - Лайлинская; 16 - одномодальные, наименее перспективные: I - Эспинская, II, III - Северная Джумба.

В ее пределах преобладающим развитием пользуются отложения раннего карбона, на юго-западном фланге развиты отложения среднего девона, сложенные песчаниками, алевролитами и известняками (рисунок 2).

Интрузивные образования разнообразны по составу и возрасту. Наиболее древним являются раннекаменноугольные интрузии гипербазитов - перидотиты, пироксениты, серпентиниты и габбро-диабазы, развитые на западном фланге. Дайкообразные и штокообразные тела среднего-основного состава (диабазы, диабазовые порфириты, габбро-диабазы, габбро-нориты, андезитовые порфириты, диоритовые порфириты, кварцевые диориты) немногочисленны. По представлениям предшествующих исследователей (Навозов О.В. и др., 2009 год), их формирование происходило в четыре этапа: раннекаменноугольное, среднекаменноугольное, средне-позднекаменноугольноеи пермское время. Дайкообразные и штокообразные тела кислого состава сформированы в позднекаменноугольное время. Среди них выделены гранит-порфиры, гранодиорит-порфиры, сиенит-порфиры, плагиогранит-порфиры, редко - кварцевые порфиры. Самыми молодыми являются крупные штокообразныеи лаколлитообразные тела гранодиоритов пермского возраста, развитые на восточном фланге структуры. Распространенность малых интрузий и даек в описываемой структуре наиболее велика на северо-западном фланге и незначительна на остальной площади. Гидротермально-метасоматические образования представлены кварцево-жильными телами, прокварцеванием, обохренностью (окисленными участками сульфидизации), лиственитизацией и бирбиритизацией.

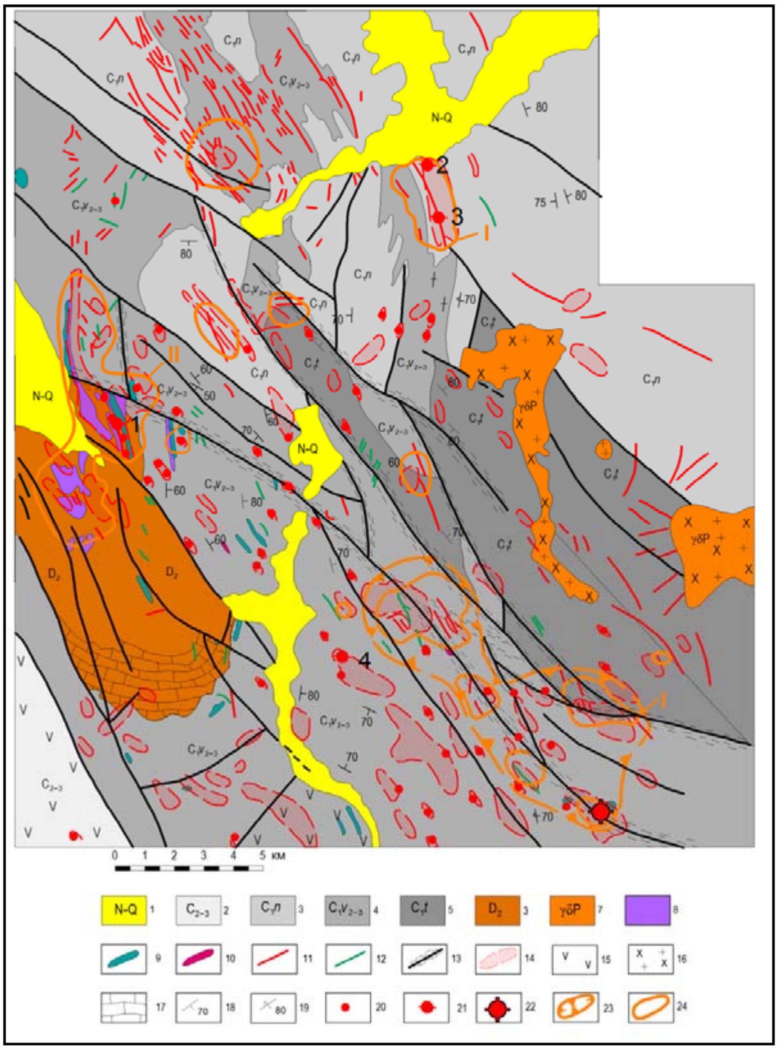

Рисунок 2 – Схематическая геологическая карта Вера-Чар - Баладжальской ОСс элементами прогноза (составлено с использованием материалов ПГО "Востказгеология").

Условные обозначения: 1 - неогеновые и четвертичные отложения нерасчлененные; 2 - средний - верхний карбон (андезитовые порфириты, их туфы, песчаники); 3 - нижний карбон, намюрский ярус (туффиты, алевролиты, глинистые сланцы, песчаники); 4 - нижний карбон, визейский ярус, средний -верхний подъяруса (кремнистые алевролиты, песчаники, порфириты, туфы, известняки); 5 - нижний карбон, турнейский ярус (песчаники, туфопесчаники с прослоями алевролитов); 6 - средний девон (песчаники, алевролиты, известняки, сланцы, кварцевые порфиры и их туфы); 7 - гранодиориты пермского возраста пострудные; 8 - гипербазиты условно раннекабонового возраста (перидотиты, пироксениты, серпентиниты и габбро-диабазы; 9 - малые интрузии среднего и основного состава нерасчлененные; 10 - малые интрузии кислого состава нерасчлененные; 11 - дайки кислого состава; 12 - дайки среднего-основного состава; 13 - разломы и зоны приразломнойтрещиноватости; 14 - зоны развития гидротермально - метасоматических образований; 15 - андезиты; 16 - гранодиориты; 17 - известняки; 18 - наклонное залегание пород; 19 - опрокинутое залегание пород; 20 - точки золоторудной минерализации; 21 - золоторудные месторождения и рудопроявления (1 - Вера-Чар, 2 - Мариновское, 3 - Кызыл-Тас, 4 - Юпитер); 22 - эталонное месторождение Баладжал; 23, 24 - результаты прогнозных построений: 23 - прогнозируемый Балажальский золоторудный подузел; 24 - площади, перспективные на выявление золоторудных месторождений (I - Мариновско-Кызылтасская;II - Вера-Чарская).

Стратифицированные отложения смяты в напряженные линейные складки (с углами падения до вертикальных) северо-западного простирания в юго-западной и центральных частях и субмеридионального на северо-восточном фланге, а также разбиты многочисленными разломами генеральной северо-западной ориентировки, конформной простиранию Чарско-Горностаевской зоны смятия.

В пределахописываемой структуры расположено "эталонное" месторождение Баладжал, а также месторождение Вера-Чар и рудопроявления Мариновское и Кызыл-Тас.

Реконструкция магматогенно-рудной системы. На первом этапе этой процедуры произведен содержательный анализ исходных геологических данных (рисунок 2). Как видно, распространенность даек и малых интрузий незначительна, при этом тела среднего-основного и кислого состава пространственно разобщены, в связи с чем не образуют совместной мультипликативной структуры даже вблизи эталонного месторождения Баладжал. Это может свидетельствовать либо о малой интенсивности магматического процесса, либо о чрезмерной генерализации при картировании площади. В связи с этим, для количественной оценки структуры размещения даек и малых интрузийсреднего-основого и кислого состава, относящихся к каменноугольным магматическим комплексам,использована аддитивная картина их развития; в анализе не участвуют гранитоиды пермского возраста, являющиеся пострудными по существующим представлениям [1]. Аналогичное решение принято в результате анализа размещения кварцево-жильных тел и метасоматических образований, которые развиты в многочисленных, но локальных узлах - на стадии реконструкции структуры их размещения они рассмотрены как единый фактор.

Структура размещения даек и малых интрузий пестрого состава и разного возраста иллюстрируется рисунок 3. Как видно, она имеет узловой характер, причем в размещении узлов прослеживаются признаки линейной (на северо-западном фланге) и концентрической организации. Это вероятно обусловлено особенностями глубинного строения, контролирующего размещение магматических очагов. На юго-восточном фланге в размещении магматических образований весьма отчетливо проявлена магмоконтролирующая роль линейных разрывов север-северо-западной ориентировки.

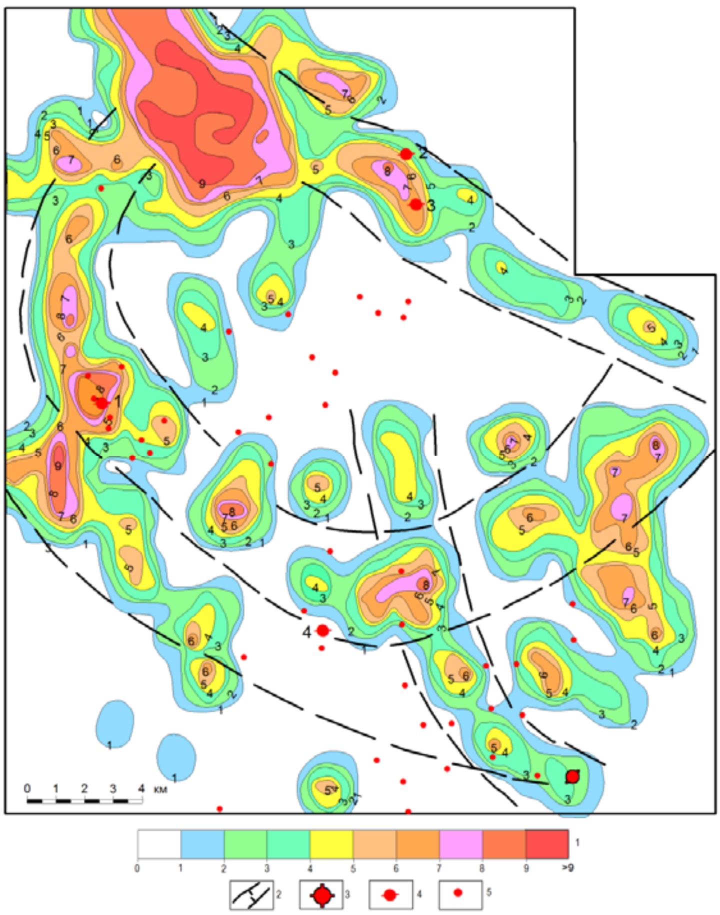

Рисунок 3 – Структура размещения даек и малых интрузий различного состава на площади Вера-Чар - Баладжальской МРС и положение золоторудных месторождений в ней (составила Г. Б. Оразбекова).

Условные обозначения: 1 - интервалы меры устойчивости размещения даек и малых интрузий различного состава; 2 - структурые элементы внутреннего строения ОС; 3 - эталонное месторождение Баладжал; 4 - золоторудные провления и месторождения (1 - Вера-Чар, 2 - Мариновское, 3 - Кызыл-Тас, 4 - Юпитер); 5 - точки золоторудной минерализации.

Наиболее устойчиво (со значениями меры до 9) описываемый процесс проявлен на северо-западном фланге ОС, в узле сочленения линейно- и концентрически ориентированных элементов. На остальной площади максимальные значения меры в локальных узлах преимущественно составляют 7-8, лишь в единичных достигают 9.

Распределение золоторудных объектов в структуре магматических образований имеет явно выраженную закономерность: как эталонное месторождение Баладжал, так и другие потенциально значимые объекты (Вера-Чарское, Мариновское, Кызыл-Тас) тяготеют к локальным узлам устойчивого развития магматического процесса (рисунок 3).

Статистической же закономерности приуроченности золоторудных объектов к определенным интервалам значений меры не наблюдается (таблица 1): распределение золоторудных месторождений охватывает значения меры от 2 (месторождение Баладжал) до 8 (месторождение Вера-Чар). Общая площадь этих интервалов - 235 км^2, что составляет 35% от изучаемой площади (673,3 км^2).

Таблица 1 – Распределение значений интервалов меры устойчивости развития даек и малых интрузий разного состава на площади Вера-Чар - Баладжальской ОС и распределение золоторудных объектов в них

<table>
<tr><th rowspan="3">Значения меры</th><th colspan="2">Площадь</th><th colspan="5" rowspan="2">Положение месторождений и рудопроявлений</th><th rowspan="3">Перспективные участки (площадь, км^2/%) от площади локального прогноза</th></tr>
<tr><th rowspan="2">км^2</th><th rowspan="2">%</th></tr>
<tr><th>Баладжал</th><th>Вера-Чар</th><th>Мариновское</th><th>Кызылтас</th><th>Юпитер*</th></tr>
<tr><td>1</td><td>64,75</td><td>20,9</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>64,75</td><td>20,9</td><td>.............</td><td></td><td></td><td></td><td></td><td rowspan="8">235/35</td></tr>
<tr><td>3</td><td>52,5</td><td>16,9</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>43,75</td><td>14,1</td><td></td><td></td><td>.............</td><td></td><td></td></tr>
<tr><td>5</td><td>28</td><td>9,04</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>20,25</td><td>6,5</td><td></td><td></td><td></td><td>..............</td><td></td></tr>
<tr><td>7</td><td>13,75</td><td>4,44</td><td></td><td rowspan="2">...............</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>12,25</td><td>4,11</td><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>9,75</td><td>3,11</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Всего</td><td>309,75</td><td>100</td><td></td><td></td><td></td><td></td><td></td><td>235/35</td></tr>
<tr><td colspan="9">*Рудопроявление Юпитер расположено вне ареала устойчивого развития даек и малых интрузий.</td></tr>
</table>

По представлению автора данной работы, наличие структурного контроля оруденения (приуроченность золоторудных объектов к локальным узлам устойчивого развития магматического процесса) свидетельствует о существовании парагенетической связи этих процессов и является структурной закономерностью.

Структура размещения гидротермально-метасоматических образований (ГМО) имеет узловой характер (рисунок 4), причем распределение локальных узлов подчинено многоуровенной иерархической концентрической организации. Выделяется два уровня структур: структура первого уровня организации развита в северной части площади, характеризуется тороидальным размещением узлов устойчивого развития ГМО во внешнем концентре (с этими узлами связаны объекты Мариновское, Кызылтас, Вера-Чар), в центральной части распределение узлов ГМО контролируется линейными структурами. Структуры второго уровня имеют менее значительные размеры и тяготеют к периферии ранее описанной. В их пределах размещение узлов ГМО так же подчинено линейным структурам.

Анализ размещения месторождений в структуре ГМО показывает, что они тяготеют к локальным узлам устойчивого развития фактора, расположенным во внешнем концентре структуры первого порядка, причем месторождения Баладжал и Вера-Чар расположены в локальных узлах, находящихся во внутренних частях структур более высокого порядка. Изложенное свидетельствует о наличии структурных закономерностей размещении месторождений в структуре гидротермально-метасоматических образований.

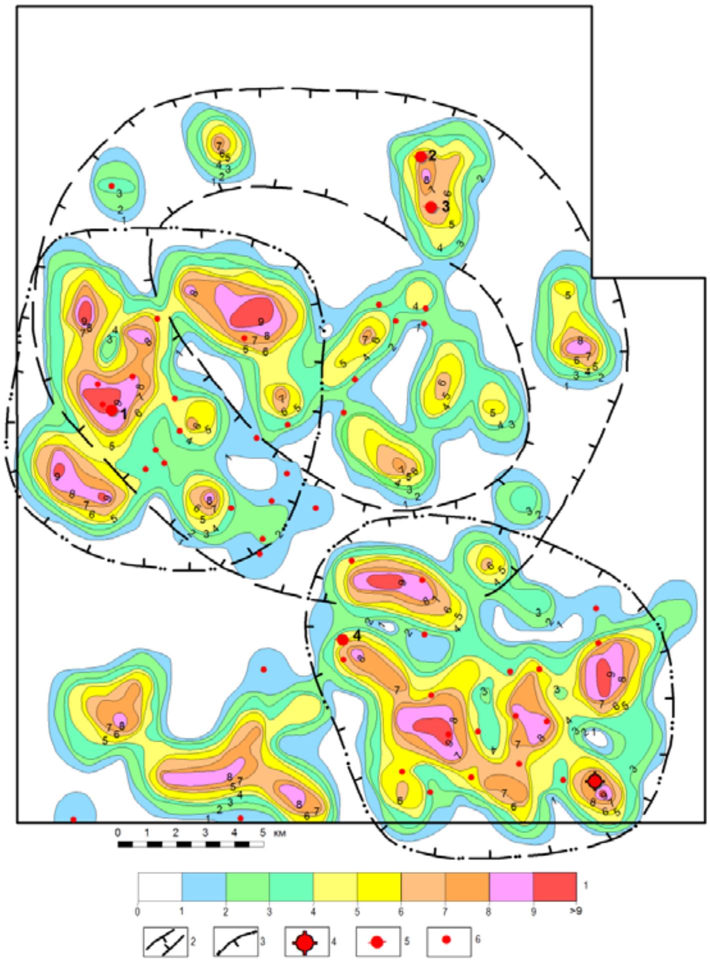

Рисунок 4 – Структура размещения гидротермально-метасоматических образований
на площади Вера-Чар - Баладжальской ОС и размещение в ней золоторудных объектов (составила Г. Б. Оразбекова).

Условные обозначения: 1 - интервалы меры устойчивости развития гидротермально-метасоматических образований; 2, 3 - структурые элементы внутреннего строения ОС; 4 - эталонное месторождение Баладжал; 5 - золоторудные провления и месторождения (1 - Вера-Чар, 2 - Мариновское, 3 - Кызыл-Тас, 4 - Юпитер); 6 - точки золоторудной минерализации.

Статистический анализ размещения золоторудных объектов в структуре ГМО (таблица 2) показывает, что область их развития охватывает интервалы значений меры от 4 до 8 общей площадью 119,7 км^2, что составляет 17,8% от площади локального прогноза.

В соответствии с парадигмой проводимых исследований, реконструкция площади синергетического эффекта выполнена путем оценки совместного устойчивого развития описанных выше элементов системы: даек и малых интрузий основного, среднего и кислого состава (объединенных в единых аддитивный элемент) и гидротермально-метасоматических образований (рисунок 5). Как видно, совместное проявление этих процессов имеет узловой характер, причем в распределении узлов отчетливо просматриваются две тенденции: очагового характера с размещением узлов во внешнем концентре в центральной части площади и линейного типа на юго-западном фланге.

Размещение эталонного месторождения Баладжал, а так же месторождений Вера-Чар, Мариновское и Кызыл-Тас в описываемой структуре отчетливо закономерно: они тяготеют к узлам устойчивого совместного развития магматического и гидротермально-метасоматического процессов.

Статистические характеристики так же показывают наличие закономерностей размещения объектов относительно описываемой структуры (таблица 3): все перспективные месторождения и рудопроявления (Баладжал, Вера-Чар, Мариновское и Кызыл-Тас) сосредоточены в интервалах меры от 20-30 до 70-80 общей площадью 37,5 км^2, что составляет 5,8% от изученной площади.

Таблица 2 – Распределение значений интервалов меры устойчивости развития гидротермально-метасоматических образований на площади Вера-Чар - Баладжальской ОС и распределение золоторудных объектов в них

Значения меры	Площадь		Положение месторождений и рудопроявлений					Перспективные участки (площадь, км²/%) от площади локального прогноза
	км²	%	Баладжал	Вера-Чар	Мариновское	Кызылтас	Юпитер	
1	58,25	20,37						
2	58,25	20,37						
3	43,75	15,3						
4	38,0	13,3					....	
5	30,75	10,75						
6	21,25	7,43				....		119,7/17,8
7	15,75	5,5	....		....			
8	13,95	4,88		....				
9	6,0	2,1						
Всего	285,95	100						119,7/17,8

Это свидетельствует об уникальности геологической ситуации этих интервалов и возможности их выделения в качестве благоприятных для формирования золотого оруденения в данной ОС.

Анализ результатов прогнозирования. Проведенные исследования позволили в пределах Вера-Бар - Баладжальской МРС выделить локальные площади, перспективные для формирования золоторудных месторождений (рисунок 2).

Баладжальский прогнозный рудный подузел расположен на юго-восточном фланге ОС и охватывает пять перспективных площадей (рисунок 2), с одним из которых связано "эталонное" месторождение Баладжал. Он вытянут в северо-западном направлении на 11 км при ширине от 1,5 до 5 км, конформно Чарско-Горностаевкой зоне смятия. Предшествующими исследователями (Навозов О.В. и др., 2009 год) в его пределах выделено 6 точек золоторудной минерализации и многочисленные первичные и вторичные ореолы мышьяка, серебра, а также шлиховые ореолы и россыпи золота. Здесь вероятно формирование золоторудных месторождений как в терригенных толщах (типа Жумбы, Кулуджуна и др.), так и в штоках и дайках.

Не менее, если не более значительны перспективы *Вера-Чарского прогнозного рудного поля,* северная часть которого расположена на участке пересечения концентрических и линейных структуроорганизующих элементов МРС (рисунок 2). В его пределах располагается известное месторождение Вера-Чар, а также ряд проявлений: Раздольный, Дмитрий, Екатерина. Предшествующими исследователями (Навозов О.В. и др., 2009 год) выявлены многочисленные точки минерализации и вторичные геохимические ореола серебра, мышьяка, меди, а также шлиховые орелы золота и арсенопирита.

Мариновско-Кызылтасское прогнозное рудное поле расположено во внешнем концентре ОС (рисунок 2) и включает два золоторудных проявления - Мариновское и Кызылтас. На проявлении Мариновское золотосодержащими телами являются бурые железняки и вторичные кварциты, пронизанные сетью кварцевых прожилков. Мощность зоны от 1-2 до 3-5 метров. Содержание золота в кварце от 1,0 до 5 г/т, иногда до 20 г/т. Во вторичных кварцитах отмечены повышенные концентрации никеля, кобальта, мышьяка, молибдена. Более интересным является проявление Кызылтас, гдезолотое оруденение связано с зонами обохренныхгидротермально измененных пород, несущих густую вкрапленность пирита, реже – арсенопирита. Оруденелые зоны кулисообразно прослеживаются на 1000-1500 м, ихмощность 5-10 метров с раздувами до 50 м, падение крутое (80-90°) простирание субмеридиональное. Содержание золота в зоне Кызылтас достигает 18,4 г/т. Золото содержится как в кварце, так и в измененных пиритизированных породах. Содержание от поверхности до глубин 8-10 м составляют 0,1-1,0 г/т (по штольням), по шурфам - 0,3-3 г/т, наиболее высокие содержания приурочены к участкам максимального развития пиритизации.

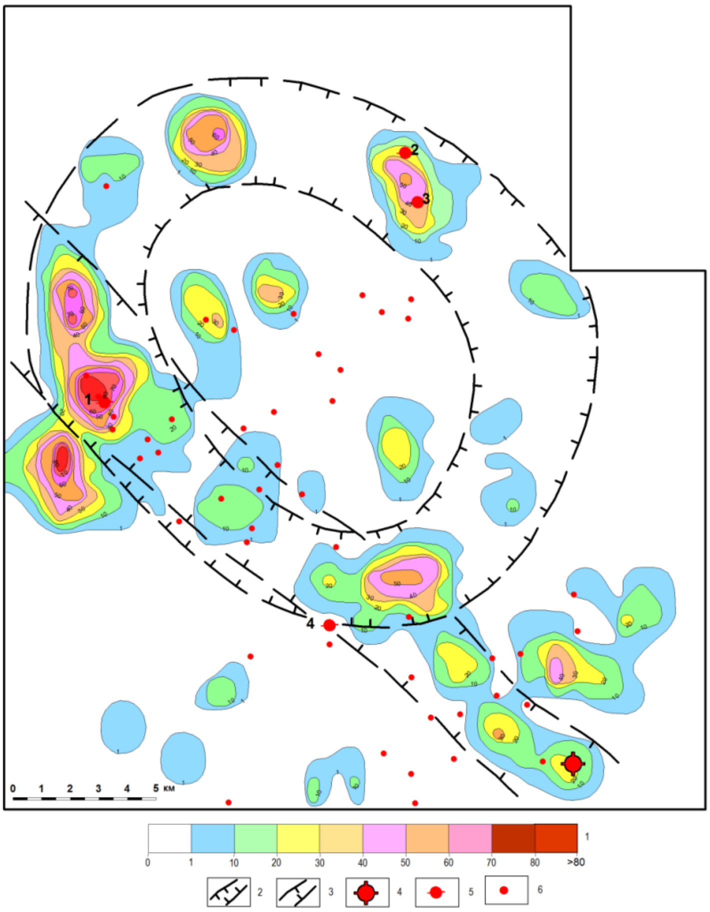

Рисунок 5 – Структура совместного устойчивого развития гидротермально-метасоматических и интрузивных образований на площади Вера-Чар-Баладжальской ОС и положение золоторудных объектов в ней (составила Г. Б. Оразбекова).

Условные обозначения: 1 - интервалы меры устойчивости совместного устойчивого развития гидротермально-метасоматических и интрузивных образований 2,3 - структурные элементы внутреннего строения ОС; 4 - эталонное месторождение Баладжал; 5 - золоторудные провления и месторождения (1 - Вера-Чар, 2 - Мариновское, 3 - Кызыл-Тас, 4 - Юпитер); 6 - точки золоторудной минерализации.

Таблица 3 – Распределение значений интервалов меры устойчивости совместного развития метасоматических образований и интрузивных тел на площади Вера-Чар - Баладжальской ОС и распределение золоторудных объектов в них

Интервал значений меры	Площадь		Положение месторождений и рудопроявлений					Перспективные участки (площадь, км²/%) от площади локального прогноза
	км²	%	Баладжал	Вера-Чар	Мариновское	Кызылтас	Юпитер*	
1-10	81,25	51,7						
10-20	37,5	23,8						
20-30	15	9,53	....		....			
30-40	7,5	4,76						
40-50	8,75	5,36				....		37,5/5,8
50-60	4,75	3,12						
70-80	1,5	0,95		....				
Более 80	1,25	0,79						
Всего	157,5	100						

Таким образом, реконструкция магматогенно-рудной системы Вера-Чар-Баладжальской ОС на локальной уровне изучения позволила выделить перспективные участки ранга рудных полей, общая площадь которых составляет 37,5 км^2 или 5,8% от площади прогнозных исследований.

Содержательный анализ результатов прогнозирования подтверждает перспективность выделенных участков имеющимися поисковыми данными.

Результаты прогнозных исследований, изложенные в статье, могут быть использованы при обосновании направления поисковых геологоразведочных работ.

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Д. Серікбаев атындағы Шығыс Қазақстан мемлекеттік техникалық университеті, Өскемен, Қазақстан

ҚОЛДАНУ ЖҮЙЕЛІ КӨЗҚАРАС БОЛЖАУ КЕЗІНДЕ КЕНДІ АЛАҢДАР, ЖЕРГІЛІКТІ АЛТЫН ОШАҚТЫ ҚҰРЫЛЫМДАРДА (мысалы, Вера-Чар - Баладжал ошақтық құрылымдар Шығыс Қазақстан облысының Батыс-Қалбақ алтынды ауданы)

Аннотация. Вера Чар - Балажал ошақтық құрылымы (OS) руда бірлігі бөлінген атағы реттегішті - AW перспективалық өңірлі конда 574.361 кг-ға дейін бағаланады болжамды ресурстары алтын зерттейді ретінде. Егжей-тегжейлі зерттеу нәтижесінде, осы баптың тақырыбы, перспективалық бағыттары кен және кенорындарына тағы орналасқан.

Вера Чарқайта алтын кен қалыптастыруға жүйелі тәсілді парадигмасынан егізделген - депозиттерді орналастыру оның алдын ала орнатылған істер заңдарына Балажал ошақты құрылымы мен кенді ірі кенорындарын қалыптастыру үшін перспективалы үш бөлінген учаскесі атағы өрістер: Балажалдын, Вера-кенболжамды Шар кенболжамды және Мариновты-Кызылтофты кенболжаған. Олардың жалпы ауданы 37,5 км^2 немесе болжамдық зерттеулер аумағының 5,8% құрайды.

Түйін сөздер: болжамды зерттеулер, алтын кенорындары, фокалды құрылымы, магматикалық білім беру, метасомалдык өзгерістер, Батыс-Қалба алтын ауданы.

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THE STATE AND COMPOUND OF THE PLATINOIDS AND RARE EARTH METALS WITHIN THE PICRITES SULFIDES OF THE KARA-TURGAI ASSEMBLAGE OF THE NORTHERN ULYTAU

Abstract. Violarite, siegenite, platinum telluride (moncheite), silver telluride, lead telluride (altaite), lead selenide, solid solutions of iridium group metals (Ir, Os, Ru), rare earth metals (Dy, Er, Y, Ce) have been discovered for the first time in picrites of the Kara-Turgai assemblage alongside previously known sulfides of copper, nickel and cobalt (copper pyrite, pentlandite, cobaltite, nickeline, gersdorffite). The sulfides constitute three mineral formations. The first two mineral formations form segregation "droplets", having a round and elongate elliptical shape, while the third one is represented by exudations of irregular acute-angled shapes. The platinoids in sulfides are established to exist only in the segregation droplets of the first formation, which accumulated of pyrrhotite, copper pyrite, pentlandite, violarite, and sphalerite. The sulfides of the second formation do not contain platinoids and are represented by pyrrhotite, copper pyrite, and sphalerite. The sulfides of the third formation are represented by pyrrhotite, copper pyrite, sphalerite, and pyrite. The whole of three mineral formations contain magnetite and are commonly confined to the most graded picrites horizons and apopicritic olivinites. Single sulfides inclusions were detected within the picritic diabases, represented by pentlandite, siegenite, millerite, pyrite, and galenite. Cu-Ni – ore formation (platinum group minerals [PGM]) – (rare earth elements [REE]) of Kara-Turgai ores was presumed to occur in an open magmatic system, which was favorable for accumulation of commercial bulk of sulfide.

Key words: Ulytau, copper-nickel ores, platinoids, rare earth metals.

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СОСТАВЫ И ФОРМЫ НАХОЖДЕНИЯ ПЛАТИНОИДОВ И РЕДКОЗЕМЕЛЬНЫХ ЭЛЕМЕНТОВ В СУЛЬФИДАХ ПИКРИТОВ КАРАТУРГАЙСКОГО КОМПЛЕКСА СЕВЕРНОГО УЛЫТАУ

Аннотация. В результате наших исследований, наряду с ранее известными сульфидами меди, никеля и кобальта (халькопиритом, пентландитом, кобальтином, никелином, герсдорфитом), в пикритах каратургайского комплекса были впервые обнаружены виоларит, зигенит, теллурид платины (мончеит), теллурид серебра, теллурид свинца (алтаит), селенид свинца, твердые растворы металлов иридиевой группы (Ir, Os, Ru), редкоземельные элементы (Dy, Er, Y, Ce). Сульфиды формируют три минеральных ассоциации. Первые две образуют ликвационные «капли», имеющие округлую и эллипсовидно-удлинённую форму, а третья минеральная ассоциация – выделения неправильных остроугольных форм. Установлено, что платиноиды в сульфидах присутствуют только в ликвационных каплях первой ассоциации, которые сложены пирротином, халькопиритом, пентландитом, виоларитом и сфалеритом. Сульфиды второй ассоциации не содержат платиноидов и представлены пирротином, халькопиритом, сфалеритом. Сульфиды третьей ассоциации представлены пирротином, халькопиритом, сфалеритом, пиритом. Все три минералогические ассоциации содержат магнетит и, как правило, приурочены к наиболее дифференцированным горизонтам пикритов и апопикритовых оливинитов. В составе пикритовых диабазов обнаружены единичные включения сульфидов: пентландит, зигенит, миллерит, пирит, галенит. Постулируется, что рудообразование Cu-Ni-(минералов платиновой группы [МПГ]) – (редкоземельных элементов [РЗЭ]) руд каратургайского типа происходило в пределах открытой магматической системы, благоприятной для накопления промышленных масс сульфидов.

Ключевые слова: Улытау, медно-никелевые руды, платиноиды, редкоземельные элементы.

Введение. На западе Центрального Казахстана в бассейне реки Каратургай (рисунок 1), что рассекает хребет Северного Улытау, давно известен диабаз-пикритовый каратургайский комплекс, с которым пространственно и генетически связаны сульфиды меди и никеля [1]. Присутствие в сульфидах металлов платиновой группы (МПГ) [2, 3] надолго предопределило интерес к их изучению [3-13].

Сростки сульфидов меди, никеля и железа присутствуют в пикритах и апопикритовых серпентинитах, которые образуют включения трех минеральных ассоциаций. Две первые ассоциации образуют ликвационные «капли», имеющие округлую и эллипсовидно-удлинённую форму, третья ассоциация – неправильные остроугольные формы.

О.Б. Бейсеев и его соавторы [6] детально изучили минеральный состав оруденения и выделили, в порядке убывания, пирротин, пентландит, халькопирит, магнетит, никелин, кобальтин, сперрилит, титаномагнетит, ильменит и хромит. К.Ш. Дюсембаева [8] дополнила эту рудную ассоциацию герсдорфитом, ковеллином, бравоитом, арсенопиритом.

На сегодня металлы платиновой группы известны в сульфидах проявлений Каратургай и Акжал, которые локализуются в составе пикритовых силлов, залегающих среди протерозойских образований (рисунок 1). По данным О.Б. Бейсеева [6] сульфидные медно-никель-кобальтовые руды Каратургайского проявления содержат Pt – 5 г/т, Pd – 16 г/т, тогда как по данным С.С Чудина [7] в медно-никелевом концентрате этих руд суммарное содержание платиноидов достигает всего 10 г/т.

Крайне низкие концентрации Pt+Pd (до 0.2-0.4 г/т), по данным С.С Чудина [7], отмечены в апопикритовых серпентинитах массива Акжал. Состав и форма нахождения платиноидов в сульфидах ранее установлены не были.

Методы исследования. Микровключения платиноидов в сульфидах меди и никеля из пикритов каратургайского комплекса были изучены в секторе минералогии ТОО ИГН им. К.И.Сатпаева (Алматы) с помощью энергодисперсионного спектрометра INCA ENERGY, фирмы OXFORD INSTRUMENTS, Англия, установленного на электронно-зондовый микроанализатор Superprobe 733, фирмы JEOL, Япония (ускоряющее напряжение 25 кВ, ток зонда 25 нА, диаметр зонда 1–2 мкм). В качестве образцов сравнения при анализе минералов использовали: для МПГ – чистые металлы, для РЗЭ (A) – искусственные соединения (A) PO_4, для Fe, Cu, S – $CuFeS_2$, для Pb – PbS, для Zn – ZnS, для остальных элементов – чистые металлы. Результаты анализов нормировали на 100%. Все фото были выполнены в режиме обратно-рассеянных электронов, в котором контраст на изображении зависит от среднего атомного номера фазы $\overline{Z}$. Чем больше $\overline{Z}$, т. е. чем больше тяжёлых элементов в изучаемой фазе, тем светлее она на изображении.

Результаты исследования. Нами в составе пикритов **каратургайского комплекса** детально были изучены сульфиды трех минеральных ассоциаций. Первая представлена ликвационными глобулами, содержащими: пирротин, пентландит, халькопирит, сфалерит, магнетит. Вторая также образует глобулы, содержащие: пирротин, халькопирит, сфалерит, магнетит. Третья ассоциация представлена включениями неправильной формы, содержащими: пирротин, халькопирит, сфалерит, пирит, магнетит.

В составе глобул первой ассоциации, наряду с ранее известными сульфидами меди и никеля (пентландитом и халькопиритом), были впервые обнаружены теллурид платины (мончеит), теллурид серебра, теллурид свинца, селенид свинца, полиметаллические твердые растворы металлов группы платиноидов (Ir, Os, Ru), редкоземельные элементы (Dy, Er, Y, Ce). В глобулах сульфидов второй ассоциации не были обнаружены микровключения теллурида серебра, платиноидов и редкоземельных элементов. Сульфиды третьей ассоциации, такие как пирротин,

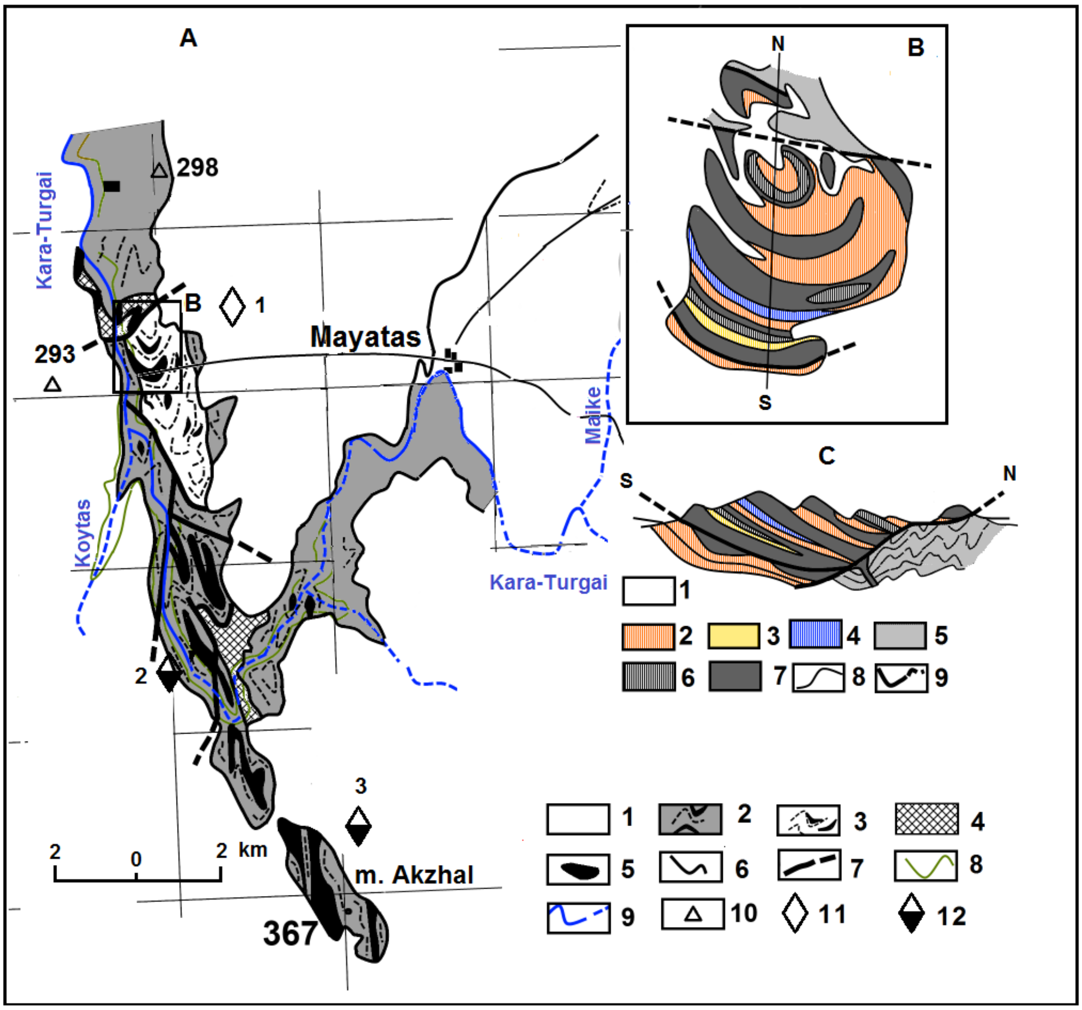

Рисунок 1 –

А. Схема геологического строения района среднего течения р. Кара-Тургай по И.И. Вишневской и И.Ф. Трусовой [4], С.С. Чудину [7] с изменениями и дополнениями авторов: 1 – кайнозойские отложения; 2–3 – карсакпайская серия (мезопротерозой): 2 – толща метабазальтов, реже андезитов с подчиненными горизонтами мусковито-кварцитовых и кварцитовых сланцев, 3 – толща пестроцветных туфов кварцевых альбитофиров и пепловых полосчатых туфов среднего состава 4 – мусковито-альбитовые и графитовые сланцы, альбитовые гнейсы и микрогнейсы аралбайской серии (PR_1ar); 5 – каратургайский диабаз- пикритовый комплекс (PR_3k); 6 – геологические границы; 7 – тектонические нарушения; 8 – топографические изолинии; 9 – река Кара-Тургай и ее притоки Койтас и Майке; 10 – тригонометрические высоты. 11–12 – генетические типы полезных ископаемых; 11– магматическая группа (ликвационный класс), сульфидные медно-никелевые руды с платиноидами и редкоземельными элементами (Dy, Er, Y, Ce) в пикритах, 12 – карбонатитовая группа (флюидно-магматический класс), карбонатитоиды кварц-карбонат-альбитового состава с сульфидами меди и платиноидами. Рудопроявления: 1 – Каратургай, 2 –Северный Акжал, 3 –Восточный Акжал.

Схема геологического строения Каратургайского массива (B) и разрез SN (C) через центральную часть массива. Построены по материалам Н.П. Михайлова, Ю.Л. Семенова [1], И.И. Вишневской и И.Ф. Трусовой [4], О.Б. Бейсеева [6] с изменениями и дополнениями авторов: 1 – кайнозойские отложения; 2-4 – карсакпайская серия (PR_2kr): 2 – туфы кварцевых альбитофиров, 3 – полосчатые туфы среднего состава; 4 – туфы основного состава; 5 – графито-альбитовые сланцы аралбайской серии (PR_1ar); 6–7 – каратургайский диабаз- пикритовый комплекс: 6 – кварцевые диабазы, диабазы, 7 – пикритовые диабазы, пикриты, апопикритовые серпентиниты, преимущественно шаровые, порфировидные; 8 – геологические границы; 9 – разрывные нарушения и надвиги.

халькопирит и сфалерит, не содержат обнаруживаемых в режиме обратно-рассеянных электронов (состав) включений минералов платиновой группы и редкоземельных элементов и только в составе фазы $FeOS_2$ были обнаружены очень мелкие включения, содержащие Ce и Os.

Минералы ликвационного класса.

Первая минеральная ассоциация. Рудообразующие сульфиды первой ассоциации пикритов представлены: пирротином, пентландитом, виоларитом, халькопиритом, сфалеритом.

Пирротин (FeS) имеет слабый избыток серы. По химическому составу он приближается к теоретической формуле троилита (см. таблицу 1). В пирротине отчетливо видны структуры распада твердых растворов (рисунок 2(B)). Он содержит микровключения теллурида платины ($PtTe_2$), теллурида серебра (Ag_2Te), алтаита (PbTe). Когда при анализе мелких тяжёлых микровключений в пирротине появляется мышьяк (As до 3.44%), то непременно наблюдается присутствие Os (до 29.77 %), Ir (до 6.89 %), Ru (до 15.27 %), а также отмечается высокое содержание Y (11.41%). С повышением концентрации мышьяка (до 10.83 %) увеличивается содержание Ir (до 16.41%) и появляется Pt (>4.62%), а также примесь Te (>0.62 %). Это даёт основание считать, что мы имеем дело с полиметаллическими твердыми растворами платиноидов.

Кристаллы пирротина образуют двухфазную область (рисунок 2(C)), где более светлые участки представлены фазой, содержащей больше Fe_2O_3 (61.85%, см. таблицу 1, 9–12), чем в темной фазе.

Пентландит ($(Fe,Ni)_9S_8$) содержит примесь кобальта (1.04-1.31 %) и характеризуется дефицитом серы, а отсутствие кобальта приводит к избытку серы. Недосыщенный серой пентландит, как правило, содержит микровключения теллурида платины ($PtTe_2$) с примесями Pd, Bi и крайне редко он содержит Rh (1.99%), Ir (1.84 %). Также иногда встречаются примеси Dy (1.65%), Er (1.6 %), и Y (0.08%). В пентландите установлена пластинчатая структура распада твердых растворов (рисунок 2(D)), где темная фаза распада обеднена Fe (<26.11%). Эта фаза по химическому составу близка виолариту (таблица 1).

Виоларит ($(Fe,Ni)_3S_4$), являющийся псевдоморфозой по пентландиту, встречается реже. Он также как и пентландит имеет недостаток серы. Виоларит содержит редкие мелкие микровключения, дающие в анализе Er до 1.76% и Os до 15.43%, что указывает на наличие самостоятельной минеральной формы осмия.

Халькопирит ($CuFeS_2$) обнаруживает постоянный избыток серы (см. таблицу 1). Редко в нём присутствуют микровключения теллурида платины ($PtTe_2$) с примесями Pd, Bi, теллурида серебра (Ag_2Te), алтаита (PbTe), но преобладает селенид свинца (PbSe), а Os (11.31 %), Ir (1.60 %) и Rh (11.17%) образуют полиметаллические твердые растворы. Халькопирит крайне редко содержит включения Ce (11.27 %) и F которые, по-видимому, совместно образуют CeF_3 фазу.

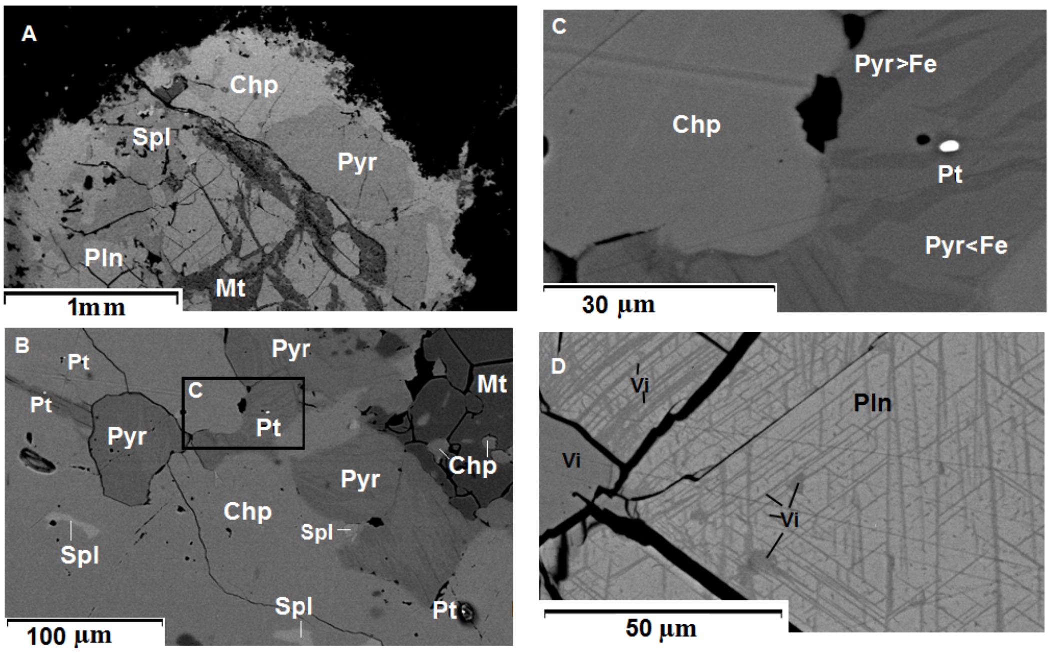

Рисунок 2 – Изображение в обратно-рассеянных электронах участков аншлифа, изготовленного из рудного материала, содержащего пирротин (Pyr), халькопирит (Chp), пентландит (Pln) виоларит (Vi), сфалерит (Spl), магнетит (Mt) с микровключениями платины (Pt). На рисунках A, B показано строение сульфидной капли и взаимоотношения минералов. Рисунок C демонстрирует характер соотношения халькопирита и пирротина (с структурой распада твердого раствор), а на рисунке D показана пластинчатая структура распада пентландит-виоларита.

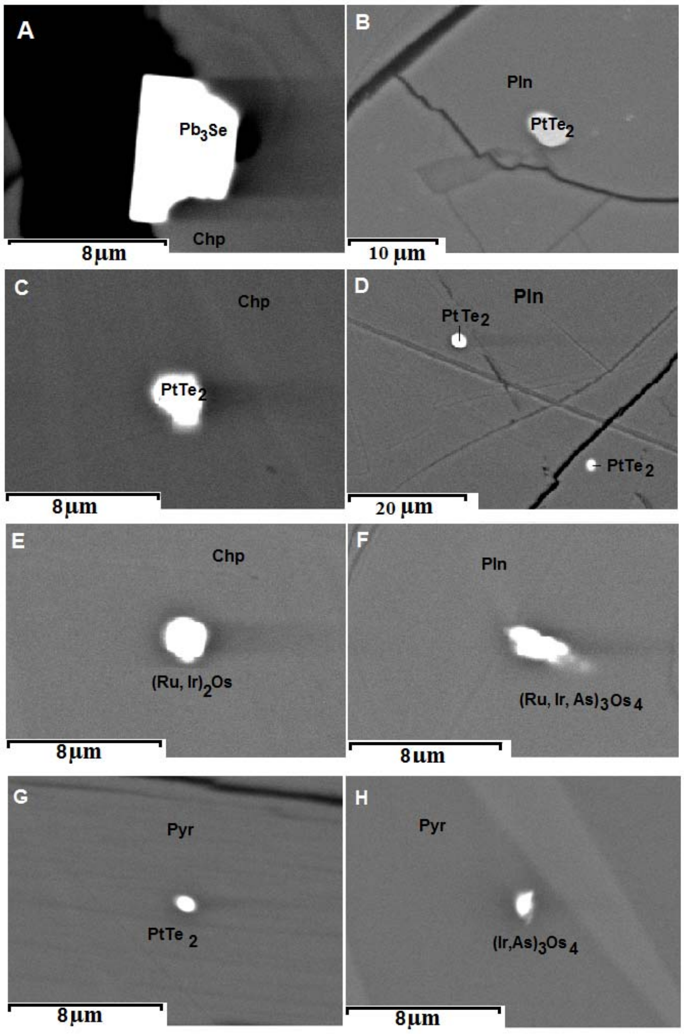

Рисунок 3 – Изображение в обратно-рассеянных электронах участков аншлифа, изготовленного из рудного материала, содержащего пентландит, халькопирит с микровключениями платиноидов и теллурида платины II ($PtTe_2$)

Сфалерит (ZnS) является относительно редким минералом, который пересыщен серой и содержит до 10.31 % Fe и до 1.02 % Cu (см. таблицу 1). По химическому составу он соответствует марматиту ($(Zn_{0.84},Fe_{0.16})_{\sum 1.00}\ S_{1.08}$). Высокий уровень содержания Fe и избыток S, по-видимому, обусловлен присутствием в ассоциации пирротина как продукта распада твердого раствора. Если учесть, что вхождение железа в структуру сфалерита сильно увеличивает общий объем системы, то при высоком давлении уменьшается количество железа в составе твердого раствора, а, следовательно, при понижении давления происходит увеличение количества железа в структуре сфалерита.

Минерал класса оксидов. Магнетит (Fe_3O_4), ассоциирующий с сульфидами первой ассоциации, содержит (мас. %): Fe (73.92 -74.66). В нём зафиксировано мелкое зерно, которое в общем анализе дало Os (6.44), Ru (2.01) и Rh (0.22). Также в этом зерне зафиксирована примесь Y (2.15). Эти данные свидетельствуют о том, что установлен твёрдый раствор платиноидов и иттрия.

Микровключения благородных и редких минералов в сульфидах первой ассоциации представлены как в виде интерметаллических соединений (интерметаллидов), которые образуют самостоятельные округлые, эллипсоидальные, реже неправильной формы выделения, диаметром не более 3 мкм (рисунок 3), так и в виде теллуридов, селенидов и арсенидов.

Наиболее распространенным является **теллурид платины** с примесями Pd, Bi, который по химическому составу приближается к стехиометрической формуле **монченита $PtTe_2$** (см. таблицу 2. №1-3). **Теллурид серебра** образует зерна идеально округлой формы (рисунок 3). Включения в

Таблица 1 – Состав сульфидов первой минеральной ассоциации с магнетитом, а также МПГ, РЗЭ пикритов каратургайского комплекса (мас.%, сумма 100%)

№ п/п	Минерал	S	Fe	Cu	Co	Ni	Zn	Pb	Er	Os	Te
1	2	3	4	5	6	7	8	9	10	11	12
Первая минеральная рудная ассоциация с магнетитом, а также МПГ, РЗЭ.											
1	Халькопирит	36.61	30.00	33.39							
2	Халькопирит	36.44	30.19	33.37							
3	Халькопирит	36.46	29.97	33.57							
4	Халькопирит	33.50	30.05	33.45							
5	Халькопирит	37.28	29.43	33.19	0.10						
6	Халькопирит	34.99	30.52	34.50							
7	Халькопирит	35.53	30.04	34.43							
8	Халькопирит	35.39	30.44	34.17							
9*	Халькопирит	35.23	28.89	32.43							3.44
10	Сфалерит	35.09	9.05	1.02			54.83				
11	Сфалерит	34.98	8.88	0.32			55.82				
12	Сфалерит	35.29	10.31	0.80			53.60				
13	Сфалерит	35.12	9.41	0.71			54.75				
14	Сфалерит	33.65	10.19	0.54		1.17	54.45				
15	Сфалерит	33.83	9.44	1.19		0.16	55.38				
16*	Пирротин	41.20	49.35	0.59		0.50				8.36	
17	Пирротин	38.15	61.85								
18	Пирротин	38.16	61.84								
19	Пирротин	38.15	61.85								
20	Пирротин	38.15	61.85								
21	Пирротин	40.37	59.63								
22	Пирротин	40.29	59.71								
23	Пирротин	40.52	59.48								
24	Пирротин	40.39	59.61								
25	Пирротин	38.93	61.07								
26	Пирротин	38.82	61.18								
27*	Пирротин	39,73	59.03							1.24	
28*	Пирротин	33.50	52.60								4.74
29*	Пирротин	31.54	61.98								6.47
30	Пентландит	35.04	33.24		1.18	30.54					
31	Пентландит	35.28	33.56		1.04	30.13					
32	Пентландит	35.75	32.78		1.31	30.16					
33	Пентландит	35.28	33.56		1.04	30.13					
34	Пентландит	35.75	31.78		1.31	30.16					
35	Пентландит	34.01	32.82			31.60			1.57		
36	Пентландит	34.00	33.60			31.55			0.85		
37	Пентландит	34.13	33.54			31.46			0.88		
38	Пентландит	34.37	33.55			30.55			1.24		
39	Пентландит	33.91	33.59			30.90			1.60		
40	Виоларит	40.66	24.81			32.86			1.68		
41	Виоларит	40.27	26.11			31.86			1.76		
42	Виоларит	40.70	22.95			35.19			1.16		
43*	Виоларит	39.84	25.49			31.36			1.42	15.43	
44	Виоларит	41.58	24.20			34.22					

*Точка анализа содержит мелкое включение.

Кристаллохимические формулы.

1. $Cu_{0.999}Fe_{1.011}S_{2.149}$;
2. $Cu_{0.996}Fe_{1.014}S_{2.133}$;
3. $Cu_{0.992}Fe_{1.008}S_{2.136}$;
4. $Cu_{0.989}Fe_{1.011}S_{2.08}$;
5. $Cu_{0.99}Fe_{1.0}S_{2.21}$;
6. $Cu_{1.0}Fe_{1.01}S_{2.0}$;
7. $Cu_{1.0}Fe_{1.01}S_{2.04}$;
8. $Cu_{1.0}Fe_{1.01}S_{2.04}$;
9. $Cu_{0.97}Fe_{0.98}Te_{0.05}S_{1.99}$;
10. $Zn_{0.838}Fe_{0.161}S_{1.030}$;
11. $Zn_{0.843}Fe_{0.157}S_{1.080}$;
12. $Zn_{0.816}Fe_{0.184}S_{1.096}$;
13. $Zn_{0.832}Fe_{0.167}S_{1.089}$;
15. $Fe_{1.00}S_{1.075}$;
16. $Fe_{1.00}S_{1.075}$;
17. $Fe_{1.00}S_{1.075}$;
18. $Fe_{1.00}S_{1.075}$;
19. $Fe_{1.00}S_{1.179}$;
20. $Fe_{1.00}S_{1.175}$;
21. $Fe_{1.00}S_{1.187}$;
22. $Fe_{1.0}S_{1.18}$;
23. $Fe_{0.91}S_{1.09}$;
24. $Fe_{0.92}S_{1.08}$;
25. $Fe_{0.95}S_{1.05}$;
26. $Fe_{0.95}S_{1.05}$;
27. $Fe_{0.99}S_{1.16}$;
28. $Fe_{0.96}Te_{0.04}S_{1.07}$;
29. $Fe_{0.95}Te_{0.05}S_{0.85}$;
30. $(Fe_{4.72}Ni_{4.12}Co_{0.16})_{\sum 9.0}S_{8.66}$;
31. $(Fe_{4.78}Ni_{4.08}Co_{0.14})_{\sum 9.0}S_{8.75}$;
32. $(Fe_{4.70}Ni_{4.12}Co_{0.18})_{\sum 9.0}S_{8.94}$;
33. $(Fe_{4.78}Ni_{4.08}Co_{0.14})_{\sum 9.0}S_{8.75}$;
34. $(Fe_{4.63}Ni_{4.19}Co_{0.18})_{\sum 9.0}S_{9.08}$;
35. $(Fe_{4.66}Ni_{4.27}Er_{0.07})_{\sum 9.0}S_{8.04}$;
36. $(Fe_{4.73}Ni_{4.23}Er_{0.04})_{\sum 9.0}S_{8.34}$;
37. $(Fe_{4.73}Ni_{4.23}Er_{0.04})_{\sum 9.0}S_{8.39}$;
38. $(Fe_{4.79}Ni_{4.15}Er_{0.06})_{\sum 9.0}S_{8.55}$;
39. $(Fe_{4.76}Ni_{4.17}Er_{0.07})_{\sum 9.0}S_{8.37}$;
40. $(Fe_{1.33}Ni_{1.37}Er_{0.03})_{\sum 3.03}S_{3.79}$;
41. $(Fe_{1.39}Ni_{1.61}Er_{0.03})_{\sum 3.03}S_{3.73}$;
42. $(Fe_{1.39}Ni_{1.61}Er_{0.03})_{\sum 3.03}S_{3.73}$;
43. $Fe_{1.38}Ni_{1.62}Er_{0.03})_{\sum 3.03}S_{3.76}$;
44. $(Fe_{1.28}Ni_{1.72})_{\sum 3.0}S_3$

халькопирите по химическому составу отвечают **Ag_2Te** (см. таблицу 2. №4). Редко встречаются включения **алтаита** (**PbTe**) в пирротине и халькопирите (см. таблицу 3)

В пентландите обнаружено соединение **(Ru, Ir)Os** (см. таблицу 3), его эмпирическую формулу можно представить как $(Ru_{0.61}Ir_{017}As_{0.08})_{\sum 0.86}Os_{1.14}$ при химическом составе (мас. %) (без элементов матрицы): Os (29.77), Ru (8.60), Ir (4.39), As (0.87).

В халькопирите (см. таблицу 3) встречено зерно размером не более 1.0 мкм, которое в анализе наряду с железом, медью и серой содержит (мас.%): Ru (11.17), Os (11.31), Ir (1.60), Bi (0.11). Эмпирическую формулу такого высокотемпературного твердого раствора можно представить как $(Ir_{0.153}Ru_{01.841})_{\sum 2.004}Os_{0.996}$, что соответствует в идеале формуле осмистого иридия **$(Ru, Ir)_2O$**s. Также в халькопирите встречено эллипсовидной формы зерно размером до 3-х мкм, которое имеет сложный химический состав (мас. %): Pt (11.87), Pd (1.11), Te (13.69), Mo (10.42), Bi (3.42), Ag (0.71). Если предположить, что молибден не связан с халькопиритом, то при пересчете на 8 единиц получается кристаллохимическая формула $(Pt_{1.624}Bi_{0.437})_{2.061}(Te_{2.864}Ag_{0.176})_{\sum 3.04}Mo_{2.9}$, в идеале формулу этого твердого раствора можно представить как – **$(Pt,Bi)_2(Te,Ag)_3Mo_3$**

Арсениды. Высокотемпературные металлы платиновой группы **IPGM** (Ir, Os, Ru) и As образуют арсениды платиноидов, которые встречаются в составе пирротина и реже в сульфиде железа (см. таблицу 3). Все они представлены крайне мелкими зернами неправильной формы (рисунок 3), что осложняет получение достоверного состава этих зерен, поскольку при анализе регистрируется характеристическое рентгеновское излучение не только от элементов, входящих в состав включения, но и от элементов матрицы.

Если из этих анализов вычесть сумму железа и серы, то можно условно выделить два типа соединений. Первое соединение с химическим составом (мас.%): As (3.44), Ir (6.89), Os (1.09) при пересчете их суммы на 100%, имеет следующую эмпирическую формулу: $(Ir_{0.85}Os_{0.13)\sum 0.98}As_{1.02}$, то в идеале его формула соответствует арсениду иридия **(Os, Ir)As**. Второе соединение (мас.%): As (10.83), Ir (16.41), Pt (4.62), Te (0.62) при пересчете их суммы на 100%, имеет эмпирическую формулу $(Ir_{0.68}Pt_{0.18)\sum 0.86}(Te_{0.04}As_{1.1})_{\sum 1.14}$, что соответствует идеальной формуле **(Ir, Pt)As.**

Селенид свинца (II) (PbSe) заключен в халькопирит (см. таблицу 2. №5). Также выявлена фаза Pb_3Se (см. таблицу 2. № 6), которая образует кристалл правильной прямоугольной формы, размером 8x4 мкм (рисунок 3). С сульфидом железа он имеет прямолинейные границы, в то время как халькопирит поглощает его, это свидетельствует, что фаза селенида свинца образовалась раньше, чем халькопирит.

Алтаит (PbTe) встречается крайне редко. Он образует изометричные микровключения в зёрнах пирротина и халькопирита (см. таблицу 3).

Вторая минеральная ассоциация. Сульфиды второй ассоциации (пирротин, халькопирит, сфалерит), по химическому составу ничем не отличаются от таковых первой ассоциации (см. таблицу 4), но при этом пентландит в ней отсутствует. Ни в одном из сульфидов (пирротине, халькопирите и сфалерите) этой ассоциации нам не удалось обнаружить **мончеита**, который широко представлен в сульфидах первой ассоциации.

Таблица 2 – Анализы микровключений в сульфидах первой ассоциации пикритов каратургайского комплекса (мас.%) без элементов матрицы

№ п/п	Минерал	Pt	Pd	Rh	Ru	Te	Bi	Ag	Pb	Se	∑
1	$PtTe_2$(pln)	35.66	2.37	1.27		47.94	7.99				95.23
2	$PtTe_2$ (pln)	32.03	1.65	1.99		42.66	8.83				87.16
3	$PtTe_{2(}$chp)	32.73	2.10		0.02	42.48	8.58				85.91
4	Ag_2Te (chp)					30.89		51.46			82.35
5	PbSe(chp)								62.38	20.41	82.79
6	Pb_3Se (chp)								83.51	11.01	94.52

Кристаллохимические формулы.

1.$(Pt_{0.89}Pd_{0.11}Rh_{0.06})_{\sum1.06}(Te_{1.77}Bi_{0.18})_{\sum1.95}$;

2.$(Pt_{0.86}Pd_{0.08}Rh_{0.10})_{\sum1.04}(Te_{1.74}Bi_{0.22})_{\sum1.96}$;

3. $(Pt_{0.84}Pd_{0.10})_{\sum0.94}(Te_{1.873}Bi_{0.191})_{\sum2.06}$;

4. $Ag_{2.02}Te_{0.98}$;

5. $Pb_{0.54}Se_{0.46}$;

6. $Pb_{2.97}Se_{1.03}$.

Таблица 3 – Химический состав минеральных фаз в сульфидах первой ассоциации пикритов каратургайского комплекса (мас.%, сумма 100%)

Мин.	pyr	pyr	pyr	pyr	pyr	pyr	pyr	pyr	pyr	pyr
Эл/№п	1	2	3	4	5	6	7	8	9	10
S	34.32	39.35	33.66	32.12	36.62	37.89	36.54	33.50	31.54	39.10
Fe	19.70	49.34	39.95	35.39	37.71	43.59	51.55	52.60	61.98	50.20
Cu						0.54				
Ni	1.71									
Co										
As	2.15	3.44	7.49	10.83	1.29	0.99				3.06
Os	15.43	0.99			14.03	12.20				1.09
Ir		6.89	14.21	16.41	2.15					6.55
Ru	15.27		0,21		6.25	4.51				
Pt			4.24	4.62	1.94					
Ag							7.89	9.16		
Te			0.24	0.62			4.01	4.74	6.47	
Bi										
Y	11.41									
Pb						0.28				

Таблица 3. Продолжение 1

Мин	pyr	pyr	chp	chp	chp	chp	chp	chp	chp	chp
Эл/№п	11	12	13	14	15	16	17	18	19	20
S	27.79	23.42	26.24	22.55	19.63	14.38	15.55	31.22	30.00	31.22
Fe	40.97	31.06	27.85	18.59	15.24	12.10	8.87	25.89	24.65	25.89
Cu			14.91	12.90	13.96	11.39	2.78	28.16	25.99	28.16
Pt		18.05							9.08	
Pd		0.95							1.05	
Ag			1.43			39.32		9.73		9.73
Te	10.14	21.12	11.30			22.81		5.01	9.23	5.01
Bi		5.41								
Pb	21.09		18.27	45.96	44.96		72.16			6.08
Se					2.03		0.64			
O					4.17					

Таблица 3. Продолжение 2.

Мин.	chp	chp	chp	pln	pln	pln	gm
Эл/№п	22	23	24	25	26	27	28
S	37.16	22.62	17.66	31.65	33.33	30.18	
Fe	19.59	19.41	13.13	13.78	30.31	27.14	19.45
Cu	18.83	7.01	7.03				
Ni			4.15	10.93	28.53	24.01	
Co					0.61	0.72	
As				0.87			
Os	11.31			29.77			
Ir	1.60			4.39	1.84		
Ru	11.17			8.60			
Pt					2.23	7.17	25.50
Te						7.48	25.71
Bi	0.11					3.30	10.93
Dy					1.62		
Pb		47.84	45.30		1.52		
Ce							
Se		1.87	3.44				
Zn		1.25					
Si			0.95				
Mg			0.57				1.21

Таблица 3. Продолжение 3.

Мин.	chp	chp	mg	chp	mg	mg	
Эл/№п	29	30	31	32	33	34	35
S	22.55	19,63	4,38	23.52	9,62	3.27	13,71
Fe	18.59	15,24	53,35	18.99	33,72	53.74	16,18
Cu	12.90	13.96		20.26			
As			1,59				
Os			6,44				
Ir			1,74				
Ru			2,01				
Rh			0.22				
Y			2,15				
Pb	45.96	44.96			22.43	11.53	53.61
Ce				11.27			
Se		2.03			3.14	1.25	6.82
Si				2.05	4.13	2.81	
Mg				3,72	2.33	2.27	
Al				0,68			
F				0.55			
O			28,11	18,96	24.64	25.13	9,68

Халькопирит по составу приближается к стехиометрической формуле (**$CuFeS_2$**). В **пирротине** (рисунок 4(В)) явно прослеживаются структура распада твердых растворов, где светлая часть пирротина по составу отвечает теоретической формуле троилита (**FeS**), а темная часть пирротина пересыщена серой ($FeS_{1.13}$). **Сфалерит** по химическому составу приближается к теоретической формуле марматита ($(Zn_{0.8},Fe_{0.2})_{\sum 1.0}S_{1.0}$). С увеличением роли Fe (17.97%) увеличивается уровень концентрации Cu (9.03%) и его кристаллохимическая формула изменяется ($(Zn_{0.6}Fe_{0.3}Cu_{0.1})_{\sum 1.00}S_{1.00}$).

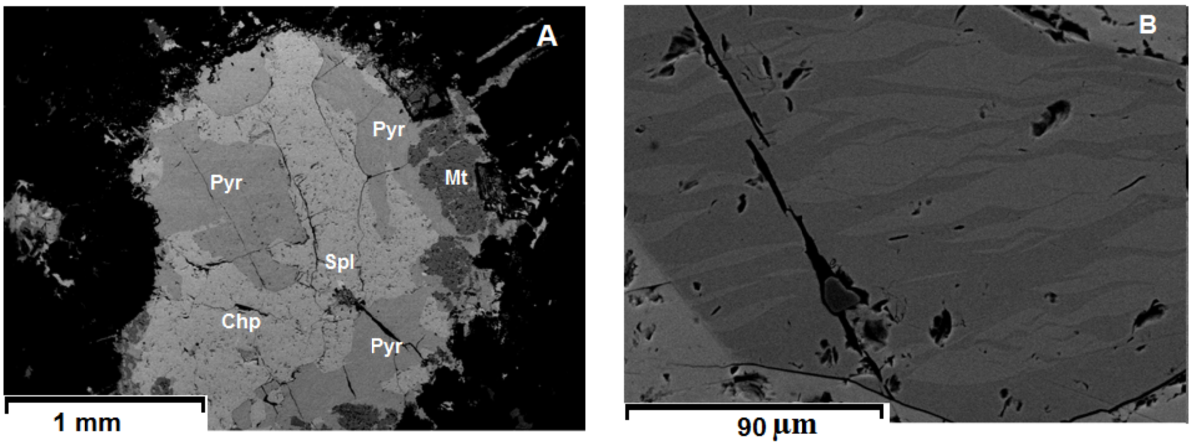

Рисунок 4 – Изображение в обратно-рассеянных электронах участков аншлифа, изготовленного из сульфидов второй ассоциации пикритов каратургайского комплекса. А. Рисунок демонстрирует характер взаимоотношений сульфидов с силикатными минералами. На рисунке В показана структура распада твердых растворов пирротина.

Минерал класса оксидов. Магнетит (Fe_3O_4), ассоциирующий с сульфидами второй ассоциации, содержит Fe (72.06 -72.36 %), что ниже, чем в таковых первой ассоциации.

Таблица 4 – Состав минералов второй ассоциации пикритов каратургайского комплекса (мас.%)

№ п/п	Минерал	S	Fe	Cu	Zn	O
1	Халькопирит	35.64	30.47	33.88		
2	Халькопирит	35.35	30.45	34.21		
3	Халькопирит	35.33	29.98	34.69		
4	Сфалерит	33.59	11.69	1.55	53.17	
5	Сфалерит	33.64	17.94	9.03	39.40	
6	Пирротин	37.62	62.38			
7	Пирротин	37.02	62.98			
8	Пирротин	36.87	63.13			
9	Пирротин	39.42	60.58			
10	Пирротин	39.34	60.66			
11	Пирротин	39.24	60.76			
12	Магнетит		72.06			27.94
13	Магнетит		72.36			27.64
14	Магнетит		72.18			27.82

Кристаллохимические формулы.
1. $Cu_{0.99}Fe_{1.01}S_{2.06}$;
2. $Cu_{0.99}Fe_{1.01}S_{2.04}$;
3. $Cu_{1.01}Fe_{0.99}S_{2.04}$;
4. $(Zn_{0.78}Fe_{0.20}Cu_{0.02})_{\sum 1.0}S_{1.00}$;
5. $(Zn_{0.57}Fe_{0.31}Cu_{0.15})_{\sum 1.03}S_{1.00}$;
6. $Fe_{0.98}S_{1.02}$;
7. $Fe_{0.99}S_{1.01}$;
8. $Fe_{0.99}S_{1.01}$;
9. $Fe_{0.94}S_{1.06}$;
10. $Fe_{0.94}S_{1.06}$;
11. $Fe_{0.94}S_{1.06}$

Третья минеральная ассоциация. Сульфиды третьей ассоциации представлены пирротином, халькопиритом, пиритом, сфалеритом, которые по химическому составу несколько отличаются от таковых первой и второй ассоциации (см. таблицу 5) и имеют ряд структурных и текстурных особенностей. Для этой ассоциации не характерно присутствие пентландита, однако, появляется пирит и фаза $FeOS_2$**.** Объединяющим их с минералами ликвационного класса фактором является присутствие селенида свинца и магнетита, а также наличие твердого раствора Os и присутствие примеси Ce.

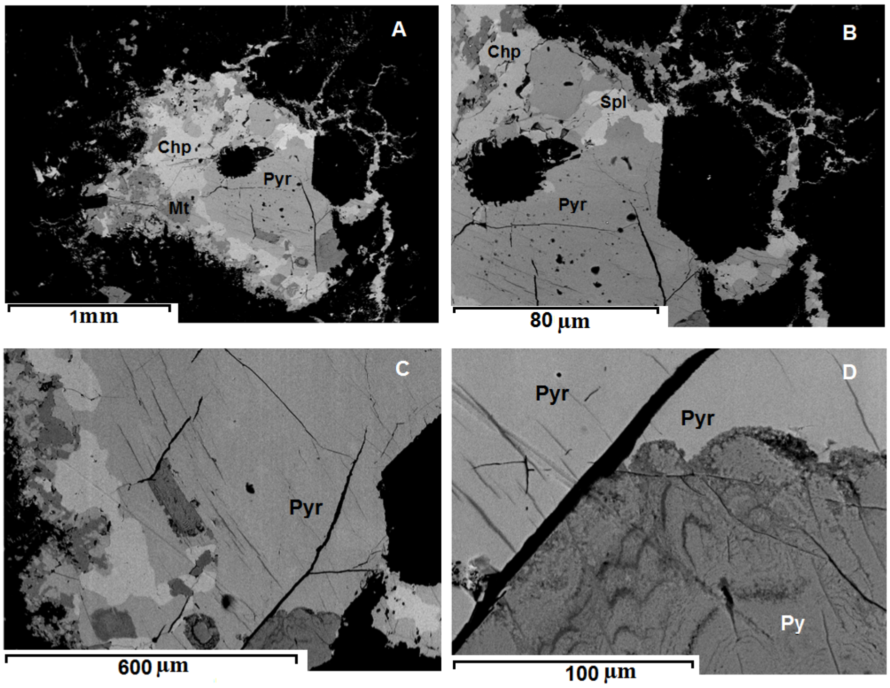

Рисунок 5 – Изображение в обратнорассеянных электронах участков аншлифа, изготовленного из сульфидов третьей ассоциации пикритов каратургайского комплекса. Рисунок демонстрирует характер взаимоотношений сульфидов с силикатными минералами. На рисунках C, D показан характер замещения пирротина минералом с характерной волнистой коллоидно-гелевой структурой.

Таблица 5 – Состав минералов третьей ассоциации пикритов каратургайского комплекса (мас.%)

№ п/п	Минерал	S	Fe	Cu	Zn	Ni	Ce	Os	Si	O
1	Пирротин	39.59	60.41							
2	Пирротин	39.49	60.51							
3	Пирротин	39.56	60.44							
4	Пирротин	39.19	60.81							
5	$FeOS_2$	41.79	47.08						0.69	10.44
6	$FeOS_2$	41.87	47.64						0.76	9.73
7	$FeOS_2$	42.36	47.96						0.67	9.01
8	Спектр$FeOS_2$	42.73	47.36			0.12			0.11	9.68
9	$FeOS_2$	37.96	46.67				1.08		0.43	13.86
10*	$FeOS_2$	36.99	46.44					0.92	0.40	15.25
11	$FeOS_2$	40.18	48.26						0.72	10.85
12	$Fe_2O_3S_1$	17.38	54.97						0.48	27.17
13	Пирит	51.95	48.05							
14	Халькопирит	35,25	30.18	34.57						
15	Халькопирит	35.48	30.50	34.02						
16	Халькопирит	35.38	30.55	34.06						
17	Халькопирит	35.33	30.68	33.99						
18	Сфалерит	34.16	9.61		56.23					
19	Сфалерит	34.10	9.72		56.19					
20	Сфалерит	34.42	9.47		56.11					
21	Сфалерит	34.36	9.53		56.11					
22	Магнетит		72.62							27.38
23	Магнетит		71.47							28.11
24	Магнетит		72.56							27.44
25	Магнетит		72.45							27.55
26	Магнетит		72.23							27.77
27	Магнетит		72.61							27.39

*Точка анализа содержит мелкое включение.

Кристаллохимические формулы.

1. $Fe_{0.94}S_{1.06}$;
2. $Fe_{0.94}S_{1.06}$;
3. $Fe_{0.94}S_{1.06}$;
4. $Fe_{0.94}S_{1.06}$;
5. $Fe_{1.17}O_{0.90}S_{1.80}$;
6. $(Fe_{1.16}O_{0.84})_{\sum 2.0}S_{1.80}$;
7. $(Fe_{1.17}O_{0.77})_{\sum 1.94}S_{1.80}$;
8. $(Fe_{1.16}O_{0.83})_{\sum 1.99}S_{1.83}$;
9. $(Fe_{1.23}O_{1.28})_{\sum 2.52}S_{1.75}$;
10. $(Fe_{1.25}O_{1.43})_{\sum 2.68}S_{1.73}$;
11. $(Fe_{1.21}O_{0.95})_{\sum 2.16}S_{1.75}$;
12. $Fe_{1.91}O_{3.30}\ S_{1.05}$;
13. $Fe_{1.04}S_{1.96}$;
14. $CuFeS_{2.02}$;
15. $Cu_{0.99}Fe_{1.01}S_{2.05}$;
16. $Cu_{0.99}Fe_{1.01}S_{2.04}$;
17. $Cu_{0.99}Fe_{1.01}S_{2.03}$;
18. $(Zn_{0.81}Fe_{0.16})_{\sum 0.97}S_{1.00}$;
19. $(Zn_{0.81}Fe_{0.16})_{\sum 0.97}S_{1.00}$;
20. $(Zn_{0.80}Fe_{0.16})_{\sum 0.96}S_{1.00}$;
21. $(Zn_{0.80}Fe_{0.16})_{\sum 0.96}S_{1.00}$;
22. $Fe_{2.99}O_{4.01}$;
23. $Fe_{2.92}O_{4.08}$;
24. $Fe_{2.99}O_{4.01}$;
25. $Fe_{2.98}O_{4.02}$;
26. $Fe_{2.96}O_{4.04}$;
27. $Fe_{2.99}O_{4.01}$.

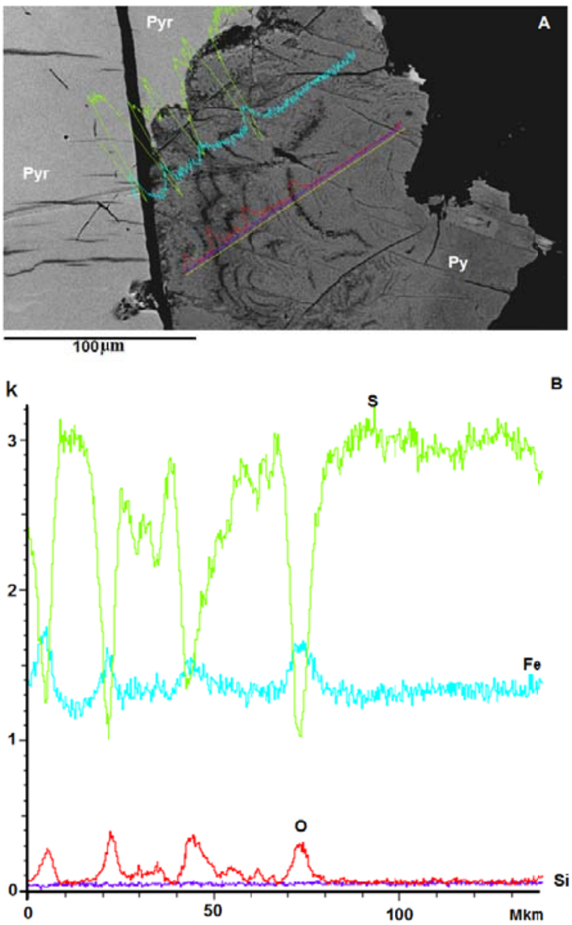

Рисунок 6 –
А – Изображение коллоидно-гелевой структуры пирита (марказита) с наложенной записью концентрационных кривых отдельных элементов по белой линии.
В – Отдельная запись концентрационных кривых.

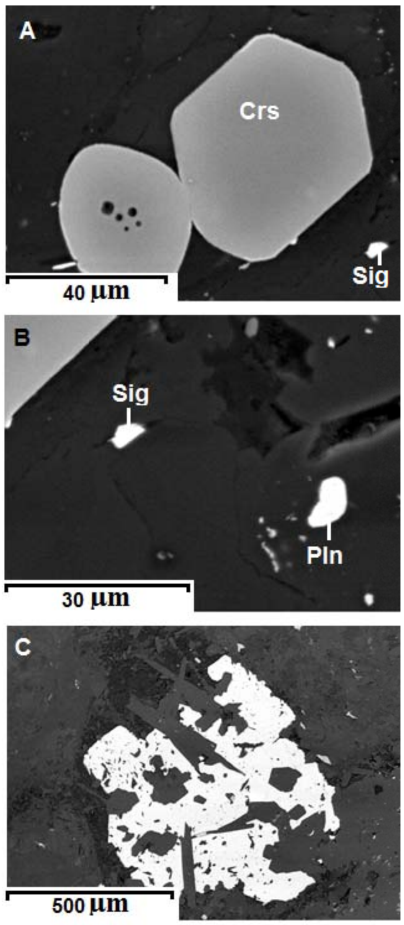

Рисунок 7 – Изображение в обратно-рассеянных электронах участков аншлифа, изготовленного из пикритового диабаза, содержащего хромшпинель (Crs), зигенит (Sig), пентландит (Pln), пирит (Py)

Характерной особенностью, к примеру, **пирротина** ($FeS_{1.1}$) (рисунок 5(C)) является отсутствие структур распада твердых растворов, что характерно для платиносодержащего пирротина первой ассоциации (рисунок 2 и 3). **Халькопирит** по составу приближается к стехиометрической формуле и по отношению к платиносодержащему халькопириту не имеют избытка серы ($CuFeS_2$). **Сфалерит** $(Zn_{0.81}Fe_{0.16})_{\sum 0.97}S$ не содержит Cu, что характерно и для сфалеритов первой ассоциации (см. таблицу 5). Одной из особенностей этой ассоциации является присутствие **пирита** (FeS_2) и образования с коллоидно-гелевой структурой. Присутствие в составе этого образования Ce (1.08 %), не исключает его формирования за счёт пирротина, в процессе окисления последнего образуется фаза $FeOS_2$. Его идеальную формулу в системе Хилл, в расчете на общее количество атомов равное 4, можно представить как $FeOS_2$, содержащего 11.77% O, 41.07% Fe и 47.16% S. Магнетит и халькопирит содержат включения селенида свинца (PbSe) (см. таблицу 2).

Минерал класса оксидов. Магнетит (Fe_3O_4), ассоциирующий с сульфидами третьей ассоциации, содержит Fe (<72.62%), что ниже, чем в магнетите первой ассоциации.

Единичные включения сульфидов в пикритовых диабазах представлены минералами класса сульфидов**:** пентландитом, пиритом, зигенитом (этот минерал обнаружен впервые), миллеритом, галенитом.

Пентландит (Fe, Ni)$_9$S$_8$) образует мелкие редкие зернышки в основной массе (рисунок 7(В)). По химическому составу приближается к стехиометрической формуле пентландита (см. таблицу 6). Он пересыщен S (38.23 %), не содержит Со и слабо обогащен Cr (0.16 %) по отношению к пентландиту пикритов.

Зигенит ((Co,Ni)$_3$S$_4$) образует мелкие зёрнышки в основной массе породы (рис. 6(А)). В его составе присутствует примесь железа (5.01–7.91 %, см. таблицу 6), а в формуле зигенита отмечается постоянный избыток серы и преобладание никеля над кобальтом.

Миллерит (NiS) встречается в интерстициях клинопироксена, где образует мелкие кристаллы. В качестве примеси в его составе обнаружено железо (см. таблицу 6).

Галенит (PbS) присутствует в виде мелких зерен в ассоциации с миллеритом. В его составе отмечаются примеси Fe и Ni, содержание Pb достигает 83.18 %, а S – до 12.37%.

Пирит (FeS_2) содержит S=56.31 % и Fe=43.69 %.

Минералы класса оксидов. Титаногематит и манганоильменит образуют структуры распада твердых растворов, а **хромшпинель** – зерна изометричной формы.

Таблица 6 – Состав сульфидов пикритовых диабазов каратургайского комплекса (мас.%)

№ п/п	Минерал	**S**	**Fe**	**Co**	**Ni**	Cr	Pb	Сумма
1	Пентландит	36.36	33.05		30.59			100.0
2	Пентландит	38.23	33.87		27.75	0.15		100.0
3	Зигенит	44.29	5.01	9.72	40.47	0.51		100.0
4	Пирит	56.31	43.69					100.0
5	Зигенит	44.51	7.91	15.25	32.33			100.0
6	Зигенит	44.32	7.97	15.60	32.11			100..0
7	Зигенит	45.30	10.79	12.53	31.38			100.0
8	Миллерит	37.58	1.83		60.58			100.0
9	Миллерит	37.89	1.70		60.41			100.0
10	Миллерит	37.89	1.70		60.41			100.0
11	Галенит	12.37	1.68		2.77		83.18	100.0

Кристаллохимические формулы.

1. $(Fe_{4.786}Ni_{4.214})_{\sum 9.0}S_{9.171}$;
2. $(Fe_{5.045}Ni_{3.933}Cr_{0.022})_{\sum 9.0}S_{9.920}$;
3. $(Ni_{2.168}Co_{0.519}Fe_{0.281}Cr_{0.093})_{\sum 3.062}S_{4.345}$;
4. $Fe_{0.924}S_{2.076}$;
5. $(Ni_{1.737}Co_{0.816}Fe_{0.447})_{\sum 3.0}S_{4.378}$;
6. $(Ni_{1.719}Co_{0.832}Fe_{0.449})_{\sum 3.0}S_{4.345}$;
7. $(Ni_{1.705}Co_{0.679}Fe_{0.616})_{\sum 3.0}S_{4.507}$;
8. $(Ni_{0.97}Fe_{0.03})_{\sum 1.0}S_{1.1}$;
9. $(Ni_{0.97}Fe_{0.03})_{\sum 1.0}S_{1.11}$;
10. $(Ni_{0.97}Fe_{0.03})_{\sum 1.0}S_{1.11}$.

Обсуждение результатов. В результате наших исследований установлено, что наряду с ранее известными сульфидами (пирротитом, пентландитом и халькопиритом) в пикритах каратургайского комплекса впервые обнаружены зигенит, теллурид платины (мончеит), теллурид серебра, теллурид свинца (алтаит), селенид свинца, твердые растворы металлов иридиевой группы (Ir, Os, Ru), редкоземельные элементы (Dy, Er, Y, Ce). Сульфиды формируют три минеральных ассоциации. Первые две образуют ликвационные «капли», имеющие округлую и эллипсовидно-удлинённую форму, а третья минеральная ассоциация – неправильно остроугольные формы (рисунок 8). Установлено, что платиноиды в сульфидах меди и никеля присутствуют только в ликвационных каплях первой ассоциации, которые сложены пирротином, халькопиритом, пентландитом, сфалеритом. Сульфиды второй ассоциации не содержат платиноидов и представлены пирротином, халькопиритом, сфалеритом. Сульфиды третьей ассоциации представлены пирротином, халькопиритом, сфалеритом, пиритом. Все три минералогические ассоциации содержат магнетит и, как правило, приурочены к наиболее дифференцированным горизонтам пикритов и апопикритовых оливинитов. Выявленная нами закономерность в распределении платиноидов в составе ликвационных сульфидов дает ответ, почему происходило разубоживание рудного концентрата [7].

Глобулы сульфидов пикритов каратургайского комплекса не имеют идеально ровных границ, как и метасоматического ореола (рисунок 8), что характерно для большинства сульфидных глобул медно-никелевых руд ультрабазит-базитовых плутонических комплексов [14]. Извилистая граница, как и нередкое проникновение сульфидов в силикатный матрикс, свидетельствует, что процесс формирования глобул сопровождался одновременным сжатием. Также не установлена и классическая архитектура глобул, характерная для плутонических комплексов, где нижняя часть сложена пирротином, верхняя – халькопиритом, а в центральной части находится пентландит.

Наибольшее сходство сульфидные глобулы каратургайского типа находят с глобулами сульфидов в пикритах норильско-талнахского типа, где халькопирит располагается вверху, пирротин и пентландит – в нижней части, а магнетит располагается по краю сульфидных капель в рудах пикритового горизонта. [15]. Однако глобулы первой ассоциации имеют существенное отличие в распределении магнетита, как правило, он локализуется в центральных частях рудных платиносодержащих глобул (рисунок 8.1А), тогда как магнетит второй ассоциации каратургайского типа располагается по краям сульфидных капель (рисунок 8.2А).

Одной из особенностей третьей минеральной ассоциации является присутствие редких зерен фазы $FeOS_2$ с коллоидно-гелевой структурой, образование которой было обусловлено взаимодействием пирротина с кислородом, что сопровождалось уменьшением уровня содержания серы, уве-

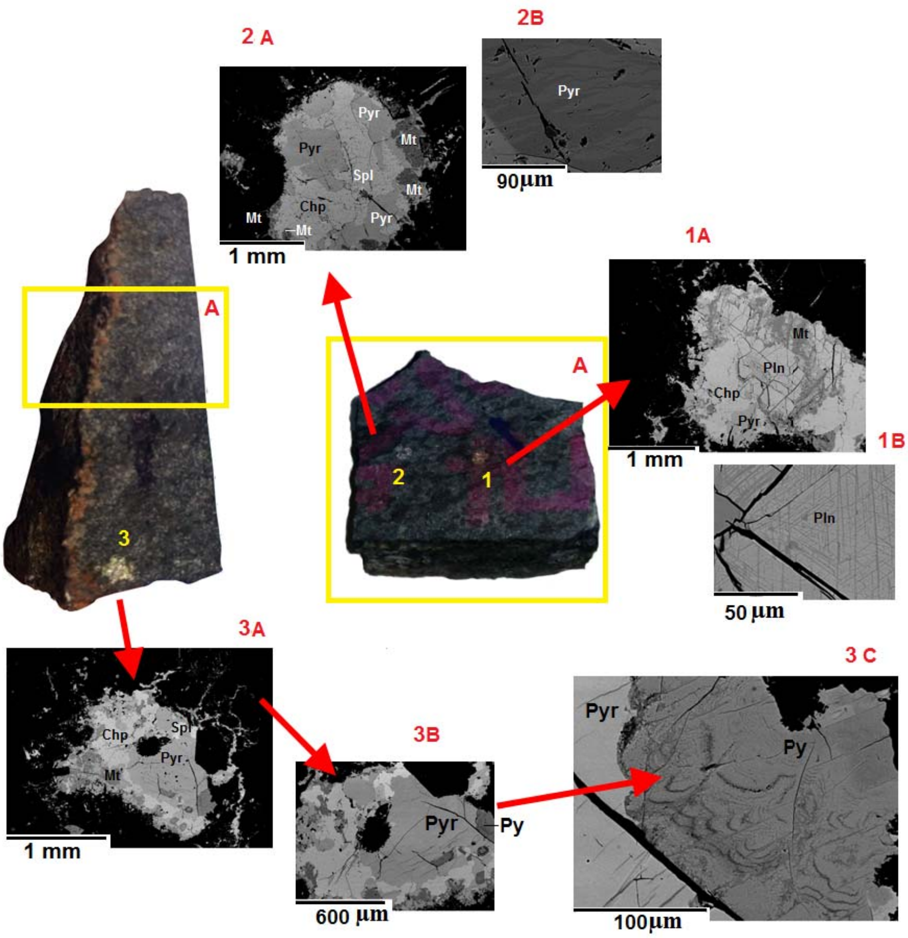

Рисунок 8 – Общие сведения о составе и старении сульфидов каратургайского комплекса.
Пояснение смотри в тексте главы «Обсуждение результатов»

личением кислорода и образованием оксида железа, формирующего на изображении тёмную сыпь во фронте движущихся волн (рисунок 8.3C). Это может служить доказательством образования такой минералогической ассоциации в гипабиссальных условиях, где существенная роль отводится окислительным процессам.

В целом набор минералов сульфидных капель идентичен рудам ликвационного типа, однако отмечаются некоторые отличия их состава. Например, пирротин руд каратургайского типа не содержит никеля и кобальта, что характерно для пирротина руд норильско-талнахского типа. Если в рудах последних присутствует палладий, сперилит, золото, серебро и селен, то в рудах пикритов каратургайского типа нет сперилита, палладий и селен встречается крайне редко, но широко представлены редкоземельные элементы. Теллурид платины в рудах каратургайского типа встречается во всех главных рудных минералах (пентландите, халькопирите и пирротине) первой ассоциации, а вот золото не обнаружено, зато много теллурида серебра. Одной из характерных особенностей руд каратургайского типа является присутствие селенида свинца, арсенидов иридиевой группы и высокий уровень содержания редкоземельных элементов иттриевого (Y, Dy) подсемейства.

В составе пикритовых диабазов наряду с пентландитом, пиритом и галенитом впервые обнаружены зигенит и миллерит, которые не были описаны ранее в составе пород каратургайского комплекса. Характерно, что пентландит пересыщен S, не содержит Co и слабо обогащен Cr по отношению к пентландиту пикритов каратургайского типа.

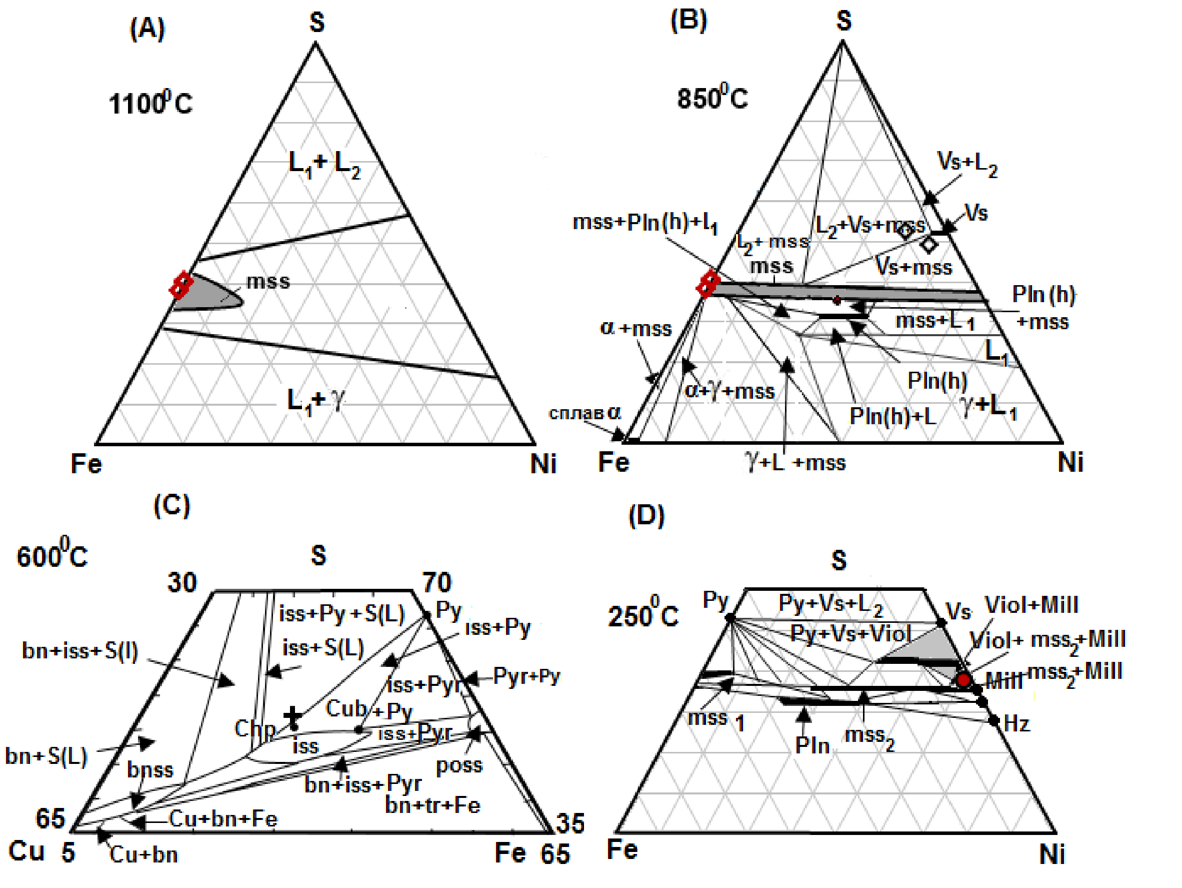

Рисунок 9 – Изотермические сечения конденсированных систем Fe-Ni-S [16] при температурах 1000^0C (A), 850^0C (B), 250^0C (D) и Cu-Fe-S [17] при температуре 600^0C (C) для пирротина (красный ромб), пентландита (черный кружек), халькопирита (черный крест), зигенита (черный ромб) и миллерита (красная точка) из пикритов и пикрито-диабазов каратургайского комплекса. mss – моносульфидный твердый раствор; iss – промежуточный твердый раствор; халькопирит (Chp); пентландит (Pln); ваэсит (Vs); пирротин (Pyr); пирит (Py); виоларит (Viol); миллерит (Mill); расплав (L).

В системе Fe-Ni-S (рисунок 9(A, B)) предложенной А. Налдреттом [16] фигуративные точки пентландита располагаются ниже барьера изолирующей фазу, обогащенную S, от фаз, богатых металлами, и тяготеют к полю моносульфидного твердого раствора (mss). Пирротин в этой системе располагается на стороне Fe-S, но при этом его фигуративные точки лежат в области барьера mss, чем, вероятно, можно объяснить присутствие минералов IPGE, $PtTe_2$ и Ag_2Te в пирротине, так и в пентландите. В системе Cu-Fe-S (рисунок 9(C)) халькопирит, учитывая избыток в нём серы, располагается в поле iss+Py+S(L), что, по-видимому, согласуется с понижением температуры кристаллизации халькопирита.

Учитывая последовательность выделения минеральных фаз и анализ изотермических сечений конденсированной системы Fe-Ni-S [16], генезис сульфидной медно-никелевой минерализации каратургайского типа, по-видимому, подчиняется следующей схеме.

Если учесть современную трактовку температуры и формирование mss, то можно предположить, что при 1190^0C на линии Fe-S появляется $Fe_{(1-x)}S$ (троилит), который при температуре 1100^0C распространяется во внутреннюю часть системы, формируя поле mss (рисунок 9(A)). Как предполагает А. Налдретт [16], на этом этапе mss обогащен Fe и обеднен Ni относительно жидкости, с которой он находится в равновесии. Впоследствии mss, образующейся из фракционированной жидкости при продолжении фракционной кристаллизации, по Д. Ибел и А. Налдретту [18] становится более богатым Ni. При 865^0C, как предполагают А. Сугаки и А. Китакаце [19], в результате реакции между mss и жидкостью образуется высокотемпературный полиморфный пентландит (рисунок 9(B)). Если учесть данные А.А. Федорова и А.В. Синякова [20.], что в нашей системе вместо ваэсита ($Ni_{3\pm x}S_2$) присутствовал зигенит, то можно предположить, что температура в магматической камере опускалась ниже 806^0C. Если принять во внимание состав изученных сульфидов и согласиться с выводами Дж. Крэйга и Г. Куллеруда [21], то можно заключить, что жидкость, находящаяся в равновесии с mss при 850^0C, была обогащена Cu, но обеднена Ni относительно mss. Если учесть изотермические сечения системы Cu-Fe-S (рисунок 9(C)), то можно утверждать, что промежуточный твердый раствор (iss) выделяется из Cu-содержащего mss. При снижении температуры (до 400^0C и менее) iss, предположительно, разлагается на халькопирит-пирротиновые минеральные фазы. Присутствие в системе Fe-Ni-S (рисунок 9(D)) миллерита позволяет предположить, в соответствии с выводами Дж.Крэйга [22], что при 250^0C mss разделился на фазы mss_1 и mss_2+ миллерит. Это также согласуется с выводами К. Мисра и М. Флита [23], что при низкой температуре стабильно существует миллерит и, неустановленный нами минерал, хизлевудит.

Выводы. Вышеизложенное свидетельствует, что образование минеральных включений медно-никелевых руд, содержащих платинометальную минерализацию, протекало при понижении температуры, которая изменялась от 1200^0C до 100-135^0C. По-видимому, такое стремительное понижение температуры магматического расплава способствовало удержанию минералов платиновой группы и редкоземельных элементов в процессе его фракционирования и могло протекать в гипабиссальных условиях. Это предположение хорошо согласуется с присутствием в пикритах титаногематита. Как известно, титаногематит образуется при высоком окислительном потенциале кислорода, что является прямым свидетельством образования содержащих его пород в гипабиссальных условиях. Не противоречит этому и присутствие железа в сфалерите, поскольку при понижении давления происходит увеличение количества железа в структуре сфалерита, а также присутствие алтаита, формирующегося в условиях гидротермального среднетемпературного процесса минералообразования в качестве позднего минерала. Присутствие селенида свинца и алтаита, как и высокое содержание свинца в других сульфидах указывает, что магматические, в том числе рудные, процессы протекали в составе континентальной коры. Обнаруженные нами редкоземельные элементы, в составе сульфидов, такие как Ce, Dy, Er, Y на фоне платиноидов существенно увеличивают промышленный интерес к потенциальным рудам пикрит-диабазового каратургайского комплекса. Присутствие платиноидов и РЗЭ только в составе ликвационных капель представленных пирротином, халькопиритом, пентландитом и сфалеритом позволяет более корректно провести технологическое опробование руд каратургайского типа.

Все приведенные факты свидетельствуют, что рудообразование Cu-Ni-(МПГ)-(РЗЭ) руд каратургайского типа происходило в пределах открытой магматической системы. Исследования последних лет [24] показали, что открытые магматические системы являются благоприятными для концентрации большого количества сульфидов. Также ими [24] было отмечено, что для образования Cu-Ni-(МПГ)-(РЗЭ) руд в открытых магматических системах не обязательно должен быть привнос серы из вмещающих пород. Это также вселяет надежду, что в придонных и корневых зонах пикрит-диабазового каратургайского комплекса могут локализоваться крупные массы Cu-Ni-(МПГ) - (РЗЭ) руд.

Особо следует отметить, что образование пород каратургайского комплекса, по-видимому, связано с неоднократными импульсами магматического очага на фоне процессов сжатия в период формирования суперконтинента Роди́ния [25].

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СОТҮСТІК ҰЛЫТАУДЫҢ ҚАРАТОРҒАЙ КЕШЕНІНІҢ ПИКРИТ СУЛЬФИДЫНДАҒЫ СИРЕК КЕЗДЕСЕТІН ЭЛЕМЕНТТЕРДІҢ ЖӘНЕ ПЛАТИНОИДТАРДЫҢ ҚҰРАМЫ ЖӘНЕ ФОРМАСЫ

Аннотация. Біздің зерттеулер нәтижесінде қараторғай кешенінің пикритында ертеден белгілі мыс сульфиді, никель, кобальт (халькопипит, пентландит, кобальтитникелин, герсдорфит) басқа алғаш рет виоларит, сфалерит, зигенит, платина теллуриті (мочеит), күміс теллуриді, қорғасын теллуриді (алтаит), қорғасын селениді, ирид тобының металлдарының қатты ерітінділері (Ir, Os, Ru), сирек кездесетін элементтер (Dy, Er, Y, Ce). Сульфидтер үш минералды ассоциация құрайды. Бірінші екі ассоциация домалақ және эллипсті созылған формасы бар ликвациялық «тамшы» құрайды, үшіншісі минеарлды ассоциация – дұрыс емес өткірбұрышты формалы шығыстар. Нақытланған, егер перротин, халькопирит, пентландит, виоларит және сфалиттер құралған бірінші ассоциацияның ликвациялық тамшыларында ғана сульфидтің құрамында платиноидтар болады. Екінші ассоциация сульфидтары құрамында платиноидтар жоқ, олар пирротин, халькопирит, сфалеритпен ұсынылған. Үшінші ассоциация сульфиттері пирротин, халькопирит, сфалерит және пиритпен ұсынылған. Барлық минералогиялық ассоциациялар құрамында магнетит бар, олар еределі түрде пикриттер және апопикритті оливиниттер горизонттарына түсталған. Пикритті диабаз құрамында сульфидтердің кірістері анықталған: пентладит, зигенит, миллерит, пирит, галенит.Cu- Ni- (платина топтарының минералдары (ПТМ)) – (сирек кездесетін элементтері СКЭ) қараторғай кен түрінің, сульфидтардың өндірістік массаларының шоғырлануынына қолайлы, ашық магматикалық жүйе шегінде пайда болуы нақтыланған.

Түйін сөздері: Ұлытау, мыс-никельді кеніштер, платиноидтар, сирек кездесетін элементтер.

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FORECASTING OF PERSPECTIVE OBJECTS USING GEOPHYSICAL DATA ON THE PALEOZOIC COMPLEX OF WESTERN KAZAKHSTAN

Abstract. Clarification of the internal structure and the deep structure of the Paleozoic deposits of Western Kazakhstan, due to the emergence of new geophysical technologies to identify large promising search objects, acquire topical significance. New data on the south-eastern and eastern margins of the Pre-Caspian basin indicate the possibility of isolating large Paleozoic uplifts at the level of the Upper Devonian and Lower Carboniferous (there flecting horizon P_3). Large uplifts has of a supposedly structure are the massive character and tend to gravitate toward the inner side of the hollow. Inthesouth-east, there are the Guryev-Kulsarin zone and the Matken-Bikjalsky step while in the east of the basin there are the Borzher-Akzhar zone and the Shubarkuduk-Koskol step. The selection of objects of this category is associated with the features of the distribution of magnetic field anomalies, which are located in the contour of the region of its elevated values. In these conditions, an additional factor in matter of optimal delineation of objects of this type is the application of innovative technologies for processing and interpreting of the 2D and 3D seismic data. The substantiation of the forecast of development in the context of major uplifts in the relatively deep parts of the basin is given, in the long term, the important priority tasks of the exploration phase will be to bring the surveys in line with the geological exploration stage and adapt the strategy to the conditions of deep-lying promising zones and objects.

Key words: Paleozoic complex, Pre-Caspian basin, geophysical seismic survey, geological exploration, local features, eastern and south-eastern framing of the basin, sedimentation, oil and gas forecast, structure reflecting the horizon.

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ПРОГНОЗИРОВАНИЕ ПЕРСПЕКТИВНЫХ ОБЪЕКТОВ В ПАЛЕОЗОЙСКОМ КОМПЛЕКСЕ ЗАПАДНОГО КАЗАХСТАНА ПО ГЕОФИЗИЧЕСКИМ ДАННЫМ

Аннотация. Уточнение внутреннего строения и глубинной структуры палеозойских отложений, в связи с появлением новых геолого-геофизических данных и технологий выявления крупных перспективных поисковых объектов приобретают актуальное значение. Новые данные по юго-восточному и восточному обрамлению Прикаспийского бассейна свидетельствуют о возможностях выделения крупных палеозойских поднятий на уровне верхнего девона и нижнего карбона (отражающий горизонт $П_3$). Крупные поднятия предположительно, структурного массивного характера закономерно тяготеют к глубинной внутренней части обрамления. На юго-востоке – это Гурьевско-Кульсаринская зона и Маткен-Биикжальская ступень, на востоке бассейна – Боржер-Акжарская зона и Шубаркудук-Коскольская ступень. Выделение объектов такой категории увязывается с особенностями распределения аномалий магнитного поля, которые в плане располагаются в контуре области его повышенных значений. В этих условиях, дополнительным фактором в вопросах оптимального оконтуривания объектов данного типа, является применение инновационных технологий обработки и интерпретации сейсмических данных 2Д и 3Д (МФ, дифракционный МФ, многоазимутальное ВСП и АК повышенной глубины проникновения). Дается обоснование прогноза развития в разрезе крупных поднятий в относительно глубинных частях обрамлений бассейна, в перспективе важными приоритетными задачами поискового этапа будут являться приведение исследований в соответствии с этапностью геологоразведочных работ и адаптации стратегии поисков к условиям глубоко залегающих перспективных зон и объектов.

Ключевые слова: скважина, палеозойский комплекс, Прикаспийский бассейн, геофизические сейсмические исследования, геологоразведочные работы, локальный объект, восточное и юго-восточное обрамление бассейна, осадконакопление, прогноз нефтегазоносности, структура, отражающий горизонт и др.

Рынок углеводородов Западного Казахстана характеризуется наличием большого числа месторождений со значительным сроком эксплуатации. В этих условиях для поддержания планового уровня добычи на передний план выступает необходимость расширения поисковых работ, с целью подготовки новых крупных объектов в палеозойских отложениях, что связано с повышенными глубинами залегания (6,5-8,0 км). Восполнение ресурсной базы за счет крупных подсолевых палеозойских структур в настоящее время приобретает большое значение для всего Прикаспийского региона (Мангышлак и Прикаспийский бассейн). Это наиболее актуально, в первую очередь, для юго-восточной и восточной бортовых зон Прикаспийского бассейна, по которым в последние годы на ряде структур получены принципиально важные новые данные [1, 2].

В бортовых зонах Прикаспийского бассейна, крупные палеозойские объекты залегают на более доступных для бурения глубинах, порядка 4,5-5,5 км (рисунок 1). В большей части из них значимые залежи УВ приурочены к зонам преимущественно карбонатного осадконакопления, формирующим высокоамплитудные сооружения – платформы и постройки, как Тенгиз, Астраханское, Карачаганак, Кашаган, Королевское (рисунок 2). Крупные месторождения УВ на восточном борту (Жанажол, Кожасай, Алибекмола и др.) приурочены к карбонатным отложениям несколько иного формационного облика, в которых получили развитие и формируются резервуары для УВ преимущественно пластового массивного типа (рисунок 3).

За последние годы по юго-восточной и восточной части Прикаспийского бассейна получены новые данные о характере залегания палеозойских объектов. Как свидетельствуют положительные результаты бурения, наряду с бортовыми зонами (Урихтау, Алибекмола, Сазтобинская группа), крупные перспективные объекты могут связываться также с прибортовыми относительно погруженными (более «внутренними») районами бассейна осадконакопления (Тасым Юго-Восточный, Акжар Восточный, Кузбак, Биикжал, Улькентобе Юго-Западный, Есекжал и др.). Аналогично, данные о возможной продуктивности локальных поднятий в палеозое получены также по юго-западному обрамлению Прикаспийского бассейна (Кобяковская, Алга).

Сейсмические построения и данные бурения немногочисленных скважин указывают на связь вероятных зон нефтегазонакопления с крупными локальными объектами – поднятиями структурного и конседиментационного характера развития. Крупные поднятия в палеозое, предположительно, формируются в условиях далеко выступающего к центральной глубоководной части бассейна континентального склона. Площадь простирания древнего континентального склона, предположительно, определяется поведением и особенностями аномального магнитного поля. Так, контур обширной области, соответствующей аномалиям высокого значения магнитного поля, с ее северо-западной стороны ассоциируется с гигантской «геомагнитной ступенью», которая обращена выпуклой тыльной стороной на юго-восток. С учетом возможных различий в составе земной коры и фундамента, которые характеризуются соответствующим поведением основной магнитоактивной границы в разрезе осадочного чехла, предположительно, данная область указывает на относительно приподнятое (до 8,0 км) положение и залегания додевонского комплекса и девонской толщи.

В работах [2, 4] по мнению исследователей в качестве альтернативного варианта при определении структурно-тектонической и пространственной приуроченности и положения континентального склона предпочтение отдается влиянию седиментационных процессов и формированию Астрахано-Актюбинской системы выступов фундамента или Южно-Прикаспийского свода.

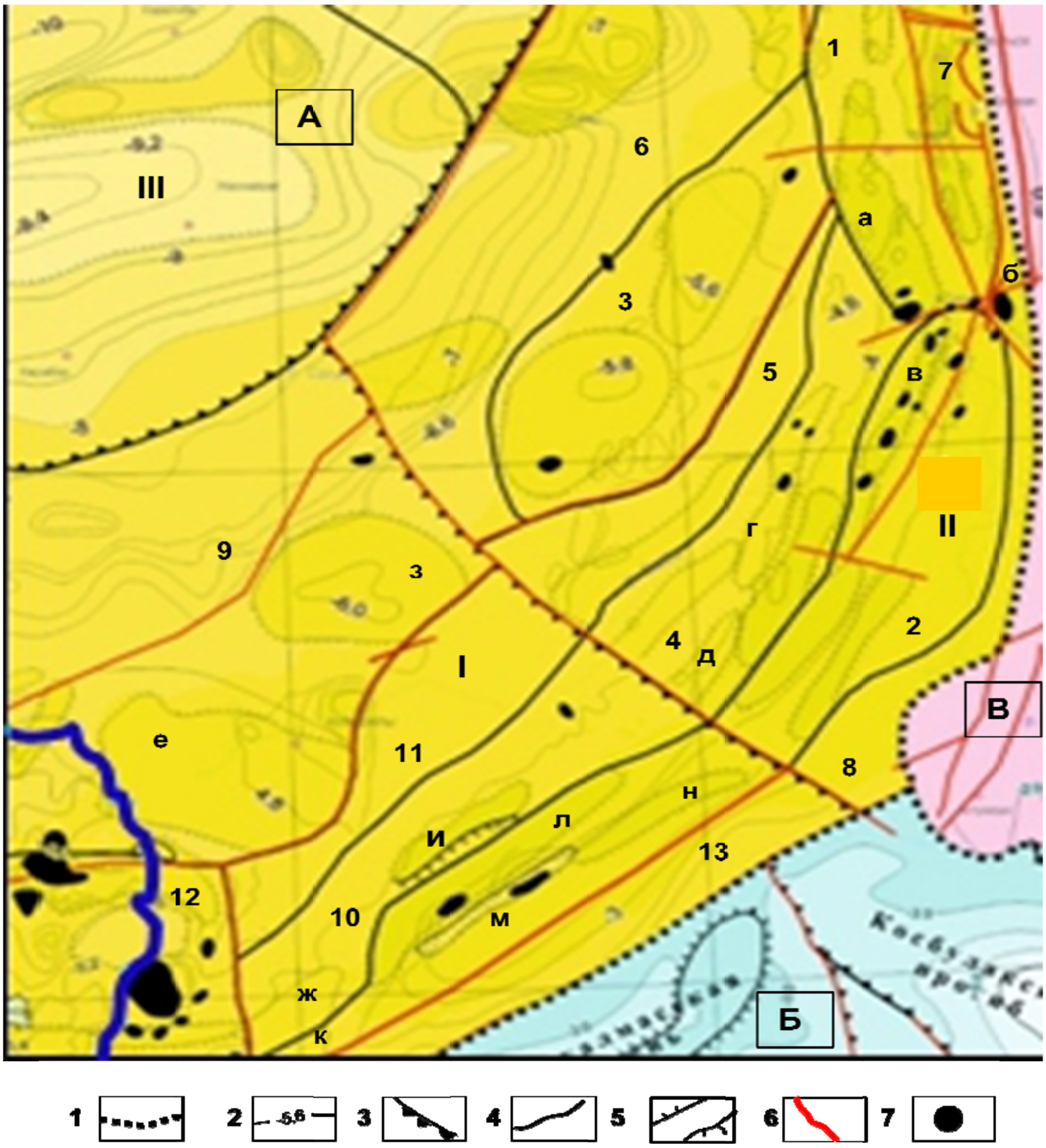

Рисунок 1 - Восточный и Юго-восточный борт Прикаспийского бассейна.
Тектоническая схема палеозойского комплекса (по данным Акчулакова У.А. и др.; 2012 г.)

1. Геоструктуры I порядка: А – Прикаспийский бассейн, Б – Устюрт-Бозаши, В – Уральская складчатая система; 2. Изогипсы по кровле палеозоя, км; 3. Контуры геоблоков и бортовых зон Прикаспийского бассейна: I – Юго-восточная, II – Восточная, III – Центральный); 4. Элементы II порядка: Восточный борт (зоны поднятий: 1 – Темирская, 2 – Жанажол-Торткольская, 3 – Шубаркудук-Коскольская; ступени: 4 – Боржер-Акжарская, 5 – Байганинская, 6 – Егенды-Сарыкумакская, прогибы: 7 – Остансукский, 8 – Терескенский). Юго-восточный борт (ступени: 9 – Гурьевско-Кульсаринская, 10 – Маткен-Биикжальская, 11 – Намазтакырская, 12 – Каратон-Тенгизская зона поднятий, 13 – Южно-Эмбинское поднятие). 5. Структуры нижнего порядка: Восточный борт (валы: а – Кенкияк-Аккудукский, б – Алибекмолинский, в – Жанажол-Синельниковский, г – Урихтау-Кожасайский, д – Тузкумский). Юго-восточный борт (зоны: е – Кульсаринская, ж – Елемес-Арманская, з – Сарыниязское поднятие; валы: и – Кумшетинский, к – Сазтобинский, л – Шолькара-Равнинный, м – Тортайский, н – Уртатау-Сарыбулакский). 6. Разломы; 7. Месторождения УВ.

Новое видение авторов в отношении зон развития крупных палеозойских поднятий, наряду с бортовыми зонами (традиционными в этом отношении по оценкам предыдущих лет), связывается с прибортовыми более погруженными и глубокопогруженными внутренними районами бассейна осадконакопления с отметкой залегания кровли палеозойской толщи порядка 7,0-8,0 км. При этом, авторами предполагается, что выделяемые во внутренних более погруженных районах Прикаспийского бассейна приоритетные перспективные объекты характеризуются преимущественно

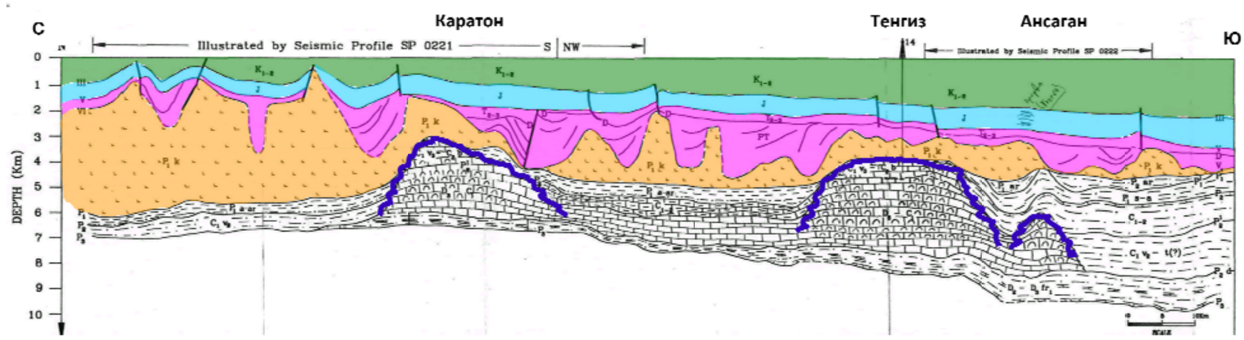

Рисунок 2 – Юго-восток Прикаспийского бассейна. Каратон-Тенгизская карбонатная платформа

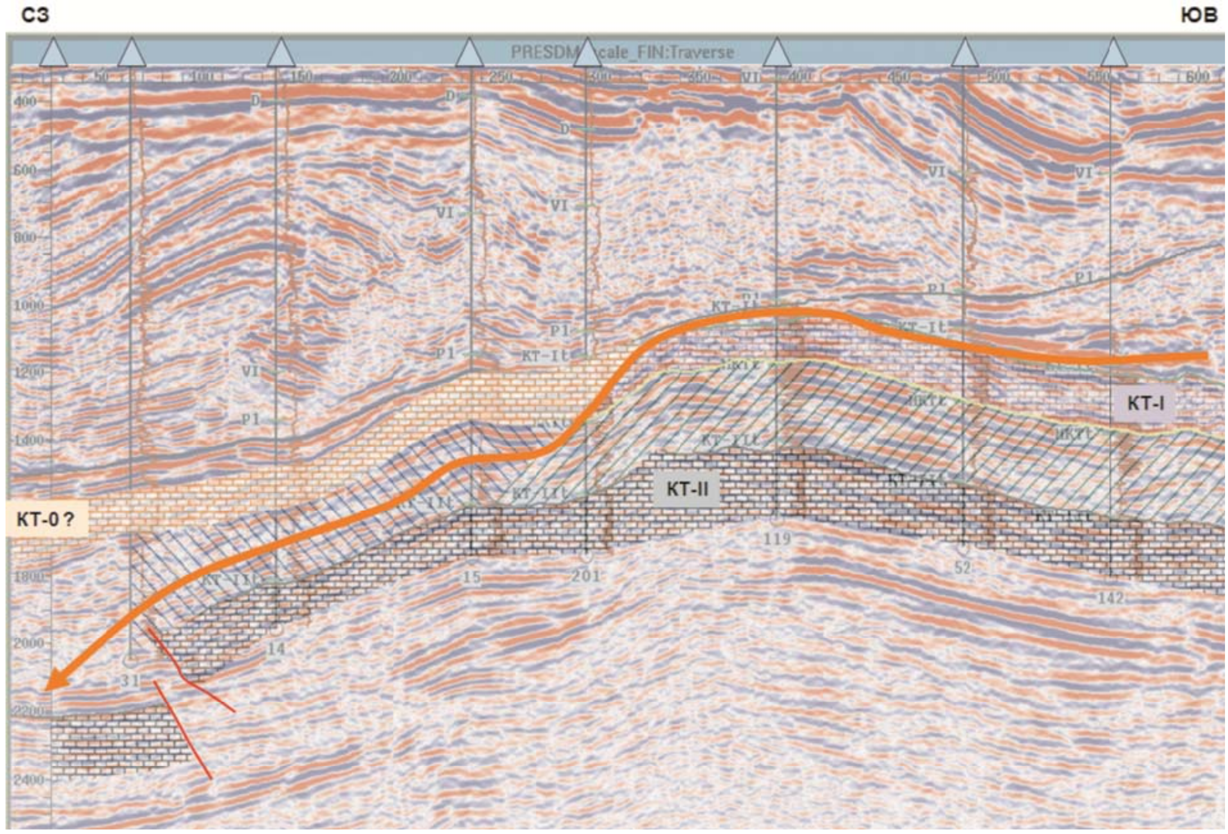

Рисунок 3 – Восточный борт Прикаспийского бассейна. Принципиальный сейсмогеологический разрез и характеристика карбонатных толщ КТ-II и КТ-I

терригенным и карбонатно-терригенным составом разреза с невысоким, минимальным содержанием или отсутствием в пластовых флюидах сероводорода и элементарной серы [3]. Следует отметить также, что с одной стороны прогноз нефтегазоносности больших глубин сопряжен со сложностями технического осуществления проводки скважин и, соответственно, значительными экономическими издержками. С другой стороны, изучение палеозойских отложений, залегающих на повышенных глубинах, в том числе в относительно более погруженных районах бассейна, предопределяет более предпочтительные условия залегания с учетом возможных масштабов и коммерческих характеристик залежей УВ, всевозрастающей роли в качестве надежного флюидоупора соленосной толщи кунгура.

Обосновываемые благоприятные предпосылки и возможности для выделения крупных потенциально нефтегазоносных объектов в бортовых и относительно погруженных районах Прикаспийского бассейна существенно расширяются с привлечением (наряду с техническим обеспечением бурения на повышенных глубинах) методов современной обработки сейсмических данных и технологии комплексирования с другими видами геофизических исследований (гравиразведка, электроразведка, магниторазведка, новые методы ГИС). Эти новые методы дают возможность более обоснованной интерпретации геолого-геофизических данных в отношении прогноза перспективных горизонтов на больших глубинах.

Основная достоверная информация о геологическом строении глубокозалегающих палеозойских горизонтов извлекается из полевых сейсмических материалов. Среди полевых сейсмических методов выделим, наряду с высокотехнологичными наземными технологиями МОГТ-3Д и также скважинную сейсморазведку ВСП, МА-ВСП (многоазимутальное и многоуровенное ВСП). Они позволяют получить более детальное сейсмическое изображение в около скважинном пространстве и ниже забоя, пробуренных на палеозойские отложения одиночных поисковых скважин. К сожалению, решение актуальных задач исследований глубокозалегающих палеозойских горизонтов сдерживаются несоответствием параметров полевых систем сейсморазведочных наблюдений [5].

В этих условиях, большое значение приобретает применение современных технологий углубленной переобработки существующих полевых данных 2Д/ 3Д, полученных с относительно малой плотностью и ограниченной базой наблюдения. Качество сейсмического изображения зон с фрагментарным и спорадическим прослеживанием отражающих надсолевых и подсолевых горизонтов значительно улучшается на разрезах и кубах, полученных по методу Мультифокусинг (далее – МФ) и технологии глубинной миграции до суммирования на основе улучшенных сейсмограмм МФ (рисунок 4) [5]. При этом метод МФ обеспечивает выделение групп энергетически слабых отражающих горизонтов, которые могут быть связаны с крупными поднятиями внутри девонских и каменноугольных отложений, по примеру ранее выделенного поднятия Урихтау на восточном борту Прикаспийского бассейна. Вместе с этим детализация контуров данных поднятий или объектов неструктурного типа предоставляет дополнительные возможности для расширения зоны поисковых исследований за счет новых локальных объектов, которые имеют вероятное развитие по периферии или в пределах известных крупных по площади и толщине палеозойских поднятий. Оконтуривание крупной палеозойской структуры Урихтау позволила выявить и обосновать перспективность новых объектов Урихтау Восточный и Урихтау Южный, которые располагаются в плане между ранее и относительно хорошо изученными поднятиями Урихтау и Жанажол, Урихтау и Кожасай, соответственно (рисунок 1).

На примере площади Алибекмола ее вытянутая структурная конфигурация по палеозойскому комплексу при детализационных работах позволила выделить перспективную часть залежи на севере структуры (рисунок 5). Фактически поднятие Алибекмола имеет «зажатый» характер

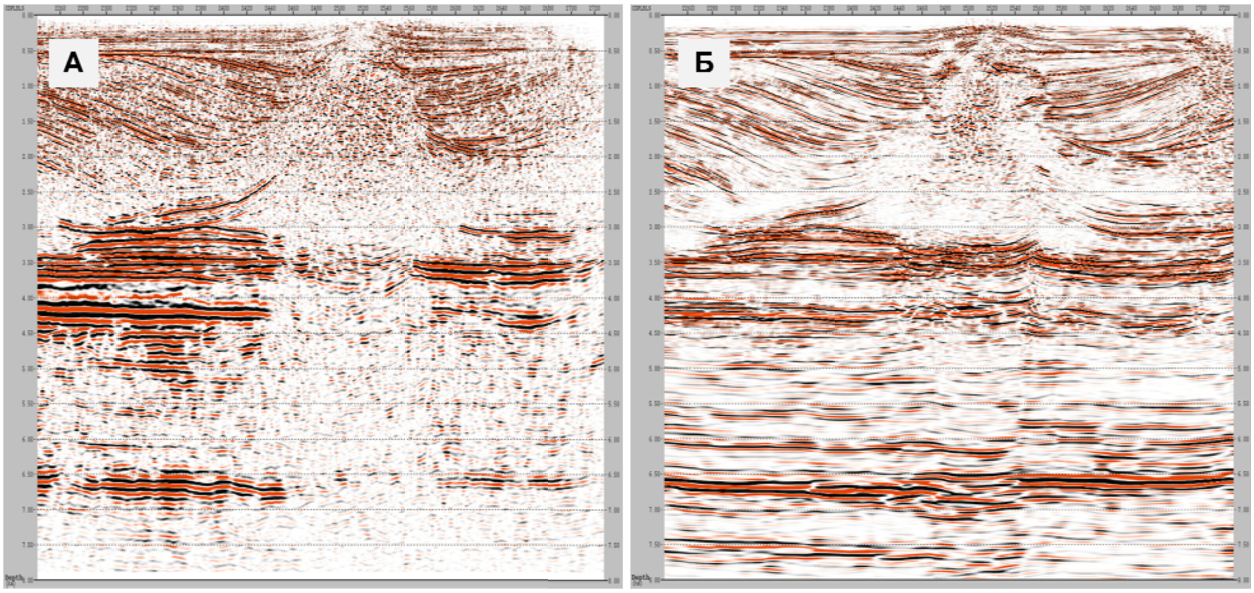

Рисунок 4 – Сравнение глубинных кубов: а) стандартная обработка PSDM, б) методика Мультифокусинг + PostSDM (пример месторождения на восточном борту Прикаспийского бассейна)

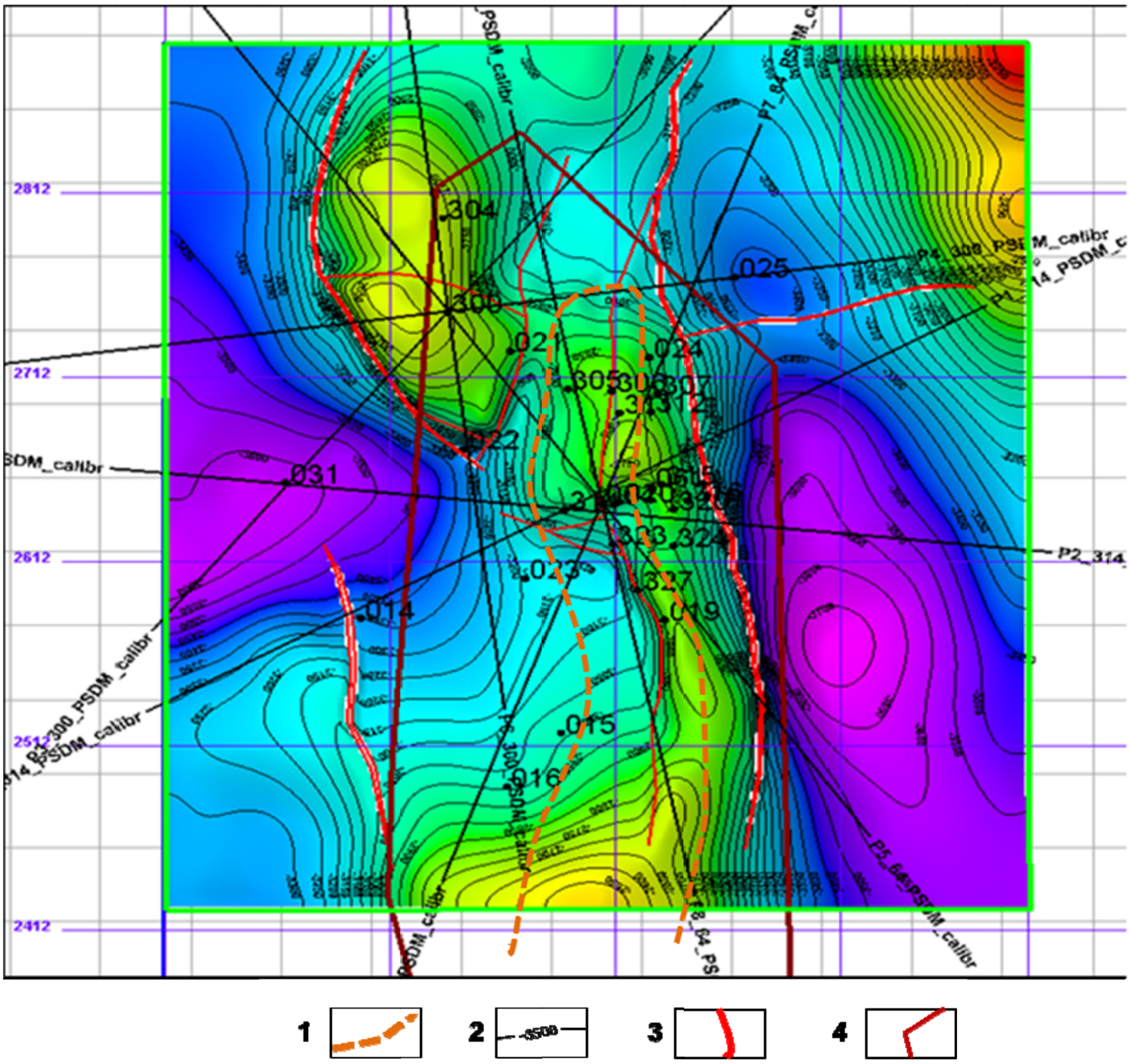

Рисунок 5 - Площадь Алибекмола. Структурная схема по кровле пачки КТ-II
(по данным АО НК «КазМунайГаз»; 2011 г.)

1. Зона повышенной плотности трещин в породах; 2. Изогипсы по кровле пачки КТ-II; 3. Тектонические разломы; 4. Контуры контрактной территории

строения и контуры в плане. Таким образом, ранее на практике из-за отсутствия в достаточном объеме кондиционных данных о строении поднятия часть территории потенциальной ловушки «отсекалась» и оставалась вне поля зрения поисковиков. Результаты новых сейсмических методов повышают детальность изучения геологического строения разреза в целом и продуктивной толщи, что позволяет в большей мере учесть зоны с дополнительными запасами промышленных категорий, что и было продемонстрировано в последние годы при оценке новых перспектив нефтегазоносности поднятия Алибекмола.

Так, на основе комплексной интерпретации материалов региональных профилей 2Д и новой объемной сейсморазведки 3Д-МОГТ по ряду крупных палеозойских структур в настоящее время внесены существенные коррективы и дополнены модели внутреннего строения. В результате на юге в междуречье Урал-Волга (Новобогатинск, Сарайшик), юго-востоке (Кызылкудук, Буйыргын, Кырыкмерген – Мунайлы Северный), востоке (Урихтау) и северо-востоке (Ширак, Кобланды) Прикаспийского бассейна новые данные, в случае постановки поисковых исследований, позволяют рассчитывать на благоприятный сценарий и возможности обнаружения значительных по масштабам залежей УВ [1, 3]. На ряде объектов в последние годы данные прогнозы о нефтегазоносности палеозойской толщи на глубинах 5,5-7,5 км находят подтверждение (Тасым Юго-Восточный, Ансаган, Урихтау, Кобланды, Кобяковская, Алга).

Особо отметим, что благодаря кооперации усилий нескольких компаний по реализации целенаправленных Программ на площадях и месторождениях восточного борта Прикаспийского бассейна удалось внедрить ряд уникальных технологий, позволяющих повысить в значительной мере в качественном отношении прогноз внутреннего строения и нефтегазоносности сложнопостроенных подсолевых палеозойских объектов. Проведение сервисных услуг вспомогательного характера и, в первую очередь, сейсмических исследований в различной модификации представляется большим подспорьем для бурения скважин на большие глубины. Немаловажным фактором следует учитывать благоприятно развитую инфраструктуру (близость трубопроводов и транспортных магистралей, объектов реальных потребителей нефти и газа) и достаточность в регионе квалифицированных кадров.

В северной части площади Алибекмола (восточный борт Прикаспийского бассейна) ряд скважин не давал притоков, соответствующих проектному уровню. В связи с этим, в 2010-2012 гг. АО НК «КазМунайГаз» совместно с компаниями «Шлюмберже» и«Азимут» впервые в СНГ реализовали в районе расположения трех глубоких скважин комплексные наземные и скважинные исследования по технологии многоазимутального МА-ВСП, АК (повышенной глубины проникновения), 2Д-МОГТ (по 6 радиальным профилям). Эти исследования позволили объяснить причины и более четко оконтурить зоны трещиноватости и потери дебита, изучить закономерности распределении коллекторов и межкарбонатной толщи, насыщения разрезов карбонатных пластов КТ-I и КТ-II нефтью, изучить глубокие интервалы палеозойского разреза ниже отметки забоя скважин (рисунок 5).

Уникальные результаты по повышению информативности и разрешенности сейсмического сигнала получены при применении новейших программных технологий на материалах 3Д съемки также на месторождении Кожасай [5]. К слову, уникальность технологии МФ видна не только по выразительности отражений от кровли соляного купола и прилегающих пермотриасовых отложений. Данная технология совершенна в решении задачи в части подсолевого комплекса, включая подкупольную зону разреза. Обычно – это немые участки из-за многообразия помех в этой зоне. Дифракционный метод МФ позволяет получить, кроме выразительности волновой картины, также четкую корреляционную связь между амплитудами дифракционных аномалий непосредственно с дебитом УВ в скважинах. Это открывает новые возможности для применения данной технологии на освоенных месторождениях для прогноза дебитов и контроля (мониторинга) проектных показателей при последующей разработке.

На основании анализа новых данных и результатов предлагается применение новейших технологий (в части «передовых» методов сейсмических исследований) в пределах перспективных участков и поднятий Жанажол-Торткольской зоны. С учетом этого, локальные объекты и площади на восточном борту в перспективе можно представлять в определенной мере в качестве полигонов для применения передовых методов и новейших технологий сейсмических исследований на остальной перспективной территории Прикаспийского бассейна.

В связи с этим, в юго-восточной прибортовой зоне поисковый интерес с точки зрения возможностей обнаружения значительных по запасам залежей на основе полученного опыта применения новых технологий приобретают, в первую очередь, внутренние погруженные районы бассейна осадконакопления. Основную часть юго-восточной относительно погруженной территории представляет Маткен-Биикжальская тектоническая ступень (рисунок 1). По кровле подсолевого палеозоя (ОГ $П_1$) данная ступень выделяется в интервале глубин -3,4-5,6 км. Оценивая степень перспективности данной ступени, необходимо отметить, что ее изученность в сравнении с юго-восточными от нее районами несколько ниже.

К северо-западу Маткен-Биикжальская ступень сопряжена с Намазтакырской ступенью. Еще далее в северном направлении по кровле палеозоя фиксируется слабый региональный подъем в сторону Гурьевско-Кульсаринской региональной ступени (рисунок 1). К этим региональным элементам II порядка приурочиваются практически все выявленные за последние годы крупные палеозойские поднятия, в которых при оценке перспективности ряд факторов позволяет акцентировать в данном отношении верхнедевонско-нижнекаменноугольную часть разреза.

Для этого несколько подробнее отметим некоторые особенности строения объектов данного типа. Локальные объекты (поднятия) в пределах рассматриваемой территории, как правило, отли-

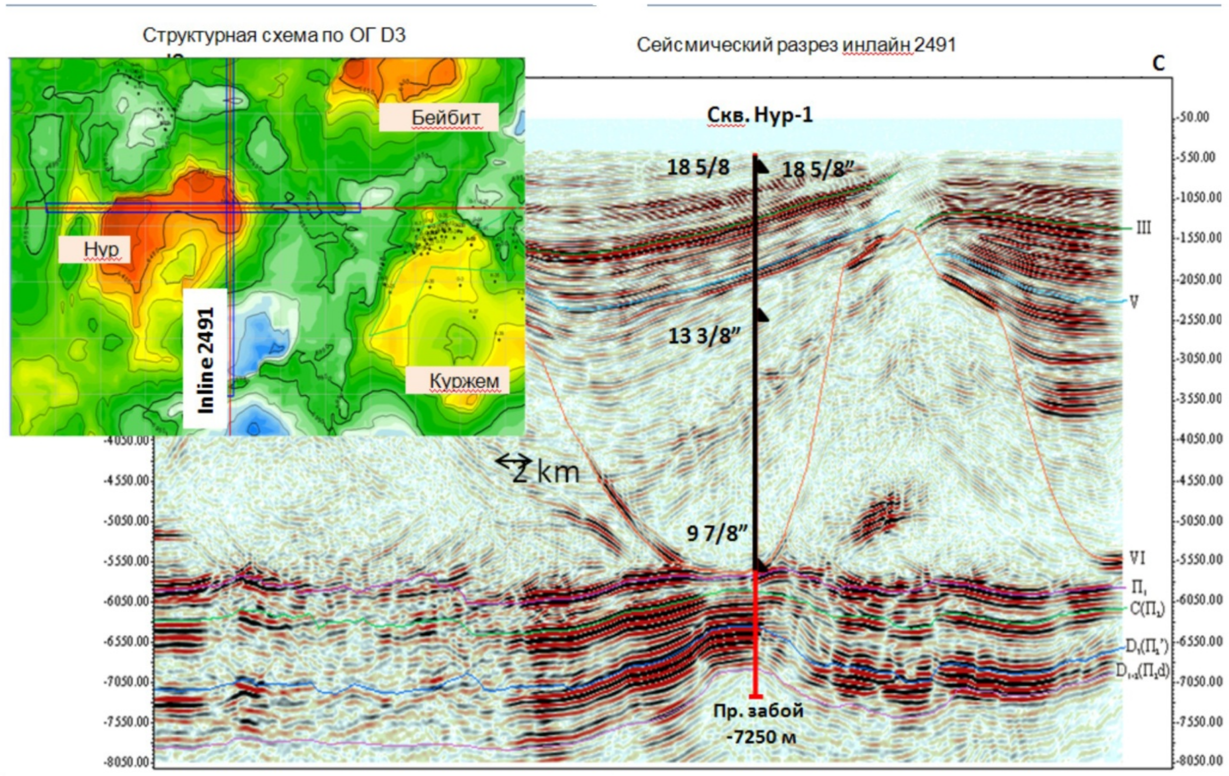

Рисунок 6 – Гурьевско-Кульсаринская тектоническая ступень. Поднятие Кузбак
(по данным ТОО «Самек Интернешнл»; 2013 г.)

чаются крупными размерами, высокой амплитудой и, предположительно, в большей мере, конседиментационным характером развития (рисунок 6). Авторы, склонны относить выделяемую часть юго-восточного обрамления к области континентального склона палеобассейна. На всем его протяжении условия формирования отложений способствовали образованию крупных локальных структур – поднятий по девону и нижнему карбону (Кызылкудук, Буйыргын, Кузбак, Тасым Юго-Восточный, Есекжал, Кырыкмерген – Мунайлы Северный, Улькентобе Юго-Западный и др.). По аналогии с этим, на восточном борту в продвинутой части бассейна осадконакопления с учетом результатов комплексного изучения осадочных бассейнов (2009-2013 гг.) прогноз крупные структурных поднятий связывается с Шубаркудук-Коскольской зоной (Шиликты) и Боржер-Акжарской ступенью (Акжар Восточный – Курсай).

Данные анализа особенностей распространения аномалий магнитного поля показывают общие черты строения и состава додевонского комплекса и девонских отложений в разрезе указанных крупных элементов II порядка. Обособленность Маткен-Биикжальской ступени просматривается при анализе и прослеживании литолого-фациальной обстановки нижнепермского этапа осадконакопления (ассель – сакмар). На этом отрезке развития данная ступень характеризовалась более интенсивным осадконакоплением. Северо-западнее в пределах Намазтакырской и Гурьевско-Кульсаринской зоны в ассель-сакмарское время накопление осадков ослабевало или носило прерывистый характер. В региональном плане Маткен-Биикжальская ступень продолжается во вдольбортовой ориентировке в направлении на северо-восток и, на восточном борту ее структурным «продолжением» является Боржер-Акжарская ступень (рисунок 1). В направлении на юго-запад Маткен-Биикжальская и Намазтакырская ступень структурно «упираются» в Каратонский вал, выступающий как северное ограничение Каратон-Тенгизской зоны поднятий. Данный переход фиксируется на структурном плане и, в направлении к Каратон-Тенгизской зоне поднятий территория испытывает резкий гипсометрический подъем.

К юго-востоку в полосе более активной складчатой и разломной тектоники основными крупными структурными элементами являются Елемес-Арманская зона поднятий, Кумшетинский вал (-3,7-4,8 км). Южнее выделяется серия контрастно выраженных протяженных антиклиналей, структурных валов (Шолькара-Равнинный, Тортайский, Сазтобинский вал), ориентировка которых более четко определяется по полосе сгущения изогипс по подсолевым отражающим поверхностям, маркирующей непосредственно «переход» на юго-востоке к Южно-Эмбинскому палеозойскому поднятию (рисунок 1).

С учетом обосновываемой структурной и литолого-фациальной дифференциацией рассматриваемой территории, а также новых данных бурения, полученных по относительно продвинутой внутренней части юго-востока Прикаспийского бассейна ниже отметим некоторые важные особенности строения палеозойской толщи и ее нефтегазоносности.

– Разрез палеозоя имеет выраженное трехчленное строение, снизу-вверх выделены терригенный нижний карбон (C_1v_{1-2}-s), карбонатно-терригенные отложения среднего карбона верхне-визейско-московского возраста (C_1v-C_2m) и терригенный обломочный комплекс нижней перми (P_1as-s).

– В относительно продвинутой от борта бассейна части территории в ряде скважин (площади Улькентобе Юго-Западный, Карашунгыл, Маткен, Есекжал) ранее получены притоки нефти в отложениях среднего карбона (C_1v_3-C_2m). Данные притоки зачастую носили пульсирующий характер. На площадях Биикжал и Тортай притоки УВ получены также из отложений нижнего карбона.

– Юго-восточнее в полосе относительно приподнятого залегания кровли палеозоя (Елемес-Арманская зона, Кумшетинский, Шолькара-Равнинный и Тортайский валы) нефтегазоносность в палеозойском комплексе больше связана с нижнепермскими терригенными отложениями конусов выноса и палеорусловых потоков (P_1 ar), а также сульфатно-терригенной пачкой филипповского горизонта (P_1k). В итоге, несмотря на отсутствие достаточно «совершенной» методики поисков на ранних этапах изучения, в подсолевом комплексе на юго-востоке выявлено два мелких ограниченных по запасам месторождения в карбоне (Равнинное, Тортай).

– Отмечается ряд особенностей в распространении и характере залежей и нефтегазопроявлений на Маткен-Биикжальской ступени (средний карбон, нижняя пермь), свидетельствующие об их приуроченности к локальным зонам в опущенных частях у флексурных перегибов и разломам, ловушкам линзовидного строения, связанным с областями преимущественно терригенного осадконакопления. Эти особенности, в свою очередь, определяют общие региональные закономерности линейного характера в пространственном размещении залежей УВ.

– Структурный план локальных поднятий, как правило, на уровне сейсмических горизонтов $П_2^1$, $П_2$, $П_1$ в целом носит унаследованный характер без значительных колебаний значений толщин сейсмокомплексов, заключенных между отражающими границами. В силу заданных глубин для сейсмического сигнала (не более 4,4-5,0 км) ранее ставились общие ориентиры поисковых исследований, которые корректировались в зависимости от ряда факторов (качество структурных построений, состояние фонда и более подготовленные в нем структуры, поставленные перед бурением геологические задачи и др.). Вследствие этого не ясной в полной мере оставалась сейсмическая картина по нижнему терригенному комплексу, залегающему ниже границы $П_2^1$.

– Заметно улучшилась картина представления структурного плана по нижней части подсолевого разреза на уровне и ниже сейсмического горизонта $П_3$ (девон – нижний карбон). По результатам исследований в последние годы (АО «Казахстанкаспийшельф», 2005-2006 гг.; ТОО «Ойлгеоконсалтинг», 2007-2008 гг.) связь данного интервала с отражающей границы находит довольно четкое подтверждение и увязку. По ряду районов на уровне горизонта $П_3$ отмечается довольно дифференцированный характер структурного плана и относительно более контрастная морфологическая выраженность локальных поднятий на структурной основе.

Так, контрастный рисунок структурного плана и локальных поднятий по нижним подсолевым сейсмическим горизонтам в разрезе более выражены в северной и северо-восточной части Маткен-Биикжальской ступени. Выделяется Кульсаринская зона поднятий, соответствующая южной части Гурьевско-Кульсаринской региональной ступени (Акчулаков У.А. и др., 2012г.) [1]. Поднятия в пределах указанной структурной зоны характеризуются в большинстве крупными размерами, значительной амплитудой и контрастным развитием, особенно на уровне горизонта $П_3$. Главными особенностями локальных объектов в связи с этим является погребенный характер и постепенное сглаживание их развития вверх по разрезу. В рельефе отражающей границы $П_1$ они фиксируются менее контрастно. Немаловажным фактором в прогнозе перспективности крупных поднятий во внутрибассейновой части территории является их приуроченность в плане к межкупольным зонам, что получило подтверждение по результатам сейсмической интерпретации по району крупных поднятий Кырыкмерген – Мунайлы Северный и Кузбак и указывает на достаточно высокий уровень объективности, сделанных предположений (Ескожа, Воронов; 2008 г.) [4]. При этом довольно характерно контрастное проявление структуры по нижнему девонско-нижнекаменноугольному интервалу разреза и, «замок» структуры проявлен на уровне ОГ $П_3$ (рисунок 6).

В оценке и обосновании высокой перспективности крупных структурных поднятий в девоне – карбоне, наряду с тектоническим критерием, доминирующей представляется также роль литолого-фациального критерия. Глубокозалегающие локальные структурные объекты формировались в обстановке преимущественно терригенного и карбонатно-терригенного осадконакопления. Высокие значения фильтрационно-емкостных свойств обеспечивались проявлением разломной тектоники и развитием процессов трещиноватости, активностью палеорусловых систем и глубоководных конусов выноса, обуславливающих местами линзовидный характер ловушек, а также палеотечений. Положительные результаты и характер проявлений УВ на поднятиях Улькентобе Юго-Западный, Есекжал, Карашунгыл, Маткен, Биикжал подтверждают данные выводы и предположения.

В этом, полагаем, значительна роль и новые возможности сейсмических методов обработки и интерпретации данных, позволяющие на более высоком качественном уровне обосновать и рассматривать выявленные крупные палеозойские поднятия. В практическом плане возможности новых методов успешно апробированы при подготовке и обосновании характерных палеозойских поднятий в юго-восточной части подсолевого Прикаспия Кузбак (Нур – Куржем – Бейбит), Кызылкудук, Буйыргын, Кырыкмерген – Мунайлы Северный и др.

Выводы.

1. Условия формирования и осадконакопления в палеозойском комплексе внутренней, относительно погруженной части на юго-востоке (Маткен-Биикжальская, Намазтакырская, Гурьевско-Кульсаринская зона) и востоке (Боржер-Акжарская и Егенды-Сарыкумакская ступень, Шубаркудук-Коскольская зона) Прикаспийского бассейна благоприятствуют образованию крупных поднятий массивного конседиментационного характера развития. С применением новых технологий сейсмической обработки и интерпретации ожидается в значительной мере улучшить степень изученности глубоко залегающего комплекса палеозойских отложений и прогнозирования перспективных локальных структур и объектов.

2. Для оптимального изучения строения глубоких горизонтов в палеозое необходимо научно-исследовательским институтам выработать и реализовывать совместно с нефтяными компаниями четкую этапность ГРР и стратегию адаптации к условиям глубоко залегающих перспективных зон технологических приемов сейсморазведки, как на этапе полевых исследований, так и на этапе обработки первичных данных.

3. Детальный комплексный анализ геолого-геофизических данных должен лежать в основе совершенствования технологии поисковых работ и повышения эффективности нефтепоисковых работ по Западному Казахстану в целом.

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ГЕОФИЗИКАЛЫҚ ДЕРЕКТЕР БОЙЫНША БАТЫС ҚАЗАҚСТАННЫҢ ПАЛЕОЗОЙЛЫҚ КЕШЕНІНДЕ ПЕРСПЕКТИКАЛЫҚ ОБЪЕКТІЛЕРДІ БОЛЖАУ

Аннотация. Ірі перспективалық іздестіру объектілерін анықтаудың жаңа геологиялық-геофизикалық деректері мен технологияларының пайда болуына байланысты палеозой шөгінділерінің ішкі құрылысы мен терең құрылымын нақтылаудың өзекті маңызы бар. Каспий маңындағы бассейнді оңтүстік-шығыс және шығыс жиектеуі бойынша жаңа деректер үстіңгі девон және астыңғы карбон (П3 көкжиегін көрсететін) деңгейінде ірі палеозойлық көтеруді бөлудің мүмкіндіктері туралы куәландырады. Ірі көтерілулер құрылымдық жаппай сипатта жиектеудің ішкі тереңдетілген бөлігіне заңды түрде болжалды тартылады. Оңтүстік-шығыста – бұл Гурьев-Құлсары аймағы және Мәткен-Биікжал деңгейі, бассейннің шығысында - Боржер-Ақжар аймағы және Шұбарқұдық-Қоскөл деңгейі. Осындай санаттағы объектілерді бөлу магнитті өрістің ауытқуларын бөлу ерекшеліктерімен байланыстырылады, бұл тұрғыда оның жоғарылатылған мәндері облыстың сызығында бар. Бұл жағдайда, осындай түрдегі объектілердің оңтайлы кескіндеу мәселелеріндегі қосымша фактор 2Д және 3Д (МФ, дифракциялық МФ, көп азимуталды ВСП және енудің жоғарылатылған тереңдігінің АК) сейсмикалық деректерін өңдеу және түсіндірудің инновациялық технологияларын қолдану болып табылады. Бассейн жиектеуінің тереңдетілген бөліктеріне қатысті ірі көтерілулер бөлінісінде даму болжамының негіздемесі беріледі, келешекте іздестіру кезеңінің маңызды басым міндеттері тереңде жатқан перспективалық аймақтар мен объектілердің шарттарына іздеу стратегиясын бейімдеу және геологиялық барлау жұмыстарының кезеңділігіне сәйкес зерттеулерді келтіру болып табылады.

Түйін сөздер: ұңғыма, палеозойлық кешен, Каспий маңындағы бассейн, геофизикалық сейсмикалық зерттеулер, геологиялық барлау жұмыстарды, жергілікті объекті, бассейнді шығыс және оңтүстік-шығыс жиектеу, шөгінді жиналуы, мұнайгаздылық болжамы, құрылым, деңгейжиегін көрсетуші және т.б.

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Требования для авторов журнала НАН РК Серия геологии и технических наук

Уважаемые авторы!

Прошло более семидесятипяти лет, как издается журнал «Известия НАН РК. Серия геологическая», а с 2011 г. «Серия геологии и технических наук». За период существования журнал завоевал широкий круг читателей и стал известен не только в Казахстане, но и в странах ближнего и дальнего зарубежья.

В журнале на русском, казахском, английском языках публикуются статьи о результатах исследований по актуальным проблемам обширной геологической науки (региональной геологии, минерагении, нефти и газа, геофизики, сейсмологии, гидрогеологии, экологии, географии), а так же статьи методического характера.

Все эти годы журнал служит источником оперативной информации о новейших достижениях геологической науки Казахстана и призван способствовать повышению эффективности научных исследований.

Авторы несут ответственность за достоверность и значимость научных результатов и актуальность научного содержания работ. Не допускается плагиат.

1. Представленные для опубликования материалы должны удовлетворять следующим требованиям.

Статья сопровождается разрешением на опубликование от учреждения, в котором выполнено исследование и представляется рецензия.

Статья представляется в одном экземпляре. Размер статьи не должен превышать 15 страниц включая аннотацию в начале статьи перед основным текстом, которая должна отражать цель работы, метод или методологию проведения работы, результаты работы, область применения результатов, выводы (**аннотация** не мене 15 предложений – 1/4 стр. (на английском языке) через 1 компьютерный интервал), таблицы, рисунки, список литературы (через 1 компьютерный интервал), напечатанных в редакторе Word, шрифтом Times New Roman, поля – верхнее и нижнее – 2 см, левое – 3 см, правое – 1,5 см. Количество рисунков не более 10. Название рисунков и подрисуночная подпись, а также название таблиц печатается на русском и английском языках.

СТАТЬЯ НАЧИНАЕТСЯ **на английском языке**. В начале, посередине страницы, идет название статьи прописными жирными буквами, далее на следующей строчке – инициалы и фамилии авторов обычным жирным шрифтом, затем на следующей строчке – название организации(ий), в которой выполнена работа, город, страна, затем на новой строчке – адреса E-mail авторов. С красной строки идут ключевые слова (**Key words**), и с новой строчке – сама аннотация (**Abstract – не мене 150 слов**).

Далее, после отбивки одной строки, начинается на **русском языке**.

В начале статьи вверху слева следует указать индекс **УДК.** Затем, посередине страницы, пишется: 1) название статьи; 2) авторы; 3) название организации; с красной строки – **Ключевые слова**, затем – **Аннотация** (оформление шрифтов, как на английском языке).

Отбиваем одну строку и начинается сама **статья**. Следом за статьей идет список **Литературы**. Ссылки на литературные источники даются цифрами в прямых скобках по мере упоминания (не менее 20). Список литературы оформляется следующим образом:

[1] Иванов А.А. Процессы протаивания грунта // Известия НАН РК. Серия геологии и технических наук. – 2007. – № 1. – С. 16-19.

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2) убираем специальные разделители между полями (“//”, “-”);
3) выделяем курсивом название источника;
4) выделяем год полужирным шрифтом;
5) указываем язык статьи (in Russ.).

Пример:

[1] White S.R., Sottos N.R., Geubelle P.H., Moore J.S., Kessler M.R., Sriram S.R., Brown E.N., Viswanathan S. *Nature,* **2001***,* 409, 794-797 (in Eng.).

[2] Soldatenkov N.M., Koljadina I.V., Shendrik A.T. Fundamentals of organic chemistry of medicinal substances. M.: Himija, **2001.** 192 p. (in Russ.).

В конце статьи дается резюме на казахском языке. Оформляется аналагично русскому варианту. Посередине страницы пишется: 1) название статьи; 2) авторы; 3) название организации; с красной строки – **Түйін сөздер**, после – **Аннотация**.

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Уважаемые авторы!

В настоящее время около 250 казахстанских вузов и научных организаций имеют доступ к информационным ресурсам авторитетных международных компаний таких как Thompson Reuters и Springer. За последние четыре года обращений казахстанских подписчиков, согласно статистике использования ресурса Web of Scince Core Collection компании Thompson Reuters, увеличилось в 4 раза. Доступ к мировым базам научных знаний был определен президентом Нурсултаном Назарбаевым как один из приоритетных инструментов развития науки на Первом форуме ученых в декабре 2011 года.

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