ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казахский национальный исследовательский
технический университет им. К. И. Сатпаева

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Kazakh national research technical university
named after K. I. Satpayev

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

1 (433)

JANUARY – FEBRUARY 2019

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология мен техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 30.04.2010 ж. берілген **№10892-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

Редакцияның мекенжайы: Қазақстан, 050010, Алматы қ., Қабанбай батыра көш., 69а.
Қ. И. Сәтбаев атындағы геология ғылымдар институты, 334 бөлме. Тел.: 291-59-38.

Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№10892-Ж,** выданное 30.04.2010 г.

Периодичность: 6 раз в год
Тираж: 300 экземпляров

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
http://nauka-nanrk.kz /geology-technical.kz

Адрес редакции: Казахстан, 050010, г. Алматы, ул. Кабанбай батыра, 69а.
Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 10892-Ж, issued 30.04.2010

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
http://nauka-nanrk.kz/geology-technical.kz

Editorial address: Institute of Geological Sciences named after K.I. Satpayev
69a, Kabanbai batyr str., of. 334, Almaty, 050010, Kazakhstan, tel.: 291-59-38.

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 6 – 22 **https://doi.org/10.32014/2019.2518-170X.1**

UDC 552.125.4; 550.4; 552.23; 552.11

Yertlek Suiekpayev[1], Yerzhan Sapargaliyev[1, 2], Galiya Bekenova[3], Mikhail Kravchenko[2], Alla Dolgopolova[4], Reimar Seltmann[4]

[1]Serikbaev East Kazakhstan State Technical University (EKSTU), Kazakhstan,
[2]LLP "Altaiskiy Geologic-Ecological Institute", JSC "NSTH Parasat", Ust-Kamenogorsk, Kazakhstan,
[3]LLP "Institute of Geological Sciences named after K. I. Satpaev", Almaty, Kazakhstan,
[4]Natural History Museum, Earth Sciences Department, CERCAMS, London, U.K.
E-mail: y.suiekpayev@gmail.com; er_sapar@mail.ru; bekenova@mail.ru;
e-31-90@mail.ru; a.dolgopolova@nhm.ac.uk; r.seltmann@nhm.ac.uk

MINERALOGICAL AND GEOCHEMICAL FEATURES OF SATPAEV Ti-Zr PLACER DEPOSIT, EAST KAZAKHSTAN

Abstract. The data of mineralogical and geochemical studies of Ti-Zr mineral sands and heavy fraction of the mineral concentrate of Placer No. 1 of the Satpaev deposit (East Kazakhstan) are obtained. The mineralogical composition of the mineral sands: quartz, albite, ilmenite, and feldspar; micro-sized crystals of barite, zircon, monazite, a mineral of pyrochlore composition, were identified by electron microprobe. Crystal morphology of ore minerals: ilmenite and zircon and chemical composition of ilmenite were determined. The development of leucoxenization in microcracks and edges of ilmenite crystals have also been revealed.

Geochemical features of productive horizons include the apparent enrichment of light rare-earth elements (LREE) in comparison with heavy rare-earth elements (HREE), and pronounced negative Eu anomaly that indicate high degree of fractionation of source rocks. Granitoids of the Preobrazhensk intrusion are the likely source of the Satpaev placer deposit.

Results of petrological and geochemical research indicate that localization of ore minerals took place during chemical weathering, which enabled release of ore minerals of titanium and zirconium with their further redeposition in local continental coastal settings in warm and humid climate.

Keywords: Satpaev Ti-Zr placer deposit, Preobrazhensk intrusion, rare-earth elements, East Kazakhstan.

1. Introduction. Titanium is widely used in the production of pigmentary titanium dioxide, titanium sponge, titanium ferroalloys, and various compounds used in metallurgy. The main minerals of titanium ores include ilmenite, rutile, anatase and brookite, leucoxene, loparite, titanite, perovskite and titanomagnetite. In complex titanium deposits the accompanying elements of economic value include: Fe, V, Zr, Sc, P, Nb, Ta, Th and rare-earth elements (REE) [1, 2].

Titanium deposits are divided into three main groups: magmatogenic (25.3% of all reserves of titanium dioxide), metamorphogenic (19.5%), and exogenetic (55.2%) [3]. In the world mineral base of titanium, exogenetic deposits occupy the leading position in terms of reserves (52.3%), production (65-70%) and their economic value (67-73% of produced titanium dioxide in concentrates) [4].

The Kazakhstani producer of titanium is JSC "Ust-Kamenogorsk Titanium Magnesium Plant" (JSC "UK TMP") that manufactures a wide range of titanium products; the main ones include titanium sponge, pigmentary titanium dioxide and metallic titanium. Mineral resources of titanium production in Kazakhstan are represented by three geological-economic deposits types: coastal (Obukhovsk, Shokash, Kumkol', Zayach'e, Tobol'sk and other placer deposits), alluvial-proluvial (Satpaev deposit) and proluvial-alluvial (Karaotkel deposit) [5].

At present JSC "UK TMP" receives ilmenite concentrates from the nearby located Satpaev titanium-zirconium placer deposit [6]. The Satpaev deposit is located in the northwestern part of the Zaysan depression, 220 km to the south of Ust-Kamenogorsk city (the regional center of the East Kazakhstan

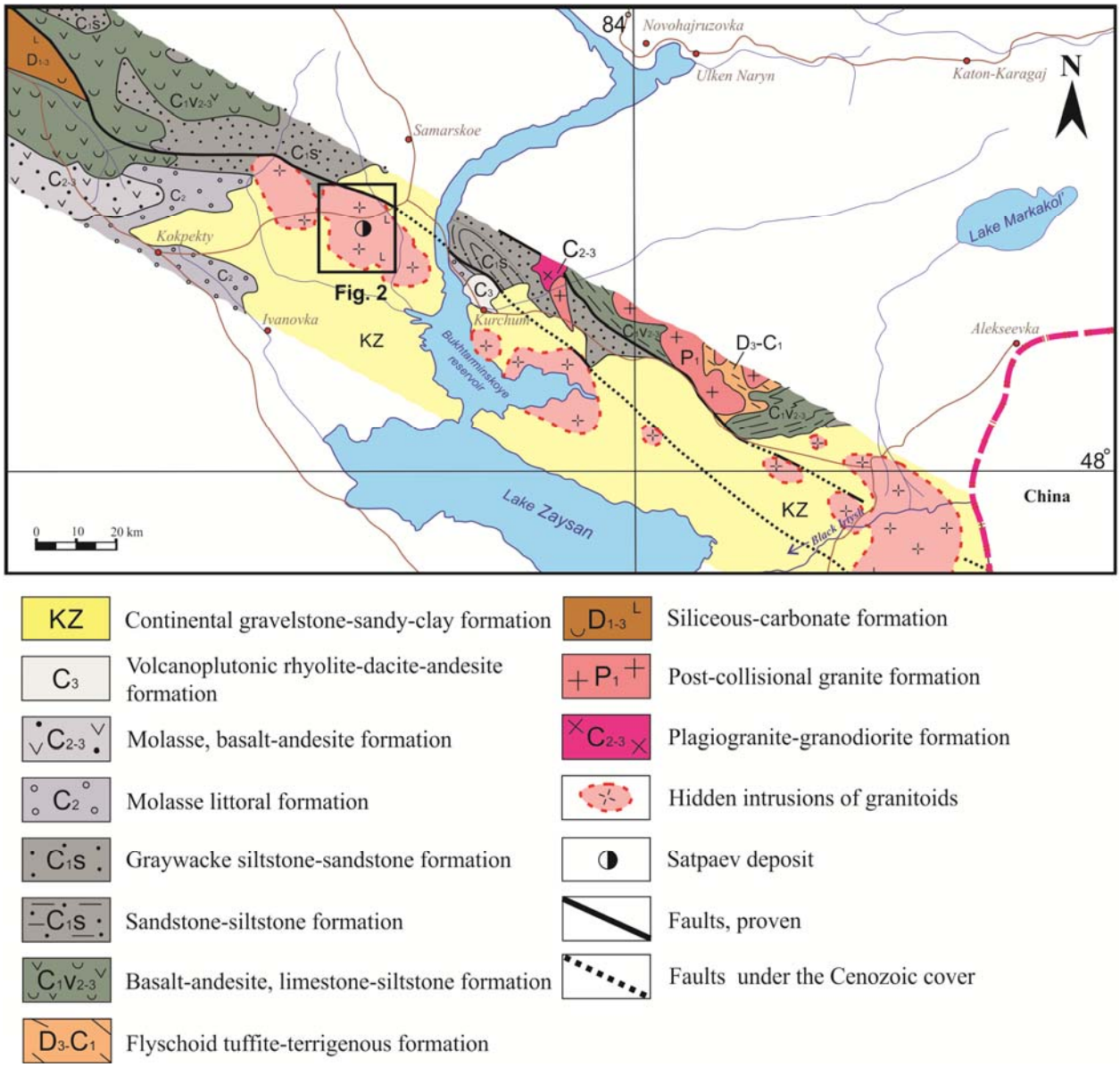


Figure 1 – Overview location map of the Satpaev Ti-Zr placer deposit

region) and 40 km to the east of the Kokpekty village (figure 1). Placers are localized within the Preobrazhensk multiphase intrusion and are composed mainly of gabbro and gabbro-norites with subordinated role of granitoids and subalkaline rocks (monzonite, diorites, quartz diorites, syenites), that collectively comprise the Maksut Late Permian – Lower Triassic gabbro-granitoid complex [7].

Due to poor quality of ilmenite concentrates from the Satpaev placer, JSC "UK TMP" is forced to import additional high-quality ilmenite concentrates to be able use the technology of a combined thermal melting to obtain titanium slags of required composition.

Major mineralogical factors that define technological properties of placers include: granulometric composition of sands and morphological features of ore minerals, the content of economic elements, impurity elements in ore minerals, presence of deleterious elements for this type of mineral resources, and physical (technological) features of minerals.

The quality of ilmenite sands is characterized by the content of TiO_2 and by the mineral form of titanium, as well as by the content of zircon, furthermore by mineral-carriers of elements that worsen the quality of sands; first of all, these include chromium, phosphorus and clay content of sands [9]. Technological properties of Ti-Zr placers vary depending on conditions of formation, mineral size, isomorphic

substitutions, and presence of impurity elements. The most harmful impurities influencing technological processing of Ti-Zr placers are phosphorus and chrome that are often represented by own mineral phases.

Complete replacement of imported high-quality ilmenite concentrates by domestic supply is an urgent and relevant problem for the titanium industry of East Kazakhstan. One possibility includes improving the technological parameters of mineral sand processing. In addition, studies of accompanying economic components are important for the integrated development of the Satpaev deposit, which can contribute to increased profitability of exploration.

The purpose of this research is to study mineralogical-geochemical features of mineral sands of the Satpaev deposit and to determine paleogeographic conditions of accumulation of mineral sands. This paper provides geological characteristics of the wider study region, including mineral sands of the Satpayev deposit, as well as the results of mineralogical-geochemical research of mineral sands and ilmenite concentrate as their end product.

2. Exploration history of the Satpaev Ti-Zr placer deposit. The main regional data on stratigraphy, tectonics, magmatism and metallogeny of the region of the northwest of the Zaysan depression, prospecting criteria for Ti-Zr placers, and state of knowledge and prospects of discovery of new deposits have been summarized in works of V.P. Nekhoroshev, V.S. Erofeyev, B.A. Borisov, A.K. Kayupov, P.V. Yermolov, V.S. Kuzebny, G.N. Shcherby, A.M. Mysnik, Y.M. Sapargaliyev, M.M. Kravchenko, B.A. Dyachkov and many others [10–19].

G.I. Sokratov and A.P. Nikolsky carried out the first geological mapping of the region, of 1:200 000 scale in 1952. Later in 1961 N.N. Popova, V.E. Popov and others conducted the geological survey of 1:200 000 scale that allowed the definition of the stratigraphic scheme of sedimentary sequences and intrusive magmatism of the region [20].

In 1980-82 the exploration crew of nonmetallic raw material division of the Altai geologic-geophysical expedition, represented by M.M. Kravchenko and others carried out prospecting and evaluation works of 1:10 1000 scales and conducted preliminary investigation of the Karaotkel ilmenite-zircon placer deposit [6, 8].

During 1988-92, the advanced geophysical and geochemical surveys of 1:50 000 scale have been carried out in the area of northwest Zaysan that led to the discovery of the Bektemir deposit in 1989 (=Satpaev) [21].

In the period of 1990-95 the prospecting and prospecting-evaluation works carried out by N.M. Pakharukov and others led to the discovery of the Placer No. 1. Subsequently, the scientific and technical Council of “Vostkaznedra” approved C_2 reserves of the Placer No. 1.

In 1997-99 LLP “Geoincentre” has investigated Placer No.1, calculated reserves and conducted the feasibility study. The deposit was renamed into the Satpaev deposit. Having considered materials of this work, the State Commission of Mineral Reserves of the Republic of Kazakhstan has approved evaluating criteria and approved the following C_2 reserves: mineral sands of 9 269.66 thous. m^3, ilmenite of 1 634.1 thous. tons with the average content of ilmenite of 176.29 kg/m^3.

During 2000-2003 exploration works at the Satpaev deposit were continued by LLP “Geoincentre” jointly with the Japanese company "MINDECO" to evaluate the following Ti-Zr placers: Placer No. 1, Placer No. 3, Southern Bektemir, Northern Site, and Eastern Bektemir. As a result, there were identified zones with ilmenite mineralization localized in the negative relief forms of Paleozoic basement.

The deposit has been in operation since 2002 [22]. Nowadays, extraction of sands has been conducted by LLP “Satpaev Gornoobogatitelnoye Predpriyatiye”, which delivers mineral concentrates to JSC “UK TMP”.

The main data about state of knowledge, geological and economic evaluation and the prospects of development of the Satpaev deposit in the near future have been published in the monograph on "Mineral resources of the titanium industry of Kazakhstan and modelling of the development of its mineral base until 2030" [3].

3. Geological characteristics of the Satpaev deposit. The Satpaev deposit is situated in the southwestern part of the Maityube syncline at the border between the West Kalba and the Zharma-Saur metallogenic zones of the Greater Altai that is part of the Central Asian Orogenic Belt (CAOB) [6]. Three structural levels comprise the geological architecture of the area: (1) rocks of Paleozoic basement represented by terrigenous and volcanogenic sedimentary rocks, intermediate-mafic lavas with the subvolcanic

intrusions, which cut through; (2) lateral weathering crust formed as a result of intense reworking of Paleozoic rocks; and (3) Cenozoic depositions represented by sedimentary rocks of the Neogene-Quaternary age, including clays with various sand content, and gravel-pebble sediments [23].

Paleozoic sediments in the region of the Satpaev deposit are represented by the Bukon (C_2bk) and Maityuba (C_{2-3}mt) Formations. These sediments are intruded by the Preobrazhensk and the Karaotkel intrusive bodies. At the southeastern and southwestern flanks of the Preobrazhensk intrusion there are located five placers with increased ilmenite content, collectively forming the Satpaev (Bektemir) ore field.

Intrusive formations within the Preobrazhensk and Karaotkel massifs are represented by the following three independent complexes of different age: 1) Maksut P_2-T_1 (andesite porphyrite), 2) Saykan T_{2-3} (diorites, syenites, syenites-diorites and granosyenites), and 3) Delbegetey J_{1-2} (alkaline granites, granosyenites). Subvolcanic formations and intrusions of dike series represented by granite-porphyries, alkaline granite-porphyries, granodiorites and syenites are also widespread within the area. Studies of interaction between gabbroid and granitoid magmas during formation of the Preobrazhensk intrusion (S.V. Khromykh, G.N. Burmakina, A.A. Tsygankov and others; [25]) established that rocks of four intrusive phases participated in the structure of the massif as follows: 1) medium and coarse-grained monzonite and quartz monzonite; 2) medium-grained gabbro-norite; 3) medium-grained biotite to biotite-amphibole granite with the facies of leucogranite and leucogranosyenite; 4) monzodiorite (gabbro- monzodiorite) [25].

The Preobrazhensk granitoids are considered to be the source of the Satpaev Ti-Zr placer deposit. The structural position of the Satpaev deposit is controlled by the Preobrazhensk intrusion (figure 2) as reflected also by its occurrence along the frame of the intrusion.

Geotectonic epochs of the Zaysan depression include 6 stages: Permian (255-265 and 275-290 million years); Triassic (210-230 million years); Jurassic (135-145 and 160-200 million years); Cretaceous (65-85 and 125-135 million years); Oligocene (23-33 million years) and Neogene - Quaternary (1.2-7.6 million years ago) [26].

The basic structural elements of the Satpaev deposit include the Northern Terektinsk and Southern Terektinsk dislocations of the northwest extension and the perpendicularly oriented Bektemir Fault with series of sub-parallel branches. They occupy a crosscut position and displace sediments of the Bukon and Maityuba Formations. They are manifested byzones of brecciation, intensive fracturing, linear distribution of weathering crusts and occurrence of concordant dikes of intermediate and acidic composition. These faults may have been favorable pathways for the formation of channels for ancient rivers and for fluviatile transfer of ore material.

Over the entire area of the deposit, the Paleozoic rocks developed a weathering crust with a thickness of 10-20 m. In the profile of weathering crusts, the following zones (from top to bottom) are distinguished:

a) zone of kaolin clays, representing bleached clay eluvium; the structure of parent rocks is completely lost;

b) zone of hydromica - clay structural eluvium, composed of clay products of chemical decomposition, retaining the structure of parent rocks;

c) zone of disintegration - zone of structural eluvium, consisting of weathered, strongly fractured bleached rocks; bleaching is caused by partial removal of alkalis and hydration of mica.

The Satpaev deposit includes 5 sites: Placer No. 1, Placer No. 2, Placer No. 3, East Bektemir and Terektinsk. The lower horizon of the Aral Formation (N_1^{1-2}ar) is also of economic importance as it contains Ti-Zr placers. These deposits overlie with angular unconformity the eroded surface of the Paleozoic basement and, in some cases, the weathering crusts. The Aral Formation is overlaid by Quaternary sediments.

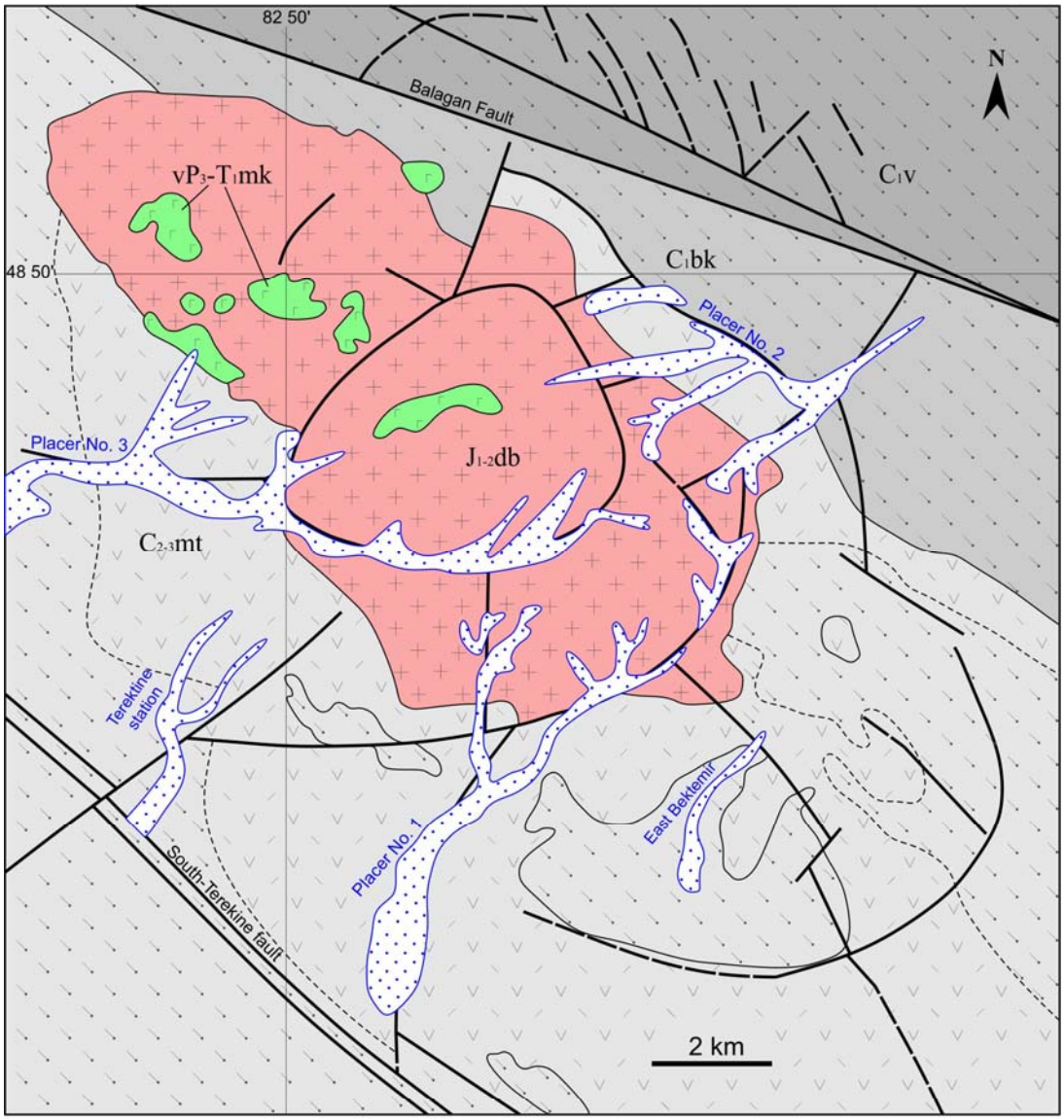
Geomorphologically the area is comprised of the following relief forms:

a) alluvial - the relief forms created by the channel accumulation are represented by gravel-pebble deposits, sand, loam, silt; the forms of alluvial plains are represented by loams with crushed rock;

b) accumulative-denudational - form weakly inclined surfaces created by a complex of slope processes and lithologically represented by loess-like loams with clays in the basement;

c) structurally denudational - form slopes of elevations, predetermined by destructive preparation of the marginal parts of the intrusion.

Generally, Ti-Zr mineralization in the continental deposits of the Cenozoic in the northwest of the Zaysan depression is distinguished by nature of their sources. In the Paleogene and Neogene, they are



$C_{2-3}mt$ Maityuba suite: volcanomictic sandstone of lavas and tuff of andesite porphyte

C_1bk Bukon suite: interbedding of clayey, argillaceous clayey aleurolite

C_1v Visean suite: polymictic calcareous sandstone, siltstone, siliceous and argillaceous shale, covers of lavas and tuff of andesite and dacite porphyrite

$J_{1-2}db$ Delbegetei complex: alkaline granite, granosyenite, syenite

vP_3-T_1mk Maksut complex: gabbro-norite, gabbro-diorite, diorite, monzonite

Siltstone, sandstone, shale

Lava, tuff of andesite porphyrite

a) b) Deep faults (regional): a) established; c) proposed

Ti-Zr placers

Figure 2 – Geological-tectonic scheme of the Satpaev deposit of Ti-Zr placers.
(*Note:* Cenozoic cover is removed) [24]

associated with redeposition of the chemical weathering crust. In the Quaternary period - with redeposition of older sediments enriched with quartz psammites and dilution of polymictic detrital material.

The lithological-formation analysis determines the time for the formation of weathering crusts and the accumulation of quartz psammites in the Paleogene and Neogene deposits, which coincides with early Alpine geotectonic movements [15, 23, 27, 28]. The total mass of the accumulated precipitates in the sediments, variations in their lithologic-petrographic and granulometric compositions depend on the degree of maturity of the weathering crust, the duration of formation and altitude position of the peneplain over the basis of erosion, the material composition and geochemistry of the original rocks, climatic data, the dynamics of geotectonic movements, the participation of organic matter in decomposition of the parent rocks and many other factors.

Figure 3 shows lithological and paleographic conditions of the Zaysan depression: during periods of the formation of the Preobrazhensk intrusion (Permian, Triassic, Jurassic); during periods of weathering crust formation and Ti-Zr placers.

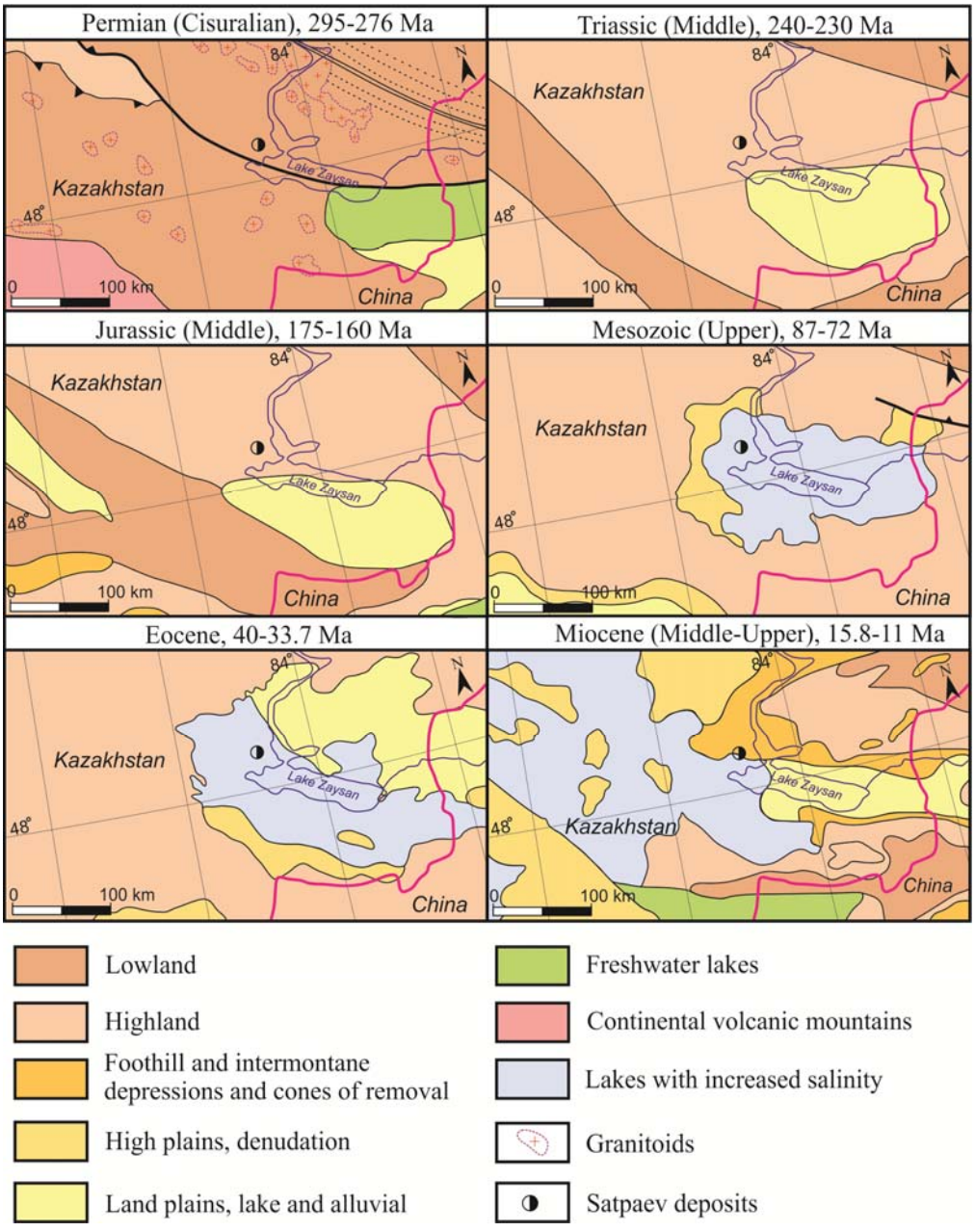


Figure 3 – Lithologic-paleographic maps of the Zaysan depression, *modified after Fedorenko et al., 2002* [29]

4. Features of the geological structure of productive deposits. The combination of favorable geological and geomorphological conditions is facilitated by the formation of productive Ti-Zr placer deposits in certain epochs of the geologic history of the region, i.e. presence of the bedrock source of metal-bearing crystalline rocks, shallow occurrence of primary sources, and widespread development of predominantly chemical weathering processes - reaching to a considerable depth. The lithologic-stratigraphic column of the Satpaev deposit is shown in figure 4.

Stratigraphic index	Horizon number	Lithologic description of rocks	Layer thickness, m	Geological section
Q_I	1	Gravel and pebble deposits	3.4	
	2	Boulder-gravel-pebble deposits	4.4	
$N_1^{1-2}ar$	3	Clays: dense, viscous, plastic, with oolites of limonite and with hematite flakes, with rare dust-like impregnation of ilmenite up to 1%. Gradual increase of the sand portion to 15%, ilmenite content 1-2%	15.4	
	4	Ore horizon: sandy iron-rich clays with fragments of quartz	7.8	
K_2ma	5	Weathering crust developed over gray to greenish-gray, fine-grained sandstones, less often over yellowish-gray iron-rich sandstones	8.0	

Figure 4 – Lithological stratigraphic column of the region of the Satpaev deposit [24]

In the vertical section, clays are characterized by varying degrees of sand content, and inequigranular quartz-feldspar sand, more rarely by sand and sand-gravel material with small pebbles. Further down the column are sandy-clay deposits, which, according to the formation conditions, are alluvial and located on the weathering crusts of the Paleozoic basement.

In very rare cases, alluvial deposits forming placers are underlined by clays or feather out in clays. The thickness of productive deposits ranges from 2.4 to 15.6 m, average is 7.8 m. There are two specific features of the mineralised zone that can be also observed: a) almost everywhere the boundaries of this zone begin with sand; b) due to presence of ilmenite, the productive strata are distinguished by a darker color.

Ilmenite mineralization has a very close correlation with the lower sandy part of the deposits of the Aral Formation (table 1) and ilmenite content is directly dependent on the amount of sand in the stratum. The intensity of ilmenite mineralization is even greater close to the bedrock. The gradual increase in the content of ilmenite with depth is visible in the vertical zoning, which is the most important feature of the internal structure of the placer deposits. Clays overlaying the sands of the ore-bearing horizon contain only a rare impregnation of very thin ilmenite. According to the mineral analysis it is in the order of 0.1-1 kg/t. Closer to the boundary of the ore-bearing horizon there are small lenses enriched in quartz-feldspar sand and ilmenite.

Table 1 – Average chemical composition of ore-bearing rocks of the Aral Formation of the Satpaev deposit and calculated petrological parameters

#	Component	The Aral Formation	
		Lower horizon 4	Upper horizon 3
1. Average chemical composition [24]:			
1	SiO_2	59.81	50.11
2	TiO_2	1.39	1.18
3	Al_2O_3	17.25	14.46
4	Fe_2O_3	7.69	6.35
5	FeO	0.14	0.16
6	MnO	0.02	0.09
7	MgO	2.11	2.06
8	CaO	3.44	7.39
9	Na_2O	0.10	0.10
10	K_2O	1.98	1.74
11	P_2O_5	0.06	0.09
12	∑	93.99	83.73
2. Petrological parameters:			
13	$(Al_2O_3+TiO_2+Fe_2O_3+FeO)/SiO_2$	0.44	0.44
14	Al_2O_3/SiO_2	0.29	0.29
15	TiO_2/Al_2O_3	0.08	0.08
16	Na_2O+K_2O/Al_2O_3	0.12	0.13
17	$FeO+ Fe_2O_3+MnO/Al_2O_3+TiO_2$	0.42	0.42

Sandy-argillaceous deposits are characterized by zonal coloration. In the lower part of the sequence, they have a darker gray color with a greenish, less often bluish, shade. Higher in the section, clays gradually change the color to a lighter yellowish-gray and light gray shades with a weak greenish tinge. Clays in the southern part of the placer are often marked by beans of the hydroxides of manganese, iron and the inclusion of marls.

Sands are represented by clastic material of different granularity. They are of quartz-feldspar composition containing ilmenite. Feldspar grains have a light color and can be clearly distinguished on the common gray background. Feldspar is completely decomposed to clay. Only 15% of feldspars remain in the light fraction of the concentrates and 85% is quartz. Generally, productive deposits have the appearance of sand and contain 30-65% of clays due to decomposed grains of feldspars.

Clays stand out in sands as lenticular nests and thin interlayers, whereas sandy clays are composed of greenish-gray clay with lenses and nests of quartz-feldspar sand.

Table 1 shows petrological parameters of ore-bearing deposits of the Aral Formation that indicate the following:

- the hydrolysis parameter ($(Al_2O_3+TiO_2+Fe_2O_3+FeO)/SiO_2$-0.44) [31] shows that deposits are characterized by average level of maturity, which indicates their formation as a result of predominantly mechanical destruction of parental rocks with subordinate role of chemical weathering;
- according to the values of the alumosilicate parameter (Al_2O_3/SiO_2= 0.17) [32], the deposits belong to the class 0.22-0.35, that is typical for clay rocks;
- the increased value of the titanium parameter (TiO_2/Al_2O_3=0.8) [33] is characteristic for sedimentary rocks that accumulate in continental coastal conditions, in humid climate;
- the iron parameter ($FeO+Fe_2O_3+MnO/Al_2O_3+TiO_2$=0.42) and the total alkalinity (Na_2O+K_2O/Al_2O_3=0.12, 0.13) characterize deposits as hypo-alkaline and normally-ferruginous.

5. Sampling and methods of research. Sample B-1 (ilmenite concentrate) was selected to study mineral and chemical composition of a mineral concentrate of Placer No. 1 of the Satpaev deposit. A representative stream sample B-2 from the mine site of Placer No. 1 was selected to study mineralogical and geochemical features of the Ti-Zr placers of the Satpaev deposit. Sampling has been carried out through the full thickness of the mineral sands sequence.

Sample B-2 is a sandy-clay material (clay - 46% approx., sandy material - 54% approx.), has a grayish-white color with a red tint, impregnated with iron hydroxides. It contains about 20 minerals, main ones include quartz, ilmenite, potassium feldspar and kaolinite.

The mineral processing scheme consists of the following stages:

1) filtration of the clay fraction, removal of gravel and pulping of light mineral fraction;

2) concentration to grey sand stage to preserve minerals with low density (zircon, monazite, cassiterite, ilmenite, etc.) and to obtain more complete information about mineral composition;

3) weighing of the concentrate and collection of a representative sample.

Study of mineral and chemical compositions of samples has been carried out in the mineralogical laboratory of the K. I. Satpaev Institute of Geological Sciences in Almaty. X-ray diffractometric analysis of samples has been carried out using an automated diffractometer Dron-3 with Ci_{Ka} radiation, β – filter. Conditions of obtaining the diffractograms are: U=35 kV; I=20 mA; shooting ENU 2-ENU; detector 2 deg/min. X-ray semi-quantitative phase analysis has been performed on diffractograms of powdered samples using the method of "equal lots and artificial mixtures". Quantitative relations of crystal phases have been determined. Interpretation of diffraction patterns was carried out using the ICDD data of base powder diffractometric PDF2 (Powder Diffraction File) data and diffraction patterns of pure (from impurities) minerals.

Chemical composition of micron-sized minerals has been studied by electron microprobe analysis, using JCXA 733 with the use of energy dispersive spectrometer INCA ENERGY at accelerating voltage 15 kV, probe current of 25 na, using a focused (1-2 μm diameter) probe. For a comparison purposes the following samples were used: albite (Na), MgO (Mg); Al_2O_3 (Al); SiO_2 (Si); adular (K), $CaSiO_3$ (Ca); TiO_2 (Ti); $Fe_2O_3 \cdot MnO$ (Fe, Mn), a metal (Zn); metal Zn, V, Nb, TA, Sn, U, Co (Zn, V, Nb, TA, Sn, U, Co); ThO_2 (Th); SrF_2 (Sr); ZrO_2 (Zr); CaF_2 (F), $BaSO_4$ (Ba), $x(PO_4)$ (*x* - REE).

The elemental chemical analysis of the sample B-2 was carried out in the laboratory of "Metal analysis" CPHMA at the Kazakh National University named after Al-Farabi in Almaty. Tracer and rare earth elements have been determined by mass spectrometry with inductively coupled plasma (ICP-MS Agilent 7500a, Japan). For calibration of the mass spectrometer and to obtain calibration parameters there were used standard solutions for ICP-MS. Calibrating solutions were prepared by successive dilution of standard solutions of 2.5% HNO_3. The error of construction of the calibration plots does not exceed 1-3%.

6. Results of mineralogical and geochemical studies. The Satpaev deposit of Ti-Zr mineral sands has been the main object of mineralogical study [34]. The bulk chemical composition of deslimed mineral sands (sample B-2) has been investigated by electron microprobe analysis and results are shown in table 2.

Table 2 – Bulk chemical composition (wt. %) of deslimed mineral sands (sample B-2)

Analysis #	Element oxide, wt. %									
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	MnO	Na_2O	K_2O	Σ
1	52.01	12.83	6.95	12.02	0.36	0.76	0.87	1.30	1.43	88.53
2	46.57	14.53	8.45	13.44	0.22	1.12	0.66	1.93	1.83	88.74
3	52.03	11.56	7.46	11.45	0.27	0.91	0.83	1.75	1.78	88.04
Average	50.19	12.98	7.61	12.30	0.28	0.92	0.79	1.67	1.69	88.43

According to the semi-quantitative X–ray phase analysis the following mineral content in deslimed mineral sands (%) was identified: quartz – 62.9, albite – 17.2, ilmenite – 11.3, feldspar – 8.5. Crystal morphology of minerals and their composition have been studied using electron microprobe analysis in SEI and BEI modes (figure 5). The chemical composition of ilmenite from deslimed mineral sands is presented in table 3. The morphology of crystals is shown in figure 5 (a-c).

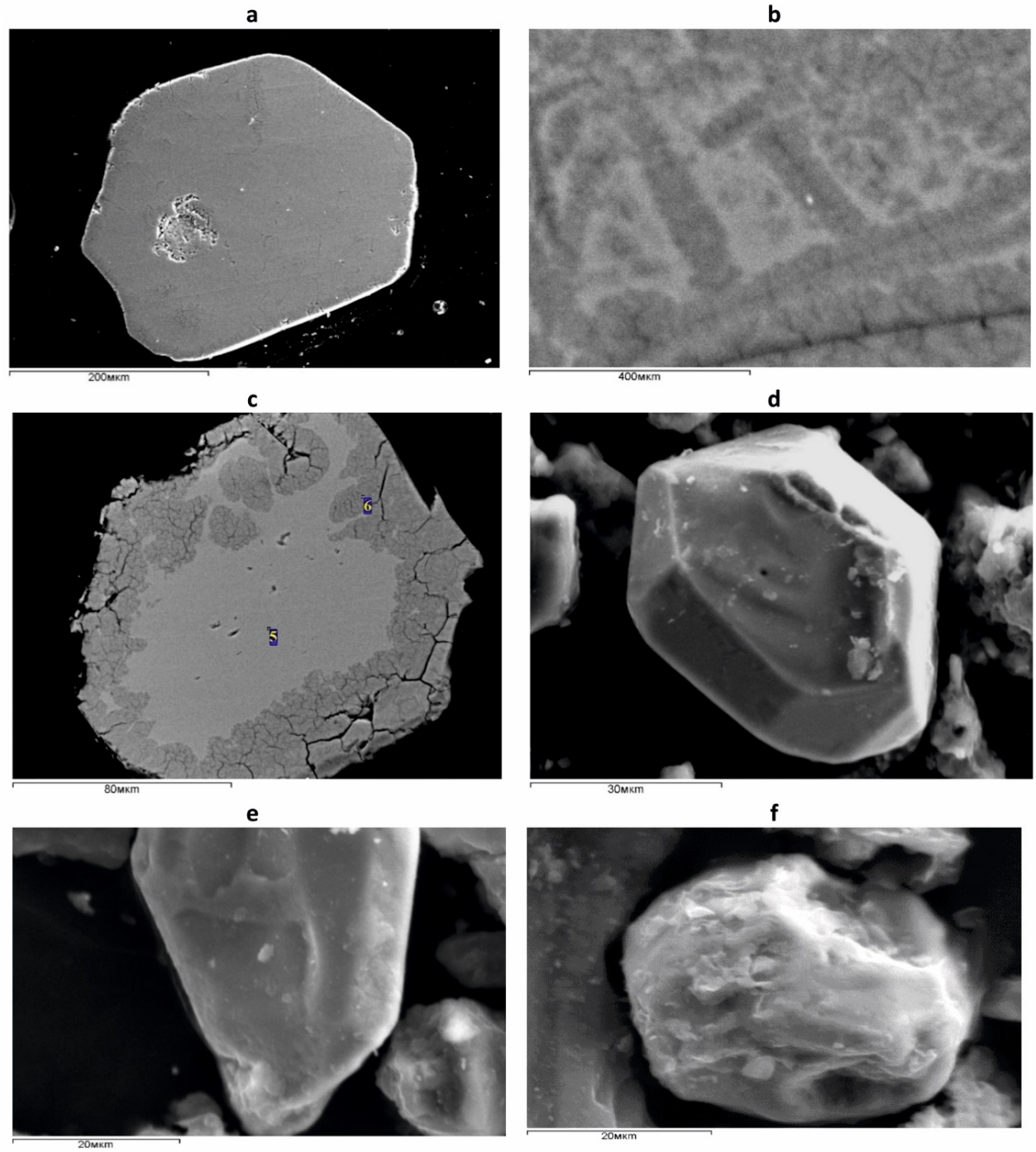


Figure 5 – Crystal morphology of minerals shown by electron microprobe analysis in SEI/BEI modes:
a – ilmenite crystal in the form of a slightly rounded hexagon (table 3, analysis 1), SEI;
b – section of ilmenite crystal. Iron content in light areas is higher than in dark areas,
where as titanium content is dark areas is higher than in light areas (table 3, analyses 3-4). BEI;
c – replacement of ilmenite by leucoxene is along cracks and weak zones at the edges of the crystal
(table 3, analyses 5 and 6), BEI;
d – microsized slightly rounded zircon crystal, SEI;
e – rounded shape of the elongated zircon crystal head with diverse composition:
Zr, Si, Al and Fe (table 4, analysis 2), SEI;
f – microsized monazite grain (in the center), SEI.

Table 3 – Chemical composition (wt. %) of the ilmenite sample B-2

#	Element oxide				
	TiO_2	V_2O_5	MnO	FeO	Σ
1	46.93	0.54	1.79	47.45	96.71
2	52.79	0.86	6.27	40.21	100.13
3	54.25	1.19	1.85	39.85	97.14
4	55.64	0.97	1.01	33.15	90.77
5	51.46	0.83	1.63	44.72	98.63
6	58.04	0.46	1.34	35.11	94.95

Zircon from mineral sands (sample B-2) has chemical composition free of isomorphic impurities. A large number of mineral crystals have prismatic or elongated prismatic form with pyramidal peaks (figures 5d, e).

The sample B-2 also contains micro-crystals of barite (figure 6a) with traces of aluminium and iron in its composition. It should be noted that previous researchers [34] did not describe findings of barite before.

Presence of microsized (up to 50 μm) rounded phosphate crystals (figure 5f) allowed the study of forms of occurrence of rare earth elements. The qualitative chemical composition of monazite detected in mineral sands is rather stable and contains apart from Ce, elevated concentrations of Nd and La; with Pr, Sm, Gd, Ca, Th also present.

Chemical composition of a single grain of the mineral with pyrochlore composition in deslimed mineral sands (sample B-2) is presented in table 4.

Table 4 – Chemical composition (wt. %) of different areas of the polished section of the grain of water-containing mineral with pyrochlore composition

Analyses #	Element oxide										
	WO_3	UO_3	Ta_2O_5	Nb_2O_5	SiO_2	TiO_2	ThO_2	CaO	FeO	K_2O	Σ
1	3.53	30.03	1.11	24.35	0.38	20.06	1.32	1.66	1.73	0.33	84.50
2	2.99	27.92	1.14	24.82	3.61	21.37	1.55	1.78	1.37	0.69	87.24
3	2.28	27.45	1.68	22.93	6.01	19.58	1.33	1.22	1.23	0.69	84.41

Presence of cracks in the mineral and low total sum of elements hints on significant content of water in the mineral structure.

In figure 6b, numbers 1 and 3 indicate the points of chemical analysis of barite crystals; areas enriched with heavy elements (light gray), areas with lower content (dark gray).

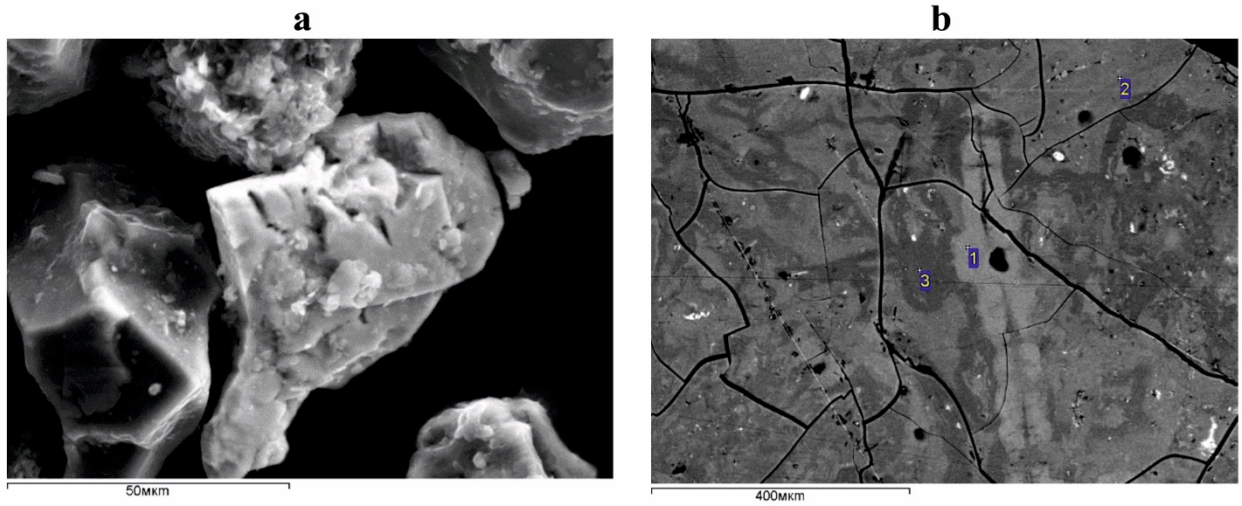


Figure 6 – The morphology of barite crystals and of mineral of pyrochlore composition:
a – microsized barite grain (center), SEI;
b – variations in water composition of the mineral with pyrochlore composition, BEI.

Results of semi-quantitative and quantitative analyses of the ICP-MS are shown in table 5.

Table 5 – Results of elemental chemical analysis of sample B-2
in comparison with the reference content of chemical elements in shale [35]

#	Sample B-2		Content of the sample / Shale clark	#	Sample B-2		Content of the sample / Shale clark
	Element	Content, g/t			Element	Content, g/t	
1	Li	5.49	0.084	33	In	0.69	8.41
2	Be	0.78	1	34	Sn	22.6	3.53
3	B	198	1.98	35	Sb	0.73	0.49
4	Na	7291	0.73	36	I	245	128.95
5	Mg	1446	0.10	37	Cs	0.37	0.06
6	Al	7486	0.10	38	Ba	333	0.50
7	K	4316	0.16	39	La	17.1	0.12
8	Ca	2815	0.13	40	Ce	43.2	0.69
9	Sc	10.7	0.82	41	Pr	4.79	0.75
10	Ti	7 440.00	1.69	42	Nd	19.8	0.73
11	V	90.7	0.70	43	Sm	3.83	0.59
12	Cr	118	1.26	44	Eu	0.93	0.85
13	Mn	5324	6.66	45	Gd	4.05	0.62
14	Fe	48244	1.09	46	Tb	0.61	0.61
15	Co	66.6	3.51	47	Dy	3.4	0.71
16	Ni	31.1	0.42	48	Ho	0.76	0.54
17	Cu	83	1.73	49	Er	2.36	0.87
18	Zn	1179	12.68	50	Tm	0.3	1.30
19	Ga	28.2	1.28	51	Yb	2.08	0.69
20	Ge	5.41	3.18	52	Lu	0.33	0.50
21	As	45.3	3.78	53	Hf	0.43	0.12
22	Se	0.93	1.60	54	W	0.16	0.11
23	Br	815	185.23	55	Ir	0.15	15
24	Rb	15.9	0.11	56	Au	11.1	3363.64
25	Sr	58.1	0.18	57	Hg	0.7	1.67
26	Y	21.7	0.72	58	Pb	44.8	2.24
27	Zr	16.1	0.09	59	Bi	0.35	3.61
28	Nb	1.5	0.08	60	U	5.8	1.57
29	Mo	6.75	2.60	∑REE		103.54	0.39
30	Pd	7.34	7340	∑LREE		89.65	0.37
31	Ag	2.76	38.33	∑HREE		13.89	0.68
32	Cd	0.41	0.98	∑LREE/ ∑HREE		6.45	

Table 6 – Bulk chemical composition (wt. %) of the ilmenite concentrate (sample B-1)

Element oxide	Analysis #			Average
	1	2	3	
SiO_2	4.21	4.39	5.22	4.60
TiO_2	46.42	48.16	46.09	46.89
Al_2O_3	0.98	1.30	0.96	1.08
Fe_2O_3	39.35	40.20	38.05	39.20
V_2O_3	0.34	0.24	0.59	0.38
MnO	2.57	2.35	2.79	2.57
CaO	0.25	0.08	0.14	0.15
Σ	94.12	96.72	93.83	94.87

The bulk chemical composition of the ilmenite concentrate (sample B-1) was studied by electron microprobe analysis and results are presented in table 6.

Results of semi-quantitative x-ray phase analysis showed the following elemental concentrations in the ilmenite concentrate, (%): ilmenite ($FeTiO_3$) - 68.0; quartz (SiO_2) - 10.0; hematite (Fe_2O_3) - 7.9; oxide Ti, V ($Ti_{0.93}V_{0.07})_2O_3$ - 7.7; leucoxene (pseudorutile) ($Fe_2Ti_3O_9$) - 6.4 and a minor feldspar impurity.

7. Mineralogical-geochemical features of the Satpaev Ti-Zr placer deposit. Mineralogical study of mineral sands by electron microprobe identified, apart from traditional minerals of quartz, albite, ilmenite, and feldspar, also microsized crystals of zircon, monazite, barite, and a mineral with pyrochlore composition. The latter two have not been detected by previous investigators.

Chemical composition of the ilmenite, the main ore mineral, varies from grain to grain, as well as within individual grains (table 3). Chemical composition of ilmenite is relatively stable and contains iron, titanium, manganese and vanadium; the ratio of titanium to iron varies. Weakened zones within ilmenite crystals exhibit substitution of titanium by iron. The substitution of ilmenite by leucoxene is observed in cracks and weakened areas at crystal edges (figures 5b, c). There can be observed progressing isomorphism of iron by titanium (or increase of Ti content).

Microsized slightly rounded zircon crystals have a prismatic or elongated prismatic shape with pyramidal tips (figures 5d, e), indicating the formation of zircon in more acidic environment. Chemical composition of the main part of crystals contains no indication of isomorphic impurities.

The sample of heavy fraction contains tiny grains of monazite-(Ce) (figure 5f) and of mineral with pyrochlore composition (figure 6b).

The mineral composition of ilmenite concentrate contains ilmenite, quartz, hematite, oxides of Ti, V, leucoxene (pseudorutile).

Results of elemental chemical analysis (table 5) show that mineral sands of the Satpaev deposit are characterized by a predominance of light rare-earth elements (REE) in comparison to heavy REEs. Figure 7 shows REE contents of sample B-2 from the Satpaev deposit normalized to chondrite plotted together with the Akhmirovsk and Alabaster clay deposits situated about 230 km away and localized within the same Aral Formation.

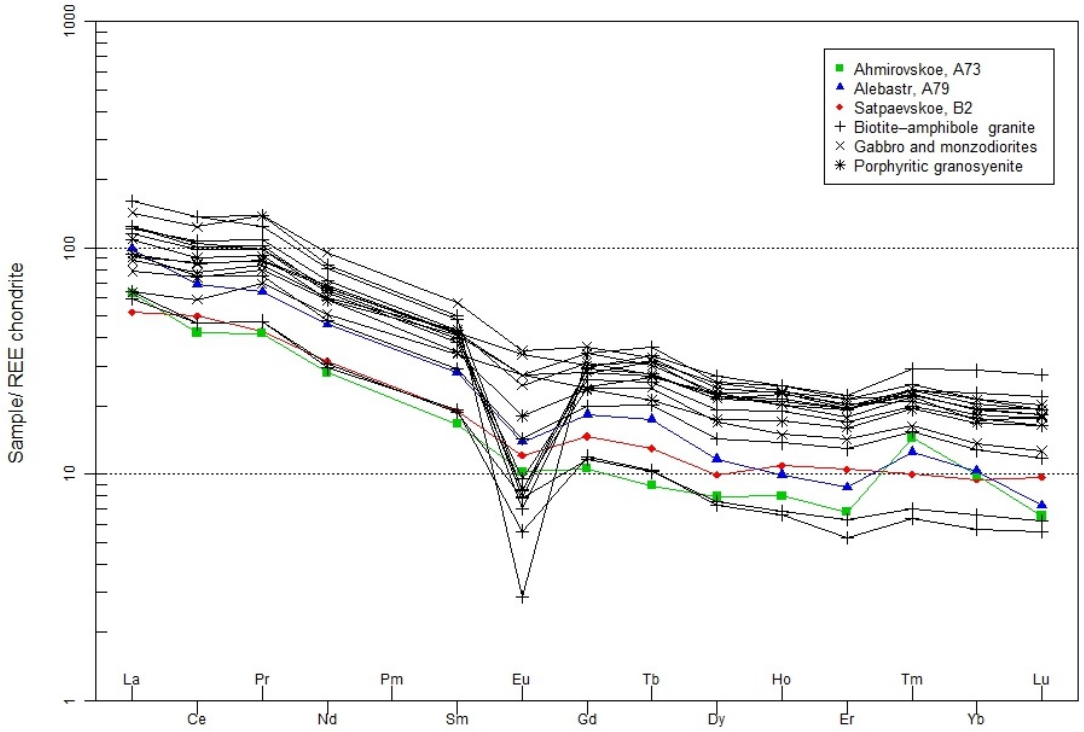


Figure 7 – Chondrite normalized REE patterns of the Satpaev Ti-Zr placer deposit (sample B-2) and two clay deposits also localized in the Aral Formation (Akhmirovsk deposit (sample A73) and Alabaster deposit (sample A79)). Potential source rocks of the Preobrazhensk intrusion (biotite-amphibole granites, gabbro and monzodiorite, porphyritic granosyenites) [25] are also plotted. Normalization values are after Nakamura (1974) [36]

REE patterns of all three deposits show negative Eu anomaly of samples and some tetrad effect, indicating relatively high degree of fractionation of their source rocks (figure 7). Samples of all three deposits are enriched in light rare-earth elements (LREE) in comparison with heavy rare-earth elements (HREE) and have similar LREE patterns compared to granitoids of the Preobrazhensk intrusion. Sample B-2 of the Satpaev deposit localized within the Aral Formation has REE patterns (both light REE and heavy REE) nearly parallel to the pattern of granitoids of the Preobrazhensk intrusion, whereas samples from the Akhmirovsk (sample A73) and Alabaster (sample A79) deposits show different behavior of heavy REEs. It can be concluded that granitoids and specifically gabbro and monzodiorites of the Preobrazhensk intrusion can be considered as source rocks of the Satpaev Ti-Zr placer but less likely of the Akhmirovsk and Alabaster deposits as behavior of heavy REE differs significantly. Therefore, distinct REE patterns exhibited by the Satpaev deposit can serve also as an exploration tool for similar deposits.

Classification diagram for sandstones (figure 8) shows that horizons of the Aral Formation have a polymictic composition that is typical for continental margins.

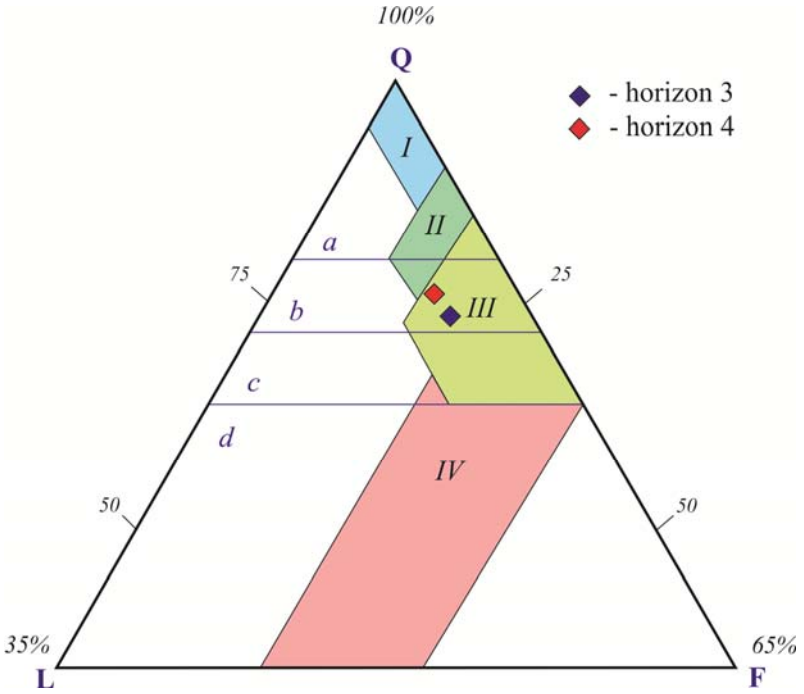


Figure 8 – Classification diagram for sandstones, after M.R. Bhatia (1983) [37]:
1. **Q** = SiO_2, **F** = Al_2O_3 + CaO + Na_2O + K_2O, **L** = Fe_2O_3 +FeO+MgO+TiO_2;
2. I-IV - sandstone fields: **I** - quartz, **II** - oligomictic, **III** - polymictic, **IV** - volcanoclastolithic [38];
3. Fields of arenaceous rocks characterizing **(a)** passive and **(b)** active continental margins, **(c)** marginal-oceanic and **(d)** intra-oceanic arcs

8. Conclusions. Mineralogical study of mineral sands from the Satpaev Ti-Zr placer deposit revealed that apart from quartz, albite, ilmenite and feldspars, also barite and a mineral of pyrochlore composition have been detected. Mineralogical investigation uncovered as additional mineralogical features the hexagonal shape of ilmenite crystals and development of leucoxenization processes along microcracks and crystal edges [39]. Microsized zircon crystals have prismatic or elongated-prismatic shape with pyramidal peaks.

Sample B-2 from the Satpaev placer is enriched in light rare earth elements (LREE) in comparison with heavy REEs. Generally, the content of REEs in sample B-2 has a similar range with the Akhmirovsk and Alabaster clay deposits that are also situated within the Aral Formation. However, their distribution patterns of heavy REEs are rather different and when compared with granitoids of the Preobrazhensk intrusion, similarities are evident only in LREE and HREEs patterns of the Satpaev Ti-Zr deposit only establishing that granitoids of the Preobrazhensk intrusion can be considered as likely source for the Satpaev placer deposit.

As a result of studying the geological framework of the Satpaev deposit the following main conclusions can be drawn:

a) geochemical features of the Satpaev deposit and the Preobrazhensk intrusion [24], which also determines structural position of the Satpaev ore field due to its location along the intrusion margin and in the areas of local tectonic faults, indicate that the Preobrazhensk intrusion can be considered as a source of the Satpaev placer deposit (figure 2);

b) REE patterns of sediments of the Aral Formation that contain mineral sands (e.g., Satpaev deposit) have a very distinctive character compared to barren sediments of the same Formation; therefore it can serve as an important exploration tool for Ti-Zr placers localized within this Formation;

c) formation and localization of ore minerals took place in the environment of chemical weathering caused by the marine transgression that began in the Meso-Cenozoic when the Zaisan depression was submerged. Sea regression began after the Oligocene, and as the result the clayey Aral Formation has been formed in the Miocene. All of these factors contributed to release of titanium-zirconium minerals, followed by their redeposition in local coastal continental conditions of warm and humid climate.

Е. С. Суйекпаев[1], Е. М. Сапаргалиев[1, 2], Г. К. Бекенова[3], М. М. Кравченко[2], А. В. Долгополова[4], Р. Селтманн[4]

[1]Дәулет Серікбаев атындағы Шығыс Қазақстан мемлекеттік техникалық университеті, Өскемен, Қазақстан,
[2]«Парасат» ҰҒТХ» АҚ, «Алтай геология-экологиялық институт» ЖШС, Өскемен, Қазақстан,
[3]«Қ. И. Сәтпаев атындағы геология ғылымың институты» ЖШС, Алматы, Қазақстан,
[4]Natural History Museum, Earth Sciences Dept, CERCAMS, London, U.K.

ШЫҒЫС ҚАЗАҚСТАННЫҢ САТПАЕВ КЕНОРНЫНДАҒЫ Ti-Zr ТАУ ШАШАЛЫМДАРЫНЫҢ МИНЕРАЛОГИЯЛЫҚ-ГЕОХИМИЯЛЫҚ ЕРЕКШЕЛІКТЕРІ

Аннотация. Сәтпаев кенорнының (Шығыс Қазақстан облысы) ауыр фракциялы №1 Шашылымдар минералдық концентраты мен Ti-Zr кенді құмының минералдық-геохимиялық зерттеулеріне нақты деректер алынды. Кенді құмның минералдық құрамын зерттеу кезінде келесі минералдар белгіленді: кварц, альбит, ильменит, КДШ, барит, циркон, монацит және пирохлорлы құрамды минерал. Минералдар электрондық микрозондтық талдауларды пайдалана отырып зерттелген. Ильменит және цирконмен ұсынылған кенді минералдардың кристалды морфологиясына минералогиялық зерттеулер барысында сипаттама берілді. Ильмениттердің минералдық химиялық құрамы зерттелді және кристалдар жиектері мен микро сызаттардағы олардың лейкоксенделуі анықталды. Өнімді горизонттардың геохимиялық ерекшеліктері ауыр сирек жерді (HREE) элементтермен және айқын теріс Eu ауытқумен салыстырғанда алғашқы жыныстардың жоғары фракциялау дәрежесін көрсететін жеңіл сирек жерді (LREE) элементтердің анық байытуын қамтиды. Преображенка интрузиясының гранитоидтары Сәтпаев шашыранды кенорнының ықтимал көзі болып табылады. Петрохимиялық зерттеулер нәтижелері кенді минералдардың оқшауланыу жылы және ылғалды климатта, кейіннен қайта түзілуімен оқшауланған континенттік жағалау жағдайында, титан мен циркон кенді минералдардың босап шығуына ықпал ететін химиялық мүжілу жағдайында болғанын көрсетеді.

Түйін сөздер: Сәтпаев Ti-Zr кенорны, Преображенский интрузиясы, жеңіл сирек жерлер элементтері, Шығыс Қазақстан.

Е. С. Суйекпаев[1], Е. М. Сапаргалиев[1, 2], Г. К. Бекенова[3], М. М. Кравченко[2], А. В. Долгополова[4], Р. Селтманн[4]

[1]Восточно-Казахстанский государственный технический университет им. Д. Серикбаева, Усть-Каменогорск, Казахстан,
[2]ТОО «Алтайский геолого-экологический институт» АО «ННТХ «Парасат», Усть-Каменогорск, Казахстан,
[3]ТОО «Институт геологических наук им. К. И. Сатпаева», Алматы, Казахстан,
[4]Natural History Museum, Earth Sciences Dept, CERCAMS, London, U.K.

МИНЕРАЛОГО-ГЕОХИМИЧЕСКИЕ ОСОБЕННОСТИ Ti-Zr РОССЫПИ САТПАЕВСКОГО МЕСТОРОЖДЕНИЯ ВОСТОЧНОГО КАЗАХСТАНА

Аннотация. Получены фактические данные минералого-геохимических исследований Ti-Zr рудных песков и тяжелой фракции минерального концентрата Россыпи №1 Сатпаевского месторождения (Восточный Казахстан). При изучении минерального состава рудных песков установлены кварц, альбит, ильменит, КПШ; электроннозондовым микроанализом – микроразмерные кристаллы барита, циркона, монацита, мине-

рала пирохлорового состава. Минералогическими исследованиями выявлена морфология кристаллов, рудных минералов ильменита и циркона, определен их химический состав и установлено развитие лейкоксенизации по микротрещинкам и краям кристаллов ильменита. Геохимические особенности продуктивных горизонтов включают явное обогащение легких редкоземельных элементов (LREE) по сравнению с тяжелыми редкоземельными элементами (HREE) и выраженную отрицательную аномалию Eu, которые указывают на высокую степень фракционирования исходных пород. Гранитоиды Преображенской интрузии являются вероятным источником Сатпаевского россыпного месторождения. Результаты петрохимических исследований указывают на то, что локализация рудных минералов происходила в условиях химического выветривания, которое способствовало высвобождению рудных минералов титана и циркона с их последующим переотложением в локальных континентальных прибрежных условиях, в обстановках теплого и влажного климата.

Ключевые слова: Сатпаевское Ti-Zr россыпное месторождение, Преображенская интрузия, легкие редкоземельные элементы, Восточный Казахстан.

Information about authors:

Suiekpayev Yertlek, Serikbaev East Kazakhstan State Technical University (EKSTU), Kazakhstan; y.suiekpayev@gmail.com; https://orcid.org/0000-0003-0145-0751

Sapargaliyev Yerzhan, Serikbaev East Kazakhstan State Technical University (EKSTU), Kazakhstan; LLP "Altaiskiy Geologic-Ecological Institute", JSC "NSTH Parasat", Ust-Kamenogorsk, Kazakhstan; er_sapar@mail.ru; https://orcid.org/0000-0001-7678-3476

Bekenova Galiya, LLP "Institute of Geological Sciences named after K.I. Satpaev", Almaty, Kazakhstan; bekenova@mail.ru; https://orcid.org/0000-0002-0633-199X

Kravchenko Mikhail, LLP "Altaiskiy Geologic-Ecological Institute", JSC "NSTH Parasat", Ust-Kamenogorsk, Kazakhstan; e-31-90@mail.ru; https://orcid.org/0000-0002-1579-9068

Dolgopolova Alla, Natural History Museum, Earth Sciences Department, CERCAMS, London, U.K.; a.dolgopolova@nhm.ac.uk; http://orcid.org/0000-0002-8567-4631

Seltmann Reimar, Natural History Museum, Earth Sciences Department, CERCAMS, London, U.K.; r.seltmann@nhm.ac.uk; http://orcid.org/0000-0002-4590-6485

REFERENCES

[1] Malyshev I.I. Zakonomernosti obrazovanija i razmeshhenija mestorozhdenij titanovyh rud. Gosgeoltehizdat, **1957**. 272 p. (in Rus.).

[2] Borisenko L.F. Mestorozhdenija titana // V kn.:"Rudnye mestorozhdenija". Vol. 1. M.: Nedra, **1974**. 233 p. (in Rus.).

[3] Akylbekov S.A., Azelgareeva R.T., Kiselev A.L. and others. Mineral'no-syr'evaja baza titanovoj promyshlennosti Kazahstana i modelirovanie sostojanija otrasli na period do 2030 goda. Almaty, **1999**. 94 p. ISBN 9965-01-268-7 (in Rus.).

[4] Uzhkenov B.S., Mazurov A.K., Selifonov E.M., Frejman G.G., Lapaev I.G. Svojstva, potreblenie i proizvodstvo osnovnyh vidov mineral'nogo syr'ja. Komitet geologii i ohrany nedr Respubliki Kazahstan. Kokshetau, **2003**. 252 p. ISBN 9965-25-081 (in Rus.).

[5] Abdulina A.A., Vocalevskogo Je.S., Miroshnichenko L.A., Daukeeva S.Zh. Mestorozhdenija titana Kazahstana: spravochnik, vtoroe izdanie. Almaty. **2014**. 153 p. (in Rus.).

[6] Kravchenko M.M., D'jachkov B.A., Sujekpaev E.S., Sapargaliev E.M., Azel'hanov A.Zh., Ojceva T.A. Perspektivy ukreplenija i razvitija syr'evoj bazy titanovogo proizvodstva v Vostochnom Kazahstane // Vestnik Permskogo universiteta. **2016**. N 1. P. 78-86 (in Rus.).

[7] Dolgopolov V.F., Dolgopolova A.V., Seltmann R. Ore formations of the platform cover of Kazakhstan // CERCAMS Report. **2009**. 159 p.

[8] Kravchenko M.M., Suiekpayev Y.S., Sapargaliev Y.M., D'jachkov B.A., Azel'hanov A.Zh. Perspektivy ukreplenija mineral'no-syr'evoj bazy titanovogo proizvodstva v Vostochnom Kazahstane // Mater. mezhdunar. soveshh. po geologii rossypej i mestorozhdenij kor vyvetrivanija (24–28 avgusta 2015). Permskij gosudarstvennyj nacional'nyj issledovatel'skij universitet. Perm', **2015**. P. 113-114 (in Rus.).

[9] Levchenko E.N. Vlijanie veshhestvennogo sostava na tehnologicheskie svojstva titan-cirkonievyh rossypej // Razvedka i ohrana nedr. **2004**. N 11. P. 44-47 (in Rus.).

[10] Nehoroshev V.P. Tektonika Altaja. M.: Nedra. **1966**. 307 p. (in Rus.).

[11] Erofeev V.S. Geologicheskaja istorija juzhnoj periferii Altaja v paleogene i neogene. Alma-Ata: Nauka, **1969**. 165 p. (in Rus.).

[12] Borisov B.A. Stratigrafija kajnozojskih otlozhenij Zajsanskoj vpadiny. Leningrad: VSEGEI, **1964**. 20 p. (in Rus.).

[13] Kajupov A.K., Zhautikov T.M., Li V.G., Bublichenko N.L., Ermolaev K.F., Kuzebnyj V.S., Litvinovich A.N., Mar'in A.M. Voprosy geologii i metallogenii Zajanskoj skladchatoj oblasti. Izdat. «Nauka» KazSSR, **1973**. 186 p. (in Rus.).

[14] Bol'shoj Altaj. Geologija i metallogenija. Kniga 2: Geologicheskoe stroenie / Pod red. G. N. Shherby. Almaty: Gylym, **1998**. 299 p. ISBN 5628024392 (in Rus.).

[15] Bol'shoj Altaj. Geologija i metallogenija. Kniga 2: Metallogenija / Pod red. G. N. Shherby. Almaty: RIO VAK RK, **2000**. 398 p. ISBN 9965520445 (in Rus.).

[16] Mysnik A.M., Bochkova O.I., Kravchenko M.M. Vozrastnye rubezhi formirovanija kor vyvetrivanija Vostochnogo Kazahstana // Mater. II mezhdun. nauchno-tehn. konf.; ch. I. Ust'-Kamenogorsk, **2003**. P. 46-49 (in Rus.).

[17] Mysnik A.M., Bochkova O.I., Kravchenko M.M. Tipy kor vyvetrivanija Vostochnogo Kazahstana i svjazannye s nimi poleznye iskopaemye // Mater. II mezhdun. nauchno-tehn. konf.; ch. I. Ust'-Kamenogorsk, **2003**. P. 193-196 (in Rus.).

[18] D'jachkov B.A., Chernenko Z.I., Matajbaeva I.E., Frolova O.V., Sujekpaev E.S. Geologicheskoe stroenie i poleznye iskopaemye Buranskogo uchastka (Severnoe Prizajsan'e). Zapiski Ust'-Kamenogorskogo Kazahstanskogo geograficheskogo obshhestva. VKGTU im. D. Serikbaeva. Ust'-Kamenogorsk, **2015**. P. 94-104 (in Rus.).

[19] Ermolov P.V., Vladimirov A.G., Izoh A.Je., Poljanskij N.V., Kuzebnyj V.S., Revjakin P.S., Borcov V.D. Orogennyj magmatizm ofiolitovyh pojasov (na primere Vostochnogo Kazahstana). Novosibirsk: Nauka, **1983**. 207 p. (in Rus.).

[20] Sokratov G.I., A.P. Nikol'skij. Geologicheskaja karta SSSR masshtaba 1:200 000, serija Chingiz-Saurskaja, list M-44-XXIX. M.: Nedra, **1965**. 92 p. (in Rus.).

[21] Kudinov V.F., Azovskij Ju.G. Otchet Zyrjanovskoj partii o rezul'tatah operezhajushhih geofizicheskih i geohimicheskih issledovanij masshtaba 1:50 000 v Severo-Zapadnom Prizajsan'e, na uchastke Karaotkel'skom za 1988-1992. **1992.** 210 p. (in Rus.).

[22] Al'-Kareni R.S. Problemy effektivnosti razvitija otraslej narodnogo hozjajstva Kazahstana, tom chetvertyj. Karaganda: «Arka i K», **2016**. 206 p. ISBN 978-9965-786-22-8 (in Rus.).

[23] Sapargaliev E.M., Kravchenko M.M., D'jachkov B.A. and others. Bol'shoj Altaj. Geologija i metallogenija. Kniga 3: Nerudnye iskopaemye. Almaty: Gylym, **2003**. 304 p. ISBN 9965-07-309-0 (in Rus.).

[24] Selifonov E.M., Frejman G.G., Frolov N.I., Pashov V.Ja. i dr. Otchet o rezul'tatah geologo-poiskovyh rabot v rajone Satpaevskogo mestorozhdenija v Vostochnom Kazahstane za 2000-2002. Ust'-Kamenogorsk: «Geoincentr», **2003**. 90 p. (in Rus.).

[25] Khromykh S.V., Burmakina G.N., Tsygankov A.A., Kotler P.D., Vladimirov A.G. Interactions between gabbroid and granitoid magmas during formation of the Preobrazhensky intrusion, East Kazakhstan // Geodynamic & Tectonophysics. **2017**. 8(2). P. 311-330. DOI:10.5800/GT-2017-8-2-0243 (in Rus.).

[26] Novikov I.S. Reconstructing the stages of orogeny around the Junggar basin from the lithostratigraphy of Late Paleozoic, Mesozoic, and Cenozoic sediments // J. Scopus. February **2013**. Vol. 54, Issue 2. P. 138-152. ISSN 1068-7971. DOI 10.1016/j.rgg.2013.01.002.

[27] Stratigraficheskij kodeks Rossii. Izdanie tret'e, utverzhden bjuro MSK 18 oktjabrja 2005. SPb.: VSEGEI, **2006**. 96 p. (in Rus.).

[28] International hronostratigraphic chart. Copyright International Commission on Stratigraphy / v **2017**/02. http://www.stratigraphy.org /ICSchart/ChronostratChart2017-02.jpg.

[29] Fedorenko O.A., Bykadorov V.A., Daukeev S.Zh., Miletenko N.V., Morozov A.F., Uzhkenov B.S. et al. (Editors, 2002): Atlas of lithological-paleogeographical, structural, palinspastic and geoenvironmental maps of Central Eurasia. Publisher: Scientific Research Institute of Natural Resources YugGeo. Almaty, **2002**. 38 p. ISBN 9965-13-566-5.

[30] Remezova E.A., Vasilenko S.P., Svival'neva T.V., Naumenko U.Z., Jaremenko O.V. Uslovija nakoplenija cirkona v titan-cirkonievyh mestorozhdenijah pridneprovskoj rossypnoj zony Ukrainy // Vestnik VGU. Serija: geologija. **2014**. 80, N 3. P. 79-84 (in Rus.).

[31] Judovich Ja.Je. Dembovskij B.Ja. Ketris M.P. Geohimicheskie priznaki pereotlozhenija kor vyvetrivanija v ordovikskih otlozhenijah Pechorskogo Urala // Ezhegodnik, 1976 In-ta geol. Komi fil. AN SSSR. Syktyvkar. **1977**. P. 133-142 (in Rus.).

[32] Ketris M.P. Petrohimicheskaja harakteristika terrigennyh porod. Ezhegodnik-1974 In-ta geol. Komi fil. AN SSSR. M.: VINITI, **1976**. P. 32-38 (in Rus.).

[33] Migdisov A.A. O sootnoshenii titana i aljuminija v osadochnyh porodah. Geohimija. 1960. N 2. P. 149–163. Efremova S. V., Stafeev K. G. Petrohimicheskie metody issledovanija gornyh porod. Spravochnoe posobie. M.: Nedra, 1985. 512 p. (in Rus.).

[34] Ananin A.I., Ivanov G.I., Shvedunov M.A. Otchet o nauchno-issledovatel'skoj rabote «General'noe oprobovanie tehnologicheskoj shemy na obogatitel'noj fabrike TOO «STM» DGP «VNIICVETMET». Ust'-Kamenogorsk, **2008**. 51 p. (in Rus.).

[35] Skljarov E.V., Gladkochub D.P., Donskaja T.V., Ivanov A.V., Letnikova E.F., Mironov A.G., Barash I.G., Bulanov V.A., Sizyh A.I. Interpretacija geohimicheskih dannyh. Intermetinzhiniring. M., **2001**, 288 p. UDK 551.1/4(07). ISBN 5-89594-063-3 (in Rus.).

[36] Nakamura N. **1974**. Determination of REE, Ba, Fe, Mg, Na and K in carbonaceous and ordinary chondrites. Geochim. Cosmochim. Acta 38, 757.

[37] Bhatia M.R. Plate tectonic and geochemical composition of sandstones // The Journal of Geology. **1983**. Vol. 91, N 6. P. 611–627.

[38] Kossovskaja A.G., Tuchkova M.I. On problems of mineralogical-petrochemical classification and genesis of arenaceous rocks // Lithology and mineral resources. **1988**. N 2. P. 8-24 (in Rus.).

[38] Kossovskaja A.G., Tuchkova M.I. On problems of mineralogical-petrochemical classification and genesis of arenaceous rocks // Lithology and mineral resources. **1988**. N 2. P. 8-24 (in Russ.).

[39] Bekenova G.K., Stepanov A.V., Dolgopolova A.V., Seltmann R., Levin V.L., Baisalova A.O. Features of titanium-bearing minerals of the Verkhnee Espe rare-metal deposit (East Kazakhstan) // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. **2017**. 5(425): 36-54 (in Rus.). https://doi.org/10.32014/2018.2518-170X; ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 23 – 31 **https://doi.org/10.32014/2019.2518-170X.2**

UDC 622.24, MRNTI 38.59.15

I. A. Piriverdiyev[1], M. D. Sarbopeyeva[2], G. Sh. Asadova[3]

[1]Institute of Oil and Gas of Azerbaijan National Academy of Sciences, Baku, Azerbaijan,
[2]Caspian State University of Technology and Engineering named after Sh. Yessenov,
Aktau, Mangystau region, Kazakhstan,
[3]Azerbaijan State Oil and Industry University, Baku, Azerbaijan
E-mail: igorbaku@yandex.ru, manshyk84@mail.ru, gjulshan-asadova@rambler.ru

ANALYSIS OF MODELING AND DECISION-MAKING PROCESSES FOR DRILLING WELLS UNDER UNCERTAINTY

Abstract. A review of the studies devoted to modeling and decision making in the process of drilling wells accumulated in recent years has been performed. The review identified the range of issues on which attention should be focused. In particular, it is noted that in order to solve optimization problems, first of all, data are required. The next step is data processing and drilling model construction. Then variant calculations are carried out and the decision-making stage is coming.

The solution of problems of optimization of the drilling process is complicated by the uncertainty of the decision-making situation, expressed by multifactority, multicriteria, inaccuracy, ambiguity. To successfully solve problems taking into account the mentioned uncertainties, it is necessary to apply appropriate methods. These methods should take into account uncertainty. Besides, they should be based on the results of geological and technological studies that became widely used in recent years. Proceeding from this, ways of perfection of methods of a choice of bits and drilling modes, as well as interpretation of the results of geological-technological researches are considered in the present article. The models based on processing and analyzing data of geological and technological researches have been constructed. Ways of decision-making taking into account uncertainty were shown. The decision is made using the provisions of the theory of fuzzy sets.

Based on the data of geological and technological studies on several wells, calculations were carried out. The appropriate program was applied for that purpose. As the result, physical and mechanical and baric characteristics of the sections were obtained. These calculations were held on the example of some deposits of Azerbaijan and Kazakhstan. The article shows the change in the indices of the physical and mechanical properties of the rocks of the Karabakhli deposit. Lithological-stratigraphic characteristics of the section are given. Graphs of the change of petrophysical (porosity, permeability), strength (hardness, abrasiveness) and elastic (Young's modulus, Poisson's ratio) characteristics of rocks with depth were constructed. As a result of the analysis, the ways of forecasting well drilling parameters and making optimal decisions on the data of geological and technological research in the drilling process are shown. This allows us to find the optimum values of the regime parameters from the condition of ensuring the maximum run speed and the minimum cost per 1 meter of penetration.

Key words: rate of penetration (ROP), run speed, cost per penetration meter, bit, mode parameters, membership function, uncertainty.

Introduction. In the world practice of drilling and scientific research, to date, quite a rich experience in studying the processes of rock destruction and associated bit work has been accumulated. A long time has been spent and large funds have been released for these studies. However, as the research results show, for today there is no scientifically grounded method of searching for the optimal combination of rock, bit type and regime parameters, which, in our opinion, is explained, in particular by the fact that during the management of technological processes, including drilling, the most important stage is the decision-making process, which includes: setting goals, shaping the decision-making task, and finally, making decisions; while decisions can be made in connection with the goals aimed at increasing the

efficiency of the drilling process by rising rate of penetration, as well as reducing the costs of drilling, eliminating the consequences of complications and accidents, etc., and under different kinds of uncertainty; great labor intensity in carrying out bench and field experiments and their high cost and, as a result, limited volumes of these studies; lack of a reliable theoretical and methodological basis for designing optimal drilling regimes and choosing the types of bits for highly dissected, heterogeneous in drillability cuts, which is typical for almost all geological sections [1, 4, 5, 10, 17].

The solving of optimization problems of a choice of bits and parameters of a drilling mode is complicated by uncertainty of a situation of decision-making, expressed by multifactority, multicriteria, inaccuracy, ambiguity. To successfully solve the problem, taking into account the mentioned uncertainties, it is necessary to apply appropriate methods that take into account this circumstance, as well as the results of geological and technological research received in recent years. Based on the noted, in this article, ways of improving the methods of selection of bits and mode parameters are considered on the basis of processing and analysis of geological and technological research data, taking into account uncertainty.

Brief review of recent research. The development of modern technical facilities and technologies for informational support of the drilling process and their widespread introduction allow improving the quality of the information received and requires its corresponding analysis. Operational information obtained during drilling is of great importance in drilling wells, especially in poorly studied regions with complex mining, geological and environmental conditions.

As follows from the analysis of drilling experience in different conditions, the desired result can be achieved when considering the problem in the form of a system that takes into account the interrelationship between various technical, technological and geological characteristics that affect well drilling performance. In addition, it is also necessary, in our view, to use the level of development of various mathematical methods and software in the course of the classification of objects, the construction of models, that allow to make technological decisions that are hampered in the usual conditions by the presence of uncertainty. This indicates the urgency of the problem of improving decision-making methods when drilling wells, taking into account the uncertainty of conditions. To date, various systems and tools for monitoring the drilling process have been developed, which make it possible to solve a number of geological and technological problems [2]. In all the works, the role of optimization of the drilling process is noted, which is a very important stage during drilling operations. This is caused by the reason that optimization allows to save time and money spent on drilling a well, achieve a high drilling speed and, thus, increase profits. Optimization of the drilling process is aimed at selecting the controlled variables during the drilling process, such as the regime parameters (weight on bit, bit speed, mud flow rate), mud parameters, bit type, based on the desire to achieve the maximum drilling speed. For many years, so-called basic models have been developed and used (Badalov R.A., 1958, Fedorov V.S., 1958, Cunningham, R.A. and J.G. Eenink, 1959; Garnier, A.J. and N.H. van Lingen, 1959; Graham, J.W. and N.L. Muench, 1959; Galle E.M. and Woods H.B., 1963; Bingham M.G., 1965; Bourgoyne Jr., A.T. and F.S. Young, 1974; et al.). These works were further developed in the studies [3,4,8,11,12,13,14,16], on their basis optimization methods have been proposed, for which patents [5-7] were obtained. For example, in [4], based on the statistical analysis of information on the operation of bits of cutting action with the application and development of the basic model of Bingham, a model of rate of penetration is constructed that takes into account the influence of the rock properties (hardness and abrasiveness), the depth of their bedding, regime parameters, mud density. Based on the generalization of the studies, the reliability of the bits and their service life was estimated. The parameters of the model in each case were specified by the random search method. The method [5] includes the characteristics of rocks selected from drilled wells, the establishment of the characteristics of at least one drilling rig; iterative modeling of the borehole wiring. The proposed method involves calculating the economic criterion at each stage of the modeling. Based on the results of modeling at various stages, a package of proposals is created. Thus, an iterative drilling modeling system and a corresponding computer program are created. Using the appropriate information, scenarios of various virtual combinations of equipment, drilling rig, bits, solutions, etc. are modeled. The company provides a virtual modeling service with logging (geophysical) information from exploratory wells and information about the rig, and the service, in turn, develops an economic model based on this information. The flowcharts shown in the work show the input and output (output) information. Based on the input geological and technological information, an analysis of the working time and

bit wear is made, a model of the rate of penetration and an economic model, according to the authors, are constructed. The bit is selected based on the minimum cost of drilling and the minimum drilling time. The bit selection model is built by gradual approximation (improvement) using a computer program, which, according to the author, more accurately describes the process than previously proposed methods, and thereby provides a more correct economic solution and recommendations for drilling contractors and operators. In [3], the well-known Burgoyne and Yang model [2] was chosen as the base, taking into account the influence of several parameters on the rate of penetration. The main factors, such as depth, pore pressure, equivalent circulating density, bit speed, wear of drilling bit teeth and jet impact force, are obtained from the drilling report. To study their correlation, a statistical analysis was performed using multiple regression analysis, and as a result, a model of the rate of penetration for the field was constructed. First, private dependences of the rate of penetration on each of the parameters including the factors under consideration, which were subsequently generalized to the plural, were constructed. As a result, using the results of the marked analysis, optimal values of the weight on bit are determined, which provide the best performance. The optimum weight on bit was calculated for several data points. With the help of the same approach, the model of the rate of penetration was constructed in the paper [8], the cost of one foot of penetration, the specific mechanical energy taking into account the values of the weight on bit, bit speed and rate of penetration were calculated, and expressions are obtained for determining the optimum values of the weight on bit and bit speed providing the minimum cost. In this case, the authors tried to take into account a large number of factors, which is the main advantage of the model. A model based on field observations and statistical analysis of their results, takes into account rock properties for two categories (soft and hard) at a qualitative level, whereas rocks have a wide variety of hardness and abrasivity, which are one of the main factors. In this regard, various methods for evaluating hardness and abrasiveness have been proposed: experimental; using core-slime material; using the results of geophysical studies, For example, in [9], a method is proposed for using geological and geophysical information on the geological section of wells in the assessment of rock drillability, which allows one to quantitatively take into account these important properties of rocks when constructing a model of rate of penetration. In recent years, a sufficient number of studies have been accumulated.

In [12], in order to compile the drillability model for PDC bits, the entire array of data on the performance of PDC bits in the Uzen field is divided into groups by the number of drillhole intervals for the production string, in which each bit is used up to full working, i.e. before replacement. Then the resulting variational series were processed by mathematical statistics methods to obtain the average drilling speed and time of the interval, taking into account the previous bit wear, dispersion, standard deviation and coefficient of variation. As a result, the technique of the approximate evaluation of the process of gage wear of PDC bit after the penetration of each interval under the production casing, taking into account its previous use, has been established. A mathematical model of drillability, taking into account the initial rate of penetration of the new, unused bit, the rate of decrease in the rate of penetration in time, has been established. The same model of drillability is also made for roller bits used earlier in the Uzen field. A comparative evaluation of both tools showed that the PDC bit exceeds the rolling cutter bit by 7 times in durability, and by 1.6-1.8 times in productivity. In general, the works performed can be divided into four groups: works devoted to assessing the properties of rocks and associated intervals with complications, matching the design features of the bit [9, 15], constructing models for rate of penetration and making decisions. In recent years, methods that take into account the uncertainty of the decision-making conditions when drilling wells, in particular, multicriteria, as well as the classification of geological objects, have been applied in solving these problems. In this connection, the theory of fuzzy sets has been used, which allows to make compromise decisions in conflict situations, to classify geological objects taking into account the fuzziness of boundaries, and to correctly assess the risks of emergency situations in drilling [2, 8, 9].

It should be noted that while being very useful in solving specific problems, existing methods and tools for studying the sections in the drilling process due to the lack of comprehensive studies and insufficient program and methodological support still make it difficult to control the drilling process, optimize and accurately estimate productive intervals, ecological situation, etc. This is also caused by the fact that when setting a goal, in addition to tasks solved at one or another stage, there are also unnoticed ones, that

should consider diversity, different kind of uncertainty of conditions for obtaining the information and decision-making.

Analysis of geological and technological information about drilling wells. The system of obtaining and using geological and technological information [14], including three main aspects (geological, technical and technological, ecological), also provides: data collection and processing (information retrieval); construction of models expressing the relationship between drilling performance and natural, technical and technological characteristics, forecasting of drilling parameters and the situation of drilling operations using that; evaluation and provision of optimal values of drilling performance indicators (information use).

When collecting and processing data, it is necessary to strive to obtain and use the most complete information, and this work is carried out throughout the decision-making process. As the transition from one stage to another, if necessary, the need for information can be clarified. The results of the work performed in the previous stages serve as initial information for the subsequent stages. Wherein, the nature of the initial information can be different (from previously drilled wells or information coming in during drilling). Depending on this, the approach to decision-making will be different. Therefore, the obtaining and proper use of complex geological and technological information for the purpose of prompt decision making while drilling wells and the problem of the performance of the bits, depending on its nature, is actual and requires appropriate attention. Very often, there are difficulties associated with the lack of information about the properties of rocks and its fuzzy nature. In the absence of the corresponding core material, it is often necessary to use information that is descriptive in nature, i.e. to evaluate the mechanical properties of rocks on the basis of their geological and petrographic description. Such methods exist. In particular, the well-known technique of VNIIBT [7] allows, using the noted information, to estimate the parameters of rock properties.

In recent years, the assessment of the properties of rocks and their impact on drilling performance, as well as the intervals of possible complications, are carried out with the help of geological and technological studies. As can be seen from the above review, over this period, and especially over the past 20 years, researchers have accumulated considerable experience and proposed various criteria [16], taking into account also the stressed state of the rocks composing the walls of the drilling well.

Based on the results of the assessment of the influence of these factors on the drilling performance, a corresponding model is constructed. This model, along with parameters that take into account the properties of rocks, also includes technological factors and parameters that take into account the type of bit. In the construction of the model, it should be noted that due to the complexity of the drilling conditions it is impossible to construct such a universal model that could successfully describe the process in different geological and technological conditions. The presence of a large number of factors, including factors that are of a random nature and thus not amenable to recording, clearly demonstrates the difficulty in constructing a model of rate of penetration. Taking into account that the models constructed up to the present time were constructed for different conditions, we previously carried out their comparative analysis, during which parameters for the same interval were determined by the random search method. When considering the methodology for selecting bits and regime parameters, it is necessary, as already noted, to take into account the nature of the initial information, which can be different. The choice of bits and parameters depends on the nature of this information. If preliminary information is available from previously drilled wells, complex information is generated based on the collection and processing of well drilling data, field observations, and information on rock properties, which is used to identify models. The model is constructed within each homogeneous interval. First, private dependencies are constructed, which subsequently include unaccounted factors. One of the known basic models, as, for example, in [11, 13, 19], is used as a basis. Next, the corresponding cost of 1m of penetration is calculated. The best mode parameters and types of bits are refined (selected) by variant calculations using the provisions of the theory of fuzzy sets. If such data on previously drilled wells are not available or if they are available in an insufficient amount, the calculations are carried out according to the data of geological and technological studies in the process of drilling as they are received. According to this algorithm, the decision-making process is implemented depending on the nature of the initial information. The characteristics of the geological section, estimated with the help of the above program, allow solving a number of tasks in the drilling process, in particular, the problem of selecting bits and regime parameters, assessing complications and making

decisions in complicated conditions. At the same time, the results of geological and technological studies are of great importance for quick determination of the characteristics of geological sections in the process of drilling wells [1, 4, 16-18]. Based on the data of geological and technological studies on several wells with the application of the corresponding program, physico-mechanical and baric characteristics of the sections of some deposits were obtained. In addition, according to geological and technological studies, stresses are calculated around the well. Figure 1 shows the change in the indices of physico-mechanical properties of the rocks of the Karabagly deposit. The figure shows the lithologic-stratigraphic characteristics of the section, the graphs of the change of petrophysical (porosity, permeability), strength (hardness, abrasiveness) and elastic (Young's modulus, Poisson's ratio) rock characteristics with the depth. As a result of the statistical analysis of geological and technological information on drilling wells at the Karabaghli (Azerbaijan), Aktum, Kokmai, Karamandybas, and South Koktau (Kazakhstan), we constructed models of rate of penetration [14]. The complex of geological-technological and geophysical studies performed in the wells under consideration allows to have a complete picture of the conditions, technology and indicators of the drilling process. To make decisions, first, it is necessary to create the initial array.

The approach to decision-making depends on the nature of the initial information (figure 1).

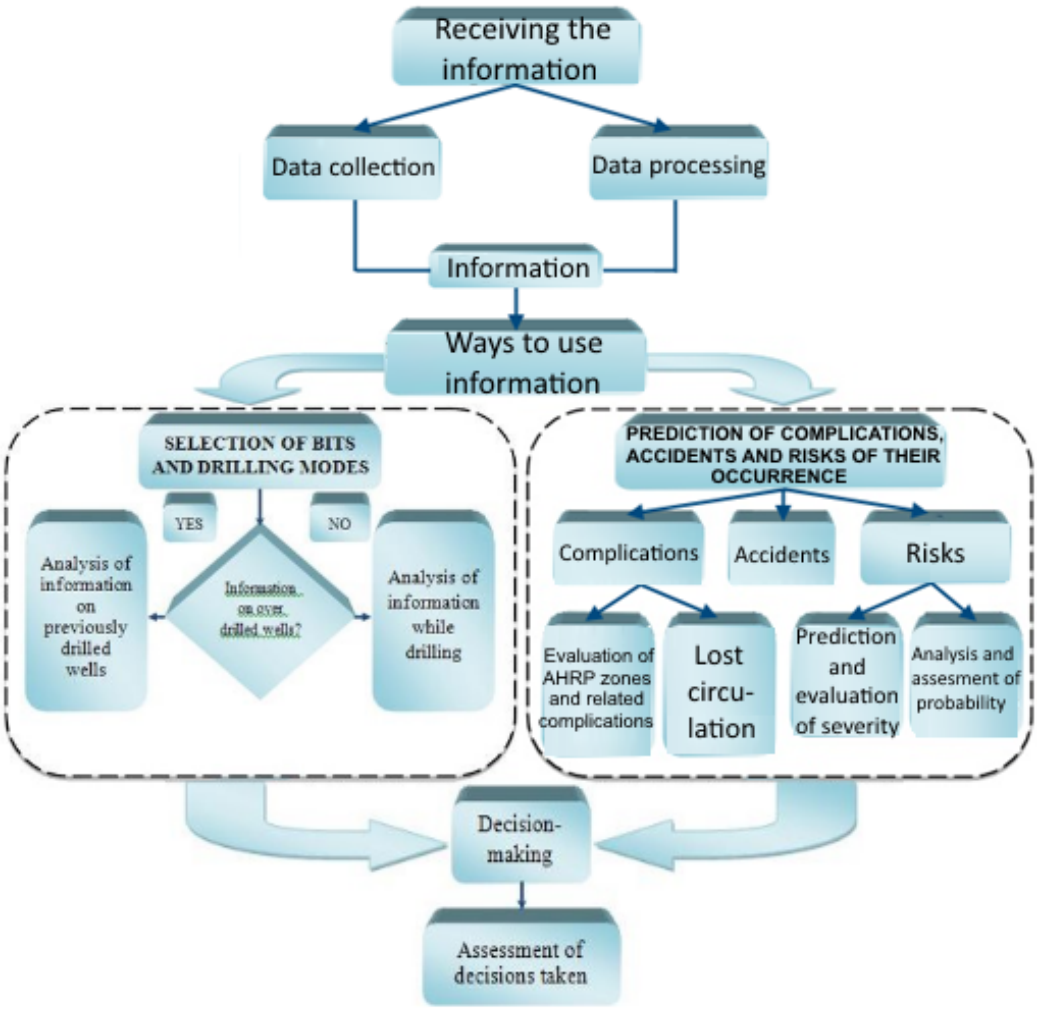


Figure 1 – Block diagram of obtaining and using information about drilling wells

In the process of analysis, equations for the corresponding bit types in the considered rock were obtained, expressing the dependence of the initial rate of penetration on the regime parameters and rock properties, the parameters of which were refined in the course of processing by the random search method [14].

The choice of bits and parameters is made by two criteria – the rate of penetration and the cost per meter of penetration. The solution of this problem is hindered by the presence of uncertainty. In general, t is often needed to build models in drilling [20], make decisions under conditions of uncertainty [10]. In the presence of models of rate of penetration, variant calculations are carried out in the same way as was done in [1, 4, 12]. For the purpose of carrying out variant calculations, the boundaries for changing the value of the regime parameters and their steps were set. For all these options, calculations of the run speed and the cost per meter of penetration were made. The best regime parameters according to predictions were determined using the above two criteria via the theory of fuzzy sets.

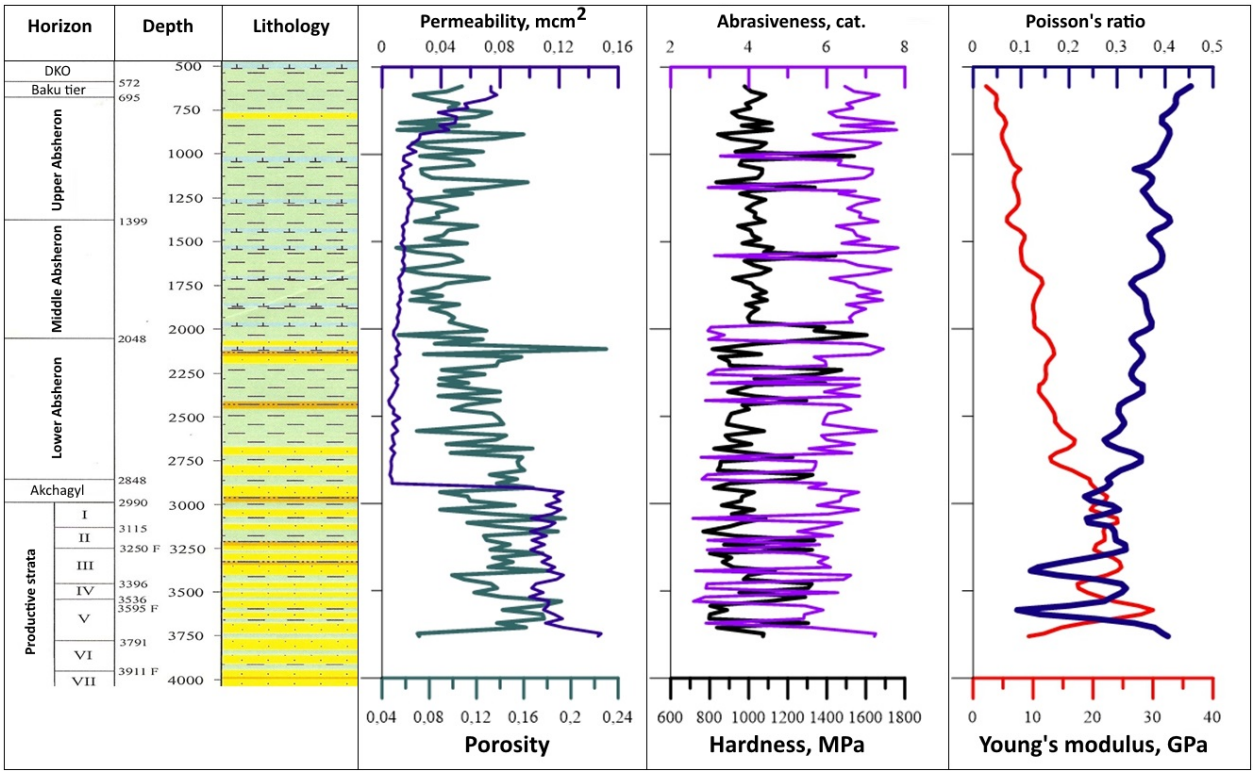


Figure 2 – Changes in the indices of physical and mechanical properties of the rocks of the Karabagli deposit

According to this, the set of solutions is the intersection of sets of goals (to achieve the highest run speed) and restrictions (with the lowest cost of 1 m penetration). For this purpose, the form of the membership function of the sets of goals and constraints was chosen. In this case, the membership function for the run speed increases with the increase in the run speed, which expresses the desire of the person making the decision to achieve high run speed, that is, the maximum value of the run speed of drilling corresponds to the value of the membership function close to one, and the minimum value of the run speed corresponds to the smallest value of the membership function, close to zero. The membership function of the cost per meter of penetration, on the contrary, decreases with the increase in the cost of the penetration meter, since in this case we are striving to achieve a low cost per meter of penetration. That is, in all cases, our aspiration is expressed by a result corresponding to the largest value of the membership function, close to one, and the lowest value of the membership function, close to zero, corresponds to the largest value of the penetration meter. The membership function of the solution set according to the noted theory was estimated as min (μ_v, μ_c). The greatest value of the membership function of the solution set in the totality of calculated data corresponds to the best solution. In the same sequence, the algorithm was implemented for another homogeneous group of rocks. As a result of calculations on models, the distribution surfaces of the values of the run speed and the cost of the penetration meter depending on the mode parameters are also constructed, [21]. As an example, figure 3 shows the surface of the change in the membership function. Via this figure, it is possible to track the change in drilling performance in three-dimensional space, as well as determine their optimal values.

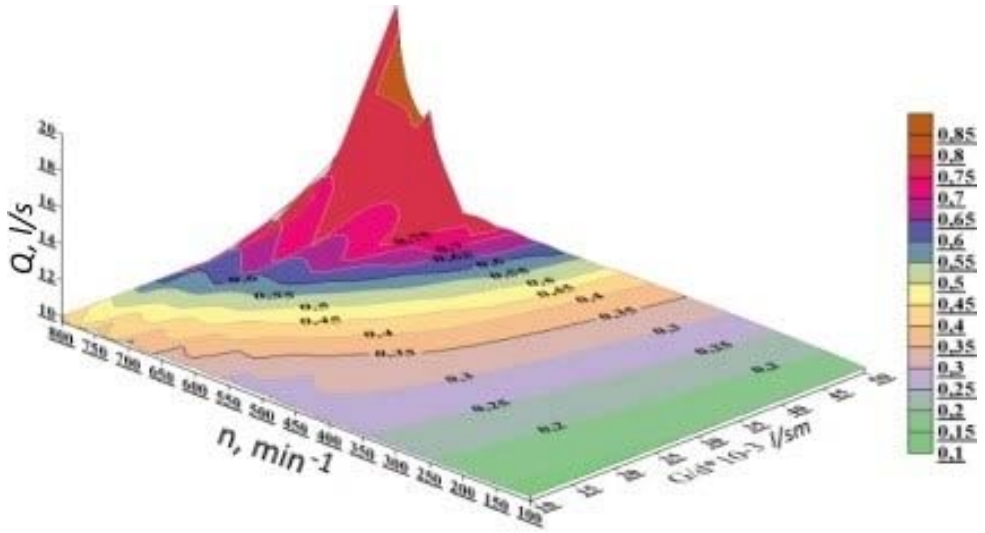


Figure 3 – The distribution surface of the membership function of the solution set depending on the regime parameters.

Conclusion. Over the past decades, a large number of studies and data on the interaction of the tool with the rock have been accumulated, methods and means for determining the physico-mechanical properties and abrasiveness of rocks have been proposed. The mechanism of destruction of rocks was studied, the influence of various factors on it, attempts of the mathematical description were made [1, 17, 19]. In this regard, mathematical models of the drilling process are proposed, the main elements of which are the rate of penetration, as well as the factors that influence its values; the possibility of using these models to study the main integral indicators of the drilling process efficiency is shown: the run speed, the cost of one meter of penetration and bit footage; an improved scheme of predictive calculations of drilling performance and decision-making in the selection of bits and regime parameters, taking into account the rock properties, depending on the nature of the initial information has been proposed; by analyzing and studying the drilling process, an algorithm has been proposed for predicting the parameters of drilling wells and making optimal decisions based on data of geological and technological research in the drilling process, the use of which makes it possible to find the optimum values of the regime parameters from the condition of ensuring the maximum of the run speed and the minimum cost of 1 meter of penetration. When making decisions it is very important to take into account the conditions under which the drilling process takes place, namely: the heterogeneity, fuzziness and random nature of the factors, for which the development of methods of control theory and decision-making with insufficient information in recent years can serve as a reliable basis.

И. А. Пиривердиев[1], М. Д. Сарбопеева[2], Г. Ш. Асадова[3]

[1]Әзербайжанның ұлттық ғылым академиясының мұнай және газ институты, Баку, Әзербайжан,
[2]Ш. Есенов атындағы Каспий мемлекеттік технологиялар және инжиниринг университеті,
Ақтау, Маңғыстау облысы, Қазақстан,
[3]Әзербайжан мемлекеттік мұнай және өнеркәсіп университеті, Баку, Әзербайжан

МОДЕЛДЕУ ҮДЕРІСІН ТАЛДАУ ЖӘНЕ ҰҢҒЫЛАРДЫ БҰРҒЫЛАУДА АЙҚЫН ЕМЕСТІКТІ ЕСЕПКЕ АЛА ОТЫРЫП ШЕШІМ ҚАБЫЛДАУ

Аннотация. Моделдеу мен ұңғыларды бұрғылауда шешім қабылдауға арналған соңғы жылдарда жинақталған зерттеулерге шолу орындалған. Шолу барысында назарды баса аудару қажет сұрақтар аясын анықтау мүмкін болды. Соның ішінде, оңтайландыру міндеттерін шешу үшін бірінші кезекте қажет мәліметтердің болуы атап көрсетілген. Бұл кезеңнен соң мәліметтерді өңдеу, бұрғылау моделін тұрғызу жасалады. Одан соң нұсқалық есептеулер жасалып, шешім қабылдау кезеңі келеді.

Бұрғылау үдерісін қолайландыру міндеттерін шешу шешім қабылдау жағдайларының айқындалмауы, көпфакторлық, көпталаптылық, дәлдіктің болмауы, біржақтылық болмауы себептерінен күрделенеді. Мәселені табысты түрде шешу үшін анықталған айқын еместіктіктерді есепке ала отырып сәйкес әдістерді қолдану қажет. Бұл әдістерде айқын еместікті есепке алу керек. Бұдан басқа, олар соңғы жылдарда белең алған геологиялық технологиялық зерттеулер нәтижесіне де негізделуі тиіс. Осыған байланысты, осы мақалада қашауларды және режимдік көрсеткіштерді таңдау әдістерін жетілдіру жолдары, сонымен қатар, геологиялық технологиялық зерттеулер нәтижесін интерпретациялау қарастырылады. Геологиялық технологиялық зерттеулерді өңдеу және талдау негізінде моделдер тұрғызылған. Айқын еместікті ескере отырып шешім қабылдау жолдары көрсетілген. Шешімдер дәл емес көпшелер теориясы ережелерін қолданып қабылданады.

Геологиялық технологиялық зерттеулер негізінде бірнеше ұңғылар бойынша есептеулер жүргізілді. Ол үшін тиісті бағдарлама қолданылды. Нәтижесінде қималардың физикалық механикалық және қысымдық сипаттамалары алынды. Есеп жұмыстары Әзірбайжан мен Қазақстанның бірнеше кенорындары мысалымен орындалған. Мақалада Қарабаглы кенорны қимасындағы тау жыныстарының физикалық механикалық қасиеттерінің өзгеруі көрсетілген. Қиманың литологиялық стратиграфиялық сипаттамасы келтірілген. Тау жыныстарының тереңдігіне қарай петрофизикалық(кеуектілік, өткізгіштік), беріктік (қаттылығы, абразивтілігі), серпімділік (Юнг модулі, Пуассон коэффициенті) қасиеттерінің өзгеру қисық сызықтары салынған. Талдау қортындысында ұңғыларды бұрғылау көрсеткіштерін болжау және бұрғылау үдерісінде геологиялық технологиялық зерттеулер мәліметтері бойынша ұтымды шешімдер қабылдау жолдары көрсетілген. Бұл 1 метр қашау жүрісі құнын төмендету және рейстік жылдамдықтың ең жоғары мәнін қамтамасыз ету шарттары арқылы режимдік көрсеткіштердің оңтайлы мәндерін табуға мүмкіндік береді.

Түйінді сөздер: механикалық жылдамдық, рейс жылдамдығы, ену көрсеткішінің құны, режим параметрлері, мүшелік функция, белгісіздік.

И. А. Пиривердиев[1], М. Д. Сарбопеева[2], Г. Ш. Асадова[3]

[1]Институт нефти и газа Национальной Академии наук Азербайджана, Баку, Азербайджан,
[2] Каспийский государственный университет технологий и инжиниринга им. Ш. Есенова, Актау, Мангистауская область, Казахстан,
[3]Азербайджанский государственный университет нефти и промышленности, Баку, Азербайджан

АНАЛИЗ ПРОЦЕССОВ МОДЕЛИРОВАНИЯ И ПРИНЯТИЯ РЕШЕНИЙ ПРИ БУРЕНИИ СКВАЖИН С УЧЕТОМ НЕОПРЕДЕЛЕННОСТИ

Аннотация. Выполнен обзор исследований, посвященных моделированию и принятию решений в процессе бурения скважин, накопившихся за последние годы. Обзор позволил определить круг вопросов, на которых необходимо сосредоточить внимание. В частности, отмечается, что для решения задач оптимизации в первую очередь необходимы данные. За этим этапом следует обработка данных, построение модели бурения. Затем проводятся вариантные расчеты и наступает этап принятия решений.

Решение задач оптимизации процесса бурения усложняется неопределенностью ситуации принятия решений, выраженной многофакторностью, многокритериальностью, неточностью, неоднозначностью. Для успешного решения проблемы с учетом отмеченных неопределенностей необходимо применять соответствующие методы. Эти методы должны учитывать неопределенность. Кроме того, они должны основываться также на результатах, получивших в последние годы широкое распространение геолого-технологических исследований. Исходя из этого, в настоящей статье рассматриваются пути совершенствования методов выбора долот и режимных параметров, а также интерпретации результатов геолого-технологических исследований. Построены модели на основе обработки и анализа данных геолого-технологических исследований. Показаны пути принятия решений с учетом неопределенности. Решение принимается с применением положений теории нечетких множеств.

На основе данных геолого-технологических исследований по нескольким скважинам проводились расчеты. Для этого применялась соответствующая программа. В результате получены физико-механические и барические характеристики разрезов. Расчеты выполнены на примере некоторых месторождений Азербайджана и Казахстана. В статье показано изменение показателей физико-механических свойств пород разреза месторождения Карабаглы. Приведены литолого-стратиграфические характеристики разреза. Построены графики изменения с глубиной петрофизических (пористости, проницаемости), прочностных (твердости, абразивности) и упругих (модуль Юнга, коэффициент Пуассона) характеристик пород. В результате анализа показаны пути прогнозирования показателей бурения скважин и принятия оптимальных решений по данным геолого-технологических исследований в процессе бурения. Это позволяет найти оптимальные значения

режимных параметров из условия обеспечения максимума рейсовой скорости и минимума стоимости 1 метра проходки.

Ключевые слова: механическая скорость, рейсовая скорость, стоимость метра проходки, долото, режимные параметры, функция принадлежности, неопределенность.

Information about authors:

Piriverdiyev Igor, Institute of Oil and Gas of Azerbaijan National Academy of Sciences, Baku, Azerbaijan; igorbaku@yandex.ru; https://orcid.org/0000-0002-6915-8266

Sarbopeyeva Manshuk, Caspian State University of Technology and Engineering named after Sh. Yessenov, Aktau, Mangystau region, Kazakhstan; manshyk84@mail.ru; https://orcid.org/0000-0003-1721-119X

Asadova Gulshan, Azerbaijan State Oil and Industry University, Baku, Azerbaijan; gjulshan-asadova@rambler.ru; https://orcid.org/0000-0001-5965-7240

REFERENCES

[1] Ocenka pokazatelej burenija i prinjatie reshenij na osnove kompleksnoj geologo-tehnologicheskoj informacii. Neftjanoe hozjajstvo / T.V. Hismetov, G.M. Jefendiev, O.G. Kirisenko, 2006(10): 42-5.

[2] Bourgoyne Jr., Young A.T. and F.S., 1974. A Multiple Regression Approach to Optimal Drilling and Abnormal Pressure Detection. SPE 4238.

[3] Irawan S., Mahfuz A., Rahman A., Tunio S.Q. Optimization of Weight on Bit During Drilling Operation Based on Rate of Penetration Model. Research Journal of Applied Sciences // Engineering and Technology 4(12): 1690-1695, 2012.

[4] Efendiyev G.M, Djafarova N.M., Djevanshir R.D. The optimum decision in cutting-type drilling bits selection with regard to their operating conditions and the vagueness of the task posed // Energy Sources 13.2 (1991): 243-250.

[5] King, William W. Iterative drilling simulation process for enhanced economic decision making // U.S. Patent No. 7,085,696. 1 Aug. 2006.

[6] Goldman, William A., et al. "Method and system for predicting performance of a drilling system for a given formation." U.S. Patent No. 7,261,167. 28 Aug. 2007.

[7] Strachan Michael, Martin Paulk. Method and system for predicting performance of a drilling system having multiple cutting structures // U.S. Patent No. 8,274,399. 25 Sep. 2012.

[8] Maulana D.T., Marbun B.T.H. ROP Modeling for Volcanic Geothermal Drilling Optimization. Proceedings World Geothermal Congress 2015 Melbourne, Australia, 19-25 April 2015

[9] Spravochnik po mehanicheskim i abrazivnym svojstvam gornyh porod neftjanyh i gazovyh mestorozhdenij / M.G. Abramson, B.V. Bajdjuk, V.S. Zareckij i dr. M.: Nedra, 1984. 207 p.

[10] Mysljuk M.A., Bliznjukov V.Ju., Mysljuk N.M. Nauchno-metodicheskie osnovy proektirovanija racional'nyh konstrukcij skvazhin v uslovijah informacionnoj neopredeljonnosti. Obz. inform. Ser. Burenie gazovyh i gazokondensatnyh skvazhin. M.: IRC Gazprom, 1996. 55 p.

[11] Kompleksnyj mehaniko-statisticheskij metod ocenki burimosti gornyh porod s cel'ju prognozirovanija i optimizacii processa obrabotki sharoshechnyh dolot / B.V. Bajdjuk, M.G. Abramson, A.M. Matveeva i dr. V sb. «Processy razrushenija gornyh porod i puti uskorenija burenija skvazhin». Ufa, 1978. P. 264-267.

[12] Fedorov B.V., Ratov B.T., Sharauova A.B. Model' burimosti dolotami PDC dlja prohodki skvazhin na neftegazovom mestorozhdenii Uzen' // Izvestija Nacional'noj Akademii nauk Respubliki Kazahstan. Serija geologii i tehnicheskih nauk. 2017. 4(424). P. 170-177.

[13] Pogarskij A.A., Chefranov K.A., Shishkin O.P. Optimizacija processov glubokogo burenija. M.: Nedra, 1981. 296 p.

[14] Piriverdiyev I.A., Sarbopeyeva M.D. Selection of the best combination of bit types and technological parameters during drilling, taking into account uncertainty // 9th International Conference on Theory and Application of Soft Computing, Computing with Words and Perception, ICSCCW 2017, Budapest, Hungary, August 22-23, 2017. Procedia Computer Science (ELSEVIER). P. 67-74.

[15] Kershenbaum V.Ja., Torgashov A.V., Messer A.G. Burovoj porodorazrushajushhij instrument. Vol. I. Sharoshechnye dolota. M.: Rinko-Al'jans, 2003. 253 p.

[16] Svincickij S.B. Prognozirovanie gorno-geologicheskih uslovij provodki skvazhin v solenosnyh i glinistyh otlozhenijah s anomal'no vysokimi davlenijami fljuidov: Avtor. dokt. diss. Stavropol', 2006. 47 p.

[17] Levickij A.Z. Ispol'zovanie dannyh geologo-tehnologicheskogo kontrolja dlja optimizacii burenija // Obzornaja informacija. Ser. "Burenie". VNIIOJeNG, 1987. Vyp. 5. 52 p.

[18] Tehnologija provodki podsolevyh skvazhin v Prikaspijskoj vpadine / Min-vo geol. SSSR, Kazahskij nauch.-issled. geol.-razved. in-t. Sost.: U.S. Karabalin, M.A.Tankibaev, B.D. Al'seitov i dr. M.: Nedra, 1989. 160 p.

[19] Hairov G.B. Jekologicheski bezopasnaja tehnologija stroitel'stva glubokih razvedochnyh skvazhin: monografija. M.: VNIIOJeNG, 1996. 203 p.

[20] Litvinov M.A. Sistema kompleksnogo modelirovanija processov pri burenii neftjanyh skvazhin na osnove nechetkih mnozhestv: Avtor. kand. diss. Orenburg, 2005. 24 p.

[21] Jefendiev G.M., Dzhanzakov I.I., Kirisenko O.G., Piriverdiev I.A., Gurbanov V.Sh., Buktybaeva S.K. Analiz i ocenka jeffektivnosti prinimaemyh reshenij pri burenii skvazhin // XX Mezhdunarodnaja konferencija «Porodorazrushajushhij i metallo-obrabatyvajushhij instrument – tehnika, tehnologija ego izgotovlenija i primenenija», g. Truskavec, Ukraina. 17-22 sentjabrja 2017.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 32 – 37 **https://doi.org/10.32014/2019.2518-170X.3**

UDC 669.181
MRNTI 53.31.15/53.31.17

S. Tleugabulov[1], D. Ryzhonkov[2], N. Aytbayev[3], G. Koishina[1], G.Sultamurat[3]

[1]Kazakh National Research Technical University named after K. I. Satpayev (Satpayev University), Almaty, Kazakhstan,
[2]National University of Science and Technology (MISIS), Moscow, Russia,
[3]Karaganda State Technical University, Karaganda, Kazakhstan.
E-mail: suleiman_70@mail.ru, diryzhonkov@mail.ru, nurlan_2303@mail.ru, gulzada.koishina@mail.ru, sultamurat_gi@mail.ru

THE REDUCTION SMELTING OF METAL-CONTAINING INDUSTRIAL WASTES

Abstract. Metal containing scrape accumulation is not only issue of the ecological safety of regions, but is a new paradigm in development of the black metallurgy (direct production of iron) obtaining the energy and resources conservation policy.

The purpose of the work: use of metal-containing and carbon-containing industrial waste – converter sludge and coal sludge of the JSC "ArcelorMittal Temirtau" metallurgical enterprise.

The process structuring chain consists of: 1) ore-coal mixture conditioning from converter and coal slimes; 2) production of ore-coal pellets from the fine ore-coal mixture; 3) metallization of ore-coal pellets; 4) reduction smelting of metallized pellets and production of natural-alloyed steel.

The solid carbon was used as a reducing agent, while preparing the ore-coal mixture we adhere to the principle of complete reduction of the net extracted iron and manganese metals. Therefore, the stoichiometric consumption of prepared coal sludge per unit of iron ore concentrate was determined according to the developed procedure, taking into account the sequentially phase transformation of oxides. As a result of performed calculations, the coal feed rate per unit of concentrate in the amount of 0,265 kg/kg was obtained. The ore-coal mixture consisted of the sum of prepared converter and coal sludges.

On the basis of metal- and carbon-containing sludge of JSC "ArcelorMittal Temirtau" the ore pelletized pellets with stoichiometric carbon content areobtained. Sequential processing, drying, metallization and reduction smelting made it possible to obtain metal ingots corresponding to high-quality steel in composition in the final stage.

Key words: metal-containing waste, converter sludge, coal sludge, metallization, pellets, steel, carbon, phosphorus, reduction, smelting, crystallization.

The conventional technology of metallurgical production of cast iron and steel is based on the two-stage complex "Blast furnace-Converter". At the initial stage of the complex, conventionally, agglomerate oxide materials are used as raw materials in the form of sinter and pellets in predetermined weight ratios to the mass of coke. The mass fraction of coke in the charge provides the thermal balance of the reduction smelting process as a source of hot reducing gases (HRG) used to heat the charge column and to reduce iron, and also to melt the ore portion of the charge.

In addition, the coke layer plays an important role as a nozzle in which counterflow filtration of HRG and melts is realized, as well as a source of direct reduction of iron and hard-to-reduce metals by solid carbon. As can be seen, under the conditions of implementation of the reduction-smelting process in the blast furnace there is a stable excess of coke and the melted metal product is cast iron.

In view of high performance of blast furnaces, the worldwide mass production of structural materials is based on the oxygen converter processing of pig iron via oxidation smelting into steel. The problem of oxidation smelting of cast iron in the oxygen converter is metal decarburisation. However, during oxygen

lancing of the iron melt, not only the oxidation of the carbon of the cast iron occurs, but also the oxidation of a significant part of iron and the complete oxidation of the valuable alloying metals with formation of metal oxides, which are transported into the converter slag. In converter smelting, not only the formation of metal-containing slags occurs, but a significant mass of sludges with concentration of metals many times higher than in slag. They are also accumulated in dumps.

Metal-containing wastes accumulation is a problem nowadays not only for the environmental security of the regions, but also as a secondary source of raw materials for the production of metal [1].

Pursuance of the most low-cost use of these wastes is associated with their return, if possible, according to the current scheme of the metallurgical cycle, in particular, to the agglomeration process. However, the possibility of introducing dispersed metal-containing waste into the sintering charge is limited and the mass of the incandescent metal-containing waste is expanding every year.

Analyzing new theoretical propositions [2] and the organization of the processes of mini production of iron and steel [3-5], one may come to the conclusion that the last word of science is related not only to the existing principle of the preparation of the agglomerated oxide raw material and its reducing melting, but a new principle of preparation of disperse metal-containing raw materials and its reduction-smelting processing.

Such an approach opens the prospect of not only the full use of current and accumulated waste, but also the direct production of high-quality steels and alloys from them.

The principle of agglomerated oxide raw material (agglomerate, pellets) preparation is based mainly on the use of HRG as a reducing agent, which requires high gas permeability of the burden layer. The very organization of the reduction processes in countercurrent of the agglomerated charge column and HRG from the position of the process kinetics has a number of significant drawbacks. The commonly advertised adsorption-catalytic mechanism (ACM) [6] is not a determining factor in the realization of metal reduction. On the contact surface between the agglomerated raw material and HRG, the metal reduction mechanism is associated with a topochemical mass transfer regime [7], by the successive phase transformation of the oxides into a metallic state from the surface to the center of the pieces. Such a sequence of the process is limited by the slowest contact-diffusion mechanism.

In the processes of metallization of dispersed metal-containing waste, HRG cannot be used as a reducing agent. The most effective reducing agent is solid carbon, which does not require gas permeability of the layer, while at the same time provides a high rate of reaction depending on the value of the RSC coefficient (reaction-contact surface). The value of the RSC in the 1,0 mm thick dispersible waste layers reaches up to 20,000 m^2/kg, and below 1,0 mm can reach up to 30,000 m^2/kg.

Conditions for the realization of direct reduction of metals is, first of all, the uniform distribution of a carbon-containing reagent of a similar reaction in a layer of dispersed oxide waste. Based on this principle of charge preparation, experimental studies were carried out.

Experimental procedure. In the experimental studies, metal-containing and carbon-containing industrial wastes - converter sludge and coal sludge chemical compositions of which are presented in table 1 from the JSC “ArcelorMittal Temirtau” metallurgical enterprise were used.

It can be seen from the composition of the initial slimes that the content of the basic CaO oxide is almost 4-times higher than the concentration of acid oxides (SiO_2+Al_2O_3) in fluxes. Hence it can be seen that phosphorus and sulfur with concentration of 0,5 and 0,2% are in the form of chemical compounds of $Ca_3(PO_4)_2$ and CaS, respectively. Coal sludge also contains rather high concentration of slag-forming oxides - SiO_2и Al_2O_3.

Table 1 – Chemical composition of initial components

Name of components	Chemical composition, %									
	Fe_{com}	FeO	MnO	SiO_2	Al_2O_3	CaO	MgO	S	P	C
Converter sludge	60,3	12,5	1,75	2,54	3,25	22,0	2,32	0,20	0,50	2,65
Coal sludge	–	–	–	18,2	7,65	2,32	0,72	0,18	0,05	52,3

Therefore, the initial sludge was pretreated to remove a part of the slag-forming gangue. Both sludges were enriched: converter sludge - by magnetic separation, and coal sludge - by gravity concentration.

In the dry coal sludge the specific weight of slag-forming oxide particles (SiO_2, Al_2O_3, CaO, MgO) is, on average, five times greater than the specific mass of solid carbon particles. Within respective limits, their hovering velocities vary, i.e. particles removal rate. These variations were used for separation in the wind tube, which was charged with dry coal sludge and the layer was purged with air at a rate of 5,0-6,0 m/s, which corresponds to fine carbon particles hovering velocity. Smaller and lighter particles are blown through a special vent and enters the second container - dust collector. The trapped dust mainly contained carbon particles.

The compositions of enriched converter and coal sludges are presented in table 2.

Table 2 – Chemical composition of processed converter and coal sludges

Name of components	Chemical composition, %									
	Fe_{com}	FeO	MnO	SiO_2	Al_2O_3	CaO	Mg	S	P	C
Converter sludge	71,25	14,75	1,93	1,51	1,92	12,75	1,33	0,02	0,12	2,95
Coal sludge	–	–	–	6,86	2,87	0,87	0,27	0,06	0,02	65,74

As can be seen from the results of the analysis presented in table 2, rather qualitative components - iron ore concentrate with high iron content and a carbonaceous reagent with a carbon content of 65% were obtained from the initial converter and coal sludges. Only phosphorus content in the concentrate is much higher than the allowable rate. However, it should be stipulated that high concentration of basic CaO oxide in converter sludge is associated with the technology of dephosphorization of pig iron in an oxygen converter in which oxidized phosphorus P_2O_5 is bound by calcium oxide according to the following reactions:

$$2[P]+2{,}5O_2 = P_2O_5 \quad (1)$$

$$P_2O_5 + 3\ CaO = Ca_3(PO_4)_2 \quad (2)$$

As can be seen, phosphorus dissolved in the cast iron, oxidized in P_2O_5 by reaction (1), binds firmly to calcium phosphate by reaction (2). Considering the high chemical strength of $Ca_3(PO_4)_2$, in the organization of subsequent reduction and smelting processes, it is advisable to regulate the temperature-heat regime of phosphorus reduction. Based on this formulation of tasks, the following sequence of organization of the process was adopted.

1. Preparation of ore-coal mixture from converter and coal sludges.
2. Obtaining ore-coal pellets from the fine ore-coal mixture.
3. Metallization of ore-coal pellets.
4. Reduction smelting of metallized pellets and obtaining nature-alloyed steel.

Since solid carbon is used as the reducing agent, when preparing the ore, the coal mixture is based on the principle of complete reduction of the useful extractable metals of iron and manganese. Therefore, the stoichiometric consumption of the prepared coal sludge per unit of iron ore concentrate was determined according to the developed procedure, taking into account the successive phase transformation of oxides [8]. As a result of the performed calculations, the consumption of coal cuttings per unit of concentrate in the amount of 0,265 kg/kg was obtained. The ore-coal mixture consisted of the amount of prepared converter and coal sludges in the amount of 1+0,265 = 1,265 kg. The resulting dispersed ore-coal mixture was thoroughly mixed, then ore-carbon pellets were obtained from the pellet granulator. An aqueous solution of nitrocellulose varnish was used as a binder. Mixing of converter and coal sludges inevitably leads to a change in the chemical composition of the mixture, in which the mass fraction of ore and coal parts was determined from the ratio γ_p=1,0:1,265=0,79 and γ_y= 0,265 : 1,265 = 0,21. Based on these mass ratios, the average chemical composition of the mixture was determined, which is presented in Table 3.

Obtained crude pellets with fraction of 8,0-20,0 mm after drying at 400^0C have acquired sufficient strength and have been prepared for metallization.

Since the pellets contain an increased concentration of phosphorus and a stoichiometric amount of carbon in choosing the temperature regime, not only the direct reduction of metals by carbon was taken into account, but also the possibility of limiting the transition of phosphorus to the metal. Here the favorable effect is due to the fact that phosphorus is completely in the compounds of calcium phosphate, from which it begins to recover only at temperatures above 1200 °C. Therefore, the metallization process was limited to heating to 1000-1100 °C.

The dried pellets with a mass of 200 g were placed in a sealed cell made of a quartz tube with a diameter Ø40 mm and introduced into the tubular furnace SUOL-044 12-M2, preheated to 550 °C, then heated at a rate of 10 °C/min. At 650 °C, the beginning of expelling of the gas - the reaction products of CO and CO_2 was recorded. When temperature reached 1100-1120 °C, a time delay of 25-30 minutes was observed until the gas expelling ceased, which meant the completion of the direct reduction of metals.

The chemical composition of ore-coal and metallized pellets is presented in table 3.

Table 3 – Chemical composition of ore-coal and metallized pellets

Name of pellets	Chemical composition, %										
	Fe_{com}	Fe_{met}	FeO	Mn	SiO_2	Al_2O_3	CaO	MgO	S	P	C
Ore-coal	56,29	–	11,65	1,18	2,63	2,12	10,25	1,107	0,036	0,10	16,13
Metallized	86,6	84,0	3,34	1,81	4,05	3,26	15,77	1,70	0,04	0,154	2,15

Samples of metallized materials together with the cell were removed from the furnace, cooled and further reloaded into a refractory crucible and installed in a "Tamman" melting furnace. The furnace was heated at a rate of 15-20 °C/min. In order to avoid secondary oxidation of the metallized pellets, the surface of the crucible was blown with neutral gas - argon. When the temperature reached 1600 °C, the pellets were completely transferred to the melt, which was drained into a refractory baking sheet.

The yield of metal was 68,0 g. from the initial 200 g. of ore-coal pelletized pellets. Analysis of metals obtained from two runs is provided in table 4.

Table 4 – Chemical composition of samples of molten metal

Metal samples	Chemical composition, %				
	[Mn]	[C]	[Si]	[S]	[P]
Test № 1	1,20	0,57	0,15	0,02	0,028
Test № 2	1,25	0,62	0,12	0,025	0,030

As can be seen from the results of the analysis, melted samples of metal are nature-alloyed steels. The content of contaminants - sulfur and phosphorus meets the technical requirements of high-quality steel.

Conclusion. On the basis of metal-containing and carbon-containing sludge of JSC "ArcelorMittal Temirtau", ore pelletized pellets with stoichiometric carbon content are obtained. Sequential processing of drying, metallization and reduction smelting made it possible to obtain in the final stage metal ingots, which in composition correspond to high-quality steel.

**С. М. Тлеугабулов[1], Д. И. Рыжонков[2],
Н. Б. Айтбаев[3], Г. М. Қойшина[1], Е. Көбеген[3], Г. И. Сұлтамұрат[3]**

[1]Қ. И. Сәтбаев атындағы Қазақ ұлттых техникалық зерттеу университеті (Сәтбаев Университеті),
Алматы, Қазақстан,
[2]Ұлттық технологиялық зерттеу университеті, Мәскеу, Ресей,
[3]Қарағанды мемлекеттік техникалық университеті, Қарағанды, Қазақстан

ҚҰРАМЫНДА МЕТАЛЛ БАР ӨНЕРКӘСІПТІК ҚАЛДЫҚТАРДЫ РЕДУКЦИЯЛАП БАЛҚЫТУ

Аннотация. Құрамында металл бар қалдықтардың жинақталуы бүгінгі таңда тек өңірлердің экологиялық қауіпсіздігі мәселесі ғана емес, сондай-ақ энергия мен ресурстарды үнемдеу саясатын есепке ала отырып, қара металлургия саласы дамуының жаңа парадигмасына (тікелей темір өндірісі) байланысты болуы керек.

Жұмыстың мақсаты: «АрселорМиттал Теміртау» АҚ металлургиялық комбинатының құрамында металл бар және көміртегі бар қалдықтар – конвертерлік шлам мен көмірді байыту шламдарын пайдалану.

Процесті ұйымдастыру кезектілігі мынадай: 1) конвертер және көмір шламдарынан кенді көмірлі қоспаны дайындау; 2) ұсақ кен көмірлі қоспадан кен көмірлі окатыштер алу; 3) кен көмірлі окатыштерді металлизациялау; 4) металданған окатыштерді редукциялап-балқыту және легірленген болат алу.

Тотықсыздандырғыш реагент ретінде қатты көміртегі қабылданған-дықтан, кен көмірлі қоспаны дайындау кезінде темір мен марганец металдарынан алынған пайдалыларды толық тотықсыздандыру принципіне сүйенеміз. Сондықтан оксидтердің реттік-фазалық түрленуін ескерумен әзірленген әдістеме бойынша темір рудалы концентрат бірлігіне дайындалған көмір шламының стехиометриялық шығыны анықталды. Есептеулерді орындау нәтижесінде 0,265 кг/кг мөлшерінде концентрат бірлігіне кететін көмір шламының мөлшері алынды. Көмір кенді қоспа конвертерлік және көмір шламдарының сомасынан құралды.

«АрселорМиттал Теміртау» АҚ жағдайындағы құрамында металл бар және көміртегі бар шламдарының негізінде көміртегінің стехиометрлік құрамымен көмірлі окатыштер дайындау ұйымдастырылды. Оларды ретімен өңдеу, кептіру, металдандыру және редукциялап-балқыту соңында сапалы болаттың құрамына сәйкес келетін металл құймасын алуға мүмкіншілік береді.

Түйін сөздер: құрамындаметалл бар қалдықтар, конвертерлік шлам, көмір шламы, металдау, окатыш, болат, көміртегі, фосфор, редукциялау, балқыту, кристалдану.

**С. М. Тлеугабулов[1], Д. И. Рыжонков[2],
Н. Б. Айтбаев[3], Г. М. Қойшина[1], Е. Көбеген[3], Г. И. Сұлтамұрат[3]**

[1]Казахский национальный исследовательский технический университет им. К. И. Сатпаева
(Сатпаев Университет), Алматы, Казахстан,
[2]Национальный исследовательский технологический университет (МИСиС), Москва, Россия,
[3]Карагандинский государственный технический университет, Караганда, Казахстан

ВОССТАНОВИТЕЛЬНАЯ ПЛАВКА МЕТАЛЛОСОДЕРЖАЩИХ ПРОМЫШЛЕННЫХ ОТХОДОВ

Аннотация. Накопление металлсодержащих отходов сегодня является проблемой не только экологической безопасности регионов, но и должно быть связано с новой парадигмой развития черной металлургии (прямое получение железа) с учетом политики энерго- и ресурсосбережения технологий.

Цель работы: использовать металлосодержащие и углеродсодержащие промышленные отходы металлургического комбината АО «АрселорМиттал Темиртау» - конвертерный шлам и шлам углеобогащения.

Последовательность организации процесса состоит из: 1) подготовка рудоугольной смеси из конвертерного и угольного шламов; 2) получение рудоугольных окатышей из мелкий рудо угольной смеси; 3) металлизация рудоугольных окатышей; 4) восстановительная плавка металлизованных окатышей и получение природолегированной стали.

В качестве восстановительного реагента принят твердый углерод, при подготовке рудо угольной смеси исходим из принципа полного восстановления полезных извлекаемых металлов железа и марганца. Поэтому был определен стехиометрический расход подготовленного угольного шлама на единицу железорудного

концентрата по разработанной методике с учетом последовательно-фазового превращения оксидов. В результате выполненных расчетов получен расход угольного шлама на единицу концентрата в количестве 0,265 кг/кг. Рудоугольная смесь состояла из суммы подготовленных конвертерных и угольных шламов.

На базе металлсодержающих и углеродсодержающих шламов АО «АрселорМиттал Темиртау» организована подготовка рудоугольных окатышей со стехиометрическим содержанием углерода. Последовательная обработка сушка, металлизация и восстановительная плавка позволила получить на завершающей стадии слитки металла, которые по составу соответствуют качественной стали.

Ключевые слова: металлсодержащий отход, конвертерный шлам, угольный шлам, металлизация, окатыш, сталь, углерод, фосфор, восстановление, плавка, кристаллизация.

Information about authors:

Tleugabulov Suleiman, doctor of technical science, academician NEA of the RK, Professor of the Department «Metallurgy and Mineral Processing" Kazakh National Research Technical University named after K. I. Satpayev (Satpayev University), Almaty, Kazakhstan; suleiman_70@mail.ru; http://orcid.org/0000-0002-2006-6950

Ryzhankov Dmitriy, doctor of technical science, academician RANS, professor of the Department "Functional Nanosystems and High-Temperature Materials", National University of Science and Technology (MISIS), Moscow, Russia; diryzhonkov@mail.ru; http://orcid.org/0000-0002-3833-7931

Aytbayev Nurlan, PhD student. Department «Nanotechnology and metallurgy», Karaganda State Technical University, Kazakhstan; nurlan_2303@mail.ru; https://orcid.org/0000-0002-7469-4442

Koishina Gulzada, doctor PhD. Department «Metallurgy and Mineral Processing" Kazakh National Research Technical University named after K. I. Satpayev (Satpayev University), Almaty, Kazakhstan; gulzada.koishina@mail.ru; http://orcid.org/0000-0003-0592-3843

Sultamurat Gulmira, candidate of Technical Sciences. Department «Nanotechnology and metallurgy», Karaganda State Technical University, Kazakhstan; sultamurat_gi@mail.ru; https://orcid.org/0000-0002-0206-1638

REFERENCES

[1] Shomanova Z.K. et al. Study of composition of waste from metallurgy production aimed in use them as active phases of catalysts for hydrocarbon raw materials refining // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences. **2017**. 6(426): 195-200. https://doi.org/10.32014/2018.2518-170X (in Eng.).

[2] Tleugabulov S.M. Theoretical provisions of direct production of steel by reduction smelting // International Scientific and Technical and Production Journal "Steel". **2003**. N 8. P. 18-20.

[3] Smirnov N.A. About introduction of innovative technology for direct iron reduction / / Journal of Electrometallurgy. **2011**. N 4. P. 46-47.

[4] Usachaev A.B., Leherzak V.E., Balasanov A.V. Reduction of iron in the process of ROMELT // Journal of Ferrous Metals. **2000**. N 12. P. 14-21.

[5] 1B124. Midrex and Kobe Develop New Direct Iron Reduction Process // Iron and Steelmaker. **1996**.

[6] Chufarov G.I., Tatievskaya E.G. Adsorption-catalytic theory of the reduction of metal oxides // Problems of metallurgy. M.: USSR AS, **1953**. P. 15-32.

[7] Rybkin V.S., Leont'ev L.I., Leushin V.N., Evstyugin S.N., Gorbachev V.A. Systems for reducing Kachkanarsk pellets // Steel in Translation. **2008**. Vol. 38, N 7. P. 550–555. DOI 10.3103/S0967091208070139.

[8] Tleugabulov S.M. Metallurgical processes theory. Almaty: edition of the EPB for educational and methodological literature. **2007**. 351 p. ISBN-9965-495-57-2.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 38 – 50 **https://doi.org/10.32014/2019.2518-170X.4**

UDC 551.521.64

A. L. Shepetov[1], T. Kh. Sadykov[2], K. M. Mukashev[3], L. I. Vildanova[4], A. D. Muradov[3], O. A. Novolodskaya[2], M. E. Alieva[5]

[1]P. N. Lebedev Physical Institute of the Russian Academy of Sciences (FIAN), Moscow, Russia,
[2]Institute for Physics and Technology, Almaty, Kazakhstan,
[3]Al-FarabiKazakh national university, Almaty, Kazakhstan,
[4]Tien Shan Mountain Cosmic Ray Station of FIAN, Almaty, Kazakhstan,
[5]Abai Kazakh national pedagogical university, Almaty, Kazakhstan.
E-mail: ashep@www.tien-shan.org, turlan43@mail.ru, mukashev.kms@gmail.com, luvild@mail.ru, abyl.muradov@gmail.com, novololga@yandex.ru, moldir-2008@mail.ru

THE GEANT4 SIMULATION OF AN ELECTRON-PHOTON AVALANCHE DEVELOPMENT IN THUNDERCLOUD ATMOSPHERE

Abstract. On the basis of Geant4 toolkit we created a special program for simulation of the electron-photon avalanche development in a large-size atmospheric electrical fieldunder typical environmental conditions of the Tien-Shan mountain cosmic ray station. This code is especially aimedat planning and analysis of experimental results obtained in the frames of thunderstorm investigation program *Groza*.

The main simulation predictions concerning the electromagnetic components of avalanche: relative abundance of the electron and gamma ray components (30:1), their energy spectra (approximately, a power law shape with differential index -1.5-2 in the range of 30-10000 keV), and the anisotropy of their angular distributions occur in a good agreement with the results of theoretical and experimental studies which have been made so far under mountain conditions. The predicted value of the gamma ray ox which is of the order of 10^2cm2 at observation level also correspond reasonably well to direct measurements made at Tien - Shan station. These agreements confirm the adequacy of the used simulation model to real thunderstorm events.

At the same time, the predicted ox of avalanche neutrons seems to be an order of magnitude underestimated in comparison with data of corresponding experimental measurements; such a rough discrepancy can be an evidence of the existence of some effectivemechanism of neutron generation in natural atmospheric discharges, besides the fully electromagnetic photo-nuclear and electron-nuclear interactions which have been applied in simulation.We discuss the requirements to design of experimental $set - ups$ appropriate for study of thunderstorm connected radiations at mountain height which follow from presented simulation.

Keywords: thunderstorm, lightning, atmospheric electricity, runaway breakdown, Geant4.

Introduction. An investigation of the processes of atmospheric electric discharge in thunderclouds (lightnings), and of the role of cosmic rays in discharge initiation is held at the Tien Shan mountain cosmic ray station during two last decades. The complex experimental installation *Groza* (i.e. "Thunderstorm") which has been created especially for this purpose gives a possibility of simultaneous registration of various types of energetic radiations generated at the time of discharge: the X-ray and gamma radiation [1 - 3], accelerated electrons [4, 5], the 0.1-30 MHz and 250 MHz radio emission [6-8]. A separate task is registration of the extensive air showers being born in thunderstorm atmosphere by energetic cosmic ray particles, and the study of their role in the initiation of lightning discharge [5, 9, 10]. Another open question which remains so far unclear is connected with multiple observations of neutron signal probably associated with lightning discharge, which have been made both at Tien Shan [11, 12], and reported in publications of other groups [13-18].

Specificfeature of the *Groza* experimental complex is its mountain location just at the height of thunderclouds, so at thunderstorm times its detectors frequently occur being immersed immediately inside the lower part of active zone of the cloud where intensive electric field is present, and acceleration of charged particles have its place. Hence, for analysis of the data gained in this experiment, it is convenient to use the theoretical information concerning expected behavior of the charged particles ow within the range of a large scale atmospheric electric field. Such information could be obtained by the means of Monte-Carlo simulation of discharge development in a media which corresponds to characteristic conditions of Tien Shan experiment: the height of detector disposition between 3-4 km above the sea level, the spatial size of electric field region of the order of some kilometers, a rather low energy threshold of the used particle detectors (the thresholds about 30-50 keV for gamma-radiation, 1-3 MeV for electrons, and of the order of thermal energy for the neutrons aretypical for *Groza* experiment). Also, it is desirable to use a possibly complete set of existing particle models with precise account for interaction physics in a wide range of particle energies: from some hundreds of eV for secondary avalanche electrons, and up to some GeV for initial cosmic ray particles. These demands are met successfully by the modern program toolkit *Geant*4 [19] which is commonly used for simulation of particle interaction by analysis of the results of high energy physics and cosmic ray experiments in the leading centers of modern particle research:CERN, FERMILAB, IceCube, Auger installation etc.

The subject of present paper is the development of a proper *Geant*4 model for simulation of the particle avalanche behavior in thundercloud atmosphere, and the testing of its predictions in comparison with known theoretical and experimental data on thunderstorm generated particles axes. Later on, the simulations of this kind are intended for using in quantitative analysis of experimental data and in planning of appropriate detector design, in particular for the Tien Shan complex installation Groza, and can be useful in realization of other similar experiments.

Simulation model. Especially for the analysis of the data of Groza experiment, a simulation model was built on the basis of Geant4 toolkit which takes into account typical characteristics of as it is shown in figure 1, the spatial region to trace the particle trajectories in is a 5x5x5 km^3 cube, and its geometrical center is accepted as an origin of the general coordinate system, with Z axis being directed "vertically" to the top side of considered volume. The whole space is supposed to be filled by the air with standard gas composition (75.5 mass percent of N, 23.2% O, 1.28% Arand 0.01% C). The air pressure and temperature at "bottom" side of model volume are set to 675 mbar and 10^oC correspondingly, in agreement with average atmospheric conditions at the altitude of Tien Shan station, and with elevation h above this level both the pressure and air density diminish exponentially ($\sim\exp(-h/H_0)$) with characteristic scale height H_0 = 8,4 km. The temperature decrease with altitude is accepted to be linear with the rate of 6^0C/km. of the local Tien Shan environment.

According to common views, the key role in generationof electric eld in thunderclouds must play the convection mechanism of charge separation driven by the *E*arth'sgravitation [20], which generally acts in vertical direction.Correspondingly, in considered model it is set a uniformelectricfield *E* within a 1.5 km^3 km high vertical cylinder with its direction parallel to axis, to ensure downward acceleration of the negatively charged particles (electrons). This supposition agrees with modern data on existence of the lower positively charged region in thundercloud structure [21]. The geometric center of cylindrical field region coincides with the center of enclosing cube.Hence, the bottom side of the model cubic space corresponds to observation level of *Groza* experiment, and1 km above it occurs the lower border of the electricfieldregion, like a situation commonly met in real thunderstorm events. The value of the field strength ε was kept constantin each simulation run, and have been varied between 0.5-2.0 kV/m in different calculation series (more on this seebelow in section 3).

As one of the reasons which could trigger an electricdischarge within thundercloud it is often considered thepresence of charged seed particles in atmosphere, in particular electrons of extensive air showers (EAS) which areborn abundantly by the 10^{14}-10^{16} eV primary cosmic raysnuclei [22, 23]. Following to this mechanism, in each simulation series the seed electrons with fixed energy wereplaced just in the center point of considered model volume, and the directions of their initial momentum wererandomly spread inside the 4π solid angle (since the real EAS particles can y into thundercloud internals from anyside).A number of simulations was made with primary energy varied in the limits of 100-1000 MeV since these are the energies which are typical for the most part of EASelectrons. The

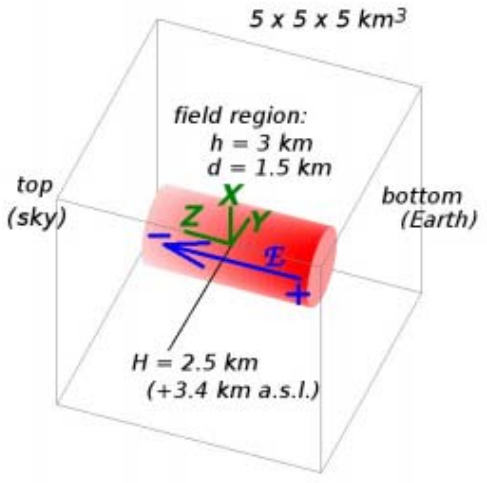


Figure 1 –Geometry of the Geant4 simulation model.
It is supposed that the "bottom" side of model volume sits at the altitude of Tien Shan mountain station (3.4 km above the sea level)

subsequent history of the seed particles soas of all succeeding avalanche products was traced in every simulation run: the energy, momentum direction, 3D-coordinates of the start and final track point, and arrivaltime to the end of trajectory (counted since the momentof primary interaction) were kept for each product particlefor further analysis.

The set of *Geant*4 physical models included insimulation involves the common processes of electromagnetic physics: the bremsstrahlung, multiplescattering, and ionization losses for electrons; thephoto-, and Compton-effects, and pair productionfor gamma-radiation; and the positron annihilation (correspondingly, the modules *G4eBremsstrahlung*, *G4eMultipleScattering*, *G4eIonisation*, *G4PhotoElectricEffec*t, *G4ComptonScattering*, *G4GammaConversion*, *G4eplusAnnihilation* of theGeant4 toolkit [24, 25]). Electromagnetic interactions ofany charged hadrons were taken into account throughcorresponding model processes *G4hMultipleScattering* and*G4hIonisation*.

Since the presence of low-energy charged particles whichcould be accelerated by the fieldis essential for the taskwe are interested in, the trajectories of both electrons andgamma-quanta were traced until their kinetic energy fallsdown a rather low threshold of 100 eV (due to ionizationlosses and photoelectric effect correspondingly). At thesame time, in the output set of resulting simulation datafor further analysis (e.g. to make a deposit into distributions presented below) were included only the particleswhich had the energy above 30 keV in point of theirtrajectory, in accordance with lower registration limit ofsome tens of keV which is typical for *Groza* detector complex.

The possibility of neutron production inside the developing electron-photon avalanche was ensured by the means of photo- and electronuclear reaction models from the standard Geant4 distribution (*G4GammaNuclearReaction, G4ElectroNuclearReaction*). Specific feature of neutron secondaries is chaotic trajectories resulting from a series of elastic collisions with nuclei of surrounding matter. Since we are interested in distribution of various characteristics of avalanche productsat a number of fixed distances from the active zone of thundercloud, every neutron born in simulated avalanche was traced completely along its trajectory through all intermediate elastic interactions, and in the final dataset wereincluded only its characteristics (the energy, momentumdirection, etc) which happened to be in the most distant points from the center of model ”thundercloud” volume (but which can occur being not a final point of the wholetrack). The simulation module for neutron physics takesinto account the Geant4 models of elastic coincidences inthe range from thermal and intermediate energies ($\sim 10^{-2}$–4 eV, G4NeutronHPThermal Scattering) to the high neutron energies (4 eV–20 MeV, *G4Neutron HPElastic*), andfurther on up to some GeV (*G4LElastic*). Correspondingly, the inelastic neutron interactions are presented bythe low- ($\sim 10^{-2}$eV–20MeV, G4NeutronHPInelastic) andhigh-energy (20 MeV–5 GeV, G4BinaryCascade) reaction models. Besides, the low- and high-energy neutron capture models (*G4NeutronHPCapture and G4LCapture*) aretaken into account.

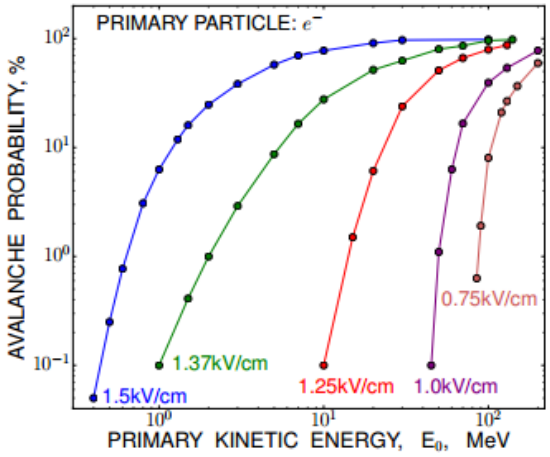


Figure 2 – The probability of an electron-photon avalanche generation in dependence on initial energy of the seed particle E_0 and the strength of electric field E (varied from 0.75 up to 1.5 kV/cm)

The necessity to consider rather high energy of theorder of some GeV in present simulation is stipulated bythe need to take into account the product particles of thehigh energy cosmic ray interactions.

For protons, anti-protons, and charged pionstogetherwith analogous processes of elastic and inelastic hadronicinteractions the models of multiple scattering and ionization losses are considered (for negative pions-alsothe process of their nuclear capture at rest, and for antiprotons, the annihilation process). Interaction sets ofall unstable particles include the process of their decay(*G4Decay*).

Simulation results. *Generation probability of a discharge avalanche.* The conditions of effective avalanche generation in thunderstorm atmosphere are the subject of a number of theoretical papers concerning the theory of runaway breakdown mechanism [26-28] which is connected with energetic electrons from the tail of thermal energy distribution and seems now to be one of the leading probable hypothesis on the development of electric discharge in thunderclouds.The main conclusions which follow from this theory are the following: (1) the development of an electron-photon avalanche is possible in the field ε with the strength above some critical value ε_c, which is about 2.0−2.2 kV/cm at the sea level, and for the heights of the Tien Shan detector complex $\varepsilon_c \approx 1.3-1.4$ kV/cm; (2) some charged seed particles must be presented within the filed region, e.g. the fast electrons from cosmic ray interaction with typical energy $E > m_e c^2 \varepsilon_c / 2\varepsilon$ (which corresponds to condition of $E \geq 200 - 500$ keV for a near-critical field); (3) the characteristic spatial size of the field region must exceed the typical length of exponential avalanche development (about 100 m). The geometry of considered simulation model does satisfy all these demands.

In present simulation, the probability of an electron-photon avalanche was defined as a relation of the events with multiple generations of secondary product particlesto the total number of simulated events. As a sign ofavalanche development the threshold condition $N_{sum} > 10000$ was applied, where N_{sum} is the sum number of secondary particles with the energy above 100 eV born in successive interactions of primary electron; as preliminarysimulations have shown, in the absence of field this condition gives a correct (zero) probability of avalanche generation excluding from the count δ-electrons and the particlesof usual low-energy electron-photon cascades.The resulting distributions of the avalanche generationprobabilityare presented in figure 2 in dependenceonthe strength of electric field ε and the energy of primaryparticleε_0. It is seen that the probability of avalanche appearance depends strongly both on the energy of the seed particle and on the tension of electric fieldε.

This probability starts to be noticeable (>10% of the total number ofsimulated events) by the strength of model field E ~1.2-1.5 kV/cm, just about the value of critical field $\varepsilon_c$atwhich the discharge development do occur at the altitude of Tien-Shan station due to the runaway breakdown mechanism (according to [28], $\varepsilon_c \sim$ 1.0 kV/cm for the height position of the model "cloud" center, $\varepsilon_c \sim$ 1.2 kV/cm atits lower border, and $\varepsilon_c \sim$1.4 kV/cm at the altitude ofTien Shan station). On the other hand, the test simulation runs have shown that any attempts to increase the model field above 1.5 kV/cm lead to exponential growth of the multiplicity of secondary products even with the seed particle energy ε_0 below 1 MeV, which means an

excess of the ε_c threshold and transition into overcritical regime. Such an almost quantitative coincidence can confirm the principal correctness of the used simulation model.

Since it is well known that in real thunderstorm clouds the field values $\varepsilon>\varepsilon_c$ were never observed [29, 30] all simulation results presented below were obtained in the runs with a fixed tension of the model electric fieldε = 1.5 keV/cm.

*Electromagnetic components of avalanche.*The spatial and energy particle distributions in discharge avalanche was studied through building the energy spectra of generated secondary particles at different distances ***d*** from the center of the field region. Since in accepted simulation model this center coincides with the origin of coordinate system, the distance was defined as $d = \sqrt{X^2 + Y^2 + Z^2}$, where the coordinates (x, y, z) correspond to the end of simulated particle track.The resulting energy spectra for electron and gammaray avalanche components are presented in two plots on the top of figure 3. The spectra are shown separately for various ranges of distance *d* which correspond both to inside of the spatial region of electric field: *d* = 0.75-1 km (curves 1), *d* = 1.25-1.5 km (2), *d*=1.5-1.75 km (3); and the space outof the field: d=2.0-2.25 km (4) *d* =2.5-2.75 km (5), *d*=2.75-3 km (6), *d*=3.25-3.5 km (7).

A characteristic feature of figure 3 spectra is the fast decrease of their intensity at the boundary of electric field: just at the 2 km distance from center point theparticle intensity is an order of magnitude below its average value within the field region, and at the distance~2.5 km (which corresponds to observation level in considered simulation model) it is up to 100-300 times lowerthan in the field center. Hence, a practical conclusion canbe drawn that for effective registration of the high-energyelectromagnetic components of a discharge avalanche it isextremely desirable to place the detector system just inside the spatial region of particle acceleration i.e. at apossibly high altitude above the sea level, just within thethundercloud region.

Analogous conclusion on rapid recession of the particledensityhas been made in theoretical work [28] where the equations of kinetic theory were applied to study of therunaway breakdown effect. Also, the fast absorption ofgamma-radiation emitted by lightning discharges was immediately observed at Tien Shan installation with a set ofsynchronously operating gamma-detectors distributed in a wide range (~500 m) of altitudes over a mountain slope [2, 3].

For comparison with situation of the real thunderstormevents, the energy spectra of some transient radiationbursts which have been registered experimentally in the moments of close lightning discharge at Tien Shan areshown on the top plots of figure 3 with triangle-shapedmarkers. In these measurements, the gamma-rays wereregistered with a scintillation detector based on a cylindrical NaI crystal, 110 mm in diameter and 110 mm in the height, which has been equipped with a number ofthreshold counter schemes to select scintillation pulses indifferent amplitude ranges, while the electron spectra wereobtained with a multi-layer absorption spectrometer ona set of ionization counters.

The registration system of signal intensity in these measurements was strictly synchronized with the moment of atmospheric discharge by aradio-pulse from the lightning and operated with a 160 μstime resolution, so the pulses of transient radiation wereseen distinctly around the discharge moment, and their relative excess above the background count level can becalculated. A more detailed description of the Tien Shandetector system and the current experimental setups canbe found in [31].

In the two upper plots of figure3 it is seen a rather satisfactory agreement both in general form and slope between the simulated and experimental spectra.The expected angular and time distributions of the electron and gamma ray intensity are presented in the middle panels of figure 3. Zenith angle of particle arrival at a distinct distance d by simulation was calculated as$\theta = \arccos(z/d = \sqrt{X^2 + Y^2 + Z^2})$, where the (x, y, z) coordinates relate to the final point of particle trajectory. Since in accepted simulation geometry the electric fieldis supposed to be directed along the *Z* axis, the angle $\theta = 180^o$ corresponds to acceleration direction of the negatively charged particles.

It is seen that angular distributions have an asymmetricshape which is strongly elongated in backwardhemisphere,i.e. along the acceleration direction of electrons. Such a concentration means that the scattering processes do notplay any significant role, and the most part of electron andgamma radiations keep the direction distribution formedinside the acceleration area until the distance up to somekilometres. Similar anisotropy for distribution of gamma radiation has been obtained also in [28] on the basis ofkinetic theory, and in a study of the behaviour of highenergy charged particles in a strong atmospheric electricfield made with the use of CORSIKA simulation package[32].

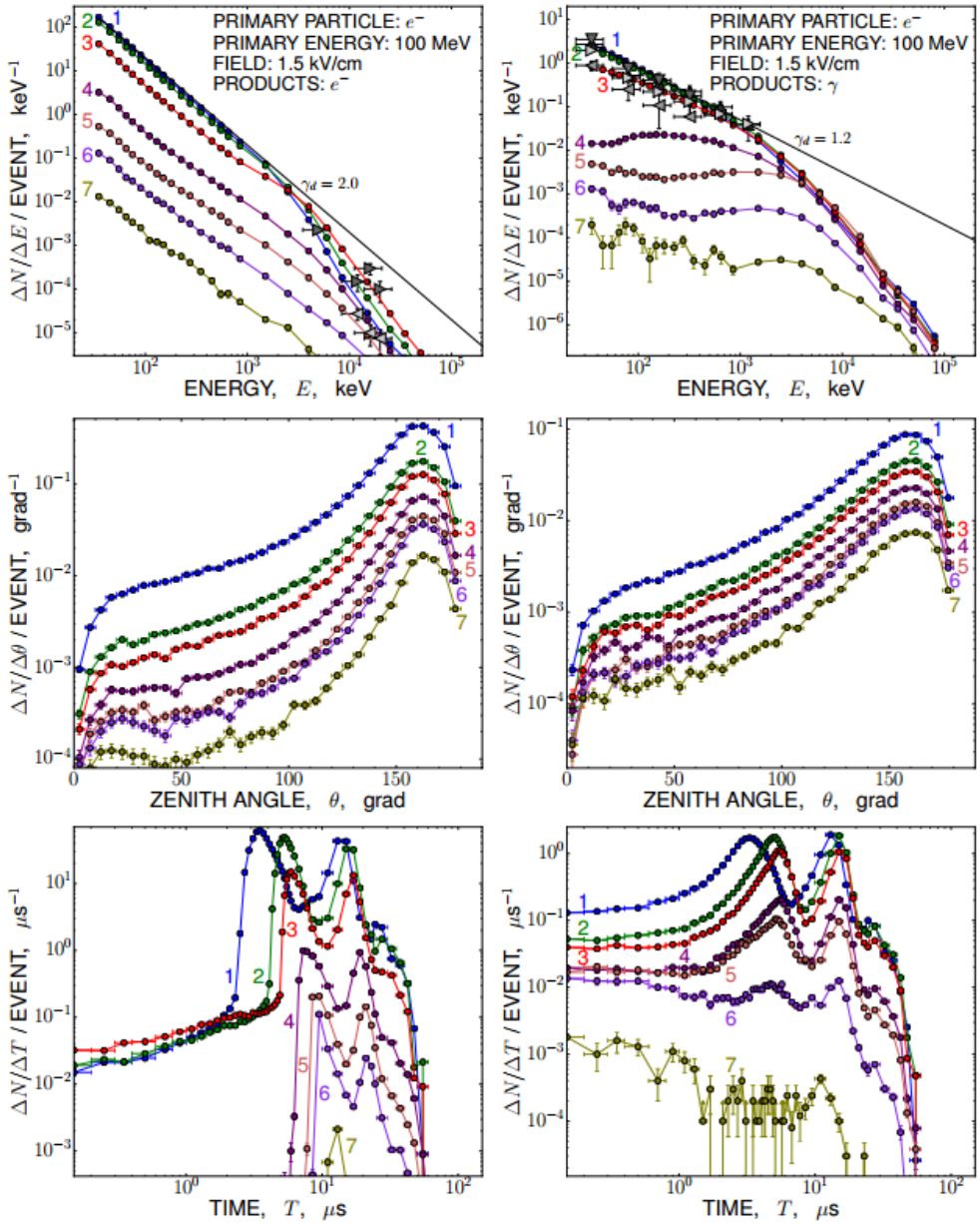


Figure 3 – The simulation results concerning electromagnetic avalanche components. Top plots: differential energy spectra of the electrons (top left) and gamma-ray quanta (top right) obtained in simulation and seen both in- (curves 1–3) and outside (curves 4–7) of electric field region (see text); with separate triangle marks are shown the spectra of real radiation bursts registered experimentally by close lightning discharges [31]. The middle and bottom plots: the angular and time distributions of the intensity of avalanche electrons (left), and gamma rays (right); the curve numbers and distance intervals in these plots are the same as for corresponding energy spectra. Error bars correspond to statistical errors of either Monte Carlo simulation or experimental data points

Two distributions in bottom plots of figure 3presentthe time delay between the beginning of avalanche development and arrival of corresponding radiation particles tothe points placed at the distance ***d*** from the center of thefield region. At observation level (d~2-3 km) both distributions have a prominent maximum in the region of 10-30 μs, in agreement with characteristic spike-like recordsof the gamma radiation signal which have been repeatedlyregistered in Tien - Shan experiments [2, 3, 8] held with a100–200 μs time resolution. This result means that the requirement of a precise timing analysis of signal intensitywith a better resolution time of the order of some microseconds is essentially desirable by design of experimental setups aimed to the investigation of thunderstorm connected radiations.

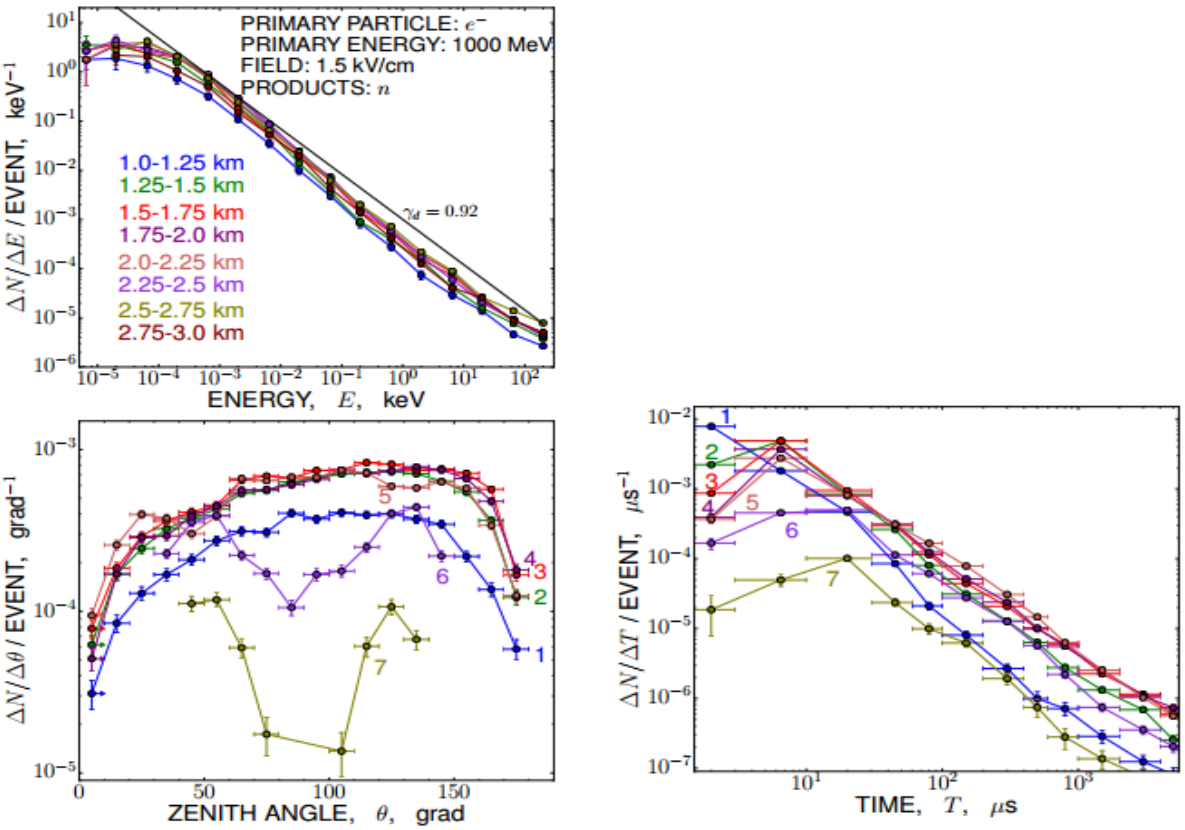


Figure 4 – The simulation results concerning the neutron component.
From top to bottom: the differential energy spectra of avalanche neutrons both within and out the region of electric field;
the angular and time distributions of the neutrons born
by avalanche curves 1 in both plots correspond to the distance range d=0.5–1.0 km from the field center,
(curves 2 to the range 1.0-1.5 km, 3 - to 1.5-2.0 km, 4 - to 2.0-2.5 km,
5 - to 2.5-3.0 km, 6 - to 3.0-3.5 km, and 7 - to 3.5-4.0 km)

Besides electrons, the trajectories of positron typeavalanche products were traced in simulation as well, andcorresponding energy spectra, zenith angle, and time distributions were obtained analogously to the case of electron particles. The shape of all these distributions is quite similar to the shape of electron ones, but relative intensityof positron component is 2.5–3 orders of magnitude lower. Fromthis one can state that the positively charged particles do not play any significant role in formation of signaldetectable in installations of *Groza* experiment.

Generally, a rather satisfactory agreement achieved between the computation, experimental, and theoretic results on the electromagnetic avalanche components can beconsidered as an ample correctness proof of presented simulation.

The neutron component.In the upper plot of figure 4theenergy spectra of the neutrons born by avalanche development are shown which have been calculated over thevarious distance ranges from the center of electric field. Incontrast to the case of gamma ray and electrons, the differential energy spectra of neutron component demonstratetheir practical independence on the distance; all of themhave the same power law shape with differential index $\gamma \approx$-0.92, and the close absolute intensity. Hence, a noticeableneutron signal could be expected at a rather significant distance, up to 2-3 km from discharge region; and the lowenergy neutrons must absolutely prevail among this signal:it is seen that the intensity of thermal neutrons is up to$\sim 10^6$times above its value in the MeV energy range.The angular distribution of the neutron type products in simulated avalanche is shown on the middle plot of figure 4.This distribution is much more isotropic than in the caseofelectromagnetic component, and both within the fieldregion (curves 1,2,3) and at a rather significant distancefrom it (curves 4,5) it is practically uniform in a wide range of zenith angles.

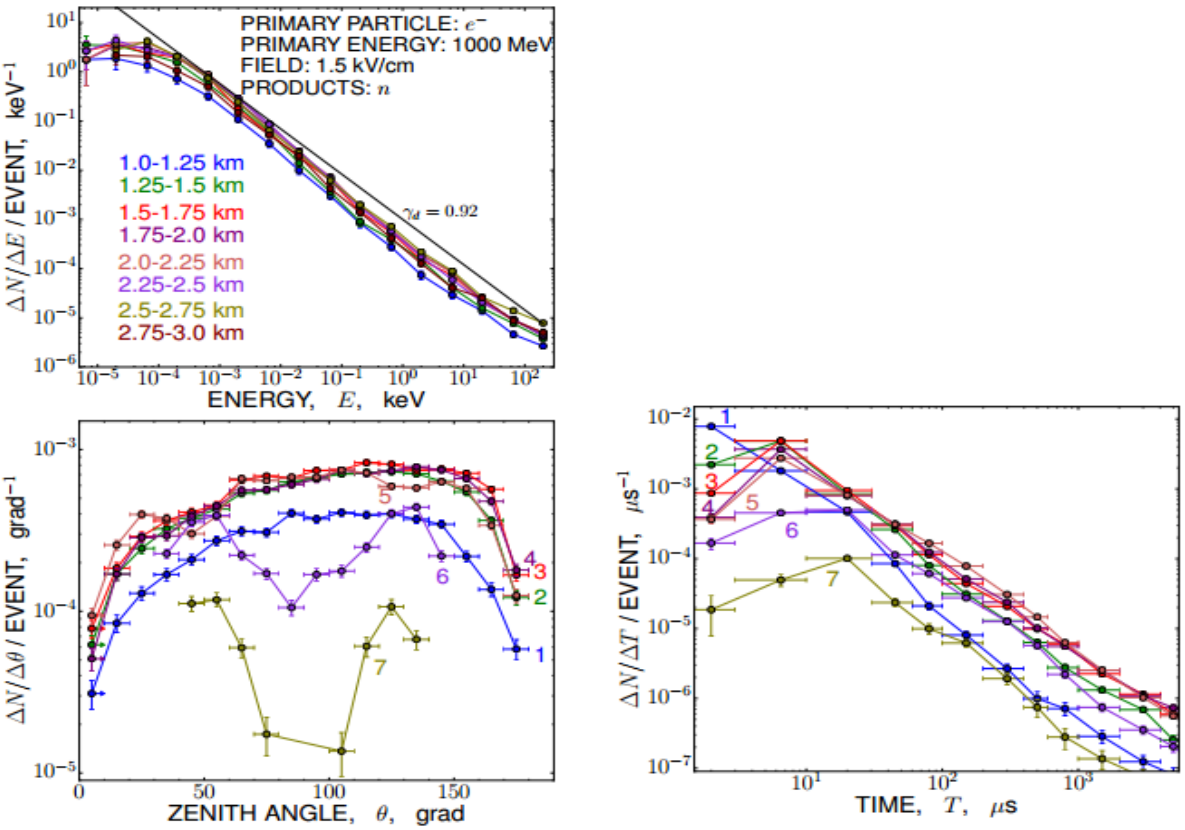


Figure 4 – The simulation results concerning the neutron component. From top to bottom: the differential energy spectra of avalanche neutrons both within and out the region of electric field; the angular and time distributions of the neutrons born by avalanche curves 1 in both plots correspond to the distance range d=0.5–1.0 km from the field center, (curves 2 to the range 1.0-1.5 km, 3 - to 1.5-2.0 km, 4 - to 2.0-2.5 km, 5 - to 2.5-3.0 km, 6 - to 3.0-3.5 km, and 7 - to 3.5-4.0 km)

The distribution of the neutron arrival times at differentobservation distances is shown in bottom plot of figure 4.It is seen that the maximum of neutron signal is achievedat typical times about 1-10 μs after initiation of discharge avalanche. Up to the times of ~30-50 μs the relative decrease of neutron intensity does not exceed an order ofmagnitude, in contrast to electrons and gamma raywhichtend to disappear completely at this time. The neutronintensity remains at noticeable level (above 1% of its initial intensity) until the times of 100-300 μs which is theconsequence of a comparatively long life time of thermal-neutrons in atmosphere. From this, a practical conclusionfollows that any detector system aimed for experimentalregistration of neutrons born in an atmospheric discharge must have a considerable collection time of neutron signals,and the duration of data sampling periods of the order ofsome milliseconds besides the microsecond scale time resolution are desirable. At present time, these requirementsare satisfied in detector design accepted in *Groza* experiment.

It should be stressed that the low time delays ≤10 μsbefore registration of neutron signal at a distance of somekilometers from discharge region predicted by simulationare direct consequence of the accepted mechanism of neutron production, where relativistic particles: the gammarays and high energy electrons play an intermediate role,and can be responsible for the fast neutron origin just invicinity to observation level. In practice, both the momentary and largely delayed (over a time of millisecond order) signals from neutron detectors have been registeredin Tien - Shan experiments [12].

Relative composition of discharge avalanche. The figure 5presents distribution of simulated events over the multiplicity M of different types of secondary product particles generated at avalanche development. For both electromagnetic components$M$was calculated as a sum number of,correspondingly, electrons and gamma ray quanta with theenergy above 30 keV which have been found in simulate-davalanche, for the neutron component the multiplicity was counted without any energy threshold; all distributions arenormalized to a total number of generated avalanche events.

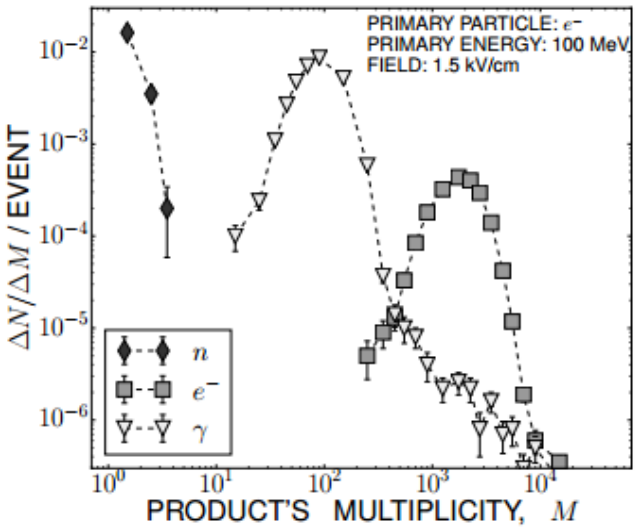


Figure 5 – Probability density functionsofmultiplicity distribution of secondary products in simulated discharge avalanche

In comparison of distribution maxima positions in figure 5 it is seen that electrons do prevail in the avalanche,while the relative intensity of gamma ray flux must be 20-30 times lower. Obviously, the significant abundance difference between electromagnetic components in an avalanche driven by electric field results from acceleration of low-energy electrons, and this is a specific feature ofthis type of atmospheric cascade which principally differs from the cascades of extensive air showers (EAS) initiatedby cosmic ray particles, where a dynamic equilibrium constantly exists between both the electron and gamma raycomponents.

According to figure 5, the multiplicity of neutron signals is quite negligible, about some particles per a simulateddischarge avalanche. Seemingly, this prediction does contradict to existing observations of thunderstorm relatedneutron signal in experiments mentioned above within the introduction section. This discrepancy may be caused by a lack in the used list of physical simulation models ofsome neutron production channel (besides the photo- electronuclear processes) which is significant in the realevents.

A qualitative estimation of the absolute amount of particles participating in a real atmospheric discharge can bedrawn from following considerations. In the frames of hypothesis of a crucial role which play the cosmic ray particles of 10^{14}-10^{16}eV EAS in lightning initiation [22, 23]the multiplicity of primary seed electrons N_e which simultaneously can give a start to development of the multitude of partial avalanches inside the electrically chargedregion of a thundercloud must be of the order of showersize, i.e. $N_e \sim 10^5$-$10^6$for EAS of the said energies [33],and the great part of these particles must have the energy of the order of critical energy of the electromagnetic cascade theory (about 80 MeV in the air).According to figure 2, the particles with the energy of such an order mustgenerate an avalanche practically with 100% probabilitywhen coming into the region of field with the strength about runaway breakdown threshold E_c, so the sum multiplicity of the charged particles participating in dischargemust be of the order of $N_e \times$ hni, where hni is the mean particles number in a partial avalanche. The distributions from figure 5 predict the most probable multiplicities about $\langle n_e \rangle \sim 2000 - 3000$ and $\langle n_\gamma \rangle \sim 100$ correspondingly for electron and gamma ray components in a partialavalanche initiated by a 100 MeV seed particle. After multiplication, the sum multiplicity of discharge electrons occurs being about $\sim 10^9$, and that of the gamma ray quanta $\sim 10^8$. Analogous estimation for neutron component givesthe value about $\sim 10^6$. Because of their roughness and awide scattering of conditions in real thunderstorm events,all these estimations must be taken in the sense of lowerlimit.

Taking into account the tendency to anisotropy of angular distribution which is specific for electromagnetic components, and supposing the area of the emitting thundercloud region to be of the order of 1 km^2 (i.e. $10^{10}cm^2$),the total gamma-radiation flux from discharge area can be estimated as

$I = 10^8/10^{10}\text{cm}^{-2} = 0.01\ \text{cm}^{-2}$, andthis flux as a whole is concentrated spot like in a nearlyvertical direction. In this case, the number of signalsobtained from a gamma ray sensor of *Groza*experimentwhen detecting a discharge related radiation flash must be $n_\gamma \sim I \cdot S/\epsilon$, where $\boldsymbol{S}$ is the detector sensitive area, and ϵ - its registration efficiency. Taking the typical values as $\boldsymbol{S}/\epsilon \sim (300/0.5)\ \text{cm}^2$[31] the resulting amount of detectorpulses n_γ must be about 1-10. This is just the case oftypical experimental measurements like [2] and [3] which have been routinely obtained at Tien Shan station. Hence,in spite of its roughness the result of present estimation is quite reasonable.

Similar estimations concerning neutron component leadto resulting neutron flux about 10^{-5}cm^{-2}at observation level, and to signal multiplicity about $n_n \sim 0.1$ pulses froma neutron detector (for isotropic angular distribution of theneutron avalanche component, and for a typical effectivearea of neutron detector about 1000 cm^2). In reality, bythe measurements with enhanced time resolution the number of neutron signals frequently occurs quite comparablewith that of gamma ray, i.e. of some units or tens of neutron pulses registered from a single atmospheric discharge[12]. This contradiction may be another sign of essentialdiscrepancy between the models of neutron generation accepted at simulation procedure and with what does takeplace in real events.ϵ

Conclusion. The program code for as far as possible complete simulation of the processes of particle acceleration inside a large-scale atmospheric electric field region was createdinthe frames of *Groza* experiment. The program is basedonthe*Geant4* simulation toolkit and takes into account thespecific environmental features of the Tien - Shan mountain station. The simulation results concerning observable parameters of the electromagnetic component of particleavalanche agree well with the data both of theoretical andexperimental studies of avalanche development in atmospheric electric fields. This is an evidence of adequacyofthe set of physical models put into simulation, and gives the reason for using the described program code by furtherquantitative analysis of experimental results.

From the practical point of view, the simulation resultsconcerning an extremely anisotropic angular distributionof the electromagnetic avalanche components, and their limited path by realistic atmospheric conditions mean thatfor effective registration the active region of a thundercloudmust occur just above, and as close as possible to detector system. Also, a large scattering must be expected inpractise between the results obtained even in similar environment at different thunderstorm times. For precise registration of the time profile of excessive electromagneticradiation from an atmospheric discharge the resolution ofdata acquisition system must be at least of the microsecond order.

At the same time, the intensity of neutron flux predictedby simulation seems to be significantly below the existingexperimental data. This can be an indication of eitheran existence in real thunderstorm events of some unaccounted additional channel of neutron generation, besides the mechanisms of photo- and electron production whichhave been included into simulation physics list, or thiscan be a sign of an extremely high influence of electromagnetic interference on electronics of neutron detectorsfrom nearby electric discharges which mask or imitate the real neutron signal.Correspondingly, the design of neutron detector system for the next measurement seasons atTien - Shan now is greatly modified with special attentionpaid to its electromagnetic shielding. On the other hand,the very fact of a possibility to exist for some effective mechanism of neutron generation in natural atmosphericdischarges, besides any intermediate electromagnetic channel, is quite interesting in itself, and this problem remainsopen for further experimental investigations at Tien–Shanstation.

In spite of low intensityprediction whichresultsof simulation, the registration of neutron signal may occurmorepreferable at a distance of some kilometers from theactive thundercloud region than that of the electromagnetic components, due to more uniform angular distribution and prolongedlife time of emitted neutrons. Becauseof latter circumstance, any data acquisition system usedfor neutron registration must have a rather long samplinginterval, at least of the order of some tens of millisecondsafter a primary lightning trigger signal, and a microsecond scale time resolution.

А. Л. Шепетов[1], Т. Х. Садыков[2], К. М. Мукашев[3],
Л. И. Вильданова[4], А. Д. Мурадов[3], О. А. Новолодская[2], М. Е. Алиева[5]

[1]Ресей ғылым академиясы, П. Н. Лебедев ат-ы Физика Институты, Москва, Ресей,
[2]Физика-технологиялық институты, Алматы, Қазақстан,
[3]әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
[4]Ғарыш сәулелерінің Тянь-Шань биік таулы ғылыми станциясы, Алматы, Қазақстан,
[5]Абай атындағы Қазақ ұлттық педагогикалық университеті, Алматы, Қазақстан

GEANT4 ПРОГРАММАСЫ НЕГІЗІНДЕ КҮН КҮРКІРЕУГЕ БАЙЛАНЫСТЫ ТУЫНДАЙТЫН ЭЛЕКТРОН-ФОТОН АҒЫНЫН ЖОБАЛАУ

Аннотация. Тянь-Шань биік таулы кеңістіктігінде орналасқан ғарыштық сәулелердің ғылыми зерттеу станциясының деңгейінде ауқымды электр өрісінде туындайтын электрон-фотон ағынының дамуын моделдеуге арналған Geant4 инструментарилық программа құрылды. Бұл инструментарий Гроза программасы аумағында өндірілген эксперименталдық нәтижелерді талдау және жоспарлау мақсатымен дайындалды. Тасқынды процестің электромагниттік құраушыларын моделдеуге байланысты болжаунәтижелері: электрондық құраушының гамма-сәулелеріне қарағанда салыстырмалы қарқындылығы 30:1 еседей жоғары, олардың энергетикалық спектрлері (30-10000 кэВ аралығында дифференциалдық индексі 1,5–2 дәреже шамасындағы функция), бұрыштық таралуы теориялық және бұған дейін таулы деңгейде өндірілген эксперименталдық нәтижелерге сәйкес келеді. Болжау арқылы табылған гамма-сәулесінің эмиссиясы 10^2 см^2 Тянь-Шань станциясы деңгейінде анықталған тікелей өлшеу нәтижелеріне тұспа-тұс. Сондықтан күннің күркіреуінен туындайтын шынайы құбылыстарды имитациялық модель арқылы болжау нәтижелері шындыққа сәйкес келеді деп санауға негіз бар. Дегенменде, болжау барысында көрсетілген нейтрондар ағыны шамасы жағынан эксперимент нәтижелерінен он шақты есе төмен екендігі байқалды. Оның себебін табиғи атмосфералық разряд кезінде пайда болатын нейтрондардың моделдеу кезінде қолданыс тапқан электромагниттік фотоядролық және электронядролық әсерлесулерден басқа да ескерілмеген механизімінің орын алуымен түсіндіруге болады. Сонымен қатар, моделдеу нәтижелерін негізге алу арқылы биік тау деңгейінде күннің күркіреуіне байланысты туындайтын түрлі сәулелерді зерттеуге қолайлы эксперименталдық қондырғыларды жобалау мәселесі де қарастырылады.

Түйін сөздер: күннің күркіреуі, найзағай, атмосфералық электр, қашқын электрондар, моделдеу, Geant4 жобасы.

А. Л. Шепетов[1], Т. Х. Садыков[2], К. М. Мукашев[3],
Л. И. Вильданова[4], А. Д. Мурадов[3], О. А. Новолодская[2], М. Е. Алиева[5]

[1]Институт физики им. П. Н. Лебедева РАН, Москва, Россия,
[2]Физико-технический институт, Алматы. Казахстан,
[3]Казахский национальный университет им. аль-Фараби, Алматы, Казахстан,
[4]Тянь-Шаньская высокогорная научная станция космических лучей, Алматы, Казахстан,
[5]Казахский национальный педагогический университет им. Абая, Алматы, Казахстан

МОДЕЛИРОВАНИЕ РАЗВИТИЯ ЭЛЕКТРОННО-ФОТОННОЙ ЛАВИНЫ В АТМОСФЕРЕ ОТ ГРОЗОВЫХ ТУЧ С ПОМОЩЬЮ ПРОГРАММЫ GEANT4

Аннотация. На основе инструментария Geant4 была разработана специальная программа для моделирования развития электронно-фотонной лавины в электрическом поле большого размера в типичных условиях окружающей среды Тянь-Шаньской высокогорной научной станции космических лучей. Этот инструментарий предназначен, в частности, для планирования и анализа экспериментальных результатов, полученных в рамках программы Гроза. Основные предсказания моделирования относительно электромагнитных компонентов лавины: относительное превышение интенсивности электронной компоненты над гамма-лучами (30: 1), их энергетические спектры (примерно, форма степенного закона с дифференциальным индексом -1,5-2 в диапазоне 30-10000 кэВ), а анизотропия их угловых распределений находится в хорошем согласии с результатами теоретических и экспериментальных исследований, которые были получены до этого в горных условиях. Прогнозируемое значение эмиссии гамма-излучения порядка 10^2 см^2 на уровне наблюдения также достаточно хорошо соответствует прямым измерениям, выполненным на станции Тянь-Шань. Эти данные подтверждают адекватность используемой имитационной модели для реальных событий

грозы. В то же время предсказанные нами лавинные нейтроны, по-видимому, на порядок недооценены по сравнению с данными соответствующих экспериментальных измерений; такое грубое несоответствие может быть свидетельством существования некоторого эффективного механизма генерации нейтронов в естественных атмосферных разрядах, помимо полностью электромагнитных фотоядерных и электрон-ядерных взаимодействий, которые были применены в моделировании. Обсуждаются требования к проектированию экспериментальных установок, подходящих для изучения грозовых излучений на высоте горы, которые следуют из представленного моделирования.

Ключевые слова: гроза, молния, атмосферное электричество, убегающие электроны, моделирование, программа Geant4.

Information about authors:

Shepetov A.L., P. N. Lebedev Physical Institute of the Russian Academy of Sciences (FIAN), Moscow, Russia; ashep@www.tien-shan.org; https://orcid.org/0000-0002-5521-1855

Sadykov T.Kh., Institute for Physics and Technology, Almaty, Kazakhstan; turlan43@mail.ru; https://orcid.org/0000-0002-4349-4616

Mukashev K.M., Al-Farabi Kazakh national university, Almaty, Kazakhstan; mukashev.kms@gmail.com; https://orcid.org/0000-0002-0516-8983

Vildanova L.I., Tien Shan Mountain Cosmic Ray Station of FIAN, Almaty, Kazakhstan; luvild@mail.ru; https://orcid.org/0000-0001-8558-9026; https://orcid.org/0000-0001-8558-9026

Muradov A.D., Al-Farabi Kazakh national university, Almaty, Kazakhstan; abyl.muradov@gmail.com; https://orcid.org/0000-0002-7052-8228

Novolodskaya O.A., Institute for Physics and Technology, Almaty, Kazakhstan; novololga@yandex.ru; https://orcid.org/0000-0002-1978-2781

Alieva M.E., Abai Kazakh national pedagogical university, Almaty, Kazakhstan; moldir-2008@mail.ru; https://orcid.org/0000-0003-0440-6211

REFERENCES

[1] Chubenko A.P., Antonova V.P., Kryukov S.V., Piscal V.V., Ptitsyn M.O., Shepetov A.L., Vildanova L.I., Zybin K.P., Gurevich A.V. (2000) Intensive X-ray emission bursts during thunderstorms // Phys. Lett. A 275, 90–100. doi:10.1016/S0375-9601(00)00502-8.

[2] Chubenko A., Karashtin A., Ryabov V., Shepetov A., Antonova V., Kryukov S., Mitko G., Naumov A., Pavlyuchenko V., Ptitsyn M., Shalamova S., Shlyugaev Y., Vildanova L., Zybin K., Gurevich A. (2009) Energy spectrum oflightning gamma emission // Phys. Lett. A 373 (39).

2953–2958. doi:10.1016/j.physleta.2009.06.031.

[3] Gurevich A., Chubenko A., Karashtin A., Mitko G., Naumov A., Ptitsyn M., Ryabov V., Shepetov A., Shlyugaev Y., Vildanova L., Zybin K. (2011) Gamma-ray emission from thunderstorm discharges // Phys. Lett. A 375 (15) 1619–1625. doi:10.1016/j.physleta. 03.005.

[4] Chubenko A.P., Amurina I.V., Antonova V.P., Kryukov S.V., Mukhashev K.M., Nam R.A., Nesterova N.M., Oskomov V.V., Piscal V.V., Ptitsyn M.O., Sadykov T.K., Shepetov A.L., Vildanova L.I., Zybin K.P., Gurevich A.V. (2003) Effective-growth of a number of cosmic ray electrons inside thundercloud // Phys. Lett. A 309, 90–102. doi:10.1016/S0375-9601(03)00062-8.

[5] AntonovaV.P., Vildanova L.I., Gurevich A.V., Zybin K.P., Karashtin A.N., Kryukov S.V., Ryabov V.A., Ptitsyn M.O., Chubenko A.P., Shlyugaev Y.V., Schepetov A.L. (2009) Influence ofcosmic rays and the runaway-electron breakdowns on thunderstorm processes in the atmosphere // Radiophys. Quantum Electron. 52 (9), 627–640. doi:10.1007/s11141-010-9172-5.

[6] Gurevich A.V., Karashtin A.N., Chubenko A.P., Duncan L.M., Ryabov V.A., Shepetov A.L., Antonova V.P., Kryukov S.V., Piscal V.V., Ptitsyn M.O., Shlyugaev Y.V., Zybin K.P. (2004) Experimental evidence of giant electron-gamma bursts generated by extensive atmospheric showers in thunderclouds // Phys. Lett. A 325, 389–402. doi:10.1016/j.physleta.2004.03.074.

[7] Gurevich A., Karashtin A. (2013) Runaway breakdown and hydrometeors in lightning initiation // Phys. Rev. Lett. 110, 185005. doi:10.1103/PhysRevLett.110.185005.

[8] Gurevich A., Antonova V., Chubenko A., Karashtin A., Mitko G., Ptitsyn M., Ryabov V., Shepetov A., Shlyugaev Y., Thu W., Vildanova L., Zybin K. (2013) Correlation of radioand gamma emissions in lightning initiation // Phys. Rev. Lett. 111, 165001. doi:10.1103/PhysRevLett.108.125001.

[9] Gurevich A.V., Mitko G.G., Antonova V., Chubenko A.P., Karashtin A.N., Kryukov S.V., Naumov A.S., Pavljuchenko V.P., Ptitsyn M.O., Ryabov V.A., Shalamova S.Y., Shepetov A.L., Shlyugaev Y.V., Vildanova L.I., Zybin K.P. (2009) An intracloud discharge caused by extensive atmospheric shower // Phys. Lett. A 373 (39), 3550–3553. doi::10.1016/j.physleta.2009.07.085.

[10] Gurevich A.V., Karashtin A.N., Ryabov V.A.., Chubenko A.P., Shepetov A.L. (2009) Nonlinear phenomena in the ionospheric plasma. Effects of cosmic rays and runaway breakdown on thunderstorm discharges // Phys.-Uspekhi 52 (7), 735–745. doi:10.3367/UFNe.0179.200907h.0779.

[11] Gurevich A., Antonova V., Chubenko A., Karashtin A., Mitko G., Ptitsyn M., Ryabov V., Shepetov A., Shlyugaev Y., Vildanova L., Zybin K. (2012) Strong flux of low-energy neutrons produced by thunderstorm // Phys. Rev. Lett. 108, 125001–4.doi:10.1103/PhysRevLett.108.125001.

[12] Gurevich A., Antonova V., Chubenko A., Karashtin A., Kryakunova O., Lutsenko V., Mitko G., Piscal V., Ptitsyn M., Ryabov V., Shepetov A., Shlyugaev Y., Thu W., Vildanova L., Zybin K. (2015)The time structure of neutron emission during atmospheric discharge // Atmospheric Res. 164-165, 339–346.doi:10.1016/j.atmosres.2015.06.004.

[13] Chilingarian A., Daryan A., Arakelyan K., Hovhannisyan A., Mailyan B., Melkumyan L., Hovsepyan G., Chilingaryan S., Reymers A., Vanyan L. (2010) Ground-based observations of thunderstorm-correlated fluxes of high-energy electrons, gammarays, and neutrons // Phys. Rev. D 82 (8), 043009.

[14] Chilingarian A., Bostanjyan N., Vanyan L. (2012) Neutron bursts associated with thunderstorms // Phys. Rev. D 85, 085017.

[15] Carson B.E., Lehtinen N.G., Inan U.S. (2010) Neutron production in terrestrial gamma ray flashes // J. Geophys. Res. 115 (4), A00E19.

[16] Shyam A., Kaushik T.C. (1999) Observation of neutron bursts associated with atmospheric lightning discharge // J. Geophys. Res.104, 6867–6870. doi:10.1029/98JA02683.

[17] Tsuchiya H., Hibino K., Kawata K., Hotta N., Tateyama N., Ohnishi M., Takita M., Chen D., Huang J., Miyasaka M., Kondo I., Takahashi E., Shimoda S., Yamada Y., Lu H., Zhang J., Yu X., Tan Y., Nie S., Munakata K., Enoto T., Makishima K. (2012) Observation of thundercloud-related gammarays and neutrons in Tibet // Phys. Rev. D 85, 092006.

[18] Kozlov V.I., Mullayarov V.A., Starodubtsev S.A., Toropov A.A. Recording neutrons with 10-μs resolution during a thunderstorm in Yakutsk // Bull. Russ. Acad. Sci. Phys. 79 (2015) 685–687. doi:10.3103/S1062873815050275.

[19] Geant4 Collaboration, Geant4 – a simulation toolkit (2003) // Nucl. Instrum. Methods A 506 (3) 250–303. doi:10.1016/S0168-9002(03)01368-8.

[20] MacGorman D.R., Rust W.D. (1998) The Electrical Nature of Storms. New York: Oxford Univ. Press.

[21] Chilingarian A., Hovsepyan G., Hovhannisyan A. (2011) Particlebursts from thunderclouds: Natural particle accelerators aboveour heads // Phys. Rev. D 83 (3), 062001–11. doi:10.1103/ 675PhysRevD.83.062001.

[22] Gurevich A.V., Zybin K.P., Roussel R.A. (1999) Dupr´e, Light ninginitiation by simultaneous effect of runaway breakdown and cosmic ray showers // Phys. Lett. A 254 (1–2), 79–87.

[23] Ermakov V.I. (1992) Lightning initiation by galaxy cosmic rays // Proceedings of the 9th Int. Conf. on Atmospheric Electricity, St-Petersburg, Russia. P. 485–488.

[24] Geant4 Collaboration, Geant4 User's Guide for Application Developers. Version: geant4 10.2 (2015). URL http://geant4.web.cern.ch/geant4/ UserDocumentation/UsersGuides/ForApplicationDeveloper/fo/BookForAppliDev.pdf

[25] Geant4 Collaboration, Physics Reference Manual. Version:geant4 10.2 (2015). URL http://geant4.web.cern.ch/geant4/ UserDocumentation/UsersGuides/PhysicsReferenceManual/fo/PhysicsReferenceManual.pdf.

[26] Gurevich A.V., Milikh G.A., Roussel R. (1992) Dupr´e, Runaway electrons mechanism of the air breakdown and preconditioning during thunderstorm // Phys. Lett. A 165, 463.

[27] Gurevich A.V., Roussel R. (1996) Dupr´e, On runaway breakdown and upward propagating discharges // J. Geophys. Res. 101 (A2),2297–2311. doi:10.1029/95JA03278.

[28] Gurevich A.V., Zybin K.P. (2001) Runaway breakdown and electric discharges in thunderstorms // Physics-Uspekhi 44 (11), 1119–1140. doi:10.1070/PU2001v044n11ABEH000939.

[29] Marshall T., McCarthy M., Rust W. (1995) Electric field magnitude sand lightning initiation in thunderstorms // J. Geophys. Res.D100, 7097–7103. doi:10.1029/95JD00020.

[30] Marshall T., Rison W., Rust W., Stolzenburg H., Willett J., Winn W. (1995) Rocket and balloon observations of electric field in two thunderstorms // J. Geophys. Res. D100, 20.815–20828.doi:10.1029/95JD01877.

[31] Gurevich A., Almenova A., Antonova V., Chubenko A., Karashtin A., Kryakunova O., Lutsenko V., Mitko G., Piscal V., Ptitsyn M., Ryabov V., Salikhov N., Shepetov A., Shlyugaev Y., Thu W., Vildanova L., Zastrozhnova N., Zybin K. (2016) Observations of high-energy radiation during thunderstorms at Tien-Shan // Phys. Rev. D 94, 023003–9. doi:10.1103/Phys.RevD.94. 023003.

[32] Buitink S., Huege T., Falcke H., Heck D., Kuijpers J. (2009) Monte Carlo simulations of air showers in atmospheric electric fields // Astropart. Phys. 33 (1), 24. doi:10.1016/j.astropartphys.2009.10.006.

[33] Chilingarian A., Gharagyozyan G., Ghazaryan S., Hovsepyan G., Mamidjanyan E., Melkumyan L., Romakhin V., Vardanyan A., Sokhoyan S. (2007) Study of extensive air showers and primary energy spectra by MAKET-ANI detector on mountain Aragats // Astropart. Phys. 28, 58–71. doi:10.1016j.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 51 – 56 **https://doi.org/10.32014/2019.2518-170X.5**

UDC

I. Zh. Zhanashev[1], R. K. Nauryzbayev[1], E. T. Saparbayev[1], S. M. Abikenova[1], K. K. Anuarbekov[1], O. O. Polushkin[2]

[1]Kazakh National Agrarian University, Almaty, Kazakhstan,
[2]Don State Technical University, Rostov-on-Don, Russia.
E-mail: izhanashev@mail.ru, yerjigit1966@mail.ru, salta_84@inbox.ru, kanat.anuarbekov@kaznau.kz, o.polushkin@gmail.com

STRUCTURAL–NON-ASSURING GROUP WITHIN THE KINEMATIC CHAIN OF SELF-ALIGNING SPATIAL THREE-LINK CAM MECHANISMS

Abstract. The degree of mobility specified new three-link assuring and four-link nonassuring structural self-aligning spatial cam mechanism is defined under the new formula. The named formula easily defines a construction principle of the given mechanisms.

Key words: non-assuring, three-link, four-link, assuring, self-aligning.

Introduction. Scientific problem: "Building a harmonious theory of structural synthesis, defining clear boundaries of assuring and nonassuring structures, creating fundamentally new, statically definable - self-aligning spatial cam mechanisms, designing and implementing promising and innovative technical solutions of actuators with rational parameters within drives of various working bodies of agricultural machines, and also machines of other branches of production " [1, 2].

Relevance. Structural analysis and synthesis are the initial, early and most crucial phases in the development of fundamentally new, statically definable - self-aligning spatial cam mechanisms without hazardous redundant links and unnecessary mobility. The problem tasks of the development of structural synthesis methods for self-aligning spatial cam mechanisms are important in the theory of mechanisms not only from a scientific point of view, but also of great practical importance in improving the technical level and operational qualities of various engineering sectors. The introduction of self-aligning spatial cam mechanisms in engineering practice is very effective. The latter will significantly improve operational reliability based on the proposed actuators. Currently in machinery, inter alia: agricultural one urgently needs to use fundamentally new, statically definable - self-aligning actuators [1-7]. These requirements are best satisfied by self-aligning spatial cam mechanisms. They have a sufficiently large load capacity, durability, high efficiency, lower requirements for accuracy of manufacturing. Ways of further development of the fundamentals of rational design of spatial cam mechanisms and the creation of an innovatively new class of general-purpose machines based on self-aligning spatial cam mechanisms of assuring and nonassuring structures are relevant [8, 9].

The objects of research are fundamentally new self-aligning spatial cam mechanisms of the zero family, according to the classical classification of mechanisms by families, proposed by I.I. Artobolevskiy Academician of the USSR SA. Self-aligning - statically definable spatial cam mechanisms with rigid chains and solid kinematic pairs and of general functionality purpose are technological in manufacturing.

The theoretical development of rational design of self-aligning spatial three-link cam mechanisms is based on the further development of the classical approaches of the theory of mechanisms – the fundamental pillars of the structural theory of mechanisms and machines. Development of the proposed universal engineering methods for rational design of self-aligning spatial three-link cam mechanisms is

very important not only from a scientific point of view, but also of great practical importance - they open up a new scientific direction of research work, provide broad prospects for the design and scientific development of their unified theory of structure, kinematics and dynamics.

Methods. The idea of developing the proposed engineering methodology is extremely important in theoretical, practical and engineering activity of bachelor, master and doctor (PhD) engineers in creating the most common methods of structural, kinematic and dynamic research of nonassuring self-aligning spatial three-link cam mechanisms. The new structural feature is a structural group and will serve as the basis for the development of the theory of the kinematic chains of self-aligning spatial three-link cam mechanisms of non-assuring structure of construction. In creating a harmonious theory of synthesizing chains of self-aligning spatial nonassuring groups, the NRK will serve as a mathematical tool - a single key structural formula of the modern theory of mechanisms and machines of Professor R. K. Nauryzbayev.

This formula has the following entry:

$$\begin{cases} W = m(n + n_1 + n_2 - 1) - \sum_{k=1}^{k=m-1} (m-k)\, p_k, \\ m = 6,5,4,3,2. \end{cases} \tag{1}$$

"A nonassuring structural group is such a single-link kinematic chain, which, when attached by the outer free elements of pairs to a rack, will have a zero degree of mobility, i.e. turns into a rigid, self-aligning (statically definable) spatial fixed mechanical system". /Dr. of Technical Sciences, Professor R.K. Nauryzbaev, 2001/.

The elementary group is a non-assuring group (figure 1) single-link with the number of moving links. Its degree of freedom equals to zero. The condition of group structural synthesis is determined by a system of algorithms of the following form:

$$\begin{cases} W_{II(n)} = 6n - 5P_1 - 4P_2 - 3P_3 - 2P_4 - P_5 = 0, \\ n = 1, \\ P_1 = 1, \\ P_2 = 1,\ P_3 = 0,\ P_4 = 0, \\ P_5 = 1, \\ m = 6, \\ (n + n_2 - 1) = 0. \end{cases} \tag{2}$$

The formula for the structure of a group is that a non-assuring structural group is defined with an entry of the following form:

$$-II(n). \tag{3}$$

The class of a group – a nonassuring structural group – is determined by the number of kinematic pairs with which the group joins the rack.

The order of a group – a nonassuring structural group – is determined by the number of kinematic pairs with which the group joins the rack. For example, a space group – a nonassuring one-link group (figure 1) belongs to the zero family according to the general classification of kinematic chains of zero mobility, according to the rank recognized by the structural group, according to the families of Academician of the Academy of Sciences of the USSR, Doctor of Technical Sciences, Professor I.I. Artobolevskiy, (m = 6). The new concept structural group is a nonassuring group in the kinematic chain of a self-aligning spatial three-link cam mechanism of IInd class of the zero-family (figure 1). This is a very important structural feature from the position of the modern theory of mechanisms and machines. Thus, a spatial group is a nonassuring structural group in the chain of the cam mechanism (figure 1), this is a

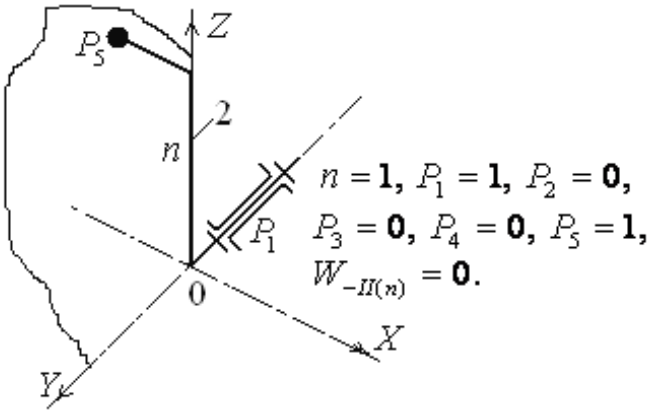


Figure 1 – The single-link structural group is a non-assuring structural group of the 2nd class and the zero family of the 2nd order

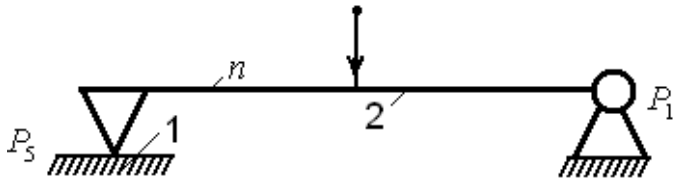


Figure 2 – Zero degree of mobility is a rigid self-aligning (statically definable) fixed spatial mechanical system

Table 1 – Fundamental classification of kinematic pairs of A.P. Malyshev in 1923

No. of class of kinematic pair	I	II	III	IV	V
S – No. of superimposed connections of kinematic pair	1.	2.	3.	4.	5.
$W_{kin.p.}$ – No. of degrees of freedom of kinematic pair	5	4	3	2	1

single link kinematic chain, which, after connecting the pair to the rack with the outer free elements, will have a zero degree of mobility, i.e. turns into a rigid statically definable spatial mechanical system (figure 2). In numerous constructive varieties of a single link kinematic chain (figure 1) almost all types of kinematic pairs may be present according to the classification of Doctor of Technical Sciences, Professor A.P. Malyshev.

The fundamental classification of kinematic pairs in the form of table 1 was first developed by A.P. Malyshev in 1923. In the system of algorithms (2) - the condition of the structural synthesis of the group, the indices of kinematic pairs correspond to the degrees of freedom of this pair construction. In accordance with the table in the system of algorithms (2) the number of superimposed connections - (S) corresponds to - (№) class of each kinematic pair. Kinematic pairs are of Ist, IInd, IIIrd, IVth, Vth class.

Cam mechanism is the base of the chain of which is single-link group, is a nonassuring structural group, which called a self-aligning (statically definable) spatial three-link cam mechanism of a nonassuring structure of the construction - figure 3.

Self-aligning i.e. statically definable. 1-leading link (cam), modeled by the parameter (n_1) - 2-slave link (rocker) is modeled by the parameter (n) - 3-rack (bed).

A new principle of formation (of logical formation) of self-aligning (statically definable) spatial three-link cam mechanisms of nonassuring structure consists in joining the driving link – to the mechanism of the Ist class and the rack - of nonassuring structural groups. The formula for the structure of the mechanism (figure 3) will be written as a record of the form:

$$I\ (1,3) \longrightarrow II\ (2) \tag{4}$$

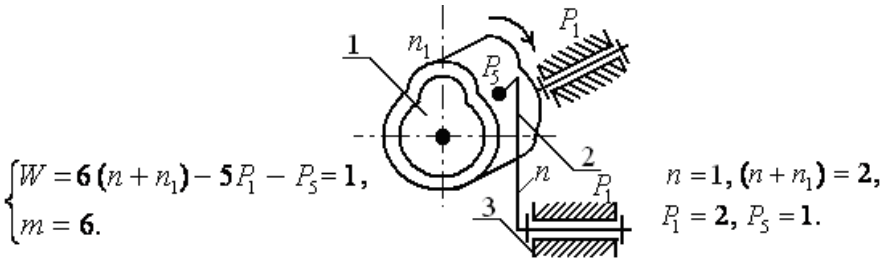


Figure 3 – The self-aligning (statically definable) spatial,
three-link cam mechanism of a nonassuring structure of the II[nd] class and of the zero family.

$$m = 6,\ (n+n_1) = 2,\ P_1 = 2,\ P_5 = 1.$$

From the formula (4) of the structure of the three-link spatial cam mechanism the following is obvious:

- *I* (1.3) there is a formula for the structure of the mechanism of class I, cam 1 with a pair of P_1 with a rack 3. *II* (2) - there is a space group of the NRK - nonassuring one-link self-aligning (statically definable) group of the 1[st] class and zero family, 2[nd] order – link of 2 models - with pairs P_1 and P_5 (figure 1).

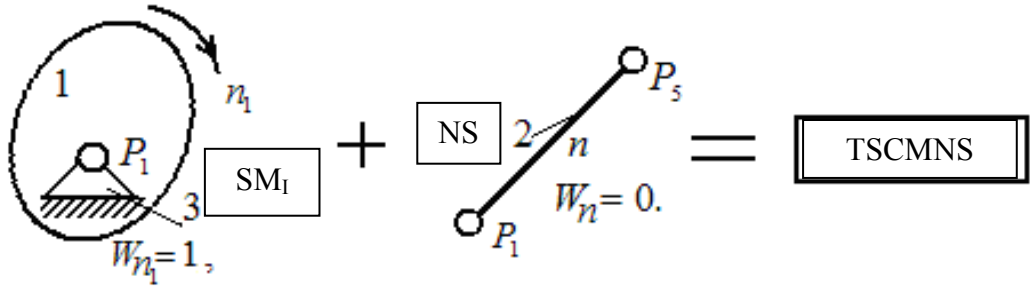


Figure 4 – TSCMNS development

SM1 - self-aligning two-link, leading cam mechanism of I[st] - class with the number of degrees of freedom W = 1. This mechanism consists of a leading link 1-(n1) and a rack 3. The number of degrees of freedom of a mechanism of I[st] class is determined by following formula:

$$W_{n_1} = 6n_1 - 5P_1 = 6 \cdot 1 - 5 \cdot 1 = 1. \tag{5}$$

NSG - space group - nonassuring structural group, link 2-kinematic chain from one link (n = 1). The number of degrees of freedom of the spatial group – NSG – of the nonassuring structural group is determined, for example, by the following formula:

$$W_n = 6n - 5P_1 - P_5 = 6 \cdot 1 - 5 \cdot 1 - 1 = 1. \tag{6}$$

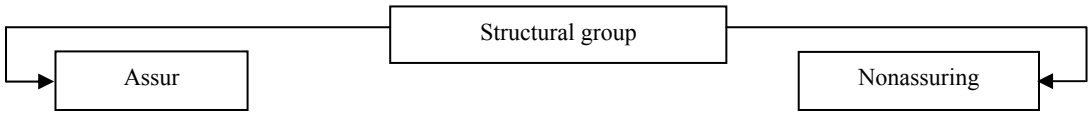
TSCMNS - three-link self-aligning cam mechanism of nonassuring structure. Note that in the development of the classical structural formula (6) of P.O. Somov - A.P. Malyshev has the following form of record [1-3]:

$$\begin{cases} W = 6(n + n_1 + n_2 - 1) - 5P_1 - 4P_2 - 3P_3 - 2P_4 - P_5, \\ m = 6. \end{cases} \tag{7}$$

P.O. Somov (1887) – A.P. Malyshev (1923) – R.K. Nauryzbaev (1991).

Results. Let us highlight some of the fundamental differences between the classical-elementary Assur group and the nonassuring group, a single-link structural group.

Table 2 – Differences between Assur and nonassuring group:

1. The elementary Assur group is two-link with the number of moving links $(n + n_1) = 2$ (see figure 5). 2. The Assur group cannot be divided into simpler independent kinematic chains of zero mobility. 3. Classically, the principle of the formation of self-aligning four-link cam mechanisms is attached to the drive link and the rack of assuring groups of two moving links. 4. Elementary mechanisms of Assur - four-link cam mechanisms, self-aligning flat and spatial.	1. The elementary nonassuring group is one-link with the number of moving links $n = 1$ (see figure 1). 2. When joining the leading link and the rack of a nonassuring group, three-link cam mechanisms do not fit into the framework of Assur classical structural theory. 3. The new principle of formation on the basis of nonassuring groups allows to synthesize nonassuring mechanisms with different design and functional capabilities, in particular, three-link cam mechanisms with self-aligning features of the structure (figure 6).
	
Classic structural attriburte in kinematic chain of self-aligning cam mechanisms.	New structural attribute in kinematic chain of self-aligning cam mechanisms.

И. Ж. Жанашев[1], Р. К. Наурызбаев[1], Е. Т. Сапарбаев[1],
С. М. Абикенова[1], К. К. Ануарбеков[1], О. О. Полушкин[2]

[1]Қазақ ұлттық аграрлық университеті, Алматы, Қазақстан,
[2]Дон мемлекеттік техникалық университеті, Ростов-на-Дону, Ресей

ҮШ ЗВЕНОЛЫ АССУРЛЫҚ ЕМЕС ҚҰРЫЛЫМДЫҚ ӨЗІҚАЛЫПТАСҚЫШ КЕҢІСТІК ЖҰДЫРЫҚШАЛЫ МЕХАНИЗМДЕР

Аннотация. Жұмыста көрсетілген жаңалық үш звенолы ассурлық емес және төртзвенолы ассур құрылымдық өзіқалыптасқыш кеңістік жұдырықшалы механизмдердің еркіндік дәреже сандары тек жаңа құрылымдық формуламен анықталады. Келтірілген формуланың көмегімен үшзвенолы және төртзвенолы ассурлық және ассурлық емес механизмдердің құрылғылық принциптері оңай шешіледі.

Түйін сөздер: ассурлық емес, үшзвенолы ассур, төртзвенолы ассур, ассурлық, жұдырықшалы механизм.

И. Ж. Жанашев[1], Р. К. Наурызбаев[1], Е. Т. Сапарбаев[1],
С. М. Абикенова[1], К. К. Ануарбеков[1], О. О. Полушкин[2]

[1]Казахский национальный аграрный университет, Алматы, Казахстан,
[2]Донской государственный технический университет, Ростов-на-Дону, Россия

СТРУКТУРНАЯ–НЕАССУРОВАЯ ГРУППА В СОСТАВЕ КИНЕМАТИЧЕСКОЙ ЦЕПИ САМОУСТАНАВЛИВАЮЩИХСЯ ПРОСТРАНСТВЕННЫХ ТРЕХЗВЕННЫХ КУЛАЧКОВЫХ МЕХАНИЗМОВ

Аннотация. В статье структурная–неассуровая группа в составе кинематической цепи самоустанавливающихся пространственных трехзвенных кулачковых механизмов определен под новой формулой. Названная формула легко определяет принципиальное строительство данных механизмов.

Ключевые слова: ассуровых и неассуровых конструкции, кулачковый механизм, трехзвенный, четырехзвенный.

Information about authors:

Isabek Zhanashev, Candidate of Technical Sciences, Professor of the Department of "Mechanics and design of agricultural equipment", Kazakh National Agrarian University, Almaty, Kazakhstan; izhanashev@mail.ru; https://orcid.org/0000-0003-2412-0261

Rakhymzhan Nauryzbayev, Doctor of Technical Sciences, Professor of the Department of "Mechanics and design of agricultural equipment", Kazakh National Agrarian University, Almaty, Kazakhstan; izhanashev@mail.ru; https://orcid.org/0000-0002-1561-5994

Yerzhigit Saparbayev, senior lecturer of the Department of “Mechanics and design of agricultural equipment”, Kazakh National Agrarian University, Almaty, Kazakhstan; yerjigit1966@mail.ru; https://orcid.org/0000-0001-7167-1571

Saltanat Abikenova, PhD doctor, senior lecturer of the Department of “Water resources and melioration”, Kazakh National Agrarian University, Almaty, Kazakhstan; salta_84@inbox.ru; https://orcid.org/0000-0001-7786-741X

Kanat Anuarbekov, PhD doctor, senior lecturer of the Department of “Water resources and melioration”, Kazakh National Agrarian University, Almaty, Kazakhstan; kanat.anuarbekov@kaznau.kz; https://orcid.org/0000-0003-0832-6980

Oleg Polushkin, Doctor of Technical Sciences, Professor, Director of Scientific Laboratory, Rostov-on-Don, Russia; o.polushkin@gmail.com; https://orcid.org/0000-0002-8046-917X

REFERENCES

[1] Nauryzbaev R.K. Analysis, synthesis and development of self-aligning hinged - pivotal mechanisms with flexible connections: Diss. Doctor of Technical Sciences. Almaty, 1993. 484 p. (spec. 05.02.18 - Theory of mechanisms and machines).

[2] Nauryzbaev R.K., et al. Theory of self-aligning kinematic chains of spatial actuators: Monograph. Almaty: “Tauar” IA of Sciences RoK., 2000. 494 p. MES RoK.

[3] Nauryzbaev R.K. The concept of a scientist to solve the problem of creating a common structural theory of self-aligning spatial mechanisms. Alma-Ata: KazAI , 1991. P. 1-17.

[4] Nauryzbaev R.K., Zhanashev I.Zh. Actual problems of synthesis of self-installing spatial cam mechanisms. Proceedings of the V International Scientific Conference of the Russian Federation, "Problems of Mechanics of Modern Machines" Ulan-Ude ed. VSTU, 2012. P. 100-103.

[5] Nauryzbaev R.K., Zhanashev I.Zh. New self-aligning spatial assuring and nonassuring cam mechanisms. Boundaries of the theory of their synthesis: Monograph. ed., Dulat. Almaty, 2014. 280 p.

[6] Nauryzbaev R.K., Zhanashev I.Zh. Self-adjusting spatial three-link cam mechanisms of nonassuring structure // Proceedings of the VIIth International Scientific Conference of the Russian Federation, "Problems of Mechanics of Modern Machines" Ulan-Ude ed. EESTU, 2018. P. 60-64.

[7] Nauryzbaev R.K., Zhanashev I.Zh. The general model of the synthesis of self-aligning spatial cam mechanisms // Proceedings of the International Scientific Conference "Innovative Technologies in Science and Education, (ITSE-2018)" ed. DSTU, 2018, Rostov-on-Don. P. 94-96.

[8] Anuarbekov K.K., Aldiyarova A.E., Zubairov O.Z., Mengdibayeva G.Zh., Radzevicius A., Burketbayeva A.N. Water-saving technology of irrigation of corn // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. ISSN 2224-5278. Vol. 2, N 428 (2018), 149-155. https://doi.org/10.32014/2018.2518-170X

[9] Mekhtiyev A.D., Yurchenko A.V., Bulatbayev F.N., Neshina Y.G., Alkina A.D. Theoretical bases of increase of efficiency of restoration of the worn out hinged joints of mine hoisting machine // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. ISSN 2224-5278. Vol. 5, N 431(2018), 66-75. https://doi.org/10.32014/2018.2518-170X.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 57 – 62 **https://doi.org/10.32014/2019.2518-170X.6**

UDC 502/504

G. A. Sainova[1], A. D. Akbasova[1], G. G. Abdikarim[1], N. A. Kalieva[1], Ali Ozler Mehmet[2]

[1]International Kazakh-Turkish University named after Khoja Ahmed Yasawi, Turkistan, Kazakhstan,
[2]Mugla Sitki Kochman University, Mugla, Turkey.
E-mail: ecolog_kz@mail.ru

ENVIRONMENTAL MONITORING ON THE LANDFILL OF SOLID DOMESTIC WASTES OF THE TOWN KENTAU

Abstract. The article presents the results of an analysis of environmental problems arising from the disposal and operation of solid domestic waste landfills. The most important of them can be a negative impact of landfill on the state of environmental medium in the area of its location. The result of this impact is the degradation of the existing ecosystem, namely soils, groundwater, atmospheric air, vegetation. Pollution of environment can hurt the life of biological resources, including human resources.

The results of experimental studies have been presented on the qualitative and quantitative composition of greenhouse gases (methane, carbon dioxide) and other toxic gaseous substances (nitrogen dioxide, nitric oxide, soot, sulfurous anhydride, carbon monoxide, formaldehyde, hydrogen sulfide, ammonia, xylene, toluene, ethylbenzene) released to the atmosphere from the landfill surface of the town Kentau . Based on the experimental measurement of the landfill territory, it was determined that there is no radiation pollution above the maximum permissible level. An average morphological composition of solid domestic waste is identified. A significant part of the fractional components of SDW is represented by a wide variety of organic and synthetic materials. Ashes (46%), manure (20%), bones of domestic animals (11%), paper and textiles (6%) are considered as basic fractional groups.

A conclusion is made on the expediency of regular environmental monitoring for taking measures to protect the environment and the rational use of valuable components of waste as secondary raw materials.

Key words: landfill, sanitary protection zone, solid domestic waste, monitoring, greenhouse gases, biogas.

The actuality of the problem. Waste is a source of pollution of atmospheric air, ground and surface waters, soils and vegetation [1-3]. Initially, the solution of waste problem was mainly in their destruction-burial in the upper layers of the geosphere or burning, but with increase of environmental pollution more environmentally acceptable measures for disposal of waste – their sorting and reuse came to the fore, in other words recycling as well as using low-waste technologies [4]. When harmful impact on the environment does not exceed the level permitted by sanitary and hygienic norms is considered as low-waste production, while a part of raw materials and materials are passed to waste which are sent for processing or disposal. waste minimization in various industries can be achieved with the following ways: improvement of technological processes towards reducing the amount of waste generated; waste recycling, preferably in the process of their generation, processing of waste into useful by-products; decrease in volumes and toxicity of waste to facilitate subsequent disposal and processing [5, 6].

In accordance with the Environmental Code of the Republic of Kazakhstan, individuals and legal entities that generate waste in the course of their economic activities are obliged to provide for safe handling measures, to comply with environmental and sanitary and epidemiological requirements and to carry out measures for their disposal, decontamination and safe disposal [7]. Removal of solid domestic waste ensures sanitation of cities and provides necessary sanitary and ecological conditions for the existence of the settlement.

At the present time the most common facilities for decontamination of removed SDW from the town are their storage at specially equipped landfills [8].

Landfills are a complex of nature conservation facilities designated for SDW storing, isolating and decontamination, providing protection from pollution of the atmosphere, soil, surface and groundwater, preventing the spread of rodents, insects and causative organisms of disease.

The objective of this work is conduction of environmental monitoring over environmental components in the area of influence of the landfill of Kentau town.

Objects and methods of research. The object of our research is a state of the Kentau town landfill (area 33.0 ha) and determination of action spectrum on the natural environment. It is designed for receiving and burial of solid domestic waste generated from residential, industrial, commercial, public, etc. buildings in Kentau. The storage area is the main structure of the landfill. It occupies about 85-95% of the landfill area.

The nearest settlements are Khanatagi and Kentau located at 6 km and 3 km, respectively to the western direction of the landfill. In geological consideration, the location area is composed by Upper Quaternary sediments of the left bank floodplain terrace of the Hanatagi River. The soil is represented by brownish-brown loams with plant roots and light yellow loam with a high content of crushed stone.

The capacity of SDW landfill is 1251152 m^3, expected useful life is 20 years. SDW landfill has been operating since 2010. The service life of landfill is 15 years. The standard of waste disposal for the years of 2018-2020 is fixed in the volume of 20643,412 tons in 2018; 20643,412 tons in 2019, 20134.3966 tons in 2020. At the same time, the capacity of landfill is 1111490m^3 (646,000 tons). All wastes belong to the green hazard level with code GO060. According to the sanitary and epidemiological rules and norms approved by Government decree of the Republic of Kazakhstan on January 17, 2012 No. 93, the sanitary protection zone (SPZ) of landfill is 1000 m, and I hazard class.

The following main types of work are performed at the site: reception, storage and isolation of SDW.

Reception of solid domestic waste is done:

- in a packless state (i.e. in the same physical state, in which the waste comes from the population and organizations), the average density is 190-200kg / m^3;
- in a packed state: when compacted by garbage truck equipped with compaction mechanisms, the average density is 500 kg/m^3, and sometimes it reaches upto780 kg/m^3.

The intermediate and final isolation of the compacted layer of SDW is carried out by the soil. When storing SDW on open, non-deep plots, an intermediate isolation in the warm season is carried out on a daily basis, in the cold season - with an interval of no more than three days. The layer of intermediate insulation is 0.25 m. In winter, a construction waste, waste products (lime, chalk, soda, gypsum, etc.) are used as an insulating material.

The following parameters and pollutants have been determined for air pollution sources:

- environment and gas temperature;
- barometric pressure and pressure of gas-dust flows;
- geometric characteristics;
- nitrogen dioxide, nitrogen oxide, carbon black, sulfurous anhydride, carbon monoxide, formaldehyde, hydrogen sulphide, kerosene, ammonia, methane, xylene, methylbenzene (toluene), ethylbenzene.

To assess the amount of greenhouse gases emitted into the atmosphere by a SDW dump, trap caps have been installed on its surface near the wells to collect methane and carbon dioxide (metal cubes with screwed nipples).

When determining the concentration of pollutants, the well-known normative documents [9-13] and the following measuring instruments were used: combined instrument "TKA-PKM", aspirator "PU-3E", manometer "DMC-01", pressure tubes RIGAA and PITO, gas analyzer " HANK-4", equal arm laboratory weight "VLR-200 g-M", photometric photometer "KFK-3-01-" ZOMZ ", radiometer-dosimeter RKS-01-Solo.

Results and discussion. Various wastes in composition are stored in the landfill. When they come into contact with the geological environment, complex chemical and biochemical reactions begin to occur. A number of toxic substances are released into the environment in solid, liquid and gaseous form from the waste. As a result of exothermic processes, thermal energy is released, which leads to a fire hazardous state due to the ignition of the landfill gas of methane and other flammable substances [14].

This year, due to a sharp increase in air temperature up to 40^0C and above, there has been multiple spontaneous combustion of waste in many landfills, including the considered landfill. Taking into account

this condition, a regular moistening of SDW was carried out at the Kentau landfill in summer during fire-hazardous periods. Average water consumption for irrigation in this landfill is 10 liters per 1 m^3 of SDW.

A biothermal anaerobic process of decomposition of the waste organic component takes place under the influence of microflora in the thickness of solid domestic and industrial waste buried in landfills. During the initial period (about a year), the process of waste decomposition is characterized by their oxidation occurring in the upper layers of waste, due to the oxygen of the air contained in the voids and penetrating from the atmosphere. Then, as natural and mechanical compaction of wastes and their isolation by the soil are intensified, anaerobic processes are intensified with formation of biogas, which is a final product of the biochemical anaerobic decomposition of the waste organic component under the influence of microflora [15-21].

A simplified stoichiometric equation on the reaction of anaerobic decomposition process of organic matter is as follows: $n\ C_6H_{10}O_5 + n\ H_2O > 3n\ CH_4 + 3n\ CO_2$. The final product of this process is biogas, the bulk of which is methane, carbon dioxide. Methane and carbon dioxide are greenhouse gases; they greatly enhance the effect of global climate change. In order to avoid the negative impact of greenhouse gases to the state of environment, in the work [22] shown possibility of their use in the mix with natural gas as a fuel . Co-combustion of natural gas and greenhouse gases leads to a dramatic phenomenon of harmful emissions into the atmosphere. Along with these components, biogas contains water vapor, carbon monoxide, nitrogen oxides, ammonia, hydrocarbons, hydrogen sulphide, phenol and in minor amounts other impurities.

The process intensity and specific volume of gas emissions depend on the environmental conditions, the age of landfill and the fractional composition of waste. The main factors influencing the intensity of biological conversion are temperature, humidity, value of hydrogen index, content of organic matter.

Tables 1, 2 present the characteristics of main greenhouse gases and other gases formed in the landfill area and their volumes.

Table 1 – Characteristics of greenhouse gases (tons/year)

#	Name of greenhouse gas	Chemical formula	Number of emissions by types of greenhouse gases	Number of greenhouse gas emissions in the equivalent to CO_2
1	Carbon dioxide	CO_2	301.715	301.715
2	Nitrous oxide	N_2O	0.00253	0.7873
3	Methane	CH_4	0.0544	1.1421
	Total			**303,6444**

Table 2 – Content of gas emissions (mg/m^3)
in the territory of sanitary protection zone of the Kentau landfill

Component name	MPC	South	East	West	North
Nitrogen dioxide	0,2	0,086	0,087	0,085	0,08
Ammonia	0,2	N / A	N / A	N / A	N / A
Sulphurous anhydride	–	N / A	N / A	N / A	N / A
Carbon monoxide	5,0	3,0	3,0	3,5	3,0
Methane	1,0	N / A	N / A	N / A	N / A
Xylene	0,2	N / A	N / A	N / A	N / A
Methylbenzene (toluene)	0,6	N / A	N / A	N / A	N / A
Ethylbenzene	0,04	N / A	N / A	N / A	N / A
Formaldehyde	0,035	N / A	N / A	N / A	N / A

In order to prevent unauthorized storage of waste containing radionuclides, when entering the landfill, the waste passes radiation dosimetric control. For these purposes, the geological prospecting devices СРП-68-01 or СРП-88Н are used. Table 3 shows the averaged indicators of radiation measurements carried out at different sites of the landfill's upper layer.

Table 3 – Results of radiation measurements

Name of indicators	Units	Normative values	Actual results
Gamma radiation	Mk3v/hr	0,2	0,05-0,12
Radon exhalation	mBq/(m^2·s)	80	36-43

Solid domestic waste is a complex heterogeneous mixture. A morphological composition of solid domestic wastes stored in the landfills, according to the average data of our studies as percentages by mass, is presented in table 4.

Table 4 – Morphological composition of solid domestic wastes of the Kentau landfill

#	Waste	Content of components, %
1	Ash	46
2	Manure and litter	20
3	Waste in the form of wood	3,7
4	Plastic masses (bottles, packaging materials, etc.)	5
5	Bones of pets	11
6	Broken glass	5,4
7	Metal	0,5
8	Leather, rubber	1,5
9	Paper and textiles	6,0
10	Stones	0,9

As can be seen from the data in table 4, a significant part of SDW fractional components is represented by a wide variety of organic and synthetic materials. Ash, manure, animal bones, paper, and textiles are considered to be the main faction groups. Their ratio depends on a number of factors, which primarily include the level of economic development of the region, its geographical location and the formed mentality. Morphological composition may vary depending on the season, weather conditions. So in autumn, an increase in the amount of food waste, this is associated with a large consumption of vegetables and fruits in the food intake. And in winter and spring, the content of small residues (street sweepings) is reduced.

When analyzing the results of waste management works for the last year, the trend on increase of SDW generation can be clearly traced. The volume of generation of solid domestic waste is directly related to the life activity of population and production processes of the enterprises located in the serviced territory. The quantitative and qualitative content of waste depends on the production factors of enterprises, the development of infrastructure in the living territory of the population and the number of people served.

Based on the development prospects of the town Kentau for 2018-2020, it can be assumed that this volume of SDW generation will increase by at least 10% each year. Currently, measures are taken to organize selective collection and disposal of SDW for environmental improvement, as well as lowering of harmful effects on the environment, For example, there is a separate collection of waste paper, polymeric waste, plastic bottles, scrap metal, organic waste (manure, bird droppings, sawdust), glassware. These types of waste are further sent to the relevant enterprises for further utilization with receipt of either marketable products or secondary raw materials based on a contract. This measure significantly reduces the technogenic load of the landfill on the environment. Under this approach, pollution of biosphere objects is prevented to a certain extent, as well as resource-saving is provided.

In such a way, conduction of regular environmental monitoring over the environmental objects in the area of influence of the landfill will enable to solve the following problems:

a) to receive reliable information on the level of its negative effect;

b) to assess the dynamics of pollution;

c) to take appropriate actions to protect the environment from pollution and complex rational use of valuable components contained in waste as secondary raw materials.

Г. А. Саинова[1], А. Д. Ақбасова[1], Г. Ғ. Әбдікәрім[1], Н. А. Қалиева[1], Али Озлер Мехмет[2]

[1]Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,
[2]Мугла Сыткы Кочман университеті, Мугла, Түркия

КЕНТАУ ҚАЛАСЫНЫҢ ҚАТТЫ ТҰРМЫСТЫҚ ҚАЛДЫҚТАР ПОЛИГОНЫНА ЭКОЛОГИЯЛЫҚ МОНИТОРИНГ

Аннотация. Бұл мақалада қатты тұрмыстық қалдықтарды орналастырғанда және полигондарды пайдаланғанда туындайтын экологиялық мәселелердің талдау нәтижесі көрсетілген. Ең маңыздысы, полигон орналасқан аймақтардың қоршаған орта нысандарына кері әсерін тигізуі. Осының нәтижесінде қазіргі экожүйенің бөліктері, яғни топырақ, жерасты сулары, атмосфералық ауа, өсімдіктер деградацияға ұшырайды. Қоршаған ортаның ластануы тіршілік ететін биологиялық, сонын ішінде адами ресурстарға зиян келтіруі мүмкін. Кентау қаласындағы полигоннан атмосфераға бөлінетін жылы жай газдардың (метан, көмірқышқыл газы) және басқа да улы газ тәрізді заттардың (азот диоксиді, азот оксиді, күл, күкіртті ангидрид, көміртегі тотығы, формальдегид, күкіртті сутек, аммиак, ксилол, толуол, этилбензол) сапалық және сандық құрамына жүргізілген тәжірибелік зерттеу нәтижелері көрсетілген. Полигон аумағына жүргізілген тәжірибелік өлшеулер нәтижесінде аймақтың радиациялық ластану деңгейі шекті рауалды мөлшерден аспайтыны анықталды. Қатты тұрмыстық қалдықтардың орташа морфологиялық құрамы зерттелді. Қатты қалдықтардың фракциялық құрамдас бөліктерінің көбісі органикалық және синтетикалық материалдардан тұратындығы айқындалды. Олардың негізгі фракциялық түрлері ретінде күл (46%), көң (20%), үй жануарларының сүйектері (11%), қағаз және тоқыма бұйымдары (6%) болып саналады.

Қорытындылай келе, қатты тұрмыстық қалдықтардағы құнды құрамдас бөліктерді екінші реттік шикізат ретінде қолдану үшін және қоршаған ортаны қорғау іс-шараларын жүргізуге мақсатты түрде тұрақты экологиялық мониторинг жүргізу керектігі қорытындыланды.

Түйін сөздер: полигон, санитарлық қорғау аймағы, қатты тұрмыстық қалдықтар, мониторинг, жылы жай газдары, биогаз.

Г. А. Саинова[1], А. Д. Акбасова[1], Г. Г. Абдикарим[1], Н. А. Калиева[1], Али Озлер Мехмет[2]

[1]Международный казахско-турецкий университет им. Ходжи Ахмеда Ясави, Туркестан, Казахстан,
[2]Университет Мугла Сыткы Кочман, Мугла, Туркия

ЭКОЛОГИЧЕСКИЙ МОНИТОРИНГ НА ПОЛИГОНЕ ТВЕРДЫХ БЫТОВЫХ ОТХОДОВ ГОРОДА КЕНТАУ

Аннотация. В статье приведены результаты анализа экологических проблем, возникающих при размещении и эксплуатации полигонов твердых бытовых отходов. К важнейшим из них можно отнести негативное воздействие полигона на состояние объектов окружающей среды, находящихся в зоне его расположения. Результатом такого воздействия является деградация существующей экосистемы, а именно почв, подземных вод, атмосферного воздуха, растительности. Загрязнение окружающей среды может причинить вред жизнедеятельности биологических ресурсов, включая человеческий ресурс.

Представлены результаты экспериментальных исследований качественного и количественного состава парниковых (метан, углекислый газ) и других токсичных газообразных веществ (диоксид азота, оксид азота, сажа, ангидрид сернистый, оксид углерода, формальдегид, сероводород, аммиак, ксилол, толуол, этилбензол), выделяющихся в атмосферу от поверхности полигона города Кентау. На основе экспериментального замера территории полигона установлено отсутствие радиационного загрязнения выше предельно допустимого уровня. Определен средний морфологический состав твердых бытовых отходов. значительная часть фракционных компонентов ТБО представлена большим разнообразием органических и синтетических материалов. Зола (46%), навоз (20%), кости домашних животных (11%), бумага и текстиль (6%) рассматриваются как основные фракционные группы.

Сделан вывод о целесообразности регулярного проведения экологического мониторинга для принятия мер по защите окружающей природной среды и рационального использования ценных компонентов отходов в качестве вторичных сырьевых ресурсов.

Ключевые слова: полигон, санитарная защитная зона, твердые бытовые отходы, мониторинг, парниковые газы, биогаз.

Information about authors:

Sainova Gaukhar Askerovna, Doctor of technical sciences, Professor, Chief Researcher of the Scientific Research Institute of "Ecology" at Khoja Akhmet Yassaw International Kazakh-Turkish University, Turkistan; ecolog_kz@mail.ru; https://orcid.org/0000-0002-0709-7453

Akbasova Amankul Dzakanovna, Doctor of technical sciences, Professor, Director of the Scientific Research Institute of "Ecology" at Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan; ecolog_kz@mail.ru; https://orcid.org/0000-0002-0842-4647

Abdikarim Gulzat Galimzhankizi, Second year master student of Khoja Akhmet Yassawi International Kazakh-Turkish University; https://orcid.org/0000-0002-0116-9428

Kalieva Nurzya Abdeshovna, Doctoral student, International Kazakh-Turkish University named after Khoja Ahmed Yasawi, Turkistan, Kazakhstan; https://orcid.org/0000-0001-8137-9427

Ali Ozler Mehmet, Doctor, Mugla Sitki Kochman University, Mugla, Turkey; https://orcid.org/0000-0001-7547-0080

REFERENCES

[1] Sharova O.A., Barmin A.N. Ecological monitoring at solid domestic and industrial waste landfills // Scientific statements: a series of natural sciences. N 3 (N 146). Issue 22. P. 166-169.

[2] Sadchikov A.V. Degassing of landfills of solid municipal waste // Fundamental research. 2017. N 2. P. 82-86.

[3] Pellow D.N., Park L.S.-H. Garbage Wars: The Struggle for Environmental Justice in Chicago. Cambridge: MIT Press, 2004. 256 p.

[4] Starostina V., Damgaard A., Rechberger H., Christensen T. Waste management in the Irkutsk Region, Siberia, Russia: Environmental assessment of current practice focusing on landfilling // Waste Management & Research. 2014. Vol. 32(5). P. 389-396.

[5] Shaufique F. Sidique, Satish V. Joshi, Frank Lupi. Factors influencing the rate of recycling: An analysis of Minnesota counties, Resources // Conservation and Recycling. 2010. Vol. 54(4). P. 242-249.

[6] Yoshida A., Terazono A., Ballesteros F.C., Nguyen D., Sukandar S., Kojima M., Sakata S. E-waste recycling processes in Indonesia, the Philippines, and Vietnam: A case study of cathode ray tube TVs and monitors // Resources Conservation and Recycling. 2016. Vol. 106. P. 48-58.

[7] Ecological Code of the Republic of Kazakhstan 2007.

[8] Ngo K. C., Pham Q. L. Solid waste management associated with the development of 3R initiatives: case study in major urban areas of Vietnam // Journal of Material Cycles and Waste Management. 2011. Vol. 13(1). P. 25-33.

[9] State standard 17.2.4.06-90 Protection of Nature. Atmosphere. Methods for determining the velocity and flow rate of gas-dust flows leaving stationary sources of pollution.

[10] State standard 17.2.4.07-90 Protection of Nature. Atmosphere. Methods for determining the pressure and temperature of gas-dust flows leaving stationary sources for pollutants.

[11] Methodology for performing measurements - 4215-002-56591409-2009 Measurement procedure mass concentration of harmful substances in the air with the HANK-4 gas analyzer.

[12] Methodology for performing measurements - 4215-006-56591409-2009 Measurement procedure mass concentration of dust in the air with a gas analyzer HANK-4.

[13] Methodology for performing measurements - 4215-007-565914009-2009 Method for performing measurements of the mass concentration of saturated hydrocarbons and petroleum hydrocarbons in atmospheric air using the HANK-4 gas analyzer.

[14] Ham G., Lee D. Consideration of high-efficient Waste-to-Energy with district energy for sustainable solid waste management in Korea // Energy Procedia. 2017. Vol. 116. P. 518-526.

[15] Liikanen M., Sahimaa O., Hupponen M., Havukainen J., Sorvari J., Horttanainen M., Updating and testing of a Finnish method for mixed municipal solid waste composition studies // Waste Management. 2016. Vol. 52. P. 25-33.

[16] Papageorgiou A., Barton J.R., Karagiannidis A. Assessment of the greenhouse effect impact of technologies used for energy recovery from municipal waste: A case for England // Journal of Environmental Management. 2009. Vol. 90(10). P. 2999-3012.

[17] Hong J., Chen Y., Wang M., Ye L., Qi C., Yuan H., Zheng T., Li X. Intensification of municipal solid waste disposal in China // Renewable & Sustainable Energy Reviews. 2017. Vol. 69. P. 168-176.

[18] Lykov I.N., Safronova S.A., Morozenko M.I., Efremov G.V. Methanogenesis and global climatic processes // Nature. 2009. N 8. P. 40-44.

[19] Grechko A.V. Modern Methods of Heat Treatment of Solid Domestic Waste // Prom. Power engineering. 2006. N 9. P. 20-23.

[20] Dozorov V.A. Physical and chemical methods of environmental protection / Competencies and education: models, methods, technologies. Monograph. Part VI / Ed. E.V. Comic. M.: Publishing House "Perot", 2015. P. 40-77.

[21] Ezhov V.S. Reduction of harmful gaseous emissions from central heating sources // Industrial energy. 2006. N 12. P. 44-47.

[22] Zhirnova O.V., Suleimenov B.A., Toigozhinova A.Zh., Wojcik W. T. Construction of mathematical model the combustion of biogas to reduce greenhouse gas emissions // News of the national academy of sciences of the republic of Kazakhstan. Series of geology and technical sciences. 2017. Vol. 1(421). P. 177-185. https://doi.org/10.32014/2018.2518-170X ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 63 – 67 **https://doi.org/10.32014/2019.2518-170X.7**

UDC 681.518

I. K. Sagynganova[1], V. B. Markin[2]

[1]D. Serikbayev East Kazakhstan state technical university, Ust-Kamenogorsk, Kazakhstan,
[2]I. Polzunov Altay state technical university, Barnaul, Russia.
E-mail: diko_s777@mail.ru, Mvb.v.1942@mail.ru

THE ORGANIZATIONS OF THE TASKS IMPLEMENTATION IN THE DISTRIBUTED AUTOMATIC CONTROL SYSTEMS OF HEAT SUPPLY STATIONS

Abstract. In this article we proposed a data processing technology that provides the ability to form the efficiency indicators of the different processors that implement pipeline plans of data processing systems (DPS) and automated control systems (ACS) of the heat supply stations in general. The implementation of this technology will have a significant effect in practice as the internal technology of ACS work is being improved. In addition, the described approach offers the following advantages: the increase of the capacity of the pipeline data processing system; the implementation of the functions uniformity of the pipeline data processing system which allows to reduce the requirements for the ACS of the heat supply stations; the reduction of the time and the improvement of the quality of communications in the system linking and coordinating the work of several heat supply stations.

Keywords: a data processing system (DPS), an automated control system (ACS) with heat supply stations, a district heating supply system (DHS).

Introduction. Currently distribution and regulation of thermal energy, both inside and outside buildings, according to demand is considered one of the most fundamental approaches to energy conservation in Kazakhstan, and just as so in all developed countries.

In December 2017 the chairman of Kazakhstan power association, Shaimerden Urazalinov, mentioned the following while discussing problems in the heat supply sector [1]:

– there is high intellectual and physical wear of primary and secondary equipment on heat stations, in boiler rooms, in heat networks and heat consumptions systems;

– the most pressing problem of elimination of excess losses of heat energy is not being dealt with;

– there is a lack of resolution concerning financial and organizational issues that would arise during reconstruction and modernization of individual components of the heat supply system;

– currently operating centres of heat consumption, used in buildings which are connected to the city's district heating systems, usually don't have any automatic machinery and only an insignificant amount of them have heat meters and coolant meters at heat points;

– most consumers connected to district heating systems don't have the capability to regulate the consumption of heat used for heating according to their wishes.

Whereas the use of modern technology for control of heat supply points, connected into a single network, would allow for significant power savings and smoother heat distribution in living and industrial spaces.

The advantages of having pipelined task completion machinery in distributed automated control systems logically follow from the theory of production development and information conversion. In this work we offer a methodology for typification of tasks in an automated control system of a heat station with pipelined data processing, since one of the stages of organising data processing technology is the stage of identifying typical tasks and typical task queues, which are then organized into a pipelined data

processing plan. It's obvious that organising homogenous task queues into a pipelined plan leads to raised effectiveness of distributed automated control systems.

Theoretical and methodological aspects of task typification in modular data processing system are reflected in the works of domestic and foreign authors, such as A.G. Mamikonov [2], V.V. Kul'ba, S.A. Kosyachenko [3, 4], A.S. Mironov, Ye.N. Sidorov, A.A. Ashimov [5], YU.YU. Kess, V.M. Revako [6], A.V. Tovmasyan, B. Dyuran, P. Odell [7], Kh. Berzh, O. Ore [8]. Models and methods of data processing in technical and logistical system are examined in the works of V.V. Voyevodina [9-11], B.A. Golovkina, K.G. Samofalova [12], G.M. Lutskogo, A.B. Barskikh, Ye.L. Shlimovicha [13], A.P. Shabanova, D. Fillipsa, A. Garsia-Diasa [14], R.V. Konveya, V.L. Maksvella [15], L.V. Millera. Pipelined typical task completion in distributed automated control systems signifies a new stage in automated control system design and requires model-algorithmic task completion guarantees and adaptation of task typification methodology for pipelined data processing system [16].

The technology offered here grants the opportunity of forming the performance identifiers of individual processors realising pipelined plans, of the data processing system and of an automated control system of the heat station in general. Implementing this technology gives significant practical advantages, since the internal technology of operation of an automated control system is being perfected. Besides that, the explained approach grants the following advantages: increase in throughput of pipelined data processing system; guaranteeing the homogeneity of functionality of pipelined data processing system, which allows to decrease the requirements to an automated control system of a heat station; the decrease in latency and improvement of the quality of system communications linking and coordinating the operation of several heat stations.

Research methodology. Let's examine model-algorithmic procedures allowing to trace back the influence of data collection process in an automated control system on the effectiveness of task planning assuming pipelined execution. For a task class in distributed automated control systems, the problem of the minimization of resources is solvable in general form using the method of estimating the sufficient capacity of the data processing system.

The method is based on the mathematical apparatus of the queueing theory. The problem of developing a model allowing to get an estimate of the capacity of a data processing system with data collection is currently relevant. Said problem is related to the problem of the minimization of resources of the automated control systems of the heat stations. Using the known mathematical apparatus as an instrument, let's use the following model of estimation of the influence of the data collection process on the effectiveness of the pipelined data processing in an automated control system:

$$P(\leq T_z) \geq \frac{1}{Q}\left(P_{const}^{k=1}(0) + P_{const}^{k=2}(1) + P_{\varphi\{\tau[V(t)]\}}^{k\geq 3}\right.$$

where T_z is the specified maximum allowed waiting time for a service demand; P(≤Tz) is the specified minimum allowed probability of not exceeding T_z; Q is the maximum amount of demands serviced in a continuous time period (busy period); V(t) is the amount of recorded information. The value of V(t) changes with time; τ [V(t)] is the duration of a single servicing period. It is a dependent quantity of the amount of information V(t) and is defined as:

$$\tau[V(t)] = \frac{\tau_{const} + \tau_{\text{var}}[V(t)]}{M}$$

M is the amount of processor in a data processing system; τ_{const} is the constant component of the servicing interval, determined mostly by the time directly spent on demand handling; $\tau_{var}[V(t)]$ is the component of the servicing interval dependent on the amount of information.

The parameter of $\tau_{var}[V(t)]$ is determined by the time spent on managing information and decision-making,

k is the ordinal position of the demand in the busy period,

j is the waiting period for the demand numbered k expressed in the amount of servicing intervals,

$P_{const}^{k=1}(0)$ is the probability that the demand received in the data processing system isn't waiting for service. In a single busy interval only one demand (k=1) can be such a demand, such that $P_{const}^{k=1}(0)$ for every Q is a constant of 1,

$P_{const}^{k=2}(0)$ is the probability that the waiting period of the second, in the order of servicing, demand (k=2) is equal to one servicing interval. In a single busy interval $P_{const}^{k=2}(0)$ for every Q is a constant of 1.

$P_{\varphi\{\tau[V(t)]\}}^{k\geq 3}(j \leq J)$ is the probability that each demand, starting with the third one in the order of servicing in a busy interval, waits for no more than j servicing intervals,

j=1,2,…,J, J – is the maximum allowed servicing time expressed in the amount of servicing intervals. The parameter of J corresponds to the parameter of Тзад and is dependent on the parameter of τ [V(t)].

The model allows to obtain the dependence between the maximum amount of Q demands serviced in a data processing system during a continuous time interval (busy interval) and the amount V(t) of recorded information under the assumption of adherence to the given values of waiting time T for servicing demands and probability P(≤Tz) that it's not exceeded. The considered model allows identifying the dependence between the capacity of the data processing system and the amount of information, gradually collected and mastered by processors of pipelined data processing plan. An important application of the model is selecting a strategy for organising the process of demand servicing with the capability of quantitative assessment of different alternatives during distribution of the major tasks between processors.

Results. Having carried out calculations with real parameters of the network of heat supply stations, we defined the dependence of the information volume and the duration of the service interval from the time of information update.

The dependency of the amount V(t) of information on time t is determined based primarily on the composition of the entities in the production environment of task consumers and on the operating conditions of the data processing system providing such tasks. For example, figure 1 provides the dependency of the amount of recorded information on its update time in the conditions of organising an automated control system of a heat station with pipelined data processing.

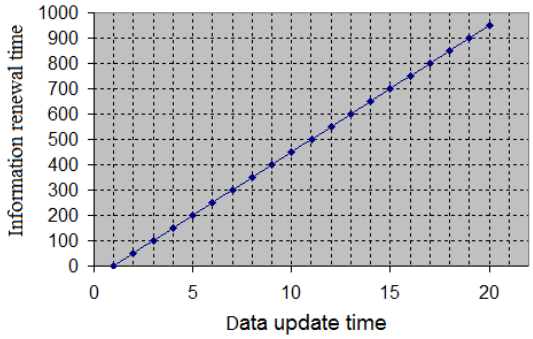


Figure 1 –
The dependence of the amount
of recorded information
on its update time

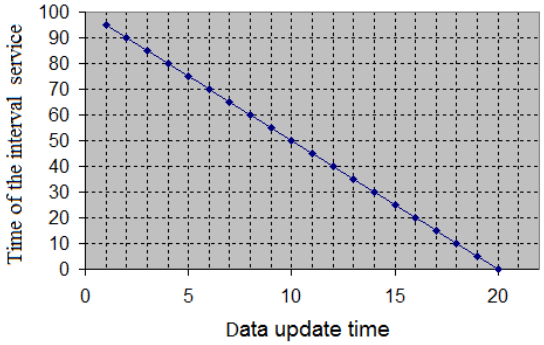


Figure 2 –
$\tau_{var}[V(t)]$ as a function
of the data update time

The dependence of the variable component $\tau_{var}[V(t)]$ of the servicing interval is mostly determined from the type of processors of the data processing system, from organization of servicing of the demands being received from task consumers. For example, figure 2 shows the change of variable $\tau_{var}[V(t)]$ as a function of the data update time.

Using derived dependencies, we have selected an optimal time for the data update while processing the next nine parameters at ten heat stations: the temperature of network water in the supply line, the temperature of network water in the return line, the flow temperature, the flow rate of network water in the supply line, the flow rate of network water in the return line, the pressure of network water in the supply line, the pressure of network water in the return line, the indoor temperature, the heat released. Using four personal computers, each with an i5 CPU (4x4=16 cores) with pipeline processing of all the parameters from 10 heat stations the optimal update time for the data is 10ms. Adding to that, the time to receive full information decreased approximately tenfold compared to the current technology of gathering and processing data from the heat stations.

Conclusion. The developed model of the system with pipelined data processing with data collection has practical applications most obviously seen in the task of organizing the operation of several heat stations into a uniform system, where said approach tested.

The obtained results show that it is possible to create information systems with the new architecture proposed in [17]. In particular, by calculating the duration of the service interval it is possible to set the optimal switching time between tasks performed by the processor. This will allow creating a software complex for the management of heat supply stations with pipelined data processing.

И. К. Сагынганова[1], В. Б. Маркин[2]

[1]Д. Серікбаев атындағы Шығыс Қазақстан мемлекеттік техникалық университеті, Өскемен, Қазақстан,
[2]И. И. Ползунов атындағы Алтай мемлекеттік техникалық университеті, Барнаул, Ресей

ЖЫЛУ ПУНКТТЕРІН ҮЛЕСТІРІЛГЕН АВТОМАТТЫНДЫРЫЛҒАН БАСҚАРУ ЖҮЙЕЛЕРІНДЕ МІНДЕТТЕРДІҢ КОНВЕЙЕРЛІК ОРЫНДАЛУЫН ҰЙЫМДАСТЫРУ

Аннотация. Мақалада, мәліметтерді өңдеу жүйелерінің (МӨЖ) және жалпы жылыту пункттерінің басқару жүйелерінің автоматтандырылуын, конвейерлік жоспарларды іске асыратын жеке процессорлар жұмысының тиімділік көрсеткіштерін қалыптастыру мүмкіндігін беретін мәліметтерді өңдеу технологиясы ұсынылған. Бұл технологияны іске асыру, АБЖ жұмысының ішкі технологиясы жетілдірілетіндіктен, тәжірибеде маңызды нәтиже береді. Сонымен қатар бұл сипатталған тәсіл келесі артықшылықтарға ие: мәліметтерді өңдеудің конвейерлік жүйесінің өткізу қабілетін арттырады; жылыту пунктінің АБЖ талаптарын төмендетуге мүмкіндік беретін, мәліметтерді өңдеудің конвейерлік жүйесі қызметінің біркелкілігін қамтамасыз етеді; бірнеше жылыту пункттерінің жұмысын байланыстыратын және үйлестіретін жүйедегі коммуникация сапасын жақсарту және уақытын азайту.

Түйін сөздер: мәліметтерді өңдеу жүйесі (МӨЖ), жылу пункттерін (АБЖ) автоматты басқару жүйесі, орталықтандырылған жылумен қамту жүйесі (ОЖҚЖ)

И. К. Сагынганова[1], В.Б. Маркин[2]

[1]Восточно-Казахстанский государственный технический университет им. Д. Серикбаева,
Усть-Каменогорск, Казахстан,
[2]Алтайский государственный технический университет им. И. И. Ползунова, Барнаул, Россия

ОРГАНИЗАЦИЯ КОНВЕЙЕРНОГО ВЫПОЛНЕНИЯ ЗАДАЧ В РАСПРЕДЕЛЕННЫХ АВТОМАТИЗИРОВАННЫХ СИСТЕМАХ УПРАВЛЕНИЯ ТЕПЛОПУНКТОВ

Аннотация. В статье нами предложена технология обработки данных, которая предоставляет возможность формирования показателей эффективности работы отдельных процессоров, реализующих конвейерные планы, системы обработки данных (СОД) и автоматизированные системы управления (АСУ) теплопунктов в целом. Реализация этой технологии даст существенный эффект на практике, так как совершенствуется внутренняя технология работы АСУ. Помимо этого описанный подход дает следующие преимущества: увеличение пропускной способности конвейерной системы обработки данных; обеспечение однородности функций конвейерной системы обработки данных, что позволяет снизить требования к АСУ теплопункта; уменьшение времени и улучшение качества коммуникаций в системе, связывающие и координирующие работу нескольких теплопунктов.

Ключевые слова: система обработки данных (СОД), автоматизированная система управления (АСУ) теплопунктами, система централизованного теплоснабжения (СЦТ).

Сведения об авторах:

Сагынганова Индира Кенесовна – докторант кафедры «Приборостроение и автоматизация технологических процессов» Восточно-Казахстанского государственного технического университета им. Д. Серикбаева, Казахстан, специальность 6D070200 – Автоматизация и управление; e-mail: diko_s777@mail.ru; https://orcid.org/0000-0003-2654-3348

Маркин Виктор Борисович – доктор технических наук, профессор Алтайского государственного технического университета им. И. И. Ползунова, РФ, Барнаул, Россия; Mvb.v.1942@mail.ru; https://orcid.org/0000-0003-3094-8479

Information about authors:

Sagynganova I. K., D. Serikbayev East Kazakhstan state technical university, Ust-Kamenogorsk, Kazakhstan; diko_s777@mail.ru; orcid.org/0000-0003-2654-3348

Markin V. B., I. Polzunov Altay state technical university, Barnaul, Russia; Mvb.v.1942@mail.ru; orcid.org/0000-0003-3094-8479

REFERENCES

[1] http://eenergy.media/2017/12/19/shajmerden-urazalinov-problemy-v-sektore-teplosnabzheniya-i-puti-ih-resheniya/

[2] Novikov D.A., Ashimov A.A., Sultanov B.T., Adilov Zh.M., Borovsky Yu.V., Alshanov R.A. Macroeconomic Analysis and Parametric Control of a National Economy. M.: Springer, 2013. 256 p.

[3] Designing subsystems and links of ACS: Proc. allowance. M.: H. Shk., 1975. 248 p. Co-authors: Kosyachenko S.A., Mamikonov A.G.

[4] Mikrin E.A., Kulba V.V., Kosyachenko S.A., Pavlov B.V., Kononov D.A., Kovalevsky S.S., Shelkov A.B., Chernov I.V., Somov S.K., Gladkov M.Yu. Information support of organizational management systems (theoretical basis). In 3 parts. M.: Publishing House of Physical and Mathematical Literature, 2012. 528 p.

[5] Novikov D.A., Ashimov A.A., Sultanov B.T., Adilov Zh.M., Borovsky Yu.V., Alshanov R.A. Macroeconomic Analysis and Parametric Control of a National Economy. M.: Springer, 2013. 256 p.

[6] Revako V.M. Methods and models in the tasks of managing production. M.: B. and. Tallinn, 1979. 171 p.

[7] Benjamin S. Duran, Patrick L. Odell CLUSTER ANALYSIS, SPRINGER -VERLAG, BERLIN-HEIDELBERG-NEW YORK, 1974. 129 p.

[8] O. Ore Theory of Graphs. M.: URSS, 2008. 352 p. ISBN 978-5-397-00044-4.

[9] Voevodin V.V. Mathematical Foundations of Parallel Computations. MSU Publishing House, 1991. 345 p.

[10] Voevodin V.V. Information structure of algorithms and programs. Izd-vo MGU, 1997. 139 p.

[11] Voevodin V.V., Voevodin Vl. B. Parallel calculations. BHV-Petersburg, 2002. 608 p.

[12] Samofalov K.G., Rimankevich A.M., Valuisky V.N., Kanevsky Yu.S., Pinevich M.M. Applied theory of digital automata. Head and Publishing House, 1987. 375 p.

[13] Petrov Yu.A., Shlimovich E.L., Iriupin Yu.V. Integrated automation of enterprise management. M.: Finance and Statistics, 2001. 160 p.: ill. ISBN 5-279-02314-0.

[14] Phillips D., Garcia-Días A. Methods of network analysis / Trans. with English. M.: Mir, 1984. 496 p.

[15] Conway R.V., Maxwell V.L., Miller L.V. Theory of schedules Moscow: Nauka. The main revision of the phys. Literature, 1975. 360 p.

[16] Bogdanova O.V. Modeling and algorithmic support of pipelined tasks in distributed ACS. The thesis for obtaining the scientific degree of Candidate of Technical Sciences, specialty 05.13.06 - Automation and management of technological processes and industries (industry). Krasnoyarsk, 2008.

[17] Rybakova D.A., Sagynganova I.K., Kumargazhanova S.K., Baklanov A.E., Shvets O.Y. Application of a Processors for the Computer with Data Coming from the Network on the Example of a Heating Station // 18th International Conference of Young Specialists on Micro/nanotechnologies and Electron Devices (Edm). P. 128-130. Published: 2017.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 68 – 72 **https://doi.org/10.32014/2019.2518-170X.8**

UDC 541. 053.669

V. K. Bekbayeva[1], A. T. Kanayev[1],
Xinze Luo[2],
G. P. Metaksa[3], N. Zhalgassuly[3]

[1]Kazakh National Agrarian University, Almaty, Kazakhstan,
[2]Kuldzhinsk Pedagogical University (CNR),
[3]D.A. Kunaev Mining Institute, Almaty, Kazakhstan.
E-mail: ashim1959@mail.ru; 643389520@qq.1com;
aliya-ismailova@inbox.ru1; gmetaksa@mail.ru

FEATURES OF THE CHANGE IN THE PHYSICAL PROPERTIES OF QUARTZ IN ALTERNATING ELECTRIC FIELDS

Abstract. The paper presents the results of experimental work on mechano-chemical activation (MCA) of quartz. MCA was carried out with different duration from 3 to 20 minutes. Polyhydric alcohols were used as catalysts. The magnetic properties of dispersed compositions were measured. It is shown that new properties of quartz with MCA arise due to the processes of the nanoscale of analysis.

Key words: quartz, mechanochemical activation, properties, magnetic permeability, electric effect.

Crystalline quartz has a hexagonal close-packed lattice with parameters a = 4.913A$^{\perp}$ ° and c = 5.405A$^{\perp}$ ° [1-4]. The pronounced anisotropy of properties in different crystallographic planes is used in the electrical industry: piezoelectric element, frequency stabilizers, ultrasonic equipment, etc. When dispersing quartz in conditions of mechanochemical activation (MCA), powders with magnetic properties of [5-8] were obtained. Moreover, the magnetic properties varied depending on the duration of activation, the time of aging. Therefore, it became necessary to study these properties when changing external conditions in order to reveal the mechanism of interaction with the environment [9-15]. Electric fields superimposed on the test sample are selected as external changing factors in static (0.05 V - 5 V) and dynamic modes (frequency 5-5000 Hz). According to N.N. Mofa and V.P. Ryabikin [16-20] In activated quartz, the number of paramagnetic centers varies depending on the milling time, i.e. the duration of the MCA promotes an increase in the magnetic susceptibility of small quartz particles. Therefore, the behavior of these particles, structured by surface-active substances (surfactants) of one nature, but with different structure and density, is of interest. Alcohols are selected as surfactants: one, two and three-atom, i.e. ethanol, ethylene glycol and glycerin.

Methods of research. The actuality of the work is conditioned by a large number of contaminants arising during the production and transportation of oils. For elimination of large volumes of oil waste, appropriate devices have been developed and used, the operation of which is cost-effective at specified volumes. For small-scale contamination, such devices are not available. Hence, there is a need to search for new cost-cutting ways to solve problems associated with the restoration of disturbed soils. In this work we investigate the properties of quartz subjected to MCA.

Figures 1 and 2 show the experimental data on the change in the magnetic permeability of quartz milled during 20 min placed in a variable field of different voltages (0.5, 5 V). For low-energy action (u = = 0.5 V), a change in the magnetic permeability μ was observed as a function of the frequency of the action with maximum values near 30, 50, and 500 Hz, where the amplitude of μ increases with respect to

EXPERIMENTAL PROCEDURE

Quartz activation 20 min

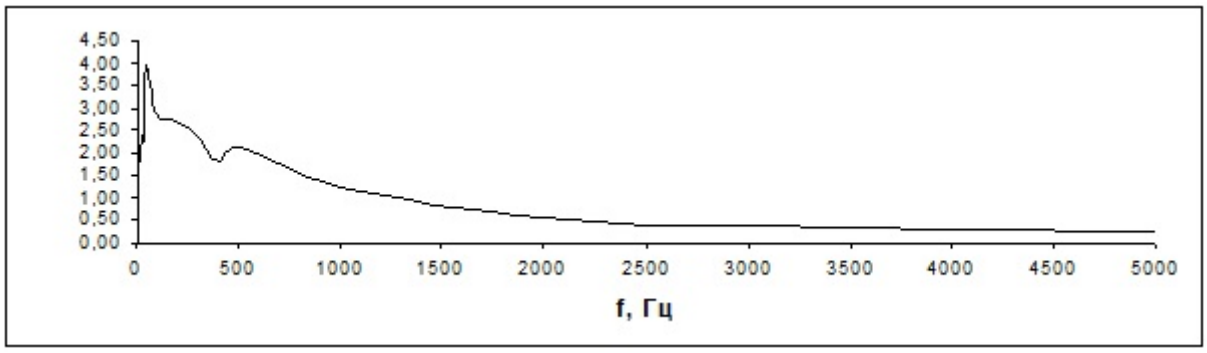


Figure 1 – Change in the magnetic permeability of quartz in variable fields (u = 0,5 V)

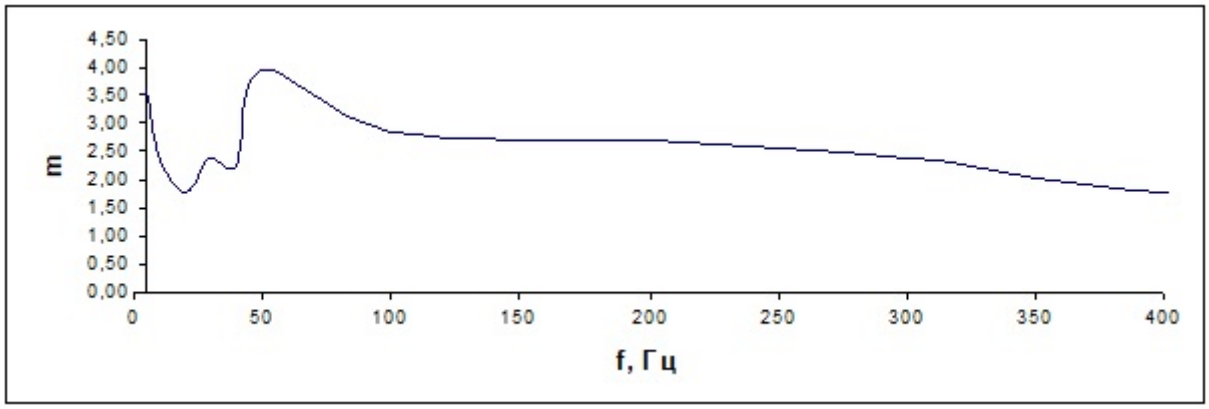


Figure 2 – Change in the magnetic permeability of quartz in variable fields (u = 5 V)

the background to 500-800%. The increase in the impact potential by 10 times (5 V) at the same frequencies showed the reverse effects, i.e. the magnetic permeability decreased sharply at all frequencies, and its maximums were detected near 36, 100 and 300 Hz. These facts indicate a shift in the balance between the electrical and magnetic components of the milled quartz structure.

Milling with surfactants (figure 3) leads to an acceleration of MCA and the samples show the maximum values of μ after a 5-minute milling, increase in the milling time leads to a sharp decrease in magnetic activity. All samples have maximum near 10 Hz and 50 Hz, and samples with a minimum MCA time (5 min) show a sharp increase in μ at 400 and 800 Hz. The absolute values of μ range between 0 and 2.7. An increase in voltage in the same experimental conditions up to 5 V (figure 4) leads to a redistribution of the maximums on the frequency scale and a decrease in the absolute values of $0 \leq \mu \leq 0.78$. Here the samples with the maximum MCA time (20 min), which showed maximum at 50, 70, 300÷200, 900 Hz are most active.

A change in the form of surfactant (ethylene glycol) leads to an increase in the absolute values of μ at the extreme points, which are distributed for low-energy effects near 10, 50 Hz. There is also a special maximum near 500 Hz for a sample with T_{MCA}=15 min. The increase in voltage helps to reduce the absolute values of μ, and the maximums arise for samples with a higher activation time near 50, 200 and 900 Hz.

Quartz activated with glycerin shows the highest values of μ, which for a low-energy variable effect are $0 \leq \mu \leq 0.32$, and for u = 5 V $0 \leq \mu \leq 5.4$. Frequency maximums in the first case occur near 10, 50 Hz, and for u = 5 V - near 500 Hz.

Due to the fact that all quartz samples activated in different conditions show maximums near the frequency - 50 Hz, we conducted an additional experiment in which the external action was performed at a frequency of 50 Hz, and the voltage in the range of $0.05 \leq u \leq 5$ V varied. The results of this experiment

Quartz activation 20 min.
Quartz + ethanol 0,5 V

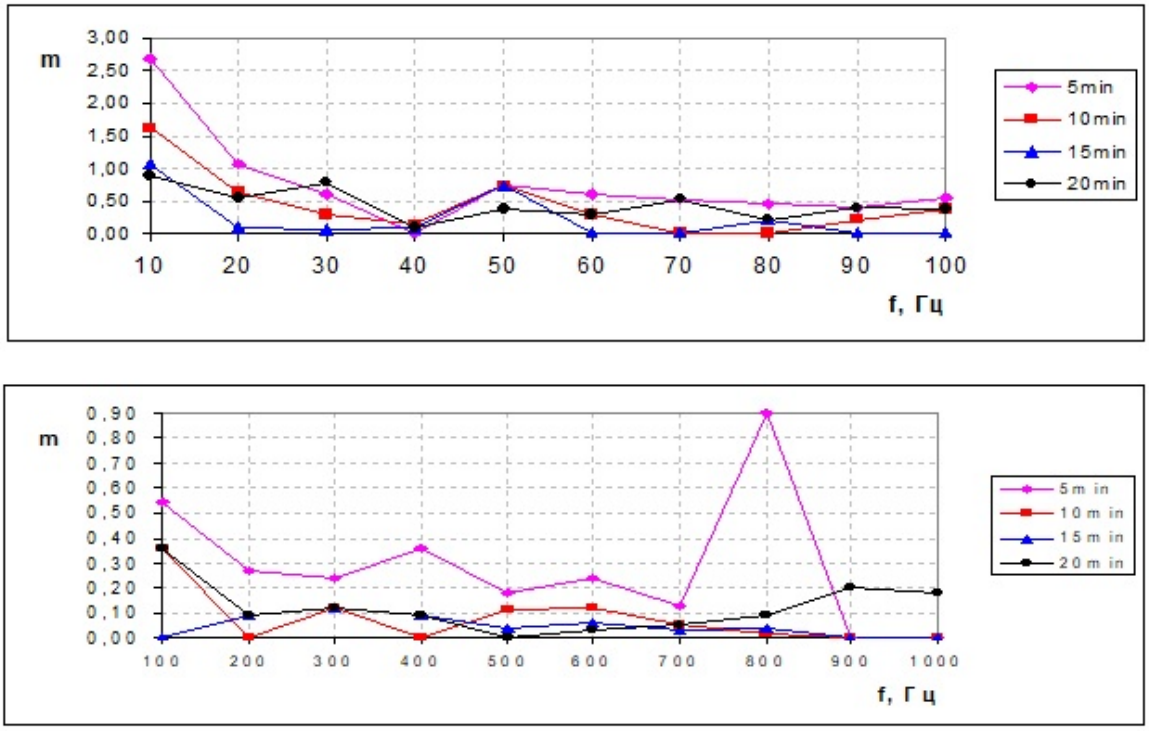
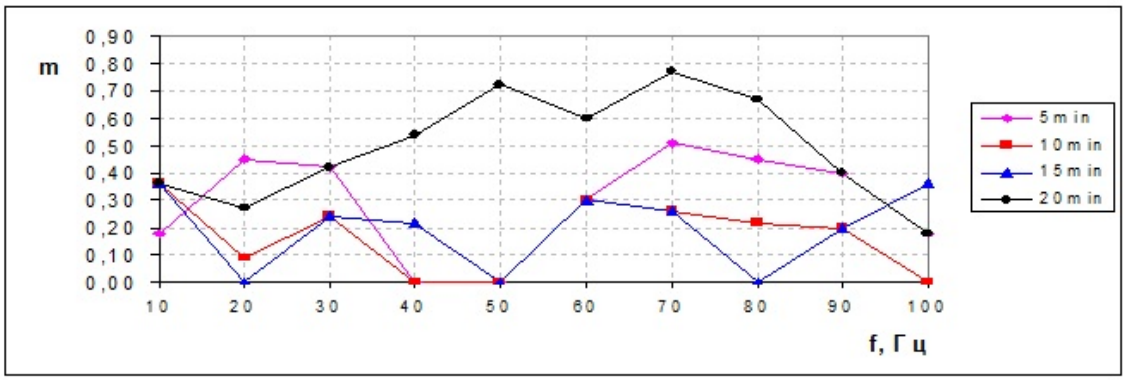
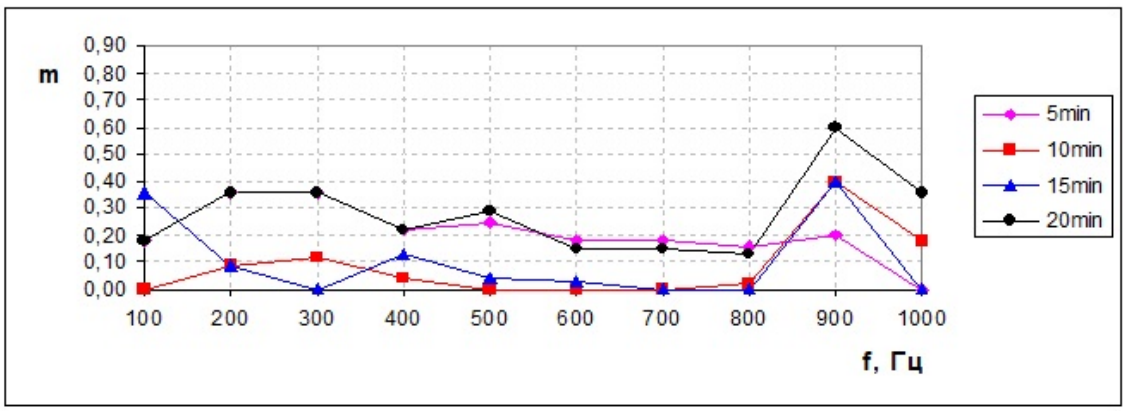


Figure 3 – Magnetic permeability of quartz + ethanol in a low-energy variable field (u = 0,5 V)

Quartz + ethanol





Activation time

Figure 4 – Magnetic permeability of quartz + ethanol in a variable field (u = 5 V)

showed that the highest values of μ correspond to the minimum voltage u = 0.05 V, here: 3.59≤μ≤ 17.93. As voltage increases it can be observed that at this frequency there are abrupt readings near 0.5; 1.0; 3.0 V for samples with surfactant - ethanol. Zero values are observed for samples with 5-minute activation near 5 V, with 15 minutes - near 4.5 V, and 20 minutes - 0.15; 0.25; 0.4 V.

In the same conditions, but with surfactant-ethylene glycol, quartz samples showed the highest μ = 17.93 with a 5-minute MCA. As voltage increases, μ falls as in the previous case, showing jumps near 0.45; 2.5; 3.5 and 4.5 V. Zero values were shown in samples with T_{MCA}=10 min at 0.1; 0.25; 0.3; 0.4 - 1.0 V, with T_{MCA}=15 min: at 0,1 – 0,15; 0,25 – 0,3 V.

The highest magnetic properties showed quartz samples activated with glycerin, here 7.17≤μ≤39.45. With an activation time of 15 minutes, it reaches its limit value and then, as the duration of the MCA increases, begins to decrease. Here we also see jumps in properties near u = 0.5; 1.5-4.5 V. Zero values are only shown by samples with T_{MAX} = 5 min near 0.1; 0.25-0.35, 3-3.5 V.

The presented experimental facts altogether indicate that the behavior of quartz in alternating fields depends both on the frequency and the magnitude of the applied voltage. In order to identify the mechanism of interaction in these conditions, it is necessary to know the algorithm for the correspondence of dynamic attributes of the external field and the form of the dynamic response to this effect. For this purpose, it is necessary to develop a compliance matrix for quartz and the surfactants used.

The obtained experimental data make it possible to make the following conclusions:

1. It is shown that in the MCA process quartz acquires the ability to attract oppositely charged particles, especially of organic origin. This effect is proposed to be used in the liquidation of small-scale oil waste.

2. Mechano-chemical activation of quartz with different milling duration has shown that the achievement of maximum dispersion depends both on the milling time and on the selection of the quality of the catalytic active substances. The optimal mode for conducting an MCA shall be determined experimentally.

В. К. Бекбаева[1], А. Т. Қанаев[1], Лошын Зы[2], Г. П. Метакса[3], Н. Жалғасұлы[3]

[1]Қазақ ұлттық аграрлық университеті, Алматы, Қазақстан,
[2]Құлжа педагогикалық университеті (ҚХР),
[3]Д. А. Қонаев атындағы Кен істері инситуты, Алматы, Қазақстан

АУЫСПАЛЫ ЭЛЕКТР ӨРІСІНДЕ КВАРЦТЫҢ ФИЗИКАЛЫҚ ҚАСИЕТТЕРІНІҢ ӨЗГЕРУ ЕРЕКШЕЛІКТЕРІ

Аннотация. Жұмыста кварцты механохимиалық белсендіру (МХБ) бойынша жүргізілген эксперименталды жұмыстардың нәтижелері ұсынылды. МХБ әртүрлі ұзақтыпен 3-тен 20 мин аралығында жүргізілді. Катализатор ретінде көп атомды спирттер қолданылды. Ұсақталған композициялардың магниттік қасиеттері өлшенді. Көрсетілгендей, МХБ кезінде кварцтың жаңа қасиеттері нанодеңгейлік процестік қарау есебінен пайда болды.

Түйін сөздер: кварц, механохимиалық белсендіру, қасиеттері, магниттік өтімділік, электр әсері.

В. К. Бекбаева[1], А. Т. Канаев[1], Лошын Зы[2], Г. П. Метакса[3], Н. Жалгасулы[3]

[1]Казахский национальный аграрный университет, Алматы, Казахстан,
[2]Кульджинский педагогический университет (КНР),
[3]Институт горного дела им. Д. А. Кунаева, Алматы, Казахстан

ОСОБЕННОСТИ ИЗМЕНЕНИЯ ФИЗИЧЕСКИХ СВОЙСТВ КВАРЦА В ПЕРЕМЕННЫХ ЭЛЕКТРИЧЕСКИХ ПОЛЯХ

Аннотация. В работе представлены результаты экспериментальных работ по механо-химической активации (МХА) кварца. МХА проводили с разной продолжительностью от 3 до 20 мин. В качестве катализаторов использовали многоатомные спирты. Измерены магнитные свойства диспегированных композиций. Показано, что новые свойства кварца при МХА возникают за счет процессов наноуровня рассмотрения.

Ключевые слова: кварц, механо-химическая активация, свойства, магнитная проницаемость, электрическое воздействие.

Information about authors:

Bekbayeva Vinera Koshanovna, PhD, Kazakh National Agrarian University, Almaty, Kazakhstan

Kanaev Ashimhan Toktasynovich, Candidate of Biological Sciences, Kazakh National Agrarian University, Almaty, Kazakhstan; ashim1959@mail.ru

Xinze Luo, Kuldzhinsk Pedagogical University; 643389520@qq.1com

Metaksa Galina Pavlovna, Doctor of Technical Sciences, D. A. Kunaev Mining Institute, Almaty, Kazakhsta; gmetaksa@mail.ru

Nariman Zhalgassuly, Head of the Department of "Ecology and Safety of Mining", Doctor of Technical Sciences, D. A. Kunaev Mining Institute, Almaty, Kazakhstan

REFERENCES

[1] Bokiy G.B. Crystal chemistry. Moscow State University, 1960. 840 p.

[2] Handbook of the Chemist. Vol. 1 // Ed. V. P. Nikolskiy. M-L., 1070 p.

[3] Krasilnikov V.A. Sound and ultrasonic waves in air, water and solids. M., 1960. 560 p.

[4] Khodakov G.S. The physics of grinding. M.: Nauka, 1972. 308 p.

[5] Berestetskaya I.V., Bystrikov A.V. Mechanochemistry of the surface of quartz // Kinetics and catalysis, HH1, 1 edition. P. 1019-1022.

[6] Metaksa G.P., Clays, Quartzites and shungites of Kazakhstan. Ecological aspect. Almaty, 2006. 146 p.

[7] Kolbanev I.V., Butyagin P.Yu. Study of the process of quartz dispersion by the EPR method // Mechanoemission and mechanochemistry of solids. Frunze: Ilim, 1974. P. 215-217.

[8] Lapteva Ye.S., Yusupov T.S. Physico-chemical changes of layered silicates in the process of MCA. Novosibirsk, 1981. 88 p.

[9] Metaksa G.P., Mofa N.N. Mechano-chemical properties of natural aluminosilicates. Analytical review. Almaty, 1995. 22 p.

[10] Beresteckaja I.V., Bystrikov A.V. Mehanohimija poverhnosti kvarca // Kinetika i kataliz, HH1, vyp. 1. P. 1019-1022.

[11] Koroleva S.M., Arhipenko D.K., Grigor'eva T.N., Jusupov T.S. Obrazovanie struktur, podobnyh ß-kvarcu i ß-kristobalitu pri mehanicheskoj aktivacii a-kvarca // Tez. dokl. XI Vses. simp. po mehanohimii i mehanojemissii TT. Chernigov, 1990. Vol. 2. P. 7-8, 454.

[12] Metaksa G.P. Gliny, Kvarcity i shungity Kazahstana. Jekologicheskij aspekt. Almaty, 2006. 146 p.

[13] Kolbanev I.V., Butjagin P.Ju. Izuchenie processa dispergirovanija kvarca metodom JePR // Mehanojemissija i mehanohimija tverdyh tel. Frunze: Ilim, 1974. P. 215-217.

[14] Lapteva E.S., Jusupov T.S. Fiziko-himicheskie izmenenija sloistyh silikatov v processe MHA. Novosibirsk, 1981. 88 p.

[15] Metaksa G.P., Mofa N.N. Mehano-himicheskie svojstva prirodnyh aljumosilikatov. Analiticheskij obzor. Almaty, 1995. 22 p.

[16] Radcig V.A. Paramagnitnye centry na poverhnosti raskola kvarca // Kinetika i kataliz. 1979. Vol. 20, N 2. P. 456-464.

[17] Gorobec L.Zh., Gorobec V.I., Kulebakin V.G. i dr. Issledovanie mehanicheskoj aktivacii magnetitovyh kvarcitov v razlichnyh izmel'chitel'nyh apparatah // Tez. dokl. VIII Vses. simp. po mehanojemissii i mehanohimii TT. Tallin, 1981. P. 159-160.

[18] Paje A.Ja., Ujbo L.Ja., Hint I.A. O nekotoryh jeffektah, voznikajushhih pri dezintegratornom dispergirovanii kvarca // Dokl. AN SSSR. 1971. Vol. 199, N 1. P. 66-68.

[19] Isaev V.A. Termicheskie prevrashhenija molochno-belogo kvarca. M.: MGGU, 2003. 99 p.

[20] Rjabikin Ju.A., Zashkvara O.V., Mofa N.N., Chervjakova O.V., Mansurov Z.A. Magnitnye svojstva dioksida kremnija, modificirovannogo v mehanicheskom reaktore // Zhurnal NAN RK. 2001. P. 358-359.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 73 – 79 **https://doi.org/10.32014/2019.2518-170X.9**

UDC 538.9:539.8

E. A. Dmitriyeva, D. M. Mukhamedshina, K. A. Mit',
I. A. Lebedev, I. I. Girina, A. I. Fedosimova, E. A. Grushevskaja

Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan.
E-mail: dmitriyeva2017@mail.ru, muk-daniya@yandex.ru,
konstantin-mit@yandex.ru, lebedev692007@yandex.kz

DOPING OF FLUORINE OF TIN DIOXIDE FILMS SYNTHESIZED BY SOL-GEL METHOD

Abstract. Optical properties, surface resistance, adsorption sensitivity to ethanol vapor and the structure of SnO_2 nanofilms synthesized by the sol-gel method are considered in the article. An increase in the adhesion of films to the surface of a glass substrate with the addition of NH_4F has been observed. Films obtained from the sol with the addition of NH_4F have a 4-5% higher transparency than the films obtained from the sol without additives. An increase in the adhesion of films, synthesized with the addition of NH_4F, to the surface of the glass substrate was observed. The presence of F^- ions in the SnO_2 matrix is shown as additional sources of free charge carriers. Films obtained both from the sol and with the addition of ammonium fluoride exhibit a nonlinear dependence of the resistance on temperature characteristic of SnO_2. The film obtained from the sol consists of globules, separately standing or grouped. The addition of ammonium fluoride to the sol leads to the formation of a dendritic structure of the films. Films obtained both from the sol without additives and with the addition of NH_4F can be used as a sensitive element in gas analyzers to determine small concentrations of ethanol vapor. An important technical result that is a decrease in the response time to 2 seconds for ethanol vapor for both films with addition of NH_4F and without additives, is obtained. However, in order to determine concentrations from 0.1 to 0.6 mg/l, films synthesized from a sol with the addition of NH_4F are more preferred.

Key words: fluorine doping, sol-gel technology, tin oxide, structure, thin films, sensitivity to ethanol.

Introduction. Sol-gel technology is used in the production of foam for firefighting [1], the creation of continuous refractory fibers [2], to produce porous materials that are used as sorbents, catalysts or catalyst carriers [3]. The conversion of sols to gels is the basis of the latest nanotechnologies for the production of ceramic ultrafiltration membranes, optical and anticorrosion coatings, photographic materials, highly dispersed abrasives and other materials with unique properties and controlled structure [4-9].

Composite systems based on tin dioxide are a promising material for the creation of film coatings for use as active layers in gas analytical equipment [10-14]. To improve the functional properties, the films are doped. The decisive influence on the energy of surface centers is made by the defectiveness of the crystal structure (the degree of deviation from stoichiometry) [15]. Doping leads not only to the introduction of the necessary element, but also to a change in the structure and morphology of the surface of the films [16].

In this paper, the main functional properties of thin films of tin dioxide obtained from finely divided sol are investigated. The effect of the addition of NH_4F on the transparency, surface resistance, structure, and adsorption sensitivity to ethanol vapor of thin SnO_2 films is considered.

Experiment. Microscope glass slides with the following dimensions were used as the substrate for the deposition of films: length - 7.6 cm, width - 2.6 cm, height - 0.1 cm. These slides were washed with a liquid detergent, then with running water, and after that they were rinsed with distilled water. They were washed in rubber gloves to avoid contamination from contact with the skin of the hands. Then glass slides were air dried.

Ethanol (96%) was chosen as the solvent for the preparation of solutions, since it wets the glass surface better than water, has a low evaporation temperature and a high dielectric constant to ensure the dissociation of precursors. Anhydrous tetrachloride of tin was used as a reagent.

The sol of tin oxide was prepared from a solution of $SnCl_4$ in ethanol. Tin acid was completely precipitated by the addition of NH_4OH. The resulting tin-acid gel was stirred at a speed of 160 rpm and heated in parallel to 100°C to remove solvents and tin-oxide-bound water. The procedure lasted 11 hours. A white powder was obtained.

The powder of tin oxide was mixed with ethanol. Tin dioxide concentration in the solution was 0.13 mol / l. The contents of the vessel were stirred at a speed of 100 rpm (revolutions per minute) without heating until the precipitate completely transferred into solution. The procedure lasted 4 hours.

The fluorinating agent-ammonium fluoride (NH_4F) was added to the sol of tin oxide. The ratio of tin ions to fluorine ions was 10/4. The NH_4F crystals in the ethanol of tin dioxide were dissolved during 2 hours of stirring at 140 rpm with 35°C heating. The resulting sols started to coagulate 30 minutes after the stop of the flask rotation. Before applying each layer, the flask was shaken until its contents became uniform and transparent.

The sols were applied to the entire surface of the glass substrate and rotated by a centrifuge rotor to a speed of 3000 rpm for 3-5 seconds. Substrates with the remaining thin layer of sol were dried using an infrared emitter at a temperature of 80°C for 2-3 minutes. Then the sample was placed in a muffle furnace and annealed at a temperature of 400°C for 15 minutes to fix the layer on the substrate. After cooling, the next layer was applied. In total, 15 layers were applied.

Results and discussion. The thickness of the films after application of 15 layers was estimated from the change in the mass of the sample. When calculating the film thickness, the following formula was used:

$$d = \frac{m_{sample} - m_{sub}}{\rho_{SnO_2} \cdot S_{sub}}, \quad (1)$$

where d is the thickness of the film, m_{samle} is the mass of the sample, m_{sub} is the mass of the glass substrate, is the density of cassiterite taken as 7,0 g/cm^3, S_{sub} is the area of the glass substrate.

The calculated thickness of the films obtained from the sol was 60±7 nm. The films synthesized from the sol with the addition of ammonium fluoride had a larger design thickness of 90±7 nm. Since the conditions for the deposition of films on the surface of the glass substrate were the same, it is possible to assume an increase in the adhesion of the film to the substrate when NH_4F is added. In the previous work [17], films synthesized from a solution of stannous tetrachloride in ethanol were considered, their calculated thickness was 250±7 nm, under equal conditions of precipitation. It can be concluded that the formation of tin acid in the form of a gel directly on the surface of the glass substrate leads to a denser film with stronger adhesion properties than films obtained from sols containing individual dispersion particles.

Optical properties. Glasses coated with a film synthesized both from sol without additives and with the addition of NH_4F are transparent, with a white tinge and uniform throughout the surface. A photograph of the samples is shown in figure 1.

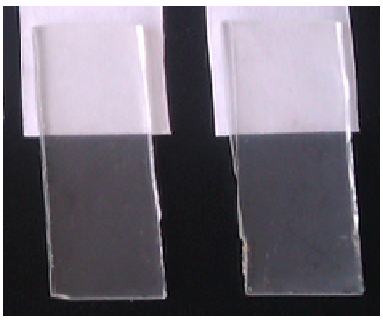


Figure 1 – Photo of samples of glasses with deposited SnO_2 films.

Left – film obtained from the sol without additives. Right – film synthesized from the sol with the addition of NH_4F

Figure 2 shows the transmission spectra of the investigated films. As can be seen from figure 2, in the visible part of the spectrum, the transparency of the films obtained from the sol varies from 58.1% at a wavelength of λ = 380 nm to 74.4% at λ =780 nm. Transparency of films synthesized from sol with the addition of NH_4F is 57.5% at λ =380 nm and 77.1% at λ =780 nm. At maximum sensitivity of the human eye to electromagnetic radiation (λ=555 nm), the films have a transparency of 70 and 71%. Transparency of films with increasing wavelength increases to 85 and 86%. Films obtained from the sol with the addition of NH_4F in the wavelength range from 550 to 2300 nm have a transparency 4-5% higher than the films obtained from the sol without additives. Optical excitation of electrons in a semiconductor thin-film structure does not have any noticeable effect on the semiconductor [18]. However, determination of the optical parameters of the layer and its thickness is possible, if the transmission spectrum demonstrates interference fringes. As the thickness of the films decreases, the interference extrema are removed from each other [19]. In our case, interference fringes on transmission spectra are not observed, which may be due to the absorption in the film or to the scattering of electromagnetic radiation from uneven surfaces.

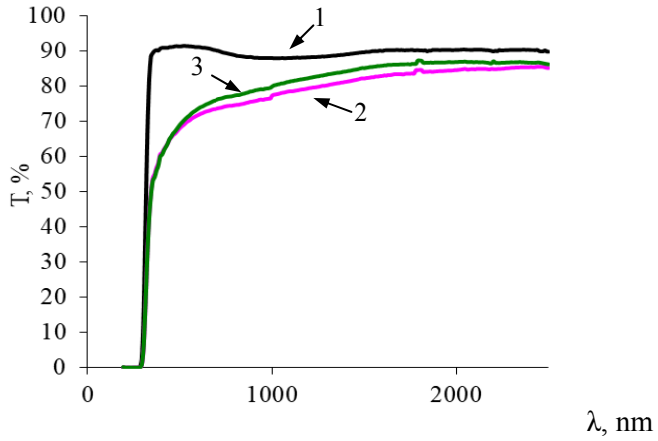


Figure 2 – Transmission spectra of tin dioxide films:
1 – glass substrate; 2 – film obtained from sol without additives; 3 – film synthesized from a sol with the addition of NH_4F

Surface resistance. The surface resistance of the films was measured at room temperature by the Van der Pauw method. The films obtained from the sol had a surface resistance of 78.9±6.9 kΩ/square. Films synthesized from the sol with the addition of ammonium fluoride had a surface resistance of 69.4±8.3 kΩ/square. The decrease in the surface resistance confirms the inclusion of F^- ions in the SnO_2 matrix [20] as additional sources of free charge carriers. The high resistance of the samples can be due to the small calculated film thickness. Belousov et al. [21] noted an increase in the resistance of films synthesized from solutions after gelling.

The dependence of film resistance on temperature, which is used in thin-film thermistors, is of practical importance. Figure 3 shows the temperature dependence of the resistance of the investigated films. It can be seen that the films obtained both from the sol and with the addition of ammonium fluoride exhibit a nonlinear dependence of the resistance on temperature, which is characteristic of SnO_2. When heated, the kinetic energy of the valence electrons rises, a disruption of individual bonds occurs, and the number of electrons that are released increases, and the resistance decreases (the initial part of curves 1.2 in figure 3).

At a temperature of 120°C, adsorption and chemisorption of oxygen from the air by the oxygen vacancies of the SnO_2 film begin to predominate. The formation of chemisorbed oxygen molecules (O_2^-, O^-, O^{2-}) requires the transition of electrons from the conduction band to the surface states, which leads to a decrease in the concentration of free charge carriers, and so the decrease in resistance stops (a flat section on curves 1 and 2 in figure 3).With a further increase in temperature from 260°C and higher, the scattering of free charge carriers on structural defects is affected, and the resistance begins to grow.

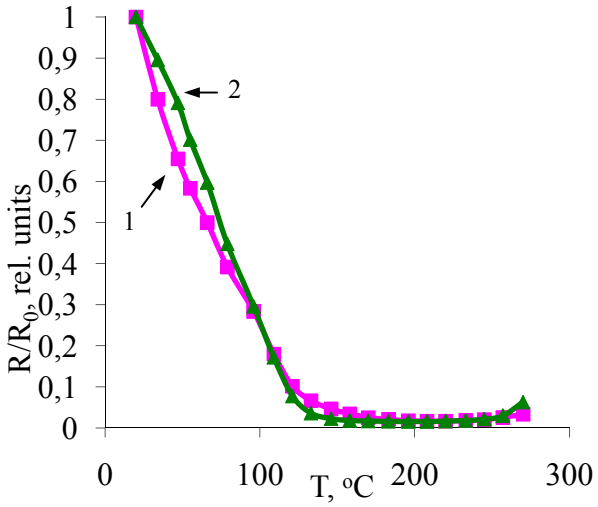


Figure 3 – Dependence of resistance on temperature:
1 – film obtained from sol without additives; 2 – film synthesized from a sol with the addition of NH_4F

Structure of the films. Figure 4 shows the surface images of the investigated films. It can be seen that the film obtained from the sol consists of globules separately standing or grouped. The size of separately standing globules is of the order of 5μm. It can be assumed that this type corresponds to the dispersed phase of SnO_2 obtained in solution. The presence of free space between globules can cause high resistance of the films, as well as it can be a source of light scattering. The addition of NH_4F led to the formation of the dendritic structure of the films. Separate globules are not observed. The free space between the structures reaches 10-15μm. The resulting structures do not exclude the presence in the film of many chaotically oriented crystallites of SnO_2.

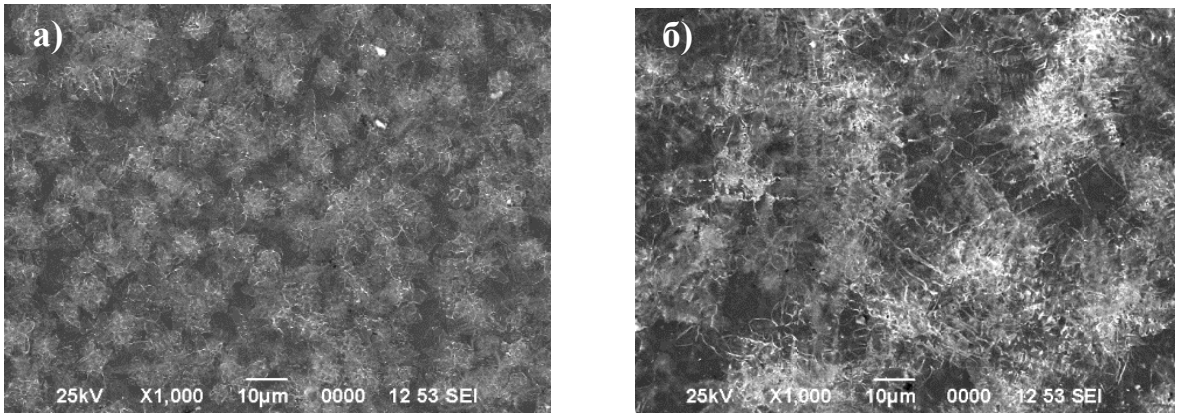


Figure 4 – Surface topography of SnO_2 films:
a – film obtained from sol without additives; b – film synthesized from sol with the addition of NH_4F

Sensitivity to ethanol vapor. The sensitivity to ethanol vapor was determined as the ratio of film resistance in pure air to the film resistance in the presence of ethanol vapor of a certain concentration and it was carried out in two stages. At the first stage, the sample temperature T_s was set, at which the maximum sensitivity of the film under study to ethanol vapor was achieved. At the second stage, at the temperature found, the change in film resistance was measured under the action of various concentrations C_{eth} of ethanol vapor.

Figure 5a shows the temperature dependence of the sensitivity of thin SnO_2 films to ethanol vapor at a concentration of 1mg/l. Films obtained from sol without additives begin to exhibit sensitivity (R_0/R =1.02) at a temperature of 160°C.

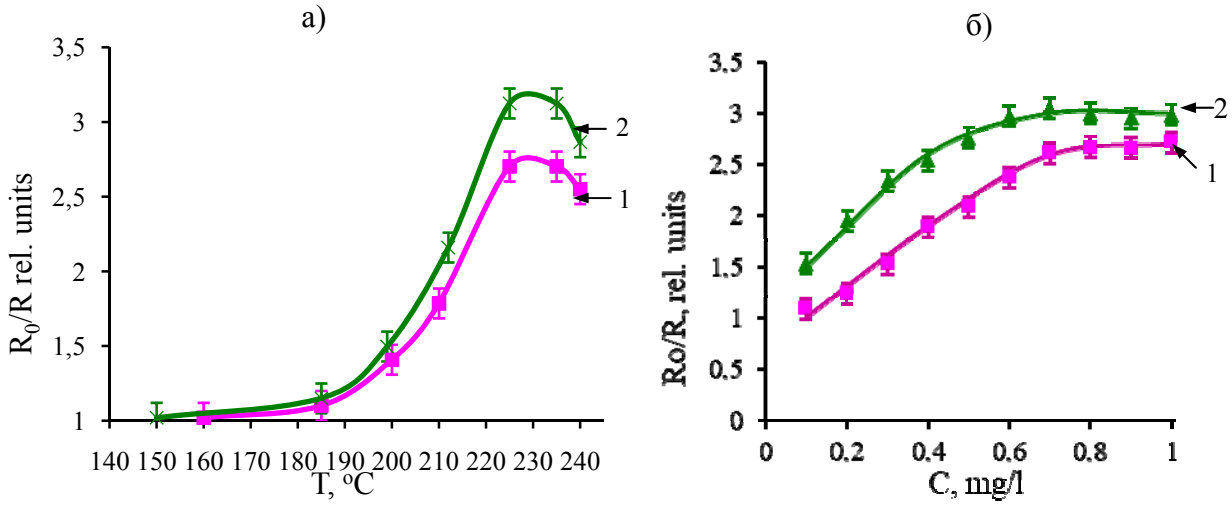


Figure 5 – Sensitivity of thin SnO_2 films to ethanol vapor:
1 – film obtained from sol without additives; 2 – film synthesized with the addition of NH_4F;
a) on different sample temperatures at the ethanol concentration of C_{eth}=1mg/l;
b) on different concentrations of ethanol at the sample temperature of T_s=230°C

Fluorine doping led to a decrease in the temperature, at which a change in the resistance of the films was detected in the presence of ethanol vapor, and it was 150°C. At this temperature, the horizontal section of the curves of the film resistance versus temperature begins (figure 3). This indicates the reaction of chemisorbed oxygen molecules on the surface of films with ethanol molecules. Further increase in substrate temperature leads to an increase in sensitivity. The maximum sensitivity was observed at a substrate temperature of 230°C.

An increase in substrate temperature above 230°C leads to a decrease in sensitivity. The sensitivity of films synthesized from the sol of tin oxide without additives was 2.7±0.1 rel. units at a temperature of 230°C. For films with the addition of ammonium fluoride, it was 3.0±0.1 rel. units. The increase in film sensitivity may be due to an increase in the amount of SnO_2 particles on the surface of which adsorption-desorption reactions occur, due to an increase in the contact between individual sol particles and the formation of a dendritic structure.

Figure 5b shows the sensitivity versus the concentration of ethanol vapor. It can be seen that films obtained from sol without additives do not have sensitivity to ethanol vapor of 0.1mg/l, and films doped with fluorine have a sensitivity of 1.5 rel. units. An increase in the concentration of ethanol vapor leads to an increase in sensitivity. When ethanol vapors of concentrations of 0.6-0.7mg/l and above are used, the sensitivity of the films varies within the limits of measurement accuracy.

The effect of the same change in the film resistance for various gas concentrations is related to the "saturation" of the active centers on which adsorption-desorption reactions occur. That is, all the centers of chemisorbed oxygen, which are on the surface of the film, are already involved in the interaction with ethanol, and so a further increase in the concentration of ethanol does not lead to an increase in the released electrons.

Thus, films obtained both from the sol without additives and with the addition of NH_4F can be used as a sensitive element in gas analyzers to determine small concentrations of ethanol vapor. However, in order to determine concentrations from 0.1 to 0.6 mg/l, films synthesized from a sol with the addition of NH_4F are more preferred.

One of the important parameters for the gas analyzer equipment is the response time of the sensor. Serially produced breathalyzers (in particular: Pft-838 digital, Breathalyzer at65s, Breathalyzer 2017, Professional Breath Alcohol Tester, Pft-642s 2017 popular mini) have a response time of about 5 seconds. The response time is 90% of the time for which the film resistance reaches a minimum value when ethanol vapor is released. Films obtained both from the sol without additives and with the addition of NH_4F have a response time to ethanol vapor absorption of 1mg/l in concentration of less than 2 seconds. Thus, an important technical result is obtained, that is a decrease in the response time to 2 sec.

Conclusion. An increase in the adhesion of films to the surface of a glass substrate on the addition of NH_4F into sol has been observed. Films obtained from the sol with the addition of NH_4F are 4-5% more transparent than the films obtained from the sol without additives. The presence of F^- ions in the SnO_2 matrix is shown as additional sources of free charge carriers. The film obtained from the sol consists of globules, separately standing or grouped. The addition of NH_4F led to the formation of the dendritic structure of the films.

The technical result is consisted in decreasing the response time to 2 seconds to ethanol vapor for films obtained both from the sol without additives and with the addition of NH_4F. Films obtained from sol with the addition of NH_4F are more preferable for use as a sensitive element in gas analyzers, for determination of ethanol vapors from 0.1 to 0.6 mg/l.

The work was carried out with the financial support of the Ministry of Education and Science of the Republic of Kazakhstan in the framework of the project of BR05236404.

Е. А. Дмитриева, Д. М. Мухамедшина, К. А. Мить, И. А. Лебедев, И. И. Гирина, А. И. Федосимова, Е. А. Грушевская

Физика-техникалық институты, Сәтбаев университеті, Алматы, Қазақстан

ЗОЛЬ-ГЕЛЬ ӘДІСІМЕН СИНТЕЗДЕЛГЕН ҚАЛАЙЫ ДИОКСИДІ ҚАБЫРШАҒЫН ФТОРМЕН ЛЕГІРЛЕУ

Аннотация. Мақалада золь-гель әдісімен синтезделген SnO_2 наноқабыршақтың және этанолдың буының адсорбциялық сезгіштігі, үстіңгі қабатының кедергісі және оптикалық қасиеттері қарастырылды. Шыны төсеніштің бетіне NH_4F қоспасымен қосу барысында, қабыршақтың адгезиясының ұлғаюы анықталды. NH_4F қоспасымен алынған қабыршақтар, қоспасыз алынған қабыршақтардан 4-5% жоғарғы мөлдірлі қасиеті бар. SnO_2 матрицасындағы F^- иондарының болуы, еркін заряд тасымалдаушыларының қосымша көзі ретінде көрсетілді. Зольмен алынған және аммоний фторидының қоспасынан алынған SnO_2 қабыршағы, температура бойынша кедергінің сызықты емес тәуелділігі сипаттамасын көрсетеді. Зольмен алынған қабыршақ, жекеленген немесе топтастырылған глобулдан тұрады. Зольмен қоспасыз және NH_4F қоспасымен алынған қабыршақтарды, этанол буының шағын концентрациясын анықтау үшін, газды анализаторда сезгішті элемент ретінде қолдануға болады. NH_4F қоспасымен және қоспасынсыз алынатын қабыршақтары үшін,этанол буының кему уақытының әсері 2 секунд болатын, маңызды техникалық нәтижесі алынды. Алайда, 0,1–0,6 мг/л аралығындағы концентрацияны анықтау үшін, зольмен және NH_4F қоспасымен алынған қабыршақтары қолайлы болып келеді.

Түйін сөздер: фтормен легірлеу, золь-гель технологиясы, қалайы оксиді, жұқа қабыршақтар, этанолға сезгіштігі.

Е. А. Дмитриева, Д. М. Мухамедшина, К. А. Мить, И. А. Лебедев, И. И. Гирина, А. И. Федосимова, Е. А. Грушевская

Физико-технический институт, Сатпаев университет, Алматы, Казахстан

ЛЕГИРОВАНИЕ ФТОРОМ ПЛЕНОК ДИОКСИДА ОЛОВА СИНТЕЗИРОВАННЫХ ЗОЛЬ-ГЕЛЬ МЕТОДОМ

Аннотация. В статье рассмотрены оптические свойства, поверхностное сопротивление, адсорбционная чувствительность к парам этанола и структура нанопленок SnO_2, синтезированных золь-гель методом. Пленки, полученные из золя с добавлением NH_4F, имеют на 4-5% более высокую прозрачность, чем пленки, полученные из золя без добавок. Обнаружено увеличение адгезии пленок, синтезированных с добавлением NH_4F, к поверхности стеклянной подложки. Показано наличие ионов F^- в матрице SnO_2 в качестве дополнительных источников свободных носителей заряда. Пленки, полученные как из золя, так и с добавлением фторида аммония демонстрируют характерную для SnO_2 нелинейную зависимость сопротивления от температуры. Пленка, полученная из золя, состоит из глобул, отдельно стоящих или сгруппированных. Добавление фторида аммония к золю привело к образованию дендритной структуры пленок. Пленки, полученные как из золя без добавок, так и с добавлением NH_4F, могут быть использованы в качестве чувствительного элемента в газоанализаторах, для определения малых концентраций паров этанола. Получен важный технический результат – уменьшение времени отклика до 2 секунд к парам этанола как для пленок с добавлением NH_4F, так и без добавок. Однако, для определения концентраций от 0,1 до 0,6 мг/л более предпочтительны пленки, синтезированные из золя с добавлением NH_4F.

Ключевые слова: легирование фтором, золь-гель технология, оксид олова, структура, тонкие пленки, чувствительность к этанолу.

Information about authors:

Dmitriyeva E. A., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; dmitriyeva2017@mail.ru; https://orcid.org/0000-0002-1280-2559

Mukhamedshina D. M., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; mukdaniya@yandex.ru; https://orcid.org/0000-0003-2513-6855

Mit' K. A., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; konstantinmit@yandex.ru; https://orcid.org/0000-0002-0078-6723

Lebedev I.A., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; lebedev692007@yandex.kz; https://orcid.org/0000-0002-7562-9925

Girina I.I., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; https://orcid.org/0000-0002-4706-5261

Fedosimova A.I., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; https://orcid.org/0000-0001-9607-6074

Grushevskaja E.A., Institute of Physics and Technology, Satbayev University, Almaty, Kazakhstan; https://orcid.org/0000-0001-6745-5462

REFERENCES

[1] Lebedeva N.Sh., Taratanov N.A., Barinova E.V. (2017) Promising materials [Perspektivnye materialy] 5: 45-55. (In Rus.).

[2] Zimichev, A.M., Varrik, N.M., Sumin, A.V. (2017) Proceedings of RSRIAV [Trudy VIAM] 1: 1-6. (In Rus.).

[3] Akpan U.G., Hameed B.H. (2010) The advancements in sol–gel method of doped-TiO_2 photocatalysts, Applied Catalysis A: General, 375: 1–11. DOI: 10.1016/j.apcata.2009.12.023.

[4] Pronin I. A. (2012) Young Scientist [Molodoj uchenyj] 5: 57-60. (In Rus.).

[5] Sevast'janov E.Ju., Maksimova N.K., Novikov V.A., Rudov F.V., Sergejchenko N.V., Chernikov E.V. (2012) Physics and technology of semiconductors [Fizika i tehnika poluprovodnikov] 46(6): 820-828. (In Rus.).

[6] Millon E., Nistor M., Hebert Ch., Davila Y., Perrière J. (2012) Phase separation in nanocomposite indium tin oxide thin films grown at room temperature: on the role of oxygen deficiency, J. Mater. Chem, 22: 12179-12185. DOI: 10.1039/c2jm16753k.

[7] Hwang S., Kim Y.Y., Lee J.H., Seo D.K., Lee J.Y., Cho H.K. (2012) Irregular Electrical Conduction Types in Tin Oxide Thin Films Induced by Nanoscale Phase Separation, J. Am. Ceram. Soc., 95(1): 324–327. DOI: 10.1111/j.1551-2916.2011.04791.x.

[8] Korotcenkova G., Cho B.K., Gulina L.B., Tolstoy V.P. (2012) Gas sensor application of Ag nanoclusters synthesized by SILD method, Sensors and Actuators B, 166: 402– 410. DOI: 10.1016/j.snb.2012.02.081.

[9] Xiaoli Ji, Weiwei Lou, Qi Wang, Jianfeng Ma, Haihong Xu, Qing Bai, Chuantong Liu, Jinsong Liu (2012) Sol-Gel-Derived Hydroxyapatite-Carbon Nanotube/Titania Coatings on Titanium Substrates, Int. J. Mol. Sci., 13: 5242-5253. DOI: 10.3390/ijms13045242.

[10] Ponomareva A.A. (2013) Hierarchically organized porous gas-sensitive layers of the SnO_2-SiO_2 system obtained by the sol-gel method [Ierarhicheski organizovannye poristye gazochuvstvitel'nye sloi sistemy SnO_2-SiO_2, poluchennye zol'-gel' metodom]. Dissertation, St. Petersburg.

[11] KadhimImad H., Abu Hassan H., Abdullah Q.N. (2016) Hydrogen Gas Sensor Based on Nanocrystalline SnO_2 Thin Film Grown on Bare Si Substrates, Nano-Micro Lett.8(1):20–28 DOI 10.1007/s40820-015-0057-1.

[12] Fedorenko G., Oleksenko L., Maksymovych N., Skolyar G. and Ripko O. (2017) Semiconductor gas sensors based on Pd/SnO_2 nanomaterials for methane detection in air, Nanoscale Research Letters.12:329. DOI 10.1 186/s11671-017-2102-0.

[13] Sokovykh E.V., Oleksenko L.P., Maksymovych N.P. and Matushko I.P. (2017) Influence of conditions of Pd/SnO_2 nanomaterial formation on properties of hydrogen sensors, Nanoscale Research Letters. 12:383. DOI 10.1 186/s11671-017-2152-3.

[14] Korotcenkov G., Brinzari V., Cho B.K. (2016) In_2O_3- and SnO_2-based thin film ozone sensors: fundamentals, Journal of Sensors, ID 3816094, 31p. DOI: 10.1155/2016/3816094.

[15] Pronin I.A., Averin I.A., Aleksandrova O.A., Moshnikov V.A. (2013) Sensors and systems [Datchiki i sistemy] 3: 13-16. (In Rus.).

[16] Kanunnikova O.M., Murav'ev A.E., Mihajlova S.S. (2007) Glass and ceramics [Steklo i keramika] 6: 28-31. (In Rus.).

[17] Dmitrieva E.A., Mukhamedshina D.M., Beisenkhanov N.B., Mit' K.A. (2014) The Effect of NH_4F and NH_4OH on the Structure and Physical Properties of Thin SnO_2 Films Synthesized by the Sol-Gel Method, Glass Physics and Chemistry, 40:31–36. DOI: 10.1134/S1087659614010076.

[18] Karpov A.G., Klemeshev V.A., Trofimov V.V. (2015) SPbSU Bulletin [Vestnik SPbGU] 4:13-26. (In Rus.).

[19] Kondrashin V.I. (2016) Determination of SnO_2 thin optically transparent films' thickness by the envelope method, Engineering sciences. Electronics, measuring equipment and radio engineering, 2(38):93–101. DOI 10.21685/2072-3059-2016-2-8.

[20] Deva Arun Kumar K., Valanarasu S., Jeyadheepan K., Hyun‑Seok Kim, DhanasekaranVikraman (2018) Evaluation of the physical, optical, and electrical properties of SnO_2: F thin films prepared by nebulized spray pyrolysis for optoelectronics, Journal of Materials Science: Materials in Electronics, 29:3648–3656. DOI: 10.1007/s10854-017-8295-2.

[21] Belousov S.A., Nosov A.A., Men'shikova T.G., Rembeza S.I. (2016) Bulletin of the Voronezh State Technical University [Vestnik Voronezhskogo Gosudarstvennogo Tehnicheskogo Universiteta] 12(2): 22-25. (In Rus.).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 80 – 89 **https://doi.org/10.32014/2019.2518-170X.10**

UDC 547.992.2

O. K. Beysenbayev[1], S. I. Umirzakov[3], A. S. Tleuov[1], B. M. Smaylov[1], A. B. Issa[1], Kh. Dzhamantikov[3], B. S. Zakirov[2]

[1]M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan,
[2]Institute of General and Inorganic Chemistry, Tashkent, Uzbekistan,
[3]I. Zhahaev Kazakh Research Institute of Rice, Kyzylorda, Kazakhstan.
E-mail: oral-kb@mail.ru, pniiaesx@mail.ru, Tleuov@mail.ru, baha_uppr@mail.ru, isa.aziza@mail.ru, kz_ris@mail.ru, ionxanruz@mail.ru

OBTAINING AND RESEARCH OF PHYSICAL AND CHEMICAL PROPERTIES OF CHELATED POLYMER-CONTAINING MICROFERTILIZERS ON THE BASIS OF TECHNOGENIC WASTE FOR RICE SEED BIOFORTIFICATION

Abstract. The way of obtaining the chelated polymer-containing microfertilizers on the basis of technogenic waste is developed. The optimum conditions of their obtaining with the use of water-soluble polyelectrolytes are established. Element composition of the cottrell dust and brown coal was studied by mean of scanning electron microscope ISM-6490-LV (JEOL, Japan). The mechanism of formation of chelated polymer-containing microfertilizers by elemental analysis and electron microscopy was studied. It was found that mainly in microfertilizers, structure formation occurs in the form of an amorphous structure with a small inclusion of metals. The characteristics of microelements and their physiological significance before and after biofortification in the cultivation of rice grain have also been studied. At the same time it is established that the resulting microfertilizer, along with potassium and sodium humates, also contains Ba, Fe, Mn, Ti and Mg. These trace elements are involved in the formation of the crop and determine its qualitative and quantitative components, i.e., are rich in trace elements that activate the action of enzymes, hormones and vitamins.

The received microfertilizers are characterized by the high content of humic substances which participate in structurization of the soil layer which is around the biofortified of seeds, accumulation of nutritious elements and minerals in a form, available to plants, promote regulation of geochemical streams of metals in water and soil ecosystems. In the end, all this provides a living organism with mineral substances and vitamins, which affects the protective functions of a living organism, to a large extent, activates its immune properties.

Keywords: chelate polymer-containing microfertilizers, technogenic waste, cottrell dust, humic acid, esterified derivatives of the hydrolyzed polyacrylonitrile.

Introduction. In accordance with the norms, which developed by the Kazakh Academy of Nutrition, the annual demand of the Republic of Kazakhstan for rice is 132.6 thousand tons per year (8.5 kg/year for 1 person). The statistics for 2008-2013 shows growth tendency in consumption of rice, and the percentage ratio of production of the peeled rice annually decreases in the ratio with the imported volumes. Therefore, in the near future not only remain, but the deficiency of this major food product even more will amplify [1-4]. It is also necessary to note that the satisfaction of the growing need of the population of the globe for food is the main problem of the present. This problem gains more and more acuity in developing countries where the increase in population advances a production gain. Due to small opportunities of expansion of acreage of crops now by further increase in agricultural production his comprehensive intensification is only. Today search of new nontoxical and highly effective mineral fertilizers and the chelate of microfertilizers which can be used successfully at cultivation of agricultural raw materials and also for the solution of narrower, but very important problem - receiving materials with the increased contents the essential of minerals is extremely relevant.

Along with this, some plants show the increased need for certain minerals, and microfertilizers provide a balanced set of minerals for requirements of various cultures [1, 2].

Nutrition of modern man is characterized by an increased content of cereals, potatoes, confectionery, and insufficient intake of milk, meat, fish, fresh vegetables, fruits. This indicates an insufficient supply of the body with vitamins and minerals. Mineral compounds affect the protective functions of a living organism, largely providing its immune properties. Microelements, primarily activate the action of enzymes, hormones, vitamins and thus participate in all types of metabolism [5-7].

From positions of the classical theories stated by Frenkel Ya.I. and Landau L.D., [8, 9] the absence of anions in solution have to change qualitatively mobility of cations and it is essential to change processes of formation of interfaces of a liquid and firm phase in respect of essential decrease in coefficient of a superficial tension that in turn will create thicker adsorptive layer of the dissolved connections on an interface (the surface of the parenchymal tissues of the leaf plate, the meristem membrane, the seed coat, etc.). In this regard, use of the amphoteric polyelectrolytes with complex-forming groups i.e. hydrolyzed and the modified polyacrylonitriles promote the formation of stable helated complex compounds with metal ions [10].

The presence of water-soluble polyelectrolytes in the system leads to the formation of thick films at the interface, causing an increase in the chemical potential gradient, which in turn forms directed flows into plant tissues and then through the membranes of the plasmolemma into the cytoplasm.

Methods. The way of obtaining the chelated polymer-containing microfertilizers of the Helafos series [11, 12] on the basis of technogenic waste is developed for the cardinal solution of the above-stated tasks: cottrell dust and brown coal of the Lenger field.

Element composition of the cottrell dust and brown coal was studied by mean of scanning electron microscope ISM-6490-LV (JEOL, Japan).

Chemical composition was calculated on the basis of elemental composition which was obtained from the spectra of scanning electron microscopy.

Results. The chemical composition of the cottrell dust is shown in table 1.

Table 1 – Chemical composition of cottrell dust

Composition, %										Specific surface, sq.m/g
The substances which are a part of cottrel dust	sq.m/g	CaO	MgO	SiO_2	Al_2O_3	F	Na_2O K_2O	Fe_2O_3	Σ	
Rich slime	37,5	8,0	3,0	26,0	10,1	2,1	10	1,52	98,22	

Element and mineralogical composition of withdrawal of brown coal of the Lenger field are given in figure 1, in table 2.

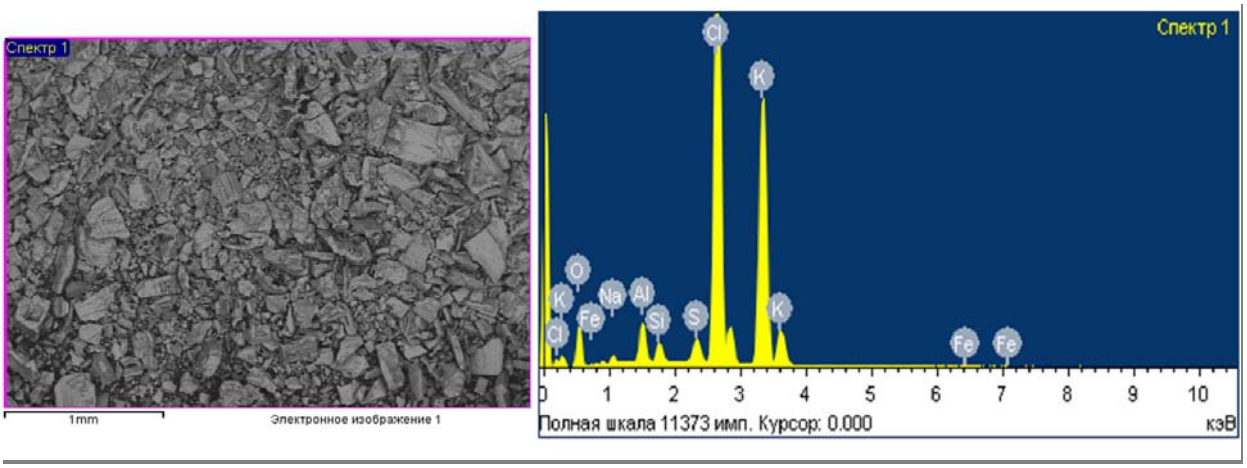


Figure 1 – Elemental composition and microstructure of a sample of brown coal of the Lenger field

Table 2 – Element and mineralogical structure of a sample of brown coal of the Lenger field

Element	Weight, %	Oxides	Elemental composition, converted to oxides, %
O	55,17		
Na	0,23	Na_2O	0,31
Mg	0,36	MgO	0,59
Al	10,60	Al_2O_3	20,03
Si	21,11	SiO_2	45,15
S	3,34	SO_3	8,35
K	1,31	K_2O	1,58
Ca	1,85	CaO	2,59
Ti	0,67	TiO_2	1,12
Fe	5,39	Fe_2O_3	7,41

From the figure 1 and from table 2 it is visible what in element structure of a sample of brown coal of the Lenger field contains in %: Al - 10,6, Si - 21,11, Fe - 5,39, Mg - 0,36, Ti - 0,67, etc. Such maintenance of elements as a part of brown coal is enough for his use as initial raw materials for receiving humic acids and on their basis of microfertilizers. Receiving humates is carried out from dumps of brown coal of the Lenger field by oxidation by 1% KOH or NaOH solution (environment 12,0 pn) [13, 14]. The oxidation of brown coal is carried out at a reaction mixture temperature of 80 °C for 2 hours, the weight ratio of alkali to crushed coal being 0.125 ÷ 0.150: 1. To produce humic acid, humates were precipitated with a 5% solution of hydrochloric acid, then filtered in a nutch filter (the pH of the filtrate was 0.85).

As a part of the emitted humic acid, besides organic compounds, contain as well mineral substances. For definition of an inorganic component the received humic acid was exposed to calcination at 500 °C. The element and mineralogical structure of the received cindery rest was analyzed on a raster electronic microscope. Results of researches are given in table 3 and in figure 2.

Table 3 – Mineralogical composition of a sample of solution of the evaporated humic acid

Element	Weight, %	Elemental composition, converted to oxides, %	Weight, %
O	23,68	–	–
Na	1,06	Na_2O	1,43
Al	2,70	Al_2O_3	5,1
Si	1,28	SiO_2	2,74
S	1,51	SO_3	3,77
Cl	34,52	–	–
K	34,97	K_2O	42,14
Fe	0,28	Fe_2O_3	0,40

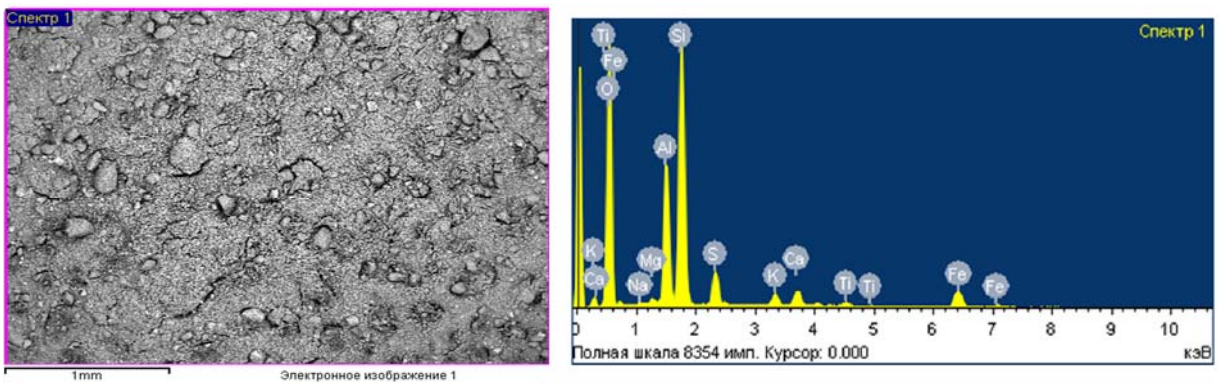


Figure 2 – Elemental composition and microstructure of a sample of the evaporated humic acid

From figure 2, it is visible that the investigated ashes have difficult and crystal mineral structure. Colourless detrital and fragmental crystals of a rhombic and cubic gabitus are characteristic of potassium and sodium chlorites. The intermediate fine-grained structure with some isometricity of tabletless colorless crystals is characteristic of aluminosilicate potassium compounds. Fine granular clusters of crystals characterize the presence of insignificant inclusions of aluminum silicates in the microstructure of the test sample, and dark, fossil, diffuse structures are characteristic of insignificant inclusions of iron silicates. Availability of sulfur up to 1.2% is obligatory for all humic acids that is confirmed in this case. The lack of phosphorus which content usually reaches 0,5%, is explained by the fact that initial raw materials for receiving humic acids were coal mining waste. Rather large amount of potassium and chlorine is explained by the fact that when leaching initial raw materials potassium hydroxide was used, and the humates received at the same time were acidified by hydrochloric acid.

To increase in content of the general phosphates and enrichment of finished product minerals are added to initial raw materials 1% of boric acid, 1% of sulfate of copper, 1% of sulfate of iron, 0,5% of sulfate of manganese, 1% of ammonium molybdate. Process is carried out in the temperature-controlled reactor from stainless steel with the mixer and a shirt at a temperature of 60 °C within 60 minutes. The received mix is filtered in the Nutsche filter and for receiving the chelating microfertilizers it is used a liquid component. Then add 0.2% of esterified derivatives of the hydrolyzed polyacrylonitrile (EPPAN) to the received solution of 25 cm^3 (pH = 4.16).

To increase the content of total phosphates and to enrich the finished product with microelements, 1% of boric acid, 1% of copper sulfate, 1% of ferrous sulfate, 0.5% of manganese sulfate, 1% of ammonium molybdate are added to the feed. The process is carried out in a thermostated stainless steel reactor with a stirrer and jacket at a temperature of 60°C for 60 minutes. The resulting mixture is filtered in a nutch filter and a liquid component is used to prepare the chelating microfertilizers. Then 0.2% of the ethylenated derivatives of hydrolyzed polyacrylonitrile (EPPAN) are added to the resulting 25 cm^3 solution (pH = 4.16).

The chemism of process of decomposition of cottrel dust in acidic environment of water humic acid can be described by the following equation:

$$Ca_5(PO_4)_3F + 8 \text{ humic acid} + 4H_2O = H_3PO_4 + 4Ca(\text{humate})_2 + Ca(H_2PO_4)_2 + HF$$

Use of humic acid for decomposition of mix of cottrel dust and also EPPAN will allow to exclude sulfuric acid from process and to reach contents of assimilable phosphates in a finished liquid product to 10%, in a firm product up to 12,5%. Element and mineralogical compositions of chelate polymer-containing microfertilizers are presented in table 4.

Table 4 – Elemental and mineralogical composition of a sample of chelate polymer-containing microfertilizer

Element	Weight, %	Oxides	Weight, %
C	28,75	–	–
O	36,64	–	–
F	1,89	–	–
Na	1,23	Na_2O	1,66
Mg	0,74	MgO	1,22
Al	0,76	Al_2O_3	1,44
Si	3,58	SiO_2	7,66
P	13,34	P_2O_5	30,56
S	0,22	SO_3	–
Cl	8,65	–	10,42
K	3,40	K_2O	4,76
Ca	0,11	CaO	0,14
Mn	0,42	MnO	0,60
Fe	0,28	Fe_2O_3	0,35

From table 4 it is visible that the developed polymer-containing chelate microfertilizer also has in structure minerals and minerals necessary for the normal growth and development of plant (K_2O – 4.76%, P_2O_5 – 30.56%). The element composition and a microstructure of a sample of chelated polymer-containing microfertilizer are presented in figure 3.

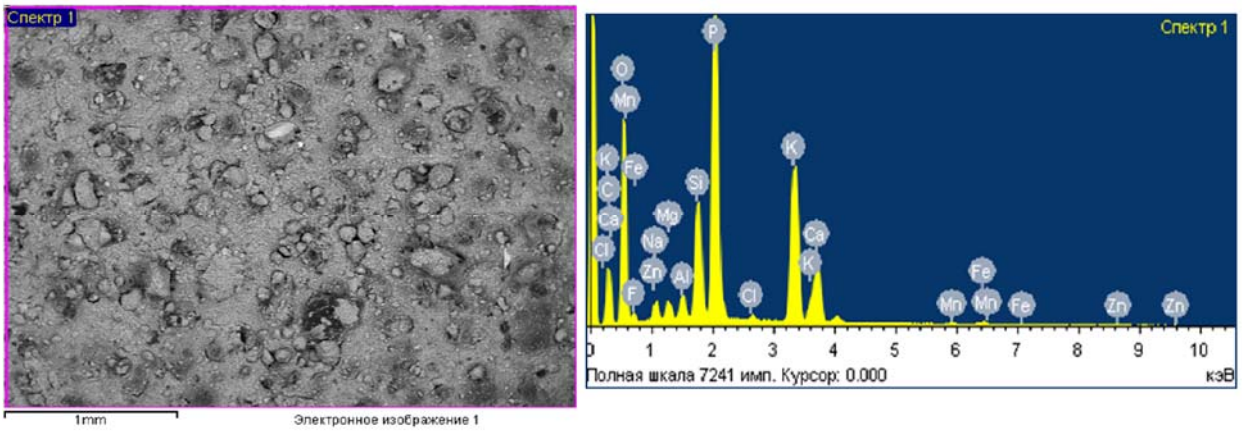


Figure 3 – Element composition and microstructure of a sample of chelated polymer-containing microfertilizer

Results of microscopic pictures (figure 3) reflect the results received when carrying out the element analysis. At the same time presence of the hydrolyzed polyacrylonitrile provides formation of granular crystal structure the chelated of microfertilizers.

Rice seed biofortification process before crops on fields of LLP "I.Zhahaev Kazakh Research Institute of Rice" is carried out and also process of influence of chelated microfertilizer throughout a stage of growth of a plant and its blossoming (rice) on the subsequent productivity of culture has been investigated. For biofortification of seed of rice connections complex the chelated polymer-containing of microfertilizers are chosen.

The following operational stage the chelated polymer-containing of microfertilizers is spraying of plants during growth and blossoming. Results of field tests on identification of efficiency complex the chelated polymer-containing of microfertilizers received on the basis of phosphoric slime, cottrell dust have been received. Results of field tests have shown that the productivity of seed of rice increases by 3 times, i.e. from 25 to 75 grain/vessel.

The element composition and the microscopic picture of samples of rice before introduction of microfertilizers are given in figure 4 and in table 5.

In table 6 and also in figures 4 there are presented element composition of grains before crops of rice after biofortification with application the chelate of microfertilizers. From figure 4 it is visible that after biofortification of seed rice is dispersed and as a result becomes more small granular with increase in an amorphous part.

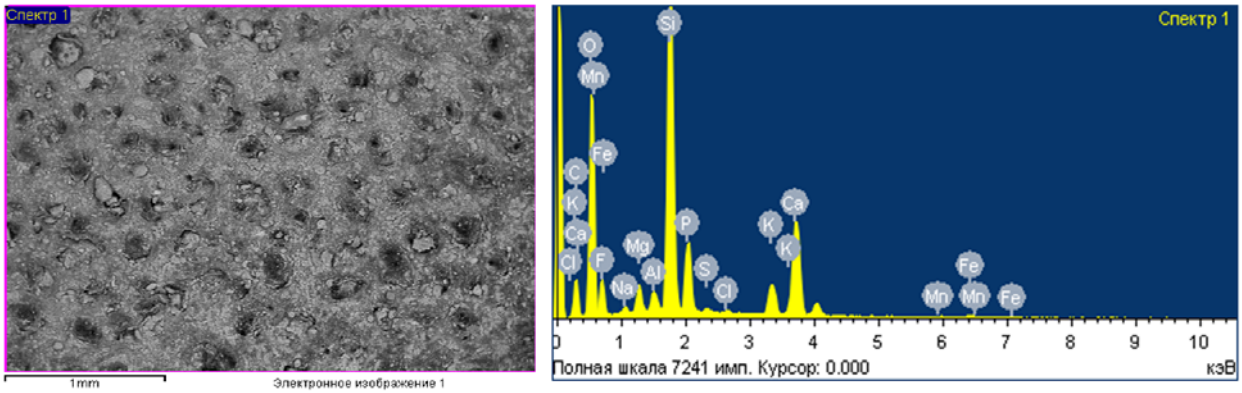


Figure 4 – Element composition and microstructure of grains before crops of rice after biofortification

Table 5 – Element composition of a sample of rice before biofortification

Element	Weight, %	Oxides	Weight, %
O	51,81		
Na	0,62	Na_2O	0,83
Mg	1,56	MgO	2,59
Si	32,19	SiO_2	68,85
P	6,00	P_2O_5	13,75
S	0,44	SO_3	0,48
K	6,18	K_2O	7,45
Ca	1,18	CaO	1,65

Table 6 – Element composition of grain before crops of rice after biofortification

Element	Weight, %	Oxides	Weight, %
O	46,79		
Na	0,22	Na_2O	0,29
Mg	4,16	MgO	6,9
Al	3,31	Al_2O_3	6,25
Si	11,57	SiO_2	24,75
P	5,96	P_2O_5	13,65
S	0,29	SO_3	0,72
K	1,84	K_2O	2,22
Ca	19,30	CaO	27,00
Ti	0,47	TiO_2	0,78
Mn	0,24	MnO	0,31
Fe	5,69	Fe_2O_3	8,14
Ba	0,14	BaO	0,16

The element and mineralogical composition and also rice seed sample microstructure after harvesting with use of the chelated polymer-containing microfertilizer is presented in table 7 and in figure 5. From figure 5 it is visible that the rice seed sample microstructure after harvesting is condensed and as a result of which gets a crystal form with reduction of an amorphous part. It is explained by the fact that probably the large role is played by presence at composition of seed of rice of various minerals: Na – 0.40, Mg – 1.76, Al – 0.14, Si – 31.80, P – 5.29, S – 0.84, K – 6.77, Ca – 0.93, Mn – 0.17, Fe – 0.09.

Table 7 – Elemental and mineralogical composition of rice grain after harvest with the use of chelated polymer-containing microfertilizer

Element	Weight, %	Oxides	Weight, %
O	51,80	–	–
Na	0,40	Na_2O	0,54
Mg	1,76	MgO	2,92
Al	0,14	Al_2O_3	0,26
Si	31,80	SiO_2	68,02
P	5,29	P_2O_5	12,12
S	0,84	SO_3	2,1
K	6,77	K_2O	8,16
Ca	0,93	CaO	1,3
Mn	0,17	MnO	0,22
Fe	0,09	Fe_2O_3	0,13

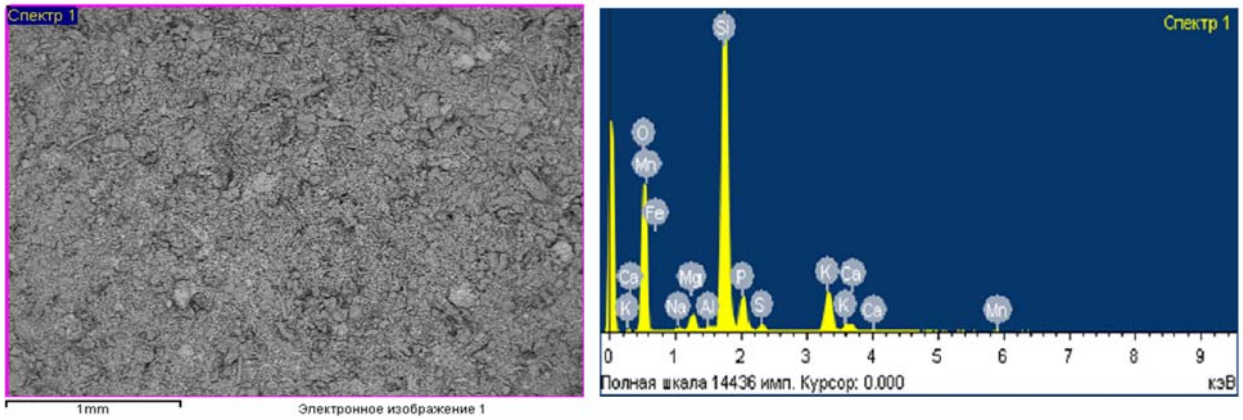


Figure 5 – Element composition and microstructure of sample of rice grain after harvest with the use of chelated polymer-containing microfertilizer

Besides the presence of humic acid and polyelectrolytes leads to the formation of crystal structure of more condensed type and confirms the previous microstructures (figures 3, 4). Thus, colourless detrital and fragmental crystals of a rhombic and cubic gabitus are formed, are characteristic of chlorites of potassium and sodium. The intermediate fine-grained structure with isometricity of tabletless colorless crystals is characteristic of aluminosilicate potassium compounds. Small granular clusters of crystals characterize the presence of insignificant inclusions of aluminum silicates in the microstructure of the test sample, and dark, fossil, diffuse structures are characteristic of insignificant inclusions of iron silicates.

Element composition of rice seed before biofortification (figure 4, table 5) following (%): Na – 0.62, Mg – 1.56, Si – 32.19, P-6.0, K – 6.18, Ca – 1.18.

Mineralogical composition of seed of rice after biofortification (figure 5, table 6) the following: Na – 46,79, Mg – 4,16, Al – 3,31, Si – 11,57, P – 5,96, S – 0,29, K – 1,84, Ca – 19,30, Ti – 0,47, Mn – 0,24, Fe – 5,69, Ba – 0,14. From figure 6, table 7 it is visible that the maintenance of elements of seed of rice after assembly of a harvest with use of changes a little Na – 0.40, Mg – 1.76, Al – 0.14, Si – 31.80, P – 5.29, S – 0.84, K – 6.77, Ca – 0,93, Mn – 0.17, Fe – 0.09.

It is visible that the developed microfertilizer contains humates of potassium and sodium with additive Fe, Mn, Si, Mg, K, Sa, Al, P. These minerals participate in formation of a harvest and define its qualitative and quantitative components that are rich with the minerals intensifying effect of enzymes, hormones and vitamins. Finally, all this provides with mineral substances and vitamins a live organism that influences his protective functions and substantially makes active its immune properties.

Data of vegetative experiment on rice of a grade of Marzhane on production crops and the experimental site of LLP "I.Zhahaev Kazakh Research Institute of Rice" are presented in table 8. At the same time the productivity of rice increases within 65-74 g/a vessel.

Table 8 – Data of vegetative experiment on rice of a grade of Marzhane

#	Options experience	Productivity (g/vessel) on repetitions				S-sum harvests	M-average harvest	M	D from helofos-1
		I	II	III	IV				
1	Without fertilizers	33	31	20	20	104	26	–	–
2	N-Na	54	53	50	43	200	50	–	–
3	NP-Na, Pc- background	68	65	55	50	240	60	–	–
4	Biofortified seeds of Chelafos-1 (100 ml)	76	76	74	70	296	74	74	14
5	Biofortified seeds of Chelafos -2 (500 ml)	76	74	70	72	292	73	73	13
The sum of harvests on repetitions		307	299	269	269	1132	56,6	Мп1~57	

On the basis of the above, the developed technology of receiving the chelated polymer-containing microfertilizer can be recommended at cultivation of grain crops, in particular, of rice.

Discussion. The way of receiving the chelated polymer-containing microfertilizer on the basis of technogenic waste - cottrell dust, brown coal of the Lenger field is developed and optimum conditions of their receiving with use of water-soluble polyelectrolytes are established.

Rice seed biofortification by chelated polymer-containing microfertilizer before crops on the experimental site of LLP "I.Zhahaev Kazakh Research Institute of Rice" is carried out.

The mechanism of formation of chelated polymer-containing microfertilizers by elemental analysis and electron microscopy was studied. It was found that mainly in the presence of chelated polymer-containing microfertilizers, structure formation occurs in the form of an amorphous structure with a partial appearance of sections of the crystallization structure. The characteristic of minerals and their physiological value before biofortified at rice seed cultivation is studied.

The received microfertilizers are characterized by the high content of humic substances which participate in structurization of the soil layer around the biofortified of seeds, accumulation of nutritious elements and minerals in a form, available to plants, promote regulation of geochemical streams of metals in water and soil ecosystems.

Influence of the microfertilizers developed the chelated polymer-containing on growth and productivity of a stalk of rice is investigated.

At the same time it is shown that increase in productivity of rice within 65-74 g/vessel demonstrates that in the initial stage the main role is played by oxides of manganese and magnesium as a part of chelated polymer-containing microfertilizers that provides high viability and germination of seeds due to rice seed biofortification. Contents as a part of microfertilizers of iron regulate breath of plants, cellular exchange, photosynthesis and resistance to chlorosis when spraying pesticides.

Thus, on the basis of the above, it can be concluded that the chelated polymer-containing microfertilizer actively participates in biochemical processes, i.e. activates enzymes, exhibits photosynthetic activity, participates in the biosynthesis of chlorophyll, affects carbohydrate and nitrogen metabolism, increases resistance to diseases, accelerates the growth and development of plants. All these processes ultimately contribute to higher yields and, especially, the quality of the rice grain.

The developed microfertilizer containing humates of potassium and sodium with additive Fe, Mn, Si, Mg, K, Sa, Al, P in a chelated form of the improved structure has shown excellent operational properties, and it can be recommended to application at cultivation of rice in the southern regions.

Acknowledgements. The work was financially supported by the Ministry of Education and Science of the Republic of Kazakhstan.

О. К. Бейсенбаев [1], С. И. Умирзаков [3], А. С. Тлеуов [1], Б. М. Смайлов [1], А. Б. Иса [1], Х. Джамантиков [3], Б. С. Закиров [2]

[1]М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Казақстан,
[2]Жалпы және Бейорганикалық химия институты, Ташкент, Өзбекстан,
[3]И. Жахаева атындағы Қазақ Күріш Шаруашылығы ғылыми-зерттеу институты, Қызылорда, Казақстан

КҮРІШ БИОФОРТИФИКАЦИЯСЫНА ТЕХНОГЕНДІ ҚАЛДЫҚТАРДАН АЛЫНАТЫН ХЕЛАТТЫ ПОЛИМЕРҚҰРАМДАС МИКРОТЫҢАЙТҚЫШТАРДЫҢ ФИЗИКА-ХИМИЯЛЫҚ ҚАСИЕТТЕРІН ЗЕРТТЕУ

Аннотация. Техногенді қалдықтар негізінде хелатты полимеркұрамдас микротыңайтқыштарды алудың технологиялық әдісі әзірленген және сулы полиэлектролиттерді пайдалану арқылы алудың оңтайлы жағдайлары орнатылған. Бастапқы шикізат болып табылатын қоңыр көмір мен котрельді шаңның элементтік құрамдары ISM-6490-LV (JEOL, Жапония) сериялы электронды микроскоп көмегімен анықталған. Сонымен қатар электронды микроскопиялық және элементтік талдау әдісімен хелатты полимеркұрамдас микротыңайтқыштарды құралу механизмі меңгерілді.

Микротыңайтқыштардың құрылымында аморфты күйде болатын біршама металдарды ілесуі жүреді. Сондай-ақ күрішті өсіру кезінде пайдаланылатын микротыңайтқыштардың қасиеттері мен физиологиялық мәндері биофортификацияға дейін және кейінгі жағдайлары қарастылған. Алынған микротыңайтқыштардың құрамында натрий және калий гуматымен қоса Ba, Fe, Mn, Ti, Mg сияқты элементтер кездеседі. Бұл микро-

элементтер өсімдіктің өсіп, өнуіне және сандық құрамымен өнімділігін анықтайды, яғни бай микротыңайтқыштар ферменттер, гармондар және дәрумендерді белсендендіруге әрекеттендіреді.

Алынған микротыңайтқыштар құрамындағы жоғары мөлшерде болатын гумин қышқылдары топырақ қабатындағы биофортификацияланған дәндердің құрылымдық түзілуіне қатысады да, жинақталған элементтер мен микроэлементтер өсімдіктерге қолайлы күйде болып, сулы және топырақты экожүйедегі металдардың геохимиялық ағынын реттеуге қатысады. Қорыта келгенде барлығы өсімдікті минералды заттармен дәрумендермен толықтырып, тірі өсімдіктің қорғаныс қызметін жағдай жасап, оның иммундық қасиетін белгілі бір дәрежеде белсендіруге әсер етеді.

Түйін сөздер: хелатты полимерқұрамдас микротыңайтқыш, техногенді қалдықтар, котрельді шаң, гумин қышқылы, полиакрилонитрилдің этерифицирленген гидролизді туынды.

О. К. Бейсенбаев [1], С. И. Умирзаков [3], А. С. Тлеуов [1], Б. М. Смайлов [1], А. Б. Иса [1], Х. Джамантиков [3], Б. С. Закиров[2]

[1]Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,
[2]Институт Общей и Неорганической химии АН РУЗ, Узбекистан,
[3]КазНИИ рисоводства им. И. Жахаева, Кызылорда, Казахстан

ПОЛУЧЕНИЕ И ИССЛЕДОВАНИЕ ФИЗИКО-ХИМИЧЕСКИХ СВОЙСТВ ХЕЛАТНЫХ ПОЛИМЕРСОДЕРЖАЩИХ МИКРОУДОБРЕНИЙ НА ОСНОВЕ ТЕХНОГЕННЫХ ОТХОДОВ ДЛЯ БИОФОРТИФИКАЦИИ ЗЕРНА РИСА

Аннотация. Разработан способ получения хелатных полимерсодержащих микроудобрений на основе техногенных отходов и установлены оптимальные условия их получения с использованием водорастворимых полиэлектролитов. Элементный состав коттрельной пыли и бурого угля отхода был изучен растровым электронным микроскопом ISM-6490-LV (JEOL, Япония).

Изучен механизм образования хелатных полимерсодержащих микроудобрений методом элементного анализа и электронной микроскопии. При этом установлено, что в основном в микроудобрениях происходит структурообразование в виде аморфной структуры с небольшим включением металлов. Также изучена характеристика микроэлементов и их физиологическое значение до и после биофортификации при выращивании зерна риса. При этом установлено, что полученное микроудобрение, содержит наряду с гуматами калия и натрия также Ba, Fe, Mn, Ti, Mg. Эти микроэлементы участвуют в формировании урожая и определяют его качественные и количественные составляющие, т.е богаты микроэлементами, активизирующими действие ферментов, гармонов и витаминов.

Полученные микроудобрения характеризуются высоким содержанием гуминовых веществ, которые участвуют в структурообразовании почвенного слоя находящегося вокруг биофортифицированных семян, накоплении питательных элементов и микроэлементов в доступной для растений форме, способствуют регулированию геохимических потоков металлов в водных и почвенных экосистемах. В конечном итоге все это обеспечивает живой организм минеральными веществами и витаминами, что влияет на защитные функции живого организма, в значительной степени активизирует его иммунные свойства.

Ключевые слова: хелатные полимерсодержащие микроудобрения, техногенные отходы, котрельная пыль, гуминовая кислота, этерифицированные производные гидролизованного полиакрилонитрила.

Information about authors:

Beysenbayev Oral Kurganbekovich, professor, d.t.s., M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; oral-kb@mail.ru; https://orcid.org/0000-0001-9442-213X

Umirzakov Serikbai Idrysovich, General director, .t.s., academician ASHN RK, I. Zhahaev Kazakh Research Institute of Rice, Kyzylorda, Kazakhstan; pniiaesx@mail.ru; https://orcid.org/0000-0002-5484-4001

Tleuov Alibek Spabekovich, professor, d.t.s., M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; Tleuov@mail.ru; https://orcid.org/0000-0001-8534-9807

Smaylov Bakyt Matkarimovich, Doctoral student, M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; baha_uppr@mail.ru; https://orcid.org/0000-0001-7976-9776

Issa Aziza Bakytzhankyzy, lecturer, Master of Chemistry, M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; isa.aziza@mail.ru

Dzhamantikov Hasyi, Chief researcher, doctor of agriculture science, professor, I. Zhahaev Kazakh Research Institute of Rice, Kyzylorda, Kazakhstan; kz_ris@mail.ru; https://orcid.org/0000-0002-4930-0683

Zakirov Bakhtiyar Sabirjanovich, director, d.ch.s., professor, Institute of General and Inorganic Chemistry, Tashkent, Uzbekistan; ionxanruz@mail.ru; https://orcid.org/0000-0001-6664-8019

REFERENCES

[1] Kabate-Pendias A. Minerals in soils and plants. M.: World, **1989,** 456 p.

[2] Concept of "Integrated program of enrichment of food products by micronutrients and their use for prevention of occupational diseases of workers working under harmful conditions" for 2013-2017. Kiev, **2013**, p. 26-29.

[3] Kovalchuk V.P., Vasilyev V.G., Boyko L.V., Zosimov V.D. Collection of methods of a research of soils and plants. Kiev, **2010**, 252 p.

[4] Concept of the state scientific and technical program: Bioformation and functional products on the basis of plant raw materials for 2012-2016 years. Kiev, **2011**, p. 71-75.

[5] Pleshkov B.P. Biochemistry of agricultural plants. M., **1975**, 496 p.

[6] Rudakova E.V. Minerals. Receipt, transport and physiological functions in plants, **1987**, 365 p.

[7] Kudrik M.A., Stebinna K.P. Research of juices with pulp obtained from stone fruits, **2011**, N 3, p. 49-51.

[8] Landau L.D., Lifshits E.M. Statistical physics. M., **1976,** Vol. 5, 583 p.

[9] Frenkel Ya.I. Kinetic theory of liquids. Leningrad, **1975,** 592 p.

[10] Beysenbaev O.K., Isa A.B., Kovaleva A.E. Research of polyacrylonitrile saponification heterophase process mechanismin different conditions // Oriental journal of chemistry. **2015**, 31, N 4.

[11] Patent RK No. 31229 from 3/8/2015., Beysenbayev O. K., Batkayev R.I., and other. Copyright certificate № 93153 from 3/8/2015.

[12] Patent RK No. 31228 from 3/8/2015. Beysenbayev O. K., Batkayev R.I., and other. cCopyright certificate № 93142 from 3/8/2015.

[13] Nazarbek U.B., Beysenbayev OK, Besterekov S.P., Nazarbekova S.P. Humic acid of udobritelny quality – technology and results of complex researches. Scientific magazine "Vestnik KazNTU", **2015**, N 5.

[14] Myrzakhmetova B.B. Development of the production technology of complex organomineralny fertilizer on the basis of humates of local origin. The thesis for a degree of the doctor of philosophy (phD), **2012**, 152.

[15] Simahina G.O., Mikoliv T.I. Teoretichni ta praktichni aspekti zbagachennja zernovih kul'tur esencial'nimi mikroelementami // Tovaroznavstvo ta inovacii. 2011. Vip. 3. P. 272-281.

[16] Shapovalova E.N., A.V. Chromatographic methods of analysis. A methodical grant for a special course. M., **2007**. 203 p.

[17] Journal «ZERNO». Chelate microfertilizers. **2012**. February.

[18] Myrzahmetova B.B., Besterekov U. Lenger brown coals raw materials for the production of organomininеralic fertilizers // The international scientific-practical conference: «Auezov reading-8». **2009.**

[19] Rusyanova N.D. Uglehimia. M.: Nauka Publishing House, **2000**. 316 p.

[20] Rogova T.V., Syundyuova K.V., Perelomov L.V., Kamaeva O.A., Shiskova A. Yu., Blokhin I.V. Phyziko-himicheskie harakteristiki i sorbtsionnyie svoistva guminovyh veschestv buryh uglei // News of the Tula State University. Natural sciences. **2013**. Edition 2, Part 1. P. 273-280 p.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 90 – 97 **https://doi.org/10.32014/2019.2518-170X.11**

UDC

D. K. Bekbergenov, G. K. Jangulova, B. K. Bektur

Mining Institute after D. A. Kunayev, Almaty, Kazakhstan.
E-mail: kdbekbergen@mail.ru

CURRENT CONDITION AND OUTLOOKS OF SUSTAINABLE DEVELOPMENT OF CHROMITE UNDERGROUND MINING AT LOWER HORIZONS OF MINES OF THE DONSKOY MINING AND PROCESSING PLANT

Abstract. The article considers the issues of current condition and outlooks of development of underground mining of Donsk chromite mines. With the transition of mining operations to deeper levels, the geomechanical situation is getting considerably more complicated, especially for the development of stope sills that poses the need to solve the issues of developing measurements ensuring the increase in working stability. One of the most radical measures is the development of designs of artificial stope sills according to the option of development systems accepted for lower horizons of the "Ten Years of Independence" mine.

Based on the analysis of the methods for the creation of artificial stope sill on the draw and delivery level, it is proposed to develop the design with reinforced concrete stable support platform of the artificial stope sill made of concrete consolidating stowing in systems of uncontrolled block caving. At the draw and delivery level there is a bearing structure of the element of the development system that can bear extremely high mine pressure and ensure enhanced stability and reliability of transport crosscuts for the delivery of ore mass with the use of self-propelled equipment. The targeted solution of the development issue is essential at the development of chromite reserves with combined geotechnology for safe and sustainable development of underground ore mining at deep levels of deposits Millionnoye and Almaz-Zhemchuzhina of the Donskoy mining and processing plant.

Keywords: development field, technogenic collapses, underground technology, the extraction of chromium, uncontrolled caving, mass, mine technical and mining geological conditions, geomechanical conditions of the massif.

Introduction. Donskoy mining and processing plant develops chromite deposits of the South-Kempirsay massif in Western Kazakhstan, which ranks second with the reserves and is one of a kind in terms of quality, thus totally providing for the Republic's own needs in chromite raw materials and the needs of the post-Soviet countries and exporting the ore and its concentrate to foreign countries.

At present, the main volume of ore at the Donskoy mining and processing plant is produced underground at mines "Molodezhnaya" and "Ten Years of Independence" commissioned in 2001. The "Ten Years of Independence" mine hosts 84% of chromite ore of the Donskoy mining and processing plant. Only its small part occurs at the depth of from 250 to 400 m from the surface. According to the existing classification, the major volume is located at medium (up to 600 m) and deep (from 600 to 1,500 m) levels [1-3].

Taking into account geomechanical and geotechnical particularities of mining of ore deposits at deep levels and especially ore bodies of the mines "Millionnoye" and "Almaz-Zhemchuzhina" of the mine "Ten Years Of Independence", the important factors are the study of the mass behavior in the process of stoping, pattern of formation of caving areas, development of geomechanical processes, formation of pressure on supports of mine workings as well as the selection of the most rational process charts of ore deposits mining.

Great thickness of ore bodies of chromite deposits developed underground and weak stability of the ore mass and host rocks once determined the selection of the system of uncontrolled caving of ore and

superincumbent rock. At present, it is applied at both mines. However, the major reserves of the "Ten Years of Independence" mine occur at deeper levels that of "Molodezhnaya" and their development is related to high pressure in less stable rocks. As mining operations go deeper in the deposits of Donsk chromites and nears 400 ÷ 600 m, the ore and rock masses with high fracturing are classified as unstable [4-6].

In these conditions, one of the significant drawbacks of the used method of technology unavoidably results in the worsening of the geomechanical situation and distribution of mine pressure in stope sills. Due to this reason, the structural elements of draw workings of the mined block are located in the zone of high (bearing) mine pressure arising and rising with the increase in the development depth and length of the stoping front. And this complicates and raises the price of maintenance and operation of the draw level [7-9].

The methods of research. In harmony with the further development of underground mining at the Kempirsay chromite deposit, there is an interest in generalization of the current condition of the chromite ore mining at the mines. For underground mining of chromite ore, the Donskoy mining and processing plant uses the technology of ore uncontrolled caving [10-12] (figure 1), which is classified as class two of the development system according to Prof. V.R. Imenitov's classification [10].

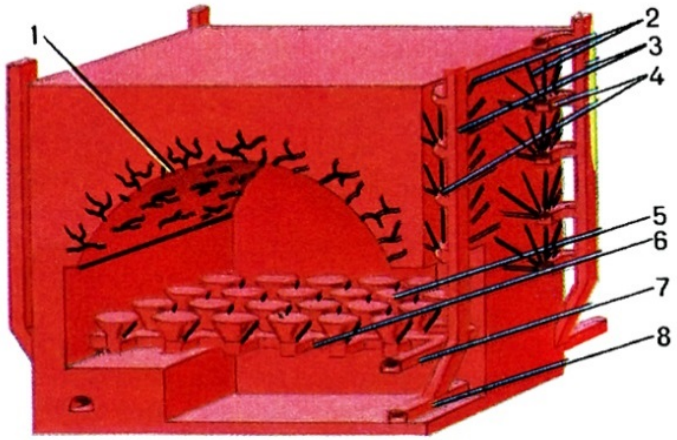


Figure 1 – Classical option of the system of ore uncontrolled block caving:
1 – Dome of the uncontrolled caving area; 2 – cutoff holes; 3 – lateral raises; 4 – drilling cuts;
5 – discharge cones; 6 – scraper drift; 7 – connecting crosscut; 8 – haulage crosscut

In spite of rather typical requirements within the technology, it provokes great interest among mining production engineers in its application due to its cheapness and simplicity since there is no need to drill holes for breaking, driving sublevels and lifting drilling and other equipment onto them. At that, it allows saving on explosives and materials, on supports of workings, ventilation and other expenses. Therefore, this technology in modern conditions remains the most appropriate and low-cost in terms of economy, efficiency and safety.

The case history of the technology at underground mines of the company *De Beers* (South Africa) revealed that the cost of mining is commensurate with the open-cast mining cost. In addition, of special interest is the practice of those working using this technology and belonging to the authors [11], as well as the description of experience of efficient operation of several foreign mining companies: diamond mines "Finch", "Premier" and "Koffiefontein" (South Africa), copper-nickel mine "North Sparks" (Australia), copper-molybdenum mine "Henderson" of the company "Climax" (USA) and mine "El Teniente" (Chili) as well as iron deposits in Ukraine in the Krivoy Rog basin.

With the transition of mining operations to deeper levels of ore mining at "Millionnoye" mine, the KAZGIPROTCVETMET project has corrected the procedure of preparation and development of reserves of the deposits of the second order of construction at the Millionnoye and Almaz-Zhemchuzhina mines. From the border of separation of applied development systems it will be mined using the system of down-rising horizontal layers using cut-and-fill stoping and self-propelled equipment.

With regards to the development system involving uncontrolled ore caving, the KAZGIPRO-TCVETMET project provides for the creation of artificial (concrete) stope sill (figure 2) at the height of

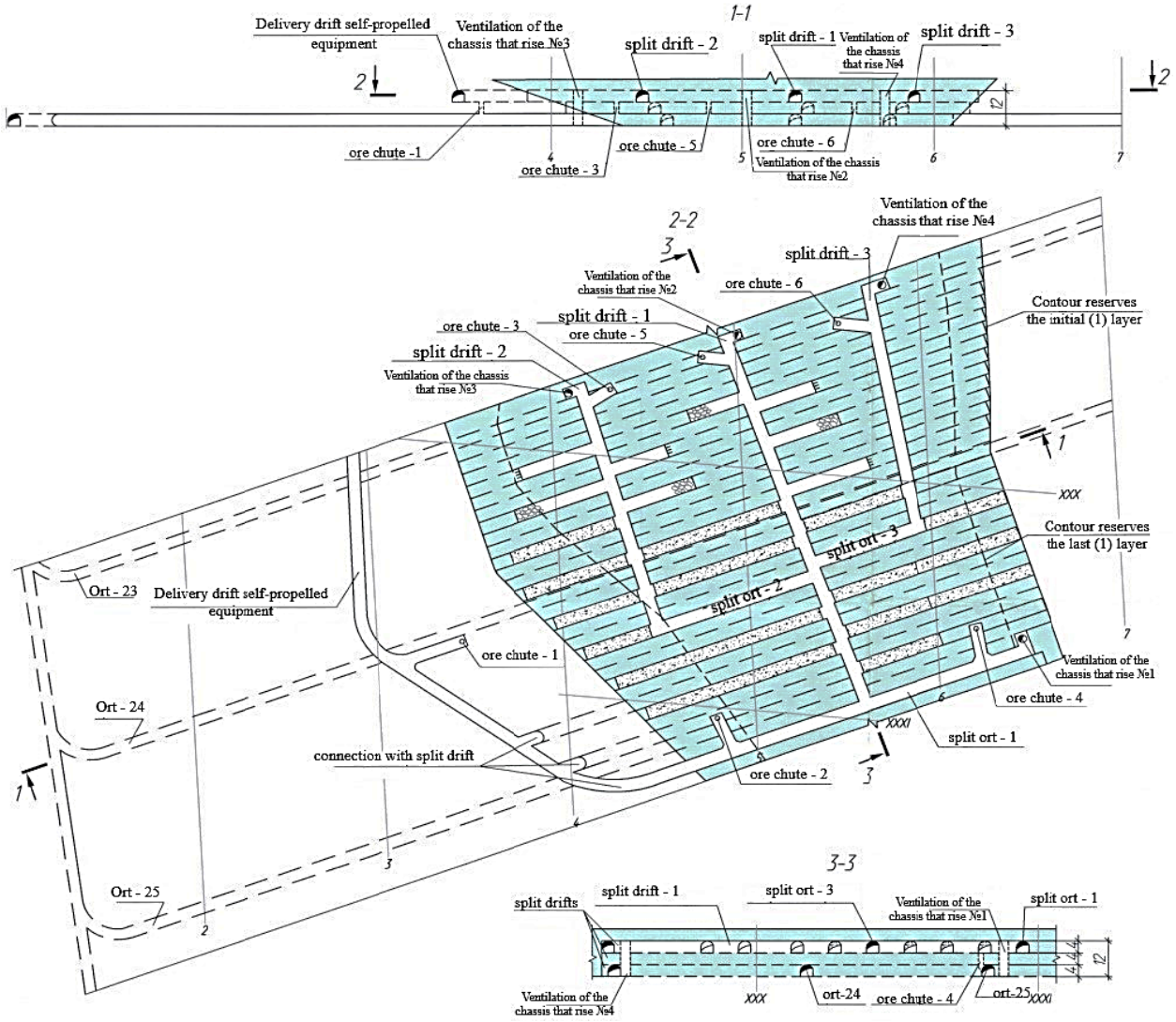


Figure 2 – System of ore block caving with artificial stope sill made of consolidating filling

12 m for the system of block caving by means of developing the reserves of the stope sill with three 4-m high filling layers. This is done with the purpose of reducing mine pressure and conserving all reserves of the block of development and face headings in the period of mining [13].

To drive and maintain development headings driven in the filling mass and to examine the strain-stress state of the filling mass and stability of headings there is very little information today related to the mining practice (at underground mines of the Arctic branch of joint-stock company "GMK" Norilskiy Nickel" in Talnakh and Octyabr deposit) [14].

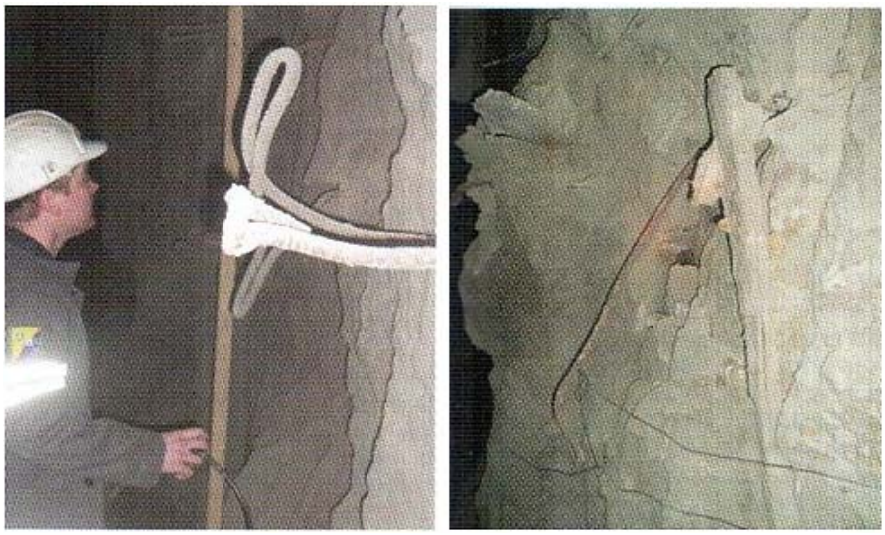
One of the perspective directions of development and improvement of process charts of preparation for blocks is allocation of development headings in the filling mass. To this end, a 1,000 m deep working was driven in the filling mass at mine 2 of the Octyabrskiy deposit, which is around 248 m long.

The deformation process of the contour mass of the heading at the development of underworking span is progressive. And as the driving increases, the deformation intensity of contour mass of workings also rises, especially in the 50-m second zone. This is accompanied with the fracturing in the concrete. Shears at the contour of the working increase and reach around 40-50 mm. In the third zone, which is around 120 m long in the filling mass, there is a sharp displacement up to 80 and more mm at the contour of the working and in the concrete there starts a process of fracture emergence and extension, fractures of layers of the filling mass. Destruction of the filling mass come in the form of sloughing zones in the sides of the working, earth spring, slip formation in the layers of the filling mass and caving of detached con-

crete slabs. Such kinds of destructions took place mainly at the sections of the working fixed with a combined support.

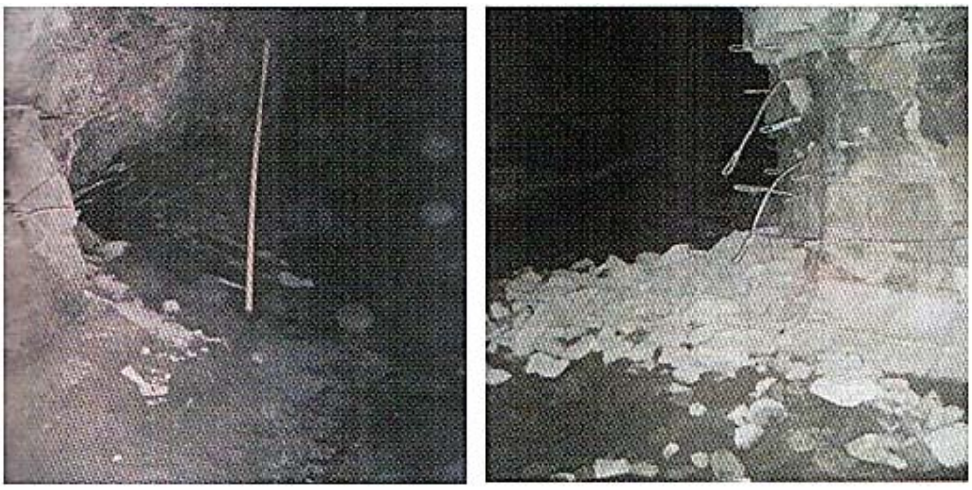
There are also destructions of the working walls driven in the filling mass at the mine "Taymyrskiy" of the Arctic branch of joint-stock company "GMK" Norilskiy Nickel" [15]. The most part of destructions in the working walls driven in the filling mass were in the middle of the working wall. At that, the wall bent inward the mass, which is evident from the wooden pole the lower part of which rests against undestroyed working wall. Figure 3a shows the initial stage of destruction of the working wall. The change of the form is accompanied by the destruction of the contour part of the filling mass. The depth of the wall destruction is around 40 cm, which is seen by the length of parts of anchors protruding from the wall (anchors are 1.8 m long). Fractures are formed in the lower part of the wall which has not yet detached from the main filling mass. Figure 3b shows on a larger scale the subsequent stage of the wall destruction with a net of large and small fractures parallel to the sidewall of the working.

Figure 4a shows "final" stage of the wall destruction in the filling mass of the working driven far from junctions. If the mine technical situation changes, the destruction of the filling mass in this place of



a *b*

Figure 3 – Stages of destruction of the working wall driven in the filling mass:
a – Initial stage of destruction of the working wall; b – Subsequent stage of the wall destruction



a *b*

Figure 4 – Final stage of destruction of the filling mass in the wall of the working:
a – Workings driven far from the junction; b – Workings driven in the filling mass

the wall can continue. At that, the depth of the wall destruction is around 2 m, which is evident from the wooden pole set at the initial contour of the wall.

Figure 4b shows the destruction of the filling mass at the section of junctions of the mine workings along the whole contour of the wall where only the roof with the incumbent lump of the filling mass is not destroyed. Besides, it was noted that staged destruction of concrete filling took place despite the fact that this exposure was fixed with horizontally established concrete bars and is inefficient since the bars turned out to be parallel to the layering. They did not connect the layers and did not enhance the stability of the concrete scour.

Based on the above-given illustrations of destruction of the filling mass and operational practice of driving the working in the filling mass at the underground mines of "Norilsk Nickel" in the Talnakh and Octyabr deposit, at the present time it is possible to mention only just-begun scientific research and practical works.

Field of application of research results. It is necessary to note that based on the research results, the most complicated in terms of geomechanics in the system of uncontrolled ore caving is workings driven in the stope sill [16-18].

In spite of a three-layer support of scraper workings, SVP 27 (interchangeable special profile) with quite dense setup of frames has not always been reliable and stable. Therefore, in the conditions of mining at lower levels of Donskoy mining and processing plant it is necessary to go over to the creation of artificial concrete stope sill [19, 20].

Widespread development of thick fractured fields resulted in the urgent need to improve the designs of stope sills with the view of considerable enhancement of their strength characteristics, stability, able to bear high dynamic loads posed by large volumes of caved ore mass. As previously noted, conventional funnel-shaped and then trench designs of stope sills in the system of uncontrolled ore caving do not demonstrate reliable resistance to both caved mass and mounting mine pressure.

At the same time, there was a need in alternative to gravity ore drawing through funnels and draw points, which is a bottleneck in highly productive caving systems. With the purpose of intensification of ore drawing process domestic mining companies have adopted vibrating mechanisms that played positive role in the growth of mining productivity.

To tackle the issues of designing artificial concrete stope sills, the staff of the Mining Institute after D.A. Kunayev developed the design of artificial concrete stope sill [21] on a stope sill-support basis ensuring sufficient reliability, stability and operability of scraping drifts.

To illustrate the process of erection of support structural elements and subsequent analytical calculations, the major working of the stope sill was considered - scraping drift with the optimal clearance of 2_{r6}=2.0 m situated at the depth of 800 m. At the first stage, in harmony with the mine technical conditions of the ore deposit development as well as thickness and accepted parameters of stopes, in particular their

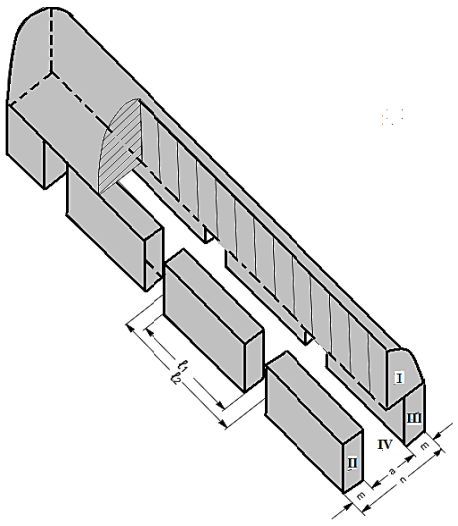


Figure 5 – Principle diagram of the concrete stope sill and sequence of its erection

height hк, the value caved rock arch hоб is calculated, which form the load on the support of workings in the stope sill. To this end, functional dependence $h_{св}=f(h_к)$ is used based on the relation:

Next, based on the established plastic range of stress, the advisability of erection of artificial stope sill is established using the parameter $h_{об} > 90\text{-}100$ m.

The principle diagram of the concrete stope sill and sequence of its erection are represented in figure 5 with a side cut for clarity of processes [22].

Discussion of results. At the erection of the design, at first service roadways I and II are driven stagewise for subsequent erection of support structures by means of filling the working s with concrete mixture with estimated bearing capacity. The design width of roadways I and II is accepted based on maximum probable loads (which will be mentioned later), namely m=2 meters or гв=1.0 m. In line with table 1, specific pressure at kH=1.0 for this working driven at the depth of H=800m in the rock mass will amount to $q_{уд}$=15.9 t/m^2, and for solid ore qуд=20.4 t/m^2. As a result, the number of framer per running meter in the first case will equal NП=1.0 pc/running meter, in the second case NП = 1.36 pc/running meter. This is true in the tough operating conditions of support SVP 22 (interchangeable special profile). The need to ensure such conditions is explained by the possibility of preliminary relief of excessive pressure caused by the formation of plastic range of stress by activating the yielding units. Later, this process favorably affects the operation of concrete supports. Thus, depending on the host rock mass (ore solid and rock mass) the permissible density of installed support frames of interchangeable special profile SVP-22 is 1.5-1.0 pc/running meter.

After driving and supporting the roadway I, it is filled with concrete mixture. At that, straight arches are installed in places of design location of draw points for the formation of the cavity of required dimension. To perform subsequent analytical calculations the following parameters have been accepted: the length of one support section=5.0m, the distance between the axis of draw points = 7.0 m (figure 4.1). Operations in roadway II are performed according to the similar chart.

After completing the operations on the workings of the first and second stage and on concrete curing during 28 days, it is possible to start operation on working III (third stage) with base width n = 6.2 m. The calculations of the support reveals that in this case to support the working it is necessary to setup a two-layer support made of interchangeable special profile SVP-27. For rock mass – 6 pc/running meter, for ore solid - 7 pc/running meter. It is necessary to note that at this stage an experimental option is considered with maximum height of caved rocks equaling $h_{об}$ = 500 m. At lesser values of hоб within 250-300 meters, structural parameters of the stope sill significantly change. The developed methodical chart allows hands down designing of calculations for real conditions.

After erecting the support, it is necessary to thoroughly cleanse the base of the working from the sides of roadways of stages I and II, to lay metal screen and lay and fasten bars of rolled steel to improve strength of ceiling of stage IV roadway (scraping drift) and improvement of connection with bearing supports [23].

Conclusions. With the transition of mining operations to deeper levels, the geomechanical situation is getting considerably more complicated, especially for the development of stope sills that poses the need to solve the issues of developing measurements ensuring the increase in working stability. One of the most radical measures is the development of designs of artificial stope sills according to the option of development systems accepted for lower horizons of the “Ten Years of Independence” mine.

Based on the analysis of the methods for the creation of artificial stope sill on the draw and delivery level, it is proposed to develop the design with reinforced concrete stable support platform of the artificial stope sill made of concrete consolidating stowing in systems of uncontrolled block caving. At the draw and delivery level there is a bearing structure of the element of the development system that can bear extremely high mine pressure and ensure enhanced stability and reliability of transport crosscuts for the delivery of ore mass with the use of self-propelled equipment.

The targeted solution of the development issue is essential at the development of chromite reserves with combined geotechnology for safe and sustainable development of underground ore mining at deep levels of deposits Millionnoye and Almaz-Zhemchuzhina of the Donskoy mining and processing plant.

Д. К. Бекбергенов, Г. К. Джангулова, Б. Қ. Бектұр

Д. А. Қонаев атындағы Тау-кен істері институты, Алматы, Қазақстан

ДӨҢ КБК ШАХТАСЫНДАҒЫ ЖЕРАСТЫ ТАУ-КЕН ЖҰМЫСТАРЫНЫҢ ҚАЗІРГІ ЖАҒДАЙЫ МЕН ДАМЫТУ МӘСЕЛЕСІ

Аннотация. Мақалада ДӨҢ хромитті шахтасының жерасты тау-кен жұмыстарының қазіргі жағдайы мен болашақта дамыту мәселесі қарастырылған. Жерасты тау-кен жұмыстарының терең деңгейжиектерде горизонттарда жүргізілуіне байланысты геомеханикалық жағдай күрделене түседі, әсіресе блоктың түпкі қазбаларында, туындаған мәселелерді шешу мақсатында қазбалардың орнықтылығын арттыруды қамтамасыз ететін іс-шараларды ойластыру қажеттілігі туындайды. Ең радикалды шаралардың бірі жасанды түп қазбалы блоктың конструкциясын әзірлеу болып табылады, қабылданған қазу жүйесінің нұсқасы «Қазақстан тәуелсіздігіне он жыл» шахтасының төменгі деңгейжиектеріне арналған.

Негізгі талдауға сүйене отырып, деңгейжиекте жасанды түп қазбалы блоктың кен шығару мен жеткізу тәсілдерін құру бойынша мәселелені шешуге бетонды-қатпалы толтырмалы темірбетонды платформалы тұрақты-тірек конструкциясын әзірлеу ұсынылады, кеннің қабатаралық өздігінен құлау жүйесінде, кен шығару мен жеткізу деңгейжиегіндегі қазу жүйесінің салмақ түсетін конструкциялық элемент ретінде қолданылады, өздігінен жүретін жабдықтарды қолданумен кен жеткізу кезінде, көліктік квершлагтердің жоғары тұрақтылығы мен сенімділігін қамтамасыз етеді.

ДӨҢ шахтасының Алмаз-Жемчужина және Миллионное кенорындарының терең деңгейжиектеріндегі горизонттарындағы кенді жерасты тәсілімен қауіпсіз және тұрақты өндіріп алуды дамыту бойынша хромит қорларын аралас геотехнологиямен пысықтауға бағытталған өзекті мәселені шешуге арналған.

Түйін сөздер: қазу жүйесі, техногендік опырылу, жерасты технологиясы, хром өндіру, өздігінен құлау, сілем, тау-кен техникасы, тау-кен геологиялық жағдай, сілемнің геомеханикалық жағдайы.

Д. К. Бекбергенов, Г. К. Джангулова, Б. К. Бектур

Институт горного дело им. Д. А. Кунаева, Алматы, Казахстан

СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ УСТОЙЧИВОГО РАЗВИТИЯ ПОДЗЕМНОЙ ДОБЫЧИ ХРОМИТОВ НА НИЖНИХ ГОРИЗОНТАХ ШАХТ ДОНГОКА

Abstract. В статье рассматриваются вопросы современного состояния и перспективы развития подземных горных работ шах донских хромитов. С переходом горных работ на глубокие горизонты геомеханическая ситуация значительно осложняется, особенно для выработок днища блока, что предопределит необходимость решение вопросов по разработке мероприятий обеспечивающих повышение устойчивости выработок. Одним из наиболее радикальных мер является разработка конструкций искусственного днища блока, по принятому варианту систем разработки для нижних горизонтов шахты «Десять лет независимости Казахстана».

На основе анализа способов по созданию на горизонте выпуска и доставки искусственного днища к решению данной проблемы предлагается разработка конструкции с устойчивоопорной железобетонной платформой искусственного днища блоков из бетонно-твердеющей закладки, при системах этажного самообрушения руды, на горизонте выпуска и доставки используется как несущая конструкция элемента системы разработки, выдерживающие экстремально высокое горное давление, обеспечивающие повышенную устойчивость и надежность транспортных квершлагов, для доставки рудной массы с использованием самоходного оборудования. Направленное решение проблемы разработки актуально при отработке хромитовых запасов с комбинированной геотехнологией для безопасного и устойчивого развития подземной добычи руды на глубоких горизонтах месторождений Миллионное и Алмаз-Жемчужина шахты ДонГОКа.

Ключевые слова: система разработки, техногенные обрушения, подземная технология, добыча хрома, самообрушение, массив, горнорудная техника, горно-геологические условия, геомеханическое состояние массива.

Information about authors:

Bekbergenov Dossanbay, candidate of technical sciences, head of the laboratory, Integrated development of mineral resources, D. Kunaev Mining Institute, Almaty, Kazakhstan; kdbekbergen@mail.ru; https://orcid.org/0000-0001-5946-6137

Jangulova Gulnar, candidate of technical sciences, assistant professor, Department of Cartography and Geoinformatics, Al-Farabi Kazakh National University, Almaty, Kazakhstan; gulnarzan@gmail.com; https://orcid.org/0000-0002-7866-1031

Bektur Bakytbek, Master of Engineering Sciences, Lecturer of the Mining Department, Kazakhstan National Research technical University after K. Satpayev, Almaty, Kazakhstan; bekturbek@bk.ru; https://orcid.org/0000-0003-0510-4995

REFERENCES

[1] Edilbaev I.B., Bitimbaev M.Zh., Zherebko L.N., Isaev M.A. Development of the Caved Zone in the Superincumbent Rock at the Development of Ore Deposits Using the System of Uncontrolled Caving at Fields of Don Chromites. Scientific and Technical Provision of Mining Production // Collection of Proceedings of the Mining Institute after D. A. Kunayev, No 68, Part I. Almaty, 2004. P. 64-66.

[2] Edilbaev I.B. Revival (1995-2005). Almaty, 2004. 274 p.

[3] Development of New Highly Efficient and Safe Technologies of Underground Mining of Ferroalloy Raw Materials at Great Depth. Stage: "Development of the Operating Procedure…" // Report on R&D, subject No 15, Mining Institute after D.A. Kunayev, Almaty, 2005. 72 p.

[4] Report on R&D "Theoretical Basics of Management of Geomechanical Condition under Pressure of Mining Operations" (final) // Head of the assignment, Doctor of engineering L. S. Shamganova, Mining Institute after D. A. Kunayev, Almaty, 2011. P. 30-35.

[5] Vozhdaev A.V., Aimbetov M.M., Tretyak A.V. Improvement of Technological Processes of Underground Mining at Mines of the Donskoy Mining and Processing Plant // Materials of the II International Scientific and Practical Conference "Current Conditions and Outlooks of Development of Mining Branches of Industry". Rudnyi, 2004. P. 35-37.

[6] Freidin A.M., Neverov A.A., Neverov S.A., Philippov P.A. Problems of Deposit Development at Great Depths. Novosibirsk, press of the Siberian Department of the Russian Academy of Sciences. 2008.

[7] Guidelines on Claculation of Loads on the Support of Mine Workings in the Conditions of Mines of the Donskoy mining and processing plant. Karaganda, 2002. 44 p.

[8] Zherebko L.N., Dzhangulova G.K., Pivovarova L.M. Formation of Cave Roof in the Superincumbent Rock Represented by Layers of Various Thickness // Scientific and Technical Provision of Mining Production. Collection of Proceedings of the Mining Institute after D. A. Kunayev, 2008. Vol. 75. P. 18-21.

[9] Zherebko L.N., Dzhangulova G.K., Pivovarova L.M. Formation of Mine Pressure in the Mass Under Caved Rocks // Proceedings of the International Conference – Press of the Institute of Physics and Rock Mechanics of the National Academy of Sciences of the Kyrgyz Republic – Bishkek, 14-15 June 2006. P. 265-267.

[10] Imenitov V.R. Processes of Underground Mining Operations at the Development of Ore Fields. M.: Nedra, 1978. 528 p.

[11] Kuzmin E.V., Uzbekova A.R. Uncontrolled Caving of Ore at the Underground Ore Mining: Tutorial. M.: Press of the Moscow Mining University, 2006. 283 p.

[12] Lomonosov G.G. Production Processes of Underground Development of Ore Fields: Tutorial for higher educational institutions. M.: Mining Book, 2013. 520 p.

[13] Correction of the Project: Explanatory Note. Vol. 2, Book 3, Part – Technological Solutions (mining, mining mechanical). KAZGIPROTCVETMET. Ust-Kamenogorsk, 2011. 118 p.

[14] Zvezdikin V.A., Smolov K.V., Nagovitcin Iu.N. Particularities of Deformation and Maintenance of Workings Driven in the Filling Mass // Mining Magazine. 2004. N 12. P. 58-60.

[15] Habulov O.Yu. Analytical Method of Determining the Ultimate Stress Limit of the Filling Mass in the Scours of Mine Workings // Mining Magazine. 2010. N 6. P. 78-82.

[16] Baikonurov O.A., Rykov A.T. Improvement of Stope Sills at Mines. M.: Nedra, 1977. 159 p.

[17] Bekbergenov D.K., Dzhangulova G.K., Aimbetov M.M., Tretyak A.V., Kabdeshev A.N. Problems and Outlooks of Uncontrolled Caving Technology with Artificial Stope Sill in the Conditions of Deep Horizons of mines of the Donskoy mining and processing plant // Mining Magazine of Kazakhstan. 2014. N 3. P. 26-30.

[18] Bekbergenov D.K., Dzhangulova G.K.,Kasymhanova K.M., Toktarov A.A., Bektur B.K. Perspective Technology of Developing Ore Reserves at Kazakhstan Mines Using the System of Uncontrolled Caving // Bulletin of the RK National Academy of Sciences. Almaty, 2016. N 6. P. 109-116.

[19] Bekbergenov D.K., Kasenov B.S., Қabdeshev A.N. Geomechanical Particularities in the Conditions of Underground Deep Mines of the Donskoy mining and processing plant // Problems and Ways of Innovative Development of Mining Industry: Materials. The Sixth International Scientific and Practical Conference. Almaty, 2013. P. 155-157.

[20] Theoretical Basics of Management of Geomechanical Condition of the Mass at the Formation of Mine Structures and Forecast of Its Behavior under the Impact of Mining Operations // Report on R&D. Funds of the Mining Institute after D. A. Kunayev. Almaty, 2009. 95 p.

[21] Author's Certificate No 79933 with regard to the Method of Erection of the Artificial Stope Sill at the Development of Unstable Ore Deposits at Great Depth. The authors of invention No 27669: Dzhangulova G.K., Zherebko L.N., Pivovarova L.M. Patent holder: Branch State Enterprise Mining Institute after D. A. Kunayev of the Republican State Enterprise "National Center for Integrated Mineral Recycling" of the Committee of Industry of the Ministry of Industry and New Technologies of the Republic of Kazakhstan. (21) 2012/0241.1 (22) 27.02.2012.

[22] Kaplunov D.R., Rylnikova M.V., Eks V.V. Major Directions and Outlooks of Development of Energy-Efficient and Environmentally Safe Geotechnologies at the Development of Fields at Great Depths // Mining Information Analytical Bulletin (Scientific Technical Magazine). 2014. N 6. P. 5-10.

[23] Zherebko L.N., Dzhangulova G.K., Pivovarova L.M. Development of the Design of the Stope Sill at the Development of Unstable Ore Bodies at Great Depths // Bulletin of the RK National Academy of Sciences. 2013. N 4. P.77-80.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 98 – 106 **https://doi.org/10.32014/2019.2518-170X.12**

UDC 669.15-198

V. M. Shevko[1], D. K. Aitkulov[2], D. D. Amanov[1], A. D. Badikova[1], M. A. Tuleyev[1]

[1]M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan,
[2]Institute of geological sciences named after K. I. Satpaev, Satbayev University, Almaty, Kazakhstan.
E-mail: shevkovm@mail.ru, dos.ait.58@mail.ru, loken666@mail.ru, sunstroke_91@mail.ru, mustafa19930508@mail.ru

THERMODYNAMIC MODELLING CALCIUMCARBIDE AND A FERROALLOY FORMATION FROM A SYSTEM OF THE DAUBABA DEPOSIT BASALT – CARBON – IRON

Abstract. The present article contains results ofthermodynamic modelling the temperature (from 900 to 2500°C) and iron content (from 0 to 8%) effect on interaction of the Daubaba deposit basalt (40,88% of SiO_2, 19,58% of CaO, 13,36% of Al_2O_3, 15,25% of FeO, 6,68% of MgO, 1,74% of Na_2O, 0,98% of TiO_2, 0,41% of MnO, 0,55% of SO_2) with carbon and formation of calcium carbide and a complex silicon and aluminium-containing ferroalloy. The investigation has been fulfilled using a software package HSC-5.1 based on a Gibbs energy minimum. It was found, that transition degree of calcium into CaC_2 at 2000^0C and 45% of C at increase in iron content from 0 to 8% decreases from 54,6% to 42,4%, and transition degree of silicon into the alloy increases and makes 88,1%. Silicon and aluminiumconcentration in the alloy and the calcium carbide capacity decrease at increase in iron quantity.87,4-89% of silicon and 50-52% of calcium can be extracted into the alloy and calcium carbide respectively from the basalt in the presence of 45% of carbon, 0-1,9% of ironand temperature of 2028-2043^0C. The ferroalloy formed contains 55-56% of Σ(Si+Al);the calcium carbide is characterised by capacity of 240-248 l/kg. The alloy containing silicon and aluminium is a complex ferroalloy – ferrosilicoaluminium of a FS45Al5 grade; the calcium carbide is related to 2-3 grades.

Keywords: basalt, reduction, carbon, temperature, thermodynamic modelling, calcium carbide, ferroalloy.

At present calcium carbide is produced in electric furnaces out of lime and coke at temperature of 1900-2100°C according to the reaction:

$$CaO + 3C = CaC_2 + CO. \quad (1)$$

The process is characterised by electric energy consumption of 2980-3350 kW·h per 1 t of calcium carbide [1, 2]. A siliceous ferroalloy is obtained at 1600-1800°C from quartz-containing raw materials by a carbothermal way in ore-thermalfurnaces. This process is characterized by power consumption from 2200 to 4750 kW·h per 1 t of a ferroalloy (depending onsilicon content in it, which changes from 25 to 45%) [3-5]. At the calcium carbide production thermal and electric losses make to 14% from the maximum power [1], and at the siliceous ferroalloy manufacture these losses make 11-14% [6]. Combination of both these processes in one electric furnace permits to reduce the thermal losses in 2 times. The combined processes have been developed for chloride sublimation of off-grade oxide ores [7-9] and processing of oxidized zinc-containing ores [10, 11]. Simultaneous production of calcium carbide and a siliceous ferroalloy may be realized from the raw materials containing SiO_2 and CaO. This raw material group includes 64,1 million tonne of Kazakhstan basalts (Daubabadeposit (19,4 m. t), Tashkursay (15,7 m. t), Dormensay (5,9 m. t), Karauzek (5,7 m. t), Kozyrevsky (3,8 m. t), Chernaya Mazarka (2,8 m. t), Dubersay (10,8 m. t)) [12]. The basalts contain 39-43% of SiO_2, 18-21% of CaO, 12-15% of Al_2O_3, 14-17% of FeO. Now these basalts are mainly used for manufacture of a fibre and a cast stone material [13], which technology is constantly improved [14-17], and also for manufacture of other production [18]. Being used the program HSC-5.1 (Reaction Equations subprogram) [19] we have preliminary calculated ΔG and found that a condition ΔG=0 for joint reduction of Ca, Si, Al oxides on the reactions

$$CaO + 2SiO_2 + Al_2O_3 + Fe2O_3 + 15C = CaC_2 + 2FeSi + 2Al + 13CO; \quad (2)$$

$$CaO + SiO_2 + Al_2O_3 + Fe + 8C = CaC_2 + FeSi + 2Al + 6CO; \quad (3)$$

is satisfied at 1738and 2092K respectively (table 1).

Table 1 – Temperature effect on ΔG (kJ) for the reactions of joint carbothermal reduction of the oxides

Reaction	Temperature, K								
	1173	1373	1673	1738	1773	1873	2073	2092	2173
2	1123,0	724,1	132,3	0	-71,0	-274,6	-679,3	-716	-879,8
3	1057,7	827,9	486,4	429,1	369,7	253,3	22,6	0	-91,9

Studying the possibility of simultaneous production calcium carbide and a silicon and aluminium-containing ferroalloy out of the Daubaba basalt comprising 40,88% of SiO_2, 19,58% of CaO, 13,36% of Al_2O_3, 15,25% of FeO, 6,68% of MgO, 1,74% of Na_2O, 0,98% of TiO_2, 0,41% of MnO, 0,55% of SO_2 has been realized by us by means of thermodynamic modelling with use of the HSC-5.1 software package, in particular the Equilibrium Composition subprogram [19]. The Daubababasalt initial weight was 100 kg. Calculation of the equilibrium is made on the basis of a Gibbs energy minimum principle taking into consideration activities of substances. The developers of the HSC-5.1 program have based on an ideology of a SGTE consortium (Scientific Group Thermodata Europe) which develops, supports and distributes the high-quality databases intended for calculation of an equilibrium composition of chemically reacting systems. The SGTE structure includes specialized scientific centers in Germany, Canada, France, Sweden, the Great Britain and the USA [20]. The error of the calculations made by means of the HSC-5.1 program makes no more than 4-6%.

Thermodynamic modelling influence of temperature (from 1000 to 2300^{0}C) and iron content (from 0 to 8% from the basalt weight) (at 45% of carbon from the basalt weight) on the equilibrium silicon distribution degree in a system of Daubababasalt (DB) – carbon – iron was carried out at pressure of 0,1MPa. The results of quantitative distribution of the silicon and calcium-containing substances are represented in figures 1 and 2.

Judging by the figures, silicon and calcium in the system are as $CaSiO_3$, Al_2SiO_5, $MgSiO_3$, TiO_2, SiO_2, FeSi, Fe_3Si, TiSi, CaSi, Si and SiO_{gas}, CaO, CaC_2, Ca_{gas}, and aluminium as Al_2SiO_5, Al_2O_3 and Al. The information about the initial temperature of formation of the compounds (T_i, ^{0}C) is given in table 2.

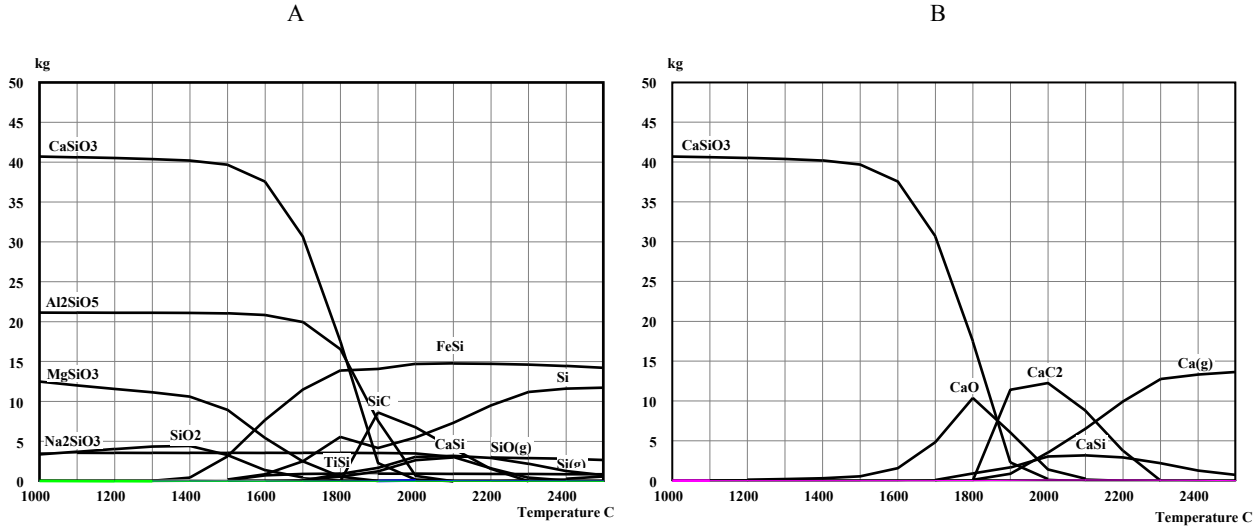


Figure 1 – Temperature effect on quantitative distribution of the Si and Ca containing substances in the system of DB-45%Cat absence of iron:
A – silicon-containing substances, B – calcium-containing substances

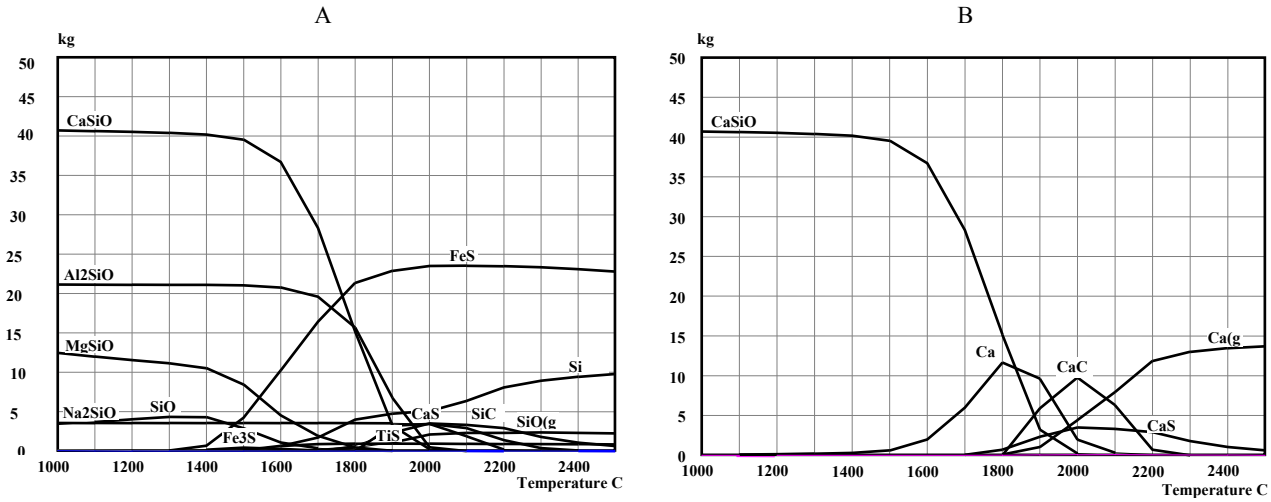


Figure 2 – Temperature effect on quantitative distribution of the Si and Ca containing substances in the system of DB-45%C at presence of 8% of iron:
A – silicon-containing substances, B – calcium-containing substances

Table 2 – Initial formationtemperature(T_i, ^{0}C)

Substances	SiC	TiSi	CaSi	Si	CaC_2	Ca_{gas}	Al	Fe_3Si	SiO_{gas}	FeSi
T_i, ^{0}C (8% of Fe)	1900	1500	1700	1400	1800	1800	1700	1300	1500	1300

As follows from the table 2 the simultaneous formation of a ferroalloy on the basis of FeSi, Fe_3Si, TiSi, Si, SiC, CaSi, Al occurs at temperature above 1800^{0}C.

The calculation results of equilibrium transition degree (α, %) of Siand Al into the alloy (αSi (alloy) and αAl (alloy)) and calcium into calcium carbide (αCa (CaC_2)) depending on temperature and iron amount are represented in figures 3 and 4.

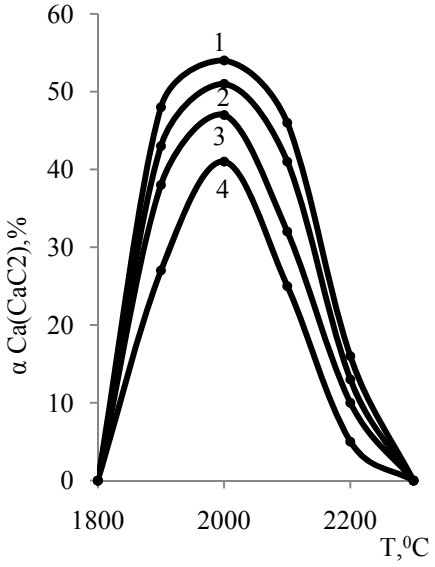


Figure 3 – Temperature and iron content effect on$\alpha Ca(CaC_2)$ at 45% of C:
1 – 0% of Fe, 2 – 2% of Fe, 3 – 4% of Fe, 4 – 8% of Fe

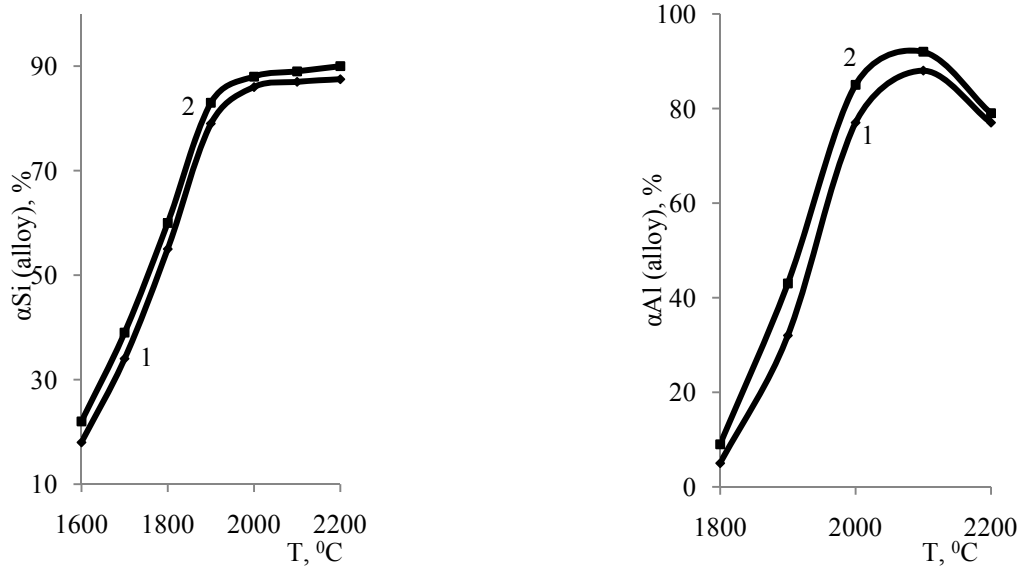


Figure 4 – Temperature and iron content effect onαSi(alloy) andαAl(alloy) at 45% of C: 1 – 0% of Fe, 2 – 8% of Fe

As follows from the figure 3, the increase in iron content from 0 to 8% from the basalt weight (at 45% of C from the basalt weight) decreases α Cainto CaC_2 from 54,6% to 42,4% at 2000^0Caccording to the equation:

$$\alpha Ca(CaC_2) = 54{,}44–1{,}5114\ Fe. \quad (4)$$

The decrease in αCa (CaC_2) at temperatures above 2000^0C can be caused by the CaC_2 decomposition [21]:

$$CaC_2 = Ca_{gas} + 2C. \quad (5)$$

The inverse picture is observed for αSi(alloy) (figure 4). The increase in iron content from 0 to 8% at 45% of C allows to raise αSi (alloy) in the temperature interval of 1600-2000^0C and to achieve 88,1-90,24% at 2000-2200^0C.

An important technological parameter of the developed technology is silicon and aluminium content in the produced ferroalloy (C_{Si}, C_{Al}) and CaC_2 content in the technical carbide (C_{CaC2}). From the figure 5 it

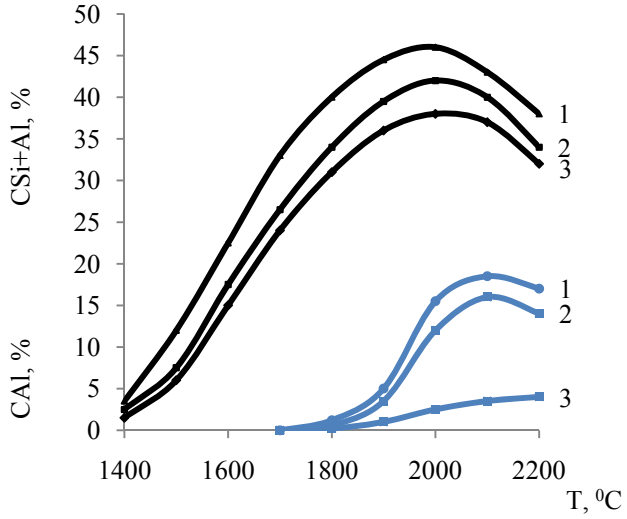


Figure 5 – Temperature and iron content effect on Si and Al content and total Si+Alcontent in the ferroalloy in the system ofDB-20%C-nFe: 1 – 0% of Fe, 2 – 4% of Fe, 3 – 8% of Fe

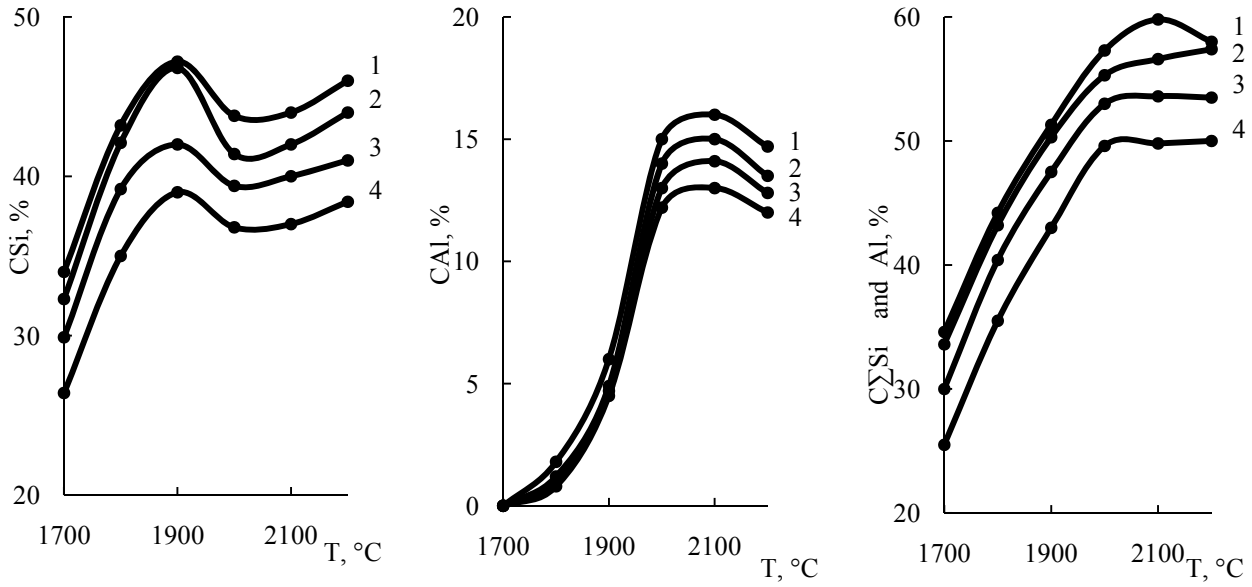


Figure 6 – Temperature and iron content effect on Si and Al content and total Si+Alcontent in the ferroalloy in the system ofDB-45%C-nFe: 1 – 0% of Fe, 2 – 2% of Fe, 3 – 4% of Fe, 4 – 8% of Fe

is obvious, that at 20% of carbon in the system the increase in iron amount from 0 to 8% reduces aluminiumconcentration and total silicon and aluminiumconcentration ($C_{\Sigma Si+Al}$)in an alloy. Maximum $C_{\Sigma Si и Al}$ (45,6%) is reached at 2000^0C in absence of iron. With growth of the carbon quantity to 45% the influence pattern of iron on Siand Alconcentration in the alloy does not change. However the pattern of temperature effect on C_{Si} and C_{Al} is a little bit other (figure 6). The increase in temperature to 1900^0C raises C_{Si}. Then we see the minimum C_{Si} at 2000-2200^0C and its increase at temperature above 2200 ^{0}C. Aluminium contentin the alloy during the temperature growth passes through a maximum at 2100^0C and makes13,1% at 8% of Fe. With increase in the temperature the totalSi and Al content in the alloy increases. In the temperature interval of 2000-2200^0Cand 2-8% of iron$C_{\Sigma Si+Al}$ makes 49-58%.

The temperature and iron amountinfluence on the calcium carbide capacityis shown in figure 7. As follows from the Figure the iron content increase leads to the capacity reduction. So, if at 2100^0C in absence of iron the calcium carbide capacity makes 265 l/kg, then at 8% of Fe it decreases to 244,1 l/kg.

For determination of the optimum temperature and iron amount we have fulfilled researches by a rototablematrix planning method in respect to a bifactorial experiment [22]. The optimization parameters

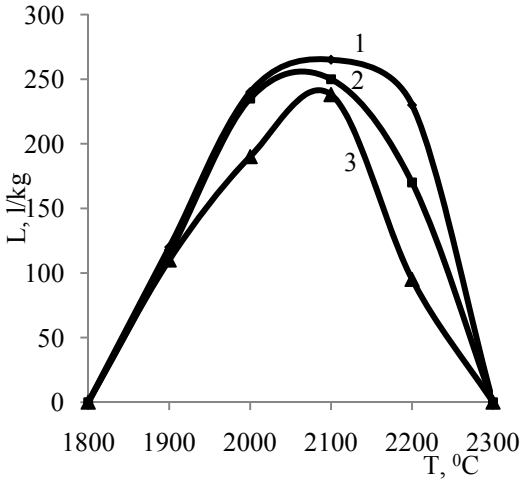


Figure 7 – Temperature and iron content effect on the CaC_2 capacity: 1 – 0% of Fe, 2 – 2% of Fe, 3 – 4% of Fe, 4 – 8% of Fe

are αSi (alloy), αCa (CaC_2), $C_{\Sigma Si+Al}$ in the alloy, calcium carbide capacity L, and independent factors are iron content(from the basalt weight) (Fe, %), temperature (T, ^{0}C). We habe obtained the following regression equations:

$$\alpha Si_{(alloy)} = -1700{,}11 + 1{,}738 \cdot T + 5{,}036 \cdot Fe - 4{,}226 \cdot 10^{-4} \cdot T^2 - 0{,}223 \cdot Fe^2 - 1{,}433 \cdot 10^{-3} \cdot T \cdot Fe \quad (6)$$

$$\alpha_{Ca(CaC2)} = -5904{,}185 + 6{,}018 \cdot T - 14{,}002 \cdot Fe - 1{,}519 \cdot 10^{-3} \cdot T^2 - 0{,}141 \cdot Fe^2 + 6{,}539 \cdot 10^{-3} \cdot T \cdot Fe \quad (7)$$

$$C_{\Sigma Si+Al} = -199{,}967 + 0{,}223 \cdot T - 2{,}764 \cdot Fe - 4{,}8 \cdot 10^{-5} \cdot T^2 - 6{,}964 \cdot 10^{-2} \cdot Fe^2 + 1{,}131 \cdot 10^{-3} \cdot T \cdot Fe \quad (8)$$

$$L_{CaC2} = -28470{,}14 + 27{,}323 \cdot T + 184{,}5 \cdot Fe - 6{,}493 \cdot 10^{-3} \cdot T^2 - 0{,}605 \cdot Fe^2 - 8{,}916 \cdot 10^{-2} \cdot T \cdot Fe \quad (9)$$

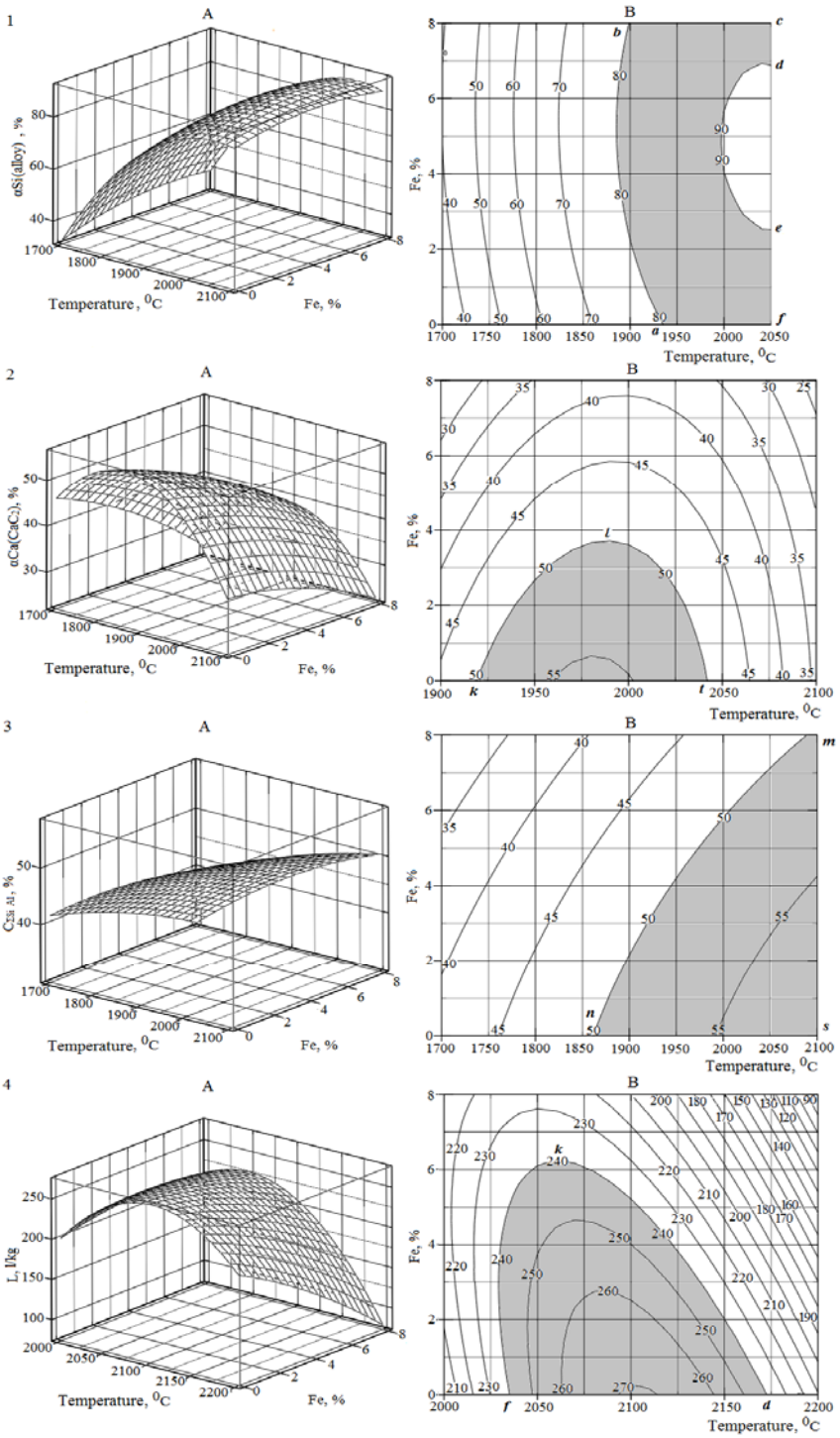


Figure 8 – Temperature and iron content effect on αSi (alloy) – 1, $\alpha Ca(CaC_2)$ – 2, $C_{\Sigma Si+Al}$ – 3 and L – 4 at the Daubaba basalt – carbon interaction. Numerals on the lines – values of a technological parameter, % andl/kg: A – 3D pictures of response surfaces, B – horizontal sections of the surfaces

Being used the MathCad program [23] on the basis of the equations 6-9 we have constructed response surfaces and their horizontal sections (figure 8). Judging by figure 8, αSi from 80 to 90% is in the area *abcdef* (1880-2050^{0}C and 0-8% of Fe). The extraction degree of Ca into CaC_2 from 50 to 56% is in the area *klt* (1918-2006^{0}C and 0-3,7% of Fe). The total Si and Alcontent in the alloy from 50 to 58% is in the area *nms* (1860-2100^{0}C and 0-4,2% of Fe). The calcium carbide with capacity of 240-271 l/kg is formed in the area *fkd* (2070-2100^{0}C and 0-6,15% of Fe). From figure 8 it is follows, that $\alpha Ca(CaC_2)$ is substantially less, than αSi (alloy). Therefore the optimum should be searched proceeding from the maximum $\alpha Ca(CaC_2)$. Figure 9 represents the superimposed information about influence of temperature and iron amount on αSi(alloy), $\alpha Ca(CaC_2)$, $C_{\Sigma Si+Al}$ in the alloy and capacity L. At the construction the minimum limiting indices were calcium carbide capacity of 240 l/kg (calcium carbide of 2 and 3 grades),$\alpha Ca(CaC_2) \geq 50\%$, $\alpha Si(alloy) \geq 87\%$, $C_{\Sigma Si+Al} \geq 55\%$.

The plane *abcd* in figure 9 is the technological area respective toset limits. Values of temperature and iron content in the border points of the *abcd* area are represented in table 3.

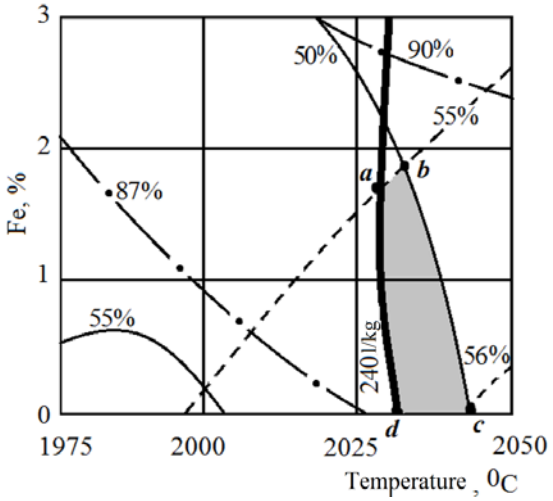


Figure 9 – l Superimposed information about temperature and iron amount effect on αSi(alloy) – (– · – · –), $\alpha Ca(CaC_2)$ – (———) , $C_{\Sigma Si+Al}$ (- - - - -) and L (▬▬)

Table 3 – Technological parameters in the border points

Point in figure 9	Technological parameter					
	αSi, %	$\alpha Ca(CaC_2)$, %	L, l/kg	$C_{\Sigma Si+Al}$	T, ^{0}C	Fe, %
a	88,6	50,8	240	55,0	2028	1,8
b	89,0	50,0	242	55,0	2032	1,9
c	88,0	50,0	248	56,0	2043	0
d	87,4	52,0	240	55,3	2031	0

Thus from the Daubaba basalt at presence of 45% of carbon and 0-1,9% of iron at 2028-2043^{0}Cit can be simultaneously extracted 87,4-89,0% of silicon into the ferroalloy and 50-52% ofcalcium in calcium carbide. In this case thecalcium carbide has capacity of 240-248 l/kg, and the total silicon and aluminium content in the alloy makes 55-56%. Such the alloy concerns to ferrosilicoaluminium ofa FS45Al5 grade[24], and the calcium carbide to 2-3 grade.

Conclusion. On the basis of the results obtained at the thermodynamic modelling the Daubaba basalt – carbon interaction at presence of iron we may draw following conclusions:

- formation of calcium carbide in the system occurs at 1800^{0}C, iron silicides – at 1300^{0}C, silicon and aluminium – at 1400-1700^{0}C;

- transition degree of calcium into CaC_2 at 2000^{0}C and 45% of C at increase in iron content from 0 to 8% decreases from 54,6% to 42,4%, and transition degree of silicon into the alloy increases and makes 88,1%;

- silicon and aluminiumconcentration in the alloy and the calcium carbide capacitydecrease at increase in iron content;

- from the Daubaba basalt at presence of 45% of carbon and 0-1,9% of iron at 2028-2043^{0}C it can be simultaneously extracted 87,4-89,0% of silicon into the ferroalloy and 50-52% of calcium in calcium carbide; the calcium carbide formed has capacity of 240-248 l/kg, and ΣSi+Alin the alloy makes 55-56%;

- thealloy containing silicon and aluminiumis a complex ferroalloy – ferrosilicoaluminium of aFS45Al5 grade, and the calcium carbide formed concerns to 2-3 grade.

The research has been fulfilled under the support of the Ministry of Education and Science of the Republicof Kazakhstan on the basis of grant financing on the theme“Combined technology for production of ferroalloys and calcium carbide from unconventional natural raw material and technogenic formations containing high-clark elements”.

В. М. Шевко[1], Д. К. Айткулов[2], Д. Д. Аманов[1], А. Д. Бадикова[1], М. А. Тулеев[1]

[1]М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан,
[2]Қ. И. Сәтбаев атындағы Геологиялық ғылымдар институты, Алматы, Қазақстан

ДАУБАБА КЕНОРНЫНЫҢ БАЗАЛЬТЫ-КӨМІРТЕК-ТЕМІР ЖҮЙЕСІНЕН ФЕРРОҚОРЫТПА ЖӘНЕ КАЛЬЦИЙ КАРБИДІНІҢ ТҮЗІЛУІН ТЕРМОДИНАМИКАЛЫҚ МОДЕЛЬДЕУ

Аннотация. Мақалада Si және Al құрайтын, кешенді ферроқорытпа мен кальций карбидінің түзілуімен көміртегімен Даубаба (40,88% SiO_2, 19,58% CaO, 13,36% Al_2O_3, 15,25% FeO, 6,68% MgO, 1,74% Na_2O, 0,98% TiO_2, 0,41% MnO, 0,55% SiO_2) кенорнының базальтымен әсерлесуіне темір (0-ден 8%-ға дейін) және температураның (1000-ден 2500-ға дейін °С) әсерін термодинамикалық модельденуі бойынша жұмыс қорытындысы келтірілген. Зерттеу Гиббс энергиясының минимумына негізделген, HSC-5.1 кешенді бағдарламаны қолдана отырып жүргізілді. Нәтижесінде 2000 ^{0}C және 45% С, темір мөлшерін 0 ден 8% жоғарылатқанда Са-дің CaC_2 өту дәрежесі 54,6% дан 42,4% -ға төмендейді, ал Si балқымаға өту дәрежесі 88,1% ұлғаяды; темір мөлшерінің артуында балқымадағы Si және Al концентрациясы және кальций карбидінің литражы төмендейді; 45% көміртегі қатысуында базальттан 0-1,9 % Fe және 2028-2043 ^{0}C бір мезетте балқымаға 87,4-89% Si және 50-52% Са кальций карбидіне бөліп алады; түзілген ферроқорытпа 55-56% Σ Si және Al құраса, 242-248 л/кг литражбен кальций карбидімен сипатталады. Si және Al құрамдас балқыма кешенді ферроқорытпаға жатады, яғни ФС45Al5 маркалы ферросиликоалминийге, ал кальций карбиді 2-3 сортқа ие болады.

Түйін сөздер: базальт, қалпына келтіру, көміртек, температура, термодинамикалық модельдеу, кальций карбиді, ферроқорыта.

В. М. Шевко[1], Д. К. Айткулов[2], Д. Д. Аманов[1], А. Д. Бадикова[1], М. А. Тулеев[1]

[1]Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,
[2]Институт геологических наук им. К. И. Сатпаева, Алматы, Казахстан

ТЕРМОДИНАМИЧЕСКОЕ МОДЕЛИРОВАНИЕ ОБРАЗОВАНИЯ КАРБИДА КАЛЬЦИЯ И ФЕРРОСПЛАВА ИЗ СИСТЕМЫ БАЗАЛЬТ ДАУБАБИНСКОГО МЕСТОРОЖДЕНИЯ – УГЛЕРОД-ЖЕЛЕЗО

Аннотация. В статье приводятся результаты работы по термодинамическому моделированию влияния температуры (от 900 до 2000°С) и железа (от 0 до 8%) на взаимодействие базальта месторождения Даубаба (40,88% SiO_2, 19,58% CaO, 13,36% Al_2O_3, 15,25% FeO, 6,68% MgO, 1,74% Na_2O, 0,98% TiO_2, 0,41% MnO, 0,55% SO_2) с углеродом с образованием карбида кальция и комплексного ферросплава, содержащего кремний и алюминий. Исследования проводили с использованием программного комплекса HSC-5.1, основанного на минимуме энергии Гиббса. Найдено, что степень перехода кальция в CaC_2 при 2000 ^{0}C и 45%. С при увеличении количества железа от 0 до 8% уменьшается от 54,6% до 42,4%, а степень перехода кремния в сплав возрастает, составляя 88,1%. Концентрация кремния и алюминия в сплаве и литраж карбижа кальция снижаются при увеличении количества железа; в присутствии 45% углерода, 0-1,9 % Fe при 2028-2043 ^{0}C из базальта можно одновременно в сплав извлечь 87,4-89% Si и 50-52% кальция в карбид кальция. Образующийся ферросплав содержит 55-56% $\Sigma_{Si\ и\ Al}$, карбид кальция характеризуется литражом 240-248 л/кг. Сплав, содержащий кремний и алюминий относится к комплексному ферросплаву - ферросиликоалюминию марки ФС45Al5, а карбид кальция обладает 2-3 сортностью.

Ключевые слова: базальт, восстановление, углерод, температура, термодинамическое моделирование, карбид кальция, ферросплав.

Information about authors:

Shevko Viktor Mihajlovich, Doctor of technical sciences, professor of the department of Metallurgy of the South Kazakhstan State University M. Auezov, Shymkent, Kazakhstan; shevkovm@mail.ru; https://orcid.org/0000-0002-9814-6248

Aitkulov Dosmurat Kyzylbievich, deputy director for development of scientific innovation activities and external relations, doctor of technical sciences, professor, institute of Geological Sciences named after K. I. Satpayev, Almaty, Kazakhstan; dos.ait.58@mail.ru; https://orcid.org/0000-0003-2571-6710

Amanov Danijel Daniarovich, Master of technical sciences, specialist of the highest qualification level South Kazakhstan State University named after M. Auezov, Shymkent, Kazakhstan; loken666@mail.ru; https://orcid.org/0000-0002-7379-1910

Badikova Aleksandra Dmitrievna, Master of engineering and technology, junior scientific associate, South Kazakhstan State University named after M. Auezov, Shymkent, Kazakhstan; sunstroke_91@mail.ru; https://orcid.org/0000-0003-0027-4258

Tuleev Mustafa Azatovich, Master of technical sciences, specialist of the highest qualification level South Kazakhstan State University named after M. Auezov, Shymkent, Kazakhstan; mustafa19930508@mail.ru; https://orcid.org/0000-0002-1439-8676

REFERENCES

[1] Ershov V.A. (1984). Electrothermal processes of chemical technology. Chemistry, Leningrad, Russia (in Rus.).

[2] Bogdanov S.P., Kozlov K.B., Lavrov B.A. (2009). Electrothermal processes and reactors. Prospect of Science. St. Petersburg, Russia. ISBN 978-5-903090-32-7 (in Rus.).

[3] Edneral F.P. (1977). Electrometallurgy of steel and ferroalloys. Moscow, Russia (in Rus.).

[4] Gasik M. (2013). Handbook of Ferroalloys: Theory and Technology 1st Edition. Butterworth-Heinemann, USA. ISBN 9780080977539.

[5] Moniz B.J. (2012). Metallurgy. Amer Technical Pub, USA. ISBN 978-0826935229.

[6] Ferroalloys furnace [Electronic resource]. URL:http://lektsii.com/2-67960.html (Date of access: 03.01.2018).

[7] Tleukulov O.M. (1986). Integrated non-waste chloride processing of polymetallic oxidized raw materials. Leningrad, Russia (in Rus.).

[8] Melnik M.A. (1992). Physicochemical basis and complex chloride technology of processing zinc-oligoitic ores of Zhayremsky deposit. Alma-Ata, Kazakhstan.

[9] Shevko V.M., Daribaev Zh.B. (2004). Agglomeration-chlorinating firing of tailings of enrichment and overburden. IKTU, Kentau, Russia (in Rus.).

[10] Shevko V.M., Kapsaljamov B.A., Bishimbaev V.K., Kolesnikov A.S., Kartbaev S.K. (2009). Complex electrothermal processing of clinkers for the waelz - process of oxide Ajisai zinc-containing ores. SKSU named after M. Auezov, Shymkent, Kazakhstan. ISBN 9965-1-9173-5 (in Rus.).

[11] Shevko V.M., Ajtkulov D.K., Atamkulov B.B., Izbashanov K.S., Najmanbaev M.A. (2017). Complex electrothermal processing of poor oxide ore of the Achisay deposit. News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and engineering sciences. [Kompleksnaja jelektrotermicheskaja pererabotka bednoj oksidnoj rudy Achisajskogo mestorozhdenija // Izvestija nacional'noj akademii nauk Respubliki Kazahstan. Serij geologii i tehnicheskih nauk] 4: 177-183 (in Rus.).

[12] Bajbatsha A.B. (2008). Geology of Mineral Deposits - Tutorial. KNTU, Almaty, Kazakhstan (in Rus.).

[13] Dzhigiris D.D., Makhova M.F. (2002). Basis for the production of basalt fibers and articles: Monograph. Heat-and-powerengineer. Moscow, Russia (in Rus.).

[14] Aspanova L.G. (2000). Method for obtaining basalt fiber and a device for its implementation [Sposob poluchenija bazal'tovogo volokna i ustrojstvo dlja ego osushhestvlenija]. Patent of the Russian Federation 2149841 [Patent Rossijskoj Federacii 2149841] (in Rus.).

[15] Bagrjancev G.I., Koryhaev V.V., Kulagina N.V. and others (2009). Method of obtaining fiber from mineral raw materials [Sposob poluchenija volokna iz mineralnogo syrja]. Patent of the Russian Federation 2352531 [Patent Rossijskoj Federacii 2352531].

[16] Osnoc S.P., Ahmadeev V.F. (2010). Basalt continuous fiber [Bazaltovoe nepreryvnoe volokno]. Patent of the Russian Federation 2381188 [Patent RossijskojFederacii 2381188].

[17] Babievskaja I.Z., Gavricev K.S. and others (2007) Method for producing basalt fiber [Sposob poluchenija bazaltovogo volokna]. Patent of the Russian Federation 2297986 [Patent Rossijskoj Federacii2297986].

[18] Aknazarov S.H., Lukjashhenko V.G., Messerle V.E. (2013). Method for processing slime of chromate production [Sposob pererabotki shlama hromatistogo proizvodstva]. Innovation patent of the Republic of Kazakhstan 27146 [Innovacionnyj patent Respubliki Kazahstan 27146].

[19] Roine A. (2002). Outokumpu HSC Chemistry for Windows. Chemical reactions and equilibrium software with extensive thermochemical database. Outokumpu research, Pori.

[20] Scientific Group Thermodata Europe: [Electronic resource]. URL:http://sgte.net/en/ (Date of access: 03.01.2018).

[21] Kozlov K.B., Lavrov B.A. (2011). Calcium carbide production in an arc furnace and its analysis. SPbGTI, Saint-Petersburg, Russia (in Rus.).

[22] Ahnazarova S.A., Kafarov B.V. (1978). Methods for optimizing the experiment in the chemical industry. High school, Moscow, Russia.

[23] Ochkov V.F. (2007). Mathcad 14 for students, engineers and designers. BHV-Petersburg, St.-Petersburg, Russia (in Rus.).

Gasik M.I., Ljakishev N.P. (1999). Theory and technology of electrometallurgy of ferroalloys. JV Intermet Enginee-ring, Moscow, Russia (in Rus.).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 107 – 111 **https://doi.org/10.32014/2019.2518-170X.13**

UDC 621.314.5

N. Isembergenov, K. Taissariyeva, U. Seidalieva, V. Danilchenko

Kazakh national research technical university named after K. I. Satpayev, Almaty, Kazakhstan.
E-mail: isembergenov@mail.ru, taisarieva@mai.ru, jalgasa@mail.ru, vladimirsan@list.ru

MICROPROCESSOR CONTROL SYSTEM FOR SOLAR POWER STATION

Abstract. In this article, there has been developed a microprocessor control system that provides synchronous operation of a solar power station with an electric grid. It is shown that, in practice, the voltage in the mains does not correspond to a pure sinusoid and has distortions to which the output voltage of the inverter must be adapted.

Keywords: microprocessors, control system, solar power station, inverter, power network, synchronization, voltage.

Currently, the electricity voltage does not correspond to a pure sinusoid and has distortions that occur when using semiconductor converters (controlled rectifiers, power converters, converters and other devices). Therefore, inverters of solar power plants must be adapted to the power grid.

The scientific novelty of this work is the development of a microprocessor-based inverter control system for a solar power plant that transforms electricity into an energy grid. It should be noted that the microprocessor control system of the inverter reacts instantly to changes in the mains voltage, excluding emergency modes. At the same time, solar cells are saved and the maximum transformation of the electric power of the solar power station into the power grid. Thus, the development and practical application of the microprocessor control system is an actual problem.

In most inverters existing to date, the output voltage is formed by a circuit that produces rectangular pulses in the form of a meander at the output. This is sufficient for working in an autonomous mode, but not suitable for working together with the power grid. To correct this shortcoming, there are two principal ways to improve the inverter output voltage curve by the circuit:

- the pulse width modulation of the output voltage curve;
- the amplitude-pulse modulation of the output voltage curve.

Figure 1 shows a stepped voltage form close to a sinusoid with amplitude-pulse modulation [1].

In this work, there was developed and presented [2, 3] a scheme of a multilevel inverter with amplitude-pulse control, where each of n sources of direct voltage (solar cells) are connected in series and through **n** switching keys are connected to a bridge inverter with a common load. In this work it is used amplitude-pulse control in such a way that a multilevel voltage is provided at the output of the inverter, which is close in shape to the sinusoid (figure 1).

Figure 2 shows a block diagram of the organization and connection of a multilevel inverter that allows tracking and synchronizing the output voltage of the inverter with the voltage of the city network in order to maximize the energy of solar cells in the grid.

To connect a power inverter to an industrial network it is very important to achieve synchronous operation of the inverter with the power network. For this, it is necessary to fulfill all the requirements for parallel operation of electric power sources (generators, inverters) and the power grid, which are expressed by the following conditions:

$$f_1 = f_c;\ U_1 = U_c;\ \propto = \pi\ , \tag{1}$$

where f_1 and f_c – respectively, are the frequencies of the source of electrical energy and the power system; U_1 and U_c – respectively, are the voltages of a source of electrical energy and a power system; $\propto$ – is an angle between the vectors of voltages U_1 and U_C and the order of rotation of the phases of the sources of electrical energy must be the same.

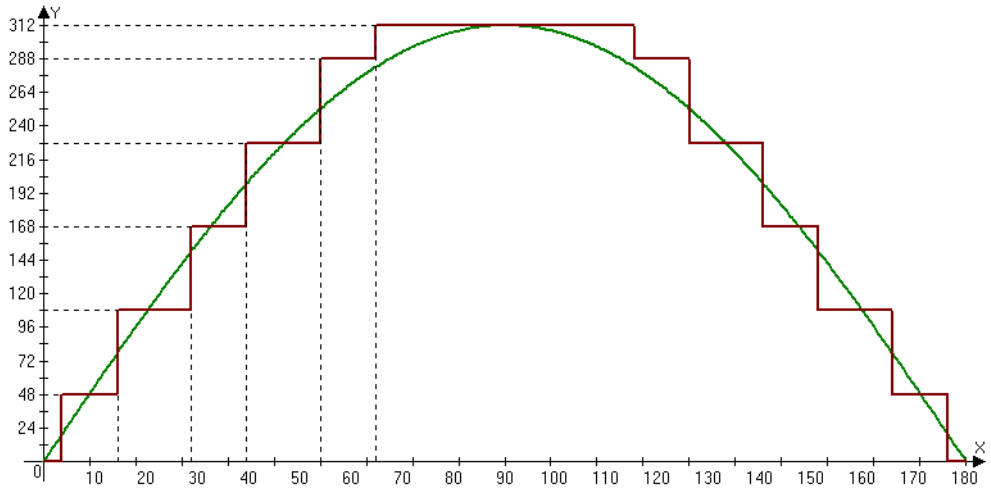


Figure 1 – Stepped voltage form close to sinusoid

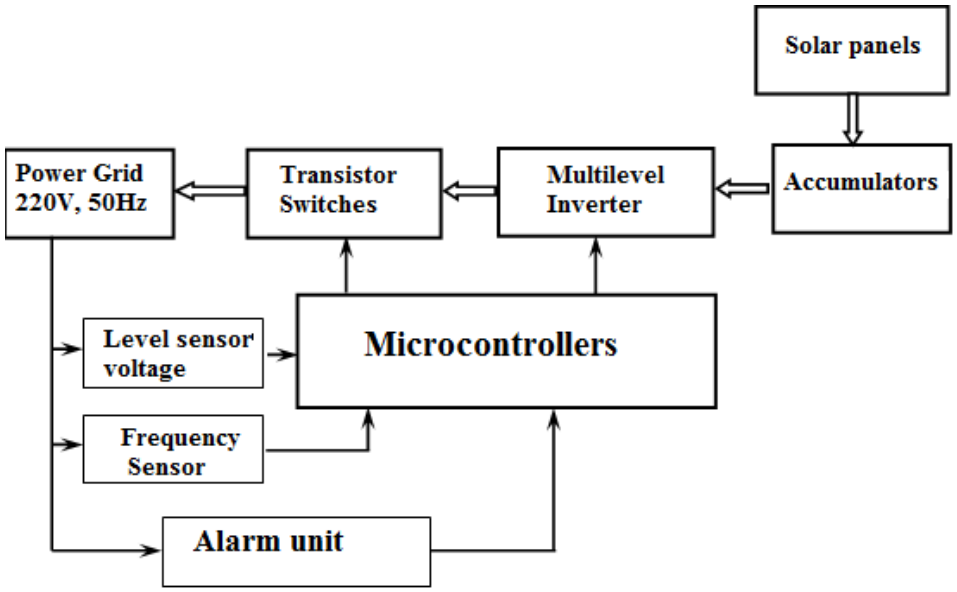


Figure 2 – The block diagram of the inverter's synchronization with the power grid

To fulfill the condition of synchronization of the inverter voltage with the mains voltage, a pulse former was developed. Sync pulses have a periodicity equal to the period of the AC network and are designed to control the frequency and phase of the AC voltage at the output of the inverter.

To synchronize the mains voltage with the voltage of the inverter, there has been developed a device that generates the front of the synchronization pulse at the time of alternating current polarity in the industrial network. A scheme for converting and matching the network voltage level with the level of the multistage inverter voltage has also been developed.

Figure 3 shows the developed circuit of the microcontroller control system of the inverter. For the inverter control system, it was decided to use the Atmel microcontroller of the Mega family. This micro-controller has three 8-bit data I / O ports, which meets the management requirements. The control system was developed in the software environment Code Vision.

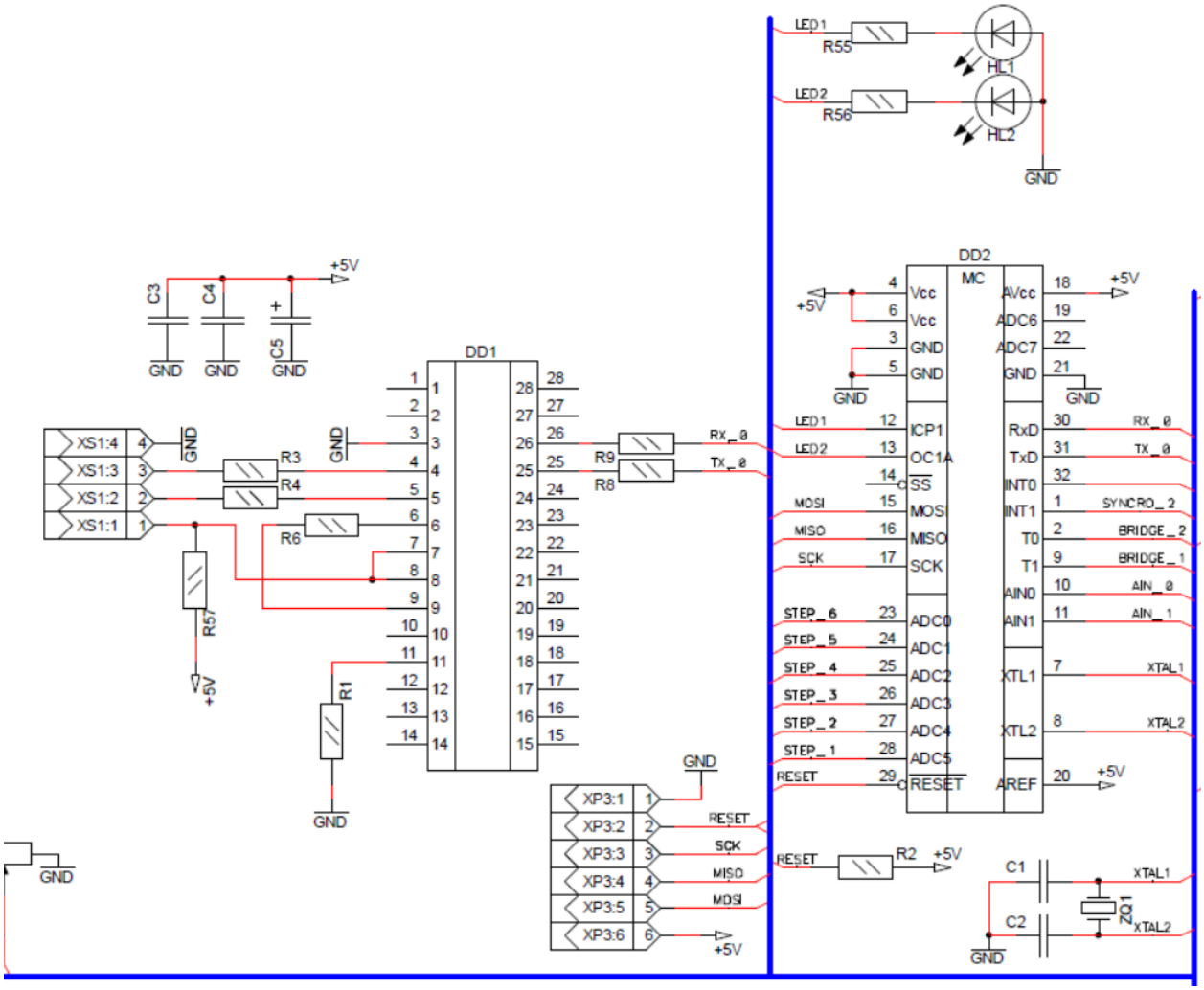


Figure 3 – The scheme of the microcontroller control system

For accuracy of compliance with the commutation angles, the minimum performance is 12 MIPS that the microcontroller AVR of the ATMEGA series can be made by connecting to a 12 MHz crystal oscillator. Programming was performed in the AVR Studio 4 environment, in the programming language C.

Figure 4 shows the scheme of the synchronization block of the inverter with the power grid. The microcontroller synchronizes with the external network and calculates the sine period. For this, the microcontroller reads pulses from the synchronization block. In this case, it uses two blocks with optocouplers to calculate the timing of the synchronization. The input SYNCRO_2 receives pulses from the optocoupler U10, which is connected to the external network through the lowering resistance R63 (figure 4). At the input SYNCRO_2, a pulse is produced for each half-period of the input voltage.

In the scheme of the synchronization block of the inverter with the power grid, there is determined the time point of the positive and negative half-cycle of the mains voltage. In order to calculate the exact time of the sinusoid transition from the positive half cycle to the negative half and back, there are used pulses arriving at the input SYNCRO_1.

In addition, the block calculates the time of the positive and negative half-cycle of the sinusoid. After calculating the time of the input voltage period, the step-on time is calculated. To do this, the analogue comparator inputs compare the voltage of the stage and the voltage of the external network and when the external voltage becomes greater than the step voltage, the value of the timer counter is recorded. Taking into account the value of the counter in the timer, the next voltage stage of the inverter is switched on in subsequent counts.

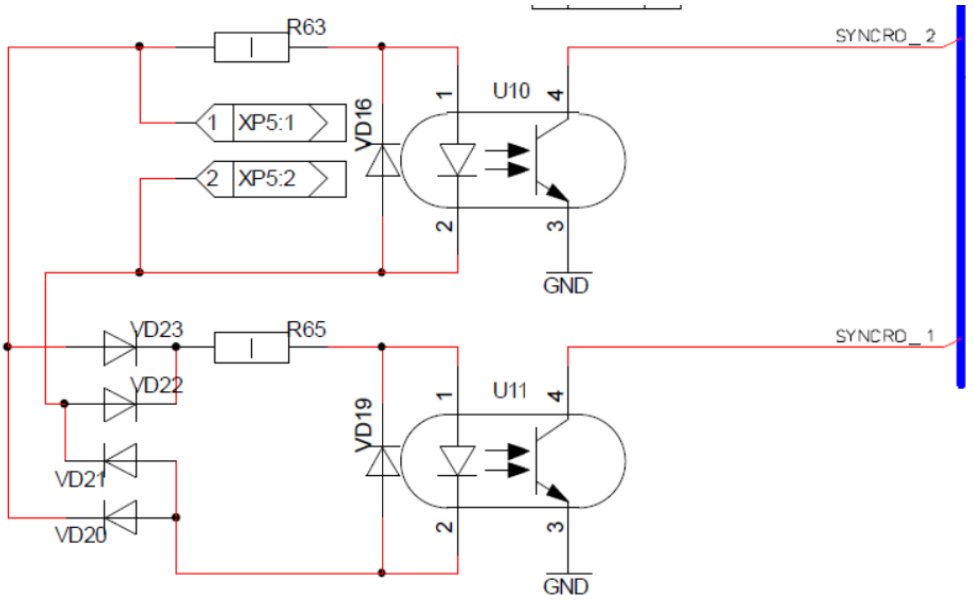


Figure 4 – The scheme of the synchronization block

After completion of reading and comparing, the inverter goes into the basic mode of operation strictly according to the countdown timer. In this case, the external voltage is monitored by the comparator. If the interrupt of the comparator occurred before the timer has tripped, then the step countdown time decreases, otherwise the run time of the step increases. In order that no false alarms occur, the minimum operating time of the stage is set.

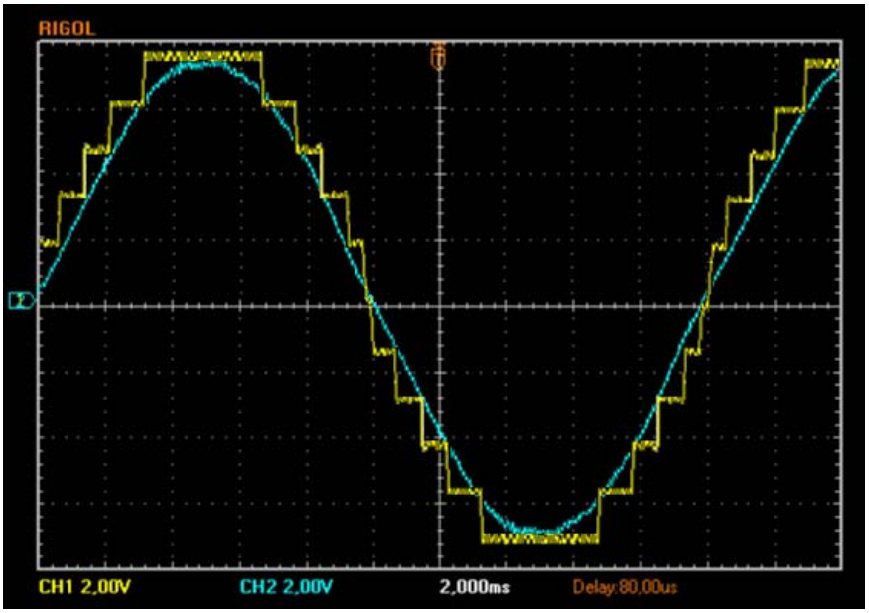


Figure 5 – The oscillogram of the output voltage of the inverter and the power grid during synchronization

In this work there have been made a microcontroller control system circuit and a synchronization block circuit. There have been carried out experimental studies of the operation of the inverter with the power network. Figure 5 shows an oscillogram of the output voltage of the inverter and the power grid during synchronization. As can be seen from the voltage oscillogram, the microcontroller control system ensures full synchronization of the output multistage voltage of the inverter with the power grid. In this case, six voltage levels are used. Thus, it was possible to realize the theoretical positions (figure 1) in practice (1) of synchronization of the output multistage voltage of the inverter with the power grid.

Н. Т. Исембергенов, К. Н. Тайсариева, У. О. Сейдалиева, В. В. Данильченко

Қ. И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университетіб Алматы, Қазақстан

КҮН ЭЛЕКТРСТАНЦИЯСЫН БАСҚАРУҒА АРНАЛҒАН МИКРОПРОЦЕССОРЛЫ ЖҮЙЕ

Аннотация. Ғылыми мақалада микропроцессорлы басқару жүйесі өңделген. Ол жүйе күн электр станциясын электжелісімен бірге синхронды жұмыс істеуін қамтамассыз етеді. Тәжірибеде көрсетілгендей, электржелісі таза синусоиданы бермейді және көптеген бұрмаланулары бар, яғни инвертордың шығыс кернеуін синусоидаға келтіру қажет.

Түйін сөздер: микропроцессорлар, басқару жүйесі, күн электр станциясы, инвертор, энергожелі, синхрондау, кернеу.

Н. Т. Исембергенов, К. Н. Тайсариева, У. О. Сейдалиева, В. В. Данильченко

Казахский национальный исследовательский технический университет им. К. И. Сатпаева, Алматы, Казахстан

МИКРОПРОЦЕССОРНАЯ СИСТЕМА УПРАВЛЕНИЯ ДЛЯ СОЛНЕЧНОЙ ЭЛЕКТРОСТАНЦИИ

Аннотация. В статье разработана микропроцессорная система управления, которая обеспечить синхронную работу солнечной электростанции с электросетью. Показано, что на практике в электросети напряжение не соответствует чистой синусоиде и имеет искажения, к которым необходимо адаптировать выходное напряжение инвертора.

Ключевые слова: микропроцессоры, система управления, солнечная электростанция, инвертор, энергосеть, синхронизация, напряжение.

Information about authors:

Isembergenov Nalik Turegalievich, Doctor of Technical Sciences, Professor, Kazakh national research technical university named after K. I. Satpayev, Almaty, Kazakhstan; isembergenov@mail.ru; https://orcid.org/0000-0001-7631-8881

Taissariyeva Kyrmyzy Nurlanovna, PhD, senior lecturer, Kazakh national research technical university named after K. I. Satpayev, Almaty, Kazakhstan; taisarieva@mai.ru; https://orcid.org/0000-0002-1949-4288

Seidalieva Ulzhalgas Omirtaevna, Master of Science, doctoral student, Kazakh national research technical university named after K. I. Satpayev, Almaty, Kazakhstan; jalgasa@mail.ru

Vladimir Danilchenko, Master, Kazakh national research technical university named after K. I. Satpayev, Almaty, Kazakhstan; vladimirsan@list.ru; https://orcid.org/0000-0001-5030-8220

REFERENCES

[1] Issembergenov N., Taissariyeva K.N., The research of the “Solar panels – commutator – inverter – load” system with the pulse-amplitude control // PROCEEDINGS OF SPIE Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments. 2014. Vol. 9290. P. 92903H-1-7 (Scopus, Web of Science).

[2] Issembergenov N., Taissariyeva K.N. The multilevel on IGBT transistors for transformation of slar energy to the electric power // Bulletin of National academy of sciences of the Republic of Kazakhstan. 2015. Vol. 2, N 354. P. 183-186.

[3] Issembergenov N, Kasymov A.O., Moldakhmetov S.S. Multilevel inverter based on level switch and H-bridge. ARPN Journal of Engineering and Applied Sciences. VOL. 10, NO. 16, SEP TEMBER 2015. (Scopus).

[4] Taissariyeva K., Issembergenov N. Experimental studies of a prototype model of the multilevel 6KW-power inverter at supply by 12 accumulators // PROCEEDINGS OF SPIE Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments. 2016. Vol. 10031.

[5] Kucheruk Volodymyr, Katsyv Samuil, Glushko Mykhailo, Wójcik Waldemar, Tomasz Zyska, Taissariyeva K. Deterministic chaos in RL-diode circuits and its application in metrology // PROCEEDINGS OF SPIE Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments. 2016. Vol. 10031.

[6] Frede Blaabjerg. Control of Power Electronic Converters and Systems. First edition. 2018. Vol. 1. ISBN 9780128052457,

[7] Mohan Undeland Robbins. Power Electronics: Converters, Applications, and Design, third edition. ISBN-13: 978-1118880944, IEEE Press Series on Power Engineering, 2014.

[8] Jean Pollefliet. Power Electronics, first edition, ISBN 9780128146439. Academic Press, 2017.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 112 – 119 **https://doi.org/10.32014/2019.2518-170X.14**

UDC 622.234.42

B. K. Kenzhaliev[1, 2], T. Yu. Surkova[1], A. N. Berkinbayeva[1], Z. D. Dosymbayeva[1], M. T. Chukmanova[1, 2]

[1]JSC "Institute of Metallurgy and Ore beneficiation", Almaty, Kazakhstan,
[2]JSC " Kazakh national research technical university named after K. I. Satpayev», Almaty, Kazakhstan.
E-mail: bagdaulet_k@mail.ru; tu-surkova@mail.ru; ainur_kbk@mail.ru; zdos@mail.ru; chukmanova_m@mail.ru

TO THE QUESTION OF RECOVERY OF URANIUM FROM RAW MATERIALS

Abstract. The problem of extracting uranium from difficult-to-hide ores can be attributed to the most important scientific and technical problems facing the modern uranium mining industry.

One of the areas of modern scientific and technological progress in the development of radioactive ore deposits is using of a practically non-waste method of mining uranium – underground leaching (UL). A great interest to the method of underground leaching is determined by the positive experience of its application and high technical and economic indicators.

In Kazakhstanin underground uranium leachinga sulfuric acidis used as a leaching reagent. In this case, the degree of transition of uranium to the productive solution can be due to a variety of reasons, primarily related to the physico-chemical properties of uranium-containing minerals.

Thus, the use of sulfuric acid as a leaching reagent allows the extraction of only uranium (VI) compounds, since uranium compounds (IV) in sulfuric acid do not dissolve. To convert uranium (VI) to uranium (IV), oxidizers are used in industry, most often-ferric compounds. In this regard, the main problem of increasing the extraction of uranium in underground leaching is the transfer of uranium (IV) to a soluble state.

Analysis of scientific and technical literature has shown that recently one of the main directions for increasing the extraction of uranium from poorly soluble ores is the use of intensifiers that allow the most complete transfer of uranium from one valence state to another.In the article, the catalyst "M-1", which is a compound of transition metals, is considered as an intensifier. Comparative data are given for the study of agitation leaching of uranium from ore in the presence of a number of oxidants. Priorityuseofthe"M-1" catalystwasnoted.

Sorption methods are used to extract uranium from productive solutions. Ion exchange has certain advantages over others, since it allows to extract uranium from solutions of various concentrations.

Comparison of the kinetic dependencies of the sorption extraction of uranium by the ionites of Purolite A-500 and Ambersep-920 from the productive solutions of leaching of uranium-bearing ore in the presence of the «M-1»catalyst showed that they differ insignificantly. The values of activation energy for sorption of uranium on these ion exchangers and diffusion coefficients are calculated. Their magnitude is characteristic of a mixed external and internal diffusion process type.

In the literature, there are data on the use of natural sorbents for the extraction of uranium from productive solutions with low content of uranium. The advantages of such sorbents are their low cost. Within the framework of the present work, the possibility of sorption of uranium from productive solutions by natural zeolite and schungite in comparison with synthetic sorbents is investigated.

Key words: uranium, leaching, sorption, intensifier, catalyst, sorbent.

Introduction. Kazakhstan ranks second in the world in terms of natural uranium reserves and the leading positions in its production. Uranium is present in ores as part of a large number of mineral formations that differ in their physicochemical properties. According to the literature, the main uranium ores are the minerals of the tetravalent uranium: oxides (nasturan, uranium black) silicates (coffinite). The most common in the ores of almost all genetic types are simple oxides of U (IV). Minerals of hexavalent uranium are of lesser industrial importance [1-3].

Specificity of technological schemes for processing uranium ores is determined by the composition and properties of raw materials. Usually, the content of uranium in ores varies from tenths to hundredths of a percent. Because of the fine impregnation of uranium minerals in ores, the latter are not amenable to mechanical enrichment and the extraction of uranium from ores is in most cases carried out chemically [4, 5].

Depending on the composition and properties of the initial ore, one or another method of chemical processing is used.

Meanwhile, the method of underground well leaching finds an increasingly wide application in the development of uranium deposits, which, due to complex bedding conditions, as well as high specific investments and operating costs, cannot be worked out by traditional methods. In Kazakhstan, underground well leaching is the only effective method of uranium mining. Sulfuric acid is used as a leaching reagent [6, 7].

Minerals of tetravalent uranium do not dissolve in sulfuric acid, unlike to hexavalent. To dissolve the minerals of tetravalent uranium in dilute solutions of sulfuric acid, leaching is conducted with the addition of oxidizing agents. It is believed that the main problem of increasing the extraction of uranium from ore during underground leaching using existing technologies is the conversion of uranium (IV) to a soluble state. Therefore, at the heart of the overwhelming majority of research works is the question of the most complete transfer of uranium compounds into a soluble state, i.e. uranium (IV) in uranium (VI) [8-10].

In this connection, the purpose of this work was to study the effect of the "M-1" catalyst on uranium leaching and to assess the extent of its subsequent extraction from the resulting productive solutions.

In accordance with the complex chemical composition of uranium-containing solutions of underground well leaching and low uranium content, the most acceptable method of their processing is sorption methods, which are based on the use of ion exchange.Ion exchange has certain advantages over other methods (precipitation and extraction) since it allows to extract uranium from solutions of various concentrations [11-15].

In the literature, there are data on the use of natural sorbents for the extraction of uranium from productive solutions with low content [16-18]. The advantages of such sorbents are their low cost. Within the framework of the present work, the possibility of sorption of uranium from productive solutions by natural zeolite and schungite in comparison with synthetic sorbents is investigated.

Experimental part. As a raw material for experimental purposes, uranium-containing ore was used, in which the main uranium-containing mineral is coffinite. The composition of the ore is given below.

Sulfuric acid was used as the reagents which has the qualification "technical", GOST 2184-77, ammonium nitrate of the qualifications " Reagent", GOST 20478-75, sodium peroxoborateof the qualification "reagent", GOST 22567.10-93, ferric chloride (III) six-grade of the qualification "pure", GOST 4147-74, as well as the synthesized “Muhamedzhan-1” (M-1) catalyst [19, 20].

Experimental technique. Experiments on the leaching of uranium ore were conducted in a thermostated reactor according to a generally accepted procedure. Stirring of the pulp was carried out with a Stirrer-BS stirrer with a variable speed. The stability of the temperature was stabilized with a thermostat of the brand "TERMEX M01M". The maximum duration of the process was 48 hours. The ratio of S:L = = 1: 4.

Sorption of uranium was carried out on the anionites Purolite-A500 and Ambersep-920 in a static mode according to the procedure described in [21] from the productive solution from leaching of uranium-bearing ore. The composition of the solution is given below. There were used the anionitesPurolite-A500 andAmbersep-920 and natural materials – zeolite and schungite.

Methods of analysis. The quantitative content of uranium was determined by chemical methods of analysis.

Results and its discussion. As mentioned above, the main task of the vast majority of research works is the question of the most complete transfer of uranium compounds into a soluble state, i.e. uranium (IV) into uranium (VI).In this connection, we chose the initial ore, in which the main mineral is U $[SiO_4]$, which makes up about 95 % of the total uranium mineralization balance.Uranium-containing minerals are also represented by leucoxene, accompanying - native selenium, cobalt-nickel pyrite (bravoite) and sphalerite. The composition of different rocks: quartz - 70–80 %, feldspars - 10–20 %, siliceous rocks - 5–10 %. The average content of uranium is 0.031 %.

At the first stage of the research, the effectiveness of the "M-1" catalyst's influence on the uranium extraction degree by agitation leaching with sulfuric acid was evaluated.

Agitation leaching is a preliminary stage in the study of technological properties of the ore, it makes it possible to estimate its excavation with an optimal concentration of leaching reagents, as well as assess the effectiveness of the effect of some additives on the process.The investigations were carried out in the presence of the "M-1" catalyst. Further, for comparison, in the presence of traditional oxidizing agents: ferric iron, ammonium nosulphateand sodium peroxoborate.

To date, great interest is, along with the study of the effect of traditional oxidants on the process of leaching of difficult-to-hide uranium-bearing ores, as well as the search for new intensifiers for increasing the extraction of uranium from persistent raw materials. In this regard, the leaching of uranium-bearing ore in the presence of the "M-1" catalyst was studied in comparison with the traditional oxidants: ferric iron, ammonium nosulphateand sodium peroxoborate.

Preliminary studies of the catalyst "M-1" are presented in [20]. The catalyst "M-1" is a mixture of nitrates, sulfates, chlorides, bromides and iodides of transition metals (Fe, V, Cu, Mn).The total concentration of metals in the catalyst was 0.3 g/dm^3. Data characterizing the extraction of uranium by sulfuric acid in the presence of a catalyst are presented in table 1.

Table 1 – Results of sulfuric acid leaching of uranium in the presence of "M-1" catalyst

Catalyst content, g/dm^3	pH	ORP, mV	Extraction U, mg/dm^3	The acid consumption (C_{H2SO4} = 5.0 g/dm^3), g/g of uranium
0	2,00	378	35	39.1
0,3	2,01	388	80	14.2
0,6	1,99	396	82	12.8
0,9	1,98	402	84	11.1
1,2	2,00	408	86	9.7

From the data presented, it can be seen that the use of the "M-1" catalyst in the leaching process leads to an increase in the extraction rate of uranium from the ore. The maximum increase in the concentration of uranium in the solution is observed at the site of the change in the catalyst content in the range 0-0.3 g/dm^3.

Figure 1 shows the leaching of uranium-bearing ore by sulfuric acid in the presence of a catalyst in comparison with oxidants.

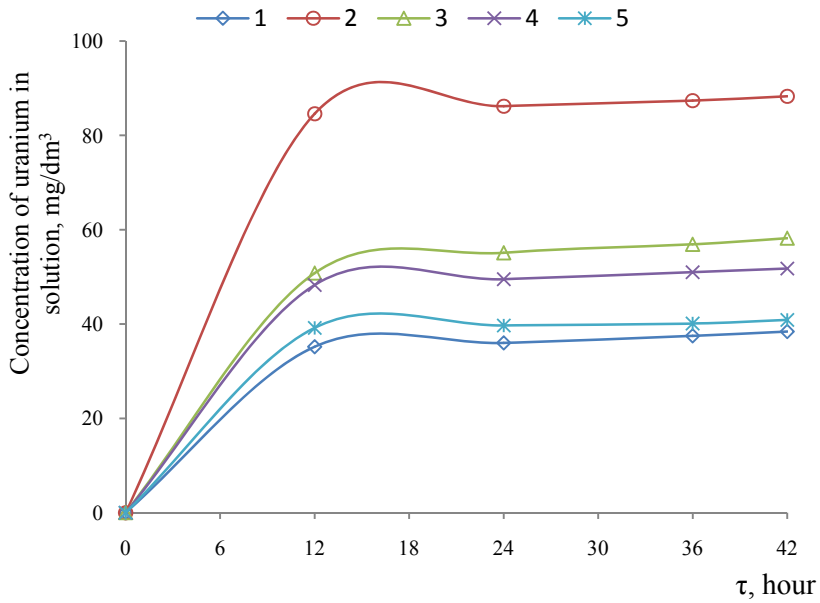


Figure 1 – Results of sulfuric acid leaching of uranium in the presence of the catalyst "M-1" and oxidants:
1 – sulfuric acid without oxidants and catalyst; 2 – "M-1" catalyst; 3 – ferric ion; 4 – ammonium nosulphate; 5 – peroxoborate

It can be seen from the table that the uranium content in the leaching solution without catalyst and oxidizers was 35 mg/dm^3 after 12 hours of the experiment and increased to 38 mg/dm^3 after 48 hours after the beginning of the leaching. In the case of using traditional oxidants, an increase in uranium extraction was also observed with increasing leaching time. The use of ferric chloride during the leaching process allowed to increase the concentration of uranium in the solution from 50.8 mg/dm^3 for 12 hours of leaching to 58.2 mg/dm^3 for 48 hours, and for ammonium nitrate and sodium peroxoborate from 48.3 and 39.2 to 51.8 and 40.9 respectively. When the "M-1" catalyst was used after 12 hours of the experiment, 84 mg/dm^3 of uranium extraction was achieved, with increasing leaching time this value varies 88 mg/dm^3.

Thus, the highest concentration of uranium in the solution is achieved when the ore is leached with sulfuric acid in the presence of a catalyst and decreases in the series: the catalyst "M-1" - ferric chloride III - ammonium perchlorate - sodium peroxoborate - sulfuric acid in the absence of oxidants and catalyst.

It should be noted that the catalyst "M-1" was successfully tested under production conditions and recommended for use.

The technological cycle of uranium mining by the method of underground borehole leaching includes the following interrelated technological processes: the actual underground uranium leaching, sorption-desorption of uranium and the production of concentrate. In accordance with the complex chemical composition of productive solutions and the low content of useful components, the most suitable variant of uranium concentrating is the sorption methods.

Unlike other methods, uranium sorption is characterized by the possibility of achieving high purification factors and a degree of concentration, high selectivity, the possibility of flexible regulation of selectivity by changing pH, oxidation-reduction conditions, complexation, simplicity and compactness of instrumentation, and a wide variety of artificial and natural sorbents.

Sorption of uranium together with the process of leaching is a kind of indicator of its extraction from this type of raw material.

Sorption of uranium was carried out in a static mode on Purolite-A500 and Ambersep-920 anion exchangers. The selected anion exchangers - strongly basic macroporous Purolite-A500 anioniteon the basis ofstyrenedivinylbenzene matrix and macroporous strongly basic anionite Ambersep-920 based on cross - linked polystyrene are effectively used in uranium mining enterprises of Kazakhstan.

At the first stage, comparative studies were conducted uranium sorption studies were carried out according to the above procedure. In the course of the experiment, a productive solution was used from the leaching of uranium-bearing ore with sulfuric acid in the presence of the "M-1" catalyst. The characteristics of the productive solutions are given in table 2, and the kinetic curves of sorption are shown in figure 2.

From the data given, it can be seen that the degree of uranium sorption most rapidly increases during the first hour, then the extraction rate decreases. The maximum degree of uranium recovery - 89.13% was achieved from the productive solution from ore leaching using the catalyst "M-1". From the leaching solution of uranium ore in the presence of an oxidizer-ferric chloride, uranium extraction amounted to 76.35%, and in directleaching with sulfuric acid (without additives) it was 63.31%.

Further, we determined the kinetic dependencies of uranium extraction from solution №1 by Purolite A-500 and Ambersep-920 ion exchangers in comparison. The results of the experiment are shown in figure 3, from which it can be seen that the ion exchangers practically equally sorb uranium from the solution. The degree of extraction of uranium on ion exchanger Ambersep-920 reaches 87.6%, Purolite A-500 - 89.0% for 8 hours of contact.

Table2 – The characteristics of the productive solutions

#	Productive solutions	U, mg/dm^3	Concentration H_2SO_4, g/dm^3	pH	Oxidation-reduction potential
1	With the use of the catalyst "M-1"	86.0	5.0	2.0	408
2	With the use of an oxidizing agent (trivalent iron chloride)	65.0	5.0	1.6	550
3	Productive solutions(without oxidizers and catalysts)	53.9	5.6	2.1	480

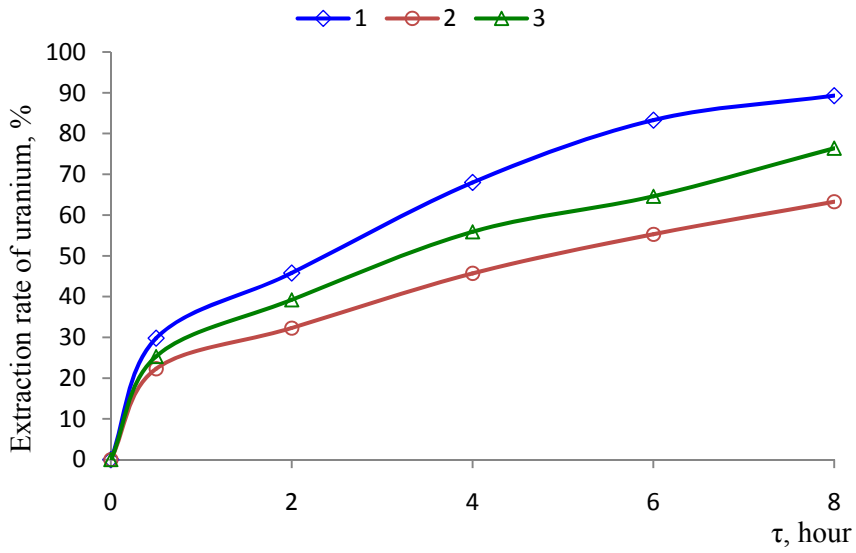


Figure 2 – The degree of extraction of uranium from solutions 1–3. The characteristics of solutions are given in table 2

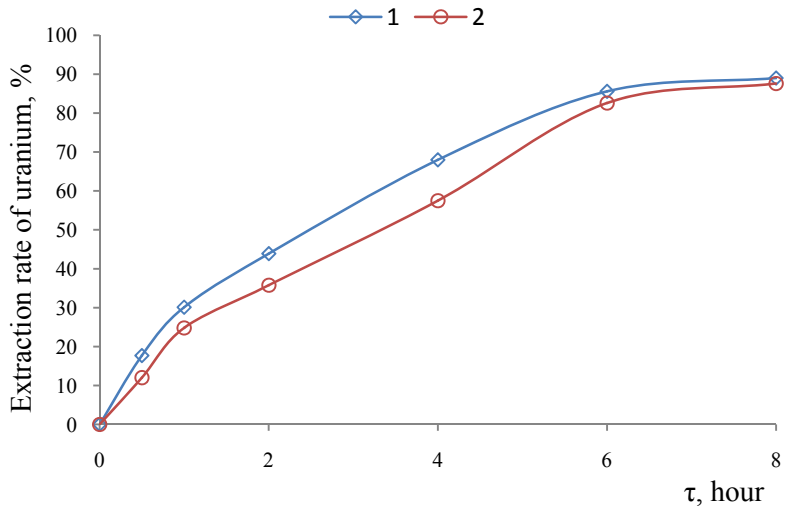


Figure 3 – Kinetic curves of sorption of uranium from the productive solution on anion exchangers:
1 – Purolite-A500; 2 – Ambersep-920

In addition, studies have shown that increasing the duration of the process beyond 8 hours is ineffective.

It is known from literature sources [16-18] that at low concentrations of uranium it is possible to use natural sorbents - shungite, zeolite - to extract it.

During the research, sorption extraction of uranium was tested with natural sorbents. The main constituents of the natural zeolite that we used are chabasite - (Ca, Na)$[Al_2Si_4O_{12}]\cdot 6H_2O$, desmin (stilbite) - $Ca[Al_2Si_7O_{18}]\cdot 7H_2O$, analcite - $Na_2[AlSi_2O_6]\cdot 2H_2O$ and the harmonic - $Ba[Al_2Si_6O_{16}]$. The composition of schungite for the main components is given in table 4. It should be noted that in the microquantities the composition of schungite includes such elements as:Sr, Co, Zn, Y, Cu, Sn, Mo, Ba, Ni, Mn, V, etc.

Table 3 – Chemical composition of schungite

Sorbent	Content, % wt.							
	C	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O
Shungite	10	26.01	6.55	3.81	2.5	13.5	0.6	1.46

The results of uranium sorption from productive solutions are presented in table 4.

Table 4 – Results of sorption of uranium from productive solutions

#	Sorbent	Sorbent weight, g	Loading U with a productive solution, mg	Uranium content in the mother liquor of sorption, mg/dm^3	The extraction of uranium into the sorbent		Calculated content of U in the sorbent without taking into account sorbed impurities, % wt.
					mg	%	
1	Shungite	10	21.25	0.85	19.3	90.9	0.193
2	Zeolite	12	22.0	0.97	19.8	90.1	0.165

It states in the table that the degree of extraction of uranium by natural sorbents is quite comparable with the synthetic ones (T: F for synthetic sorbents 1: 500, and for natural sorbents 1-1.2: 25), but their sorption capacity is low. The main disadvantage of synthetic sorbents is their high cost, and therefore, the use for uranium sorption from solutions with low concentrations (usually for pre-extraction) is unreasonable. To extract uranium from productive solutions, or from liquid waste of uranium chemical-metallurgical industries, it is more profitable to use natural sorbents. However, due to the low sorption capacity, their use is limited. At present, we are working to increase the sorption capacity of natural ion exchangers for uranium.

Conclusions. At the heart of the hydrometallurgical method of extracting uranium from ores in the industry of Kazakhstan is the method of underground leaching with sulfuric acid.

The tendency in the development of the world uranium mining industry in the development of the world uranium mining industry has also affected the uranium mining industry of the republic, which necessitated the involvement of persistent uranium-bearing ores. The minerals of tetravalent uranium insoluble in sulfuric acid represent such ores, as a rule. Therefore, at the heart of the overwhelming majority of research works is the question of the most complete transfer of uranium compounds into a soluble state, i.e. uranium (IV) into uranium (VI).

When poorly soluble uranium ores containing mainly tetravalent uranium bysulfuric acid is leached, the main task is the most complete oxidation of uranium (IV) to uranium (VI). Uranium (IV) in sulfuric acid is insoluble. In this connection, the study of the effect of new intensifiers on the process of uranium leaching is of great interest.

The influence of "M-1" catalyst on uranium leaching from persistent uranium-containing ore is studied and its advantage over traditional oxidants is shown.

Sorption methods are used to extract uranium from productive solutions. The concentration of uranium on Purolite-A500 and Ambersep-920 ion exchangers and natural sorbents - zeolite and shungitewas studied. In view of the low cost of natural sorbents, their priority use is considered for the extraction of uranium from productive solutions and liquid waste of uranium chemical and metallurgical industries.

The present work was carried out within the framework of the state order for the implementation of scientific and technical projects on the budget program "Grant financing of scientific research" on the topic: "Development of innovative technologies for selective uranium mining from uranium-containing solutions using new modified sorbents based on natural minerals of Kazakhstan", funded by the Scientific Committee of the Ministry of Education and Science of the Republic of Kazakhstan.

Б. К. Кенжалиев[1, 2], Т. Ю. Суркова[1], А. Н. Беркинбаева[1], З. Д. Досымбаева[1], М. Т. Чукманова[1, 2]

[1]«Металлургия және кенбайыту институты» АҚ, Алматы, Қазақстан,
[2]«Қ. И. СәтбаеватындағыҚазақұлттықтехникалықзерттеууниверситеті» КЕАҚ, Алматы, Қазақстан

МИНЕРАЛДЫ ШИКІЗАТТАРДАН УРАНДЫБӨЛІП АЛУ МӘСЕЛЕСІ

Аннотация. Радиоактивті кен орындарынан уран өндірудезаманауи ғылыми-технологиялық прогрестің бағыттарының бірі іс жүзінде қалдықсыз игеру әдісі жерасты шаймалау (ЖШ) болып табылады.

Күкірт қышқылын шаймалау реагент ретінде қолдану тек уранның (VI) қосылыстарын алуға мүмкіндік береді.Уранның (IV) қосылыстары күкірт қышқылында ерімейді.Индустрияда, уранды (VI) уранға (IV)

айналдыру үшін тотықтырғыштар көбінесе, құрамында темір бар қосылыстар қолданылады. Осыған байланысты жер асты шаймалауда ураны өндіруді арттырудың негізгі мәселесі - уран (IV) ерігіш күйге ауысу.

Мақалада өтпелі металдардың қосындысы болып табылатын «М-1» катализаторы күшейткіш ретінде қарастырылады. Салыстырмалы деректер рудадан ураны үдетпелі шаймалауды бірнеше оксиданттың қатысуымен зерттеулержүргізілген. «М-1» катализаторының басымдықты пайдаланылуы байқалды.

Ураны ерітінділерден алу үшін сорбциялық әдістер қолданылады.«М-1» катализаторының қатысуымен ураны бар кендерді шаймалау ерітінділерінен ураны Purolite A-500 және Ambersep-920 иониттерімен сорбциялаудың кинетикалық тәуелділіктері олардың айырмашылығының шамалы екенін көрсетті. Әдебиет көздерінде уранның аз мөлшерімен өнімді ерітінділерден уран алу үшін табиғи сорбенттерді пайдалану туралы мәліметтер кездеседі. Мұндай сорбенттердің артықшылықтары олардың құнының арзандығы болып табылады. Табиғи цеолит пен шунгитпен уранның сорбциялануы туралы мәліметтер берілген.

Түйін сөздер: уран, шаймалау, сорбция, күшейткіш, катализатор, сорбент.

Б. К. Кенжалиев[1, 2], Т. Ю. Суркова[1], А.Н. Беркинбаева[1], З. Д. Досымбаева[1], М. Т. Чукманова[1,2]

[1]АО Институт металлургии и обогащения, Алматы, Казахстан,
[2]НАО Казахский национальный исследовательский технический университет им. К. И. Сатпаева, Алматы, Казахстан

К ВОПРОСУ ОБ ИЗВЛЕЧЕНИИ УРАНА ИЗ МИНЕРАЛЬНОГО СЫРЬЯ

Аннотация. Одним из направлений современного научно-технического прогресса в разработке месторождений радиоактивных руд является применение практически безотходного способа добычи урана – подземного выщелачивания (ПВ).

Применение серной кислоты в качестве выщелачивающего реагента позволяет извлечь только соединения урана (VI), так как соединения урана (IV) в серной кислоте не растворяются. Для перевода урана (VI) в уран (IV) в промышленности используют окислители, чаще всего – соединения трехвалентного железа. В этой связи основная проблема повышения извлечения урана при подземном скважном выщелачивании - перевод урана (IV) в растворимое состояние.

В статье в качестве интенсификатора рассматривается катализатор «М-1», который представляет собой соединения переходных металлов. Приведены сопоставительные данные исследования агитационного выщелачивания урана из руды в присутствии ряда окислителей. Отмечено приоритетное использование катализатора «М-1».

Для извлечения урана из продуктивных растворов применяют сорбционные методы. Сравнение кинетических зависимостей сорбционного извлечения урана ионитамиPurolite A-500 и Ambersep-920 из продуктивных растворов от выщелачивания урансодержащей руды в присутствии катализатора «М-1» показало, что они отличаются незначительно.

В литературе имеются сведения о применении природных сорбентов для извлечения урана из продуктивных растворов с низким его содержанием. Преимущества таких сорбентов – их невысокая стоимость. Приведены данные о сорбции урана природными цеолитом и шунгитом.

Ключевые слова: уран, выщелачивание, сорбция, интенсификатор, катализатор, сорбент.

Information about authors:

Kenzhaliev B.K., Doctor of Technical Sciences, Professor, Kazakh national research technical university named after K. I. Satpaev, Vice-Rector for Science; Institute of Metallurgy and Enrichment, General Director, Almaty, Kazakhstan; bagdaulet_k@mail.ru; http://orcid.org/0000-0003-1474-8354

Surkova T.Yu., C. Tech. S. “Institute of Metallurgy and Ore beneficiation”, Leading Researcher, Almaty, Kazakhstan; tu-surkova@mail.ru; http://orcid.org/0000-0001-8271-125X

Berkinbayeva A.N., C. Tech. S. “Institute of Metallurgy and Ore beneficiation”, Senior Researcher, Almaty, Kazakhstan; ainur_kbk@mail.ru; http://orcid.org/0000-0002-2569-9087

Dosymbayeva Z.D., “Institute of Metallurgy and Ore beneficiation”, Researcher, Almaty, Kazakhstan; zdos@mail.ru; http://orcid.org/0000-0001-9144-208X

Chukmanova M.T., “Institute of Metallurgy and Ore beneficiation”, Junior Researcher; "The Kazakh national research technical University after K. I. Satpaev», doctoral student, Almaty, Kazakhstan; chukmanova_m@mail.ru; http://orcid.org/0000-0002-9626-3205

REFERENCES

[1] Gallegos T.J., Campbell K.M., Zielinski R.A., Reimus P.W., Clay J.T., Jano N.T., John R.B. (**2015**). Persistent U (IV) and U (VI) following in-situ recovery (ISR) mining of a sandstone uranium deposit // Wyoming, USA, Applied Geochemistry. 63:222-234. DOI: org/10.1016/j.apgeochem.2015.08.017 (in Eng.).

[2] Balboni E., Simonetti A., Tyler S., Nathaniel D.C., Peter C.B. (**2017**). Rare-earth element fractionation in uranium ore and its U (VI) alteration minerals // Applied Geochemistry. 87: 84-92. DOI: org/10.1016/j.apgeochem.2017.10.007 (in Eng.).

[3] Susan A.C., Barbara E., Joël B., Grant D., Katy E., Louise F., Peter K. (**2018**). Characterization of uranium redox state in organic-rich Eocene sediments // Chemosphere. 194: 602-613. DOI: org/10.1016/j.chemosphere.2017.12.012 (in Eng.).

[4] Novotnik B., Chen W., Evans R.D. (**2018**). Uranium bearing dissolved organic matter in the porewaters of uranium contaminated lake sediments // Applied Geochemistry. 91: 36-44. doi.org/10.1016/j.apgeochem.2018.01.009 (in Eng.).

[5] Rorie G., Aleksandar N.N. (**2015**). The extraction of uranium from brannerite – A literature review // Minerals Engineering. 71: 34-48. DOI.org/10.1016/j.mineng.2014.10.007 (in Eng.).

[6] Panfilov M., Uralbekov B., Burkitbayev M. (**2016**). Reactive transport in the underground leaching of uranium: Asymptotic analytical solution for multi-reaction model // Hydrometallurgy. 160: 60-72. DOI.org/10.1016/j.hydromet.2015.11.012 (in Eng.).

[7] Satybaldiyev B., Lehto J., Suksi J., Tuovinen H., Uralbekov B., Burkitbayev M. (**2015**). Understanding sulphuric acid leaching of uranium from ore by means of $^{234}U/^{238}U$ activity ratio as an indicator // Hydrometallurgy. 155: 125-131. DOI: org/10.1016/j.hydromet.2015.04.017 (in Eng.).

[8] Polyakov E.G., Sibilev A.S. (**2016**). Recycling rare-earth-metal waste using hydrometallurgical methods // Theoretical Foundations of Chemical Engineering. 50: 607-612. DOI: 10.1134/S0040579516040266 (in Eng.).

[9] Wang X., Thomas X.W., Craig M.J., Lundstrom C. **(2015**). Isotope fractionation during oxidation of tetravalent uranium by dissolved oxygen // Geochimica et Cosmochimica Acta. 150: 160-170. DOI: org/10.1016/j.gca.2014.12.007 (in Eng.).

[10] Natrajan L.S., Swinburne A.N., Andrews M.B., Randall S., Heath S.L. (**2014**). Redox and environmentally relevant aspects of actinide (IV) coordination chemistry // Coordination Chemistry Reviews. 266: 171-193. doi.org/10.1016/j.ccr.2013.12.021 (in Eng.).

[11] James T.M., Mark D.O., Richard I.F., Neilish S., Karin S., Clint A.Sh. (**2018**). Polyamine functionalised ion exchange resins: Synthesis, characterisation and uranyl uptake // Chemical Engineering Journal. 334: 1361-1370. DOI: org/10.1016/j.cej.2017.11.040 (in Eng.).

[12] Jinling W., Kun T., Jianlong W. (**2018**). Adsorption of uranium (VI) by amidoxime modified multiwalled carbon nanotubes // Progress in Nuclear Energy. 106: 79-86. DOI: org/10.1016/j.pnucene.2018.02.020 (in Eng.).

[13] Shakur H.R., Rezaee E.Kh., Abdi M.R., Azimi G. (**2016**). Highly selective and effective removal of uranium from contaminated drinking water using a novel PAN/AgX/ZnOnanocomposite // Microporous and Mesoporous Materials. 234: 257-266. DOI: org/10.1016/j.micromeso.2016.07.034 (in Eng.).

[14] Amphlett J.T., Sharrad C.A., Ogden M.D. (**2018**). Extraction of uranium from non-saline and hypersaline conditions using iminodiacetic acid chelating resin Purolite S930+ // Chemical Engineering Journal. 342: 133-141. DOI: org/10.1016/j.cej.2018.01.090 (in Eng.).

[15] Cheira M.F., Atia B.M., Kouraim M.N. (**2017**). Uranium (VI) recovery from acidic leach liquor by Ambersep 920U SO_4 resin: Kinetic, equilibrium and thermodynamic studies // Journal of Radiation Research and Applied Sciences. 10: 307-319. DOI: org/10.1016/j.jrras.2017.07.005 (in Eng.).

[16] Sineva A. (**2014**). Adsorption of Synthetic Surfactants from Aqueous Solutions on Natural Adsorbents // The Role of Colloidal Systems in Environmental Protection. 6: 143-171. https://doi.org/10.1016/B978-0-444-63283-8.00006-5.

[17] Peter J.R., Howard J.F. (**2018**). Natural and surfactant modified zeolites: A review of their applications for water remediation with a focus on surfactant desorption and toxicity towards microorganisms // Journal of Environmental Management. 205: 253-261. DOI: org/10.1016/j.jenvman.2017.09.077 (in Eng.).

[18] Maria V. (**2016**). Synthesis and characterization of new zeolite materials obtained from fly ash for heavy metals removal in advanced wastewater treatment // Powder technology. 294: 338-347. doi.org/10.1016/j.powtec.2016.02.019 (in Eng.).

[19] Aibassov Y., Aibassova S., Aibassov G., Aibassov Zh., Aibassov M., Abenov B. (**2013**). Method of catalytic oxidation of U^{+4} to U^{+6} using a catalyst Muhamedzhan-1. Patent US (in Eng.).

[20] Aibassov E.Z., Kenzhaliev B.K., Tussupbaev N.K., Berkinbayeva A.N., Chukmanova M.T., Iskhakova R.R., Bulenbayev M.Z. (**2014**). Preparation of Uranyl Complexes with Sugars // Journal of Chemistry and Chemical Engineering. 8: 641-646 (in Eng.).

[21] Abisheva Z.S., Zagorodnjaja A.N., Sadykanova S.J., Bobrova V.V., Sharipova A.S. (2011). Sorption technology of rhenium extraction from uranium-containing solutions using weakly basic anion exchangers [Sorbcionnaja tehnologija izvlechenija renija iz uransoderzhashhih rastvorov s ispol'zovaniem slaboosnovnyh anionitov] // Complex Use of Mineral Resources [Kompleksnoe ispol'zovanie mineral'nogo syr'ja]. 3:8-16 (in Rus.).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 120 – 126 **https://doi.org/10.32014/2019.2518-170X.15**

UDC 536.248.2

L. M. Musabekova[1], A. T. Kalbayeva[1], V. V. Dilman[2], N. S. Zhumataev[3], S. D. Kurakbayeva[1], B. R. Tauasarov[4]

[1]South Kazakhstan State University named after M. O. Auezov, Shymkent, Kazakhstan,
[2]Kurnakov Institute of General and Inorganic Chemistry, Moscow, Russia,
[3]South Kazakhstan Pedagogical university, Shymkent, Kazakhstan,
[4]South Kazakh College "Femida", Shymkent, Kazakhstan.
E-mail: mleyla@bk.ru, kalbaeva@mail.ru, viktor.dilman@rambler.ru,
nuralmiras@mail.ru, sevam@mail.ru, shbolat@mail.ru

MODELING OF DYNAMICAL REACTION-DIFFUSION SYSTEMS WITH MULTISTAGE AND NON-PERFECT KINETICS

Abstract. The paper deals with the problems of dynamical models describing reaction-diffusion systems characterizing by the multistage and non-perfect kinetics. The main types of dynamical behavior of such systems using two typical examples have been considered. As a result of the research it was concluded that multistage and non-perfect kinetics can strongly influence on the reactor regimes and change their main characteristics. It wasalso concluded that non-perfect kinetics in the case of high diluted solutions doesn't change types of rest points and reactor regimes. However, velocity of wave front which generates from transient oscillatory regimes differs from the velocity of wave front in a perfect system.

Concrete values of regimes characteristics have undergone changes too. It was shown that the rate of reagents supply not only controls an output of the reactor but also can essentially change a set of stationary and transition process regimes. Usually engineers connect such transformations with heat phenomena. The mentioned above factors can also cause regime transitions. In addition the set of parameters controlling the regime stability and describing the system bifurcations has been obtained.

The main types of possible dissipate structures caused by these factors as well as cases of their formation have been also determined. Besides, transition regimes are determined by a system non-linearity. However in the case of strong solutions the situation may be different. This problem needs an additional study. The results of the research are feasibly to be useful for calculating the intensity of mass transfer processes in chemical reactors.

Key words: dissipate structures,multistage kinetics, non-perfect systems, reaction-diffusion systems.

Introduction. Multistage kinetics and non-perfectness of reaction-diffusion systems have an essential influence on the process regime in chemical reactors [1]. It is well-known that multistage kinetics can stimulate the origin of multiplicity of stationary points in system dynamics. Besides, chemical oscillations are observed only in the multistage reaction-diffusion systems [2].

Non-perfectness is also very important aspect that can play an essential role under generating dynamical regimes in the point of view of chemical thermodynamics [3]. And concrete values of regimes characteristics can undergo changes too.

However engineers often do not give due attention to these aspects of chemical processes and its impact on the apparatuses design. They usually connect such transformations only with heat phenomena. But the mentioned above factors can also cause regime transitions.

In our work this problem has been theoretically investigated and illustrated by means of two model auto-catalytic reactions as examples.

Model systems with multistage kinetics. Firstly we consider the following model scheme with the main reagents X, Y and intermediate products A, C, despite the first stage is supposed to be an auto-catalytic reaction [3]:

$$X + Y \xrightarrow{k_1} X, \quad X \xrightarrow{k_2} A, \quad Y \xrightarrow{k_3} C, \tag{1}$$

where k_1, k_2, k_3 are the reactions rate constants.

Let's assume that the component Y enters the reactor continuously with constant supply rate q, and the reagent X is the initial priming-tube.

Thus the system of kinetic equations for main reagents reads [4]:

$$\begin{aligned} \frac{dX}{dt} &= k_1 XY - k_2 X, \\ \frac{dY}{dt} &= q - k_1 XY - k_3 Y. \end{aligned} \tag{2}$$

Here $X \geq 0$ and $Y \geq 0$ denote concentrations of reagents X and Y.

Provided the rate q satisfying the inequation

$$q < \frac{k_2 k_3}{k_1} \tag{3}$$

there is the only stable rest point of the system (2)

$$X_{01} = 0; \quad Y_{01} = \frac{q}{k_3}. \tag{4}$$

But when this rate exceeds the critical value

$$q > q^* = \frac{k_2 k_3}{k_1} \tag{5}$$

the system acquires yet another rest point:

$$X_{02} = \frac{qk_1 - k_2 k_3}{k_1 k_2}; \qquad Y_{02} = \frac{k_2}{k_1}. \tag{6}$$

Jacobians of the linearized system of kinetic equations at the rest points have the following

$$J_{01} = \begin{pmatrix} -k_2 + \dfrac{k_1 q}{k_3} & 0 \\ -\dfrac{k_1 q}{k_3} & -k_3 \end{pmatrix}, \tag{7}$$

$$J_{02} = \begin{pmatrix} 0 & \dfrac{qk_1 - k_2 k_3}{k_2} \\ -k_2 & -\dfrac{qk_1}{k_2} \end{pmatrix}. \tag{8}$$

Provided $q > q^*$ the rest point (4) becomes unstable. And the springing up rest point (6) becomes stable on the contrary and it has a type of stable node or stable spiral.

The regimes analysis gives the following results:

1) for $(k_3/k_2) \geq 1$ at any q the rest point (6) is a stable node, and oscillations donot exist;

2) for $(k_3/k_2) < 1$ at q exceeding the critical value q^* rest point (6) can be a spiral.

At $(k_3/k_2) < 1$ we have

$$q^* < \frac{2k_2^2}{k_1}\left[1 - \sqrt{1 - \frac{k_3}{k_2}}\right]. \tag{9}$$

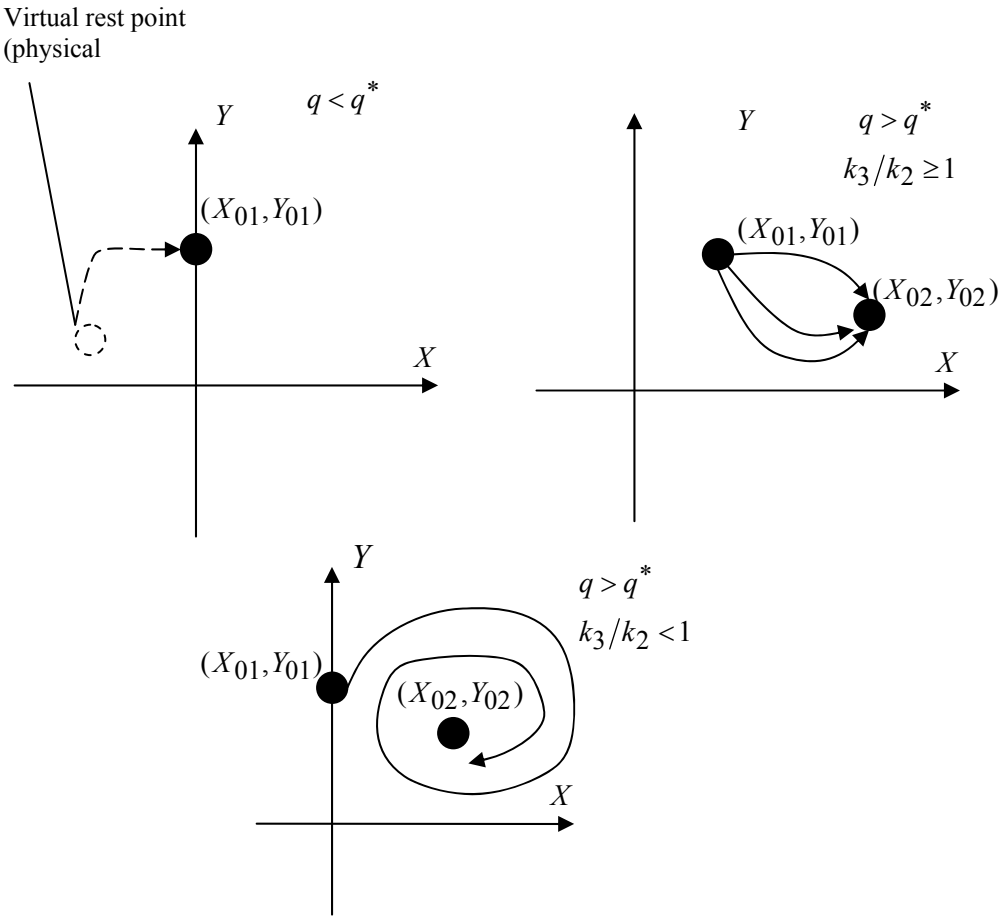
From this it follows that provided $(k_3/k_2) < 1$ and $q > q^*$ the rest point (6) is a stable spiral, and appropriate transition regime goes on in the form of oscillations at the rate range

$$q_1 < q < q_2, \tag{10}$$

where

$$q_1 = \frac{2k_2^2}{k_1}\left[1 - \sqrt{1 - \frac{k_3}{k_2}}\right], \tag{11}$$

$$q_2 = \frac{2k_2^2}{k_1}\left[1 + \sqrt{1 - \frac{k_3}{k_2}}\right]. \tag{12}$$



Phase curves near the rest points of the system (2)

Thus the system has the control parameter

$$\alpha = \frac{k_3}{k_2}. \tag{13}$$

The value $\alpha = \alpha^* = 1$ is the bifurcation point, and for the transition regime we can obtain the frequency of oscillations ω and the logarithmic fading decrement ν:

$$\omega = \sqrt{\frac{2q}{k_3} - \frac{2k_2k_4}{k_1k_3} - \frac{k_3k_4^2}{4}}, \tag{14}$$

$$\nu = -\frac{k_4}{2} \tag{15}$$

The second example is the auto-catalytic reaction of the following type [2, 3]:

$$A + X \underset{k_2}{\overset{k_1}{\rightleftarrows}} 2X + C\,. \tag{16}$$

In the perfect thermodynamic system the following relation is true

$$\mu = \mu^* + RT \ln X\,, \tag{17}$$

where μ is a chemical potential and μ^* - its standard value, R is gas constant, T is a temperature.

Impact of system non-perfectness. Let's consider the case of non-perfect reaction-diffusion system, where the chemical potentials of reagents read [5].

$$\mu = \mu^* + RT \ln X + \omega_{AX}(1 - X)^2\,. \tag{18}$$

Here

$$\omega_{AX} = \kappa[2\varepsilon_{AX} - (\varepsilon_{AA} + \varepsilon_{XX})], \tag{19}$$

and ε_{AX}, ε_{AA}, ε_{XX} are energies of interaction between molecules of reagents, κ is a parameter depending on the model of liquid state [6-8].

Supposing $X << 1$ we obtain the following approximate relation

$$\mu = \mu^* + RT \ln X + \omega_{AX}(1 - 2X). \tag{20}$$

According to thermodynamics of diluted solutions, the diffusion coefficients determine by the derivatives of chemical potentials over the concentrations [9].

Thus we obtain:

$$\frac{\partial \mu}{\partial X} = \frac{RT}{X} - 2\omega_{AX} = \frac{RT}{X}(1 - 2\omega_{AX} X), \tag{21}$$

From this it follows

$$D = D_i(1 - 2\omega_{AX} X), \tag{22}$$

where D_i is the diffusion coefficient in perfect system, D is the one in a real system [10-12].

And so, the mass transfer equation for the reaction (15) proceeding in a tubular through-reactor can be written as follows

$$\frac{\partial X}{\partial t} + q\frac{\partial X}{\partial z} = \frac{\partial}{\partial z}\left(D_i(1 - 2\omega_{AX} X)\frac{\partial X}{\partial z} \right) + f(X), \tag{23}$$

where

$$f(X) = k_1 AX - k_2 X^2\,. \tag{24}$$

Using method of an auto-model variable the equation (23) can be reduced to the following ordinary differential equation [13]

$$\frac{d^2 X}{ds^2} - \frac{q - c}{D_i(1 - 2\omega_{AX} X)}\frac{dX}{ds} - \frac{2\omega_{AX}}{1 - 2\omega_{AX} X}\left(\frac{dX}{ds}\right)^2 + \frac{f(X)}{D_i(1 - 2\omega_{AX})} = 0\,, \tag{25}$$

where $s = x - ct$, c is a phase velocity or a velocity of wave front.

Equations of the appropriate dynamical system read

$$\begin{cases} \dfrac{dX}{dt} = Y, \\ \dfrac{dY}{dt} = \dfrac{q-c}{D_i\left(1-2\omega_{AX}X\right)}Y + \dfrac{2\omega_{AX}}{1-2\omega_{AX}X}Y^2 - \dfrac{f(X)}{D_i\left(1-2\omega_{AX}X\right)} = 0 \end{cases} \tag{26}$$

There are two rest points of the system

$$X_{01} = 0, \quad X_{02} = A\frac{k_1}{k_2}. \tag{27}$$

Jacobians of the linearized system (26) at the rest points (27) read

$$J_{01} = \begin{pmatrix} 0 & 1 \\ -\dfrac{k_1 A}{D_i} & \dfrac{q-c}{D_i} \end{pmatrix}, \tag{28}$$

$$J_{02} = \begin{pmatrix} 0 & 1 \\ \dfrac{k_1 A}{D_i(1-\gamma)} & \dfrac{q-c}{D_i(1-\gamma)} \end{pmatrix}. \tag{29}$$

where

$$\gamma = 2\omega_{AX} A\frac{k_1}{k_2}. \tag{30}$$

As for diluted solutions $\omega_{AX} << 1$ the following inequation is correct

$$\gamma < 1. \tag{31}$$

From detail analysis which is analogous with the analysis of system (2) we conclude that non-perfect kinetics in the case of high diluted solutions does not change types of rest points and reactor regimes. At the same time, concrete values of regimes characteristics have undergone changes [14-17].

Particularly, the velocity of wave front which generates from transient oscillatory regimes differs from the velocity of wave front in a perfect system [18].

The appropriate relation reads

$$c_{0r} = c_0 + \gamma\sqrt{k_1 D_i A}\ . \tag{32}$$

Here c_0 is the wave front velocity calculated for the perfect system:

$$c_0 = \left|q - 2\sqrt{k_1 DA}\right|, \tag{33}$$

and $\gamma < 1$ is the special amendment coefficient for which we obtain the following relation

$$\gamma = 2\omega_{AX}\frac{k_1}{k_2}A. \tag{34}$$

Conclusion. It can be concluded that rate of reagents supply not only controls an output of the reactor but also can essentially change a set of stationary and transition process regimes. Usually engineers connect such transformations with heat phenomena [19]. At the same time the mentioned above factors can also cause regime transitions.

As regards the non-perfection of systems its influence for high diluted solutions manifests only in increasing the wave front velocity under transition regimes [20]. Incidentally, transition regimes-themselves are determined by a system non-linearity. However in the case of strong solutions the situation may be different. This problem needs an additional study [21].

Л. М. Мусабекова[1], А. Т. Қалбаева[1], В. В. Дильман[2], Н. С. Жуматаев[3], С. Ж. Құрақбаева[1], Б. Р. Тауасаров[4]

[1]М. Әуезов атындағы ОҚМУ, Шымкент, Қазақстан,
[2]Н. С. Курнаков атындағы жалпы және бейорганикалық химия институты, Мәскеу, Ресей,
[3]Оңтүстік Қазақстан педагогикалық университеті, Шымкент, Қазақстан,
[4]Оңтүстік Қазақстан "Фемида" колледжі, Шымкент, Қазақстан

ДИНАМИКАЛЫҚ РЕАКЦИЯЛЫҚ-ДИФФУЗИЯЛЫҚ ЖҮЙЕЛЕРДІ КӨПСАТЫЛЫ ЖӘНЕ ИДЕАЛДЫ ЕМЕС КИНЕТИКАМЕН МОДЕЛЬДЕУ

Аннотация. Жұмыс көп сатылы және идеалды емес кинетикамен сипатталатын реакциялық-диффузиялық жүйелерді сипаттайтын динамикалық үлгілердің мәселелеріне арналған. Осындай жүйелердің динамикалық мінез-құлқының негізгі түрлері екі типтік мысалды қолдану арқылы қарастырылды. Зерттеудің нәтижесінде көп сатылы және идеалдық емес кинетика реактор режимдеріне қатты әсер етуі және олардың негізгі сипаттамаларын өзгертуі мүмкін деген қорытынды жасалды. Сондай-ақ, жоғары дәрежелі сұйылтылған ерітінділер жағдайында идеалды емес кинетика тыныштық нүктелері мен реактор режимдерінің түрлерін өзгертпейді деген қорытынды жасалды. Дегенмен, уақытша ауытқу режимдерінен туындайтын толқындық майдан (фронт) жылдамдығы толқындық майдан (фронт) жылдамдығынан идеалды жүйеде ерекшеленеді. Режимдердің сипаттамаларының нақты мәндері де өзгерді. Реагенттердің берілу жылдамдығы тек реактордың шығуын бақылап қана қоймай, сонымен қатар стационарлық және өтпелі процестер режимдерінің жиынтығын айтарлықтай өзгерте алатындығы көрсетілді. Әдетте инженерлер мұндай өзгерістерді жылулық құбылыстармен байланыстырады. Жоғарыда аталған факторлар өтпелі режимдерді тудыруы мүмкін. Режимнің тұрақтылығын басқаратын және жүйенің бифуркациясын сипаттайтын параметрлер жиынтығы да алынды. Осы факторларға байланысты мүмкін диссипативті құрылымдардың негізгі түрлері, сондай-ақ оларды қалыптастыру жағдайлары анықталған. Сонымен қатар, өтпелі режимдер жүйенің сызықтық еместігі арқылы анықталады. Алайда, концентрацияланған ерітінділер болған кезде, жағдай басқаша болуы мүмкін. Бұл мәселе қосымша зерттеуді талап етеді. Зерттеу нәтижелері химиялық реакторларда жаппай тасымалдау процестерінің қарқындылығын есептеу үшін пайдалы болуы мүмкін.

Түйін сөздер: диссипативті құрылымдар, көп сатылы кинетика, идеалды емес жүйелер, реакциялық-диффузиялық жүйелер.

Л. М. Мусабекова[1], А. Т. Калбаева[1], В. В. Дильман[2], Н. С. Жуматаев[3], С. Д. Куракбаева[1], Б. Р. Тауасаров[4]

[1]Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,
[2]Институт общей и неорганической химии им. Н. С. Курнакова РАН, Москва, Россия,
[3]Южно-Казахстанский педагогический университет, Шымкент, Казахстан,
[4]Южно-Казахстанский колледж "Фемида", Шымкент, Казахстан

МОДЕЛИРОВАНИЕ ДИНАМИЧЕСКИХ РЕАКЦИОННО-ДИФФУЗИОННЫХ СИСТЕМ С МНОГОСТАДИЙНОЙ И НЕИДЕАЛЬНОЙ КИНЕТИКОЙ

Аннотация. Работа посвящена проблемам динамических моделей, описывающих реакционно-диффузионные системы, характеризующиеся многосдадийной и неидеальной кинетикой. Рассмотрены основные типы динамического поведения таких систем с использованием двух типичных примеров. В результате исследования был сделан вывод о том, что многостадийная и неидеальная кинетика может оказывать сильное влияние на режимы реактора и изменять их основные характеристики. Также было сделано заключение о том, что неидеальная кинетика в случае сильно разбавленных растворов не меняет типов точек покоя и режимов реактора. Однако скорость фронта волны, которая возникает из переходных колебательных режимов, отличается от скорости фронта волны в идеальной системе. Конкретные значения характеристик режимов также претерпели изменения. Было показано, что скорость подачи реагентов не только контролирует выход реактора, но также может существенно изменить набор режимов стационарного и переходного процессов. Обычно инженеры связывают такие преобразования с тепловыми явлениями. Указанные выше факторы также могут вызывать переходные режимы. Был получен также набор параметров, управляющих стабильностью режима и описывающих бифуркации системы. Определены также основные типы возможных диссипативных структур, вызванные этими факторами, а также случаи их образования. Кроме того, переходные режимы определяются системной нелинейностью. Однако в случае концентрированных растворов ситуация может быть иной. Эта проблема нуждается в дополнительном исследовании. Результаты исследования могут быть полезны для расчета интенсивности процессов массопереноса в химических реакторах.

Ключевые слова: диссипативные структуры, многостадийная кинетика, неидеальные системы, реакционно-диффузионные системы.

Information about authors:

Musabekova Leila, Doctor of Technical Sciences, professor, M. Auezov South-Kazakhstan State University, "Information Technologies and Energy" Higher School, Department of "Computing Systems and Software"; mleyla@bk.ru; Analysis of the problem, research results processing; http://orcid.org/0000-0001-8712-2446

Kalbayeva Aizhan, Candidate of technical science, associate professor, M. Auezov South-Kazakhstan State University, "Information Technologies and Energy" Higher School, Department of "Information Systems and Modeling"; kalbaeva@mail.ru; Mathematical modelling; https://orcid.org/0000-0001-7718-5857

Dilman Viktor, Doctor of Technical Sciences, Professor, Kurnakov Institute of General and Inorganic Chemistry, Russian Academy of Sciences; viktor.dilman@rambler.ru; Problem setting, consultations; https://orcid.org/0000-0002-1864-810X

Zhumataev Nurlybek, PhD, Vice-rector on research and innovation activities, South Kazakhstan Pedagogical university; nuralmiras@mail.ru; Science literature analysis; https://orcid.org/0000-0001-7840-4425

Kurakbayeva Sevara, Candidate of technical science, associate professor, M. Auezov South-Kazakhstan State University, "Information Technologies and Energy" Higher School, Department of "Information Systems and Modeling"; sevam@mail.ru; Computer simulation; https://orcid.org/0000-0001-5463-1930

Tauasarov Bolat, Candidate of technical science, associate professor, Director of South Kazakh College “Femida”; shbolat@mail.ru; Research results processing, conclusions; https://orcid.org/0000-0003-0543-2075

REFERENCES

[1] Kudryavtsev I.K. (1987). Chemical Instabilities. M.: Moscow Univ. Publ. (in Rus.).

[2] Jou D., Casas-Vazquez J., Criado-Sancho M. (2001) Thermodynamics of Fluids Under Flow. Berlin: Springer.

[3] Saul A., Showalter K. (1985). Propagation of wave fronts in reaction-diffusion systems. Oscillations and Traveling Waves in Chemical Systems / Ed. R. J. Field and M. Burger. New York: Wiley. P. 451-471.

[4] Kalbayeva A.T., Kurakbayeva S.D., Tashimov L.T., Dilman V.V., Kalbayeva A.T., Elbergenova G.Zh. Simulation of autocatalytic systems with chemical oscillations with allowing for reaction stages reversibility // News of NAS RK. Series of geology and technical sciences. 2018. N 4(430). P. 110-123. https://doi.org/10.32014/2018.2518-170X.

[5] Karapetyanz M.K. (1975). Chemical Therodynamics. M.: Himia (in Rus.).

[6] Richard J. Field, Maria Burger (1985). Oscillations and Travelling Waves in Chemical Systems. Wiley-Interscience, United States. ISBN 978-0471893844.

[7] Tauasarov B.R., Kalbayeva A.T., Brener A.M. (2003). Modeling of a two-stage reactor recycle autocatalytic // Search [Poisk]. Series natural sciences and engineering. 4(2): 175-179 (in Rus.).

[8] Kalbaeva A.T., Tauasarov B.R. (2004). Numerical research reaction-diffusion systems in the flow tube reactor // Proceedings of the International scientific conference "Science and education on the threshold of the XXI century", dedicated to the 10th anniversary of M. Saparbayev. Shymkent: South Kazakhstan Humanitarian Institute. Vol. 2. P. 81-85 (in Rus.).

[9] Kalbaeva A.T., Tauasarov B.R. (2004). Numerical modeling of stationary modes autocatalytic flow reactors // Proceedings of the International scientific-theoretical conference of young scientists. Shymkent. P. 86-89 (in Rus.).

[10] Kalbaeva A.T., Tauasarov B.R., Brener A.M. (2003). Numerical solution of kinetic equations for the "brusselator" system with allowing for the reversibility of two kinetic stages // Science and Education of South Kazakhstan, chapters: Chemistry, chemical technology. Processes and apparatuses. Shymkent. Vol. 2, N 35. P. 120-123 (in Rus.).

[11] Kalbaeva A.T., Tauasarov B.R., Brener A.M. (2003). Simulating the kinetics of reactions of the "brusselator" type accounting to the kinetic stages reversibility. Numerical solution of kinetic equations for the "brusselator" system with allowing for the reversibility of two kinetic stages // Science and Education of South Kazakhstan, chapters: Chemistry, chemical technology. Processes and apparatuses. Vol. 2, N 35. Shymkent. P. 44-46 (in Rus.).

[12] Kalbaeva A.T., Kurakbayeva S.D., Zhidebayeva A.N., Musrepova E. (2014). Modelling the Dinamical Regimes of Mass Transfer in Cascades of Through – Reactors // 17th Conference Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction. Prague: Czech Republic. P. 1015-1020.

[13] Yunussov M.B., Kalbaeva A.T., Kurakbayeva S.D., Brener A.M.. (2013). Simulating the transient regimes and concentrate waves in through-reactors with multi-stage kinetics // Proceedings of the 7th International Conference on Computational Chemistry (COMPUCHEM '13). Paris: France. P. 18-22.

[14] Barkanyi A., Nemeth S., Lakatos B.G. (2013). Modelling and Simulation of a Batch Poly(Vinyl Chloride) Reactor // Chemical Engineering Transactions. 32: 769-774.

[15] Carvajal D., Jara C.C., Irrazabal M.M. (2012). Dynamic Modelling of the Reactive Absorption of CO_2 in Ionic Liquids and its Effect on the Mass Transfer and Fluid Viscosity // Chemical Engineering Transactions. 29: 175-180.

[16] Field R.J., Koros E., Noyes R.M. (1972). Oscillations in chemical systems, II. Thorough analysis of temporal oscillation in the bromate-cerium-malonic acid system // Journal of the American Chemical Society. 94(25). P. 8649-8664.

[17] Holodniok M., Klıc A., Kubıcek M., Marek M. (1984). Methods of Analysis of Nonlinear Dynamical Models. Prague, Czech Republic: Academia.

[18] Baetens D., Van Keer R., Hosten L.H. (1997). Gas-liquid reaction: absorption accompanied by an instantaneous, irreversible reaction. Comp. Mech. Publ. Moving boundaries IV. Boston. P. 185-190.

[19] Cussler E.L. (2009). Diffusion: mass transfer in fluid systems // International Journal of Refrigeration. Cambridge, UK, 16(4): 282-294.

[20] Musabekova L.M. (2011). Method of calculation of reaction-diffusion processes taking into account non-ideal system // International scientific-technical conference NERPO 2011. M.: MSOU. P. 294-299 (in Rus.).

[21] Musabekova L.M., Dausheeeva N.N., Jamankarayeva M.A. (2012). Methodology of calculating reaction-diffusion processes with moving boundaries of kinetic zones // 15-th Conference Process Integration, Modeling and Optimization for Energy Saving and Pollution Reduction.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 127 – 132 **https://doi.org/10.32014/2019.2518-170X.16**

UDC 545.25

A. S. Mussina, G. U. Baitasheva, N. O. Myrzakhmetova,
M. A. Zholmaganbetova, E. M. Imanova, A. A. Sartayeva

The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan, Almaty, Kazakhstan.
E-mail: mussina_as@mail.ru; musina.63@mail.ru

HIGHLY SENSITIVE METHODS FOR DETERMINING TRACE AMOUNTS OF MERCURY IN THE ENVIRONMENTAL OBJECTS

Abstract. The studies for the development of highly sensitive methods for determining heavy metals in the environmental objects have been carried out, using the example of determining mercury by the inversion voltammetry method, based on the investigation of the regularities of mercury electro-deposition and electro-oxidation on a solid electrode.

Key words: toxic substances, mercury, indicating electrodes, inversion voltammetry, environment.

An increased interest to the problem of determining mercury in the environmental objects is caused by the wide occurrence of this element, its greater toxicity in comparison with the other heavy metals, and its ability to bioconcentration [1]. The major part of mercury, reaching the environment, is of a technology-related character [2]. Maximum permissible concentrations (MPC) of elemental mercury in the atmospheric air are standardized at the level of 0.3 μg/m^3, in water bodies – at the level of 0.0005 mg/l, and in soils – at the level of 2.1 mg/kg, and MPC of the alkyl derivatives of mercury, most dangerous by their physiological effect, make up 00.1 μg/l in water bodies [3].

The issues of global environmental monitoring include monitoring the pollution levels not only in the industrial, but also in the relatively environmentally clean areas for detecting the so-called natural background [4]. The concentration of mercury in the atmosphere varies from 0.005 to 50 ng/m^3, and in waters from 2 ng to 2-3 μg/l. In the contaminated rocks, sand and soil an average content of mercury is 0.1-0.5 mg/kg [5].

The data of analytical control alone may offer people a thread to managing the environmental purity and indicate the moment of the required intervention to protect it from the accumulation of toxic substances and environmental poisons, whereto heavy metals and mercury, in particular, are directly related.

Procedure for carrying out an electrochemical analysis. Voltammetric measurements were carried out on a PI-50.1.1 potentiostat, which made it possible to work in the mode of cyclic and inversion voltammetry with different potential sweep rates [6]. An analysis was carried out in a three-electrode cell upon stirring the solution (V = 25 ml) due to the electrode rotation at the rate of 900-960 rpm. Nickel electrode and mercury-film, nickel-based electrode, with a visible surface area from 0.03 to 0.013 cm^2, served as working electrodes.

Voltammograms were recorded on a two-coordinate self-recording potentiometer UI-21 with a potential sweep rate of 100-200 mV/s. A silver-chloride electrode EVL-1M3.1, the potential of which in relation to the saturated hydrogen electrode in a saturated solution of KC1 at 20 °C was equal to 0.237 V. Pt - wire was used as an auxiliary electrode. Removal of oxygen from the solution was achieved by purging with argon for 15 min. The studied solutions were prepared from the salts of CP and AR grades. The solutions of lower concentrations were obtained by diluting the initial solutions with the background electrolytes.

For increasing the efficiency of the study and optimizing the process through the implementation of the step-by-step principle, moving towards the optimum, the Box-Wilson mathematical planning method (the steepest ascent method) was applied [7].

Experimental. Mercury is one of the most toxic elements, widely used in various fields of science and technology. A great interest in the issue of determining mercury is caused by its wide occurrence in the environmental objects, its greater toxicity in comparison with the other metals, its ability to accumulate in living organisms and migration in the environmental objects.

High toxicity of mercury stipulates its low MPC value, which requires using the sensitive methods of analytical chemistry. One of the methods, meeting the requirements for determining the detection limit and concentration range is inversion voltammetry. A large number of works are devoted to mercury determination by the inversion voltammetry method.

Most of the published works are mainly related to the development of procedures for quantitative determination of mercury on various electrodes. The physical and chemical regularities of the process of mercury electro-deposition are insufficiently studied, and the results of the conducted studies do not provide a complete picture of the initial stages of electrochemical isolation of mercury on the electrode. The most promising and modern methods of analysis are electrochemical ones (inversion voltammetry), the value and significance of which are characterized by rapidity of chemical analysis, high sensitivity and good reproducibility of the results, which is determined by the quality of the indicating microelectrodes used.

With the purpose of further developing mercury inversion voltammetry, a more detailed study of the regularities of the electro-deposition and electro-oxidation of mercury is required.

The developed indicating microelectrodes, which may be safely attributed to the new means for controlling toxic substances, were proposed as means for controlling heavy metals [8].

The physical and chemical characteristics of these electrodes and the mechanism of the processes, taking place at the electrode-solution interface at the stages of preparing their surface and subsequent amalgamation, were studied. The optimal parameters of their functioning were determined. The factors influencing the sensitivity and resolution of the film microelectrode were studied. As noted in [9], when carrying out an electrochemical analysis of the compounds of toxic metals, the nature of the indicating electrode matrix, the background composition and the presence of other components produce a great influence upon the cathode-anodic processes. The factors influencing the sensitivity and resolution of the film electrode were studied. The prospects of using new electrodes, made of refractory materials, in an electrochemical analysis for controlling toxic and heavy metals in the technology-related and mineral raw materials of Kazakhstan were shown.

The indicated circumstances determine the necessity to solve a complex problem - the development of highly sensitive methods for the determination of heavy metals, using inexpensive and available materials with the valuable physical, chemical and electrochemical properties. Metals of iron series may be related to such materials.

We studied the processes of Hg reduction and oxidation on the nickel electrode, determined the clear maxima of the cathodic (E_{Hg} = + 0.29 V) and anodic (E_{Hg} = + 0.76 V) peaks. As it can be seen from Figure 1, the recovery of Hg (II) on the nickel electrode begins at a potential of -0.25 V with the formation of a single cathode wave, reaching a value of the limiting current of 0.925, 0.65 and 0.35 for the concentrations of 10^{-4}, 10^{-5} and 10^{-6} mol/l, respectively.

At the polarization curves of mercury oxidation two waves are expressed: at E = +0.60 V and E = +0.85 V. This testifies to the complex character of the process of mercury oxidation. In our opinion, the effect of a possible formation in the process of cathodic reduction of mercury of oversaturated amalgams, containing cluster forms of nickel compounds with mercury of non-equilibrium composition, with an increased electrochemical activity, upon the course of the anodic polarization curves, is not excluded. It is also seen from the curves of figure 1, that a concentration dependence of the cathode waves is observed, which may be used for the quantitative determination of bivalent mercury in the solution.

As for the anodic curves, in view of their complex nature, for quantitative accurate analysis it is better to use the cathodic reduction waves (figure 2). However, in case of a less accurate analysis and with the very low mercury content in the analyzed objects, the anode currents may be also used, since they surpass by their value the cathode currents.

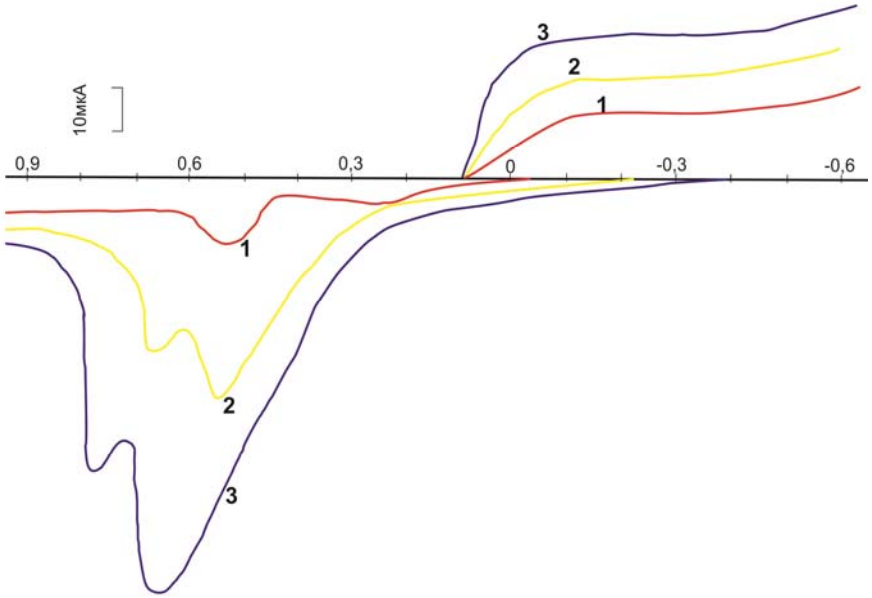


Figure 1 – Cathode-anodic voltammograms of mercury on a nickel electrode horizontal axis: potential (E), V; vertical axis: current strength (I), μA; $C_{Hg(II)}$, mol./l: 1 – 10^{-6}; 2 – 10^{-5}; 3 – 10^{-4}

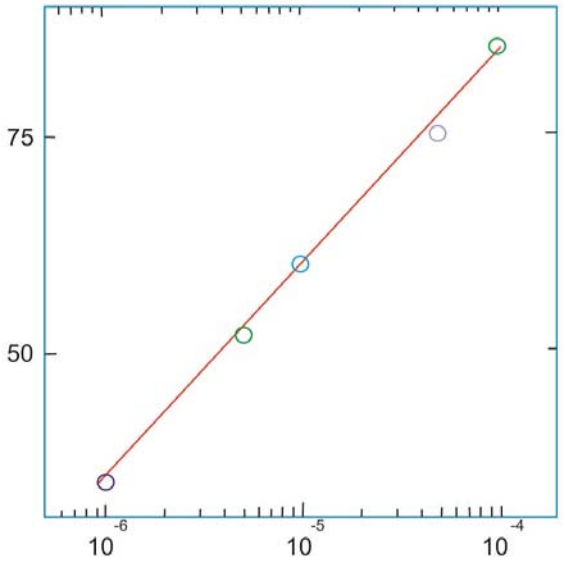


Figure 2 – Calibration chart for determining mercury on a nickel electrode horizontal axis: concentration (C), mol/l; vertical axis: current strength (I), μA

With the purpose of finding the optimal conditions for the determination of low mercury contents by the method of inversion voltammetry, the method of mathematical planning of the experiment (the Box – Wilson method) was used [7].

The study of the single-factor dependencies of the completeness of mercury isolation upon a number of factors (the concentration of ME, the nature and concentration of the background electrolyte, the surface area of the film and solid electrodes, the solution volume and rate of mixing) showed, that the most significant factors were the concentrations of Me and the background electrolyte, the surface area of the indicating electrode, and the remaining factors were insignificant and stabilized subsequently.

Therefore, when determining mercury by the inversion voltammetry method, the planning matrix 2^3 was used. The results of the experiment, related to choosing the optimal conditions for mercury determination by the inversion voltammetry method are presented in table.

Experiment planning matrix 2^3 for mercury determination

Factors	$C_м(Hg^2)$	$C_м(H_2SO_4)$	$S_{electr.}$					
Dimension	mol/l	mol/l	cm^2					
Basic level	10^{-5}	0.75	0.09					
Varying interval	10^{-1}	0.25	0.04					
Upper level	10^{-4}	1.0	0.13					
Lower level	10^{-6}	0.5	0.05					
Code	X_1	X_2	X_3	Y	Y	S^2	y	y^2
Experiment 1	10^{-6}	0.5	0.05	80.7 82.0 81.5	81.4	0.43	80.5	0.80
Experiment 2	10^{-4}	0.5	0.05	83.4 87.0 88.0	83.5	0.43	82.65	0.72
Experiment 3	10^{-6}	1.0	0.05	83.4 83.7 84.4	83.5	0.43	82.65	0.72
Experiment 4	10^{-4}	1.0	0.05	90.2 91.0 89.5	90.2	0.56	91.2	1.00
Experiment 5	10^{-6}	0.5	0.13	83.6 84.8 83.5	84.0	0.52	84.4	0.16
Experiment 6	10^{-4}	0.5	0.13	93.5 93.0 93.1	93.2	0.37	92.95	0.06
Experiment 7	10^{-6}	1.0	0.13	85.3 85.0 85.2	85.1	0.03	86.55	2.10
Experiment 8	10^{-4}	1.0	0.13	97.0 96.8 96.0	96.6	0.28	95.1	1.21
Step		0.09	0.03					
Supposed experiments 1	10^{-6}	0.84	0.12					
Implemented experiments 2	10^{-6}	0.93	0.15		85.3			
Supposed experiments 3	10^{-6}	1.02	0.18					
Implemented experiments 4	10^{-6}	1.11	0.21		97.7			
Implemented experiments 5	10^{-6}	1.20	0.24		98.8			
Implemented experiments 6	10^{-6}	1029	0.27		97.2			
Supposed experiments 7	10^{-6}	1.38	0.30					
Optimum	10^{-6}	1.2	0.29					

The calculated regression coefficients for mercury determination have the following values:
$b_0 = 87.8$
$b_1 = 4.275$
$b_2 = 1.075$
$b_3 = 1.95$
The regression equation is as follows:
$Y = 87.8 + 4.275X_1 + 1.075X_2 + 1.95X_1$

Checking:

1. reproducibility of the experiment

$S^2\{y\} = \sum S^2/N = 2.75/8 + 0.34$

2. dispersion homogeneity

$G = S^2_{max}\sum S^2 = 0.565/2.75 = 0.205$

$G_{table} = 0.51$ at $f_1 = 2$ and $f_2 = 8$

$G_{table} > G_{exp.}$ - dispersion is homogeneous

3. the values of the regression coefficients:

$S^2\{bj\} = S^2\{y\}/N = 0.34/8 = 0.0425$

$bj\} = \sqrt{S^2\{bj\}} = \sqrt{0.0425} = 0.206$

$\Delta b_j = \pm t \cdot \{bj\} = 2.12 \cdot 0.206 = 0.44$

$\Delta b_j = 0.44$

$0.44 < 3.26$ (1.53; 2.76) – all coefficients are valuable.

4. adequacy of the model:

$S^2_{ad.} = \sum y^2/f_1$

$\Delta y = y_i - y_1$

$f_1 = N - (k + 1) = 8 - (3+1) = 4$

$S^2_{ad.} = 1{,}695/4 = 0.42$

$F(f_1; f_2) = S^2_{ad.}/S^2\{y\} = 0.42/0.34 + 1.25$

$F_{table} = 3.0$ at $f_1 = 4$ and $f_2 = 16$,

where $f_2 = N(n-1) = 8(3-1) = 16$.

$F_{exp.} < F_{table}$ – the model is adequate

The calculations testify to the fact, that the dispersion of the optimization parameter is homogeneous, the model is adequate, i.e. the steepest ascent method can be applied. The component gradients were calculated by regression. Moving to the optimum was performed by adding the factors, constituting the gradient, to the basic level. Since the determination of small mercury quantities of the order of 10^{-6}-10^{-7} mol/l on the surface of the film and solid electrodes is of a practical interest, so while calculating the step-by-step procedure, moving to the optimum, we stabilized the mercury concentration by the lower level of the factor (10^{-6}M), and we carried out the step-by-step procedure by only two factors: the concentration of the background solution and the electrode surface area.

From the implemented experiments of the step-by-step procedure the optimal conditions were established for the quantitative determination of low mercury concentrations on the film electrode:

1 – the concentration of mercury at 10^{-6} mol/l;

2 – the concentration of the background solution – 1.2 M;

3 – the electrode surface – 0.24 cm^2.

Thus, as a result of the conducted studies, the methods for analytical control of mercury in the technology-related raw materials were developed by the inversion voltammetry method on the nickel indicating microelectrode in the concentration range of 10^{-5}–10^{-6} mol/l, ensuring the selectivity of metal determination.

А. С. Мусина, Г. У. Байташева, Н. О. Мырзахметова,
М. А. Жолмаганбетова, Э. М. Иманова, А. А. Сартаева

[1]Қазақ мемлекеттік қыздар педагогикалық университеті, Алматы, Қазақстан

ҚОРШАҒАН ОРТА ОБЬЕКТІЛЕРІНДЕГІ СЫНАП ҚАЛДЫҚТАРЫН АНЫҚТАУДЫҢ ЖОҒАРЫ СЕЗІМТАЛ ӘДІСТЕРІ

Аннотация. Сынапты инверсионды вольтамперметрия әдісімен оның қатты электродта тұнбаға түсу және тотығу заңдылықтарын зерттеу негізінде қоршаған ортадағы обьектілердегі ауыр металдарды анықтаудың жоғары сезімтал әдістерін анықтауға арналған зерттеулер жүргізілген.

Түйін сөздер: уытты заттар, сынап, индикаторлық электродтар, инверсия вольтаметр, қоршаған орта.

**А. С. Мусина, Г. У. Байташева, Н. О. Мырзахметова,
М. А. Жолмаганбетова, Э. М. Иманова, А. А. Сартаева**

Женский государственный педагогический университет РК, Алматы, Казахстан

ВЫСОКОЧУВСТВИТЕЛЬНЫЕ МЕТОДЫ ОПРЕДЕЛЕНИЯ СЛЕДОВЫХ КОЛИЧЕСТВ РТУТИ В ОБЪЕКТАХ ОКРУЖАЮЩЕЙ СРЕДЫ

Аннотация. Проведены исследования по разработке высокочувствительных методов определения тяжелых металлов в объектах окружающей среды на примере определения ртути методом инверсионной вольтамперометрии на основании изучения закономерностей её электроосаждения и электроокисления на твердом электроде.

Ключевые слова: токсичные вещества, ртуть, индикаторные электроды, инверсионные вольтамперометрия, окружающая среда.

Information about authors:

Mussina A.S., Doctor of Technical Sciences, Professor, The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan; mussina_as@mail.ru; https://orcid.org/0000-0002-4140-4816

Baitasheva G.U., candidate of agricultural sciences, Acting Professor, Head of the Department of Science, The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan; Gauhar75e@mail.ru; https://orcid.org/0000-0002-1299-4896

Myrzakhmetova N.O., candidate of chemical sciences, Head of the Chair of Chemistry, The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan; nmyrzahmetova64@mail.ru; https://orcid.org/0000-0001-6589-1578

Zholmaganbetova_M.A., Doctoral student of the Chair of Chemistry, The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan; marzhan.zholmaganbetova.75@mail.ru; https://orcid.org/0000-0002-7057-3969

Иманова Э. М., The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan

Сартаева А. А., The Kazakh State Women's Teacher Training University of the Republic of Kazakhstan

REFERENCES

[1] Simonova L.N. Concentration of mercury upon its determination in the environmental objects // Journal of Analytical Chemistry. 1989. 44,4. P. 581-584.

[2] Gvardzhanchich I., Kosta L., Zelenko V. A Simplified method for determining methylmercury in the biological objects, using gas chromatography // Journal of Analytical Chemistry. 1978. 33.4. P. 812-815.

[3] Environmental protection. Directory. L.: Shipbuilding, 1978. P. 204.

[4] Andreyev T., Sametov D. Problems of background monitoring of the state of natural resources. 1985. 3. P. 44.

[5] Simonova L.I., Bruskina I.I., Ivanov V.I. Concentrating mercury upon its determination in the environmental objects // Journal of Analytical Chemistry. 1981. 45.4. P. 581-596.

[6] Brainina Kh.Z, Neiman E.Ya., Slepushkin V.V. Inversion electroanalytical methods. M.: Khimiya, 1988. P. 239.

[7] Adler Yu.P. Planning an experiment upon searching for the optimal conditions. M., 1972. P. 152.

[8] Mussina A.S. Theoretical and technological bases for creating liquid metal reed relays and indicating electrodes from new materials. Almaty, 2003. P. 256.

[9] Musina E.S., Mussina A.S., Baitasheva G.U., Kalmenova A., Kuansheva Zh. Control of next amounts of metals in the environmental objects with the use of mercury-film indicating microelectrodes // News of the Ministry of Education and Science of the Republic of Kazakhstan. Geology and Engineering Sciences Series. 2018. N 4(430). P. 195-200. (Scopus). SSN 2518-170X (Online). ISSN 2224-5278 (Print).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 133 – 142 **https://doi.org/10.32014/2019.2518-170X.17**

ӘОЖ 551.243. 38.17.21

R. M. Sadykov[1], V. V. Korobkin[2]

[1]Kazakh National Research Technical University named after K. I. Satpayev, Almaty, Kazakhstan,
[2]Kazakh-British Technical University, Almaty, Kazakhstan.
E-mail: sadykovraman@mail.ru; korobkin_vv@mail.ru

GEOLOGICAL INPUT DATA ANALYSIS FOR BASIN MODELING OF THE SOUTH PART OF KARAGANDA COAL DEPOSIT

Abstract. Geological and geophysical data were analyzed to perform basin modeling of the south part of Karaganda coal basin. In this regard, the basic material was selected, including geological structure (stratigraphy, lithology, facial analysis of folded and faulted structures, geodynamic modeling, depositional environment).

Karaganda coal basin experienced multi-stage deformation, during the geological evolution. It is expressed in the multiple kinds of the structural forms, which described for southern and eastern parts of the Karaganda coal basin, in the areas of Alabass anticline, Maykuduk uplift and Spasskaya suture area. The main stages of the deformation, followed with orogenesis occurred in Late Paleozoic-Early Mesozoic time. The region experienced the multi-stage development, which is observed by lithological, paleogeographical, paleotectonical and geodynamical reconstructions.

The age of the layers was clarified using the existing biostratigraphic study results. During the modeling, initial geological information was calibrated with coal maturation and porosity variation with the depth data. Basin modeling allowed minimizing the geological uncertainties, such as geological reconstructions, depositional environment and enriching the database on the Karaganda coal basin geology.

Karaganda coal basin is located in the Central Kazakhstan (figure 1). It's one of the biggest coal basins in Central Asia with proven reserves of 41.3 billion tons. There are 11 coal mines operating and producing 11 mln. tons of coal annually [1-3]. Moreover, there is significant potential for coal bed methane (CBM) production. According to KazEnergy report [4], the gas content in Karaganda basin's coals reaches 20 cubic meters per ton of coals located up to 500 meters, 27 cubic meters for deeper coals. The estimate of reserves of CBMis 8 trillion cubic meters. This amount is enough to supply the local industry with gas for more than 100 years.

Understanding of the geological processes occurring in the territory of Karaganda coal basin is essential for commercial production start. The data on the basin are abundant and were obtained in previous studies [5]. New methods of basin analysis were developed [6]. The basin modeling is necessary to arrange the abundant information, and identify the zones which are prolific for CBM production.

The basin modeling is the one of the methods, which utilizes the simulation of heatflow and regional tectonics to reproduce the evolution of the basin, since its formation. The process of organic matter maturation occurs under the influence of temperature and time, while rock compaction under the pressure. Thermal modeling assesses the quality of geological concepts, reduces uncertainties in geological conditions and ages and finally gives the input data about physical properties and maturity of rocks through the time.

The most of Kazakhstan continent (accretionary collision paleo continent) was the extensive shelf sea basin with terrigeneous deposition in Famennian – Early Carboniferous (figure 1, 2). In the second half of Early Carboniferous the area was divided into Teniz, Zhezkazgan and Karaganda deposition basins with

small isolated troughs on the north. The first two forms cupriferous and saliferous complexes, while to the west coal-bearing complexes were formed in Karaganda, Ekibastuz and other coal fields [1-3, 7, 8, 10].

Karaganda coal basin (figure 1), located in central part of Caledonian Segment, belongs to the intracontinental area. Carbonate-terrigeneous deposits with total thickness up to 4000 meters were accumulated in Famennian – Early Carboniferous (table 1). Famennian – Middle Carboniferous deposits are conformable and forms single structural stage. The depositions below and above are separated by sharp unconformities, which unites them in a single quasi-platform complex [7, 8].

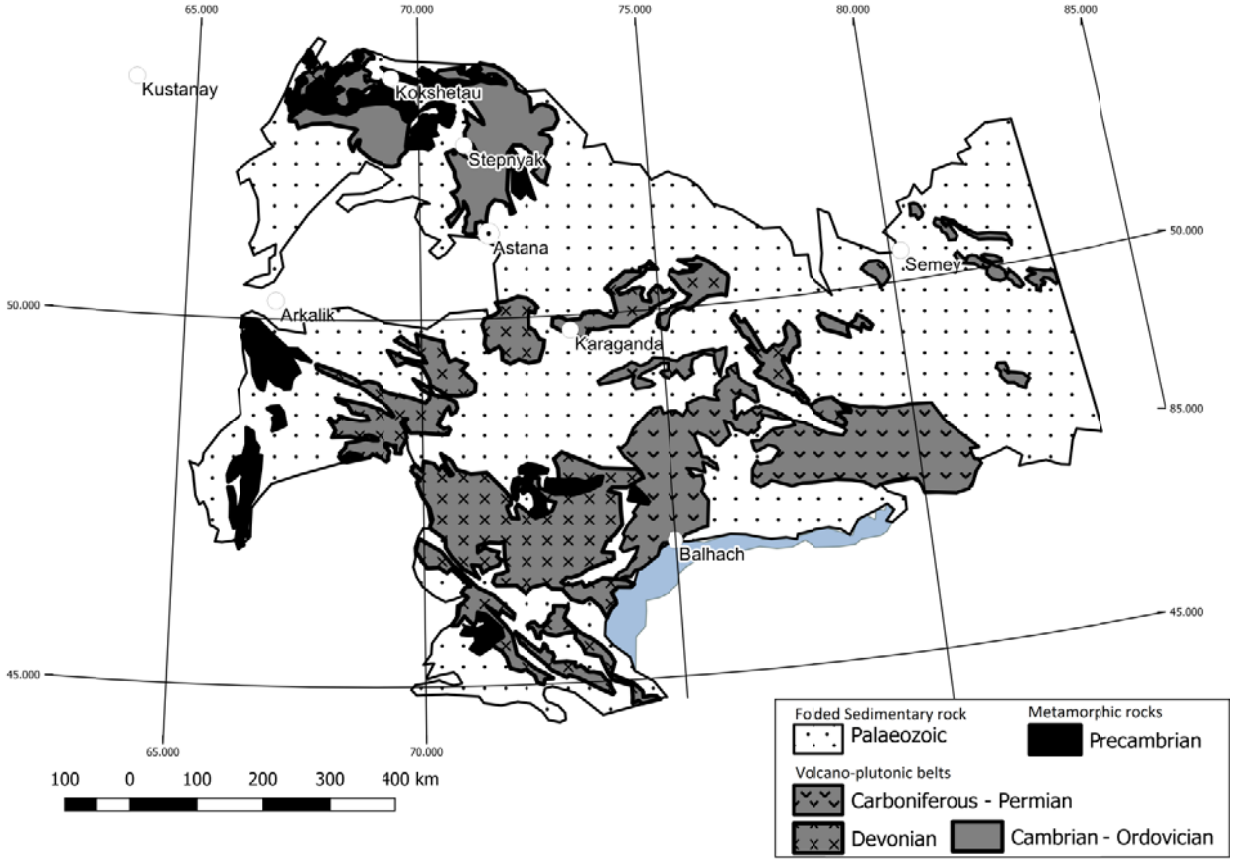


Figure 1 –Location of Karanda coalba sinrelative to Central Kazakhstan Paleozoics.

The composition and thicknesses Famennian – Middle Carboniferous stratigraphic units are shown in table 1. They are represented by interbedded green marine carbonate deposits, followed by grey lacustrine, terrigeneous and coal layers with presence of the reddish continental sediment [10]. Since the Middle Carboniferous up to Late Carboniferous terrigeneous clastic deposits are formed.

The Devonian and Late Paleozoic the subduction of Zhunghar-Balkhash oceanic crust under the Kazakhstan continent tend to the formation of volcanic belts in the south part of Kazakhstan continent. Zhungar-Balkhash paleo ocean's active continental margin adjoined to the south of Karaganda coal basin. Active magmatic events formed two continental margin type volcano-plutonic belts: 1) Devonian Central Kazakhstan and 2) telescoped Late Paleozoic (Carboniferous-Permian) Pribalkhash-Ili (figure 2). Karaganda basin was backarc basin next to active continental margin, where Devonian and Late Paleozoic magmatic events took place. Subduction was directed from south-east to north-west in Karaganda basin direction [7-10].

Devonian volcano-plutonic belts are heterogeneous structures of massive Emsian and Frasnian rheolitic-granite series type volcan over intrusion. The composition of volcanic association is represented by porfiric tuffs, lavas and ignimbrites. Among the volcanic intrusions, there is calc-alkali series, which are shown by associations with reduced alkalinity and associations with high potassium shoshonite series and continental molasses [7, 8]. The thickness of volcano-plutonic structures reaches 2000-3000 meters

Table 1 – Stratigraphic column of Karaganda Basin. Bold borders show the unconformities

SYSTEM	Serie	Stage	Suite	Subsuite	Index	Lithology	Coal Index	Faunal Index	Thickness
Quaternary					Q	Sand / Soil			0-12
Neogene					N	Neogene clay			0-20
Jurassic	Middle	Dogger	Mikhailovskaya		J_2mh	Siltstone			0-150
			Kumyskudukskaya		J_2km	Conglomerates Sandstone			30-50
	Lower	Lias	Dubovskaya		J_1db	Mudstone Sandstone	d_{VI} - d_I		40-200
			Saranskaya		T_3r-J_1sr	Sandstone Conglomerates			40-120
Tri.	Up.	Rhetian							
Carboniferous	Middle		Dolinskaya	Lower	C_2dl	Mudstone Sandstone Coalified siltstone	d_6 - d_1		300-350
			Nadkaragan-dinskaya	Upper	C_2ndk_3	Siltstone Coalified mudstone	N_4		240-260
		Namurian		Middle	C_2ndk_2	Siltstone Coalified mudstone	N_3 N_2		280-340
				Lower	C_2ndk_1	Siltstone Coalified mudstone	N_1		140-180
	Lower		Karagan-dinskaya	Upper	C_1v_3+$Skrg_3$	Sandstone Mudstone Silty coal	K_{20} - K_{16}	K_4	160-180
		Visean		Middle	C_1v_3+$Skrg_2$	Sandstone Coal Silty coal	K_{15} - K_{10}	K_3	330-380
				Lower	C_1v_3+$Skrg_1$	Shaly coal Coal Siltstone	K_{10} - K_1	K_2 K_1	120-160
			Ashlyarik-skaya	Upper	$C_1v_{1\text{-}2}ash_3$	Siltstone Mudstone Silty coal	a_1 - a_4	A_1 - A_4	220-240
				Middle	$C_1v_{1\text{-}2}ash_2$	Silty coal Sandstone Siltstone	a_5 - a_{12}	A_8 A_8' A_9	110-130
				Lower	$C_1v_{1\text{-}2}ash_1$	Silty coal Sandstone Siltstone	a_{13} - a_{20}	A_{10} - A_{11}	180-210
			Akkuduk-skaya	Upper	$C_1v_1ak_3$	Sandstone Siltstone			150
				Middle	$C_1v_1ak_2$	Siltstone Mudstone			170-210
				Lower	$C_1v_1ak_1$	Mudstone Tuffite lenses			250-440
					C_1v_1tr	Tuffite			40-60
		Tournaisian			C_1t	Limestone Marl			250-330
Devonian		Famennian			D_3fm	Marl			90-170
		Givetian-Frasnian			D_2gv-D_3fr	Effusive basement			2000

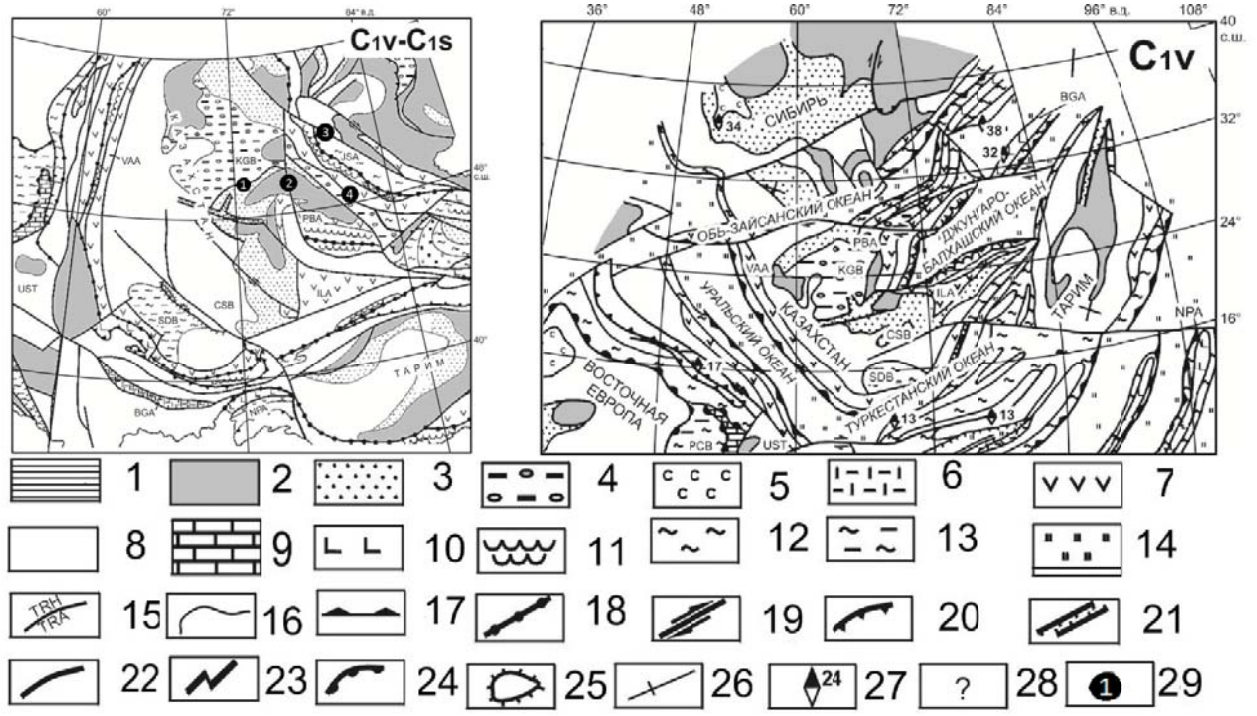


Figure 2 – Paleogeographic (1) and palynpascial (2) schemes
of Central Eurasia, Early Carboniferous – Visean-Serpukhovian [7, 8].

Continental environment: 1 - uplands, 2 - lowlands, 3 - fluvial-lacustrine, 4 - carbonaceous basins, 5 - evaporite basins, 6 - rift and orogenic volcanics, 7 - marginal continental volcanic belts and mature island arcs. Marine and oceanic environments: 8 - shelf, 9 - carbonate platforms, 10 - island arcs, 11 - accretion prisms, 12 - continental slope, bathyal, 13 - deep sea (deposits of black shales), 14 - abyssal. Tectonic and other signs: 15 - climatic boundaries (STH - subtropical humid, TRH - tropical humid, TRA - tropical arid, EQU - equatorial), 16 - facies boundaries, 17 - subduction zones, 18 - sutures, 19 - shifts, 20 - thrusts, 21 - grabens, 22 - uncertain faults, 23 - spreading axes and transform faults, 24 - shelf shelves, 25 - carbonate platforms, 26 - modern geographic coordinates direction, 27 - paleomagnetic vectors and paleolatitudes, 28 - presumed and controversial conditions, 29 - Main faults (figures in circles): Spass (1) Central Kazakhstan (2) Irtysh (3) Main Chingiz (4).

Microcontinent arrays: Ustyurt (UST). Sedimentary basins: Karaganda (KGB), Chu-Sarysu (CSB), Syr Darya (SDB); island volcanic arcs and marginal continental volcano-plutonic belts: Valerianovskaya (VAA), Ili (ILA), Pribalkhash (PBA), Jarma-Saurskaya (JSA), Bogdanshanskaya (BGA), North Pamir (NPA).

within the structure and hundreds meters outside. The belt is subdivided into Betpakdala, Sarysu-Teniz, Bayanaul (North-Kazakhstan) and Chingiz segments laterally from the west to the east [11]. Frontal and rear petrochemical zones exist within the belt. The zones are characterized by development of magmatic series on the edge of high-alkali series (rear zone) in the inner part of Kazakhstan continent. Active margin of the continent is marked by the change of petro-chemical composition in the zones between the Zhungar-Balkhash and Ob'-Zaisan paleo oceans. In Betpakdala, Sarysu-Teniz and Bayanaul segments the magmatism was active continental in Early Devonian – Famennian. Asymmetric magmatic zonation is associated with the suprasubduction area [11].

In the second part of Early Carboniferous main features took place on the border between Kazakhstan continent and Zhungar-Balkhash oceanic basin. Balkhash-Ili volcano-plutonic belt of continental margin type is formed as the result of subduction of oceanic crust under the Kazakhstan continent. In the modern structure of Kazakhstan paleozoics it has the shape of arc and divided into the segments (volcanic depressions): Ili, Ketmen, Tokrau, Kalmakemel, Bakanas, Alakol. Peculiarity of the volcanism in the belt is the equal proportion of basalt-andesitic and laparite-dacite series, but the composition changes in other segments. Plagiolaparite-dacite series was formed in early stage of belt development in conditions of ensialic island arc. It represented by Karkaraly suite (North Pribalkhash area). Lower Carboniferous basalts and andesitic basalts belong to sodium and calc-alkali series with high aluminum silicate content.

Abovementioned chemical characteristics show the affiliation to the volcanic series of ensialic island arc. The eruption of great amount of predominantly acidic volcanic rocks occurs in Middle-Late

Carboniferous and Permian. The rocks consist of rhyolites, rhyodacites, trachyriolitesand their tuffs and the intrusions of subalkalinegranitoids. Areas of basalt-andesitic volcanism related to suture zones, while acid series distributed in distal parts, forming volcano-tectonic depressions, complicated by uplifts [7-10].

Karaganda segment was located on shelf marine basin attached to Spassk thrust to the south, Central Kazakhstan fault to the east and Irtysh fault to the north-east (figure 2).

At the end of Carboniferous and Early Permian collisional stage is started. It's related with granitoid magmatism. Drainless intermountain depressions was formed in the Central Kazakhstan with its arid climate. Intracontinental sea replaced the Zhungar-Balkhash oceanic basin, connected with the ocean to the west.

Central Kazakhstan orogen growthwas terminated in Early Permian, followed by complication of the structure in Late Permian – Triassic by slip movement, caused formation of large amplitude fault systems (up to several hundred kilometers). Central-Kazakhstan fault with arc shape was formed on the more ancient Ordovician-Devonian transform fault. North-East directed left-side slips was active in Spass shear zone. Formation of the «pool-apart» type basin on the territory of Karaganda coal field was related to the system of Early Mesozoic faults in Spass shear zone.

Collisional events caused the formation of complicated thrust and slit forms, especially on the south part of Karaganda basin. Taldykuduk block, located there, has a border with Spass shear zone, with distance 10-30 km from it.

As the result of the speed of orogenic process reduced and area transformed into foreland basin. Orogenic processes tend to the formation of uplift to the south of the basin, which was the source of molasses. Most of the sediment was deposited in the south part of Karaganda basin where the depression was the most. Part of these molasses then was eroded during Permian-Triassic erosion on the most of Karaganda basin (table 2).

Table 2 – Main structural complexes within Karaganda basin and their position within the crust

Structural complex	Age, lithology	Position
Upper platform	**Neogene-Quaternary** Gravel, pebble, sand, loam, sandy loam	Karaganda basin
Lower platform	**Triassic - Jurassic** sandstones, siltstones, marls with coal	
Quasi platform	**Middle Carboniferous** molasses (conglomerates, sandstones, siltstones) **Famennian – Lower Carboniferous** carbonate and terrigenous deposits with coal	
Oceanic continental	**LowerDevonian – Frasnianstage** contrast composition of the volcanic series - rhyolites, rhyodacites, dacites and their tuffs	The rim of Karaganda basin, monoclines. On the south, next to the Spass shear zone. Has complexities in folds and faults
Ensial island arc	**Silurian** Wackes, greywackes, turbidites **Middle – Upper Ordovician** andesibasalts, andesites and their tuffs	The rim of Karaganda basin
Oceanic	**Cambrian – Lower Ordovician** jasper; flint	North-west border of the basin and basin basement

Mesozoic rocks of Karaganda basin was formed in Rhetian – Lias and Dogger time. The deposition rate increased in Rhetian – Lias was reduced to Dogger. In Rhetian the thick layer of molasses was deposited. Lias deposits were partially eroded in the Middle of Dogger, when area relief stabilized. Climate aridization in Late Jurassic caused the termination of coals formation, which is manifested in Dogger deposits (up to 150 meters) consist of reddish terrigeneous rocks (figure 4).

The area was uplifted and eroded by the Late Jurassic. The tectonic movements was caused by the Late Cimmerian phase of Cimmerian orogenesis. Hercynian thrusts reactivated and new set of thrusts like Akzhar thrust was formed. The area was exposed to denudation up to Late Jurassic – Early Paleozoic. After the erosion, the area became covered by unlithified fluvial deposits of Neogen and Quaternary Ages. The sediments sources were hills located to the south and supplied by the modern rivers Nura and Sarysu. The area get its final appearance in the Middle of Neogene [7].

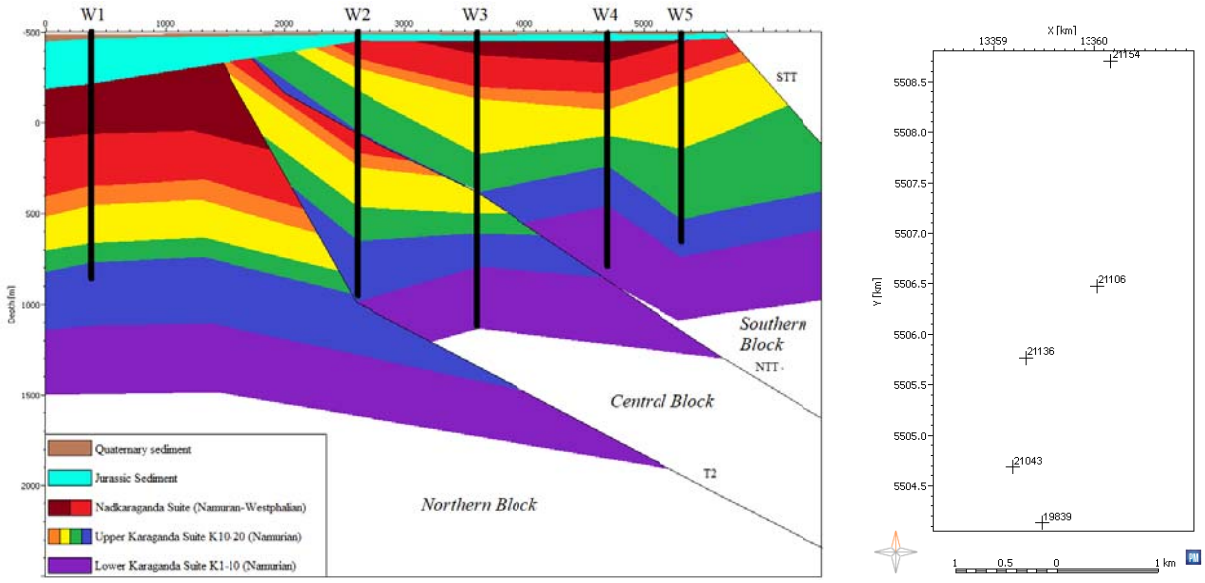


Figure 3 – Schematic cross-section and map of wells representing the modeled southern bound of Karaganda basin. Two major thrust (North-Taldykuduk ThrustNTT and Thrust 2T2) divide the model into 3 main maturation blocks. Small amplitude faults are not shown

Karaganda basin is divided into 4 zones. They are Tentek, Sherubay-Nura, Karaganda and Verkhnesokurskaya. Within the basin, there are structural complexes contain Cambrian, Ordovician – Silurian, Devonian, Carboniferous, Jurassic and Cenozoic rocks. Taldykuduk block (figure 4) suffer significant structural transformation. It has overthrusts, thrusts and other faults, which are related to Spass shear zone. Fault-blocked structure of the region results the formation of cleats within the coals. Therefore the area is interesting from the CBM production point of view.

There are four stages of Carboniferous rocks deformation [6-8].

The first stage (Asturian phase) is the commencement of the collision or initial orogenesis stage, when the depression was subdivided into Karaganda, Shiterdy, Pavlodar and Teniz synclinories (figure 2). New thrust, including modeled North Taldykuduk thrust and Thrust 2 was originated since (figure 5). The basin had western border with Teniz depression, and pinched out to the east.

The second stage (Pfalzian phase) is the collisional stage, which caused the compartmentalization of coal beds by basement movement. As the result, Karaganda coal basin was subdivided into 3 parts: western part with Zaviyalov and Samara graben-synclines, central part with Karaganda basin and eastern part with Ashisu syncline (figure 6, 7). Zaviyalov graben-syncline and Teniz depression are separated by Zhaksykart horst-anticline. Zhailmin horst-anticline is the border between Karaganda basin and Ashisu syncline.

The third stage (Early Cimmerian phase) is the postcollisional stage refers toearly epeiric platform orogenesis, which expressed in thick deposition of molasses at the end of Lias. Sediment sources were uplifted and area was depressed. After that, the area was eroded up to Middle Dogger, when relief became flatten. Complete isolation from Paleotethys resultedaridization of the climate.

The final stage (Late Cimmerian phase) is the postcollisional stage refers to late epeiric platform orogenesis, followed the dogger succession, caused the territory uplift and erosion. Furthermore, the deformation reactivates existing and generates new (Akzhar thrust) faults and thrusts. In addition to these stages, insignificant deformation occurred in Neogene and Quaternary.

Input data, required for thermal modeling, according to [12] is following (figure 2-4):

– Structural model, including layers thickness, unconformities, faults, thrusts;

–Conceptual geological model (stratigraphic column, sedimentation settings, lithologies);

– Thermal and burial history;

– Tectonic history of the basin – tectonic model (burning, uplifting, erosion etc);

– Calibration data (vitrinite reflectance, temperature and porosity);

– Boundary conditions of water depth, heatflowand surface temperature.

Conceptual geological model includes several parameters. Rock ages were defined by biostratigraphic dating and represented in table 3 as bold text. Absolute ages of those rocks were taken from International Stratigraphic Column. Rest of layers ages were defined considering their thicknesses and relatively even deposition rate [9].

The territory of Karaganda basin experienced the following deformation stages during its geological evolution: Saurian, Asturian, Pfalzian, Early Cimmerian and Late Cimmerian orogenic phases. These stages are expressed in multiple observed faults and thrusts, synclines and anticlines (figure 4). The tectonic model, used for basin modeling is shown in table 4.

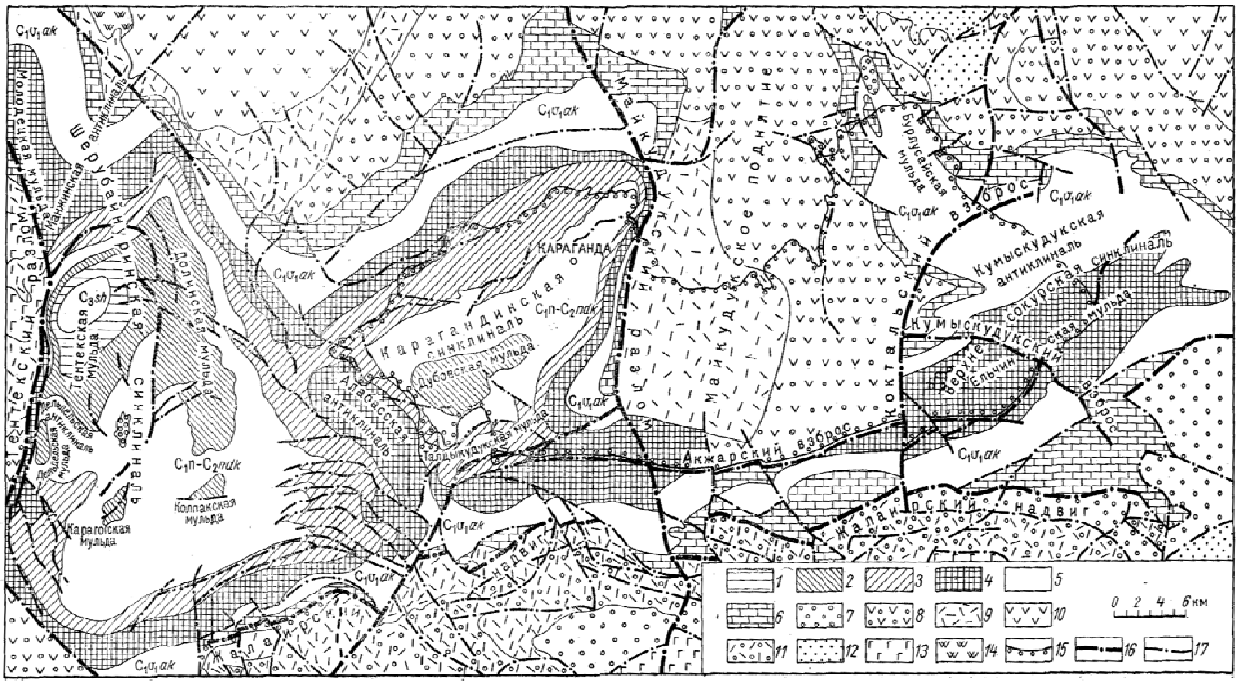


Figure 4 – Tectonical scheme of Karaganda basin

Carboniferoussediments, suiteswithsufficientcarbonation: 1 – Tentek; 2 – Dolin; 3 – Karaganda, 4 – Ashlyarik; without coal: 5 – Shahan (C_3sh), Nadkaraganda (C_1n-C_2ndk) Akkuduk (C_1v_1ak); 6 – *Tournai and Famennian deposits*; 7, 8 – *Givetian-Frasnian sediments* (upper substage) of south (7) and north(8) basin rims; 9 – *Koblenz-Givetian volcanic successions*(middle substage); 10, 11–*Lower Devonian*,effusive and their tuffs of north (10) and south (11) basin rims; 12 – *Silurian flysch*; 13 – Ordovician volcanic deposits; 14 – Cambrian terrigineous siliciclastic deposits; 15 – Mesozoic sediments contour; 16 – overthrusts and thrusts; 17 – other faults.

Thus, input data for basin modeling includes a geological concept, a tectonic model of the area geological evolution, and their thermobaric depositional conditions. The geological concept contains information about the age of the rocks, their thickness, erosion processes.

The structure of the Karaganda basin involves the rocks of six structural-material complexes. The basement is composed of the following complexes: 1) Cambrian-Lower Ordovician oceanic, 2) Middle-Upper-Ordovician island arc and Silurian pre-arc and back-arc terraces, 3) Devonian marginal continental. The cover consists of the following complexes: 4) Famennian-medium-quarry quasi-platform, 5) Triassic-Jurassic platform (lower structural stage), 6) Neogene-Quaternary (upper structural stage). Saurian, Asturian, Pfalzian, Early Cimmerian and Late Cimmerian orogenic phases influenced the formation of coal rock and created complex multi-stage formed folded and discontinuous shapes. The uncertainties of the geological concept were calibrated using data on maturity and rock deformation.

Table 3 – Absolute ages of layers and their thicknesses

Layer name	Event age	Base absolute age, Ma	Top absolute age, Ma	Av. Thickness, m
Q1	Pleistocene-Holocene	0.13	0.00	3
J_Eroded_2	Oxfordian	185.32	**154.00**	900
J_Eroded_1	Doggerian	202.72	185.32	500
J	Liasian – Doggerian	**203.00**	202.72	8
C_Eroded_2	Stephanian – Westphalian	**313.00**	**295.00**	2800
C_Eroded_1	Namurian	320.94	**313.00**	1500
Nadkaraganda		322.37	320.94	271
K20		322.85	322.37	90
K19		323.41	322.85	106
K18		323.85	323.41	83
K17-1		324.11	323.85	50
K16-K17		324.21	324.11	19
K15		324.45	324.21	45
K14		324.77	324.45	60
K13		324.93	324.77	30
K13-base		325.03	324.93	20
K12-3		325.48	325.03	84
K12		325.71	325.48	45
K11		326.00	325.71	54
K10	Late Visean	326.17	**326.00**	25
K9		326.22	326.17	8
K8-1		326.30	326.22	11
K7-K8		326.49	326.30	27.8
K6		326.72	326.49	34
K5		327.08	326.72	54
K4		327.35	327.08	40
K3		327.55	327.35	28.75
K2		328.00	327.55	67
K1	Middle Visean	329.00	**328.00**	64
A-suite			329.00	

Table 4 – Tectonic model of Karaganda basin

Age	Lithological and facial depositional environment	Tectonic movement direction	Orogenic phase
Neogene - Quaternary	Continental	Uplift	~~~ Alpine
Jurassic (eroded)	Continental Platform Arid	Uplift	~~~ Late Cimmerian
Doggerian		Immersion	~~~ Early Cimmerian
Liasian		Immersion	
Late Carboniferous - Permian	Continental Arid	Uplift	~~~ Pfalzian ~~~ Asturian
Visean – Namurian	Continental, shallow marine, boggy-lacustrine	Immersion	~~~ Saurian
Visean			
Tournai - Famennian	Continental, shallow marine		
Early Devonian - Frasnian	Andean type active continental margin	Uplift	~~~ Akkadian
~~ Unconformity			

Р. М. Садыков[1], В. В. Коробкин[2]

[1]Казахский национальный исследовательский технический университет им. К. И. Сатпаева, Алматы, Казахстан
[2]Казахстанско-Британский технический университет, Алматы, Казахстан

АНАЛИЗ ИСХОДНЫХ ГЕОЛОГИЧЕСКИХ ДАННЫХ ДЛЯ БАССЕЙНОВОГО МОДЕЛИРОВАНИЯ ЮЖНОЙ ЧАСТИ КАРАГАНДИНСКОГО УГОЛЬНОГО МЕСТОРОЖДЕНИЯ

Аннотация. Выполнен анализ геолого-геофизических материалов для проведения бассейнового моделирования южной части Карагандинского угольного месторождения. В этой связи подобран необходимый базисный материал, включающий данные по геологическому строению (стратиграфии, литологии, фациальному анализу складчатым и разрывным структурам, геодинамическому моделированию, термобарическим условиям осадконакопления) рассматриваемого объекта.

В ходе геологической эволюции Карагандинский угольный бассейн испытал многоэтапные деформации, выраженные в многочисленных сочетаниях структурных форм, которые описаны для южной и восточной частей Карагандинского бассейна в зонах Алабасской антиклинали, Майкудукского поднятия и Спасской шовной зоны. Главные этапы деформации сопровождаемые активным орогенезом приходятся на позднепалеозойско-раннемезозойское время. Начиная с фамена, и по настоящее время регион прошел сложную многоэтапную историю развития, на что указывают литолого-фациальные, палеогеографические, палеотектонические и геодинамические реконструкции.

Возраст рассматриваемых толщ горных пород был уточнен на основании биостратиграфических данных предыдущих исследований. Исходная геологическая информация в процессе моделирования увязана с калибровочными данными зрелости углей и вариациями их пористости по глубине. Бассейновое моделирование позволило существенно минимизировать геологические неопределенности, такие как геодинамические реконструкции, условия осадконакопления и пополнить базу знаний о геологическом строении Карагандинского бассейна.

Р. М. Садыков[1], В. В. Коробкин[2]

[1]Қ. И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Алматы, Қазақстан,
[2]Қазақстан-Британ техникалық университеті, Алматы, Қазақстан

ҚАРАҒАНДЫ КӨМІР БАССЕЙНІНІҢ ОҢТҮСТІК БӨЛІГІН БАССЕЙНДІК МОДЕЛЬДЕУ ҮШІН НЕГІЗГІ ГЕОЛОГИЯЛЫҚ ДЕРЕКТЕРДІ ТАЛДАУ

Аннотация. Қарағанды көмір бассейнінің оңтүстік бөлігін бассейндік модельдеу үшін геологиялық-геофизикалық деректер талданды. Осыған байланысты негізгі деректертер іріктелді, оның ішінде зерттеу объектісінің геологиялық құрылымы (стратиграфия, литология, қатпарлы және үзілімді құрылымдарды фациялық талдау, геодинамикалық модельдеу, шөгінділердің жиналуының термобарикалық жағдайы).

Қарағанды көмір бассейні геологиялық эволюция кезінде көп сатылы деформацияны бастан кешті. Ол Қарағанды көмір бассейнінің оңтүстік және шығыс бөліктерінде, Алабас антиклиналь аудандарында, Майқұдық көтерілісінде және Спасск шеткі ауданында құрылымдық пішіндердің түрлі жиынтықтарынан көрініс табады. Белсенді орогенезбен қатар жүрген деформацияның негізгі кезеңдері кейінгі палеозой және ерте мезозой уақытында болды. Фаменнен бастап бүгінгі күнге дейін бұл аймақ күрделі көрсатылы даму тарихын кешірді. Бұл аймақтың литологиялық, палеогеографиялық, палеотектоникалық және геодинамикалық реконструкция нәтижесінен байқалады.

Бұған дейін жасалған биостатиграфиялық зерттеулердің нәтижелерін пайдалана отырып қабаттардың жасы анықталды. Модельдеу кезінде бастапқы геологиялық ақпарат көмірдің пісіп-жетілуі бойынша калибрлеу нәтижелерімен және көмір қабаттарының тереңдікпен кеуектілігінің өзгеруімен сәйкестендірілді. Бассейндік модельдеу геологиялық реконструкция, шөгінділердің жиналуының жағдайы сынды мәселелерде геологиялық тұрлаусыздықты азайтуға мүмкіндік берді, және Қарағанды көмір бассейнінің геологиясы бойынша дерекқорды кеңейтті.

Information about authors:

Sadykov R.M., Kazakh National Research Technical University named after K. I. Satpayev, Almaty, Kazakhstan; sadykovraman@mail.ru; https://orcid.org/0000-0002-5936-2036

Korobkin V.V., Kazakh-British Technical University, Almaty, Kazakhstan; korobkin_vv@mail.ru; https://orcid.org/0000-0002-1562-759X

REFERENCES

[1] Zholtaev G.Zh., Zhukov N.M., Bespaev Kh.A. The theory of forecasting and evaluating the minerals and raw materials base of the Republic of Kazakhstan // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 2, N 428. P. 36-43; https://doi.org/10.32014/2018.2518-170X

[2] Bekzhanov G.R., Koshkin V.Y., Nikitchenko I.I., et al. Geological structure of Kazakhstan. Almaty: Academy of mineral resources of the Republic of Kazakhstan, 2000. P. 396.

[3] Nikitchenko I.I. Minerals of Kazakhstan. Explanatory note to the 1:1 000 000 scale map of Kazakhstan Mineral Resources. Kokshetau, 2002. P. 188.

[4] KazEnergy. The National Energy Report 2015, "KAZENERGY" ALE. P. 374.

[5] Alekseev A.D., Ulyanova E.V., Vasilkovskiy V.A., et al. Structure peculiarities of coal's hazardous zones // GIAB. 2010. N 8. P. 152-163.

[6] Kovalchuk A.B., Hardinge B.C. Coal Industry of the Former USSR: Coal Supply System and Industry Development. CRC Press, 2002. P. 144.

[7] Atlas of the Lithology-Paleogeographical, Structural, Palinspastic and Geoenvironmental Maps of Central Eurasia. Scientific Research Institute of Natural Resources YUGGEO. ISBN: 9965-13-566-5. Almaty, 2002. Fig. 38, p. 132.

[8] Korobkin V.V., Buslov M.M. Geodynamics and Tectonophysics of the western part of Central-Asian folded belt (paleozoids of Kazakhstan) // Geology and geophysics. 2011. Vol. 52, N 12. P. 2032-2055.

[9] Buslov M.M. Terrain Tectonics of the Central Asian Folded belt // Geodynamics and Tectonophysics. 2014. Vol. 5, issue 3. P. 641-665.

[10] Bekman V.M., Koshkin V.Y., Gabai N.L. Carboniferous system // Geological Map of Kazakh SSR. Scale 1:500000. Serie Central Kazakhstan. Explanatory note. Almaty, 1981. P. 98-125.

[11] Kurchavov A.M., Grankin M.S., Malchenko E.G. et al. Zonation, Segmentation and Paleogeodynamics of Devonian volcanicbelts of Central Kazakhstan // Geotectonics. 2000. N 4. P. 32-43.

[12] Hertle M., Littke R., 2000. Coalification pattern and thermal modeling of the Permo-Carboniferous Saar Basin (SW-Germany) // Int. J. Coal Geol. 42. P. 273-296.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 143 – 150 **https://doi.org/10.32014/2019.2518-170X.18**

UDC 553.493.5

V. I. Serykh, A. N. Kopobayeva

Karagandy State Technical University, Karagandy, Kazakhstan.
E-mail: serykh.vyacheslav@gmail.com; aiman_25.87@mail.ru

PATTERNS OF DISTRIBUTION OF RARE METAL DEPOSITS IN CENTRAL KAZAKHSTAN

Abstract. The article considers the main patterns of location in Central Kazakhstan of greisen-quartz-vein tungsten, molybdenum and beryllium deposits, as well as copper-molybdenum-porphyry deposits from which molybdenum is mined as a co-component. We analyzed the patterns of deposit location mainly from three perspectives: 1) magmatic control; 2) distribution over time; 3) structural control. Magmatic control of Cu-Mo-porphyry deposits is determined by their genetic connection with sodium-type orogenic granitoids ($K_2O/Na_2O<0.85$) or kalium-sodium ones (K_2O/Na_2O = 0.85-1.15). The ore-bearing intrusives are specific "porphyry" differentiates of the granodiorite phase, the additional intrusives. Magmatic control of rare metal deposits is determined by their genetic connection with the leucogranite-series intrusives. Both classes of deposits, Cu-Mo-porphyritic and rare-metal ones, are manifested in Central Kazakhstan in multiple occasions: the first class at six age levels (O_1, O_3, S_2, D_3, C_1, C_3), the second class at six levels likewise (S_1, S_2, D_2, D_3, C_3, P_1). Structural control of Cu-Mo-porphyry deposits is determined by their connection with the granodiorite formation bodies, whereas rare metal deposits are located in two tectonic positions: essentially molybdenum deposits are in connection with the late orogenic leucogranite formation, and the most of complex rare metal deposits are confined to synorogenic tectonomagmatic activation zones.

Keywords: Central Kazakhstan, magmatic, structural control, age of rare metal deposits.

Introduction. The article deals with the patterns of location of greisen quartz-vein tungsten, molybdenum and beryllium deposits in Central Kazakhstan. Since only molybdenum is produced from among the named metals in the Central Kazakhstan region during the development of copper-molybdenum-porphyry deposits, a number of deposits of this type are involved in the analysis.

Altogether these types of deposits constitute the vast majority of all rare metal deposits in Central Kazakhstan. Beyond the completed analysis there were individual deposits of tin, niobium, tantalum, and zirconium. All of these are small deposits (rarely up to medium), and often these are large shows of ore classified as small deposits for the future perspective. The deposits considered in the article are shown in figure 1.

We considered the patterns of location of deposits mainly from three perspectives: 1) magmatic control; 2) distribution in time; 3) tectonic association.

1. Magmatic control of mineralization. As will be shown below, each fold system witnesses the formation of Cu-Mo-porphyry deposits (orogenic stage), and after that rare-metal deposits (late orogenic sub-stage) are formed. We will consider the deposits in this priority.

1.1. *Genetic relations of Cu-Mo-porphyry mineralization with magmatism.* Based on the study of about 40 Cu-Mo-porphyry objects, this issue was considered in [1]. It was established that Cu-Mo-porphyry mineralization is genetically related to orogenic calc-alcalic granitoids of predominantly sodium series (K_2O/Na_2O < 0.85), more rarely to potassic-sodium granitoids (K_2O/Na_2O = 0.85-1.15). These connections are established not with the granitoids themselves, but with specific differentiations of the second, granodiorite, phase of the intrusive massifs, which are extremely porphyraceous rock of additional intrusives that complete the second phase and are commonly referred to as "porphyrites". In fact, these ore-bearing rocks can be called porphyrites only figuratively due to their sufficient crystallization. For

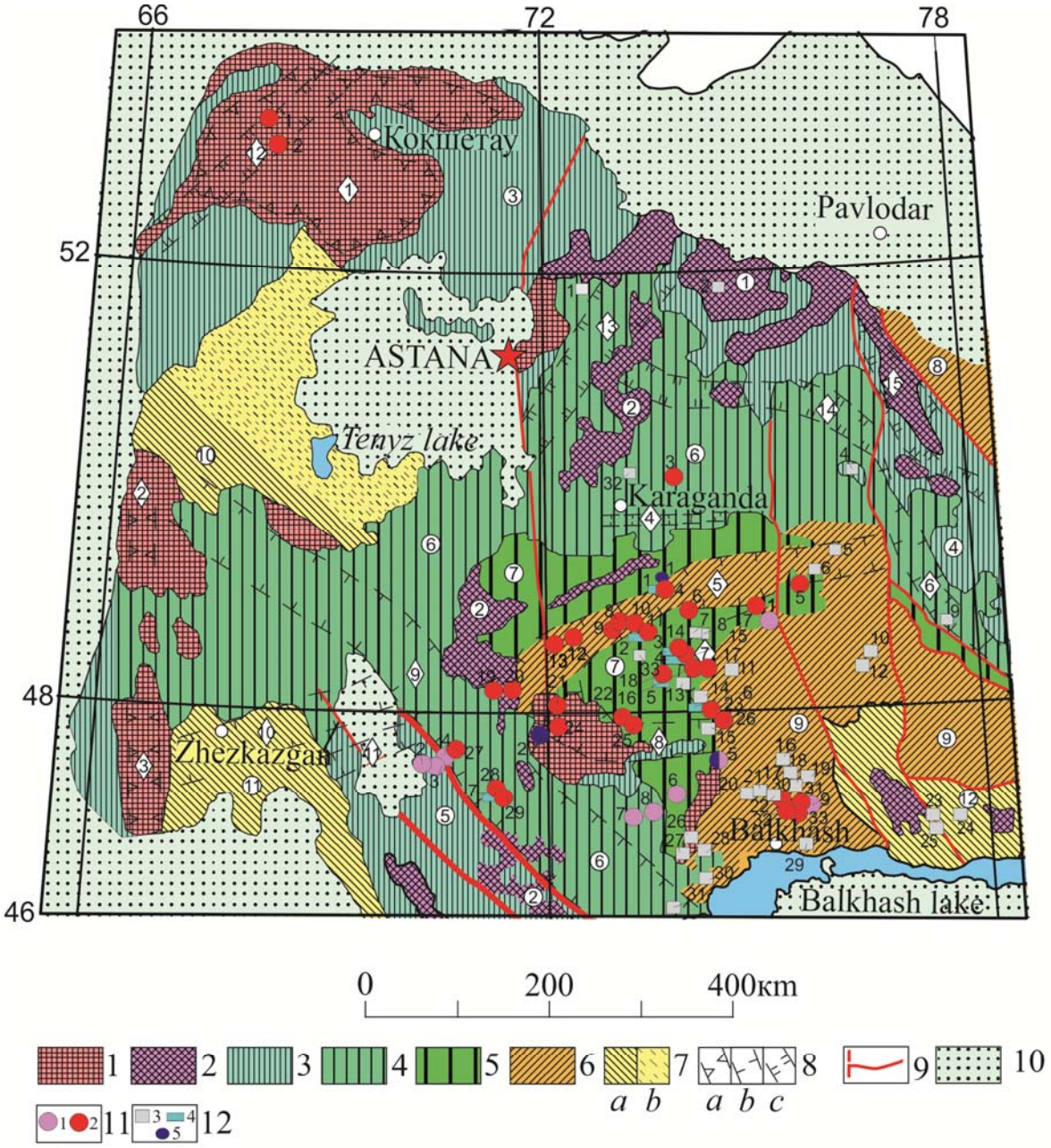


Figure 1. Diagram of location of rare metal deposits of Central Kazakhstan
Compiled by V.I. Serykh and A.N. Kopobayeva. Tectonic zoning according to [2].

Legend: **1** - projections of Precambrian basement. **2-7** - Paleozoic folded areas (figures in circles): **2** - Salair (Bozshakol - 1, Yereymentau-Burubaitalsky Rift - 2, etc). **3** - Early Caledonian (Stepnyakskaya - 3, Chingiz-Tarbagatay - 4, Chu-Balkhash - 5), **4** - Middle Caledonian (Central Kazakhstan - 6), **5** - Late Caledonian (Zhamansarysu - 7), **6** - Early Hercynian (Zaisanskaya - 8, Dzungaro-Balkhashskaya - 9), **7** - Late Hercynian (South Teniz -10, Zhezkazgan-11, Sayak-12), **8** - zones of tectonomagmatic activation (TMA) (figures in rhombuses): a) Caledonian (Kokshetau - 1, Arganatanskaya - 2, Ulytauskaya - 3), b) Early Hercynian (Spasskaya - 4, Uspenskaya - 5, South-Chingiz - 6, East-Zhamansarysu - 7, Akbastau-Akzhal - 8, Zhailma-Karaobinskaya - 9, Uitas-Zhezkazgan -10, Kenzhebai-Zhamanaybat-11) c) Late Hercynian (Chaglinskaya - 12, Koitas - 13, Bayanaulskaya - 14, Tleumbetskaya - 15). **9** - the main faults. **10** - platform cover. **11** - deposits: 1) molybdenum, 2) tungsten, tungsten-molybdenum, complex; **12**-3 - copper-molybdenum, **12**-4 - placers, **12**-5 - beryllium.

example, the grain size in the rock of the Kounrad ore-bearing stock is 0.02-0.10 mm, and those in the Baysky stock is even 0.05-0.20 mm. Of course, these are not volcanic and not subvolcanic porphyrites. If we still call it "porphyrites", then only adding the definition "plutonic porphyrites". This is confirmed by geological relations (mineralization intersects post-ore aplite veins), the same absolute age of the ore-forming intrusive complex and ore-bearing porphyraceous rocks, the same petrochemical type (sodium granodiorites - sodium "porphyrites", potassic-sodium granodiorites - potassic-sodium "porphyrites"), the greatest water content of granodiorite magmas [3], wide development of acid leaching processes in the abovementioned and other types of rocks and by other common features.

The study [1] assumed the possibility of the connection between individual Cu-Mo-porphyraceous occurrences with subalkaline granitoids. However, further elaboration on the composition of such rocks and their bonds with Cu-Mo-porphyraceous ores did not confirm these assumptions.

1.2. *Genetic relations of rare metal deposits with magmatism.* Due to the fundamental paper [4], a fairly stable opinion was established that the Hercynian rare metal deposits are genetically related to the ultra-acidic intrusives (SiO_2 > 73%); in today's nomenclature they are subgranites, leucogranites, and alkali-feldspar leucogranites (table 1).

Table 1 – The average chemical composition of leucogranite family rocks, weight % [5]

Rocks	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	Loi
Orogenic granitoids *													
Diorites	55.29	0.84	16.90	2.92	5.23	0.17	4.38	7.41	3.09	1.44	0.20	0.23	1.67
Quartzitic diorites	60.86	0.67	16.45	2.22	3.97	0.11	2.74	4.75	3.61	2.34	0.20	0.14	1.31
Grano-diorites	65.47	0.53	15.77	1.67	3.18	0.09	1.76	3.71	3.84	2.56	0.16	0.18	0.96
Plagio-granites	70.14	0.31	14.81	1.27	2.15	0.06	0.99	2.12	4.49	2.48	0.12	0.32	0.73
Granites	70.54	0.33	14.52	0.96	2.28	0.06	0.84	1.97	3.73	3.77	0.12	0.11	0.58
Late-orogenic granitoids													
Subgrani-tes *	73.94	0.20	13.50	0.85	1.47	0.05	0.45	1.16	3.37	4.50	0.06	0.10	0.36
Leucogra-nites	75.20	0.15	13.04	0.63	1.44	0.05	0.23	0.73	3.52	4.66	0.04	0.10	0.24
* Subgranites are intermediate rocks between granites and leucogranites.													

Table 2 – The average chemical composition of granitoids of tectonomagmatic activation resonance zones, weight % [5]

Rocks	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	Loi
Granitoids, synchronous, orogenic stage													
Diorites	55.29	0.84	16.90	2.92	5.23	0.17	4.38	7.41	3.09	1.44	0.20	0.23	1.67
Quartz monzo-diorites	61.68	0.66	15.79	2.20	3.95	0.10	2.66	4.40	3.26	3.59	0.20	0.10	1.09
Monzo-granodiorites	65.83	0.51	15.26	1.69	2.83	0.07	1.92	3.47	3.20	4.03	0.18	0.55	0.65
Monzo-granites	70.89	0.32	14.29	1.09	2.09	0.05	0.71	1.81	3.22	4.30	0.11	0.16	0.57
Granitoids, synchronous, late orogenic stage													
Leucogranites	75.20	0.15	13.04	0.63	1.44	0.05	0.23	0.73	3.52	4.66	0.04	0.10	0.24
Alkali-feldspar leucogranite	75.55	0.12	12.77	0.41	1.00	0.04	0.21	0.41	3.66	4.59	0.04	0.09	0.31

Over time, the opinion on the connection of rare metal deposits with ultra-acidic magmas in Balkhash region solidified and was confirmed by facts. It was found that mineralization is associated with each intrusive phase of leucogranite complexes, i.e. it actually got inside the intrusive complex and its connection with the complex became obvious. The correlation of intrusive phases and rare metal mineralization is shown in figure 2.

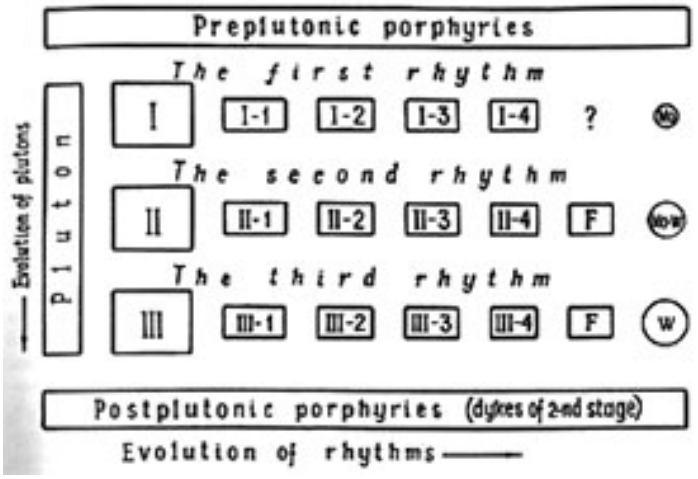


Figure 2 –
General sequence of formation
of leucogranite plutons [6].
I, II, III – the main intrusives;
I-1, II-1, III-1 – additional intrusives;
I – 2÷4, II – 2÷4, III – 2÷4 –
sheet-like bodies, dikes and
veins of aplitoid leucogranites and aplites;
F – dikes of fluid-saturated granite-porphyrites
and microcline-albite granites;
Mo, W – ore deposits

Table 3 – Periodicity of occurrence of copper-porphyry and rare metal deposits
in the polycyclic folded area of Central Kazakhstan (according to [7], with some additions and clarifications)

Megacycle	Cycle	Orogenic stage		Synorogenic activation of the consolidated frame	
		orogenic stage	late-orogenic sub-stage	synchronous with orogenic stage	synchronous with late-orogenic sub-stage
		The ore-bearing intrusive complex (q. diorites, Na-granodiorites, plagiogranites), age; *Cu-Mo-porphyry deposits (age)*	Rare-metal intrusive complex (subgranites, leucogranites), age; *Rare-metal deposits (age)*	The ore-bearing intrusive complex (sq. monzodiorites, K-Na and K-granodiorites, K-granites), age; *Cu-Mo-porphyry deposits (age)*	Rare-metal intrusive complex (leucogranites, alkaline-feldspar leucogranites), age; *Rare-metal deposits (age)*
Caledonian	Initial (Salair)	Bozshakolsky, O_1; ***Bozshakol (O_1)***	?	?	?
	Early Caledonian (Taconian)	Krykkuduksky, O_3; ***Koktaszhal, Kyzyltu (O_3)***	Karabulak (Zhamankoitassky),S; ***ore occurrences W, Mo, Bi (S_1)***	Zerendinsky, O_3-S_1; ***Cu-Mo ore occurrences in Shatsky anticlinorium*** *(S_1)*	Zolotonoshsky, S_2; ***Bayan – W, Mo, Sn, Syrymbet – Sn*,W,Bi (S_2)**
	Middle Caledonian (Erian)	Karamendinsky, chetsky (S_2-D_1); ***Nurkazgan (S_2)***	Kilchinsky, Korneevsky, D_2; ***Shalgiya, Bugul-Mo, Ulyanovskkoye – W, Mo; an others (D_2)***	*	*
	Late Caledonian (Breton, Telbessky)	Zhangeldinsky, D_3; ***Shetshoky (D_3)***	Kyzylespinsky, D_3; ***ore occurrences Mo,Sn, Bi (D_3)***	*	*
Hercynian	Early Hercynian (Saursky)	Balkhashsky, C_1; ***Konyrat, Borly, Besshoky and others (C_1)***	East Kounrad, C_2-$_3$; ***East Kounrad-Mo, North Kounrad – Be, Mo, Zhanet, Karatas -IV – Mo (C_3)***	Toparsky, C_{1-2}; ***Almaly, Bayskoe, Ozernoe – Cu-Mo (C_2)***	Kaldyrminsky, Kuinsky, C_3-P_1; ***Upper Kayrakty - W, Katpar - W, Mo, Koktenkol - Mo, W, Karaoba – W,Sn,Bi, Be; and others (P_1)***
	Late Hercynian (Sayaksky)	Kungeysayaksky, $C_{2\text{-}3}$; ***Berkara (C_3)***	Besobinsky, P_1; ***ore occurrences Arkharly – W,Mo (P_1)***	*	*

Table 4 – List of rare metal deposits

No. on the diag-ram	Name, category of the deposit	The main (associated) components	Age	No. on the diag-ram	Name, category of the deposit	The main (associated) components	Age
Copper-molybdenum porphyry deposits				32	Volframovye Sopki – S	Mo, W	C_3
8	Almaly - M *	Cu (Mo, Bi, Au)	C_2	20	Vysotnoye – S	W (Bi, Be, Mo)	C_3-P_1
14	Altuayt - S	Cu, Mo (Pb, Zn, Bi, Ag)	C_2	19	Dolinnoye (Sarybyurat) – S	W (Mo, Be, Bi)	C_3-P_1
26	Anomaly-6 (Karatas-6 C) -S	Cu (Zn Mo Au)	C_1 ?	29	Karaoba – L	W (Mo, Sn, Be)	C_3-P_1
16	Auyzbaky - S	Cu, Mo	C_2	8	North and North-East Katpar – L	W, Mo (Bi, Cu, Be)	C_3-P_1
6	Bayskoe - M	Cu, Mo	C_2	9	North Katpar (residual) – S	W	P_2
23	Berkara-S	Cu, Mo (W, Bi)	C_3				
12	Besshoky - S	Cu, Mo (Pb)	C_2	12	Koktenkol South, North and Intermediate – L	Mo, W (Bi, Be, Cu)	C_3-P_1
2	Bozshakol - L	Cu (Mo, Au, Ag, Co)	O_1	13	Koktenkol Intermediate (in the weathering crust) – L	W (Bi, Cu)	P_2
20	Borly 3. - S	Cu (Mo)	C_2	30	North Kounrad– M	Be, Mo (W, Bi)	C_3
21	Borly - M	Cu (Mo, Ag, Au, Re)	C_2	33	South Kounrad – S	Mo, W	C_3
25	Zhambas C. - S	Cu (Mo, Au)	C_3	27	Kuu – M	W	C_3-P_1
15	Zhekeduan - S	Cu (Mo, Ag, Au)	C_2	21	NW Kyzyltau – S	W (Mo, Bi)	C_3-P_1
9	Zapadnoye - S	Cu, Mo	C_2	24	SE Kyzyltau – S	W, Mo (Be, Bi, Mo)	C_3-P_1
27	Karatas-1,2 - S	Cu, Mo (Fe)	C_1 ?	4	Nurataldy – S	W (Bi)	C_3-P_1
28	Karatas-4 - M	Mo (Cu)	C_3	7	Saran – M	W, Mo (Bi)	C_3-P_1
19	Kaskyrkazgan - S	Cu, Mo (Au)	C_2	18	Seltey – S	Mo (W, Bi)	C_3-P_1
18	Kenkuduk - S	Cu, Mo (W)	C_2	31	Scorpion – S	W, Be (Mo,Bi)	C_3
17	Kepsham - S	Cu, Mo	C_2	28	Solnechnoye – S	W (Be, Bi, Mo, Sn, f)	C_3-P_1
4	Koktaszhal – M	Cu (Mo, Au)	O_3	1	Syrymbet – L	Sn (Ta, Nb, Zn, Cu, Bi, W)	D_3
				5	Tayshek – M	Bi (W, Be, Mo)	P_1
11	Korgantas – S	Cu, Mo (Pb, Ag, Au)	C_2	17	Uzynbulak – S	Mo, W (Bi)	C_3-P_1
22	Kounrad- L	Cu (Mo, Au, Re, Se, Te)	C_2	3	Ulyanovskoye – M	W, Mo (Bi)	D_2
1	Kyzyltu – S	Cu, Au (Mo, W)	O_3	15	South Zhaur– M	W (Mo)	C_3-P_1
24	Moldybay–S	Cu (Co, Mo)	P_2	Placers			
32	Nurkazgan – L	Cu, Mo (Ag, Hg)	D_1-S_2	6	Akchatauskaya – S	W	
5	Ozernoe – M	Cu (Mo, Bi, Ag)	C_2	3	Baynazarskaya– S	W	Q_{1-4}
7	Olginskoye – S	Cu (Mo, Bi)	C_2	2	Upper Kayraktinskaya – M	W	Q_{2-4}
29	Pribrezhnoye – M	Cu, Mo (Au, Re)	C_2	7	Karaobinskaya– S	Sn, W	Q_{3-4}
31	Saryshagan – M	Cu	D_1	1	Nurataldinskaya – S	W	Q_{3-4}
30	Sokurkoy Mednoye – S	Cu, Mo (Zn, Pb, Au)	C_2	5	Selteyskaya– S	W	Q_{3-4}
13	Tolagay – S	Cu, Mo	C_3-P_1	4	South Zhaur– S	W (Mo)	Q_{1-2}
10	Shatyrsha – S	Cu, Mo	C_2	Molybdenum deposits			
33	Shetshoky – S	Cu, Mo	D_3	7	East Akkuduk – S	Mo (Cu, W)	P_1
Essentially tungsten, tungsten-molybdenum, complex deposits				8	West Akkuduk – S	Mo (Cu, W)	P_1
22	Akbiik – M	W (Bi, Mo)	C_3-P_1	6	Biryuk Molibdenovoye– S	Mo (Cu, Pb, Zn)	P_1
10	Akmaya – M	W (Bi, Mo)	C_3-P_1	2	Bugul – M	Mo	D_2
25	Aksarly – S	W (Be, Bi, Mo)	C_3-P_1	5	Zhanet – L	Mo, Be (W, Bi, fl, TR)	C_2
23	Akchatau – S	W (Mo, Be)	P_1	1	Iyulskoye – S	Mo (W, Cu, Pb, Ag)	C_3-P_1
26	South-East Akchatau–S	W (Mo, Be, Sc, Li)	P_1	9	East Kounrad. – L	Mo	C_3
14	Bainazar – M	W (Mo, Bi)	C_3-P_1	3	Sarytas – S	Mo	D_2
16	Batystau – L	W, Mo (Be, Sn)	C_3-P_1	4	Shalgiya– S	Mo	D_2
2	Bayan	W, Bi, (Mo, Cu, Ag)	D_1	Substantially beryllium deposits			
6	Belkoytas – S	W (Bi, Be)	C_3-P_1	2	Darat – S	Be (W, Mo)	C_3-P_1
11	Upper Kairakty – L	W (Bi, Mo, Be)	C_3-P_1	1	Nurataldy – L	Be (Mo, Bi, W)	C_3-P_1
*Deposits: L – large, M – medium, S – small.							

The vast majority of leucogranite plutons, sufficiently exposed by erosion, are two-phase ones, while in the last decade of the 20th century several three-phase plutons have been mapped: Kyzyltau, Karaoba, Kuu, Donetsky [4]. A specialist in rare metal deposits in Kazakhstan G.N. Shcherba at first considered only the II-nd phase to be ore-bearing, but later he and his staff came to the conclusion about the possibility of a two-fold occurrence of the postmagmatic process: in the plutons of Akchatau and Zhanet, quartz veins and veinlets with molybdenite were identified, which complete the I-st phase, but the main ore-generating capacity was considered to be of the II-nd phase. The established correlations of ores with the main intrusive phases indicate that each phase may be ore-bearing. The I-st phase suggests really significant molybdenum mineralization. In particular, molybdenum mineralization in the pluton Karaoba (Molybdenum site) and Kuu (Komsomolskoye show of ore) is intersected by aplite dykes of the 2nd phase. Intrusives of the second phase are inherent with complex rare metal deposits (in Kuu pluton the main vein of the Kuu field is intersected by the II phase intrusive and its vein differentiations, aplites). The third phase of the plutons Kyzyltau, Karaoba and Kuu is associated mainly with tungsten deposits. Under favorable conditions (above the protrusions of the mantle) tin is added to these rare metals.

2. Distribution of mineralization in time. Academician of Kazakh Academy of Sciences G. N. Shcherba believed that these deposits were associated exclusively with the Hercynian cycle, and this opinion dominated for a long time. However, subsequent accumulation of information about the age of rare metal deposits and ore-bearing intrusives did not confirm this conclusion essentially, although in terms of the number of rare metal objects the Hercynian cycle proved to be the most abundant (> 65% of the total).

Table 3 shows the cyclic distribution of rare metal deposits in Central Kazakhstan with ore-bearing complexes and examples of typical deposits.

Table 4 contains a complete list of deposits examined in this paper, indicating their scale and specific age. The age of the deposits is determined by the radiological data of mineralization, but most often by geological and radiological data for ore-bearing intrusives, the nature of the relationship of rare metal mineralization with which is described in Section 1.

3. Structural control of deposits

3.1. *The tectonic association of copper-molybdenum-porphyry deposits* is completely determined by their magmatic control, a genetic bond exclusively with the orogenic granodiorite formation (see Section 1). This formation is associated with the formation of each fold system, which was repeated six times in the history of geological development of the region (see table 2).

3.2. *Primary rare metal deposits are located in two tectonic positions,* in connection with late orogenic ultra-acidic granitoids and in tectonomagmatic activation zones.

3.2.1. The structural association of essentially molybdenum deposits is determined by their connection with the leucogranite formation of the late orogenic sub-stage. This formation is known in 5 tectonic cycles (see table 2). Essentially molybdenum deposits are found in two cycles, Middle Caledonian (Shalgiya, Bugul, Sarytas, etc.) and Early Hercynian (East Kounrad, Zhanet, West and East Akkuduk, etc.). In the remaining three cycles, Early Caledonian, Late Caledonian, and Late Hercynian, there are only shows of ore.

3.2.2. Structural control of the distribution of rare metal deposits. The overwhelming majority of rare metal deposits and, above all, essentially tungsten and complex deposits (W, Mo, Be, Bi), are associated with the synorogenic zones of tectonomagmatic activation. Such TMA zones are found in two cases and are associated with the beginning of Caledonian and Hercynian megacycles, when as a result of destruction of the Karelian platform, and then after destruction of the epicaleldon platform, the interiors of the platforms were most deeply opened and maximum release of endogenous energy occurred. As a result, the Caledonian and Hercynian TMA zones were formed (figure 1). Caledonian deposits Bayan and Syrymbet are spatially confined to the Chaglinsky TMA zone located within the Precambrian Kokchetavsky protrusion. However, the age of these deposits requires further refinement.

Most of the deposits are located in the Early Hercynian TMA zones. In Uspenskaya TMA zone: Belkoytas, Upper Kayrakty, North Katpar, Koktenkol, Nurataldy, Saran, Tayshek, Dolinnoye, Vysotnoye; in East Zhamansarysu TMA zone: Akchatau, Bainazar, Batystau, Seltey, Uzynbulak, South Zhaur, Iyulskoye; in Akbastau-Akzhal zone of TMA: Aksarly, North-West Kyzyltau, North-East Kyzyltau, Darat; in Zhailma-Karaobinskaya zone of TMA: Karaoba, Solnechnoye, Kuu.

Conclusion. The study found that rare-metal deposits of Central Kazakhstan are in three tectonic positions: 1) orogenic (Cu-Mo-porphyry) in connection with the orogenic granodiorite formation; 2) late orogenic (essentially molybdenum) in connection with the ultra-acidic granites of the late orogenic substage; 3) activating (essentially tungsten, complex, essentially beryllium) in connection with the ultra-acidic granites of the synorogenic Early Hercynian tectonomagmatic activation zones.

1. The maximum number of indigenous rare metal deposits is concentrated in the synorogenic Early Hercynian tectonomagmatic activation zones (about 70% of the known deposits), which is due to the most favorable combination in these zones of all ore-controlling factors: magmatic, structural factor and host medium factor [4, p. 182-197].

2. We recommend conducting further forecasting and prospecting aimed at expanding raw materials in Central Kazakhstan within the tectonomagmatic activation zones, primarily in the synorogenic Early Hercynian zones.

В. И. Серых, А. Н. Копобаева

Қарағанды мемлекеттік техникалық университеті,
Қарағанды, Қазақстан

ОРТАЛЫҚ ҚАЗАҚСТАНДАҒЫ СИРЕКМЕТАЛДЫ КЕНОРЫНДАРДЫҢ ОРНАЛАСУ ЗАҢДЫЛЫҚТАРЫ

Аннотация. Мақалада Орталық Қазақстандағы грейзен-кварц-желілік вольфрам, молибден, бериллий, сонымен қатар молибден қосымша компонет ретінде өндірілетін мыс-молибден-порфирлі кенорындарының орналасу заңдылықтары қарастырылған. Кенорындардың орналасу заңдылықтарының анализі негізінен үш тұрғылықтан қарастырылған: 1) магмалық бақылау; 2) уақытта таралуы; 3) құрылымдық бақылау. Cu-Mo-порфирлі кенорындардың магмалық бақылауы орогенді граниттік натрийлі қатармен (K_2O/Na_2O < 0.85) немесе калийнатрийлі қатармен (K_2O/Na_2O = 0.85-1.15) генетикалық байланыспен анықталады. Өзіндік кентасушы интрузиялар – гранодиоритті өзгеше фазаның «порфирлі» дифференциатты қосымша интрузиялар болып саналады. Сирек кездесетін металдар кенорындарының магмалық бақылауы лейкогранитті интрузияларымен генетикалық байланысымен анықталады. Кенорындардың екі класы – Cu-Mo-порфирлі және шын сирек кездесетін металдар кенорындары Орталық Қазақстанда бірнеше рет танылады: бірінші класс – алты жастық кезеңде (O_1, O_3, S_2, D_3, C_1, C_3), екіншісі – тағы да алтыда жастық кезеңде (S_1, S_2, D_2, D_3, C_3, P_1). Cu-Mo-порфирлі кенорындар құрылымдық бақылау гранодиоритті формация денелерімен байланысымен анықталады. Ал сирек кездесетін кенорындар екі тектоникалық позицияда орналасады: айтарлықтай молибденді кенорындар кешорогенді лейкогранитті формациямен байланыста болады, ал кешенді сирекметалды кенорындардың көбісі синорогенді тектоникалық-магмалық активизациялық аудандарға тұтастырылады.

Түйін сөздер: Орталық Қазақстан, магмалық, құрылымдық бақылау, сирекметалды кенорындардың жасы.

В. И. Серых, А. Н. Копобаева

[1]Карагандинский государственный технический университет,
Караганда, Казахстан

ЗАКОНОМЕРНОСТИ РАЗМЕЩЕНИЯ РЕДКОМЕТАЛЛЬНЫХ МЕСТОРОЖДЕНИЙ ЦЕНТРАЛЬНОГО КАЗАХСТАНА

Аннотация. В статье рассмотрены основные закономерности размещения в Центральном Казахстане грейзеново-кварцевожильных вольфрамовых, молибденовых и бериллиевых месторождений, а также медно-молибден-порфировых месторождений, из которых добывается молибден в качестве попутного компонента. Анализ закономерностей размещения месторождений осуществлен, в основном, с трех позиций: 1) магматический контроль; 2) распределение во времени; 3) структурный контроль. Магматический контроль Cu-Mo-порфировых месторождений определяется их генетической связью с орогенными гранитоидами натрового ряда (K_2O/Na_2O<0.85) или калинатрового ряда (K_2O/Na_2O=0.85-1.15). Собственно рудоносными интрузиями

являются специфические «порфировые» дифференциаты гранодиоритовой фазы – дополнительные интрузивы. Магматический контроль редкометалльных месторождений определяется их генетической связью с интрузиями лейкогранитового семейства. Оба класса месторождений – Cu-Mo-порфировые и собственно редкометалльные – проявлены в Центральном Казахстане многократно: первый класс – на шести возрастных уровнях (O_1, O_3, S_2, D_3, C_1, C_3), второй – тоже на шести (S_1, S_2, D_2, D_3, C_3, P_1). Структурный контроль Cu-Mo-порфировых месторождений определяется их связью с телами гранодиоритовой формации. А редкометалльные месторождения располагаются в двух тектонических позициях: существенно молибденовые месторождения находятся в связи с позднеорогенной лейкогранитовой формацией, а большинство комплексных редкометалльных месторождений приурочены к синорогенным зонам тектоно-магматической активизации.

Ключевые слова: Центральный Казахстан, магматический, структурный контроль, возраст редкометалльных месторождений.

Information about the authors:

Serykh Vyacheslav Ivanovich, Doctor of geological and mineralogical sciences, docent, Department of Geology and mineral deposits exploration, Karagandy State Technical University, Karaganda, Kazakhstan; serykh.vyacheslav@gmail.com; https://orcid.org/0000-0002-1693-6466

Kopobayeva Aiman Nygmetovna, Master of Engineering and Technology, student of PhD, Department of Geology and mineral deposits exploration, Karagandy State Technical University, Karaganda, Kazakhstan; aiman_25.87@mail.ru; https://orcid.org/0000-0002-0601-9365

REFERENCES

[1] Serykh V.I., Yegorychev L.G. Genetic Relations of Copper-Porphyry Mineralization in Balkhash Region // Geology of ore deposits. 1978. Vol. XX, N 6. P. 251-260.

[2] Serykh V.I. Regional Geology and Geotectonics of Kazakhstan. Tutorial. KSTU. Karaganda: KSTU publishing house, 2017. 114 p.

[3] Serykh V.I. Geology, Petrology and Metallogeny of the Ultra-Acidic Granitoids of Central Kazakhstan. Karaganda, 2009. 318 p.

[4] Shcherba G.N. Formation of Rare Metal Deposits of Central Kazakhstan. Alma-Ata, 1960. 381 p.

[5] Glukhan I.V., Serykh V.I. The Mean Chemical Compositions (Regional Clarkes) of Igneous Rocks of Central Kazakhstan. Granite-Related Ore Deposits of Central Kazakhstan and Adjacent Areas. St. Petersburg, 1996. P. 269-286.

[6] Serykh V.I. Granitic Rock of Central Kazakhstan. Granite-Related Ore Deposits of Central Kazakhstan and Adjacent Areas. St. Petersburg, 1996. P. 24-54.

[7] Serykh V.I. Orogenic Magmatism and Metallogeny. "Smirnov Collection - 2012". M.: State Institution Akademizdattsentr "Nauka" of the Russian Academy of Sciences, 2012. P. 167-202.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 151 – 162 **https://doi.org/10.32014/2019.2518-170X.19**

UDC 625.001.05

V. G. Solonenko, N. M. Makhmetova, J. S. Musayev, S. E. Bekzhanova, M. Ya. Kvashnin

Kazakh Academy of Transport and Communications named by M. Tynyshpaev, Almaty, Kazakhstan.
E-mail: v.solonenko@mail.ru, makhmetova_n1958@.mail.ru,
mussayev75@yandex.kz, s.bekzhanova@bk.ru, kvashnin_mj55@mail.ru

THE METHOD OF LIMITING SPEED WHEN PASSING TURNOUTS OF RAILWAY VEHICLES WITH BOGIES OF MODEL ZK1

Abstract. To improve the safety of freight trains traffic, regulatory documents of railway administrations establish the maximum permissible speeds when passing small radius curves and, including, transferable curves of switches of the most common brands. Transferable curves have a number of features – the absence of transferable inserts, elevation of the outer rail, blind intersections of the combined track, which causes the need for a sharp reduction in speed when entering the station through the transferable curve of the directional on the side track. To determine the maximum speeds, it is necessary to take into account the vertical, horizontal and transverse forces transmitted from the crew to the cores of the crosspieces of the turnouts, the coefficient of vertical dynamics, the value of the frame forces arising in the crews, in order to determine the ratio of these forces to the static load and the level of dynamic impact on the turnouts.

The task is solved by a combined method: analytical-computational and experimental. To solve the problem, an analytical method is used to draw up a calculation scheme, which takes into account the stiffness of spring sets, friction coefficients, angles of rotation of the body and wheel sets with respect to the transverse, vertical and longitudinal axes. On the basis of the calculation scheme and the assumptions, using the method of d'alembert were the equations of the second order. Additional dynamic forces of reaction and communication spring kits recorded through an additional equation. The solution of the equations was carried out by the numerical method of step-by-step integration. The experimental phase of the work was carried out on the stage of the Bel station of the Shuya branch of the road. Initially, the dynamic parameters of the vertical dynamics coefficients and frame forces arising during the passage of switches with different speeds were determined. Measurements of the level of impact and check the stresses in the edges of the foot rail of the switch. The estimated values of the processed processes were defined as the most probable values of the measured values for each individual velocity. The estimated values were estimated with a probability of 0.9985.

Keywords: railway carriage, railroad switch configuration, frame strength, stability, dynamic performance.

One of the criteria for establishment of the allowed speeds are the sizes of the vertical and horizontal forces which are transferred from wheels of crews to cores of blunt and sharp frogs.

The solution of the put objective was carried out by means of the spatial calculated scheme "carriage-way" submitted in figure 1. The scheme allows to investigatethe interaction of a way and the rolling stock in the vertical and horizontal planes in cases when roughnesses are both on one, and on both rail threads.

The carriage is presented by the four-axis freight gondola car of model 12-9920 manufacturing in the People's Republic of China on carts of model 18-9996 by ZK1 type in the calculated scheme, with conic cassette bearings. The movement of one cart of the gondola carisconsideredin details as the mutual influence of wheels of various carts is insignificant.

In work [1] it is shown that the division of mass of a wheel into various quantity of elements is not affectedon the sizes of dynamic forces. It allows to consider a wheel in the form of one mass.The transfer curveis simulated in the form of the concentrated masses connected by elastic connections and specified to the points of contact of wheels with rail threads. The lateral impact on a curve of the switch transfer is considered by movements of rail threads and elements of crews in the vertical and horizontal planes and the corresponding rigidity.

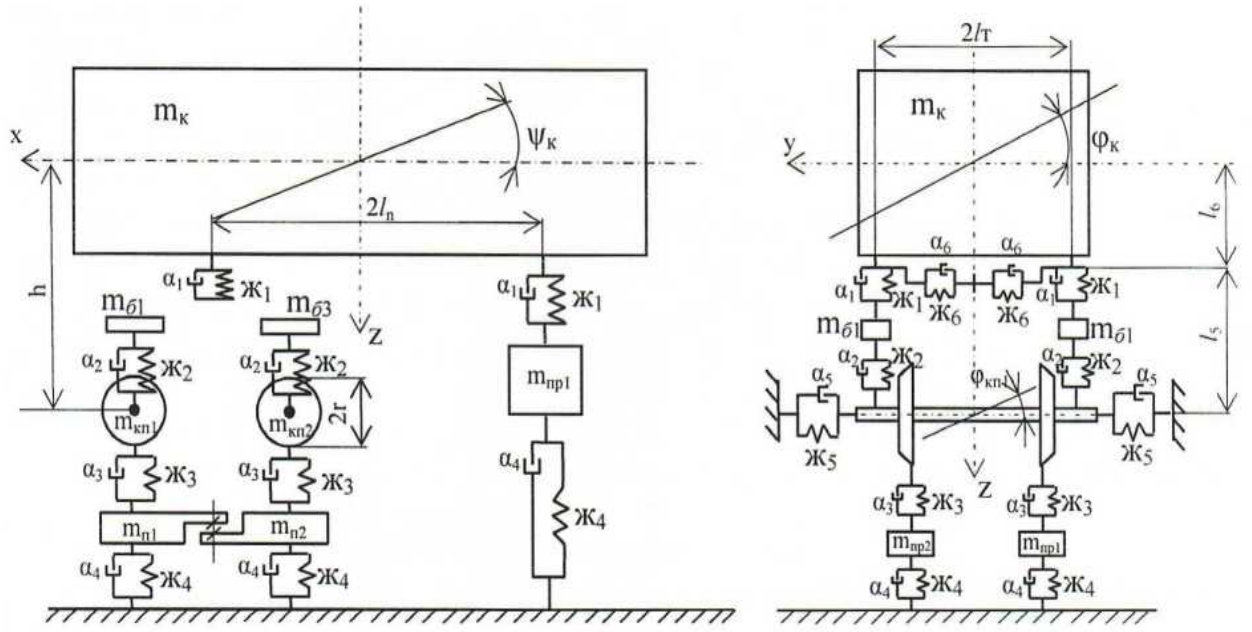


Figure 1 –The calculated scheme of системы «crew-ay» system

In the calculated scheme the following designations are accepted: $m_к$ - the mass of a cushioned part of the car; $m_{бi}$ - the mass of the wall falling on one wheel; $m_{кпj}$ - the mass of the wheel couple; n_{ni} - the mass of the way specified to i-of a cart wheel; *жс1* - rigidity of springs of spring sets; α_1 - coefficient of viscous friction of spring knots; *жс2* - rigidity of contact of a sidewall and wheel; α_2 - coefficient of viscous friction on contact of a sidewall and wheel; *жс3* - contact rigidity of a wheel and way; α_3 - coefficient of viscous friction on contact of a wheel and way; *жс4* -rigidity of the basis; α_4 - coefficient of viscous friction of the basis; *жс5* - in pairs contact rigidity of rail threads; α_5 - coefficient of viscous friction in the place of contact of a wheel and rail thread in the cross direction; *жс6* - flexural rigidity of springs of a spring set; a_6 - coefficient of viscous friction of spring sets at a bend; m_{npi}, - the specified mass of the second cart falling on i- rail thread and relating to it the concentrated mass of a way; $\psi_к$, $\theta_к$, $\varphi_к$ - angles of rotation of a body concerning cross, vertical and longitudinal axis; $\varphi_{кп1,2}$ - angles of rotation of wheel couples concerning the axis parallel to a longitudinal axis of thecarriage; x, *y, z* - respectively, longitudinal cross and vertical movements; P_i - additional dynamic forces in the corresponding elements of «carriage-way» system.

The accepted calculated scheme consists of 13 solid bodies and has seventy eight degrees of freedom.

We make imposing and we find out connections:

$$\left.\begin{gathered} x_к = x_{б1} = x_{б2} = x_{б3} = x_{б4} = x_{кп1} = x_{кп2} = x_{п1} = x_{п2} = x_{п3} = x_{п4} = x_{пр1} = x_{пр2} = 0 \\ y_{п1} = y_{п2} = y_{п3} = y_{п4} = y_{пр1} = y_{пр2} = 0 \\ \psi_{кп1} = \psi_{кп2} = \psi_{б1} = \psi_{б2} = \psi_{б3} = \psi_{б4} = \psi_{п1} = \psi_{п2} = \psi_{п3} = \psi_{п4} = \psi_{пр1} = \psi_{пр2} = 0 \\ \varphi_{б1} = \varphi_{б2} = \varphi_{б3} = \varphi_{б4} = \varphi_{п1} = \varphi_{п2} = \varphi_{п3} = \varphi_{п4} = \varphi_{пр1} = \varphi_{пр2} = 0 \\ \theta_{б1} = \theta_{б2} = \theta_{б3} = \theta_{б4} = \theta_{п1} = \theta_{п2} = \theta_{п3} = \theta_{п4} = \theta_{пр1} = \theta_{пр2} = 0 \\ \theta_{кп1} = \theta_{кп2};\ \psi_{кп1} = y_{б1} = y_{б2};\ y_{кп2} = y_{б3} = y_{б4};\ y_{кп1} = y_{кп2}; \end{gathered}\right\} \quad (1)$$

There were 21 degrees of freedom: $z_к$, $z_{б1}$, $z_{б2}$, $z_{б3}$, $z_{б4}$, $z_{кп1}$, $z_{кп2}$, $z_{п1}$, $z_{п2}$, $z_{п3}$, $z_{п4}$, $z_{пр1}$, $z_{пр2}$, $y_к$, y_m, $\psi_к$, $\varphi_к$, $\varphi_{кп1}$, $\varphi_{кп2}$, $\theta_к$, θ_m;гдеy_m=$\varphi_{кп1,2}$ и θ_m=$\theta_{кп1,2}$.

In the calculated scheme the following assumptions are accepted:

- forces arising in connections are functions of the compressed spring and speeds of compression of shock-absorbers;
- rigidity between sidewalls and wheels are defined by deformations of sidewalls, axle-box knots and necks of axes of wheel couples and also deformations in a zone of their contacts;

- the rigidity between wheels and the specified mass of a way is defined by deformations of wheels and frogs (necks of rails) and also deformations in a zone of contact of wheels and frogs [2, 3];
- forces operating in the contact plane in the presence of a gap between the crests of wheels and rail threads are determined by the theory of pseudo-sliding [4, 5]; after the choice of a gap there appears the cross forces of interaction depending on the size and speed an space of rail threads [6, 7]. At the same time the space of rail threads take place, both in the presence of gaps, and at their absence;
- the connection between the rail threads is carried out only through a wheel couple;
- the connection between the specified mass of a way is carried out by introduction of coefficient P which considersmutual influence of the adjacent wheels of the cart on each rail thread. This connection is expressed by dependence:

$$P_i = \beta \cdot P_{i+1} \tag{2}$$

where P_i - force operating on the considered specified mass of a way; β - the coefficient of influence of the adjacent wheels considering the rigidity of railways; P_{i+1} - force which is transferred on the adjacent one with considered the mass of a way.

- there are no gaps between axle boxes and jaws of sidewalls, i.e. it is assumed that the angles of turns of axes of wheel couples and an axis of carts are equal: $\theta_{кп1}=\theta_{кп2}=\theta_m$.

Proceeding from the calculated scheme and considering the given assumptions, on the basis of Dalamber's principle we will write down the differential equations of «carriage-way» system:

$$\left.\begin{gathered}
m_к \ddot{z}_к = -P_1 - P_2 - P_{19} - P_{20};\\
J_к^x \ddot{\varphi}_к = P_1 l_1 - P_2 l_1 + P_{19} l_1 - P_{20} l_1 - P_{23} l_6 + P_{24} l_6 - P_{25} l_6 + P_{26} l_5;\\
J_к^y \ddot{\psi}_к = -P_1 l_4 - P_2 l_4 + P_{19} l_4 + P_{20} l_4;\\
J_к^z \ddot{\theta} = P_{23} l_4 - P_{24} l_4 - P_{25} l_4 - P_{26} l_4;\\
m_к \ddot{y}_к = -P_{23} - P_{24} - P_{25} - P_{26};\\
m_{б1} \ddot{z}_{б1} = 0.5P_1 - P_3;\\
m_{б2} \ddot{z}_{б2} = 0.5P_1 - P_5;\\
m_{б4} \ddot{z}_{б4} = 0.5P_2 - P_6;\\
m_{кп1} \ddot{z}_{кп1} = P_3 + P_4 - P_7 - P_8;\\
J_{кп2}^x \ddot{\varphi}_{кп2} = P_6 l_1 - P_5 l_1 + P_9 l_2 - P_{10} l_2;\\
m_{n1} \ddot{z}_{n1} = P_7 - P_{11} + P_9 \beta - P_{13} \beta;\\
m_{n2} \ddot{z}_{n2} = P_8 - P_{12} + P_{10} \beta - P_{14} \beta;\\
m_{n3} \ddot{z}_{n3} = P_9 - P_{13} + P_7 \beta - P_{11} \beta;\\
m_{n4} \ddot{z}_{n4} = P_{10} - P_{14} + P_8 \beta - P_{12} \beta;\\
(2m_{б1} + 2m_{б2}) \ddot{y}_m = -P_{15} - P_{16} - P_{17} - P_{18} - P_{23} - P_{24};\\
J_к^z \ddot{\theta} = P_{15} l_3 + P_{16} l_3 - P_{17} l_3 - P_{18} l_3 + P_{27} l_2 - P_{28} l_2 + P_{29} l_2 - P_{30} l_2;\\
m_{np1} \ddot{z}_{np1} = P_{19} - P_{21};\\
m_{np2} \ddot{z}_{np2} = P_{20} - P_{22};
\end{gathered}\right\} \tag{3}$$

The accepted designationshave the following physical sense: Z_i - vertical movements of the corresponding mass of the system; y_i - horizontal movements of mass of the system; $J_к^x$ - the moment of inertia of a body of the car concerning an axis x, passing through the body center of weight; $J_к^y$ - the moment of inertia of a body of the car concerning the cross axis at; $J_к^z$ - moment of inertia of a body of the car concerning the vertical axis z; $J_{кп1,2}^z$ - themoment of inertia of a wheel couple, concerning an axis x; J_m^z - the moment of inertia of the cart concerning the vertical axis passing through the center of its weight; $2l_1$ - the distance between the centers of axle-box sets of wheel couples; $2l_2$ - the distance between the circles of driving of wheel couples; $2l_3$ - rigidbase of the cart; $2l_4$ - the distance between the axes of pintles of a cart of the car; L_5 - the distance from the center of weight of a wheel couple to an over spring beam; l_6 - the distance from the body center of weight to an over springbeam.

The characteristics of the calculated «carriage-way» system are defined by selection at the solution of a problem of the movement of a carriage on the roughnesses received experimentally. The vertical forces

determined in the course of the solution are transferred from wheels of the four-axle gondola car to cores of frogs, are compared at the same time with the similar forces received experimentally (figure 2). From figure 2 it is visible thatthe sizes of forces and also the nature of change on length of cores practically coincide with the forces received experimentally.

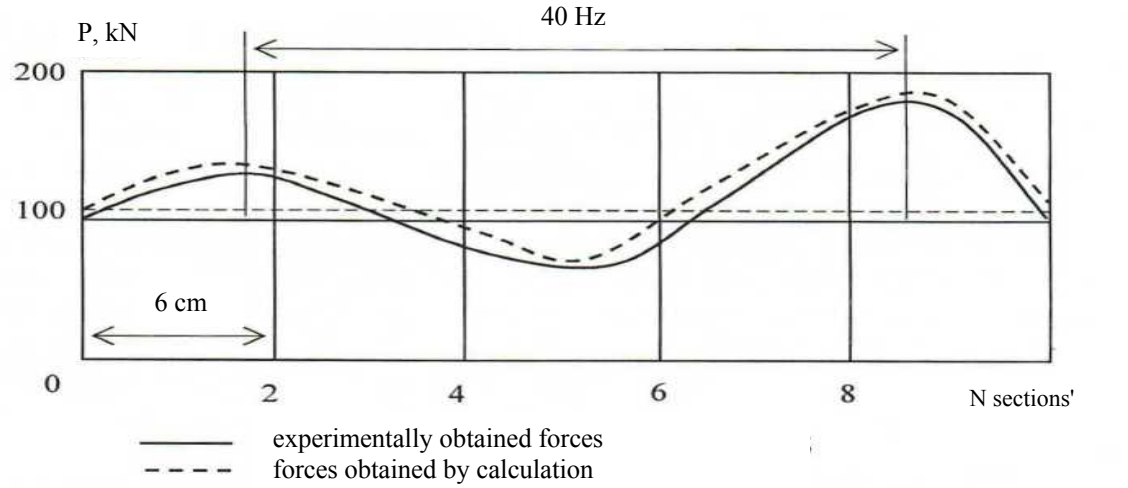


Figure 2 – Vertical forces of interaction of a wheel of the four-axle gondola car with the core of the frog of blind crossing

The oscillograms of primary measurements of the dynamic processes registered on railroad switches are provided on figures 3, 4.

Dynamic indicators of gondola cars on railroad switches are determined by the measurements executed at the passage by gondola cars of railroad switches №13 of brand 1/9 and №29 of brand 1/11 on the rails of P65 which are on the Bel.station. For a forward stroke of gondola cars it was accepted the direction when gondola cars 12-9920 moved forward by the 1st wheel couple from the station towards the entrance arrows.

The registration of dynamic processes in gondola cars in all arrivals began and came to an end on direct sites of a way.

The frame forces were measured by means of the graduated tensometric schemes pasted on side frames of carts of gondola cars.

The estimated values of the machined processes were defined as the maximum probable values of the measured values at each speed separately. The estimated values were counted on with probability 0,9985.

By the results of data processing at the given speed for each measuring scheme separate expanses of data were formed. According to these expanses there were estimated values of indicators. All the measurements were brokenon speeds and in the directions of the movement. In each arrival one maximum amplitude value of dynamic process was chosen. The values of frame forces were accepted taking into account a quastatic component, values of accelerations were processed without a quastatic component. For the assessment of size of frame forces the relations of frame forces to static load from a wheel couple of rails are considered. The indicators of influence of gondola cars on the way.

The tests on measurement of a level of influence of gondola cars on the way and railroad switches were made on the same sites of a way as testson the definition of dynamic indicators.

Forthemeasurement of a level of influence of gondola cars on the way and railroad switches the chosen sites have been equipped with tensoresistors for the measurement of tensions arising in the edges of a foot of rails, the vertical and side forces transferred from a wheel to rails. For measurement of tension in the lower edges of a foot of rails and the curvilinear pointed and forces transferred from a wheel to rails, the tensoresistors by base of 10 mm and with a nominal resistance of 100 Om which were gathered into measuring schemes have been pasted on rails. Signals from measuring schemes were given to the entrance of a measuring complex and were registered on the laptop.

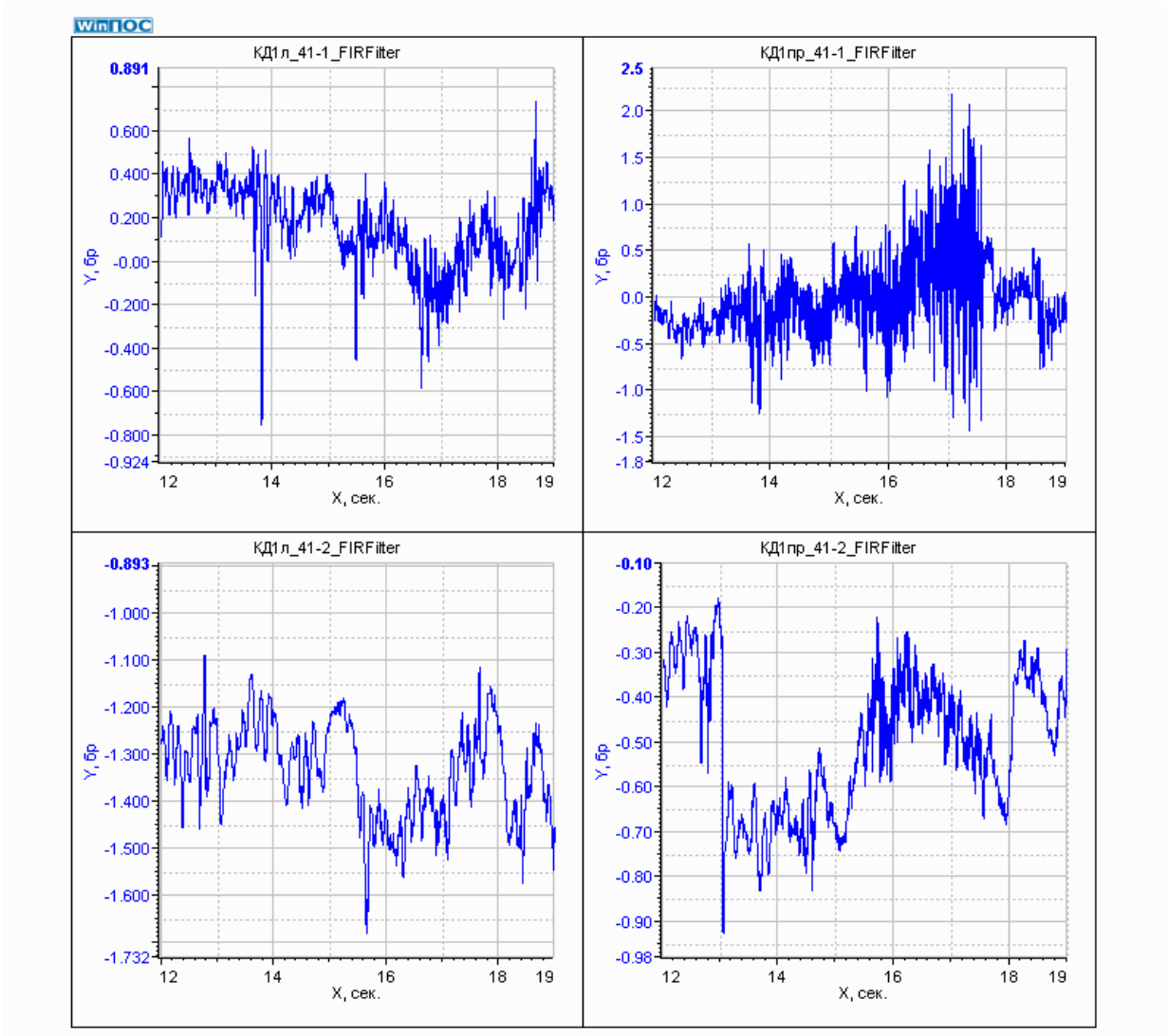


Figure 3 – Coefficient of vertical dynamics of the first step of spring suspension of gondola cars 12-9941 at the movement on railroad switches, mm

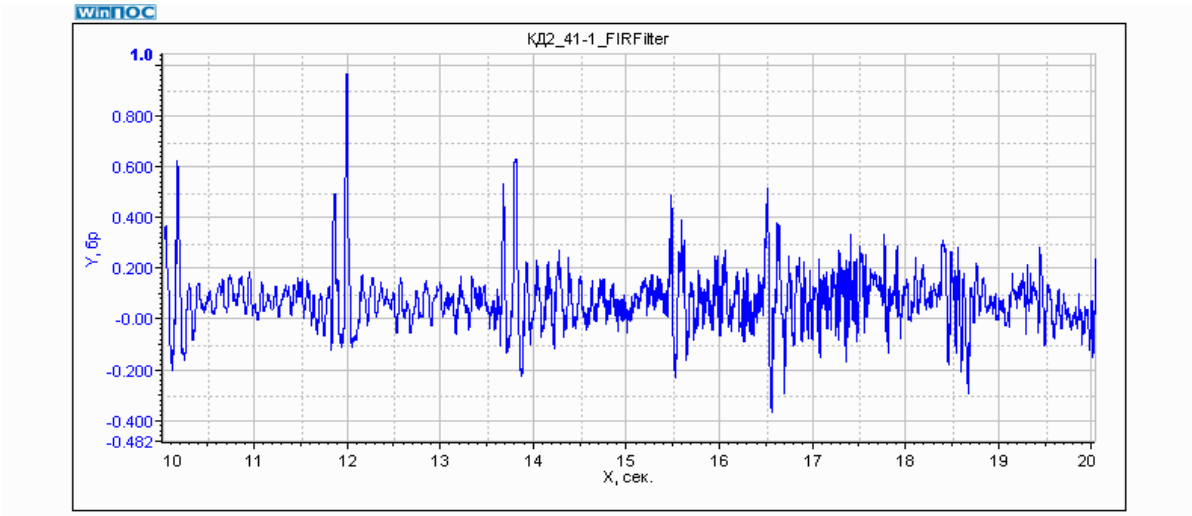


Figure 4 – Coefficient of vertical dynamics of the second step of spring suspension of gondola cars 12-9941 at the movement on railroad switches

The semi-bridge scheme, side and vertical forces from a wheel to rails – the bridge scheme is applied for the registration of tension in the lower edges of a foot of a rail. At the same time, the tensoresistor of a compensation run was pasted not on a rail, but on a separate steel plate and settled down near the rail section where the tension was measured in rail foot edges. The side forces from a wheel on rails were registered according to the bridge scheme by Schlumpf's method. The special load device with dynamometer sensors was used for graduation of tensometric schemes of measurement of side and vertical forces.

At testing on railroad switches the tensions in the lower edges of a foot of a rail were measured in a front extension of frame rails, in the curvilinear acute and in a switched curve. Forces transferred from a wheel to rails in the horizontal and vertical direction were measured in a front extension of frame rails and in a switched curve.

When calculating the following values of parameters of the gondola car have been accepted: μ - friction coefficient between a crest of the running wheel and a rail, μ =0,25; β - slope forming a wheel crest to the horizontal plane,β = 60º; Y_P - frame force taking into account a quasistatic component in curve sites of a way - the instant values registered at each measurement, кН; Q - the weight of a springed part of the gondola car coming to a neck of an axis of a wheel couple, Q=24,4 of kN for empty, Q=116,4 of kN for loaded; $K_{д1}$,$K_{д2}$ - coefficients of vertical dynamics in the first step of suspension (without dissipative forces and taking into account a quastatic component in curve sites of a way) respectively on the running and not running wheels of a wheel couple are the instantaneous values registered at each measurement; μ' - friction coefficient between the surface of driving of the running wheel and a rail, μ' =0,25; q - force of weight of the uncusioned parts falling on the wheeled couple, q=18,78 of kN; $2b$ - distance between the points of application of vertical loading to the necks of an axis of the wheeled couple, 2b = 2,036 m; a_1 - distance between the point of application of vertical loading to the neck of an axis on the running wheel and a contact point on a crest,a_1= 0,265 m; a_2 - distance between the point of application of vertical loading of an axis neck on not running wheel and a contact point on its surface of driving, a_2 = 0,228м; r - wheel radius around drivings, r= 0,479 m.

The dependence of the relation of frame to static load from the wheel couple to rails from the speed of movement is given in figure 5, a, b, c, d.

Here and in the subsequent figures it is designated:

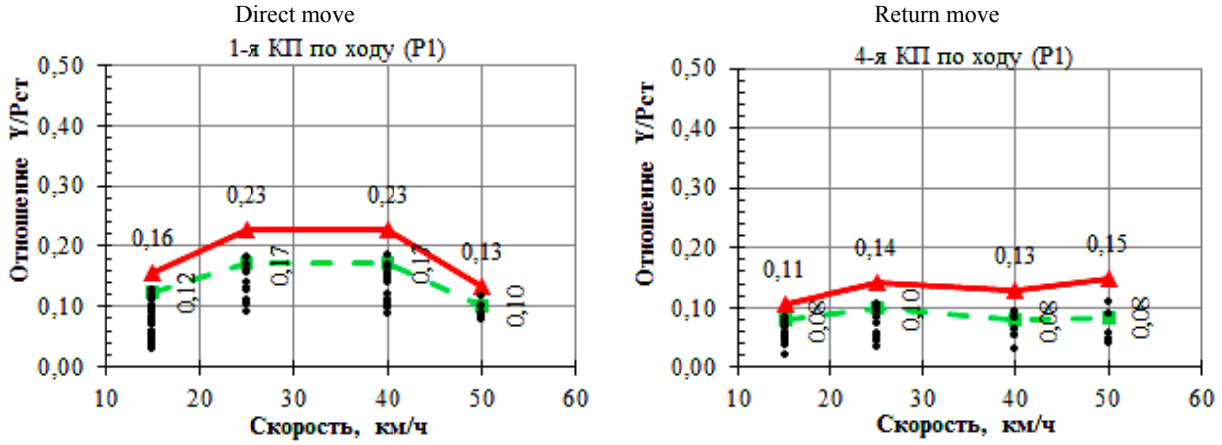
– the measured values of indicators;

– estimated values (the maximum probable);

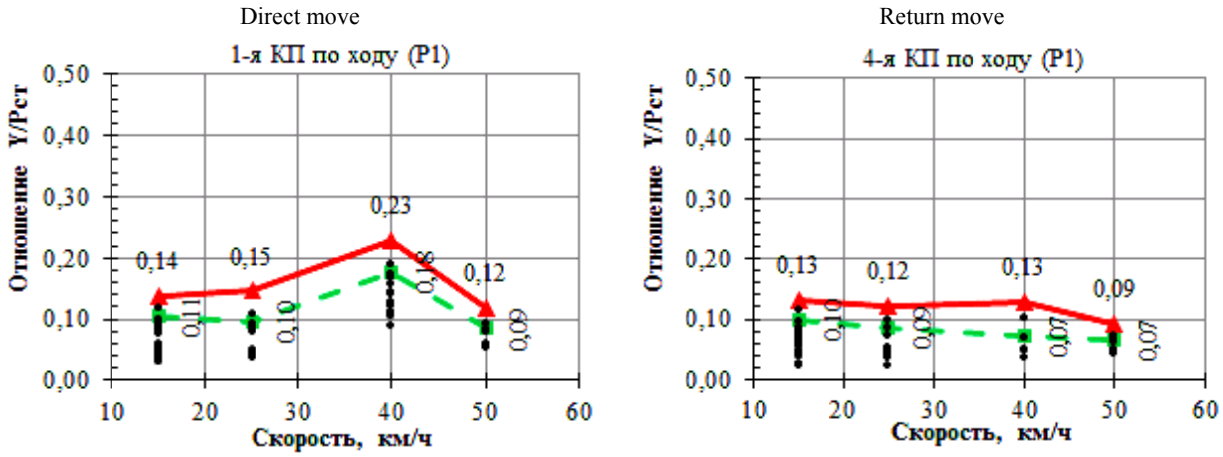
– an average from 3 maximum (for reference);figures on the schedules – estimated values.

In figure 5 it is visible that the relation of frame forces to static load from the wheeled couple to rails at the movement of gondola cars on railroad switches are in limits of admissible values. Also the big dynamics of the empty car is traced considerably.

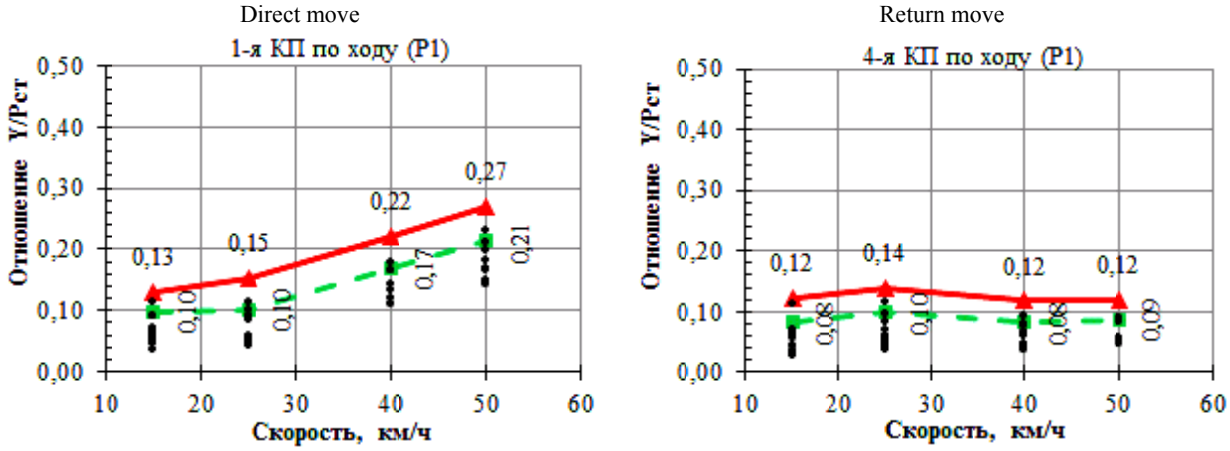
On instant values of frame forces and coefficient of vertical dynamics of the first step of spring suspension values of coefficient of a stock of stability against a wheel descent from a rail have been calculated (further in figures and in tables – KZU).



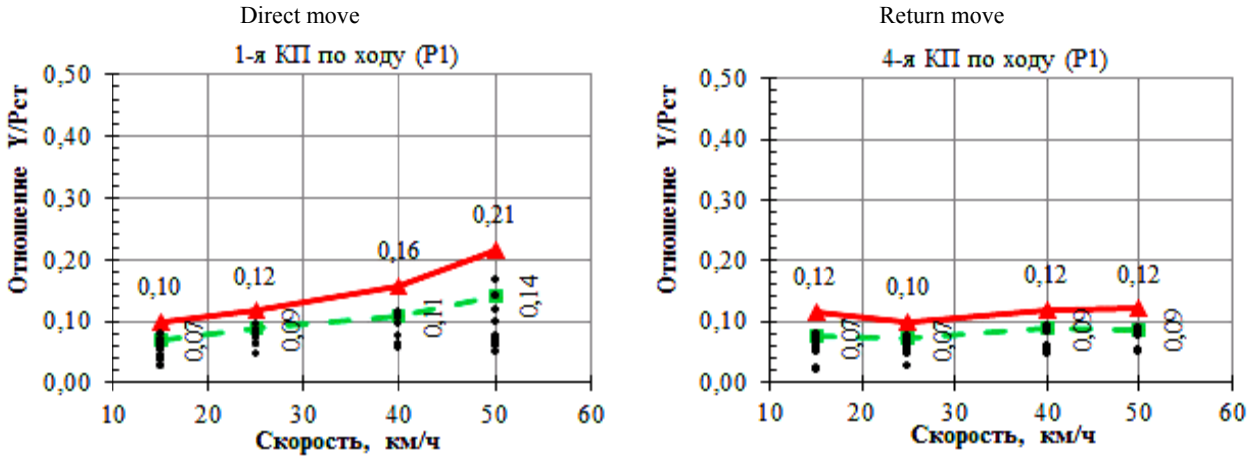
a) from the wheeled couple on rails to the empty gondola car of 12-9920 model at the movement on P65 railroads witches of brand 1/9 to the side



b) from the wheeled couple to rails of the loaded gondola car of 12-9920 model at the movement on P65 railroads witches of brand 1/9 to the side



c) from the wheeled couple to rails of the empty gondola car of 12-9920 model at the movement on P65 railroads witches of brand 1/11 to the side



d) from the wheeled couple to rails of the loaded gondola car of 12-9920 model at the movement on P65 railroads witches of brand 1/11 to the side

Figure 5 – Relation of frame forces to static loading

The minimum value of coefficient of stock of stability against a wheel descent from a rail at moving railroad switches is given in table 1.

Table 1 – Stability stock coefficient against a wheel descent from a rail

a) in railroads witches with a frog of brand 1/9										
Moving direction	KZUminimumvalue									
	Movementto a side				On a direct moving					
	At a speed, km/h									
	15	25	40	50	60	80	90	100	110	120
Empty gondola car										
Direct move	2,31	2,30	2,00	2,09	2,72	2,52	2,48	2,38	2,30	2,21
Return move	2,43	2,16	2,22	2,43	2,84	2,72	2,70	2,64	2,59	2,54
Loaded gondola car										
Direct move	2,27	2,48	2,36	2,53	3,16	3,00	2,80	2,72	2,61	2,49
Return move	1,83	1,70	1,82	1,65	3,13	2,74	2,58	2,39	2,20	2,02
The allowed value	1,4									
b) in railroad switches with a frog of brand 1/11										
Moving direction	The minimal value of KZU									
	Movement to a side				On a direct moving					
	At speed, km/h									
	15	25	40	50	60	80	90	100	110	120
Empty gondola car										
Direct move	2,71	2,77	2,24	2,26	2,79	2,75	2,73	2,71	2,69	2,67
Return move	2,84	2,68	2,93	2,87	2,91	2,72	2,63	2,53	2,44	2,34
Loaded gondola car										
Direct move	2,93	2,92	3,19	3,07	3,89	3,77	3,71	3,65	3,59	3,53
Return move	2,20	2,05	1,73	2,06	2,93	2,86	2,83	2,79	2,76	2,72
Admitted value	1,4									

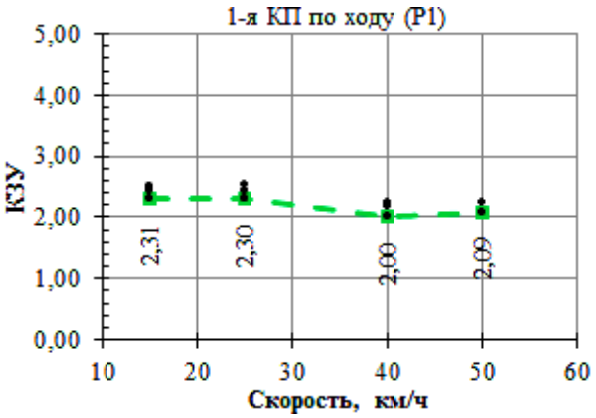
The received dependences of coefficient of a stock of stability against a wheel descent from a rail from the speed of the movement are given in figure 9, a, b, c, d. The coefficient of a stock of stability was estimated on the minimum calculated value. In figure 9 it is designated:

● – the measured values of indicators;

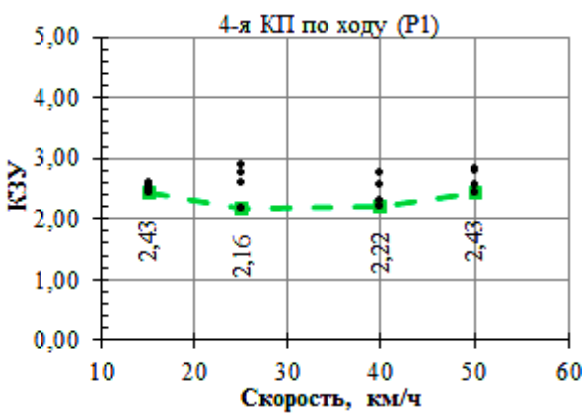
– ■ – – estimated values; figures on the schedules – estimated values.

The data provided in table 2 and in figure 6 show that the stability stock coefficient against a wheel descent from a rail at transportation by gondola cars of railroad switches to the side up to the speed of 50 km/h and in the direct direction up to 120 km/h are in the admissible limits, i.e. accept the values not less than 1,4. The given results show that dynamic indicators of the gondola car of model 12-9920 in an empty and loaded state at moving railroad switches meet the requirements of "Norms of the allowed speeds of movement of locomotives and cars on railway tracks of a track of 1520 (1524) mm of railway transport of the Republic of Kazakhstan" (further Norms of the allowed speeds of movement).

Direct move

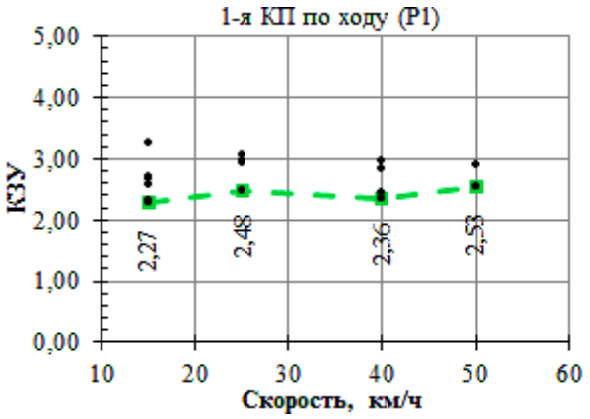


Return move

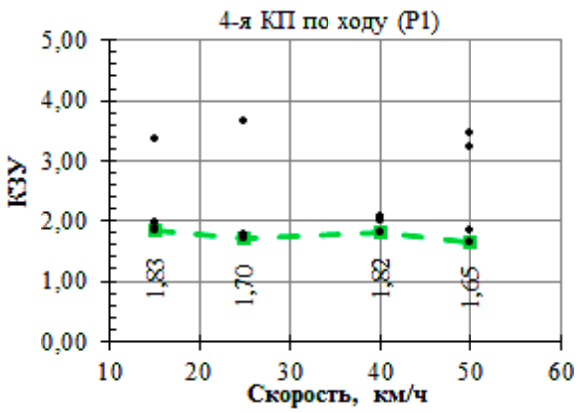


a) at moving by the empty gondola car of model 12-9920 of the railroads witch with the frog of brand 1/9 to a side

Direct move

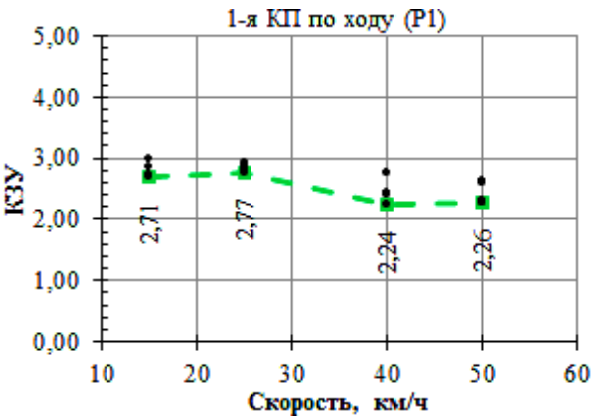


Return move

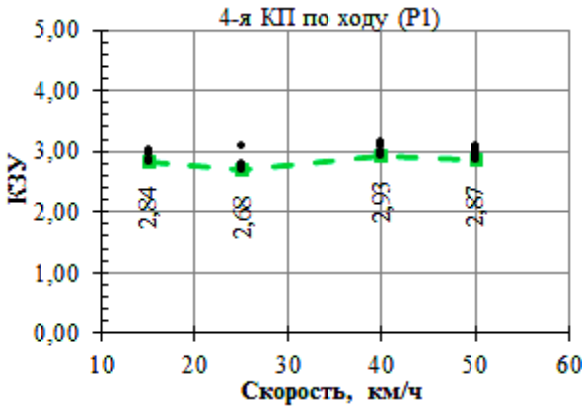


b) at moving by the loaded gondola car of model 12-9920 of the railroad switch with the frog of brand 1/9 to a side

Direct move



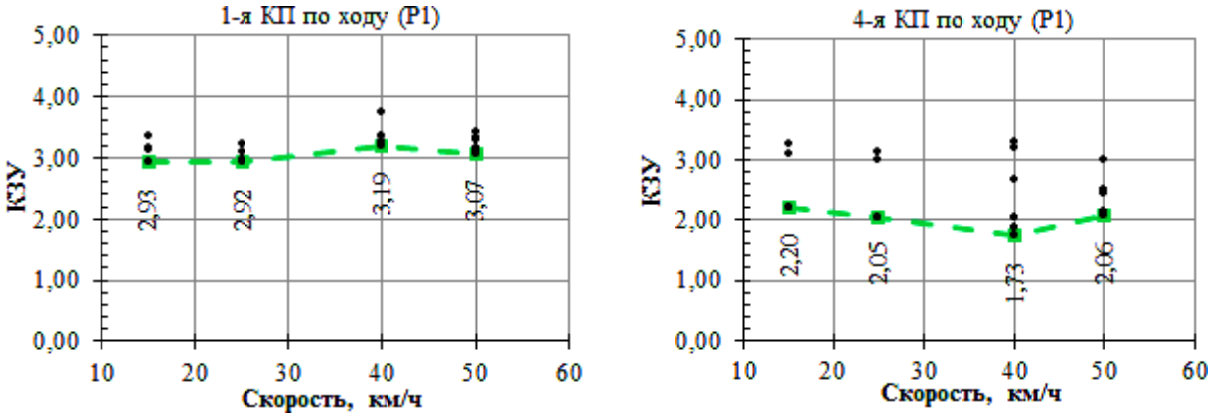
Return move



c) at moving by the empty gondola car of model 12-9920 of the railroad switch with the frogof brand 1/11 to a side

Direct move

Return move



d) at moving by the loaded gondola car of model 12-9920 of the railroad switch with the frog of brand 1/11 to a side

Figure 6 – Stability stock coefficient against a wheel descent from a rail

Conclusions. As the conducted researches show, the sizes of the vertical and horizontal forces, which are transferred from the wheels of carriages to the cores of blunt and sharp frogs are one of the main criteria for designation of the maximum speeds of the movement on blank crossings of the combined track. And the spatial scheme used in calculations is rather reliable and can be used for carrying out analytical researches of interaction of a way and the rolling stock in the vertical and horizontal planes, including, in cases when roughness both on one, and on both rail threads. The executed pilot studies show that stability stock coefficient against a wheel descent from a rail at transportation by gondola cars of railroad switches to a side up to the speed of 50 km/h and in the direct direction up to 120 km/h are in the admissible limits, i.e. accept values not less than 1,4.

In the result of the executed researches it is proved that the dynamic indicators of the gondola car of model 12-9920 in the empty and loaded state at moving railroad switches meet the requirements of "Norms of the allowed speeds of movement of locomotives and cars on railway tracks of a track of 1520 (1524) mm of railway transport of the Republic of Kazakhstan" (further Norms of the allowed speeds of movement). Therefore, the speed of the movement on railroad switches according to Norms of the allowed speeds of movement on assessment of dynamic indicators is limited of 40 km/h at the movement on railroad switches to a side and constructional speed at the movement on railroad switches on a direct move.

В. Г. Солоненко, Н. М. Махметова, Ж. С. Мусаев, С. Е. Бекжанова, М. Я. Квашнин

М. Тынышбаев атындағы Қазақ көлік және коммуникациялар академиясы, Алматы, Қазақстан

ZK1 МОДЕЛЬДІ АРБАШАЛАРЫМЕН ТЕМІРЖОЛ ЭКИПАЖДАРЫ БАҒЫТТАМАЛЫҚ БҰРМАЛАРДЫ ӨТКЕНДЕ ШЕКТІ ЖЫЛДАМДЫҚТАРДЫ АНЫҚТАУ ӘДІСТЕМЕСІ

Аннотация. Жүк поездар қозғалысының қауіпсіздігін жоғарылату үшін кіші радиустағы қисықтарды өткенде және соның ішінде кеңінен таралған маркадағы бағыттамалық бұрмалардың аудармалық қисықтарын өткен кезде рұқсат етілген шекті жылдамдықтар темiржол әкімшілігінің нормативтік құжаттарымен белгіленеді. Аудармалық қисықтардың бірқатар ерекшеліктері бар – аудармалық ендірмелердің болмауы, сыртқы рельстің жоғарыламауы, бүйір жолда аударманың бұрмалық қисығы арқылы станцияға кіргенде жылдамдықты шұғыл төмендету қажеттілігін шарттайтын біріккен жолтабанның тұйық қиылыстары. Шекті жылдамдықтарды анықтау үшін бағыттамалық бұрмалардың айқастырма өзектеріне экипаждан берілетін вертикалды және горизонталды-көлденең күштерді, вертикалды динамика коэффициентін, осы күштердің қатынасын анықтау мақсатымен экипаждарда пайда болатын рамалық күштердің шамасын және бағыттамалық бұрмаларға динамикалық әсер деңгейін ескеру қажет.

Қойылған мәселе құрама әдіспен шешіледі: аналитикалық – есептік және тәжірибелік-эксперименттік. Аналитикалықәдіспен шешу үшін рессорлар жинағының қаттылығы, үйкеліс коэффициенттері, көлденең, вертикалды және бойлық осьтерге қатысты шанақ және доңғалақтар жұбының бұрылу бұрыштары ескерілетін есептік сұлба құрылады. Есептік сұлба және қабылданған болжамдар негізінде, Даламбер әдісін қолдана отырып, екінші реттік теңдеу құрылды. Қосымша динамикалық реакция күштері және рессорлық жинақтар байланыстары қосымша теңдеулер арқылы жазылған. Теңдеулер шешімі кезең-кезеңмен интегралдаудың сандық әдісімен жүргізілді. Жұмыстың эксперименттік кезеңі Бел Шу бекеті жол бөлімшесінің өткелінде жүргізілді. Бастапқыда динамикалық көрсеткіштер: вертикалды динамика коэффициенттері және түрлі жылдамдықтармен бағыттамалық бұрмаларды өткенде пайда болатын рамалық күштер анықталды. Бағыттамалық бұрманың рельс табандарының жиектерінде кернеулердің әсер ету деңгейін өлшеу және тіркеу жүргізілген. Өңделінетін процестердің бағаланатын мәндері әрбір жеке жылдамдық үшін өлшенген мәндердің максималды ықтимал шамалары ретінде анықталды. Бағаланатын мәндер 0,9985 ықтималдықпен бағаланды.

Түйін сөздер: теміржол экипажы, бағыттамалық бұрма, есепік сұлба, рамалық күштер, тұрақтылық, динамикалық көрсеткіштер.

В. Г. Солоненко, Н. М. Махметова, Ж. С. Мусаев, С. Е. Бекжанова, М. Я. Квашнин

Казахская академия транспорта и коммуникаций им. М. Тынышпаева,
Алматы, Казахстан

МЕТОДИКА ОПРЕДЕЛЕНИЯ ПРЕДЕЛЬНЫХ СКОРОСТЕЙ ПРИ ПРОХОЖДЕНИИ СТРЕЛОЧНЫХ ПЕРЕВОДОВ ЖЕЛЕЗНОДОРОЖНЫХ ЭКИПАЖЕЙ С ТЕЛЕЖКАМИ МОДЕЛИ ZK1

Аннотация. Для повышения безопасности движения грузовых поездов нормативными документами железнодорожных администраций устанавливаются предельно допустимые скорости при прохождении кривых малого радиуса и, в том числе, переводных кривых стрелочных переводов наиболее распространенных марок. Переводные кривые имеют ряд особенностей – отсутствие переводных вставок, возвышения наружного рельса, глухие пересечения совмещенной колеи, что обуславливает необходимость резкого снижения скорости при заходе на станцию через переводную кривую стрелочного перевода на боковой пути. Для определения предельных скоростей необходимо учитывать вертикальные, горизонтально-поперечные силы, передаваемые от экипажа на сердечники крестовин стрелочных переводов, коэффициент вертикальной динамики, величину рамных сил, возникающих в экипажах, с целью определения отношения этих сил к статической нагрузке и уровень динамического воздействия на стрелочные переводы.

Поставленная задача решается комбинированным методом: аналитически - расчетным и опытно-экспериментальным. Для решения аналитическим методом составляется расчетная схема, где учитываются жесткости рессорных комплектов, коэффициенты трения, углы поворота кузова и колесных пар, относительно поперечной, вертикальной и продольных осей. Исходя из расчетной схемы и принятых допущений, используя метод Даламбера были составлены уравнения второго порядка. Дополнительные динамические силы реакции и связи рессорных комплектов записаны через дополнительные уравнения. Решение уравнений проводилось численным методом поэтапного интегрирования. Экспериментальный этап работы проводился на перегоне станции Бель Шуйского отделения дороги. Первоначально определялись динамические показатели коэффициенты вертикальной динамики и рамные силы, возникающие при прохождении стрелочных переводов с различными скоростями. Проведены замеры уровня воздействия и регистрация напряжений в кромках подошвы рельса стрелочного перевода. Оценочные значения обрабатываемых процессов определялись как максимально вероятные величины измеренных значений для каждой отдельной скорости. Оценочные значения оценивались с вероятностью 0,9985.

Ключевые слова: железнодорожный экипаж, стрелочный перевод, расчетная схема, рамные силы, устойчивость, динамические показатели.

Information about authors:

Solonenko Vladimir Gelevich, Professor, Doctor of Technical sciences, Kazakh Academy of Transport and Communications, Almaty, Kazakhstan; v.solonenko@mail.ru; https://orcid.org/0000-0001-6503-6598

Makhmetova Narzankul Musaevna, Professor, Doctor of Technical sciences, Kazakh Academy of Transport and Communications, Almaty, Kazakhstan; makhmetova_n1958 @ .mail.ru; https://orcid.org/0000-0001-7324-5832

Mussayev Janat Sultanbekovich, Professor, Doctor of Technical sciences, Kazakh Academy of Transport and Communications, Almaty, Kazakhstan; mussayev75@yandex.kz; https://orcid.org/0000-0001-7382-5626

Bekzhanova Saule Ertaevna, Professor, Doctor of Technical sciences, Kazakh Academy of Transport and Communications, Almaty, Kazakhstan; s.bekzhanova@bk.ru; https://orcid.org/0000-0001-6272-9567

Kvashnin Mikhail, Associated Professor, Candidate of Technical sciences, Kazakh Academy of Transport and Communications, kvashnin_mj55@mail.ru ; https://orcid.org/0000-0002-3969-9299

REFERENCES

[1] Dolmatov A.A., Kochinov A.D., Kudryavtsev N.N. i dr. Osobennosti dinamiki vagonov pri vysokoy skorosti dvizheniya // VNIIZHT. 1985. Vyp. 342. 160 p.

[2] Yakovlev V.F., Semenov I.I. Issledovaniye uprugodinamicheskikh kharakteristik puti i opredeleniye dinamicheskikh vertikal'nykh sil v krestovine // LIIZHT. 1994. Vyp. 222. P. 106-136.

[3] Vladimir Solonenko, Janat Musayev, Narzankul Mahmetova, Mikhail Kvashnin, Azamat Alpeisov, Algazy Zhauyt. Some aspects of the experimental assessment of dynamic behavior of the railway track // Journal of theoretical and applied mechanics. Vol. 55, issue 2. P. 421-432.

[4] Lazaryan V.A. i dr. Differentsial'nyye uravneniya prostranstvennykh kolebaniy chetyrekhosnogo gruzovogo vagona pri dvizhenii po inertsionnomu puti // DIIT. 1980. Vyp. 138. P. 3-16.

[5] Grebenyuk P.T. Prodol'naya dinamika poyezda // Trudy VNIIZHT. M.: Intekst, 2003. 95 p.

[6] Musayev Janat, Zhauyt Algazy, Buzauova Toty, Mamatova Gulnar, Yessenkluova Zhaukhar, Abdugaliyeva Gulnur. The experimental determination of the stress calculation and relative strains in the span elements of railway bridges under the influence of the rolling equipment // Journal of Measurements in Engineering. 2017. Vol. 5, issue 3. P. 125-133.

[7] Solonenko Vladimir, Musayev Janat, Mahmetova Narzankul, Kvashnin Mikhail, Zhauyt Algazy, Buzauova Toty. Modeling of dynamic characteristics of freight car with optimized parameters of wedge-type shock absorber // Journal of Vibroengineering JVE. 2017. Vol. 19, issue 2. P. 1197-1213.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 163 – 168 **https://doi.org/10.32014/2019.2518-170X.20**

UDC 514.182.7

N. S. Umbetov[1], Zh. Zh. Dzhanabaev[1], G. S. Ivanov[2]

[1]M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan,
[2]Bauman Moscow State Technical University, Moscow, Russia.
E-mail: nurlanumbetov@mail.ru; djanabaev@mail.ru; ivanov_gs@rambler.ru

GEOMETRIC MODELING OF LAYING GEODETIC LINES ON RULED SURFACES

Abstract. Geodesic lines find interesting applications during solving most tasks of the fundamental sciences (mathematics, physics and other) and engineering practice. In differential geometry, the geodesic lines are typical lines for determination of the inner properties of the surface. However, the formation of the geodesic line on the surface envisages certain difficulties, and are solved generally by methods of the computing mathematics and descriptive geometry.

In this article, the development of simple and convenient algorithm of formation of the geodesic line on ruled surfaces are considered. In common case, the three-dimensional model of the geodetic line formation algorithm on the ruled surface is expressed in following: the ruled surface we replace by sided surface, and at any position of the consideredside, the intersection point of the geodesic line with the edge of fracture (curvature of the two-sided angle) will be identified as the cross point of the adjacent generatrix with the surface of the cone of revolution – congruence of geodesic line laying directions with the peak at initial point, rotation axis, incident to the considered generatrix, and angle at the cone peak, equal to the doubled angle between rotation axis and geodesic line laying direction. Next, as the initial parameters the adjacent with mentioned generatrix, upper determined point, laying on it, and direction of the geodesic line – angle between section of the obtained geodetic and adjacent generatrix, are accepted. Thus, multiply repeating the described cycle, we obtain mass of points, which composes the desired geodetic line. Hereby the mathematic description ofthis algorithm is provided.

Key words: descriptive geometry; ruler surface; generatrix; laying direction; direction congruence; geodetic line; point of intersection.

When solving many problems of fundamentalsciences (mathematics, physics, etc.) and of engineering practice, the creation of a mathematical model of an object or process is reduced to the construction of networks of special lines (curvature, asymptotic, geodesic, level, the maximum slope, etc.) belonging to curved surfaces of objects, surfaces describing the dependence of "composition-property", etc. Families of geodetic lines occupy a worthy place among them and have great theoretical and applied value.

In differential geometry, geodesic lines are characteristic lines for determining the internal properties of a surface, and by drawing geodesic lines and measuring their lengths, you can determine all the internal properties of a surface (for example, Gaussian curvature). This is explained by the fact that any sufficiently small arc of the geodesic line represents the shortest line on the surface among all the lines connecting the ends of this arc that can be drawn on the surface [4]. However, the construction of a geodesic line on the surface is a certain difficulty, which is solved mainly by methods of computational mathematics and descriptive geometry.

In differential geometry the geodesic line is specified by differential equation of the 2nd order with ordinary derivative [4]:

$$\frac{d^2u}{dt^2} + \Gamma^1_{11}\left(\frac{du}{dt}\right)^2 + \Gamma^1_{12}\left(\frac{du}{dt}\frac{dv}{dt}\right) + \Gamma^1_{22}\left(\frac{dv}{dt}\right)^2 = 0,$$

$$\frac{d^2v}{dt^2} + \Gamma^2_{11}\left(\frac{du}{dt}\right)^2 + \Gamma^2_{12}\left(\frac{du}{dt}\frac{dv}{dt}\right) + \Gamma^2_{22}\left(\frac{dv}{dt}\right)^2 = 0, \quad (1)$$

where Γ_{ij} - Cristoffer's symbols of the 2nd order. They expressed only through the coefficients of the first quadratic form and its' derivative.

From the properties of the differential equations, it is observed that through each point on each direction one and only that one geodesic line permeates. Therefore, geodesic lines form the two-parameter plurality.These parameters are determined from the initial conditions, which are specifiedas below:

- with point A(u_o, v_o) and direction t of curve(d*u*/dt = p) in this point A;
- with two points A($u_н$, $v_н$) and B($u_к$, $v_к$),incident to that curve.

Problems solved with these initial conditions are formulated as:

1) build on the surface the geodesic line through the point in specified direction;
2) connect by geodesic line two points of the surface.

Differential equation (1) of geodesic line in common cases is not possibleto be integrated, even in case of unarysurface, therefore it is solved mainly by numerical methods [4]. The technical surfaces in general cases are constituent, therefore it is necessary to elaborate a simple and convenient algorithm, designated for the geometric modelling of the geodesic lines on composite surfaces.

In the area of the applied geometry the rank of authors elaborated the graphic ways of solving the problems of building the geodesic line on surface with usage of the descriptive geometry. These works are G.E. Pavlenko [9], V.V. Vanin [2], IvanovaL.S. [6], Elkin L.M. [11],Kovalev V.N., Harchenko A.I. [7], Scheffers [12], Glagolev N.A. [5], Ryzhov N.N. [10] and others.

Known methods [2, 5-7, 9, 10-12] of building a geodetic line on the surface do not provide thefulfillment of the condition of equality to zero of the geodetic curvature of the obtained line, and as a consequence, the accuracy of laying a geodetic line in a given direction is not provided. Increasing accuracy by reducing the iteration step results in a large amount of computing operations. Also, insufficiently developed issues that take into account the features arising when overcoming the geodetic line of points and lines of the junction of the compartments of composite surfaces. Therefore, one of the components of the tasks of mathematical support of automation of some technological processes is the development of algorithms that provide high accuracy of laying a geodetic line on the technical (composite) surface.

In order to eliminate these shortcomings as much as possible, the author [13] proposed a method of constructing a geodetic line on a technical surface based on the following property of the geodetic [4]: the g line, described by the middle M of arc AB, is geodetic for a given surface F, if an infinitely small arc AB of the curve l on this surface always moves "straight", i.e. the trajectories of movement of points A and B have equal length and are perpendicular to the arc AB.

In the paper [13] it is shown that the proposed method of constructing a geodetic line has a significant advantage. The main advantage of the developed method is a strict adherence to the specified direction of laying geodetic, as well as the exclusion of unnecessary operations - construction of the involute. The error of the method is accumulated only by the error of approximation of the arcs of geodesic triangle by the corresponding line segments. Thus, the relative error of the method at the iteration step of 2 mm amounted to 0.11%. With an increase of the iteration step to 3 mm, which for modern high-speed computers is a relatively high value, the error of the method increased to 0.823%.

This article discusses the development of a simple and convenient algorithm for a particular case, the construction of a geodetic line on ruled surfaces.

The linear surfaces, formed by move of the straight line through the specified law, make a largeclass of surfaces of zero and non-zero Gausse's curvature, which are unrolling and not unrolling. Solving of the problem of construction of the geodesic line on unrolling surfaces comes to the identification of one-to-one concordance between surface and its' involute.Then the straight line, connecting two specified points, is reflected in geodesic line on the surface. In case of non-developablesurface such method is inapplicable. Therefore the elaboration of simple and convenient algorithm of construction of geodesic line on the ruler surfaces is an important task. The developed method can be used not only for ruler surfaces. The

curvilinear surfaces can be approximated ruled lines for simplification of construction the geodesic lines on them.

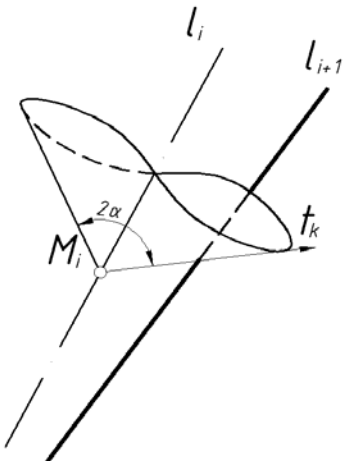
During the elaboration of the method the ruler surface was considered as approximated by sided surfaces (exposed to triangulation), where the rectilinear generatrixes of the ruler surface – are the essence of curvature of the sided surface.

Due to this, the method of construction of the geodesic line on the ruler surface was found on the next property of the geodesic line [5]: in case of compound surface the respective angles of the adjacent arcs of geodesic line to the junction line of composing ones are equal.

The proposed algorithm, based on the given property of geodesic line, consists of the following operations:

We have ruler surface Φ, formed by move of the straightforward generatrix$l$ per the advanced specified law. Let specify on this surface Φ the initial point M_0,belonging to some generatrixl_0.We know also the initial direction t_0 of laying the geodesic line g, coming from the initial point M_0.Generatrix$l$ on the surface Φ in each its' position is uniquely defined. Therefore, the choice or identification of the point M location, belonging to that line, is not difficult.

In common case, the spatial model of the algorithm of the geodesic line construction on the ruler surface, is expressed in following: when replacing the ruler surface by sided surface, at any disposition of the considered side, the point ofintersection of geodesic line with the edge of fracture (curvature of the two-sided angle)will be determined as the point of intersection of adjacentgeneratrix l_{i+1} with the surface of cone of revolution – congruence of directions t_i with the peak in point M_i, axis of rotation, incident to the generatrixl_i and to the angle at cone peak, equal to the doubled angle between axis of rotation l_i and direction t_k (figure).



Figure

Let imagine the mathematic description of the suggested algorithm.

Problem: it is required to determine the coordinates of points of intersection of the straight line with the surface of cone.

Equation of the straight line in space, passing through the two specified points, is defined by the formula:

$$\frac{x-x_1}{a} = \frac{y-y_1}{b} = \frac{z-z_1}{c}, \quad (1)$$

where $a = x_2 - x_1, b = y_2 - y_1, c = z_2 - z_1$.

Equation of surface of the straight circular cone with peak at the origin of coordinates, while axis of rotation coincide with the z-axis, is expressed by formula:

$$k^2z^2 = x^2 + y^2 \quad (2)$$

where k = tgφ, andφ – half of the angle at peak of cone of revolution.

Let solve the system of given equations. For this we express *x* and *y* by *z*

$$x = x_1 + \frac{a}{c}(z - z_1), y = y_1 + \frac{b}{c}(z - z_1)$$

and put in (2)

$$k^2z^2 = x_1^2 + 2\frac{a}{c}x_1(z - z_1) + \frac{a^2}{c^2}(z - z_1)^2 + y_1^2 + 2\frac{b}{c}y_1(z - z_1) + \frac{b^2}{c^2}(z - z_1)^2$$

grouping the terms of the same name, we obtain the expressions for solving the quadratic equation

$$\propto z^2 + 2\beta z + \gamma = 0$$

$$\propto = (a^2 + b^2) - c^2k^2,$$

$$\beta = c\,(ax_1 + by_1) - z_1(a^2 + b^2),$$

$$\gamma = c^2(x_1^2 + y_1^2) - 2cz_1(ax_1 + by_1) + z_1^2(a^2 + b^2).$$

$$z_{1,2} = \frac{-\beta \pm \sqrt{\beta^2 - 4 \propto \gamma}}{2 \propto}$$

For preparation of the mathematic provision for compiling the program of calculation on computer the trajectory of geodesic line laying, we perform the analytic description of the proposed algorithm of solving the problems in space.

For simplification of the analytical expressions, we execute the conversion of rectangular coordinate system with transfer of origin of coordinates to the point $M_i$of the sought geodesic line and superposition of z-axis with generatrix direction $l_i \supset M_i$.

Formulas of conversion of the rectangular coordinates of the point in general case are expressed with the help of Euler's angles (ψ–angle of precession, θ–angle of saltation, φ–angle of pure rotation)

$$x = x_0 + (cos\psi cos\varphi - sin\psi cos\theta sin\varphi)x' + (-cos\psi sin\varphi - sin\psi cos\varphi cos\varphi)y' + sin\psi sin\theta * z',$$

$$y = y_0 + (sin\psi cos\varphi + cos\psi cos\theta sin\varphi)x' + (-cos\psi sin\theta + cos\psi cos\varphi cos\varphi)y' + cos\psi sin\theta * z',$$

$$z = z_0 + sin\theta sin\varphi * x' + sin\theta cos\varphi * y' + cos\theta * z'.$$

In our case the rotations are performed only twice, therefore all mathematic expressions are slightly simplified.

$$x = x_0 + (cos\psi)x' + (-sin\psi)y' + sin\psi sin\theta * z',$$

$$y = y_0 + (sin\psi)x' + (-cos\psi sin\theta + cos\psi cos\varphi cos\varphi)y' + cos\psi sin\theta * z',$$

$$z = z_0 + sin\theta * y' + cos\theta * z'.$$

Since, the position of each generatrixl_i is determined, then the Euler's angles can be reckoned as known.

$$\psi = arctg\frac{(YB - YA)}{(XB - XA)},$$

$$\theta = arctg\frac{(ZB - ZA)}{sqrt\{(XB - XA)^2 + (YB - YA)^2\}}$$

Thus, multiple repeating the described cycle, we obtain the plurality of points M_i, composing the geodesic line *g*.

Afterward, we assume the making of computer program and execution of calculations of geodesic line laying on different ruler surfaces. Based on calculation results we can perform the comparative analysis of degree of accuracy of geodesic line laying.

Н. С. Үмбетов[1], Ж. Ж. Жаңабаев[1], Г. С. Иванов[2]

[1]М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан,
[2]Н. Бауман атындағы Мәскеу мемлекеттік техникалық университеті, Мәскеу, Ресей

ТҮЗУ СЫЗЫҚТЫ БЕТТЕРДЕ ГЕОДЕЗИЯЛЫҚ СЫЗЫҚТАРДЫ ЖҮРГУЗУДІҢ ГЕОМЕТРИЯЛЫҚ ҮЛГІСІ

Аннотация. Геодезиялық сызықтар түбегейлі ғылымдар (математика, физика және басқа) және инженерлік тәжірибенің көптеген есептерін шығаруда қызықты қолданыс табады.Дифференциалды геометрияда геодезиялық сызықтар беттің ішкі қасиеттерін анықтайтын ерекше сызықтар болып табылады. Алайда берілген дененің бетінде геодезиялық сызықты тұрғызу көптеген қиындыққа келіп тіреледі, сондықтан негізінде есептеу математикасы және сызба геометрия әдістерімен шешіледі.

Ұсынылып отырған мақалада геодезиялық сызықтың түзу сызықты беттерде тұрғызудың қарапайым және пайдалануға ыңғайлы алгоритмі қарастырылған. Жалпы жағдайда, геодезиялық сызықтың түзу сызықты беттерде тұрғызудың алгоритмінің кеңістіктік үлгісін келесідей тұжырымдауға болады: түзу сызықты бетті көп жақты бетпен алмастырамыз, қарастырылып жатқан жатың кез-келген жағдайында геодезиялық сызықтың сыну қырымен (екі жақты беттің ортақ қыры) қиылысу нүктесі көрші жасаушының айналу конус бетімен қиылысу нүктесі болып анықталады. Бұл жерде айналу конус беті - төбесі бастапқы нүктеде орналасқан, осі ағымдағы жасаушы түзумен беттескен, геодезиялық сызықтың бағыттарының тобы. Конус төбесінің бұрышы айналу осі мен геодезиялық сызықтың бағыты арасындағы бұрыштың екі еселенген шамасына тең. Ары қарай көрші жасаушы бастапқы жасаушы ретінде, анықталған нүкте бастапқы нүкте ретінде (келесі конус төбесі) қабылданады да, келесі нүктені табу үшін келтірілген алгоритм қайталанады. Осылайша, жазылған циклды көп рет қайталау арқылы ізделінген геодезиялық сызықты құрайтын көп нүктелер жиынын анықтаймыз. Осы алгоритмның математикалық жазбасы келтірілген.

Түйін сөздер: сызба геометрия; түзу сызықты бет; жасаушы; сызықтардың бағыты; бағыттардың конгруэнциясы; геодезиялық сызық; қиылысу нүктесі.

Н. С. Умбетов[1], Ж. Ж. Джанабаев[1], Г. С. Иванов[2]

[1]Южно-Казахстанский государственный университет им. М. Ауезова, Шымкент, Казахстан,
[2]Московский государственный технический университет им. Н. Баумана, Москва, Россия

ГЕОМЕТРИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПРОКЛАДКИ ГЕОДЕЗИЧЕСКИХ ЛИНИИ НА ЛИНЕЙЧАТЫХ ПОВЕРХНОСТЯХ

Аннотация. Геодезические линии находят интересные приложения при решении многих задач фундаментальных наук (математики, физики и др.) и инженерной практики. В дифференциальной геометрии геодезические линии являются характерными линиями для определения внутренних свойств поверхности. Однако построение геодезической линии на поверхности представляет определенные сложности, решается в основном методами вычислительной математики и начертательной геометрии.

В статье рассматривается разработка простого и удобного алгоритма построения геодезической линии на линейчатых поверхностях. В общем случае, пространственная модель алгоритмапостроения геодезической линии на линейчатойповерхности, выражается в следующем: линейчатую поверхность заменяем гранной поверхностью, при любом расположений рассматриваемой грани, точка пересечения геодезической с ребром излома (линия изгиба двугранного угла) будет определяться как точка пересечения смежной образующей с поверхностью конуса вращения – конгруэнции направлений прокладки геодезической с вершиной в исходной точке, оси вращения, инцидентной рассматриваемой образующей, и углом при вершине конуса, равной удвоенному углу между осью вращения и направлением прокладки геодезической. Далее за исходный параметры принимаются смежная с рассмотренной образующая, определенная выше точка, лежащая на ней, и направление геодезической – угол между отрезком полученной геодезической и смежной образующей. Таким образом, многократно повторяя описанный цикл, получим множество точек, составляющее искомую геодезическую линию. Приводится математическое описание данного алгоритма.

Ключевые слова: начертательная геометрия; линейчатая поверхность; образующая; направление прокладки; конгруэнция направлении; геодезическая линия; точка пересечения.

Information about authors:

Umbetov Nurlan Sagynbekovich, doctorate of technical sciences, M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; nurlanumbetov@mail.ru; https://orcid.org/0000-0002-1540-9410

Dzhanabaev Zhaksylyk Zhumadilovich, Professor, doctor of pedagogy, M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; djanabaev@mail.ru;https://orcid.org/0000-0002-0150-9963

Ivanov Gennadii Sergeevich, Professor, doctor of engineering, Honored Scientist of the Russian Federation, Bauman Moscow State Technical University, Moscow, Russia; ivanov_gs@rambler.ru; https://orcid.org/0000-0002-8935-9495

REFERENCES

[1] Alexandrov P.S. Curs lectcii po analyticheskoi geometrii. M.: Nauka, 1979. 572 p. (in Rus.).

[2] Vanin V.V. Geometricheskoe modelirovanie i postroenie razvertoktkannyh pokrytii nerazvertyvajosiihsya pokrytii: Dis. ... kand. tehn. nauk. Kiev. 1971. (in Rus.).

[3] Vygodski M. Differentcialnaya geometria. M.-L.: Gostehizdat, 1949. 511 p. (in Rus.).

[4] Gilbert D., Kon-Fossen C. Naglyadnaya geometria. M.: Nauka, 1981. 384 p. (in Rus.).

[5] Glagolev N.A. Zadacha o kratchaisiei linii v proectciah s chislovymi otmetkami // Mathematicheskii sbornik Moscowskogo mathematicheskogo obsiestva. Vol. XXXI. M., 1923 (in Rus.).

[6] Ivanova L. Modelirovanie ratcionalnyh form tkanevyh, setchatuh i kombinirovannyh pokrytii chislennymi metodami: Dis. ... kand. tehn. nauk. Kiev, 1987 (in Rus.).

[7] Kovalev S., Kharchenco A. Chislennyi method postroenia geodesicheskoi linii na regulyarnoi poverhnosti // V knige prikladnaya geometria i ingeneernaya graphica. Kiev: Budivelnic, 1978. Vol. 26. P. 24-25.

[8] Korn G., Korn T. Spravochnik po mathematice dlia nauchnyh i injenernyh rabotnikov. M.: Nauka, 1966. 831 p. (in Rus.).

[9] Pavlenco G. Osnovy konstruirovania geometrii korablya. M.: Rechizdat, 1948 (in Rus.).

[10] Ryzhov N. O postroenii kratchaishei linii na a topographicheskoi poverhnosti // Trudy Moscowskogo seminara po nachertatelnoi geometrii. M.: Sov. nauka, 1958 (in Rus.).

[11] Elkin L. Construirovanie setei spetcialnyh linii tehnicheskih poverhnostei dlia avtomatizirovannoi podgotovki upravlia i usiei informatcii ih vosproizvedenia: Dis. ... kand. tehn. nauk. Rostov-na-Donu, 1987 (in Rus.).

[12] Scheffers S. Lehrbuch der darstellendengeometrie. Bd II. Berlin, 1920.

[13] Umbetov N.S. Chislennye metody postroeniya geodezicheskih linii na tehnicheskih poverhnostyah: Thesis abstract of candidate of technical sciences. Moskow, 1993 (in Rus.).

[14] Bityukov U.I. Geometricheskoe modelirovanie tehnologicheskih protcessov namotki i vykladki konstruktcii iz volokнistyh kompozitcionnyh materialov: Dis. ... doct. tehn. nauk. Omsk, 2011 (in Rus.).

[15] Niteiskii A.S. Konstruktivno-metricheskoe i differentcialno-geometricheskoe obrazovanie lineqchatyh poverhnosteii polos: Dis. ... kand. tehn. nauk. Omsk, 2013 (in Rus.).

[16] Kalinin V.A. Teoreticheskie osnovy geometricheskogo modelirovaniya protcessov namotki i vykladki konstruktcii iz voloknistyh kompozitcionnyh materialov: Avtoref. dis. ... kand. tehn. nauk. Moskow, 1997 (in Rus.).

[17] Kudryavtseva V.I., Udler E.M. Chislennoe modelirovanie geometrii tentovyh shatrov na zhestkom kvadratnom konture. M.: Fundamental researches, 2017. N 10-3. P. 466-470 (in Rus.).

[18] Buhtyak M.S. Linii na paraboloide, blizkie k geodezicheskim // Zhurnal Tomskogo gosudarstvennogo universiteta. Mathematician and mechanic. 2015. N 6(38). P. 5-17.

[19] Sinchev B., Mukhanova A.M. The design of unique mechanisms and mashines // News of the national academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. ISSN 2224-5278. Vol. 1, N 427(2018). P. 111-117. http://www.geolog-technical.kz/ index.php/ en/archive https://doi.org/10.32014/2018.2518-170X.

[20] Ozhikenov K.A., Rakhmetova P.M., Ozhiken A.K. Investigation of the dynamics of the flight of the unmannedaerialvehicle // Bulletin of National academy of sciences of the Republic of Kazakhstan. ISSN 1991-3494. Vol. 4, N 368(2017). P. 90-95. http://www.bulletin-science.kz/index.php/ en/arhivehttps://doi.org/10.32014/2018.2518-1467.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 169 – 175 **https://doi.org/10.32014/2019.2518-170X.21**

UDC 622.24.05

D. T. Khojibergenov[1], A. S. Yanyushkin[2], Z. A. Ibragimova[1], U. D. Khozhibergenova[1], K. T. Sherov[3], B. N. Absadykov[4]

[1]M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan,
[2]I. N. Ulianov Chuvash State University, Cheboksary, Russia,
[3]Karaganda State Technical University, Karaganda, Kazakhstan,
[4]A. B. Bekturov Institute of Chemical Sciences, Almaty, Kazakhstan.
E-mail: canselyarya@mail.ru, koncel@ukgu.kz, had_ji@mail.ru, yanyushkinas@mail.ru, shkt1965@mail.ru, hadji_umida@mail.ru, Zaure_1983_as@mail.ru, b_absadykov@mail.ru

DRILLING TOOL WITH NEGATIVE DRILLING FORCE VALUE

Abstract. Unstableprices for good sintheextr active industry dictate reduction in the cost of used technologies. However, in the modern subsurface management industry, use of innovations in drilling technologies conversely increases the cost of work, complicating operating conditions. The research carried out by scientists is aimed at modernizing the drilling technology and creating new drilling tools of the same type used at the given time. In all used drilling methods, curving of drill pipes is laid in the technological process in advance, as a blunt drilling tool, before cutting into the ground, resists a drill pipe. The authors of the article have developed a new geometry of the drilling tool, which has negative drilling force values, which draws down the drill pipe. Taking into account the negative values of the drilling force *P*, it becomes possible to exclude the heavy weight drill pipes from the composition of the drill string. Naturally, when tensioning the drill string, there should be no curving process. If such theory is confirmed in industrial trials, there may not be a need for a bent housing. The absence of the borehole curving during drilling allows to exclude stabilization mechanisms in the borehole arrangement. The exclusion of some mechanisms from the drilling complex will obviously reduce the cost of drilling. The creation of such drill chart will undoubtedly reduce the cost of drilling works.

Key words: drilling, curving of drill pipes, drilling tool, drilling force, drill string rotation, borehole, drilling bit, bottom, centralizer, stabilization device, drilling fluid, drill chart, drill pump, criteria of drilling capacity.

Introduction. With the development of techniques and technology, technological processes should be cheaper and easier to use. However, the drilling process with the use of innovations is becoming more expensive and more complicated in operation.

In this regard, the group of scientists is exploring the drilling process in order to develop a drilling tool and drill charts, since the drilling process is used in various economic sectors and various types of drilling tools are used. The oil and gas industry is prevailing and resonant for the economy. Reducing the cost in the oil and gas production will significantly affect the economy of any country in a positive way.

In practice, rotary drilling (about 80%) is widely used for formation of boreholes in oil and gas deposits, where vertical, directional and horizontal drilling methods are used. It is expected to increase the volume of rotary drilling and drilling with screw downhole motors. In Europe and the USA, the main method is rotary drilling, in particularthe rotary drilling expands the volume of drilling by downhole motors [1-5].

It is necessary to pay attention to the fact that in the rotary drilling method, the work is performed due to the rotation of a rock destruction tool (drilling bit, boring head) applied against the bottom, to which the axial stress and rotation torque are transmitted. Not insignificant aspect in the drilling technology is translation of motionto drill pipes and rotation of drilling tool, since the drilling effort directly depends on this process [7, 8].

The principle of operation of the drilling process in all methods is similar, where rotor receives rotation from electric motor or internal combustion engine through driving shaft [9-11]. The shaft rotation by conical rotor gear train is transformed into rotation of the rotary table relative to the borehole axis. Drivinginsertion pieces are installed on the rotary table, to which the rotary table rotation is transmitted. Drivinginsertion pieces (of smaller sizes) are installed inside the drivinginsertion pieces, the inside dimension of which corresponds to the section of upper carrier pipe of the drill string. The section of the drill string's carrier pipe can have square, hexagon, cross and other forms. The inside dimension of the drivinginsertion pieces should have a similar form, rotating the drill string's upper carrier pipe.

The main body of the drill string is drill pipes [12-15]. Heavyweight drill pipes (HWDP) are installed between them and drilling bit, which weight should provide necessary load on the drilling bit during rotary drilling and operation of pipes in the stretched state [9-15].

The main task when borehole drilling is to prevent curving of the borehole and bring the borehole to the vertical in case of its curving.

When borehole drilling, the following basic methods are used to ensure the bore verticality [5-10]:

- use of the "pendulum" effect due to creation of maximum possible deflecting force on the drilling bit, directed to the side opposite to the direction of the borehole curving and increase at that in the borehole wall cutting intensity by the lateral face of the drilling bit;

- preservation of existing minor inclination angle of the borehole due to centering of the lower part, i.e. by the bottom hole assembly (BHA) by arrangement of support-centering element (SCE) at the optimal distance from the drilling bit;

- active reduction of the borehole curving due to the deflecting force or change in the direction of the drilling bit axis.

These methods of laying the vertical borehole are implemented by appropriate technical means: pendulous BHA; rigid BHA; stepped BHA; rotary controlled systems (RCS).

An important technological factor determining the vertical borehole curving is pitch stability of the drill string located above the drilling bit. In the drill string's stability loss, the deflecting force appears on the drilling bit, under the effect of which the drilling bit will destroy the bottom at some angle to the axis of the borehole and cut the borehole wall in the transverse direction, which will lead to the borehole curving.

The above brief analysis on the study of the borehole curving shows that in addition to the drilling tool, there are a number of technological aspects that affect the drilling process. However, the main reason for its curving is the drilling chart itself.

The main part. In the applied drilling charts, where the cutting wedge of the drilling tool crashing into the ground faces a heavystress [10-15]. In these drilling charts, direction of speed and direction of the resulting drilling force have opposite values. As a result, axial stresses are fully transmitted to the borehole of the drilling machine. Considering the length of the borehole and discontinuity of operation of the active drilling tools, the transmitted stresses have a resonant nature, which leads to the destruction of the cementing elements. In order to prevent such situations, such safety elements as a bent housing, centralizer, stabilization device, etc. are provided in advance in the borehole.

The research of the scientists to improve the drilling process and increase productivity is concentrated in:

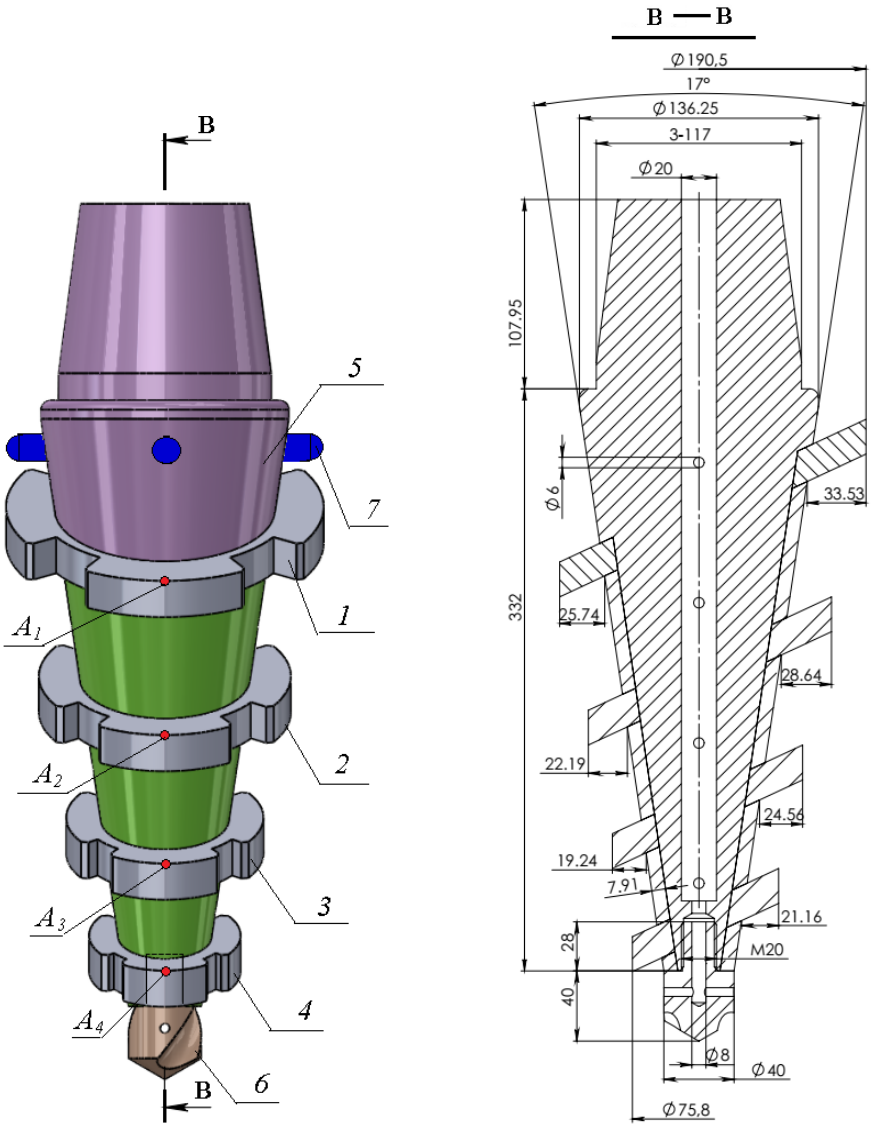
- creation of a new geometry of drilling tools, which use expensive hard alloys, increasing resistance;

- in order to increase the service life of the drilling complexes, new mechanisms, devices and equipment are created that increase the cost of drilling equipment;

- development of new drilling fluid compositions that improve the drilling process and simultaneously increase the costs of the drilling process;

However, despite the improvement of the process in all used methods, great efforts are being made in the drilling zone [16]. In addition to the cutting pattern, an important reason for the occurrence of large values of the drilling effort is the drilling tool geometry. Since basically the drilling tools are equipped with blunt cutting or raker teeth. The teeth wedge angle sometimes exceeds 90°.

The entire weight of the heavyweight drill pipe is attached from above on the blunt drilling tool. During drilling, the ratio of the applied force and value of the drilling tool rotation are significantly



Drilling tool for rotary drilling: 1, 2, 3, 4 – cutting teeth in the form of a disk; 5 – body; 6 – boring bit for crashing into the ground or rock; 7 – damper

different. In these cases, the teeth are pressed into the ground or rock, and the concentrated force acts in the opposite direction, curving the drill pipes [17-27].

Analysis of the drilling methods shows that in the existing technologies the case of "pipe curving" is laid in advance. To exclude this case, it is necessary to change the drilling tool geometry with the appropriate drilling method.

The proposed drilling method and drilling tool work perfectly according to the different drilling pattern. The geometry of the drilling tool being created allows manage the drilling process, i.e. set amount of emerging drilling forces in advance (figure).

Preliminary tests of the proposed drilling tool design on the layout showed that the cutting teeth at the point *A* touching the wall of the hole on the ground made by the rotary bit 6 begin to crash into the ground, raising the cut ground to the top. In turn, the cut ground layer, opposing, begins to press down the cutting tooth of the drilling tool. In this case the resultant force *P* will have negative values. If combine the arising forces on each tooth of the drilling tool, it can be assumed that during the drilling process the resultant drilling force value will be sufficient to draw the drill pipe down. In this case, it may be possible to make the drilling tool draw the drill strings down, rather than push them off. Having achieved this, it is possible to radically revise the role of constituent elements in the drilling process.

Conclusions. Based on the initial studies carried out, it can be concluded that for the proposed drilling pattern and design of the drilling tool:

1. The acceptable drilling method is rotary.

2. When drilling, it is better to use the drilling fluid for the cut ground with necessary technical means: drill pump; earth storage; rotary hose riser; filter; swivel; swivel sub; sludge separator; travelling block; hook; hose, etc.

3. To set rake of the cutting tooth (figure) in order to force the drilling tool to be drawn down the well within 25÷50° with respect to the criteria of the ground drilling capacity according to the classification of Academician V.V. Rzhevsky.

4. Possibly, to except from the drilling complex composition the mechanisms of the safety elements for the borehole curving:

- curving mechanism;
- stabilization device. However, after a series of experimental demonstrations.

5. Taking into account that the forces are consumed minimally with a pure shear of a rigid body and discontinuity occurs at 45° [28]:

- it is necessary to choose geometrical values of the cutting wedge so as to destruct solid rock at 45°;
- the wedge angle values should not exceed 95°. In this case, taking into account difference in the geometric values of the cutting wedge in statics and kinematics, carry out the sharpening taking into account the kinematic values. It should be noted that the rear angle in kinematics acquires negative values.

6. Install copper or plastic plates between the cutting teeth and bushings (figure) to extinguish impact loads of the drilling process. The thickness of the plates should be chosen in the ratio of the drilling tool tooth geometry:

- prepare the cutting teeth from carbide blades by baking and with subsequent mechanical processing of their plates, applying wear-resistant coatings;
- prepare the cutting teeth from high-speed steel by cutting, hardening and grinding;
- arrange the cutting teeth and bushings on the body and fasten them by isolating connection, i.e. thread. Cut the inside thread on the drilling tool body, and the outer thread on the neck of the bit in the form of a rotary bit (figure). The thread must be left, against the drilling tool rotation.

7. Provide for damper in the drilling tool construction instead of the centralizer on the drill pipe (figure). The damper must be made of structural steels by cutting, hardening and thread connection in the drilling tool body.

The damper will serve as a centralizer, preventing oscillations arising during the drilling process by extinguishing then in the drilling tool location, and at the same time will serve as the drilling tool guiding elements.

8. The drilling mode parameters should be average for solid ground, and high for soft ground.

The research carried out within the framework of the grant theme: “AP0513118 Creation of drilling tools for borehole drilling in the production of solid, liquid and gaseous minerals (Contract No. 164 dated 15.03.2013)” showed that the drill chart being developed should be worked out in such values of the drilling mode to exclude some elements in the borehole. For example, taking into account the negative values of the drilling force P, exclude from the borehole composition the HWDP. Naturally, when tensioning the borehole, there should be no curving process. If such theory is confirmed in industrial trials, there may not be a need for a bent housing. The absence of the borehole curving during drilling allows exclude stabilization mechanisms in the borehole arrangement.

The exclusion of some mechanisms from the drilling complex will obviously reduce the cost of drilling.

Д. Т. Ходжибергенов[1], А. С. Янюшки[2]н, З. А. Ибрагимова[1],
У. Д. Хожибергенова[1], К. Т. Шеров[3], Б. Н. Абсадыков[4]

[1]М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан,
[2]И. Н. Ульянов атындағы Чуваш мемлекеттік университеті, Чебоксары, Ресей,
[3]Қарағанды мемлекеттік техникалық университеті, Қарағанды, Қазақстан,
[4]Ә. Б. Бектұров атындағы Химия ғылымдары институты, Алматы, Қазақстан

ТЕРІС БҰРҒЫЛАУ КҮШІ БАР БҰРҒЫЛАУ ҚҰРАЛДАРЫ

Аннотация. Кен өндіру өнеркәсібіндегі тауарлардың тұрақсыз бағасы қолданылатын технологиялардың құнын төмендетуге алып келеді. Дегенмен қазіргі заманғы индустрияда бұрғылау технологиясындағы инновацияларды жер қойнауын пайдалану, керісінше, өндіріс құнын арттырып, өндірістік жағдайды қиындатады. Ғалымдардың жүргізген зерттеулері бұрғылау технологиясын жаңғыртуға және сол уақытта қолданылатын жаңа типтегі бұрғылау құралдарын жасауға бағытталған. Бұрғылауда қолданылатын барлық әдістерде бұрғылау құбырларының қисаюы, технологиялық процесте алдын-ала қойылған, себебі доғал бұрғылау құралы, жерді кесіп болмай, бұрғылау құбырын кері итереді. Мақаланың авторларымен бұрғылау құбырын төменге тартатын, кері бұрғылау күшіне ие бұрғылау қондырғысы әзірленді. Бұрғылау күші Р теріс мәндерін ескере отырып, бұрғылау топтамасынан ауыр бұрғылау құбырларын алып тастауға болады. Әрине, бұрғылау бағандарын тартқанда, қисықтық процессі болмауы керек. Егер мұндай теория өнеркәсіптік сынақтарда расталса, онда қисықтық механизмінің қажеттілігі болмауы мүмкін. Бұрғылау барысында бағандар қисықтығының болмауы, бағандарды құрастыру кезінде тұрақтандыру механизмдерін алып тастауға мүмкіндік береді. Бұрғылау кешенінен кейбір механизмдерді алып тастау, бұрғылаудың өзіндік құнын айтарлықтай төмендетеді. Бұрғылаудың мұндай сұлбасын жасау, бұрғылау жұмыстарының өзіндік құнын төмендетеді.

Түйін сөздер: бұрғылау; бұрғылау құбырларының қисаюы; бұрғылау құралы; бұрғылау күші; бұрғылау тобының айналуы; ұңғыма; қашау; кенжар; орталықтандырғыш; тұрақтандырушы қондырғы; бұрғылау ерітіндісі; бұрғылау сұлбасы; бұрғылау сорғысы; бұрғылану критерийлері.

Д. Т. Ходжибергенов[1], А. С. Янюшки[2]н, З. А. Ибрагимова[1],
У. Д. Хожибергенова[1], К. Т. Шеров[3], Б. Н. Абсадыков[4]

[1]Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,
[2]Чувашский государственный университет им. И. Н. Ульянова, Чебоксары, Россия,
[3]Карагандинский государственный технический университет, Караганда, Казахстан,
[4]Институт химических наук им. А. Б. Бектурова, Алматы, Казахстан

БУРОВОЙ ИНСТРУМЕНТ С ОТРИЦАТЕЛЬНЫМ ЗНАЧЕНИЕМ СИЛЫ БУРЕНИЯ

Аннотация. Нестабильные цены товаров в добывающей промышленности диктуют снижение себестоимости в используемых технологиях. Однако в современной отрасли недропользования применение новшеств в технологиях бурения, наоборот, повышает себестоимость работы, усложняя условия эксплуатации. Проводимые учеными исследования направлены для модернизации технологии бурения и создания новых буровых инструментов, аналогичных используемым в данное время. Во всех применяемых способах бурения искривление бурильных труб заранее заложено в технологическом процессе, так как тупой буровой инструмент, не успевая врезаться в грунт, отталкивает бурильную трубу. Авторами статьи разработана новая геометрия бурового инструмента, имеющая отрицательные значения силы бурения, которая втягивает вниз бурильную трубу. С учетом отрицательных значений силы бурения Р появляется возможность исключения из состава бурильный колонны утяжеленных бурильных труб. Естественно, при натяжении бурильного ствола не должно быть процесса искривления. Если такую теорию подтвердить в промышленных испытаниях, возможно, отпадет надобность применения механизма искривления. Отсутствие искривления ствола при бурении дает возможность исключить при компоновке ствола и механизмов стабилизации. Исключение

некоторых механизмов из бурильного комплекса, очевидно, снизит себестоимость бурения. Создание такой схемы бурения, несомненно, снизит себестоимость бурильных работ.

Ключевые слова: бурение; искривление бурильных труб; буровой инструмент; сила бурения; вращение бурильной колонны; скважина; долото; забой; центратор; стабилизирующее устройство; буровой раствор; схема бурения; буровой насос; критерий буримости.

Information about authors:

Khojibergenov Davlatbek Turganbekovich, Doctor of Technical Sciences, Director of Department of science and production, M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; had_ji@mail.ru; https://orcid.org/0000-0003-0039-9931

Yanyushkin Aleksandr Sergeyevich, Doctor of Technical Sciences, Professor, I. N. Ulianov Chuvash State University, Cheboksary, Russia, chair of Technological equipment, machine building and standardization, Karaganda; yanyushkinas@mail.ru; https://orcid.org/0000-0003-1969-7840

Khozhibergenova Umida Davlatbekkyzy, Candidate for a master's degree of high school "Information technologies and energetics" of M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; hadji_umida@mail.ru; https://orcid.org/0000-0003-2381-8094

Ibragimova Zaure Assilbekovna, Doctor of Philosophy (PhD), senior teacher, M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; Zaure_1983_as@mail.ru; https://orcid.org/0000-0002-7176-8186

Sherov Karibek Tagayevich, Doctor of Technical Sciences, Professor, Karaganda State Technical University, chair of Technological equipment, machine building and standardization, Karaganda, Kazakhstan; shkt1965@mail.ru

Absadykov Bakhyt Narikbayevich, Doctor of Engineering Sciences, Professor, the Corresponding member of National Academy of Sciences of the Republic of Kazakhstan, A. B. Bekturov Institute of Chemical Sciences, Almaty, Kazakhstan; b_absadykov@mail.ru; https://orcid.org/0000-0001-7829-0958

REFERENCES

[1] Vasil'chenko A. Novyye tekhnologii v stroitel'stve neftyanykh i gazovykh skvazhin [Tekst]. M.: LAP Lambert Academic Publishing, 2012. 112 p. (in Rus.).

[2] Adler M.G. Povysheniye effektivnosti razvedochnykh rabot na neft' i gaz pri provedenii geologo-tekhnologicheskikh issledovaniy na skvazhinakh [Tekst] // V sb.: Nauchno-tekhnicheskiy progress v neftepromyslovoy geofizike. Trudy BashNIPIneft'. Ufa: VNIINPG, 1987. 17. P. 27-33 (in Rus.).

[3] Volik D.A. Bureniye skvazhin na zhidkiye i gazoobraznyye poleznyye iskopayemyye [Tekst]. M.: Izd-vo MGOU, 2009. 136 p. (in Rus.).

[4] Neretin V.D. Razvitiye informatsionno-izmeritel'noy sistemy yaderno-magnitnykh issledovaniy gornykh porod i flyuidov v skvazhinnykh i nazemnykh usloviyakh [Tekst] / V.D. Neretin, Ya.L. Beloray, I.Ya. Kononenko // V sb.: Sovremennyye tendentsii razvitiya tekhniki i tekhnologii yaderno-geofizicheskikh i geoakusticheskikh issledovaniy skvazhin. M.: VNIIgeoinformsistem, 1987. P. 37-41 (in Rus.).

[5] Khalimov K.E. Evolyutsiya otechestvennoy klassifikatsii zapasov nefti i gaza [Tekst] / Pod red. K.E. Khalimov, E.M.Khalimova. M.: OOO «Nedra-Biznestsentr», 2003. 188 p. (in Rus.).

[6] https://www.rocktechnology.sandvik/Drilling, Breaking & Crushing. World Leading Solutions Provider for Mining and Construction 160.

[7] https://vuzlit.ru /317176/ osobennosti_oblast_primeneniya_razlichnyh_sposobov_ bureniya_skvazhin Osobennosti i oblast' primeneniya razlichnykh sposobov bureniya skvazhin (in Rus.).

[8] Vine A.G. Opisaniye razreza na osnove tekhnologicheskoy informatsii, poluchayemoy v protsesse bureniya [Tekst] / A.G. Vine, V.I. Dmitriyev, E.G. Karapetyan // V sb.: Izucheniye kerna, shlama i geologo-tekhnologicheskiye issledovaniya pri burenii neftegazovykh skvazhin (tez. dokl. Vsesoyuznogo seminara). Kalinin, 1986. P. 11-12 (in Rus.).

[9] Graves R.M. Star Wars Laser Technology for Gas Drilling and Completion in the 21st Century / R. M. Graves, D. G. Brien, E. A. Brien // Journal SPE 56625-MS. 1999. P. 27-30.

[10] Tagirov K.M. Bureniye skvazhin i vskrytiye neftegazovykh plastov na depressii [Tekst] / K.M. Tagirov, V.I. Nifantov. M.: OOO «Nedra-Biznestsentr», 2003. 160 p. (in Rus.).

[11] Ancient Chinese Drilling. http://www.cseg.

[12] Khalimov K.E. Evolyutsiya otechestvennoy klassifikatsii zapasov nefti i gaza [Tekst] / Pod red. K.E. Khalimov, E.M.Khalimova. M.: OOO «Nedra-Biznestsentr», 2003. 188 p. (in Rus.).

[13] Povalikhin A.S. Bureniye naklonnykh, gorizontal'nykh i mnogozaboynykh skvazhin [Tekst] / A.S. Povalikhin, A.G. Kalinin, S.N. Bastrikov, K.M. Solodkiy / Pod obshch. red. doktora tekhnicheskikh nauk, professora A. G. Kalinina. M.: Izd. TsentrLitNefteGaz, 2011. 647 p. (in Rus.).

[14] Kalinin A.G. Yestestvennoye i iskusstvennoye iskrivleniye skvazhin [Tekst] / A.G. Kalinin, V.V. Kul'chitskiy. M.: Izhevsk, 2006. 640 p. (in Rus.).

[15] http://rosmining.ru/wp-content/ Klassifikatsiya gornykh porod po kreposti *f* po shkale prof. M. M. Protod'yakonova (in Rus.).

[16] Grin'ko D.A. Metod rascheta i podderzhaniya ratsional'nykh rezhimnykh parametrov buril'noy mashiny mekhatronnogo klassa: diss. kand. tekhn. nauk [Tekst]. Novocherkassk, 2015. 157 p. (in Rus.).

[17] Leonov Ye.G. Oslozhneniya i avarii pri burenii neftyanykh i gazovykh skvazhin. V 2 chastyakh. Chast' 1. Gidroaeromekhanika v burenii / Ye.G. Leonov, V.I. Isayev. M.: Nedra-Biznestsentr, 2014. 238 p. (in Rus.).

[18] Grin'ko D.A. Metod rascheta i podderzhaniya ratsional'nykh rezhimnykh parametrov buril'noy mashiny mekhatronnogo klassa: diss. kand. tekhn. nauk [Tekst]. Novocherkassk, 2015. 157 p. (in Rus.).

[19] Basarygin Yu.M. Tekhnologiya bureniya neftyanykh i gazovykh skvazhin [Tekst] / Basarygin Yu.M., Bulatov A.I., Proselkov Yu.M. M.: OOO «Nedra-Biznestsentr», 2001. 679 p. (in Rus.).

[20] Basarygin Yu.M. Oslozhneniya i avarii pri burenii neftyanykh i gazovykh skvazhin [Tekst] / Basarygin Yu.M., Bulatov A.I., Proselkov Yu.M. M.: OOO «Nedra-Biznestsentr», 2000. 679 p. (in Rus.).

[21] Savin A.P. Fizicheskiye velichiny, primenyayemyye v razvedochnoy geofizike i ikh yedinitsy: Spravochnik. Leningrad: Nedra, 1985. 128 p. (in Rus.).

[22] Bitto R. Novaya sistema upravleniya trayektoriyey stvola skvazhin // Neft', gaz i neftekhimiya za rubezhom. 1986. N 5. P. 32-35 (in Rus.).

[23] Neskoromnykh V.V. Razrusheniye gornykh porod pri provedenii geologorazvedochnykh rabot [Tekst]. Krasnoyarsk: SFU, 2012. 300 p. (in Rus.).

[25] Iogansen K.V. Sputnik burovika: Spravochnik [Tekst]. M.: Nedra, 1990. 295 p. (in Rus.).

[26] Maslennikov I.K. Burovoy instrument. Spravochnik [Tekst]. M.: Nedra, 1989. 430 p. (in Rus.).

[27] Fertl' U.X. Anomal'nyye plastovyyedavleniya [Tekst] / Per. s angl. M.: Nedra, 1980. 398 p. (in Rus.).

[28] Yandex.kz/images/search?text=teoriiuprugosti v smeshannom vide (in Rus.).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 176 – 186 **https://doi.org/10.32014/2019.2518-170X.22**

UDC 66.047.7:66-912

Ruslan Umirzakov[1], D. N. Mukhiddinov[2], Mukhabbat Abdirova[3], Bulbul Ongar[4]

[1]Kazakh Agrotechnical University named after Saken Seifullin, Astana, Kazakhstan,
[2]TashGTU them. I. Karimova, Tashkent, Uzbekistan,
[3]Almaty State College of Energy and Electronic Technologies, Kazakhstan,
[4]Almaty University of Power Engineering and Telecommunications, Kazakhstan.
E-mail: Ars_uran@mail.ru, Muhabbatabdireva@mail.ru, Onqar_ Bulbul@mail.ru

INFLUENCE ON THE MODE OF GRAIN DRYING IN THE HEAT GENERATOR AND COMBUSTION PRODUCTS

Abstract. This article examines the heat generator impacton the drying regime of the grain and on the toxicity of the combustion products, with its operation modes, different variables and under different conditions. Timely and correct implementation of the procedure for drying grain is an extremely important aspect. We proposed several options for obtaining the optimal result. As a result of the research, the proposed method of grain drying contributes to the improvement of its quality, reduces the ripening time of the grain, and adjust the grain mass in terms of moisture content and grain maturity. It should also be noted, that this method contributes to the improvement of the grain's characteristics, and its appearance. The proposed method suspends the vital activity of microorganisms and pests. The practical and theoretical importance of this work lies in the possibility of applying the obtained data both in practice and in studies on the matter of grain drying.

Keywords: grain drying, Heat generator, Toxicity of combustion products, Drying mode, Grain moisture content, Formula, Temperature mode.

Introduction. By its nature, the grain is colloidal, and by structure it is a capillary-porous body with a complex chemical composition. General patterns of water distribution in such material were developed by S.M. Lipatov (1933), G.A. Rebinder (1933), A.V. Lykov (1968) and Yu.A. Kazakov (1973). In recent years, the teachings on the forms of the connection of moisture in the grain, the processes of internal moisture transfer, have been extended by the works of A.S. Ginzburg (1967), E.D. Kazakov (1973) and G.A. Egorov (1985).

The first Russian studies of the drying process of grain were carried by Demidov P.G. (1938) and Egorov G.A. (2000). They paid attention to the fact that grain under the action of high temperatures loses its germination. They also noticed that high temperatures are particularly detrimental to raw grain. As the drying of grain, high temperatures are also less dangerous.When drying the grain is going on, not only the temperature of the grain heating, but also the duration of the heat exposure are of great importance. The most important characteristic of grain are its thermos physical properties. Until recent time, methods of mathematical calculation of drying processes have not been properly developed, which is largely due to insufficient information about the heat-physical properties of the grain. Studies of Egorov G.A. (2000), Kazaryan Sh. (1934) and others were devoted to studying this issue. Investigations of the thermos physical characteristics of a single grain and a grain layer showed the level of value.We get grain with excess moisturecontent during harvesting. Wet grain is notsubject for long-term storage, as it quickly deteriorates. Timely and correctly carried out drying procedure not only increases the resistance of the grain during storage, but also improves its quality, accelerates the ripening of the grain, smooths the grain mass according to the moisture content (at the level of the conditioned value) and the degree of maturity (at the full ripeness level), improves color and appearance, and stops microorganisms and pests (Zhidko, Rezhchikov & Ukolov, 1982).

The most important characteristic of the grain is its thermal stability, which is determined by its humidity, the heating temperature, the duration of heating, and the temperature of the drying agent. During the drying, temperature-controlling and cooling the grain undergoes a number of profound changes associated with biochemical and physical chemical transformations, changes occur in its colloidal and capillary-porous structure. Saving and improving of grain quality during drying is provided by the use of various technological schemes and drying modes. At the same time, these are common processes for all technological systems of high-temperature grain drying:

1. receiving and storing of the grain before drying in amounts.It ensure stable operation of grain drying equipment;
2. preliminary cleaning of grain and the formation of lots of grain, homogeneous in their value and purpose;
3. the formation of grain transport flows that provide the technological scheme of grain drying (direct flow, recirculation, with or without grain preheating);
4. preparation of the drying agent for the specified parameters and its distribution along the drying zones;
5. preparation of cooling air, including the usage of artificial cold;
6. conducting heat and mass exchange processes (preheating, ripening, drying and grain cooling);
7. unloading grain with the formation of lots of grain with the specified parameters;
8. active grain ventilation, including additional cooling and its drying during cooling;
9. grainstorage (Geansburg, 1973).

Method of system analysis application makes it possible to determine the main criteria of technological flows during grain drying and their interaction with the external environment. In this case, only a combination of the above operations can ensure the drying of the grain and the preservation of its quality, i.e. the technological flow is an integral system of processes. The level of integrity is a characteristic feature of the technological flow, reflecting the measure of its organization and the technology systemic nature determined after diagnostics.

To quantify the various levels of technological processes organization and calculate the level of integrity of the technological system in terms of the stability indicators of its components, it was possible to objectively assess the reliability of the functioning of technological systems for grain drying.

At present time, there are four ways of convective grain drying: high-temperature drying; high-temperature drying with the use of active ventilation (two-stage drying); combination of high-temperature and low-temperature drying; low-temperature drying by active ventilation (Tsuglenok & Manasyan, 2005). An important element of the technological system is the heat generator, which ensures the temperature mode of drying and ecological compatibility of the system. We propose to use an air nozzle with blade adjustment outlet of recirculation zone amplifier for the heat generator. It will provide the necessary combustion intensity in the technological system of heat generator, as well as reduce the formation of toxic NO_x. 45°is an optimum ZRC, which is positively affected by the intensification of the combustion process. In this case, there is a high temperature, so it can be seen some NOx growth.The completeness of combustion has the highest value at 45° for all types of corners. This is due to the developed ZRC and good mixing, especially with perforation. The decrease in the completeness of combustion at 90° is due to the rapid displacement of the products of incomplete combustion from ZRC that are sucked by the fuel stream. At 15° with perforation, this displacement is insignificant, since the mass of the sucked air is insignificant. Due to this, the fuel is burned to the end of the experimental setup. The lower completeness of combustion at the usual angle can be explained by the insufficiency of oxygen in the ZRC. The increase in the length of the corners leads to low values of the completeness of combustion. At angles below 45° due to insufficient development of the ZRC, and higher due to low temperatures and due to the more air capture in the ZRC.

Methodology. Improvement and prospects for the heat generator development are associated with the possibility of regulating the parameters of the outgoing gas, improving their aerodynamics and reducing toxicity. As a result of generalization of the experimental data and the use of the foundations of the theory of combustion, the following basic principles of the organization of the working process constitute the design of a compact heat generator:

1) Working volume separation of the combustion chamber into two zones of combustion and mixing. At present, the average temperature of the exhaust gases T_c = 750÷950K and the total value of the air excess ratio α_Σ = 4÷10. In the space bounded by the body of (1) heat generator, (2) flame tube, isolated volume combustion zones I and mixing II (figure 1). The primary part of the volume of the flame tube (combustion zone) is directed to the primary air G_I – such part of the total air flow G_B, which ensures the formation of a highly reactive mixture that rapidly burns at a sufficiently high average process temperature.

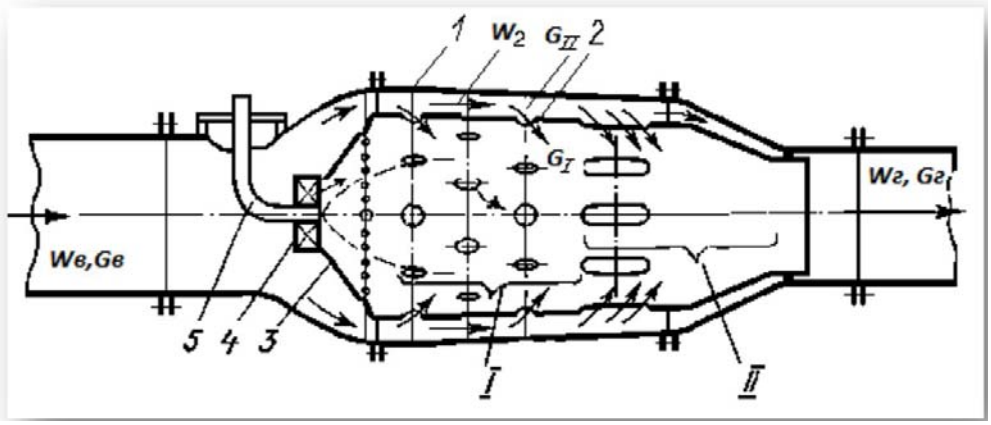


Figure 1 – Heat Generator Circuit

To the combustion zone I into the primary air flow G_I is supplied with fuel G_t by nozzle (5). The rest of the air G_{II} – secondary air, bypassing the combustion zone at a speed (ω_2), through special opening enters the mixing zone II of flame tube. Mixing with combustion products which leaving the combustion zone I, and cooling them, it ensures the set temperature of the gas at the heat generator output.

2) *Gradual (stepwise) supply of primary air along the length of the combustion zone.* For liquid fuels, a gradual dispersed supply of primary air into the combustion zone is even more necessary in contrast to natural gas.So, for example, a drop of liquid fuel before combustion should warm up and evaporate. In order to burn rapidly evaporating of the smallest drops at the very beginning of the combustion zone, a small amount of primary air G_I is required, which is expediently supplied at the injector orifice 5 through the front device 3, providing the temperature necessary for the chemical reaction in this zone.

With a step-by-step approach of the side jets of the primary air, small and burning evaporating medium and large droplets also burn out under optimal temperature conditions. In addition, the total flow is additionally turbulization, the process of mixing and combustion in general is intensified. To completely burn out the fuel, in the ideal case, a definite amount of air should be supplied to the combustion zone. As already noted, excess air is needed to facilitate and guarantee mixture formation, to prevent chemical fuel burn-up and to reduce the level of dissociation high at elevated process temperatures. When designing on the basis oftheoretical concepts of the combustion process and accumulated experience, a certain pattern of air distribution is determined, often as shown in figure 1 with a dashed line.

Primary air flow rate in the combustion zone G_I and, consequently, the coefficient of $a_I = a_c = \frac{G_I}{G_T \cdot L_0}$ its excess of heat generator, the type of fuel and the organization of the work process. Ensuring the turbulization of the flow in the combustion zone affects the efficiency of the combustion process. As a result, heat and mass transfer processes intensify, mixture formation improves and the flame propagation velocity increases. Turbulization of the flow is achieved by installing, in the front device 3, the front endof the flame tube 2 of the air nozzle 4 with the blade air recirculation zone amplifier, and also by arranging the radial flow of the air jets leaving through the holes in the walls along the length of the flame tube. Since the significant forcing of the flame tube working volume of the heat generator determines the average flow velocity much higher than the turbulent velocity $u_t$the spread of the front of the flame, to hold the torch in a certain area of the front of the combustion zone, it is necessary to carry out special measures. To stabilize the flame front, use blade recirculation zone amplifier located in the front device of

the flame tube. The zone of return currents (ZRC) behind them with reduced static pressure at the chamber axis, which is caused by the gas ejection by the ring jet flowing from the blade recirculation zone amplifier into the expanding channel, and the centrifugal effect, stabilizes the position of the flame front, which ensures ignition of the whole fuel-air mixture. Scheme of fields of axial speeds ω_a in different sections along the length of the flame tube in the combustion zone (without taking into account the effect of the side air jets) is given in figure 2.

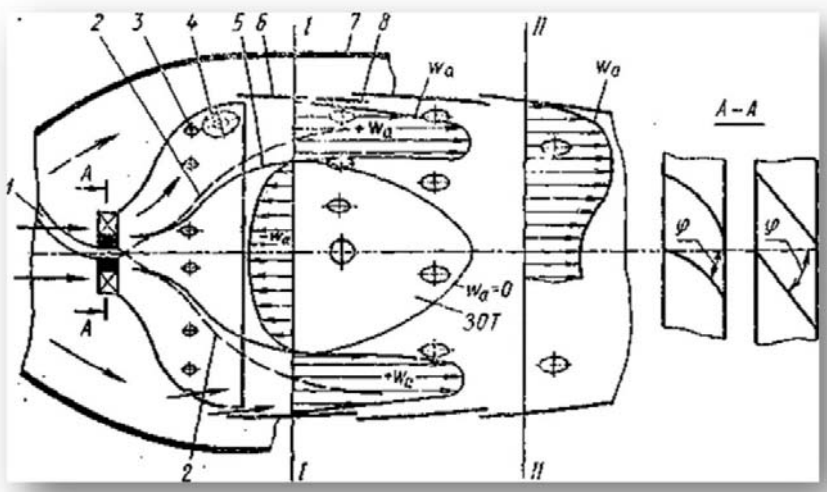


Figure 2 – Scheme of Gas Flow in the Combustion Zone.
Cconventions: 1 – nozzle; 2 – fuel cone; 3 – opening; 4 – possible flow separation zone;
5 – zone boundary of reverse flows; 6 – shell of a flame tube; 7 – body; 8 – slot for cooling air

The radial and tangential velocities depend on the construction of the front-line device and the flow parameters. For example, using a blade recirculation zone amplifier from the angle φ oftilt blades in relation to the axis of the chamber. As usual, $\varphi = 45 \div 65°$ depending on the design of the front-mounted device. In the case of large angles φ the efficiency of the blade recirculation zone amplifier is reduced due to the increase in pressure loss.

3) The optimal distribution of the concentrations (4) of fuels along the sections of the combustion zone. It is expedient, for example, to feed a hollow cone (3) of fuel in the flow region adjacent to theback current region, where the gradient of the axial velocities w_a flow is maximal, which ensures a good mixing of fuel with air. Under such a mixture formation scheme, the fuel ingress onto the wall of the flame tube and inside the zone of the reverse currents must be eliminated.

The noted basic principles of the organization of the working process, the design and calculation of the heat generator in each specific case are supplemented by other provisions related to the features of the heat generator being designed. Thus, for example, with high air inlet parameters in highly heat-stressed high-temperature combustion chambers ($\alpha_\Sigma = 2 \div 3$ and less) the provision on the division of the working volume into the combustion and mixing zones can be replaced by a more promising principle of ensuring uniform micro flame combustion of fuel in a small (especially along the length) volume. The fulfillment of this principle is possible if preliminary prepare the combustible mixture for combustion, evaporate fuel, partially mix it with air, etc.

The principle of ensuring flame stabilization is often associated with the need to create not one but several stabilization zones along the cross-section and the length of the combustion zone, which contributes to the realization of the principle of micro flame combustion, ensuring greater process stability, and, consequently, increasing the heat stress of the working volume of the combustion chamber.

Finally, the requirement to reduce the level of gas toxicity may necessitate the organization of not one but two combustion zones in a two-stage combustion of fuel, with controlled excess air or the creation of homogeneous combustion chambers with a preliminary complete mixture.Therefore, when creating an engineering methodology for the estimation of NO_x emissions, it is necessary to determine the dependence of the residence time of gases on the geometry of the micro flame front device and the conditions for the

distribution of air in the combustion zone. In the chamber under consideration with MFD (micro flame front device) the twisting of the flow at the inlet leads to the formation of reverse current ashes (RCA) which ensures stable operation of the camera in a wide range of parameters. In these conditions RCA reaches 30-40% of the total volume of the primary zone of the combustion chamber. Recirculation of gases through RCA increases the residence time of combustion products in the high-temperature zone, which, naturally, must be taken into account by the procedure for calculating the yield of nitrogen oxides. Unlike micro flame devices (MFDs) for gas, the design of liquid-fuel multifunction devices must provide preliminary preparation of the combustible mixture in the pre-chamber zone, special nozzles or in the air supply channels, and also provide dispersion of the front surface in the form of a multitude of micro flame along the input section of the combustion zone (Pchelkin, 1984). One of the approaches for coming micro flame combustion is the arrangement of a perforated cone with an air nozzle. In air (or pneumatic) nozzles, the kinetic energy of the air flow is spent on crushing the fuel jet, so a large amount of air is required to obtain a high quality spray. As part of the combustion chamber GTD with front perforation, an air nozzle stabilizer was investigated (Sudarev & Maev, 1968). The air entering the burner, twisting in the blades of the input register, picks up the fuel jets that flow out of the fuel tube at excess pressure and mix with it. Then the fuel-air mixture, flowing through the cone of stabilization and passing through the output register, exits a swirling flow into the combustion zone of the chamber,the perforated front cone of the chamber (Dostiyarov, Tumanov & Umyshev, 2016). At the same time, there is a developed micro flame combustion along the front. In this part, the role of stabilizers is performed by shaded perforation sectors.

The combustion chamber was investigated on an experimental test bench by burning Kerosene TS-1 (at the stand of Moscow State Technical University named after N.E. Bauman) (Dostiyarov, 1999) and natural gas (at the stand of AUES (Almaty University of Energy and Communications)) (Dostiyarov,2000c) in several stages:

1. assignment of blades optimum angles for input and output recirculation zone amplifiers of air nozzle;

2. accurate grinding of micro flame front device of GTD combustion chamber while natural gas combustion.

The angle choice of assignment of the recirculation zone amplifiers blades affects the quality of mixing of the fuel-air mixture and the hydraulic losses in the burner device (Sudarev & Antonovskiy, 1985). Figure 3 shows dependence of the coefficient of resistance on the angle of installation of the blades.

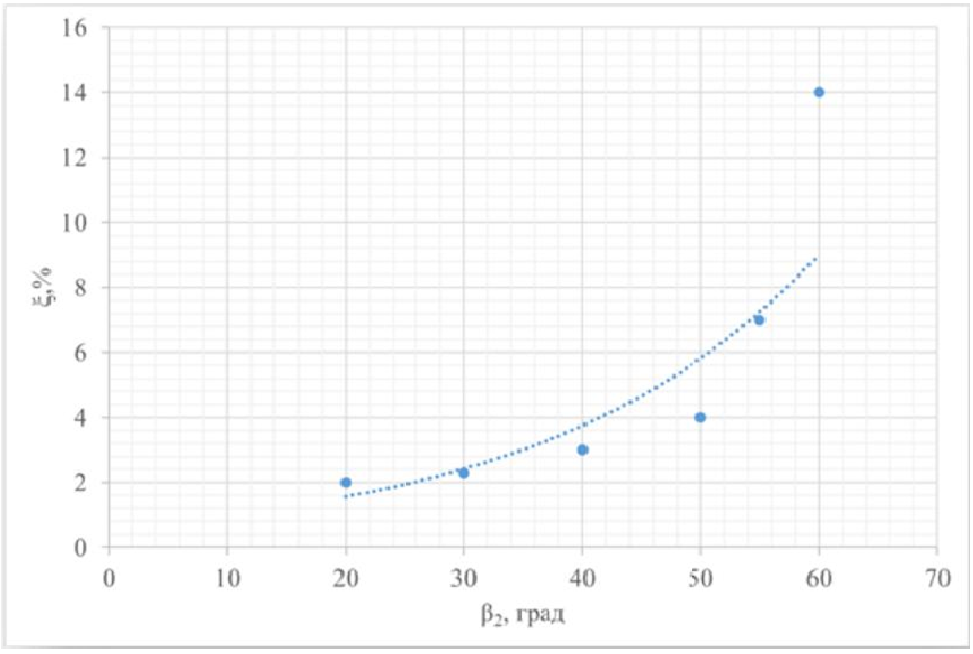


Figure 3 – Dependence of the Coefficient of Resistance on β_2

Dependence of the coefficient of resistance ξ_{op} on the assignment angle (β_1) is given in the works (Narezhniy & Sudarev, 1973), which show, that when $\beta>40°$ hydraulic losses increase dramatically, and a decrease of β_1 to 30°and less reduces the generation of turbulence in the burner chamber. For the combustion of heavy fuel draws can be used an air-stabilizer nozzle, but it should be performed as shown through (Buhman, 1994) a central hole (8) for ejection of high-temperature combustion products into the fuel-air mixture preparation chamber.

Plate perforating has certain advantages when used in combustion chambers with a preliminary preparation of a lean mixture.

The quality of the mixing was determined from the results of the experiment on the dependence $\eta_r = f(\alpha_\Sigma)$ and $C_{NO\Sigma} = f(\alpha_{dr.})$ (figures 4, 5).

The effect of the air flow twisting by the structural elements of the vortex burners on the burning rate of the fuel and the NO_x output has been repeatedly confirmed by experiments (Dostiyarov, 1983). The same effect was clearly traced in experiments with "air" nozzles (Ahmedov & Tsirulnikov, 1984). This circumstance made it possible to determine the significant influence of the installation angles of the profiles in the MFD on the NO_x emission. In order to test this assumption, special studies were carried out on

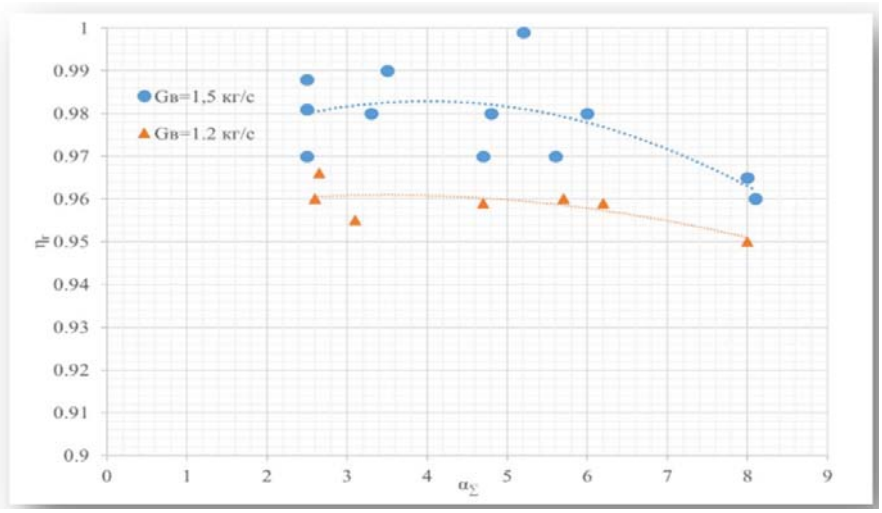


Figure 4 – Dependence of the Completeness of Combustion in the Air Nozzle on the Total Excess Air Factor

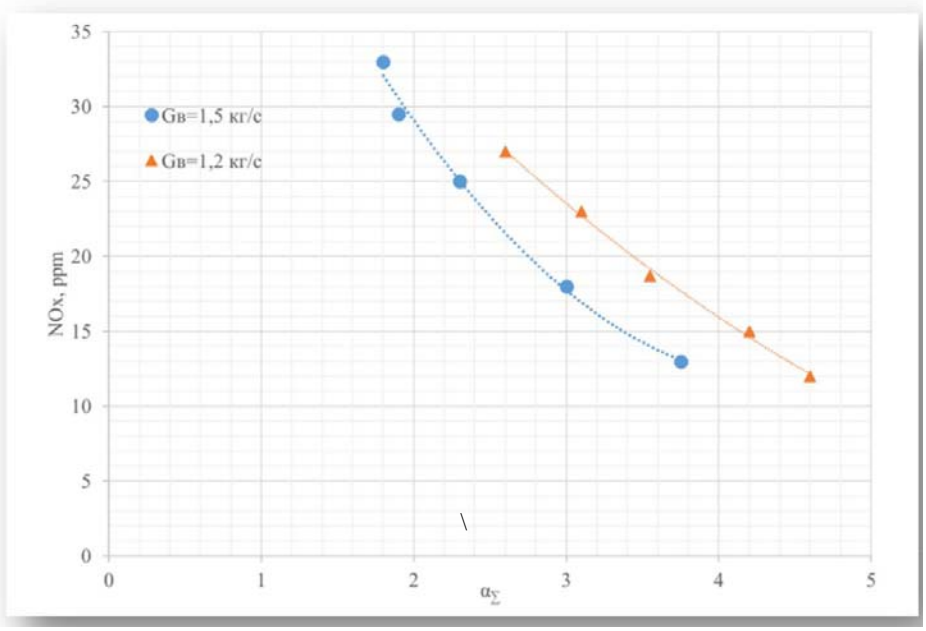


Figure 5 – Dependence of the NO_x Output on the Excess Air Factor in the Combustion Zone

the combustion chamber options equipped with an "air" stabilizer nozzle (ASN), performed by the authors (Lefebvre & Ballal, 2010) with different angles of output flow twist of the fuel-air mixture. Figures 6 and 7 show the influence of setting the output register items angle of ASN β_2- for two variants of the combustion chamber with different angles of output of the front portion of the flame tube ($\theta = 70°$ and $120°$). From the studies carried out at the corners $\beta_2 = 20°$; $30°$; $40°$ and $60°$ it follows that for the chamber version with $\theta = 70°$ the smallest output of NO_x was observed at $\beta_2 = 20°$, and for variant $\theta = 120°$, with $\beta_2 = 30°$.The explanation of the obtained results can be given by analyzing the flow structure in the head section of the flame tube, which determines the distribution of the temperature field and significantly influences the parameter of the residence time of the combustion products in the fire zone, as noted in the studies (Umyshev, Dostiyarov, Tumanov & Wang, 2017).

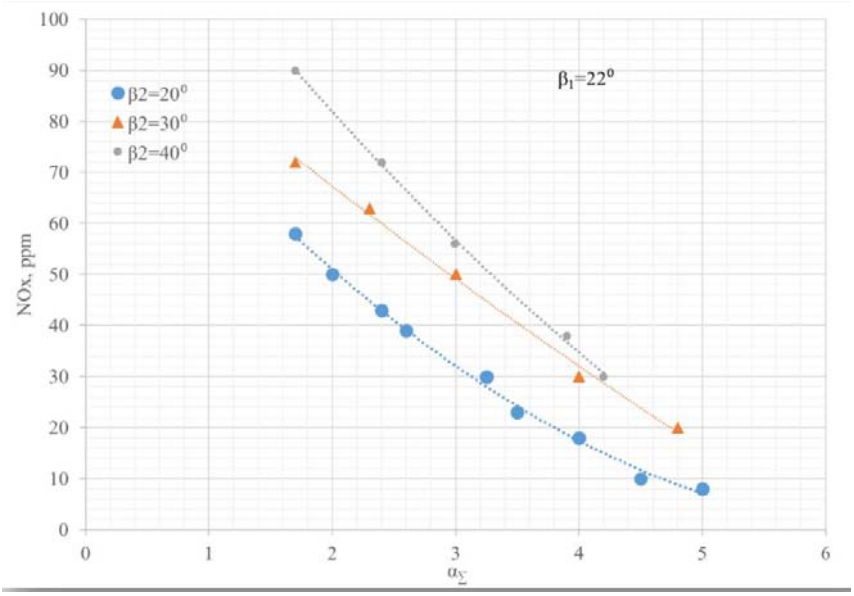


Figure 6 – Influence of the Installation Angles of the Input and Output Recirculation Zone Amplifier and the Angle of Front Opening Flame Tube on the Output of NO_x

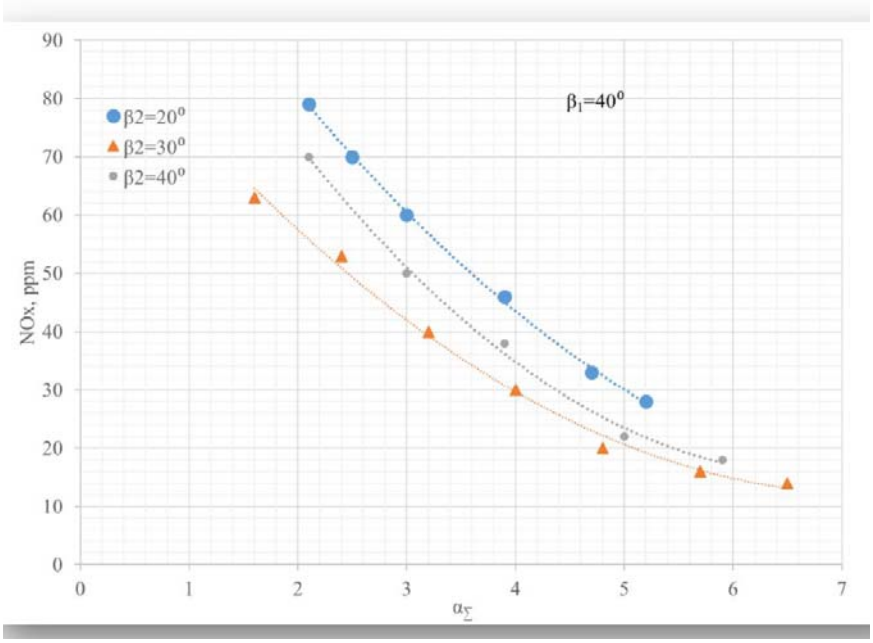


Figure 7 – Influence of the Installation Angles of the Input and Output Recirculation Zone Amplifier and the Angle of Front Opening Flame Tube on the Output of NO_x

Thus, increasing the flow twisting angle in ASN increased the size of ZRC and hence the share of circulating gases, which increased the "residence time" in the high-temperature zone. In accordance with this emission NO_x with β_2= 40° became larger than, in the case of β2= 30°. Here it should be noted that for small values of $\beta_2$in the case of flame tube as θ = 120° was a separation of the flow from the walls of the transition cone, while the amount of gas circulating here considerably exceeded that in the center of the chamber, i.e. actually in the ZRC which also increased the total "residence time" and predetermined the increased NO_x output in combustion products.

The largest emission of NO_x during the experiments was observed at β_2 = 20°, which was explained by the increased size of recycling zones (including in the peripheral sections of the transition cone). In general, the deterioration in emission results in NO_x with β_2 = especially, in comparison with the ASN options. Also, preliminary twist of the flow is being performed at the input recirculation zone amplifier β_1 = 22° and 40° (figures 6 and 7), which was caused by a significant decrease in the quality of the preliminary preparation of the combustible mixture along the ASN path. The latter once again indirectly confirmed the need for such "preparation" in MFD structural elements.

Findings. Analysis of the results shows that the correct perforation increases the efficiency of the combustion process, increases the completeness of combustion of the fuel and reduces the formation of nitrogen oxides, especially when the chamber is operating in the design mode. In air burners, it is very important to choose the correct ratio of mass flow rates of air and fuel (for liquid fuels it can vary from 3 to 5). The angle of conicity of the front part of the flame tube exerts a significant effect on the quality of combustion. Therefore, for a detailed study of the effect of the angle of installation of blade recirculation zone amplifiers, as well as the perforation of the front and the stepwise supply of cooling air, it is necessary to perform numerical simulation of the process in the burner and in the primary zone of the combustion chamber [8].

For a long time, nitrogen oxides were not given enough attention. The presence of nitrogen oxides in the air is one of the reasons for the formation of smog in industrial regions of Kazakhstan and large cities. But even today in the Republic of Kazakhstan, car toxicity is measured only on*CO* content in the exhaust gas (Dostiyarov, 2000). Analysis of the main reasons for the formation of nitrogen oxides in various devices and prospects for the development of energy showed that traditional methods of burning fuel do not provide the required parameters.

Increasing the efficiency of fuel combustion can be obtained with the use of micro flame combustion (Dostiyarov, 2000).Despite the limited amount of experimental data on the use of micro flare incineration, various authors (Dostiyarov, Userov & Maisutov, 2006) noted the following positive qualities of this method: low losses of gas head, reduction of structural dimensions, low temperature field unevenness at the outlet from CS, low yields of nitrogen oxides with products combustion, reduced radiation losses (Lebedev, 1984; Kibarin, 1991; Maisutov, 2008). It was known from the middle of the twentieth century (Patent FRG No876936, 1953), that the technology of micro flare combustion has begun to attract scientists' attention relatively recently. At present, there are several main directions of micro flame combustion, but all have one thing in common: the "smearing" of the flare along the front and the volume of combustion (Dostiyarov, 2000). For calculation the concentration of nitrogen oxides taking into account the above, the following procedure was proposed. In the combustion zone, are distinguished forward flow and zone of reverse currents. The direct stream is divided into *i-belts*, which are bounded by the surfaces of the carp tube, the zone of the reverse currents and the cross-sections of the aperture passing through the axes for supplying secondary air perpendicular to the carousel axis. With a distinguished distribution of air flows, the volume concentration of nitrogen oxides in the combustion zone can be determined by the equation:

$$(C_{NO})_I = \sum(i=1)^n \cdot (C_{NO})i + 2G_{обр} \cdot \sum_{i=1}^{n} \cdot (C_{NO})i + G_{обр} \cdot (C_{NO})зот/G_I; \quad (1)$$

n – belts count; G_i – air flow consumption through*i – belt*, kg/sec; G_{wh} – consumption of recycled gases through ZRC, kg/sec; G_I – total air flow through the combustion zone, kg/sec; $(C_{NO})i$ – volume concentration of nitrogen oxides in i-belt, whirl/%; $(C_{NO})ZRC$ – volume concentration of nitrogen oxides in in i-belt, whirl/%.

The volume concentration of nitrogen oxides NO_x in each zone is calculated by the equation:

$$(C_{NO})j = 37 \cdot 10^{11}\sqrt{(C_{O_2)j}} \cdot (C_{H_2})j \cdot \exp\left(-\frac{65000}{T_{эфj}}\right) \cdot \sqrt{0{,}1 \cdot \frac{P_B}{T_{эфj}}} \cdot \tau_{npj}; \quad (2)$$

where $j=n+1$ – count of zones (count of belts + ZRC); T_{prj} – the residence time of the combustion products in j-zone, (sec); T_{efj} – the effective temperature in j-zone chamber (K); P_v – air pressure at the input to the combustion chamber, (mPa); $(C_{O!})(C_{!!})$ – volume concentrations of oxygen and nitrogen in j-zone.

For micro flame combustion it is reasonably possible to assume uniform distribution of air-fuel ratio in the combustion zone. In this case, it can be assumed that there is an average effective temperature that determines the release of nitrogen oxides, which depends on the quantities a_g and T_v, heat loss and the coefficient of completeness of combustion. For these conditions, formula (1) and (2) for chambers with one row of holes can be formed:

$$(C_{NO})к=13 \cdot 10^{11}\left[\frac{\alpha_г(\alpha_г-1)\cdot L_o^3}{(1+\alpha_г \cdot L_o)3}\right] 0{,}5 \cdot \exp\left(-\frac{65000}{T_{эф.ср}}\right) \cdot \sqrt{\frac{0{,}1 \cdot P_B}{T_{эф.ср}}} \cdot K\left[K_{фр} \cdot \tau_1 + 2Kобр(\tau_1 + \tau_2) + K_{обр} \cdot \tau_{3OT}\right] \cdot \frac{\alpha_г}{\alpha\sum}; [млн^{-1}]$$

where a_g – coefficient of excess air in the combustion zone; L_o – stoichiometric coefficient; α_Σ – the total coefficient of excess air from the combustion chamber; $K_{фр}=\frac{C_{фр}}{G_I}$ – relative air flow through the front device combustion chamber; $\tau_1, \tau_2, \tau_{3OT}$ – the residence time in the zones, respectively, up to the secondary air intake opening, afterthe opening and in ZRC; $K_{обр}=\frac{C_{обр}}{G_I}$ – relative air flow through the back-flow zone.

For calculation it is necessary to know the size of the zone of reverse currents and the number of gases recirculating in it. These values depend on the geometry of the front device, the flow parameters and the dimensions of the hole along the length of the carpal tube. The results of calculations on the proposed method and comparison with the experimental data are shown in figures. The discrepancy of data does not exceed 12% in the whole range of parameters of the regimes studied, which allows us to recommend this technique for use [9].

The proposed method for calculating the concentration of nitrogen oxides, taking into account the structure of the flow, allows us to select the geometry of the front of the combustion chamber at the design stage, not only from the point of view of ensuring minimum hydraulic losses and stability.

Conclusion. An analysis of the causes of the toxic substances formation in the combustion of natural fuels was concluded. General principles of the combustion process and chain reactions were considered. Various options and approaches for reducing and suppressing the formation of toxic substances werepresented. Technological methods of suppression were considered, which include: injection of water and steam, recirculation of combustion products, optimal air distribution, intensification of the mixture formation, stepwise combustion, catalytic combustion.

Devices based on poorly flowing bodies in view of their simplicity and high environmental parametersare of particular interest. It is shown that the use of poorly flowing bodies allows to provide combustion in a wide range of air consumption. One of the options for using poorly flowing bodies are the angle stabilizers. The analysis of the methods of the micro flame combustion method and various devices based on the MFS makes it possible to draw the following conclusions:

the supply of fuel to the combustion zone, the placement of injectors, fuel nozzles, the location of obstacles in the form of well-worn or poorly flowing bodies greatly influence the combustion process, its characteristics and the release of toxic substances, in particular nitrogen oxides;

the main principle of micro flame combustion is the "smearing" of the flare along the combustion volume, however, the implementation of such a principle can be different. In some cases, multiple nozzles are used, others use perforated surfaces or poorly flowing bodies;

the principle of micro flame combustion has a great potential. On the basis of the principle, various devices have been developed in which the gas burns both diffusively and kinetic;

the closest to the idea of the dissertation are jet-stabilizing burners based on poorly flowing bodies.

As a result of research, the conceptual principles of creating highly efficient methods of drying grain, aimed at intensifying processes and rational use of material and energy resources were formulated, which is achieved by modeling and optimizing the perspective designs of heat generators. Also, the hydrodynamic, kinetic and heat mass-exchange regularities of the grain drying process are identified and mathematically described. Numerical values and range of variation of the main kinetic and hydrodynamic characteristics with variable heat supply are determined. Mathematical model of the process of grain drying was developed. A mathematical model of stabilization of material and heat flows has been developed. Balanced distribution of thermal and material flows allows you to achieve the fullest possible use of energy. The minimization of thermodynamic losses by 20% from the effective inside of the cyclic and external regeneration of the "heat sinks" of the main and auxiliary outfits has been achieved.

REFERENCES

[1] Tsuglenok N.V., Manasyan S.K. Theoretical bases of intensification of the process of grain drying // Proceedings from All-Russian Scientific and Practical Conference: Agrarian science at the turn of the century. Krasnoyarsk, 2005. P. 134-135.

[2] Umyshev D.R., Dostiyarov A.M., Tumanov M.Y., Wang Q. Experimental investigation of v-gutter flame holders // Thermal Science. 2017. 21(2).

[3] Zhuravlev A.P. Grain drying and grain drying devices. Kinel: RITS SGHA, 2014.

[4] Ahmedov R.B., Tsirulnikov L.M. The technology of burning combustible gases and liquid fuels. M.: Nedra, 1984.

[5] Buhman M.A. Research and development of vortex burners and cyclone combustion chambers // Energetika i toplevnie resursy Kazhakhstana. 1994; Demidov P.G. Air conditioning of durum wheat. 1938.

[6] Dostiyarov A.M. Influence of working and geometric parameters of combustion with a micro flame front device on the toxicity of combustion products // Work processes and improvement of heat engineering and electrical devices. Alma-Ata, 1983d.

[7] Dostiyarov A.M., Userov A.G., Maisutov T.B. Analysis of studies on emissions of toxic components // Proceedings from V International Scientific and Practical Conference: Energy, Telecommunications and Higher Education in Modern Conditions. 2006.

[8] Ivashov V.I., Kapovsky B.R., Plyasheshnik P.I., Pchelkina V.A., Iskakova E.L., Nurmukhanbetova D.E. Mathematical simulation of one-stage grinding of products frozen in blocks // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technical sciences. **2018**. Vol. 5, N 431. P. 48-65. https://doi.org/10.32014/2018.2518-170X.9. ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

[9] Abdeli D.Zh., Yskak A.S., Novriansyah Adi, Taurbekova A.A. Computer modeling of water conning and water shut-off technology in the bottom hole of oil well // News of the national academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Kazakhstan, Almaty, **2018**. P. 86-94. https://doi.org/10.32014/2018.2518-170X. ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

[10] Kibarin A.A. Development of a micro flame front device for the combustion chamber of the transport GTD with reduced formation of nitrogen oxides. M., 1991.

[11] Lebedev V.P. Development of devices for micro flame combustion of fuel and intermediate heating of gases in GTP. M., 1984.

[12] Lefebvre A.H., Ballal D.R. (2010). Gas turbine combustion: Alternative Fuels and Emissions, Third Edition. Taylor & Francis.

[13] Maisutov T.B. Theory and practice of assessing the environmental safety of gas turbine plants. Taraz: Ecologiya, 2008.

[14] Pchelkin U.M. Combustion chambers of gas turbine engines. M.: Mashinostroenie, 1984.

[15] Rebinder P.A. (1933). Physical and chemical flotation processes. Sudarev A.L. & Antonovskiy V.I. (1985).

Руслан Умирзаков[1], Джалолиддин Мукхиддинов[2],
Мухаббат Абдирова[3], Булбул Онгар[3]

[1]Сәкен Сейфуллин атындағы Қазақагротехникалық университеті, Астана, Қазақстан,
[2]ТашГУатындағы И. Каримова, Ташкент, Өзбекстан,
[3]Алматы мемлекеттік энергетика және электрондық технологиялар колледжі, Қазақстан,
[4]Алматы энергетика және байланыс университеті, Қазақстан.

ЖЫЛУ ГЕНЕРАТОРЫНДА ЖӘНЕ ЖАНУ ӨНІМДЕРІНДЕ АСТЫҚТЫ КЕПТІРУ РЕЖИМІНЕ ӘСЕРІ

Аннотация. Мақалада жылу генераторының әсер етуі, оның әртүрлі айнымалы және әр түрлі жағдайларда жану өнімдерінің уыттылығына әсер етуі қарастырылады. Астықты кептіру процедурасын уақтылы және дұрыс орындау өте маңызды аспект болып табылады. Оңтайлы нәтиже алудың бірнеше нұсқасы ұсынылды. Жүргізілген зерттеулер нәтижесінде астықты кептірудің ұсынылған тәсілі оның сапасын жақсартуға ықпал етеді, астықтың пісу уақытын қысқартады, сондай-ақ астықтың ылғалдылығы мен жетілуі

тұрғысынан астық массасын түзетеді. Сондай-ақ, бұл әдіс астықтың сипаттамасын және оның сыртқы түрін жақсартуға ықпал ететінін атап өткен жөн. Ұсынылған әдіс микроорганизмдер мен зиянкестердің тіршілігін тоқтатады. Жұмыстың практикалық және теориялық маңыздылығы алынған деректерді астықты кептіру мәселелері бойынша практикада және зерттеулерде қолдану мүмкіндігіне негізделеді.

Түйін сөздер: астық кептіру, Жылу генераторы, жану өнімдерінің уыттылығы, кептіру режимі, астық ылғалдылығы, Формула, температуралық режим.

Руслан Умирзаков[1], Джалолиддин Мукхиддинов[2],
Мухаббат Абдирова[3], Булбул Онгар[3]

[1]Казахкий агротехнического университета им. Сакена Сейфуллина, Астана, Казахстан,
[2]ТашГТУ им. И. Каримова, Ташкент, Узбекистан,
[3]Алматинский государственный колледж энергетики и электронных технологий, Казахстан,
[4]Алматинский университет энергетики и связи, Казахстан.

ВЛИЯНИЕ РАБОТЫ ТЕПЛОГЕНЕРАТОРА НА РЕЖИМ СУШКИ ЗЕРНА И НА ТОКСИЧНОСТЬ ПРОДУКТАХ СГОРАНИЯ

Аннотация. В статье рассматривается влияние теплогенератора, режимов его работы с различными переменными и при различных условиях на режим сушки зерна и на токсичность продуктов сгорания. Своевременное и правильное выполнение процедуры сушки зерна является чрезвычайно важным аспектом. Предложено несколько вариантов получения оптимального результата. В результате проведенных исследований предложенный способ сушки зерна способствует улучшению его качества, сокращает время созревания зерна, а также корректирует зерновую массу с точки зрения влагосодержания и зрелости зерна. Следует также отметить, что данный метод, способствует улучшению характеристик зерна и его внешнего вида. Предлагаемый способ приостанавливает жизнедеятельность микроорганизмов и вредителей. Практическая и Теоретическая значимость работы заключается в возможности применения полученных данных на практике и в исследованиях по вопросам сушки зерна.

Ключевые слова: сушка зерна, теплогенератор, токсичность продуктов сгорания, режим сушки, влажность зерна, Формула, температурный режим.

Information about authors:

Umirzakov Ruslan, Kazakh Agrotechnical University named after Saken Seifullin, Astana, Kazakhstan; Ars_uran@mail.ru; https://orcid.org/0000-0002-3047-9046

Mukhiddinov D.N., TashGTU them. I. Karimova, Tashkent, Uzbekistan; https://orcid.org/0000-0002-2778-2546

Abdirova Mukhabbat, Almaty State College of Energy and Electronic Technologies, Kazakhstan, Muhabbatabdireva@mail.ru; https://orcid.org/0000-0002-8624-2240

Bulbul Ongar, Almaty University of Power Engineering and Telecommunications, Kazakhstan; Onqar_ Bulbul@mail.ru; https://orcid.org/0000-0002-8333-8343

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 187 – 194 **https://doi.org/10.32014/2019.2518-170X.23**

UDK 551.251:622.333
MRNTI 38.37.21

A. B. Baibatsha[1], Suping Peng[2], S. B. Satibekova[1]

[1]Kazakh National Research Technical University named after K. I. Satbayev, Almaty, Kazakhstan,
[2]State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology (Beijing), Beijing, People's Republic of China.
E-mail: baibatsha48@mail.ru, psp@cumtb.edu.cn, s.satibekova@bk.ru

ESTIMATION OF THE PHYSICAL-MECHANICAL PROPERTIES OF THE ROCKS ON THE DEGREE OF COAL METAMORPHISM

Abstract. This article discusses the physical-mechanical properties of Karaganda basin coal seam wall rock, depending on the degree of metamorphism, which is determined by a maturity parameter of the reflectivity of organic matter - vitrinite. This method is significant in connection with the increase of geological exploration for coal, as well as methane, in connection with the preparation of new minefields at deep depths, when the coal core is the only substance to determine the properties of coal and their rocks. The determination of the physical and mechanical properties of coal seam wall rock, taking into account the stage of coal metamorphism, is great practical importance in the mining industry. Based on previous years' materials and laboratory data, which we conducted together with our Chinese colleagues in the State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology (Beijing, China), and based on M.A. Ermekov (1990) mathematical model of metamorphism describes the degree change of coal metamorphism and physical-mechanical properties of coal seam wall rock by a depth. This research contributes to the solution of problems related to the roof stability of coal seams in mines since the physical and mechanical properties of rocks are one of the main criteria for mining and technical works.

Keywords: vitrinite reflectivity, coal metamorphism, physical and mechanical properties of rocks, coal seam, roof stability, methane.

Introduction. Karagandy coal basin is located in Central Kazakhstan. In terms of coal reserves and quality, it occupies a leading position among the largest coal-bearing basins in the world. In the basin extended in the latitudinal direction for 120 km with an average width of 60 km, four coal-bearing areas are distinguished: Tentek, Sherubajnura, Karagandy, and Verhnesokur (figure 1).

Carboniferous coal-bearing sediments with a total thickness of about 4,000 m are divided into seven formations according to coal saturation, lithological composition, fauna, flora, and other characteristics: akkuduk, ashhylyajryk, karagandy, nadkaragandy, dolinka, tentek, shahan.

The karagandy, dolinka and partly ashhylyajryk and tentek formations are productive in the Carboniferous sediments. In this series, there are up to 80 layers and seams of coal with a total thickness of up to 110 m. The thickness of coal seams increases in the basin from west to east, and within each region from north to south [1].

Accounting for the coal metamorphism in solving mining and geological problems is of paramount importance. Metamorphism in the Karagandy basin is manifested in an increase in its degree: 1) with stratigraphic depth of formation according to the Hilt-Skok law; 2) with increases ofthe coal-bearing strata thicknesses; 3) in a section through the dip of layers with an increase in the modern depth of their occurrence [2].

In the Karagandy basin, taking into account the influence of the post-inversion component of metamorphism, it was possible to refine the predictions of the distribution of coal by grades to its deep horizons.

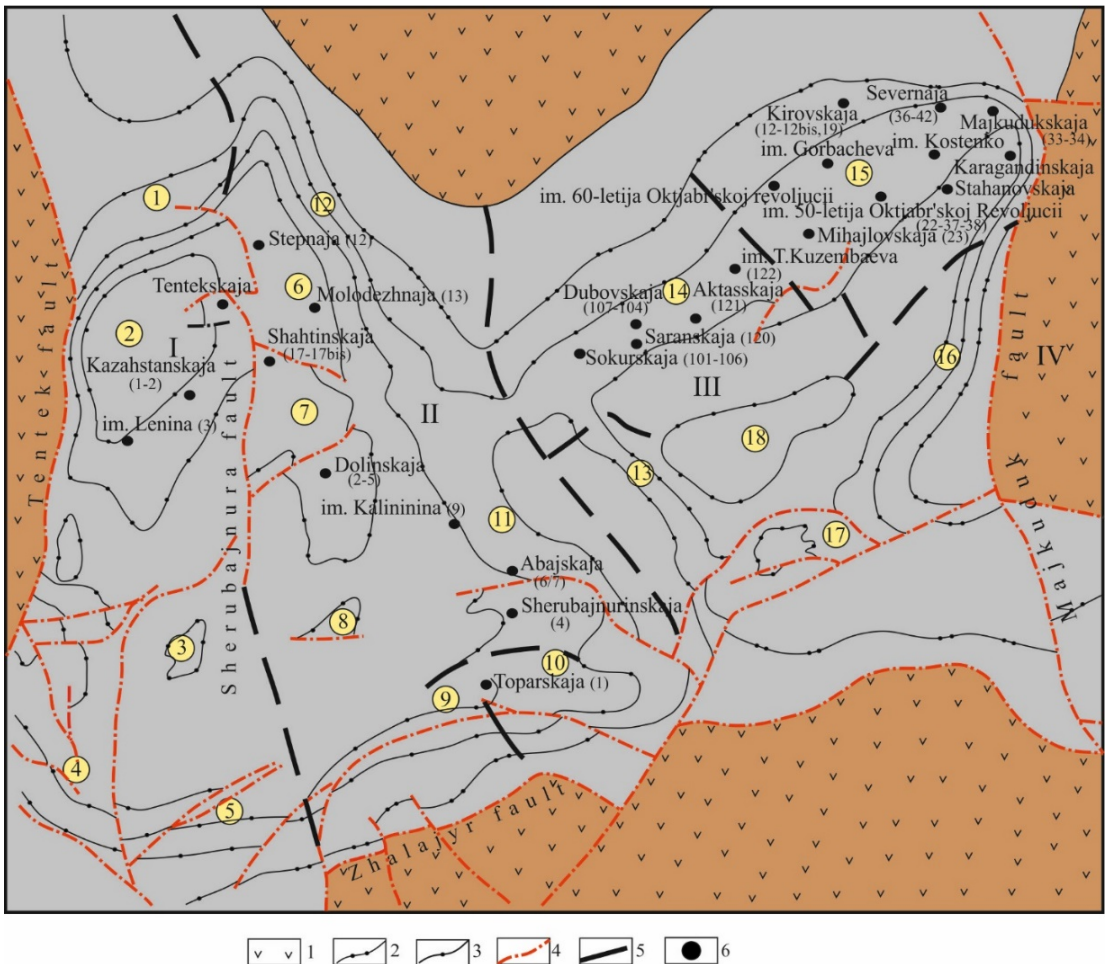


Figure 1 – Schematic geological map of the Karagandy basin:
1 – pre-Carboniferous deposits; 2 – lower border of the ashhylyajryksuite; 3 – boundaries of the karagandy suite;
4 – faults; 5 – borders of coal-bearing areas and sites; 6 – operating mines, in numbers – old name.
Coal-bearing areas: I – Tentek; II – Sherubaynura; III – Karagandy, IV – Verkhnesokur.
Basin areas (numbers in circles): 1 – Manzhin; 2 – Tentek; 3 – Karagok; 4 – Sasykkol; 5 – Taskamys;
6 – Karazhar-Shahan; 7 – Dolinka; 8 – Kolpak; 9 – Kishkenekol; 10 – Southern; 11 – Central;
11 – Northern; 13 – Alabas; 14 – Saran; 15 – Promyshlennyi; 16 – Maykudyk; 17 – Taldykudyk; 18 – Dubovka

Studying the degree of coal metamorphism allows solving problems related to predicting the roof stability of coal seams in mining, which in turn depends on the physical and mechanical properties of rocks.

Research methods. The task of the study is to assess changes in organic matter, in this case, vitrinite, to establish relationships between quantitative petrographic features, properties of coal and the physico-mechanical properties of coal seam wall rock. To quantify the degree of metamorphism of coal seam wall rock, on which their physicomechanical properties depend, we used the indices of reflectivity of vitrinite and its refractive indices, measured in immersions. We carried out such studies together with our Chinese colleagues in the State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology (Beijing, China).

As noted by J.T. McCartney, M. Teichmuller (1972), M.A. Ermekov (1990), the degree of coal metamorphism, estimated by the reflectivity of vitrinite, serves as a "geological thermometer" and allows recovering the geological history of evolution, in particular, the depth of the rocks and the duration of their stay at the maximum depth [3-5]. A mathematical model of coal metamorphism, created by Professor M.A. Ermekov (1990) based on the topokinetic Kolmogorov-Erofeev equation, has the form:

$$I = 100\left[1 - e^{-\sum \exp(B - A/T)}\right] \quad (1)$$

here I – the impulse of metamorphism according to M.V. Golitsyn (1975), °C/billion years; t – the duration of the stay of coal (coal seam wall rock) at a given depth, billion years; T – an absolute temperature of coal in the depths, °K.

For the process of regional coal metamorphism in the Karagandy coal basin, the coefficients of equation (1) take the following values: A=7300, B=21,6. The results of Professor M.A. Ermekov's calculation of (1990) lead to the following conclusions: coal metamorphism began at the beginning of the Upper Carboniferous after 30-35 million years from the beginning of the ashhylyajryk formation, i.e. after deposition of the completely coal-bearing stratum. At the same time, immersion of the lower part of the sequence was accompanied by an increase in temperature to 70°C. The process of further metamorphism was intense and was completed by the beginning of the Upper Permian when the depression exceeded 5 km, and the temperature reached 135-140°C. After inversion at the end of the Upper Permian, the lower boundary of the coal-bearing strata rises to a value of 3 km and the decrease in its temperature to 80-85°C sharply slowed down the process of metamorphism. The impulse of metamorphism was at the same time 85 %.

Adopted by M.V. Golicyn (1975) the correspondence of temperatures of regional and contact-thermal metamorphism to the stages of metamorphism of Carboniferous coals of Central Kazakhstan is preserved [6]and according to calculated impulses of metamorphism for the duration of regional metamorphism, taken equal to 10 million years, and thermal – 5 thousandyears (table1).

Table1 – Temperature and impulse values at regional and thermal metamorphism

Stage of coal metamorphism	Rank of coal	Regional		Thermal	
		Average temperature, °C (Golicyn, 1975)	Estimated impulse, % (Ermekov, 1990)	Average temperature, °C(Golicyn, 1975)	Estimated impulse,% (Ermekov, 1990)
I	LF	60	0,7	–	–
II	G	85	3,3	up to 300	3,3
III	Ft	110	11,9	325	5,3
IV	C	130	27,9	412	24,6
V	Fg	148	50,7	475	50,0
VI	Cc	163	72,4	525	72,2
VII-VIII	A	185	94,4	575	88,8
IX-X	A	250	100	695	99,8
LF - long-flame coal, G - gas coal, Ft - fat coal, C - coking coal, Fg - forge coal, Cc - carbonaceous coal, A - anthracite.					

According to the proposed model, a change in the reflectivity index of vitrinite (R□) from the metamorphism stage was established (I) (table 2).

Table 2 – Indicators of coal metamorphism

Stage of coal metamorphism	$V^{d.a.f.}_{av}$, %	R□, %	$10R_0$, unit.	I, %
L	–	0,58	73,5	0,72
G	32	0,79	80,5	3,3
Fat	25	1,07	88,5	11,9
C	17	1,40	96,5	27,9
F	12,5	1,80	104,0	50,7
CC	9	2,37	114	72,4
A	–	2,77	121	94,40

As a result of research, it was established that with the depth of the coal seams the volatile yield decreases, the reflectivity of vitrinite increases, and rank composition of coal changes from lignite to anthracite accordingly (figure 2) [3, 4].

According to ISO 11760 the physical and chemical properties of coal are determined by its geological maturity (rank), petrographic composition and quantity (as well as the nature and form of association) of

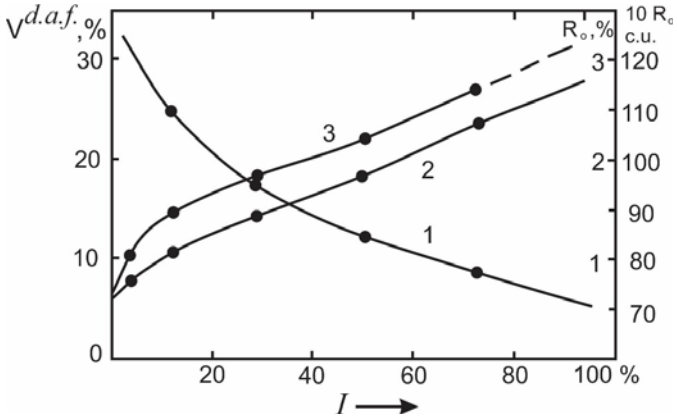


Figure 2 – Dependence of volatile yield, reflectivity indicators on the "impulse" of metamorphism (after *M.A. Ermekov, 1990*): 1 – $V^{d.a.f.}$, 2 – R□, 3 – 10R□conditional units (c.u.).

the mineral substance present. Thus, for simplicity, this classification for coal is based on the following properties of coal: vitrinite reflectance, expressed as a percentage: mean random reflection, R_r, which is directly determined or calculated from R_{max}.

According to this standard, the coals are divided into three ranks: low (lignite and sub-bituminous coals), medium (bituminous coals) and high (anthracites) [7, 8]. According to GOST 25543-88 based on the vitrinite reflectivity indicators, coals are also divided into three types: lignite, bituminous coals, and anthracites or, which, depending on their genetic characteristics, are divided into 50 classes according to the average vitrinite reflectivity R□, determined according to GOST12113-94. Lignite coals are characterized by an average vitrinite reflectivity R□ less than 0.60 %, bituminous coals – R□=0,40-2,59 %, anthracites – 2,20 and more [9, 10]. Dedicated 50 classes of coal characterize the degree of post-sedimentation transformation of their host rocks from the stage of initial catagenesis to the stage of metagenesis, inclusive [5, 11, 12]. The H_{str}, parameter, which shows the stratigraphic levels of the occurrence of terrigenous rocks according to the degree of their post-sedimentation transformation, in this case, increases from late metagenesis to initial catagenesis, acquiring values accordingly H_{str} = 1…10.

Mathematical processing of field and laboratory research results, taking into account the cumulative effect of all selected petrographic and geological [2, 13, 14] features, allowed the creation of universal geological and mathematical models of the physical-mechanical properties of rocks in terrigenous formations. So, multidimensional geological and mathematical models of ultimate strength under uniaxial compression (σ_c) for the main lithological types of terrigenous rocks expressed as follows:

for fine and medium grained sandstones:

$$\sigma_c = 166{,}46 - 0{,}37X_3 + 0{,}06X_4 + 0{,}123X_5 + 0{,}652X_6 - 0{,}42X_7 + 0{,}23CM_1 + 0{,}45CM_2 + 0{,}52CM_3 - 0{,}01C_1 - 0{,}16C_2 + 0{,}26C_3 + 0{,}017H - 2{,}99H_{str}, \quad R = 0{,}99; \qquad (2)$$

for fine grained sandstones:

$$\sigma_c = 65{,}75 - 0{,}06X_1 + 0{,}156X_2 + 0{,}7X_3 + 0{,}24CM_1 + 0{,}2CM_2 + 0{,}41CM_3 - 0{,}027C_1 - 0{,}033C_2 + 0{,}69C_3 + 0{,}032H - 2{,}24H_{str}, \quad R = 0{,}98; \qquad (3)$$

for siltstone:

$$\sigma_c = 47{,}74 + 0{,}1X_1 + 0{,}286X_2 + 0{,}012CM_1 + 0{,}0470M_2 + 0{,}067CM_3 - 0{,}06C_1 + 0{,}034C_2 + 0{,}32C_3 + 0{,}05H - 1{,}28H_{str}, \quad R = 0{,}96; \qquad (4)$$

for argillite:

$$\sigma_c = 35{,}4 + 0{,}29X_1 + 0{,}157C_2 + 0{,}515C_3 + 0{,}004H - 0{,}52H_{str}, \quad R = 0{,}92. \qquad (5)$$

where fractions, mm: X_1 – 0,01-0,05, X_2 – 0,05-0,1, X_3 – 0,1-0,2, X_4 – 0,2-0,3, X_5 – 0,3-0,4, X_6 – 0,4-0,5, X_7 – 0,5-1,0; clastic material: CM_1 – quartz, CM_2 – amount of feldspar, CM_3 – the amount of rocks; cement: C_1 – clayey, C_2 – carbonate, C_3 – siliceous; H, м – depth of terrigenous rocks.

The coefficients of multiple correlations, which is a measure of the cumulative effect of all the geologic-petrographic factors cited, have values from 0.92 to 0.99, i.e. their connection with the strength properties of rocks approaches functional. Often, the layers of rocks of the same lithological composition, occurring in different geological and structural parts of the field, due to the difference in thermodynamic conditions of formation characterized by variability of physical and mechanical properties. An example of this is the drastic changes in the properties of rocks and the coal metamorphism in the zone of deep faults and in various modern geological and structural areas that were at the same level in the pre-inversion period of the basin development. For example, along the southern border of the Karagandy coal basin in the zone of influence of the sub latitudinal Zhalajyr deep fault (thrust), the coal metamorphism degree corresponds to CC rank, whereas these same stratigraphic horizons outside the zone of influence of the deep faults include layers of coal of Fat and C ranks.

The results of a wide-scale study of rockphysical-mechanical properties of the basin minefields located in various geological and industrial areas, coal-bearing formations and depths of occurrence are summarized in the research. The averaged values of the physical-mechanical properties of the main lithological types of the coal-bearing formations of the basin, obtained as a result of generalization and analysis of previous studies and new data on deep horizons (depth up to 900-1000 m), are given in table2 [2, 15, 16].

Table 2 – Physical-mechanical properties of rocks in the Karagandy coal basin

Structural block	Lithological types	Depth, m	ρ, g/cm^3	P, %	W, %	σ_c, MPa	σ_t, MPa	Softening		
								difficult	medium	easy
Ashhylyajryk and karagandy formations										
The north wing of the Karagandy and east wing of the Sherubainura syncline	sandstones fine- and medium-grained	Up to 50	2,49	14	5	33	2,7	64	15	21
		50-100	2,51	11	3	48	3,7	71	19	10
		100-300	2,55	9	3	63	5,0	94	4	2
		300-600	2,58	8	2	78	6,0	96	4	–
		More than 600	2,60	7	2	85	6,3	100	–	–
	siltstones	Up to 50	2,35	20	6	23	1,5	30	27	43
		50-100	2,47	13	4	32	1,8	33	27	40
		100-300	2,52	11	3	45	2,6	46	18	36
		300-600	2,55	10	3	50	3,4	54	26	20
		More than 600	2,58	9	3	52	4,0	60	30	10
	mudstones	Up to 50	2,25	19	7	15	1,0	13	5	82
		50-100	2,41	13	4	32	1,8	33	27	40
		100-300	2,52	11	3	45	2,6	46	18	36
		300-600	2,55	10	3	50	3,4	54	26	20
		More than 600	2,55	9	3	40	3,0	40	30	30
Dolinka and tentek formations										
The northern half of Sherubainura syncline (Tentek region)	sandstones fine- and medium-grained	Up to 50	2,31	17	6	21	1,9	47	20	33
		50-100	2,47	11	4	38	3,2	69	18	13
		100-300	2,51	9	3	58	4,3	85	8	7
		300-600	2,55	8	3	72	5,5	93	6	1
		More than 600	2,58	8	2	78	5,8	96	4	–
	siltstone	Up to50	2,25	20	8	15	0,9	23	17	60
		50-100	2,45	12	4	28	1,9	33	14	53
		100-300	2,5	10	4	42	2,5	46	14	40
		300-600	2,54	9	3	47	3,1	54	20	26
		More than600	2,56	9	3	50	3,8	60	24	16
	mudstone	Up to50	2,22	23	11	11	0,7	13	5	82
		50-100	2,40	17	6	17	1,5	18	12	70
		100-300	2,46	14	5	30	1,8	28	18	54
		300-600	2,52	11	4	36	2,3	33	22	45
		More than600	2,55	10	3	38	2,6	40	30	30

As can be seen from table 2, the physical-mechanical properties of coal seam wall rock naturally change depending on their lithological types, depth and stratigraphic level of occurrence. The most stable rocks are medium-grained sandstones of lower coal-bearing formations, lying on deep horizons, for example, they have values of compressive strength σ_c=90-140 MPa and tensile strength σ_t=5-10 MPa at depths of more than 600 m. With a decrease in grain size, the content of a clastic material, an increase in clay material in cement and a deterioration in the degree of lithification, the strength of sandstones decreases. Of all lithological types of coal seam wall rocks, mudstones have the lowest strength.

The sharp decrease in strength and density, the increase in porosity and the natural moisture of rocks at depths of up to 100 m are associated with the evolution of a weathered zone of coalstrata. The water resistance of rocks also naturally increases with depth. At depths of more than 600 m, sandstones of all coal-bearing formations are practically non-softable, non-softable also up to 60% of siltstones and up to 40% of mudstones. The geological nature of the regular variability of the physical-mechanical properties of rocks allows them to be estimated from geological studies of the coal-bearing strata [16].

Discussion of the results. Different paleotectonic and paleogeographic conditions at different stages of the tectonic evolution of the Karaganda basin led to a change in the character of coal content and the quality of coal. At depths of more than 1000 m, the metamorphism of coals is greatly enhanced and fat coals practically disappear, the areas with coking coals are sharply reduced. Forge coal hasmain distribution. Coals of the ashhylyajryk formation and the bottom of the karaganda formation are high-ash, hard-cleaning, belong to theC, Fg, Ft ranks. These coals are used for coking. Coals of the dolinka and the bottom of the tentek formation are fat, partially coking stage of metamorphism, are characterized by easy washability of coal and serve as valuable coking chemical raw materials. Coals of the upper horizons of the tentek formation mainly relate to G rank, difficult washability of coal, energetic.

In the basin, predominantly carbon-coking coals are being developed, representing 82.2% of the total production in the basin. Karagandy basin explored to a depth of 500-700 m. The mining industry has developed the depth of 400-500 m.

Conclusions. The ability to assess the properties of coal by the vitrinite reflectivityis an important factor in the petrographic analysis since it can be used not only for coals but also for their host clay and sandy rocks. This method of evaluation is also important in connection with the increase of a volume of geological exploration for associated methane, with a preparation of new minefields at deep depths, when a coal core will be only coal substance for judging the properties of coal.

Therefore, the determination of the physical-mechanical properties of coal seam wall rock, taking into account the stage of coal metamorphism in terms of the vitrinite reflectivity, is of great practical importance in geological prospecting and mining.

Acknowledgements. This work was supported by the scientific program№ BR05233713 «Comprehensive geological study of subsurface resources for the development of resource base and mining exploitation of new sources of ore raw materials in Kazakhstan».

А. Б. Байбатша[1], Супин Пен[2], С. Б. Сатибекова[1]

[1]Қ. И. Сәтбаев атындағы Қазақ ұлттық зерттеу техникалық университеті,
Алматы, Қазақстан,
[2]State Key Laboratory of Coal Resources and Safe Mining,
China University of Mining and Technology (Beijing), Beijing, China

ТАУЖЫНЫСТАРДЫҢ ФИЗИКАЛЫҚ-МЕХАНИКАЛЫҚ ҚАСИЕТТЕРІН КӨМІР МЕТАМОРФИЗМІНІҢ ДӘРЕЖЕСІ БОЙЫНША БАҒАЛАУ

Аннотация. Мақалада Қарағанды таскөмір алабының көмір сыйыстырушы таужыныстардың физика-механикалық қасиеттерінің органикалық зат – витриниттің шағылысу қабілеті көрсеткіші арқылы анықталатын көмір метаморфизмі дәрежесіне тәуелділігі қарастырылған. Мұндай әдіс көміргежәнеілеспе метанға геологиялық барлау жұмыстары көлемінің артуында, тереңдегі жаңа шахта алаңдарын дайындауда көмір және сыйыстырушы таужыныстар қасиеттері бойынша көмір керні жалғыз ғана ақпарат көзі болған жағдайда

маңызды болып саналады. Көмір метаморфизмі кезеңдерін ескере отырып, көмір сыйыстырушы таужыныстардың физикалық-механикалық қасиеттерін анықтау кен-техникалық жұмыстарды жүргізу кезінде аса зор практикалық мәнге ие. Бұрынғы жүргізілген жұмыстар мен State Key Laboratoryof Coal Resources and Safe Mining, China University of Mining and Technology (Бейжің, Қытай) зертханасында қытай әріптестермен жүргізілген зерттеулер, сонымен қоса М.А. Ермековтың (1990) метаморфизмнің математикалық моделі негізінде көмір метаморфизмі дәрежесі мен көмір сыйыстырушы таужыныстардың физикалық-механикалық қасиеттерінің тереңдік бойынша өзгеруі келтірілген. Мұндай зерттеулер түрі кен-техникалық жұмыстардағы негізгі көрсеткіштердің бірі болып табылатын таужыныстардың физикалық-механикалық қасиеттері болғандықтан, кен үңгімелеріндегі көмір қабаттары жабыны таужыныстарының орнықтылығымен байланысты мәселелерді шешуге мүмкіндік береді.

Түйін сөздер: витриниттің шағылыстыру қабілеті, көмір метаморфизмі, таужыныстардың физикалық-механикалық қасиеттері, көмір қабаты, жабын орнықтылығы, метан.

А. Б. Байбатша[1], Супин Пен[2], С. Б. Сатибекова[1]

[1]Казахский национальный исследовательский технический университет им. К. И. Сатбаева,
Алматы, Казахстан,
[2]State Key Laboratory of Coal Resources and Safe Mining,
China University of Mining and Technology (Beijing), Beijing, China

ОЦЕНКА ФИЗИКО-МЕХАНИЧЕСКИХ СВОЙСТВ ГОРНЫХ ПОРОД ПО СТЕПЕНИ МЕТАМОРФИЗМА УГЛЕЙ

Аннотация. В статье рассмотрены физико-механическиесвойства углевмещающих пород Карагандинского каменноугольногобассейна в зависимости от степени метаморфизма, которая определяется по показателю отражательной способности органического вещества – витринита. Данный способ является значимым в связи с увеличением объемагеологоразведочных работ на уголь, а также на попутный метан, в связи сподготовкой новых шахтных полей на больших глубинах, когда керн углябудет единственным веществом для суждения о свойствах угля и ихвмещающих пород. Определение физико-механических свойств углевмещающих пород с учетом стадии метаморфизма углей имеет большоепрактическое значение при горнотехнических работах. Основываясь на материалах прежних лет и лабораторных данных, проведенных нами совместно с китайскими коллегами в лаборатории State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology (Пекин, Қытай), а также на основе математической модели метаморфизмаМ.А. Ермекова (1990) приводится изменение степени метаморфизма углей ифизико-механических свойств углевмещающих пород с глубинойпогружения. Такой вид исследований способствует решению задач,связанных с устойчивостью пород кровли угольных пластов в горныхвыработках, так как физико-механические свойства пород являются одним изглавных критериев при горнотехнических работах.

Ключевые слова: отражательная способность витринита, метаморфизмугля, физико-механические свойства горных пород, угольный пласт,устойчивость кровли, метан.

Information about authors:

Baibatsha A.B., Kazakh National Research Technical University named after K. I. Satbayev, Almaty, Kazakhstan; baibatsha48@mail.ru; https://orcid.org/0000-0002-9521-7872

Suping Peng, State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology (Beijing), Beijing, China; psp@cumtb.edu.cn; https://orcid.org/0000-0001-9644-3495

Satibekova S.B., Kazakh National Research Technical University named after K. I. Satbayev, Almaty, Kazakhstan; s.satibekova@bk.ru; https://orcid.org/0000-0002-7445-1395

REFERENCES

[1] Atlas modelej mestorozhdenij poleznyh iskopaemyh / Edited by S.Zh. Daukeev, B.S. Uzhkenovetc. Almaty, 2004 (in Rus.).

[2] Geologija mestorozhdenij uglja i gorjuchih slancev SSSR. Vol. 5. Ugol'nye bassejny i mestorozhdenija Kazahstana. Book 1. Bassejny i mestorozhdenija paleozojskogo vozrasta / Edited by M.V. Golicyn, L.F, Dumler, I.V. Orlov. M.: Nedra, 1973. 720 p. (in Rus.).

[3] McCartney J.T., Teichmuller. (1972). Classification of coals according to degree of coalification by reflectance of the vitrinite component // Fuel. 51: 64-68. DOI 10.1016/0016-2361(72)90041-5 (in Eng.).

[4] Ermekov M.A. (1990). Model' metamorfizma uglej // Izvestija AN KazSSR. Serija geologicheskaja, 1: 28-32 (in Rus.).

[5] Prasanta K. Mukhopadhyay, Wallace G. Dow (1994). Vitrinite Reflectance as a Maturity Parameter: Applications and Limitations, ACS Symposium Series; American Chemical Society. Vol. 570, ch. 1. Washington, DC, USA. P. 1-24. DOI 10.1021/bk-1994-0570 (in Eng.).

[6] Golicyn M.V. Zakonomernosti metamorfizma paleozojskih uglej Central'nogo Kazahstana: Avtoref. dis. ... dokt. geol.-min. nauk. L., 1975 (in Rus.).

[7] ISO 11760. International Standard, Classification of coals. Geneva, 2005.

[8] Koch J. (1997). Upper limits for vitrinite and bituminite reflectance as coalification parameters // International Journal of Coal Geology. 33: 169-173. DOI 10.1016/S0166-5162(96)00024-9 (in Eng.).

[9] GOST 25543-88. Ugli burye, kamennye i antracity. Klassifikacija po geneticheskim i tehnologicheskim parametram. Moscow, Russia, 1988.

[10] GOST 12113-94. Ugli burye, kamennye, antracity, tverdye rassejannye organicheskie veshhestva i uglerodistye materialy. Metod opredelenija pokazatelej otrazhenija. Moscow, Russia, 1994.

[11] Baibatsha A., Bekbotaeva A., Satibekova S. (2017). The Penecontemporaneous Transformation and Physical-Mechanical Properties of Terrigeneous Rocks // 17th International Multidisciplinary Scientific GeoConference SGEM. Vol. 17, issue 11. Sofia, Bulgaria. P. 651-658 (in Eng.).

[12] Stolbova N.F. Petrologija uglej. Tomsk: TPU, 2013. 77 p. (in Rus.).

[13] Baibatsha A.B., Bekbotaeva A.A. (2015). Stratiformnye mestorozhdenija medi // Izvestija NAN RK. Serija geologii i tehnicheskih nauk. 6: 73-78 (in Rus.).

[14] Baibatsha A.B. (2016). Metallogenicheskoe znachenie intruzivnyh i metasomaticheskih obrazovanij Karsakpajskogo rajona // Izvestija NAN RK. Serija geologii i tehnicheskih nauk. 4: 36-50 (in Rus.).

[15] Zhaoping Meng, Wu Yi, Jaochim Tiedemann (2005). Analysis of mechanical properties of sedimentary rocks of coal measures and their influencing factors // The 40th U.S. Symposium on Rock Mechanics (USRMS): Rock Mechanics for Energy, Mineral and Infrastructure Development in the Northern Regions, Anchorage, Alaska (in Eng.).

[16] Bajbatsha A.B. Inzhenernaja geologija mestorozhdenij poleznyh iskopaemyh s osnovami geoinformatiki. Almaty: Gylym, 2003. 320 p. (in Rus.).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 195 – 205 **https://doi.org/10.32014/2019.2518-170X.24**

UDC 551.4.01/.02; 556.52/.55; 627.5
IRSTI: 38.47.03; 70.03.05; 70.17.43

A. G. Valeyev [1], F. Zh. Akiyanova[2], A. D. Abitbayeva[1], Ye. Ye. Khalykov[1], M. M. Togys[1]

[1]Institute of Geography, Almaty, Kazakhstan,
[2]Institute of Geography and Nature Management of the "Astana" ISC, Astana, Kazakhstan.
E-mail: adiletv@gmail.com, akiyanovaf@mail.ru, abitbayevainagul@gmail.com

DEVELOPMENT OF ABRASION SHORES OF ALAKOL LAKE ACCORDING TO THE FIELD RESEARCH MATERIALS

Abstract. In recent years, Alakol Lake is becoming a center of recreation and tourism, its infrastructure is developing with a pronounced man-made load on the coastal areas. In addition, the nature of shore formation becomes aggravated under the impact of instability of natural-anthropogenic conditions, which leads to the destruction of infrastructure facilities, loss of land reserves, material damage. A review of scientific papers revealed that the latest studies were conducted fifty years ago. Therefore, the obtaining of new monitoring data with the use of modern measuring instrumental devices is relevant. The identification of effective methods for obtaining accurate parameters made it possible to understand and analyze shore formation. Sites for conducting field studies were allocated using a regional approach with the application of satellite images. The method of instrumental measurements of distances from reference benchmarks was used in the field researches. As a result, the dynamics of the marginal erosion over a three-year period on the south-western and eastern shores of Alakol Lake was determined. 6 monitoring sites were established on the southwestern shore. The results of observations of the dynamics of erosion of the cliff in the active zone were from 3 to 9.9 m over a three-year period. The change in the height of the coastal cliff from 5-6 meters (1964) to 9 meters was identified. Two monitoring sites were organized on the eastern shore. The dynamics of erosion of the coastal cliff in the active zone ranged from 3.7 to 14 m over a three-year period. We assume that there is a disturbance of the alongshore transport of sedimentary rocks at this site by a 168-meter breakwater, which enhances the dynamics of abrasion.

Key words: field studies, monitoring of shoreline erosion, coastal cliff, abrasion, dynamics of relief formation.

Introduction. Field studies of relief formation of the shores of Alakol Lake were carried out by the Laboratory of Geomorphology and Geoinformation Mapping and the works were partially continued in 2016 in order to monitor the dynamics of abrasion shores. As a result, it becomes possible to preliminarily analyze and determine the dynamics of the development of abrasion coastal cliffs on the basis of field and cameral studies.

The coastal zone of the lake under study is a place of active manifestation of unfavorable exogeodynamic processes. Dynamics of destruction of abrasion-denudation shores in places of economic and recreational development, in some places reaches a retrogression of more than 3 meters per year. Several residential streets of the Koktuma village on the south-western shore of Alakol Lake (Almaty region) were lost as a result of erosion of the cliff. Similarly, the capital structures of recreational facilities on the eastern shore of Alakol Lake were submerged (East Kazakhstan region).

Over the last years, the shores of the lake are experiencing a high anthropogenic load associated with a sharp increase in comprehensive tourism to Alakol Lake. A fertile climate, comfortable beaches, curative properties of the lake water, transport accessibility required the development of the routing of passenger transportation by railroad and improving the quality of highways. Accordingly, a rapid development of construction of various necessary kinds of infrastructure (sanatoriums, rest homes, etc.) is observed in the coastal territory, unfortunately, not always taking into account the factors of relief

formation of the above-water part of the coastal zone. The solution of this problem requires a comprehensive research, which is impossible without detailed field monitoring. The obtained data of field studies will allow to make an effective analysis and to elaborate a system of measures for the sustainable development of the Alakol Lake shore in the future.

Review of previous scientific works. Studies of the coastal zone of Alakol Lake began quite long ago. General characteristics of the structure of the Alakol Depression, climate, water resources, soil cover, vegetation were given in the 12th edition of the Questions of Geography of Kazakhstan "Alakol Depression and its lakes" edited by N.N. Palgov (1965) [1]. Studies of the morphology and dynamics of the shores of Alakol Lake were conducted by Ye.A. Kazanskaya (1961-1964). During the study, it was recorded by her that denudation processes prevailed over accumulative ones in the shore formation over the most part of the entire shore, due to the increase in the water level in the lake. A cumulative classification was made by the types of shores of the entire study area. The morphology and structure of the shores and islands were considered in detail. According to Ye.A. Kazanskaya, the south-western, southern, eastern, north-eastern, northern, north-western, western coastal areas of Alakol Lake were distinguished with detailed explanation of the geomorphological conditions of each of them and the proposal of applied methods of shore protection measures taking into account transverse and longitudinal shore depositions [1, 2].

T.N. Dzhurkashev studied the history of the formation of the Balkhash-Alakol Depression in the Quaternary period. His monograph "Anthropogene history of the Balkhash-Alakol Depression" gives geological-geomorphological characteristics of the Balkhash-Alakol Depression, including a description of the territory under study [3]. It is necessary to note the papers of K.V. Kurdyukov (1952) [4], Z.A. Svarichevskaya (1952) [5] from earlier works on the study of the geology of the territory under study.

Geological-geomorphological conditions were later studied by L.K. Didenko-Kislitsina (1964-1966, 1971) [6], Yu.A. Tverdislov [7], N.I. Mikhailova [8], A.N. Mitrofanova and R.Sh. Kalita [9]. The study of morphometry using the SRTM digital terrain model, monitoring of the formation of shores according to the data from different-time satellite images were performed by A.G. Valeyev, F.Zh. Akiyanova, A.D. Abitbayeva [10, 11].

The analysis of published scientific literature showed that valuable material has been accumulated, including the classification of the Alakol Lake shore according to the leading exogenous processes. However, recent data on the study of the negative impact of the development of exogeodynamic processes in the coastal zone are fifty years old. During this time, the hydrological situation has changed, recreational and economic loads have increased, climate change has been occurring and, most importantly, new effective methods of research have appeared. Therefore, the relevance of obtaining new monitoring data using modern measuring instrumental devices is beyond doubt.

Methods. The different-time satellite images of medium resolution (landsat, Alos and Sentinel) were used for the regional identification of monitoring sites [12]. The most active areas of shoreline erosion were identified by the method of interpretation and comparison of the results of the remote sensing data processing [10]. The following criteria were developed in order to select the monitoring sites: active exogeomorphogenesis within the above-water part of the coastal zone, the risk of negative impact of exogeodynamic processes of shore formation on the socio-economic and recreational infrastructure, the availability of facilities of engineering protection of the shores (breakwater, pier, cut-waters, etc.), location of objects of technogenic impact, enhancing the dynamics of relief formation of the shores.

There are several methods of monitoring the dynamics of the abrasion cliff in field studies:

1) measurement of the distance of the planned displacement of the edge of the shore along a previously marked section line for a certain period of time;

2) determination of the position of the line of the cliff with the help of the theodolite and comparing of its planned position with the position of the shore edge determined earlier;

3) investigation of erosion of abrasion cliffs using a ground-based laser scanner. The main stages of data processing: georeferenciation and stitching point clouds; interpolation of data to create a digital elevation model; creation of a digital terrain model (DTM) [13-15] and etc.

Methods for measuring and documenting the dynamics of erosion of the cliff in the papers of T. Sunamura (1992) include sequential aerosurveying, analysis of historical maps, field instrumental studies (measuring distances from benchmarks) [16]. Methods of research of A.Sh. Khabidov [17] pay special

attention to the analysis of the geomorphological conditions of the coastal zone – the morphometry of the shore is determined, soil samples are taken from the cliffs to determine the mechanical properties of rocks, the dynamics of the displacement of the coastal cliff toward the land is determined using special equipment.

In the studies of the shores of Alakol Lake, we used the method of instrumental measurements of benchmarks along the transversal profile. The method of instrumental measurements along the profile is reasonable and does not require special expensive equipment. Profile lines are marked on the terrain when organizing observations with the help of this method. First, parallel lines of the profile are laid to the cliff, and then perpendicular lines of the alignment along the magnetic azimuth to the shore cliff are determined from the set benchmarks with the compass. Benchmarks with the use of concrete and reinforcement (12 mm in diameter, 50-60 cm in length) are set as the initial ones. In addition, stationary objects (trees, corners or supports of capital embankments, foundations of buildings, towers, wells, concrete supports, lighting pillars, etc.) can be used as a benchmark, since the working group had experience in the loss of benchmarks as a result of active shoreline erosion on the territory under study.

Depending on the length of the profile between the main benchmarks, additional intermediate benchmarks are set to fix the direct profile and to exclude the loss of information in the case of the accidental loss of one of them. Measurements are done after a period of time using a laser rangefinder or measuring tape, determining the distance between the benchmark and the edge of the cliff along the line of the perpendicular alignment. The retreat of the edge is the difference between the two measurements. In order to display the monitoring profiles in the GIS programs and determine the location of the benchmark in the future, GPS coordination of all benchmarks of the profile is carried out [18]. The accuracy with such measurements is 1 cm for every 20 m of the line being determined. In order to proceed to dynamic indicators, it is necessary to obtain an average retreat of the edge across all section lines of the station for the selected time interval [14]. Documentation of the obtained data was carried out in the form of filling in the passports of the monitoring site with the introduction of all the main quantitative and qualitative data. Drawings and description of the site, schemes of transverse coast profiles are recorded in field logs in detail, preliminary granulometric composition is described, photo-fixing of benchmarks, profiles, coastal zone, infrastructure facilities of the shores, etc. is carried out.

Results and discussion. The interpretation and comparison of the results of the processing of satellite images allowed determining the monitoring sites at the regional scale for carrying out field studies in accordance with the developed criteria (figure 1) [19].

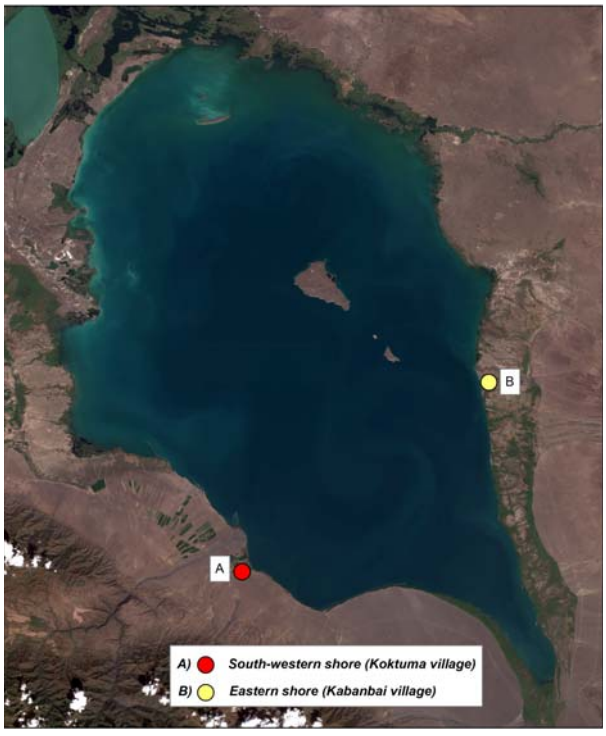


Figure 1 – Alakol Lake,
A – south-western abrasion shore (Koktuma village),
B – eastern abrasion shore (recreational zone
of Kabanbai village) [12]

South-western shore (Koktuma village). The leveled section of the south-western coastal zone of Alakol Lake stretches from the Zhamanty river delta and its turning to the east (the length of 14 km). The development of the shore is conditioned by abrasion-accumulative processes. The land is a train of debris cones, formed by rivers and temporary channels, flowing down Zhetysu Alatau. The space from the lake to the mountains is occupied by a foothill gently-sloping, debris-stony plain with elevation marks of 600-700 m at the mountains, and 350 m at the lake. In other words, the shore is composed of proluvial-alluvial sediments of Quaternary age [20].

According to Ye.A. Kazanskaya, a cliff with a height of 5-6 m, accompanied by a narrow pebbly beach with a width of up to 10 m stretched to the north and south of the Koktuma village in 1961-1964. Nowadays, the width of the beach remains unchanged, while the height of the cliff in the mentioned places reaches more than 9 m.

The cliff is the natural boundary of the residential area of the Koktuma village. Six monitoring sites were established within the coastal cliff near the Koktuma village in 2013-2014. Repeated instrumental measurements were carried out in November 2014 and 2016. The results of observations of the dynamics of the reformation of the cliff in the active zone were from 3 to 9.9 m over a three-year period. It should be noted that there is uneven shoreline erosion at the monitoring sites. However, there is a steady movement of the edge of the cliff toward the land according to all the benchmarks.

The monitoring site № 4 (figure 2) was founded in 2013. Two main benchmarks were installed at it, and geographic coordinates from two concrete supports were taken as additional benchmarks. According to the 1st and 2nd benchmarks, the dynamics of the retreat of the edge of the cliff toward the land is 9.4 m for three and a half years. At the 7th benchmark, located in the southern part of the monitoring site, the three-year values amounted to 9.9 meters. Residential buildings and infrastructure facilities are located in 50-60 meters from the coastal cliff. Local residents state the fact of the annual approaching of the coastal cliff to their houses. The asphalt road is cut off by the cliff in the south direction. The analysis of the obtained results showed an increase in the rate of shoreline erosion at the reference site from north to south.

Two main benchmarks were installed at the monitoring site № 5 in 2014 (figure 3). According to the 1st and 2nd benchmarks, the distance to the edge of the cliff at the time of the laying was 43 and 25 meters, respectively. When carrying out repeated observations in 2016, anthropogenic disturbance of the

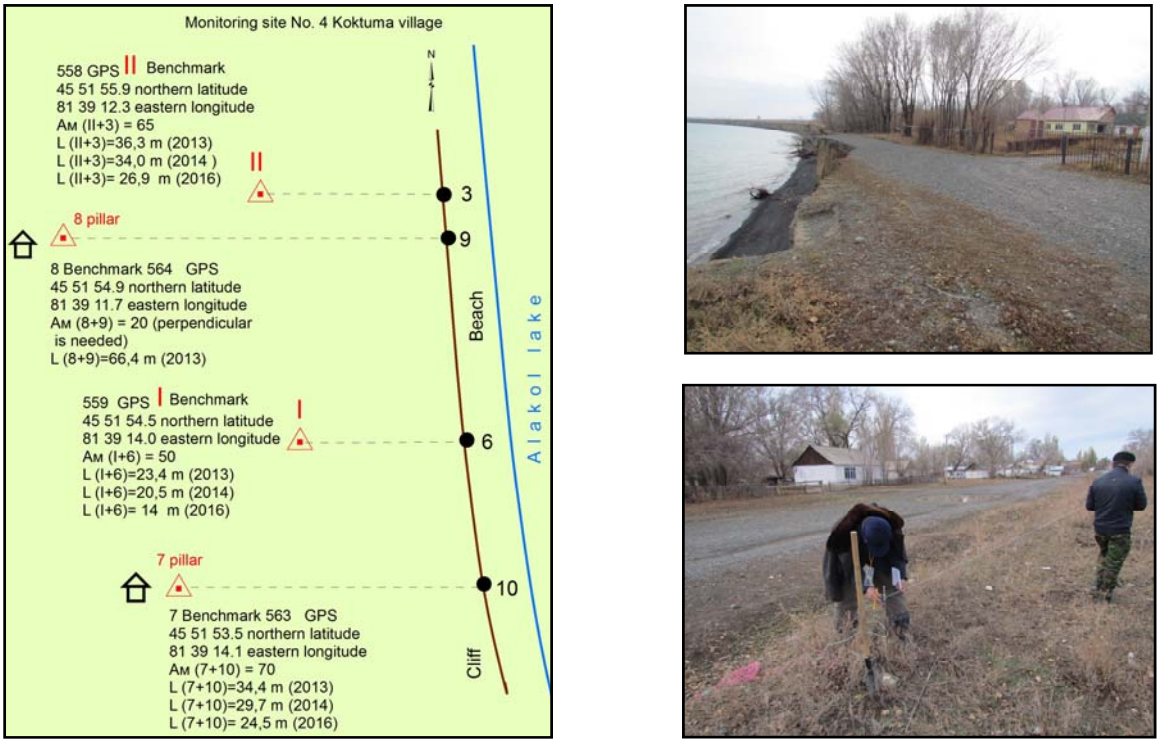


Figure 2 – Data of the monitoring site № 4, Koktuma village, Almaty region

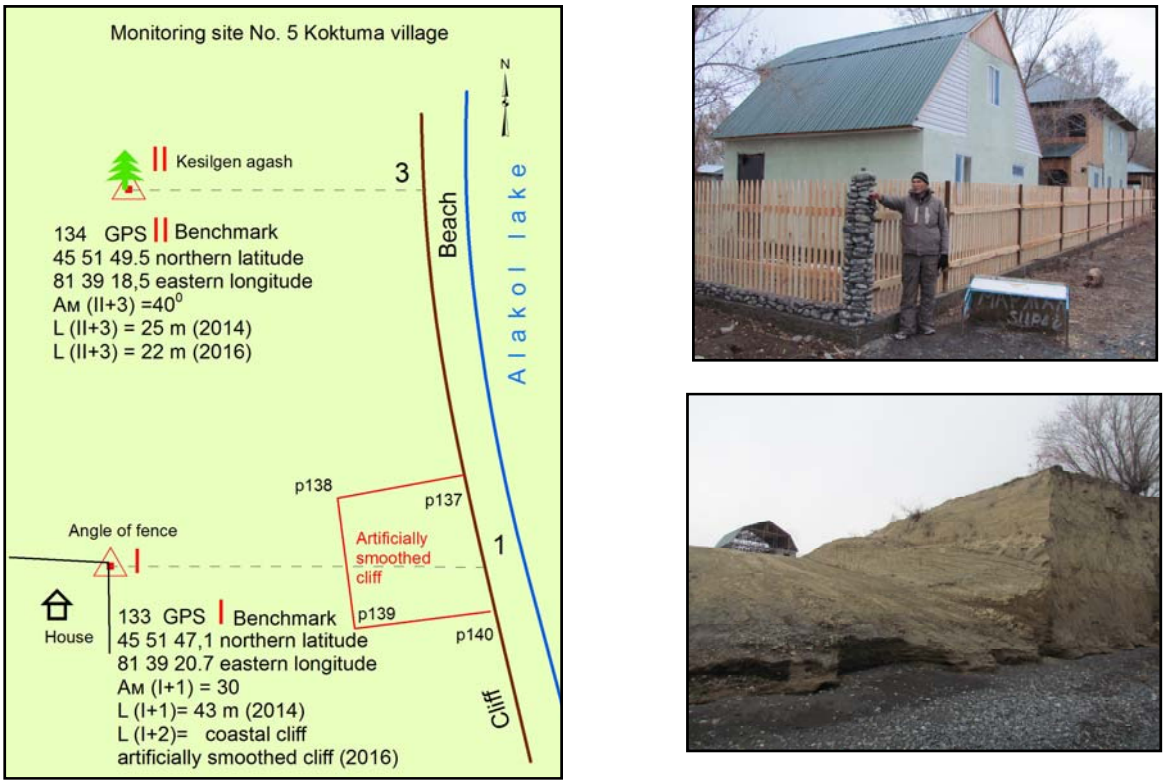


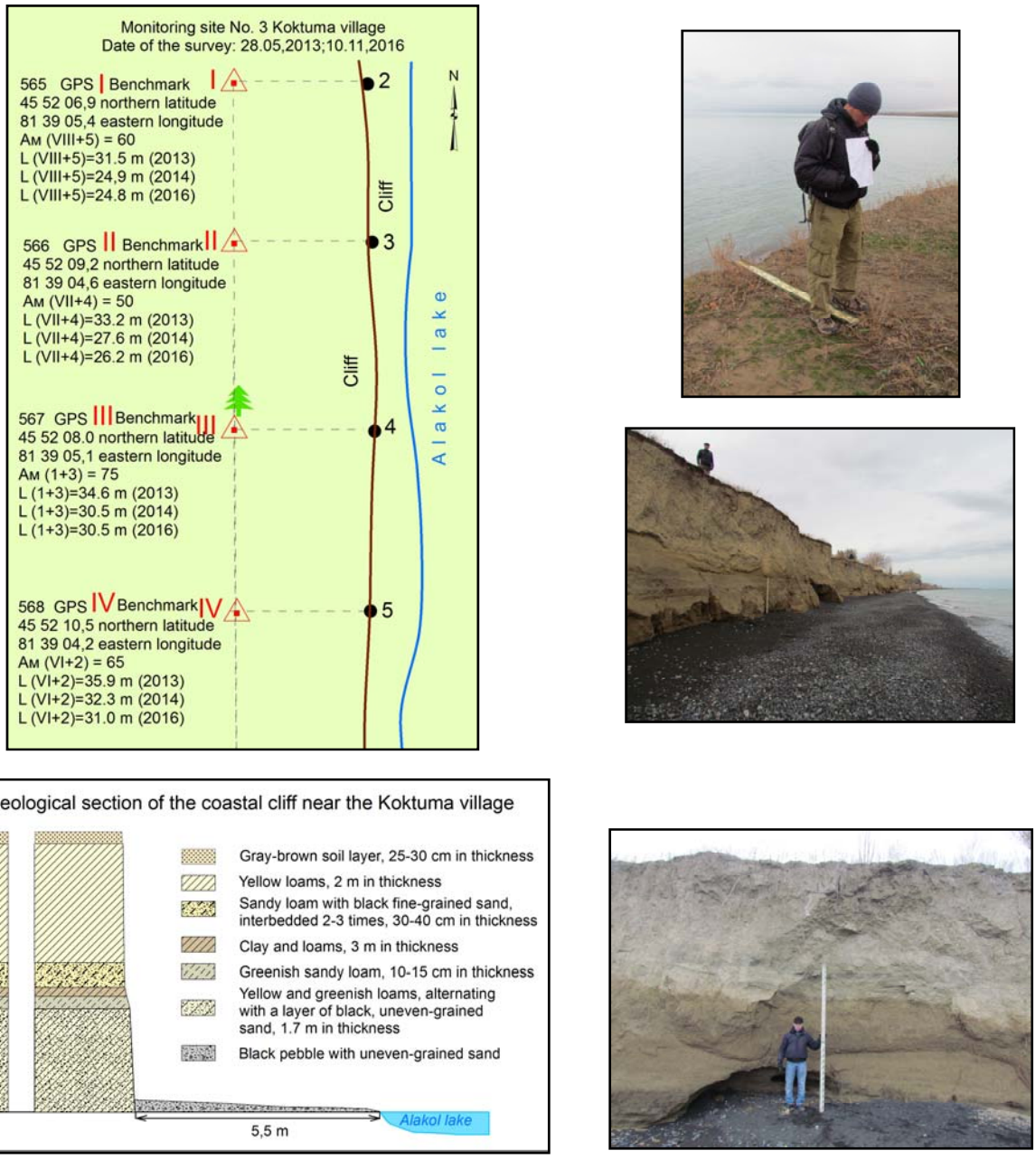
Figure 3 – Data of the monitoring site № 5, Koktuma village, Almaty region

coastal cliff was revealed opposite the buildings of the recreation center. The underlying soil with a volume of more than 1000 m^3 was removed from the surface of the cliff to the beach with the help of heavy equipment. The dimensions of the disturbed coastal area were the following: width - 25–30 meters, length - 20 meters, depth - up to 8-9 meters at the beach bottom.

Therefore, the data for the first benchmark were not measured, and the dynamics for the second benchmark was 3 meters in 2 years. The corners of this section were tied to the coordinate system for further monitoring. It is assumed that this technogenic effect pursued 2 objectives. The first was to reduce or exclude the dynamics of shoreline erosion in order to keep the summer recreation centers from destruction, and the second was to make the access to the beach area of the shore convenient. Further development of shoreline erosion will be clarified with regular field studies.

The monitoring site № 3 was laid in 2013 (figure 4). The reference site is located in the central part of the coastline of the settlement. Four benchmarks were set along the profile at a distance of an average length of 33 meters from the edge of the cliff. The territory is an undeveloped open area. Dynamics of displacement of the edge of the cliff for three and a half years at the 1st benchmark was 6.7 m, at the 2nd benchmark - 7 m, at the 3rd benchmark - 4.1 m, at the 4th benchmark - 4.8 m. The average rate of the retreat of the abrasion cliff was equal to 1–2 meters per year. Samples were taken from the steep wall of the coastal cliff for physicochemical analysis. The granulometric composition of the main strata of the coastal cliff and their thickness were determined visually.

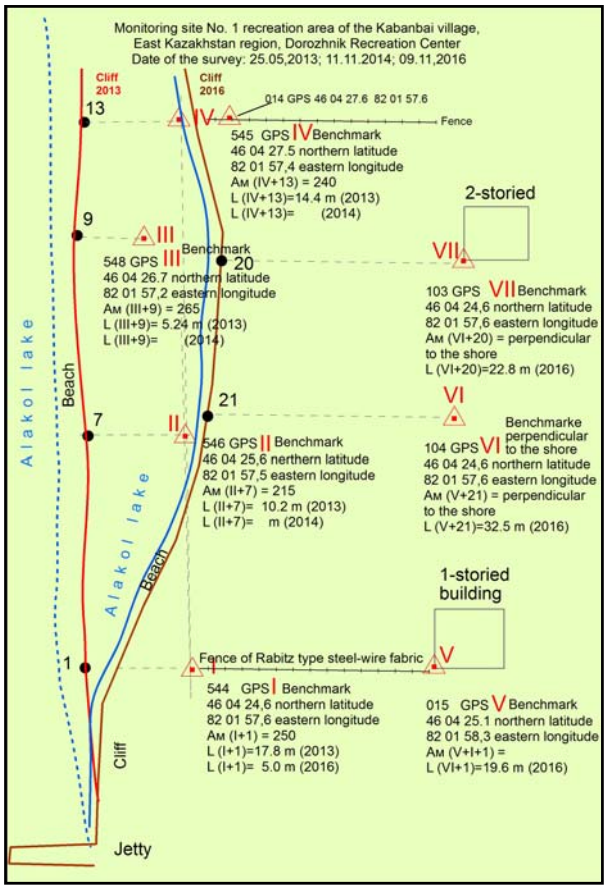
Eastern shore (Kabanbai village). According to Ye.A. Kazanskaya, the site under study is gradually rising to the south of the base of the Zharbulak spit (the cape to the north of the recreational zone of the Kabanbai village), a low loamy cliff appears, relative height of which opposite to the Kabanbai village reaches 5 meters. In the outcrops of the cliff, there are clay loams and thin-sandy clays, buried soils, indicating that the shore has repeatedly experienced a transgression of the water body. The cliff of the coast is prone to intensive abrasion, various forms of destruction of the shore - erosion niches, columnar remains, etc. can be observed here. A narrow pebble beach stretches as an almost continuous strip along the shore. Its height is up to 1 m, the average width is up to 7 m, the prevailing sizes of pebbles are 1–4 cm, less often - up to 7–10 cm. In some places, the beach strip is still flooded with water, which is washing the bottom of the cliff [20].

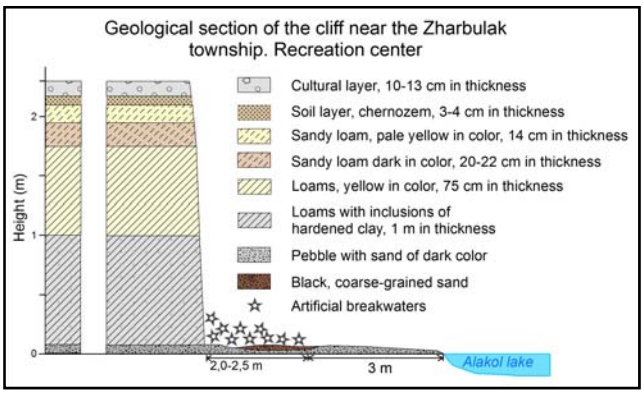


The edition of the geological section
was prepared by A. A. Bekkuliyeva

Figure 4 – Scheme of the monitoring site № 3, Koktuma village, Almaty region

Monitoring sites were organized on the abrasion shore in the western part of the recreation area of the Kabanbai village. In 2013, two sites were laid and the first instrumental survey of the shore profile along the line gauges was carried out. The nearness of recreational and infrastructure facilities to the active zone of shore reformation was a criterion for the selection of reference sites, taking into account the coast-protecting engineering structures on the abrasion shore. The site under study is located three kilometers to the west of the Kabanbai village. In recent years, the territory of the summer recreational center has increased in area. Capital construction of summer holiday homes and infrastructure facilities is carried out both along the shore in the southern and northern directions, and deep into the land. These lands need additional backfilling of soil, since salinization of soil is observed everywhere due to the close occurrence of groundwater to the surface.





The edition of the geological section was prepared by A. A. Bekkuliyeva

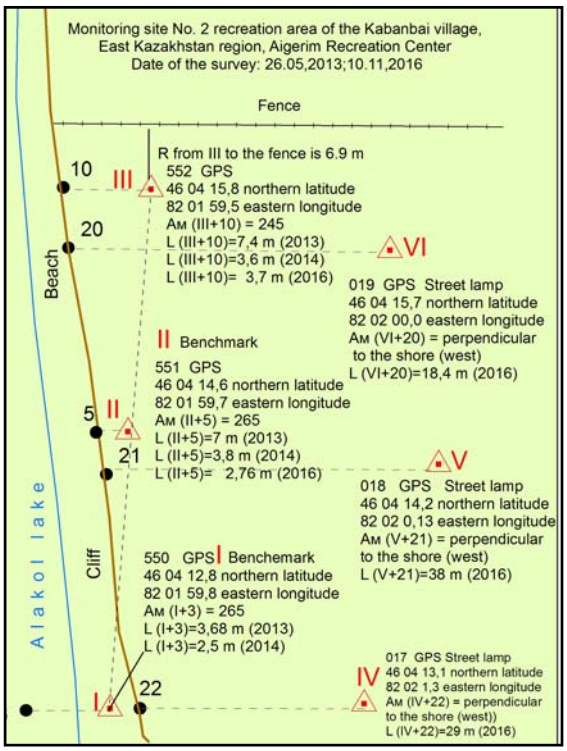
Figure 5 – Scheme of the monitoring site № 1, recreational center of the Kabanbai village, East Kazakhstan region

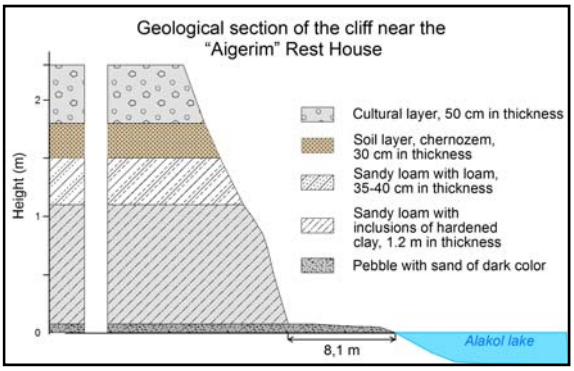
Four benchmarks were installed along the profile at the monitoring site № 1 in 2013 (figure 5). The group had no data on the current dynamics of erosion of this shoreline when choosing a profile at a distance of 5 to 17 meters from the edge of the cliff. The abovementioned short distances turned to be unacceptable for the laying of reference sites and conducting monitoring. It was recorded that a bench was developed on the place of the profile along three benchmarks during repeated instrumental measurements in 2014. The coastal cliff was destroyed together with the benchmarks. Only one benchmark № 1 was preserved. Thus, the dynamics of the retreat of the edge of the coastal cliff amounted to 12.8 m for the benchmark № 1, more than 10 m for the 2nd benchmark, more than 6 m for the 3rd benchmark, more than 14 m for the 4th benchmark for three and a half years. The data for the last three benchmarks are approximate.

In 2016, during the reconnaissance of the territory adjacent to the reference point № 1, the relevant stationary objects were identified as new line gauges. Binding of three benchmarks was carried out using a satellite navigation device, two of them were the foundations of buildings, and the third line gauge was the base of the water-pumping station. Instrumental measurements of the distance from the benchmark to the edge of the cliff were carried out. Samples were taken from the steep coastal cliff for physicochemical analysis. The granulometric composition of the main strata of the coastal cliff and their thickness were determined visually.

According to the data of field observations, the south-west wind "Saikan" and the spring eroding of the shores by surface ice actively participate in the marginal erosion. Disburdening water points were recorded, they were found in the coastal zone of the lake as a result of the retreat of the shores.

Field observations made it possible to assume than one of the reasons for the active dynamics of shoreline erosion is the disturbance of the longshore transport of sedimentary rocks due to anthropogenic engineering and technical activities in the coastal zone of the lake. In 2009, a transversal breakwater with a length of 168 meters was built on the site to protect the coastal cliff from the destructive effects of waves





The edition of the geological section
was prepared by A.A. Bekkuliyeva

Figure 6 – Scheme of monitoring site № 2, recreational center of the Kabanbai village, East Kazakhstan region

[21]. The analyses of field observations and satellite images revealed the accumulation, growth of the beach zone, composed of pebbles and sand on the territory located to the south of the breakwater. On the contrary, on the shore to the north of the breakwater, the dynamics of the shoreline erosion has intensified, and there is an active displacement of the cliff towards the land. According to the studies of Jeffrey H. List, one of the causes of shore erosion is the disturbance of the longshore transport of sedimentary deposits in the littoral zone. There is a disturbance in the balance of the arrival, consumption and the volumes of the reserve of sediments within the littoral zone, in which the longshore and transverse transport, river runoff, anthropogenic interference, and etc. participate [22].

Three benchmarks were installed along the profile on the monitoring site № 2 in 2013 (figure 6). Distances from the edge of the cliff to the benchmarks were from 3.5 to 7 meters. There is a metal fence of the private rest house parallel to the cliff at the indicated distances. Only two benchmarks along the lines of the profiles № 2 and 3 were kept when carrying out instrumental measurements in 2016. The first benchmark was destroyed by abrasion. In May 2013, the distance from the benchmark to the edge of the cliff was 3.68 m. Dynamics of development of shoreline erosion at the reference site № 4 was determined for each benchmark with a perpendicular direction to the cliff. At the 1st benchmark, it is presumably 4 m for three and half years, at the 2nd benchmark – 4.24 m, at the 3rd benchmark – 3.7 m.

New benchmarks were installed to fix the dynamics of the abrasion process for further field monitoring of the abrasion process. Three street lamps located on the territory of the summer recreation center were selected as benchmarks. They are located at a considerable distance from the edge of the cliff and are oriented along the shoreline. The coordination of new benchmarks, fixing the distances to the edge of the cliff in the west direction relative to all three lamps, was carried out.

Conclusion. The conducting of monitoring field studies of denudation-abrasion shores was caused by the need to solve the problems of sustainable recreational development of the coastal territory of Alakol Lake in order to reduce the threats and negative impact of exogeodynamic processes on valuable recreational areas, agricultural lands and residential areas. In order to solve the tasks of preserving the coastal abrasion cliff and increasing the recreational potential of Alakol Lake, the research group adapted the field method for monitoring the transformation of the relief of the shores. The method was tested in field studies. The experience of monitoring field works showed the need to install benchmarks along the profile at the distance of at least 20 m from the edge of the cliff.

The results of field studies showed a high rate of reformation of the abrasion cliff of the south-western and eastern shores. Areas with the dynamics of more than 3-4 meters per year were revealed. Uneven relief formation is observed in the coastal zone with functioning engineering shore protection structures, for example, accumulation occurs on one side of the breakwater, and there is an active denudation on the other side. Additional desktop and field studies are necessary for studying and understanding the current circumstances.

Abrasion refers to the processes that require careful study of its conditioning prerequisites, monitoring the state of the shoreline and conducting shore protection works in places where this process is particularly pronounced. The main attention should be paid to the abrasion development of the lake terrace, cliff, wave-cut notch and the relevant re-deposition of rocks of the coastal zone [19]. The obtained results of the field studies will contribute to a deep understanding of the processes of shore formation of internal lakes, arid zones, the accumulation of quantitative data, as well as the development of effective methods of shore protection and management of coastal territories.

Funding. project № AP05134437 “Monitoring studies of unfavorable exogeodynamic processes in the coastal zone of Alakol Lake – the territory of intensive recreational development” under the agreement №120 dated March 5, 2018

Acknowledgements. The most active participation in these field studies was taken by Kh.M. Kuzeubayev. The first monitoring sites were organized and the first results were obtained under his supervision. We express our sincere gratitude to the dearly departed scientific mentor.

А. Г. Валеев [1], Ф. Ж. Акиянова[2], А. Д. Абитбаева[1], Е. Е. Халыков[1], М. М. Тогыс[1]

[1]География институты, Алматы, Қазақстан,
[2]География нституты және табиғатты пайдалану МНК «Астана», Астана, Қазақстан

АЛАКӨЛ КӨЛІ ЖАҒАЛАУЫНДАҒЫ АБРАЗИЯ ДАМУЫНЫҢ ДАЛАЛЫҚ ЗЕРТТЕУЛЕР БОЙЫНША МӘЛІМЕТТЕРІ

Аннотация. Соңғы жылдары Алакөл көлі туризм және демалыс орталығына айналды, инфрақұрылым кеңінен дамыды, жағалаудағы аудандарда айқын техногенді антропогендік жүктеме пайда болды. Сонымен бірге, табиғи-антропогендік жағдайлардың тұрақсыздығы әсерінен жағалаудың қалыптасуы біраз өзгеріске ұшырап, бұл инфрақұрылым нысандарын қирап жойылуына, жер телімдерінің азаюына және материалдық шығындардың ұлғауына әкеліп соқтырды. Ғылыми еңбектердің шолуы елу жыл бұрын жүргізілген зерттеулер екені анықталды. Сол себепті, заманауи өлшемді-инструментальды аспаптар жаңа бақылау, қадағалау алаңдарынан алынған мәліметтерді өңдеу маңызды рөлге ие. Жағалаудың қалыптасуын сараптама жүргізу нақты параметрлерді алудың тиімді әдістерін анықтау түсінуге мүмкіндік берді. Далалық зерттеулер жүргізілген телімдерде белгіленген ғарыштық түсірілімдерді пайдалануда аймақтық тәсілдерді қолдану. Далалық ғылыми зерттеулерінде сілтеме нүктелерінен арақашықтықты аспаптық өлшеу әдісі пайдаланылды. 3 жылдық кезең бойынша Алакөл көлінің шығыс және оңтүстік-батыс жағалау бөліктерінің өңделген жағалау өзгерістерінің нәтижелері анықталды. Оңтүстік-батыс жағалауында 6 бақылау алаңдары орнатылды. Белсенді жүрген бөліктегі өңделген жағалау жарқабақтарының өзгерген динамикасын бақылау нәтижелері үш жылдық кезеңнен 3-тен 9,9 м-ге дейін өзгерді. 5-6 метрден (1964) 9 метрге дейін жағалаудағы жартастың биіктігінің өзгеруі анықталды. Шығыс жағалауында 2 бақылау алаңы ұйымдастырылды. 3 жылдық кезең бойынша жағалаудың белсенді өңделіп өзгеріске ұшыраған бөлігінде 3,7-ден 14 м-ге дейін жетті. Осы алаң бойынша жағалаудағы шөгінді жыныстарының жағалау бойымен шайылып бұзылуы 168 метрлік құйылған судың абразияның ұлғайып өзгеріске ұшырауын жақсартатын білуге болады.

Түйін сөздер: далалық зерттеулер, жағалауды өңдеуді бақылау, жағалау жары, абразия, жер бедері қалыптасуының өзгерісі.

А. Г. Валеев [1], Ф. Ж. Акиянова[2], А. Д. Абитбаева[1], Е. Е. Халыков[1], М. М. Тогыс[1]

[1]Институт Географии, Алматы, Казахстан,
[2]Институт географии и природопользования МНК «Астана», Астана, Казахстан

РАЗВИТИЕ АБРАЗИОННЫХ БЕРЕГОВ ОЗЕРА АЛАКОЛЬ ПО МАТЕРИАЛАМ ПОЛЕВЫХ ИССЛЕДОВАНИЙ

Аннотация. В последние годы озеро Алаколь становиться центром отдыха и туризма, развивается инфраструктура, с выраженной техногенной нагрузкой на береговые территории. При этом обостряется характер берегообразования под воздействием нестабильности природно-антропогенных условий, что приводит к разрушению инфраструктурных объектов, потере земельного фонда, материальному ущербу. Обзор научных работ выявил пятидесятилетнюю давность исследований проводимых ранее. Поэтому получение новых мониторинговых данных с использованием современных инструментально-измерительных приборов является актуальным. Определение эффективных методов для получения точных параметров позволило понять и проанализировать берегообразование. Региональным подходом с применением космоснимков были выделены участки для проведения полевых исследований. В полевых исследованиях использовался метод инструментальных измерений расстояний от реперов. В результате была определена динамика переработки берегов за трех летний период на юго-западном и восточном берегу озера Алаколь. На юго-западном береге были установлены 6 мониторинговых площадок. Результаты наблюдений за динамикой переработки берегового уступа в активной зоне составили от 3 до 9,9 м за трехлетний период. Выявлено изменение высоты берегового клифа от 5-6 метров (1964 г.) до 9 метров. На восточном берегу были организованы 2 мониторинговые площадки. Динамика переработки берегового уступа в активной зоне составили от 3,7 до 14 м за трехлетний период. На данной площадке предполагаем нарушение вдольберегового переноса осадочных пород 168-ми метровым волнорезом, который усиливает динамику абразии.

Ключевые слова: полевые исследования, мониторинг переработки берегов, береговой уступ, абразия, динамика рельефообразования.

Information about authors:

Valeyev A. G., Researcher, PhD Doctoral student, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; adiletv@gmail.com; https://orcid.org/0000-0002-9380-351X

Akiyanova F. Zh., Doctor of Geographical Sciences, Director,Institute of Geography and Nature Management of the "Astana" International Scientific Complex, Astana, Kazakhstan; akiyanovaf@mail.ru; https://orcid.org/0000-0002-8395-8497

Abitbayeva A.D., Candidate of Geographical Sciences, Senior Researcher, Head of Laboratory, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; abitbayevainagul@gmail.com; https://orcid.org/0000-0002-7335-0269

Khalykov Ye. Ye., Researcher, PhD Doctoral student, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; e.halykov@mail.ru; https://orcid.org/0000-0003-4478-7995

Togys M. M., Junior Researcher, Master, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; maulenmm@mail.ru; https://orcid.org/0000-0002-6257-0098

REFERENCES

[1] "Alakol Depression and its lakes" (1965). Questions of Geography of Kazakhstan. 12: 310 (in Rus.).

[2] Valeyev A.G., Abiyeva D.K., Mitrofanova A.N., Uksukpayeva S.A., Sharapkhanova Zh.M. (2017). Review of research materials, conducted for the territory of the Alakol-Sasykkol group of lakes // Materials of the international scientific-practical conference "Modernization of natural-science education in conditions of renewed content". P. 626-630.

[3] Dzhurkashev T.N. (1972). Anthropogene history of the Balkhash-Alakol Depression [AS of the KazSSR. K. I. Satpayev Institute of Geol. Sciences]. P. 126 (in Rus.).

[4] Kurdyukov K.V. (1952). Ancient lake basins of the South-East Kazakhstan and the climatic conditions of the times of their existence [New sletter of the AS of the USSR, geograph. series] 2:11-24 (in Rus.).

[5] Svarichevskaya Z.A. (1952). On the history of the Balkhash-Alakol Depression [Journal of the LSU, biol., geogr., geol. series] 7: 107-112 (in Rus.).

[6] Didenko-Kislitsyna L.K. (1971). The South-Balkhash, Lepsy and Alakol Depressions. Geology of the USSR. Vol. 40. Book 2 (in Rus.).

[7] Tverdislov Yu.A. (1968). Relief-forming role of eolian processes in the Alakul Depression and the eastern near-Balkhash region. Current exogenous processes (in Rus.).

[8] Mikhailova N.I., Loginovskaya A.N. (2012). The problem of destruction of the shores of Alakol Lake. Interexpo Geo-Siberia, 3 V. 2:1-6 (in Rus.).

(https://cyberleninka.ru/article/n/problema-razrusheniya-beregov-ozera-alakol) (in Rus.).

[9] Atlas of natural and man-made hazards and risks of emergencies in the Republic of Kazakhstan (2010). P. 134-135.

[10] Abitbayeva A.D., Valeyev A.G., Yegemberdiyeva K.B. (2013). Monitoring of abrasion processes (by the example of Alakol Lake, Republic of Kazakhstan) // Materials of the International Scientific and Practical Conference of Young Scientists dedicated to the 95th anniversary of the National Academy of Sciences of Ukraine "Potential of modern geography in solving problems of regional development". P. 324-330.

[11] Valeyev A.G., Akiyanova F.Zh., Abitbayeva A.D. (2016). Morphometric features of formation of river runoff in the basin of the Alakol Depression and its impact on the development of relief formation of the coastal zone of Alakol Lake // WATER RESOURCES OF CENTRAL ASIA AND THEIR USE. Materials of the International Scientific and Practical Conference dedicated to summarizing the results of the UN declared "Water for Life" decade. P. 64-73.

[12] https://earthexplorer.usgs.gov/.

[13] Tyunyatkin D.G. (2002). Comparison of methods for determining the rates of abrasion destruction of the shores of lowland reservoirs // Dynamics of ravine-gully forms and channel processes P. 99-102 (in Rus.).

[14] Frolova I.V., Smolkin A.S. (2009). GEODYNAMIC SITUATION IN THE LOWER RACE OF THE KAMA HYDROPOWER PLANT (THE RIGHT-BANK PART OF PERM) 2: 1-4. (http://press.psu.ru/index.php/geogr/issue/view/36) (in Rus.).

[15] Pauline Letortu, Stéphane Costa, Olivier Maquaire, Christophe Delacourt, Emmanuel Augereau, Robert Davidson, Serge Suanez, Jean Nabucet (2015). Retreat rates, modalities and agents responsible for erosion along the coastal chalk cliffs of Upper Normandy: The contribution of terrestrial laser scanning. 245: 3-14. https://doi.org/10.1016/j.geomorph.2015.05.007 (in Eng.).

[16] Sunamura T., (2005). Cliffs, erosion rates. [Encuclopedia of coastal science] 240-241. Springer, Netherlands. ISBN-13 978-1-4020-1903-6 (HB).

[17] Khabidov A.Sh., Marusin K.V., Fyodorova Ye.A. (2012). Monitoring of the coastal zone of the seas, lakes and reservoirs. Sea Shores - Evolution, Ecology, Economy: Materials of the XXIV International Coastal Conference dedicated to the 60th anniversary of the founding of the "Seaside Banks" Working Group. Vol. 2: 287-297.

[18] https://en.wikipedia.org/wiki/Global_Positioning_System. Access date 10.05. 2018.

[19] Ainagul Abitbayeva, Adilet Valeyev, Kamshat Yegemberdiyeva, Aizhan Assylbekova, Aizhan Ryskeldieva (2016). Monitoring of the Abrasion Processes (by the Example of Alakol Lake, Republic of Kazakhstan). 11: 4164-4174. Ijese.2016.323 (in Eng.).

[20] Kazanskaya Ye.A. (1965). Morphology and dynamics of the shores of Alakol Lake (1961–1964). Alakol depression and its lakes. [Questions of Geography of Kazakhstan] 12: 88-121 (in Rus.).

[21] http://www.inform.kz/ru/proekt-ukrepleniya-beregov-ozera-alakol-prohodit-gosekspertizu-foto_a2688815. Access date 11.05 2018.

[22] Jeffrey H. List (2005). Sediment analysis and classification – see beach sediment characteristics. [Encuclopedia of coastal science] 846-850. Springer, Netherlands. ISBN-13 978-1-4020-1903-6 (HB).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 206 – 215 **https://doi.org/10.32014/2019.2518-170X.25**

UDK 553.411

E. Y. Seitmuratova[1], V. S. Goryaeva[1], Y. K. Arshamov[2], R. T. Baratov[1], D. O. Dautbekov[1], F. F. Saidasheva[1], Sh. A. Seitzhanov[1]

[1]Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan,
[2]Satbayev University, Almaty, Kazakhstan.

RESULTS OF SURVEY WORKS ON GOLD MINERALIZATION REVALUATION FOR THE ZHUNGAR-BALKHASH FOLD BELT

Abstract. The article contains results of surveys carried out by the authors in a period from 2012 to 2014 under the Grant Project "Analysis of the epithermal gold-silver mineralization of the Zhungar-Balkhash region and allocation of promising areas for discovery of a new type of industrial deposits". Object of research is the epithermal volcanic mineralization of the North-Western, North-Eastern and Southern sectors of Zhungar-Balkhash region. The gold content of almost all 48 objects of research was confirmed through surface litho-chemical testing and classical metallogenetic analysis. Also,the forecast estimate was given to the region's industrial prospects for profitable gold-silver deposits.

Key words: gold, epithermal gold-silver deposits, volcanic-plutonic belts, pre-study, forecast.

In recent decades, in many countries of the world (Russia, the United States, Japan, Brazil, etc.), a breakthrough in the gold mining industry is attributed largely to epithermal gold deposits of volcanic-plutonic belts (VPB) (figure 1) [1-4, etc.]. A new impulse of the increased interest of gold producers to this type of gold mineralization is due to a number of known factors. **Firstly**, this group contains large and unique deposits (USA, Round Mountain - 300 tons Comstock - 266 tons, Papua New Guinea, Porgera - 555 tons, etc.)along with exceptionally wide development of small objects with bonanza nature of mineralization, which allows make work without significant expenditures. **Secondly**, a possibility of using the open cut mining for these objects, involving highly efficient modern ore processing methods (heap and tank leaching, etc.). **Thirdly**, the associated extraction of silver, bismuth, tellurium, mercury and other components. **Fourth**, and most important, finding and involvement in development the deposits with low Au content (up to 1 g/t) with large volumes of ore mass, the so-called large-volume (large-tonnage) objects [3].

The article of V.A. Narseev and V.M. Shashkin [4] states that "the large-volume deposits of squalid concentrations are on a rise and represent new direction of gold mining. According to the US Mountain Bureau, the number of deposits with gold content less than 1 g/t as of January 1, 2007 was as follows: Brazil - 2 objects, 236 tons, cont.= 0.43 g/t; Indonesia - 2 objects, more than 3000 tons, cont. = 0.84 g/t; Chile - 2 objects, 758 tons, cont. = 0.7 g/t; the USA - 7 objects, 557 tons, cont. = 0.44 g/t. The Argentine deposits are close to the abovementioned ones: 1 object, 346 tons, cont. = 1.09 g/t, Peru - 5 objects, 1400 t, cont. = 1.11 g/t. As of January 1, 2012, the number of such facilities has been doubled".

The priorities noted for this type of mineralization are the basis for making an application to the Ministry of Education and Science of the Republic of Kazakhstan in 2011 for the project: **"Analysis of the epithermal gold-silver mineralization of the Zhungar-Balkhash region and allocation of promising areas for discovery of a new type of industrial deposits"** [5].

The authors did not doubt in timeliness of the statement of this topic on Zhungar-Balkhash fold belt (ZBFB), since 75% of its territory is represented by extensive areas of volcanic-plutonic associations of rocks, forming the marginal continental coal and inland continental coal-Permian volcanic-plutonic belts

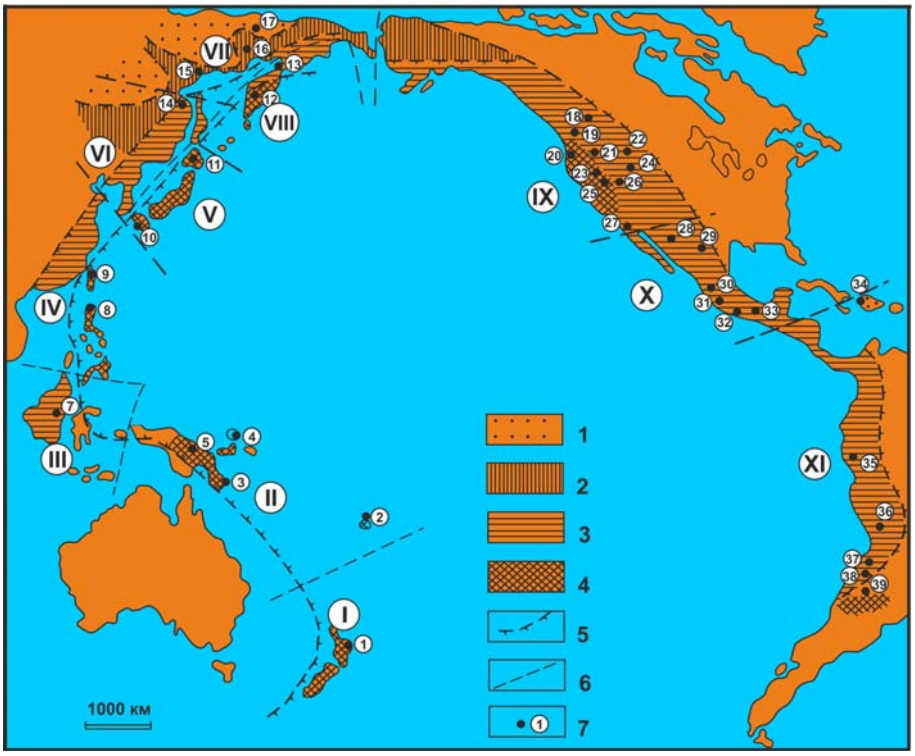


Figure 1 – Placing of large gold-silver deposits in volcanic-plutonic belts of the Pacific ore belt [1].

1 - Late Jurassic-Early Cretaceous mineralization; 2 - Late Cretaceous mineralization; 3 - Paleogene-Neogene mineralization; 4 - Neogene-Quaternary mineralization; 5 - the boundaries of different age-old metallogenic zones (bergstrich to the age decreasing);6 - boundaries of the Pacific belt segments: I - New Zealand, II - Papua New Guinea, III - Indonesia, IV - Philippine; V - Japanese, VI - Sikhote-Alin, VII - Okhotsk-Chukchi;VIII - Kuril - Kamchatka, IX - North American, X - Mexican, XI - South American;7 - individual deposits (in parentheses the average age of mineralization, million years):1 - Waihi (4.0), 2 - Tavua (4.0), 3 - Mizima (10), 4 - Ladolam (0.3) , 5 - Porgera (6.0), 6 - GunungPongkor (20.0), 7 - Kelian (20.0), 8 - Akupan (1.5), 9 - Chinquashi (1.0), 10 - Hishikari, Kushikino (1,0), 11 - Konomai (10), 12 - Agin (8), 13 - Amethyst (40), 14 - Mnogovershinnoe (65), 15 - Hakanja (71), 16 - Dukat (80), 17 - Kubaka (160), 18 - McDonald (35), 19 - Slipper (23), 20 - McLaughlin (2), 21 - Round Mountain (25), 22 - Cripple Creek (28), 23 - Komstok (13), 24 - Telluride-Silverton (22), 25 - Tonopa (20), 26 - Goldfield (20), 27 - Mesquite (25), 28 - Ocampo, 29 - Parral (30), 30 - Sunset (20), 35 - Yanacocha (15), 36 - Kori-Kollo (20), the United States of America , 37 - La Coipa, 38 - Nevada, 39 - El Indio (10).

(VPB), which are very promising for studying and searching the deposits of such geologic-industrial type (GIT) [6, etc.].

Recommendations of the predecessors on additional study of the gold content [6-9 and others] and presence of the main ore mineralization factors attributed to the world's known typical epithermal deposits (Wyehi-New Zealand; Cripple Creek, Telluride-Silverton, Goldfield-USA, El-Indio-Chile, Yanacocha-Peru, etc.) [1, 2, 6 other] are the main issues for inclusion of certain objects in the program of works.

For the three years of the Grant Project performance, the workers carried out field work at 48 points of mineralization in the North-West, North-East and Southern sectors of the ZBFB (see figure 2) [5].

In selecting objects for pre-study, first of all, the Map of Prospective Gold-ore spots and areas of ZBFB was used inthe scale 1: 1000000 (figure 3), which was based on the data from the “Registration chart of gold ore occurrences in the south of Central Kazakhstan”, made by results of helicopter searches conducted during the period from 1968 to 1973 by B.S. Zeilik, V.A. Efimenko [10], and the data from Maps of ZBFB gold content of the scale 1: 500000, compiled by E.Y. Seitmuratova, P.K. Zhukov in 1998 [6].

Finally, this map shows about 2000 manifestations and points of gold mineralization, of which, in addition to well-known deposits and ore manifestations, 364 gold mineralization points with a content of 0.01 to 0.1 g/t; 453 points with a gold content of 0.5 to 1.0 g/t; 257 points with gold content from 1.0 g/t to 5.0 g/t and 90 mineralization points with a gold content of more than 5.0 g/t.

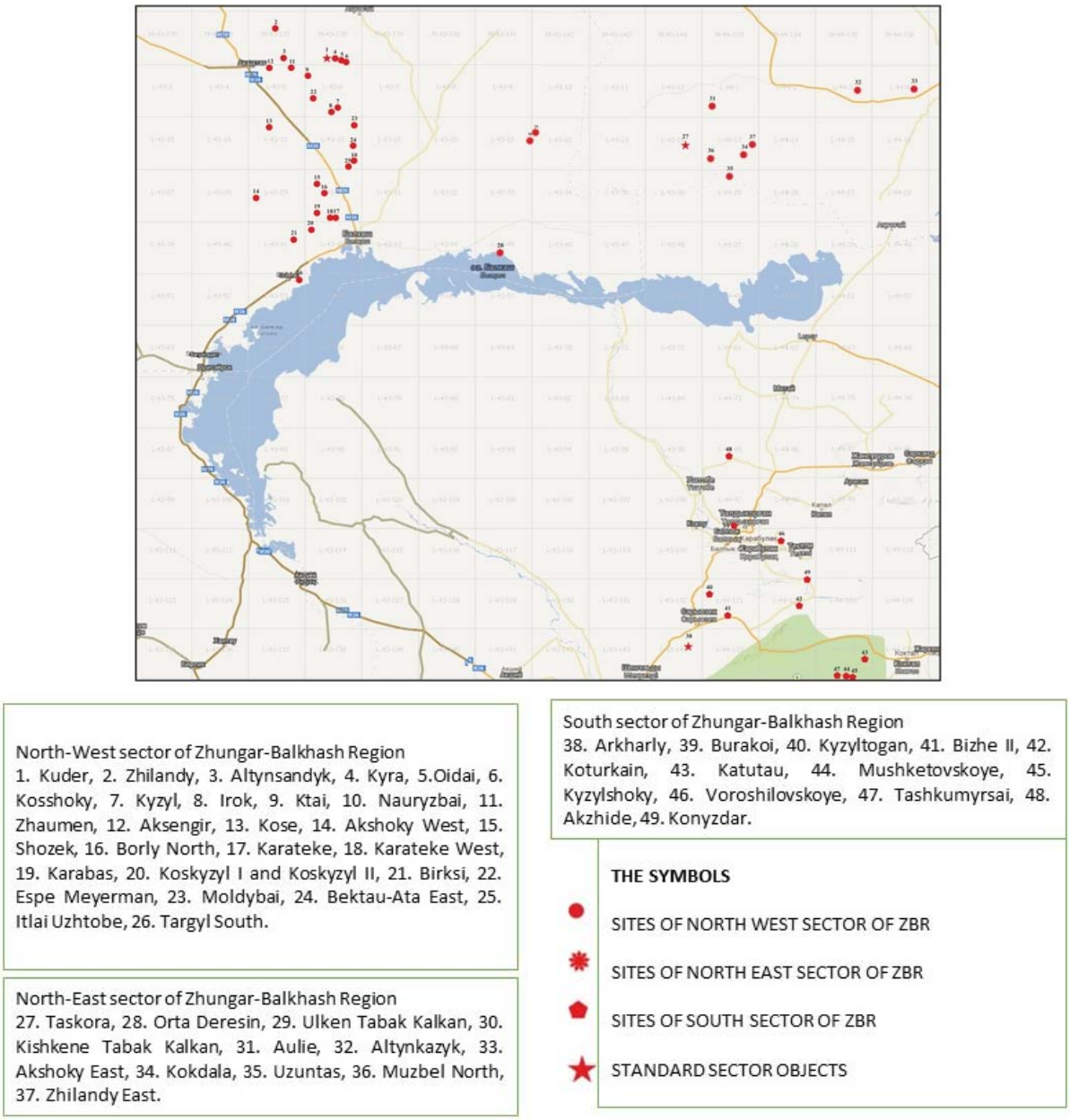


Figure 2 – Location scheme of the epithermal gold-silver mineralization of the Zhungar-Balkhash region

It should be noted that not only the objects of Au-Ag mineralization were included in the pre-study program, but also volcanogenic Cu-porphyry, Pb-Zn and Pb manifestations, where single significant Au contents were previously noted and their gold content was not specified further (SokurBirksi, Symbhil, Sargul, Kurgantas, Ktay, Akgirek, Kokdala, Bizhe, etc.) [5-10 and others]. Inclusion of not only gold ore occurrences into the study is caused by the fact of existence a number of cases when copper mineralization points (Mystobe, Sambyl, Sokurka, Birksi), polymetals (Zhosabai, Sargul, Akgirek, etc.) and others turned out to be gold ore occurences after additional study. This indicates that the final scale of the gold-bearing nature of the stiffness has not been revealed yet. The noted cases also bear witness to the complex nature of epithermal mineralization.

During the field research of the objects included in the field programs of the next year of work on the project (201-2014), the following tasks had to be solved:

1) mapping of objects with compilation of geological maps: 1: 25000-1: 10000;

2) identification and detailing of the previously and newly identified areas of metasomatically reprocessed rock propagation and conduct of an area litho-geochemical testing.

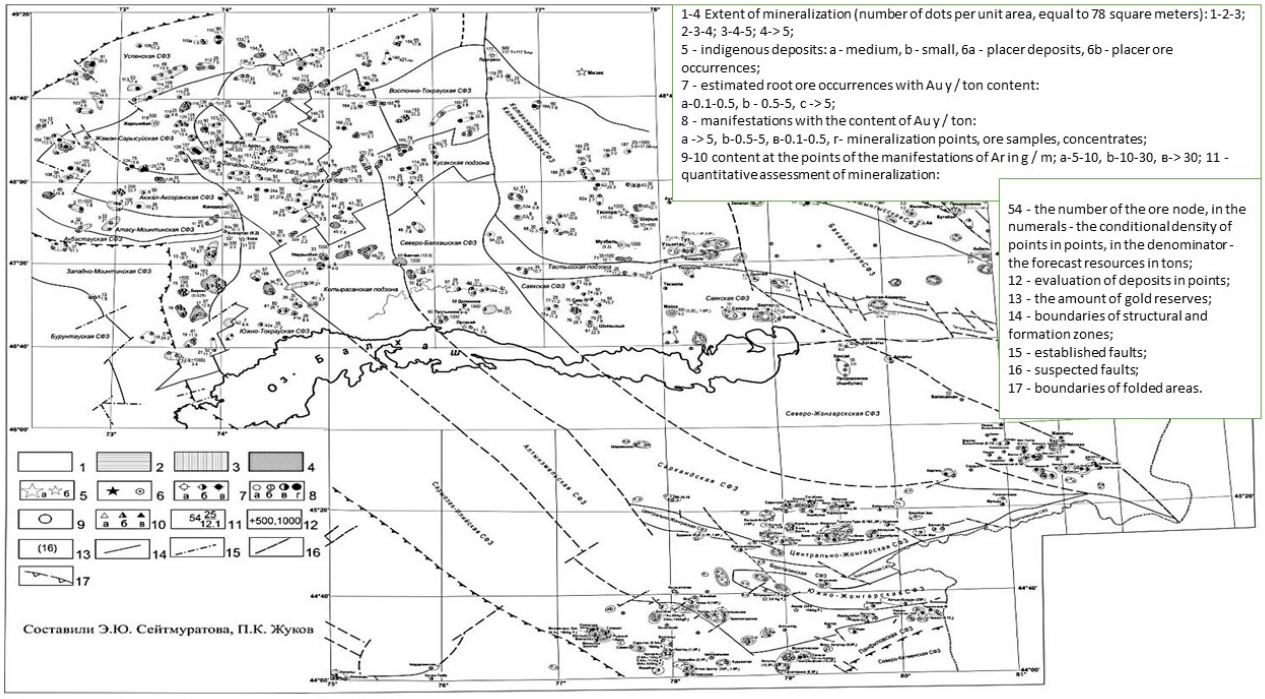


Figure 3 – Map of prospective gold ore spots and areas of the Zhungar-Balkhash fold belt.
Made by: E.Y. Seitmuratova, P.K. Zhukov, F.F. Saidasheva [6]

Areal sampling is due to the fact that this type of mineralization is characterized by an extremely uneven distribution of Au content within ore-bearing areas, which is well illustrated by the drawings of the Silverton-Telluride gold deposits, the USA - 245 tons, Tau-Wua Polo, Fiji Island-120 tons, gold province Kivatin (figure 4a, b, c) [2, 6].

So, the first two large deposits are in common structures of the caldera type with numerous non-industrial manifestations: in the first case - with 37 objects, in the second –with 23 of them [6].

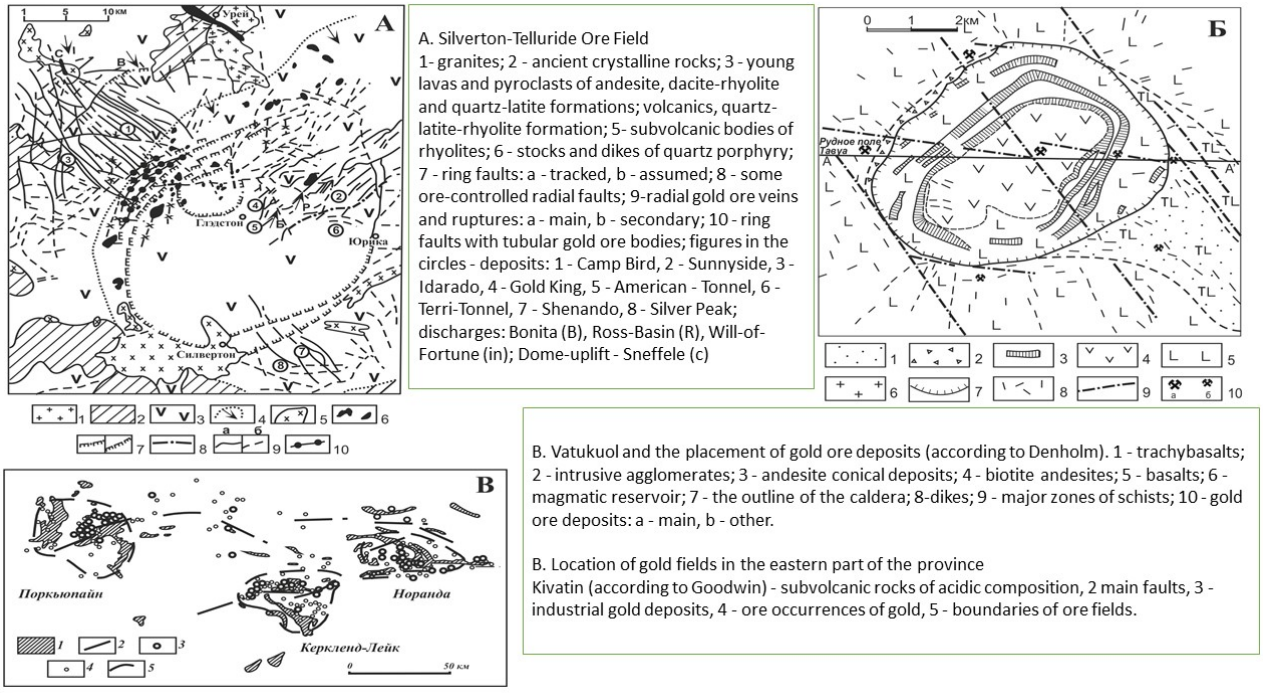


Figure 4 – Examples of uneven distribution of gold mineralization in gold ore structures and fields [6]

Consequently, when searching for epithermal deposits in VPB, there should be no limit to revealing only one or two manifestations that are within a promising ore-bearing structure, but it is necessary to estimate the potential ore-bearing capacity of the entire area that is allocated by hundreds in ZBFB. At the present time, within the framework of the Kargaly volcanic-tectonic structure (VTS), the litho-chemical sampling was carried out on indigenous rocks (G.T.Skublov, 1965-1968), which allowed discover 3 small gold-silver deposits - Slushoky, Ily and Zhosabai and large quantities of mineralization points for gold and silver, which require additional study [6, etc.].

The geological additional study of ZBFB gold ore allows state the following [5] most important results:

- The complex geological structure of all volcanic-tectonic structures revealed during the mapping process, to which the most of the studied gold ore areas are associated (Sokurkoi, Nauryzbai, Kuder-Akgireksk, Sambyl, Sargul, etc.) to, characterized by the complex heterogeneous composition of the basement of these structures and intensively manifested discontinuous tectonics established during interpretation of aerial and cosmic materials (figures 5, 6) [6].

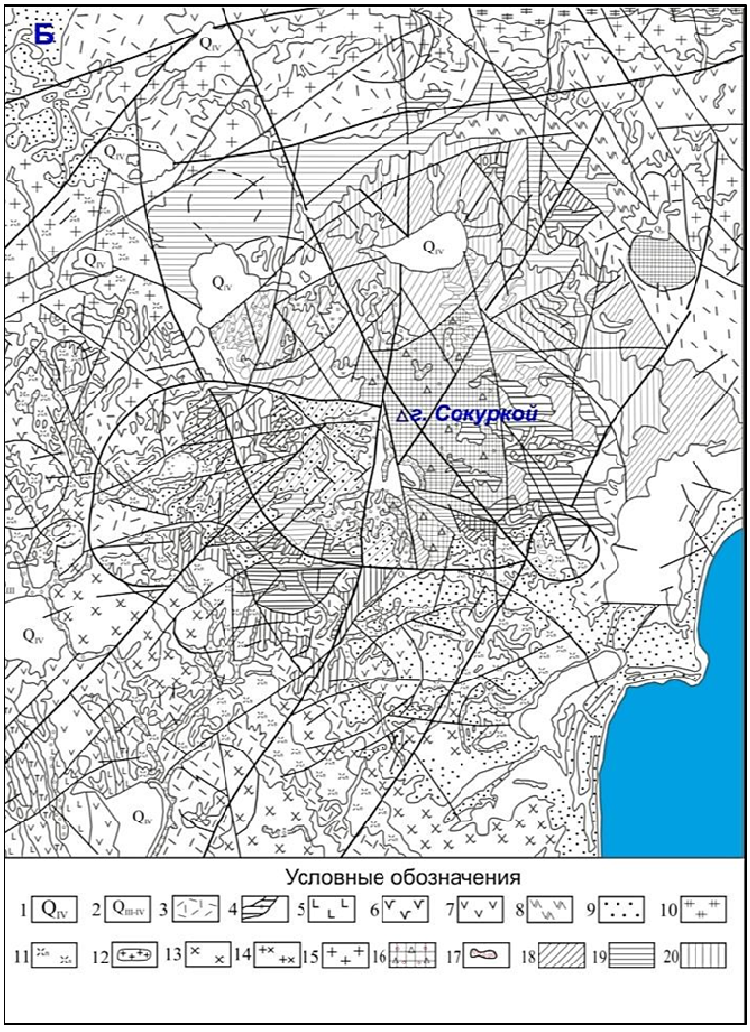


Figure 5 – Geological map of copper-porphyry with gold deposits of Sokurkoi, scale 1:25000.

1 - alluvial and lacustrine-alluvial, dry-type playa; 2 - alluvial-deluvial deposits; 3 - acidic volcanics of the Keregetas suite (C_1b_2-m_1kg); 4 - sub-volcanic intrusion of the Keregetas suite; 5 - basalts of the Kalmakemel suite (C_1s_2-b_1kl); 6 - andesibasalts of the Kalmakemel suite (C_1s_2-b_1kl); 7 - andesites and their tuffs of the Kalmakemel suite (C_1b_2-m_1); 8 - andesidicites of the Kalmakemel suite; 9 - volcanogenic-sedimentary deposits of Silurian; 10 - Proterozoic; 11 - $\gamma\xi\pi P_{1\text{-}3}tr$; 12 - granite-felsite-porphyry of the ventral facies of the keregetas suite; 13 - $\mu\gamma\delta P_{1\text{-}2}kk$; 14 - $\gamma\delta C_2$; 15 - γD_3ks; 16 - monoquartzites breccia along the vent facies; 17 - the body of monoquartzites; 18 - sericitequartzites; 19 - secondary quartzites with a limonite, sericite-kaolinite-alunite; 20 - secondary kaolinite-dickitequartzites.

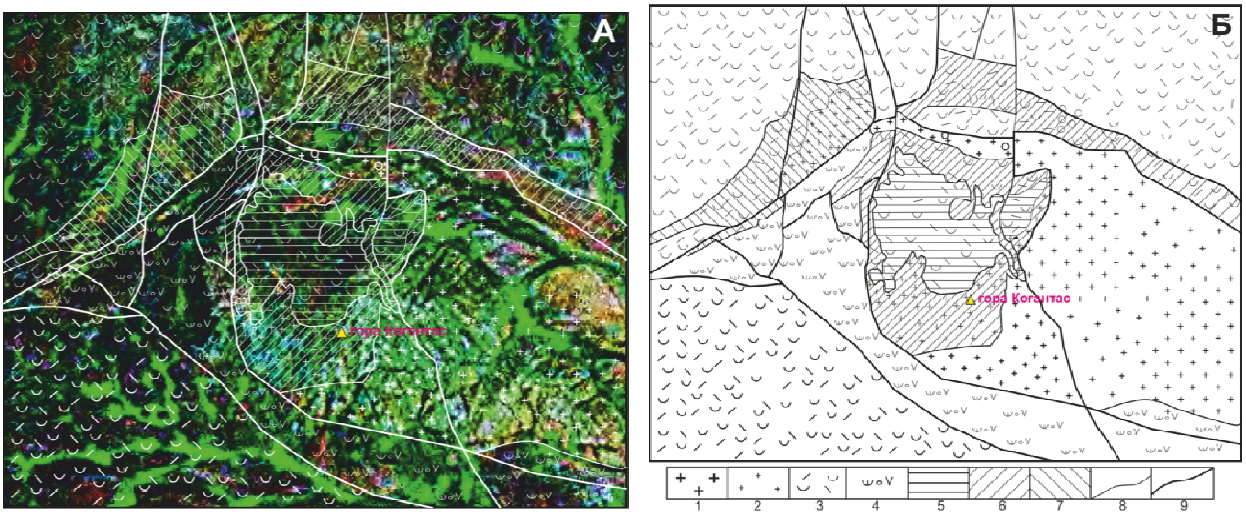


Figure 6 – The cosmogeological map (A) and the geological map (B) of the copper-gold ore manifestation Korgantas [5].

1 - fine-grained leucogranites (P); 2 - granite-porphyry (C); 3 - tuffs of the acid composition of the Keregetas suite (C2kg); 4 - tuff-conglomerates, sandstones, siltstones, sills of andesites of the Kalmakemel suite (C1-C2kl); 5 - andalusite-quartz metasomatites; 6 - metasomatitesandalusite-quartz-sericite and kaolin-quartz; 7-metasomatites quartz-sericite and quartz-kaolinic; 7- geological and facies boundaries; 8-breaking disorders

- **Distribution break down formetasomatic formations**, which form extensive fields in all areas studied, which were previously identified by a number of geologists, and definition of their facial varieties. The largest number of metasomatites facies was established on the Kuder-Akgirek area (figure 7). These are secondary quartzites of the following mineral types: monocrystal, quartz-sericite, quartz-sericite-dickite, quartz-hematite-kaolinite, alunite-kaolinite, quartz-dickite-zunite, jarosite-kaolinite.

- **Confirmation** of a previously noted fact of widespread distribution of the secondary quartzite metasomatic formation, to which the most of the epithermal gold-silver mineralization is associated to.

- **Also identification of the dependence** of ore content of the secondary-quartzite metasomatic formation of its structural position. In the case when it is manifested in the center of the volcanic construction, fixed by the products of the muzzle and prichargalfacies, the probability of revealing relatively large ore objects is most significant [4, 5, 10].

- It has also been confirmed, that peripheral zones of volcanic structures, radial and annular faults are no less **favorable for the ore deposition**.

- After processing the results of analytical studies, it was revealed that the **elements-indicators of gold mineralization** in ZBFB are Pb, Cu, Mo, Bi, and the subphonic elements are as follows: Co, Ni, V, Sn, and they are characterized by negative correlation ratios to the gold.

Schemes of geochemical haloes made on all areas and geologico-geochemical sections by profiles also allowed reveal:

1) geochemical specialization for each area;

2) close positive correlation between Au- Pb-Mo-Bi-Ag-Cu;

3) According to the correlation analysis, a productive geochemical association of elements (Au, Ag, Pb, Cu) is determined, which is supplemented with bismuth at the upper ore and ore levels, and Bi occupies the position of Mo in the positions of remotely-peri-ore and lateral wedging.

Data on the geological structure, spectral and atomic absorption analyzes allowed the authors to compute the predicted schemes for a number of gold ore areas studied (Symbhil, Akgirek, Sargul, Nauryzbai, etc.), with allocation of sites according to the prospects degree as the primary and secondary (figure 8 A, B, C). On the basis of the same data, the gold reserves were estimated at a depth of 10 m, for a number of studied gold ore deposits which may be interesting for investors.

According to the analysis of these data, the following gold-ore areas and objects are promising: Sokurkoi-61,074 tons, Symbhil-38,066 tons, Kuder-Akgirek-86.814 tons, Akshoky-10.639 tons, Kosshoky-18.096 tons, etc. [5].

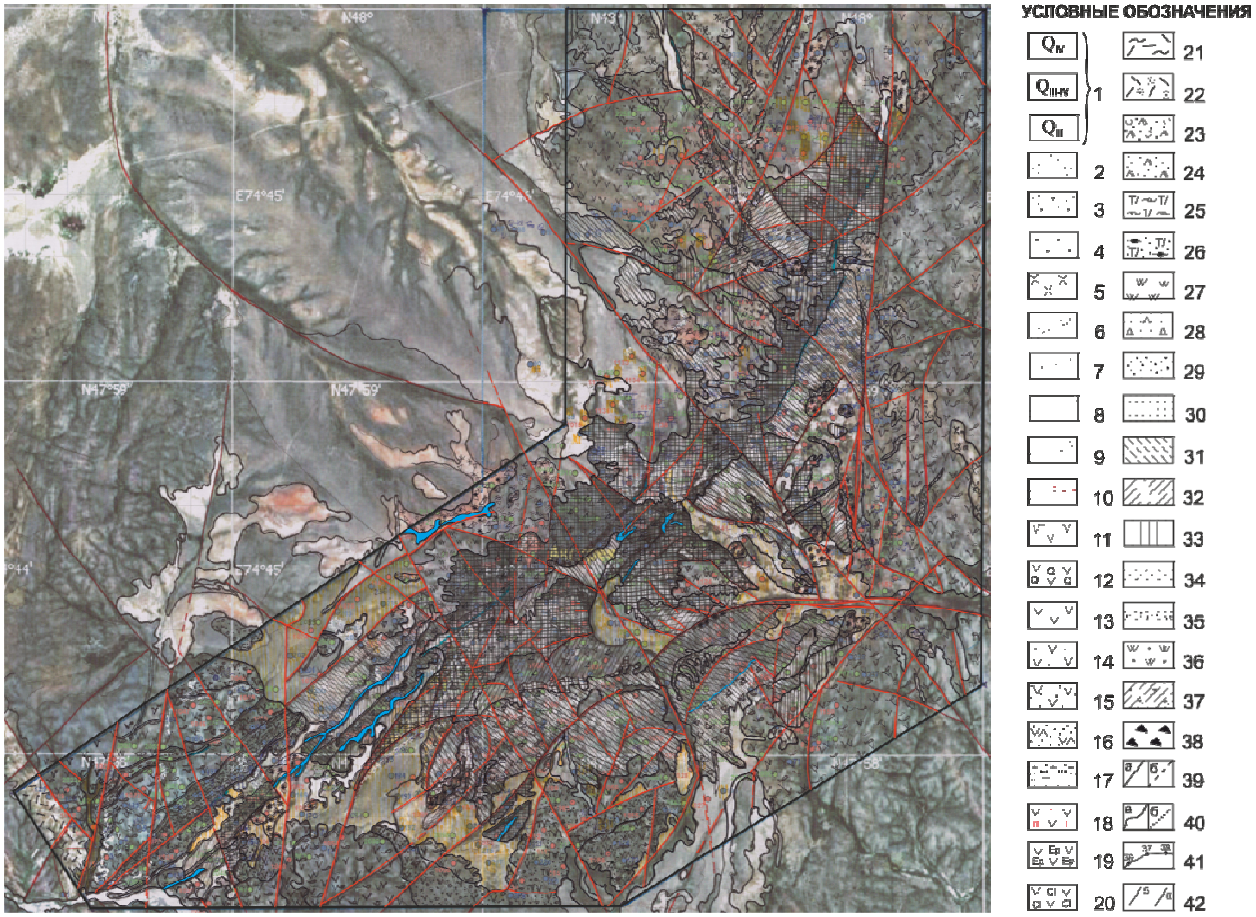


Figure 7 – Cosmogeological map of prospective gold-ore area Akgirek, the scale 1: 10000.

1 - quaternarysediments (dry-type playa, white alkali, alluvial deposits); 2 - paleogeneclays with fragments of rocks (rolledan-dacute); 3 - “iron hats” with fragments of rocks – red-colored paleogene clays with fragments of secondary quartzite; 4 - “iron hats” without fragments of rocks; 5 - intrusive bodies type of porphyritic granosienites; 6 - dykes of granosienitporphyry; 8 - dykes of rhyolite porphyry and felsite porphyry; 9 - dykes of diabases; 10 - quartz vein; 11 - andesi-basalts; 12 - quartz-bearing andesites; 13 - andesites (aphyric and porphyritic); 14 - automagmatic breccia of andesite composition; 15 - lithic-crystal tuff of andesite composition; 16 - crystallotuff of andesite-dacite composition; 17 - a pack of volcanic sedimentary rocks; 18 - propyliti-zedandesites; 19 - epidotizedandesites; 20 - chloritizedandesites; 21 - fluid lavas of rhyolite composition; 22 - spheriolite lavas of rhyolite composition; 23 - ash crystallotuff of rhyodacite composition; 24 - caked tuff of rhyodacite composition; 25 - ignispu-mites of trachyriolite composition; 26 - ignimbrites of trachyriolite composition; 27 - polymineral secondary quartzites with unindentified facial associations; 28 - monoquartzites on brecciated rocks; 29 - monoquartzites granular; 30 - monoquartzites secondary quartzites “sound” for pressure (aphyric); 31 - quartz-sericite-diccite(kaolinite secondary quartzites).

Thus, the conducted studies showed a high prospectivity of the studied areas and manifestations of epithermal Au-Ag mineralization. It has also been established that some of them can be considered as large-scale deposits with poor ores that have been successfully developed in many countries by the open cut mining method, using new technologies for extracting gold (heap, vat leaching, etc.) [3, 4, etc.].The works carried out at the first stage of search for epithermal Au-Ag manifestations in ZBFB convincingly substantiate the high prospects and the extreme necessity of setting up detailed prospecting and appraisal works to verify the manifestations to the depth and recommending conduct further exploration and subsequent extraction.

The authors are grateful to the Ministry of Education of the Republic of Kazakhstan for support of the grant 0520 for 2012-2014, results of which again confirm the prospects for the epithermal gold-silver mineralization of the Zhungar-Balkhash fold belt.

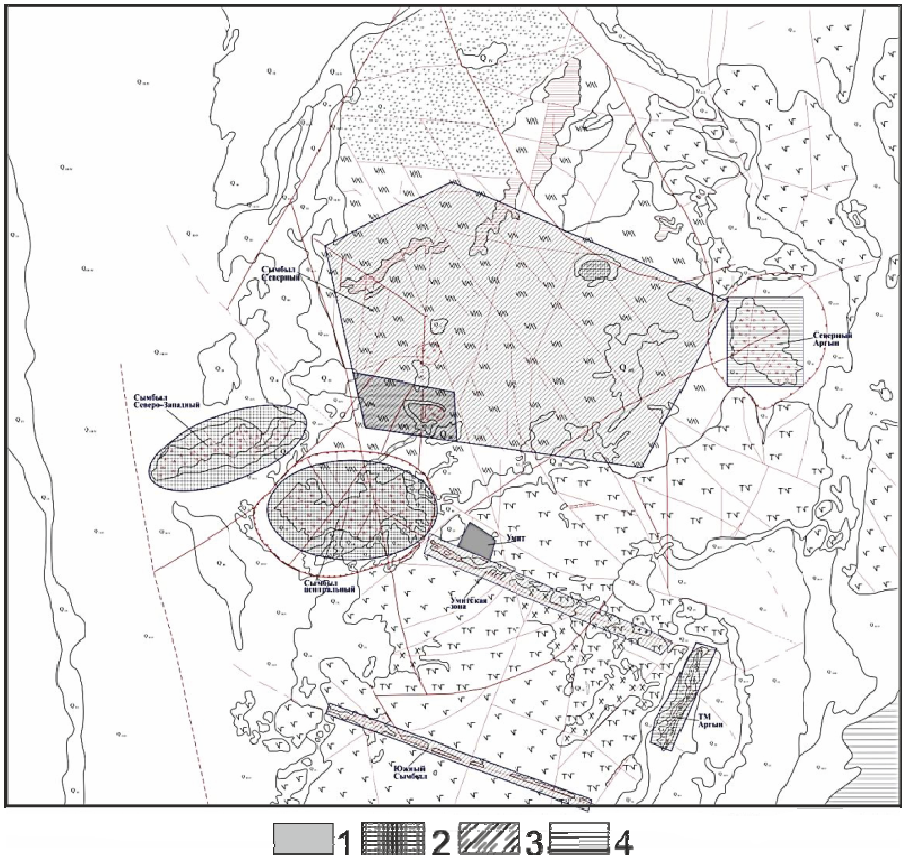


Figure 8A – Forecast scheme for the gold ore area Symbyl, the scale1: 25000.
1 - known deposit, 2- primary prospect sites, 3 - prospect secondary sites, 4 - prospect third turn sites

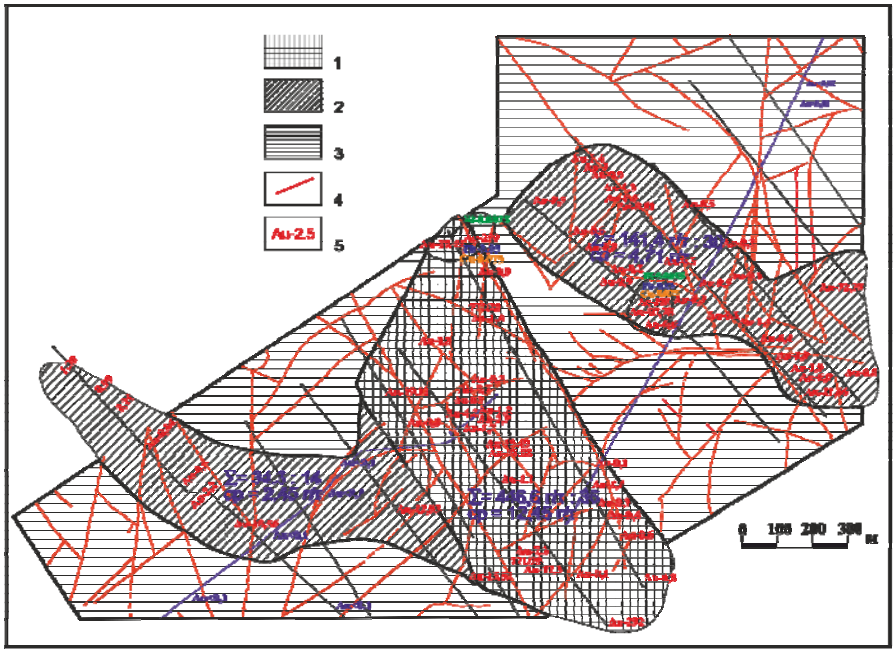


Figure 8B – Forecast scheme for the Akgirek prospective gold-ore area.
1 - primary prospect site, 2 - secondary prospect site,
3 - third turn prospect site, 4 – faults, 5 - points with significant Au content

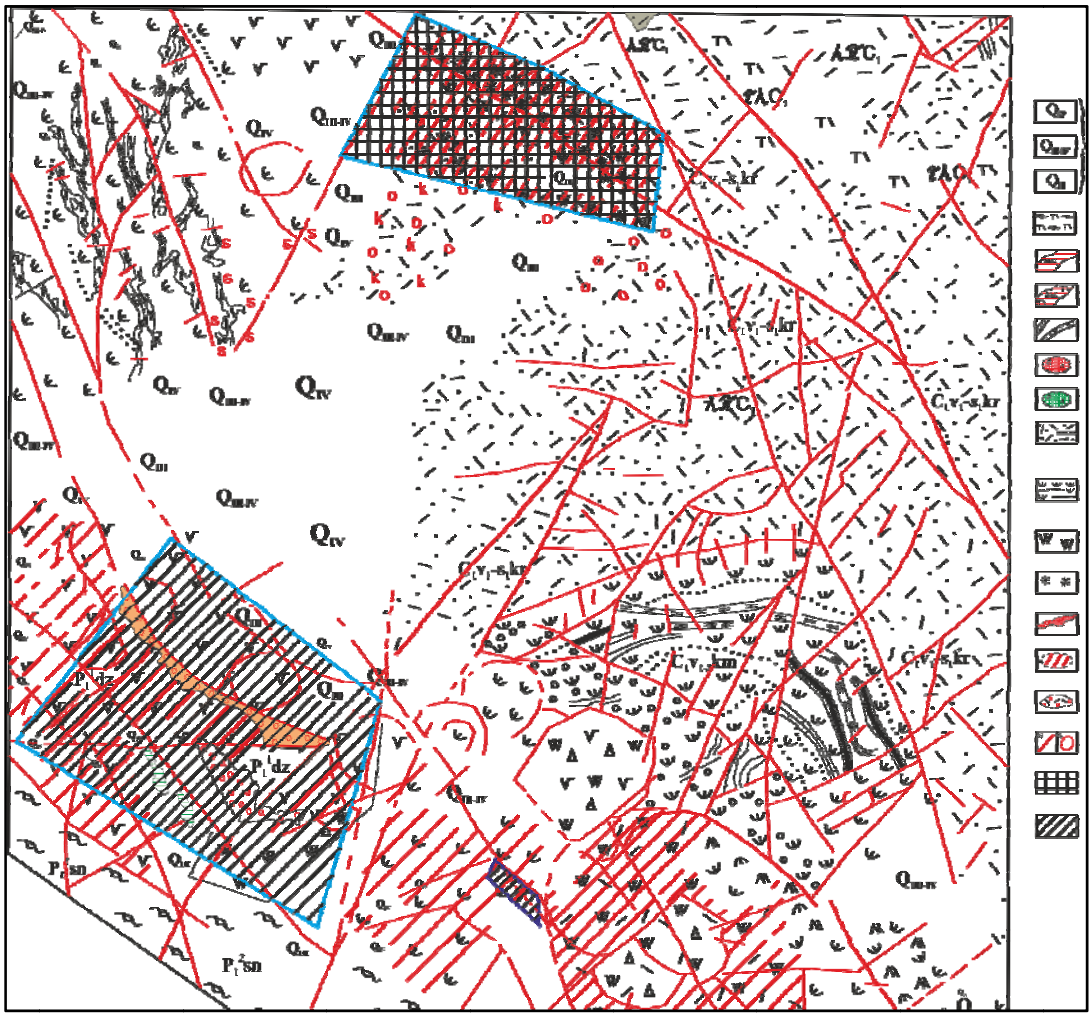


Figure 8B – Forecast scheme for the Sargul prospective gold ore area.

1 – quaternarysediments (dry-typeplaya, whitealkali, alluvialdeposits), 2 - shangelbay suite – ignimbrite-ignispumite series of the trachyrhyolite composition, 3 - sub-volcanic intrusion of the rhyolite porphyry of the karkarala suite(C_1v_2-s_1kr), 4 - sub-volcanic intrusion of the rhyolite porphyry of the karkarala suite(C_1v_2-s_1kr),5 - dykes of the microgranite-rhyolite- and felsite-porhyry of early carboniferous, 6 - heterochronouspersilicic volcanic neck, 7 - heterochronoussubsilicic and medium volcanic neck, 8 - the karkarala suit(C_1v_2-s_1kr)lithocrystalloclastic tuff of rhyolite composition with rare interbed of tuffites, tuffaceous sandstone,9 - the kemelbek suit (C_1v_2-s_1km) – volcanogenic-sedimentary series of andesite basalt, andesite, rhyodacite with interbed of tuffites, tuffaceous sandstone, limestones, ferruginous quartzites, carbonaceous-argillaceous aleurolite and coal, 10 - secondary quartzites, not dissected into mineral facies, developed in the Early Carboniferous rocks of the karkarala and kemelbek suites, 11 - ferruginization zone, 12 - quartz vein,13 – crust of weathering of quartz-kaolin profile, 14 – quartzous and sericitized volcanic rock, 15 – faults: a) linear of variety order, b) ring and arcuate, 16 – primaryprospectsite, 17 – secondaryprospectsite

Э. Ю. Сейтмуратова[1], В. С. Горяева[1], Я. К. Аршамов[2],
Р. Т. Баратов[1], Д. О. Даутбеков[1], Ф. Ф. Сайдашева[1], Ш. А. Сейтжанов[1]

[1]Қ. И. Сәтбаев атындағы геологиялық ғылымдар институты, Алматы, Қазақстан,
[2]Сәтбаев Университеті, Алматы, Казахстан

ЖОҢҒАР-БАЛХАШ ҚАТПАРЛЫ ЖҮЙЕСІНІҢ АЛТЫНКЕНДІЛІГІН ҚАЙТА БАҒАЛАУ БОЙЫНША ЖҮРГІЗІЛГЕН ҚОЛДАНБАЛЫ ҒЫЛЫМИ-ЗЕРТТЕУ ЖҰМЫСТАРЫНЫҢ НӘТИЖЕЛЕРІ ЖӨНІНІДЕ

Аннотация. Мақалада 2012–2014 жылдары аралығында орындалған «Жоңғар-Балқаш аймағындағы эпитермальды алтын-күміс кенорындарын талдау және жаңа типті өнеркәсіптік кенорындарын табу үшін перспективалық аймақтарды бөлу» гранттық жоба авторларының жүргізген зерттеу жұмыстарының нәтижелері келтірілген. Зерттеу нысаны Жоңғар-Балхаш аймағының Солтүстік-Батыс, Солтүстік-Шығыс және Оңтүстік бөліктеріндегі эпитермальды вулканогенді кендену аймақтары болып табылды. Аралық литохимиялық сынамалау мен классикалық металлогендік талдаудың нәтижелеріне сүйене отырып, зерттелінген

барлық 48 нысанның алтынкенділігі дәлелденді және эпитермальды алтын-күміс кенорындарын өндіру үшін өнеркәсіптік перспективалы аймақтарға болжамдық баға берілді.

Түйін сөздер: алтын, эпитермальды алтын-күміс кенорындары, жанартау-плутондық белдем, қосымша зерттеу, болжам.

Э. Ю. Сейтмуратова[1], В. С. Горяева[1], Я. К. Аршамов[2], Р. Т. Баратов[1], Д. О. Даутбеков[1], Ф. Ф. Сайдашева[1], Ш. А. Сейтжанов[1]

[1]Институт геологических наук им. К. И. Сатпаева, Алматы. Казахстан,
[2]Сәтбаев Университеті, Алматы, Казахстан

О РЕЗУЛЬТАТАХ ПРОВЕДЕНИЯ ПРИКЛАДНЫХ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИХ РАБОТ ПО ПЕРЕОЦЕНКЕ ЗОЛОТОНОСНОСТИ ЖОНГАРО-БАЛХАШСКОЙ СКЛАДЧАТОЙ СИСТЕМЫ

Аннотация. В статье изложены результаты исследований, проведенных авторами в 2012–2014 гг. по грантовому проекту «Анализ эпитермального золото-серебряного оруденения Жонгаро-Балхашского региона и выделение перспективных площадей для обнаружения промышленных месторождений нового типа». Объектом исследований явилось эпитермальное вулканогенное оруденение Северо-Западного, Северо-Восточного и Южного секторов Жонгаро-Балхашского региона. На основе результатов площадного литохимического опробования и классического металлогенического анализа была подтверждена золотоносность почти всех 48 исследованных объектов и дана прогнозная оценка промышленных перспектив региона на обнаружение рентабельных для отработки эпитермальных золото-серебряных месторождений.

Ключевые слова: золото, эпитермальные золото-серебряные месторождения, вулкано-плутонические пояса, доизучение, прогноз.

Information about authors:

Seitmuratova E.Y., Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan; https://orcid.org/0000-0001-8403-4635

Goryaeva V.S., Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan; https://orcid.org/0000-0001-6528-2473

Arshamov Y.K., Satbayev University, Almaty, Kazakhstan; https://orcid.org/0000-0003-0527-6797

Baratov R.T., Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan; https://orcid.org/0000-0002-0627-1536

Dautbekov D.O., Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan; https://orcid.org/0000-0002-8220-5450

Saidasheva F.F., Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan; https://orcid.org/0000-0002-5817-1158

Seitzhanov Sh.A., Institution of Geological Sciences named after K. I. Satbayev, Almaty, Kazakhstan; https://orcid.org/0000-0003-4807-8571

REFERENCES

[1] Konstantinov M.M., Nekrasov E.M., Sidorov A.A., Strunskov S.F. The Gold ore giants of Russia and the World. M.: Science world, 2006. 272 p.

[2] Nekrasov E.M. Foreign endogenous gold deposits. M.: Subsurface. 1988. 286 p.

[3] Goncharov V.I., Buryak V.A., Goryachev N.A. Large-volume gold and silver deposits of volcanogenic belts // Reports RAN. 2002. Vol, 387, N 5. P. 678-680.

[4] Narseev V.A., Shashkin V.M. Strategic direction of precious metals mining development. The Problem of Large-Volume Locations // Geology and Conservation of Subsoil. 2012. N 1. P. 2-5.

[5] Seitmuratova E.Y., Diarov A.B., Goriaeva V.S., et al. Analysis of the epithermal gold-silver mineralization of the Zhungar-Balkhash region and allocation of promising areas for detection large deposits of a new type // Report on the grant 0520 - the intellectual potential of the country, 2012-2014. Almaty, 2014. 178 p.

[6] Seitmuratova E.Y. Gold content of the Late Paleozoic volcanic-tectonic belts of the Zhungar-Balkhash province (study and development problems) // Geol. and survey of Kazakhstan. 1998. N 2. P. 13-24.

[7] Deposits of gold in Kazakhstan. Reference book. Almaty, 1996. 183 p.

[8] Bakenov M.M. Gold ore formations of Kazakhstan. Alma-Ata, 1976. P. 228.

[9] Averin Y.A., Blank V.Y., Diarov A.B., Narseev V.A., Nurmagambetov A.A. Conditions for the formation of gold deposits in the volcanogenic zones of Kazakhstan and Central Asia // Geol., geokhim. and mineralogy of gold ore areas and deposits of Kazakhstan. Alma-Ata, 1972. P. 11-32.

[10] Zeilik B.S., Efimenko V.A. Accelerated searches for gold in Central Kazakhstan // Exploration and conservation of mineral resources. M., 1972. N 4. P. 50-52.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 216 – 222 **https://doi.org/10.32014/2019.2518-170X.26**

L. I. Skrinnik, R. R. Gadeev

Institute of geological Sciences named after K. I. Satpayev, Almaty, Kazakhstan.
E-mail: lisgeo@inbox.ru, gadeev_ravil@mail.ru

ON THE CLOSING DATE OF THE JUNGAR-BALKHASH PALEOBASIN

Abstract. Analysis of materials on the Southeast of Kazakhstan and the adjacent region of China shows that the development of the Paleoasian ocean occurred through the formation of island arcs and separate sedimentation basins. Dzhungaro-Balkhash sea basin existed from the early Ordovician to the middle of the Permian period, as evidenced by the presence of marine fauna in its individual parts. Stratigraphic materials adjacent to the East of Alakol area of China show that most young marine terrigenous deposits, Jungar-Balkhash basin are of Famennian-tournaisian the tournaisian age and overlap-cannabischarlie regional volcanic volcanic belt. This is followed by a break corresponding to the rise of the area, the subsequent accumulation of ground molasses of the Gzhel century, and then the contrasting lower Permian volcanic series. The youngest ophiolites in the area are of early Devonian age. These data indicate the autonomous time of laying the pools that make up the paleo-ocean and the close time of their closure (probably early Permian). Closing method-a collision in combination with a simple filling sedimentary material. The active edge of the Dzhungaro-Balkhash basin is the Ili plate separating It from the South Tien-Shan paleocean. Volcanic accumulation of the Devonian, Carboniferous and Permian periods are part of a volcanic belt that framed Jungar-Balkhash sea basin on the part of the Kazakhstan continent, talking about the geological and petrochemical data.

Key words: Paleoocean, ophyolites, island arc, active margin, Gzhel age, petrochemical data.

Introduction. Late Paleozoic history of South-East Kazakhstan and Tien Shan is connected with development of the Paleo-Asiatic ocean and adjoining areas of the Kazakhstan continent. Initial stage of subsidence the Paleo-Asiatic ocean was connected generally accepted opinion, with disintegration paleocontinent Rodiniya and the most further his(its) development was shown in shaping the row of the insular arcs and in accordance with them Ural, Obi-Zaysan, Kirghiz-Terskey, Dzhungaro-Balhash basins [1, 2]. Time of the closing the Paleo-asiatic ocean is a subject to discussions and is taken within late Carboniferous to Permian period.

Axial for that ocean is Dzhalair-Nayman ophiolite zone, terminated its development in early Ordovician [3]. The Second ophyolite zone, Itmurundy in North Balhash area- is taken as ensimatic island arc, torn right-side shift on Itmurundin and Tekturmas branches. Her(its) development was terminated in medium of Silurian period. The Large island arc system, separated Dzhungaro-Balhash and Obi-Zaysan basins, was Chingiz-Tarbagatay ensimatic insular arc, existed in Cambrian and Ordovician [4, 5]. From located south-west Dzhungar-Balhash basin she is separated with large Chingiz shift; northeast border of the insular arc was not well-marked, it was facial, with change island-arc sediments into ocean ones to axial for Obi-Zaysan paleoocean Char-Gornostaev ophyolite suture.

Dzhungar-Balhash paleobasin occupied the space to south-west from Chingiz-Tarbagatay arc and from Ili plate to northward. In modern cut he has a wedge-shaped outlines and is framed with three sides by volcanic belts. In the opinion of leading kazakhstan specialist Bespalov V.F, Afonichev N.A., Zaycev Yu.A., V.Ya. Koshkin and others Dzhungar-Balhash sea pool was gradually narrowed and migrated in south-east direction [4-7]. Right behind for basin and in the same side framing his(its) marginal volcanic belts moved.

The contour of Dzhungaro-Balhash sea basin is outlined it enough clearly. Inwardly it composed powerful sedimentary, mainly terrigenous and siliceous-terrigenous sediments of Devonian and Carboniferous systems. Devonian, Carboniferous and Permian volcanic accumulations surrounded the sea pool with north, west and south, on measure of the removing behind it with local develop changed with terrigenous by red-colour postponing intracontinental zone [6, 7]. The time of existence Dzhungar-Balhash basin from formation of marginal rifts at the beginning Ordovician to infilling by the end of Paleozoic [8-10].

Time of the full closing Dzhungar-Balhash paleoocean on that moment is object of discussion. In his(its) Kazakhstan part by majority of geologists it is taken as early Permian or as border early and late Permian period[11]. The Reason for such dating serves presence of Permian sea fossils in layers of Durnorechen suite beside north bottom of Main Dzhungar range [12]. Here V.A.Bush and others are described sea Low Permian sediments (the sandstones and siltstones with lenses of limestone, power 220 m, containing briozoa and rugosa). The last is presented by forms Artins complex similar known on Ural.

Northward from town Zharkent, near southern bottom of Dzhungar Alatau and in Toksanbay range it is known outcrops of different-colour conglomerate-sandstone of the postponing Jamanbulak suite, containing fauna brachiopodes, and foraminifers, the remainders of the flora and palinocomplexes of late Carboniferous age. In most top of her(its) sequence L.N.Sergeev was described late Carboniferous brachiopodes, but after M.M.Marfenkova – Hemifuzulines of upper part of the Moscow stage [13]. Palinocomplex is presented by forms typical of bottom, but from sequense of Toksanbay range - by a typical upper Carboniferous forms: Florinites luberae Samoil., Cordaitina rotata Samoil., nigritellus (Lub) Shurk and others.

Carboniferous sequence of the sediments of the south part Dzhungar Alatau within active margin of paleobasin Kugaly suite presented lake grey-yellow sandstone, siltstones, argillites,tuffites, flint and algae limestones with the remainders of the flora, palinocomplex and imprint amphibious crowns. The Remainder of the flora in her(its) is typical of upper Carboniferous and bottom перми. Palinologic determinations Potoniesporites novicus Bhar., Punctatisporites granifer Pot., Shophipollenites principalis Lub. Cordaitina sp and others give the narrower age interval of the accumulation of the sediments: late Carboniferous [13]. The Imprint of amphibian Protriton Brochiozaurus Gredu from these sediments in Kurty region also have late Carboniferous or early Permian age [14]. Thereby, we have given on different parts of the region about existence sea Dzhungar-Balhash basin in late Carboniferous and, may be in early of the Permian.

Sedimental and geohronological materials of chinese geologist, studied upper Paleozoic volcanic-sedimentary sequence in mountain Barleyk West Dzhungary (the Northwest China) helped to restore time of the closing Dzhungaro-Balhash ocean in his(its) the most east, chinese part [15] Upper Paleozoy sequence of this region includes from below upwards litoral sedimentary layers, containing glauconite sandstones of shallow shelf (Famen-Tourneous),volcanic rocks of orogenic belt of Tournaisian - Early Bashkir age, sandstones and conglomerates of Gzhel stage of with gradational bedding unrepresentative for sea sediments. The sequence has been terminated by bimodal volcanic assotiation, on geochronological data corresponding to Asselianian and Sakmarian stages of lower Permian.

Northward from Zharkent town, beside south bottom of Dzhungar Alatau and in Toksanbay range known outcrops of different-colour conglomerate-sandstones of the postponing Jamanbulak formation, containing fauna brachiopods foraminifer, the remainders of the flora and palinocomplexes of late Paleozoic age. In most top of her(its) sequence L.N.Sergeeva was described late Carboniferous brachyopodes, and M.M.Marfenkova – hemifusulines of bottom the Moscow stage [13]. Palinocomplex is presented by forms of bottom upper Carboniferous, but from Toksanbay sequence - a typical Late Carboniferous forms: Florinites luberae Samoil., Cordaitina rotata Samoil.,Nigrisporites nigritellus (Lub) Shurk and others.

Carboniferous sequence of the south part Dzhungar Alatau within active margin of paleobasin Kugaly formation presented with lake grey-yellow sandstones, siltstones, tuffites, flints and limestones with the remainders of the flora, palynocomplexes and imprints of amphibious. The remainder of the flora in her(its) layers are typical of upper Carboniferous and bottom Permian formes. Palinocomplex includes Potoniesporites novicus Bhar., Punctatisporites granifer Pot., Shophipollenites principalis Lub., Cordaitina sp. and others forms give the narrower age interval of the accumulation of the retinue: late Carboniferous

[13]. The Imprint amphibian Protriton Brochiozaurus Gredu from these postponing in Kurty region also are Carboniferous or Early Permian age [14]. Thereby, we have data on different parts of the region about existence sea facet Dzhungar-Balhash pool in late Carboniferous and, may be in early Permian.

Sedimentology and geochronology data of Chinese geologist, who have studied [ate Paleozoic volcano-sedimentary sequense in mountain Barleyk of West Dzhungary (the NorthWest China) helped to restore time of the closing Dzhungar-Balhash paleoocean in his(its) the most east, chinese part [15]. Upper Paleozoic sequense of this region includes from below upwards litoral sedimentary rocks, containing glauconitic sandstones of shallow shelf(Famenian-Tourneous age), volcanic serie of orogenic belt Tourneous-Early Bashcirian age,sandstones and conglomerates of Gjhelian stage which have gradational layers unrepresentative for sea sediments. Bimodal volcanic assotiation terminates that sequence, on geochronological data corresponding to Asselian and Sakmar grade of Lower Permian.

The most young age of detrital zircon from sandstone and U|Pb age of the volcanic rocks said that these rocks sedimented in Famenian-Tourneisian, Tourneisian – Early Bashkirian , in Gjhelian and Asselian-Sakmar stages accordingly. Tourneisian Early Bashkirian age of volcanic rocks and their overland look point to their probable attribute united with Pribalhash-Ili volcanic belt, his(its) east continuation. The Absence of Upper-Baskirian, Moscow and Kasimov of the postponing, in the opinion of chinese authors data, is obliged tectonic to ascent Dzhungar Alatau. Dzhungar-Balhash paleobasin, upon their opinion, was definitively closed before Gjhelian stage, close on time with others ocean pools of the south part of Paleo-Asiatic ocean [15]. The tops of that sequense composed with the Early Permian basalts and riolite-dacitic ignimbrites. One sample of dacite from this serie gave on zircon U-Pb age ~298 mln years [15] that is indicative of Asselian stage of time to crystallizations poured.

Alongside with stated stratigraphic material reliable paleomagnetic data show that Paleo-asiatic ocean was not an united broad ocean, but included several pools, prepared by volcanic arcs and continental blocks [15, 17]. In particular, as of Bo Liu , Bao-Fu Han and others [16], narrow age interval of the shaping ophiolites shows that between Boschekul and Zaysan arcs Early Ordovic ocean pool have been existed, too as a part of Paleo-asiatic ocean. Besides, on near-border of the territory of China, adjoining to Zharma-Saur and Chingiz-Bakanas Kazakhstan systems, there else row of the zones of ophiolite mélange were revealled. Some of they include the Cambrian gabbro blocks and are overlayed with Middle Ordovician chert rocks, but then unconformable – with an Low Carboniferous sediments [15]. In central part of West-Dzhungar block, verging with orient to Alakol trough, ophiolites associate to Late Devonian chert rocks of ocean bottom, overlapped by Low Carboniferous sedimentary rocks and is torned by Carboniferous granitoids with geochemical signs of subductional zones [15]. Thereby, probably, different basins, being included in Paleo-Asiatic ocean, were formed and developed enough autonomous, but their closing occurred by simple filling of sedimentary material.

Time of existence Dzhungar-Balhash sea pool in Chinese West Dzhungar covers the length of time from beginning of Devonian period to beginning or mediums Tourneisian centure [15]. In kazakhstan part of region it is more vast: from low Ordovician riftogenezis in Tekely zone to accumulation Low Permian Durnorechen suite of the retinue Alakol region [18]. The border Dzhungar-Balhash pool and paleocontinent, referred in chinese publications Ili plate, is facial, with gradual transition overland, mainly volcanic rock of the active margin in coastal ones, containing more significant share terrigenic material and then, on removing from coast line inside pool - in sea sedimentary with gradually decreasing admixture ash [18, 19]. Dzhungaro-Balhash pool within north part Dzhungar Alatau before medium Carboniferous period was an arena of the accumulation mainly siliceous and terrigenic sea sediments. Followed time of accumulation of carbonates was short, has occupied the Bashkirian stage and occurred only in Borotal region [5]. For Moscow stage characteristics of local accumulation variegated sandstones of Jamanbulak suite in coast part of pool[6]. The Internal space Dzhungar-Balhash basin in the second half of Carbononiferous period presented itself area, removed from the sources of the demolition with very faded clay-chert accumulation.

Relatively recently appeared the publications on Tien-SHan [8, 10, 11, 19] and others], characterizing South Eeast Kazakhstan and North Tien-SHan as active margin not Dzhungar-Balhash ocean, but located to south of it Turkestan (South-Tien-Shan ocean, which developed on background subduction ocean crust with south under Ili plate [11]. To such conclusion authors of enumerated publications come, outgoing from proximity Ili segment of the volcanic belt with South-Tien-SHan ocean basin, but without regard

petrochemical zones composition of the volcanic rocks of Ili belt. The Authors were repeatedly indicated on asymmetric petrochemical zones composition of the rocks of Ili volcanic belt fragment, first of all on growing potassium on measure of the removing from Dzhungar-Balhash sea in south direction on all his(its) length from Kurty region to China[20]. The most enriching potassium Devonian, Carboniferous and Permian volcanic rocks formed the rear synclines on narrow band along south edge paleocontinent in Kirghiz range, near Issykkul lake and in Karatau Ketmen. On the contrary, calc-alkaline, more sodium-volcanic rocks are typical of adjoining to Dzhungar-Balhash basin of the north edge of the belt, where they form the extensive fields, having transition to coast-sea facies. On figures 1, 2 there are brought comparison coeval main rocks of lower Carboniferous Dzhungar Alatau (the Guantobe suite, 145 samples and Altynemel series,149 samples) and ranges of North Tien-Shan (the Ketmen, 161 samples and Kuluktau series, 60 samples). Distinctly more high contentses of alkaline are seen in Djungar volcanites contentses ferric and lowered in contrast with alkalinity. For greater contrast SiO_2:100, but Al_2O_3:10 (in mass %).

The South border of Ili plates, presenting hercinides an active margin of Dzhungar-Balhash paleobasin, tectonic, passes on Atbashi-Inylichek shift, southward from which sea faces South-Tien-Shan sea basin are presented [19, 21]. Petrochemical materials on volcanic formations of Ili plate are indicative of growing in south direction of the powers of the eath crust[20].Usually on active Andy type margin her(its) growing occurs on measure of the advancement deep into continent and only large rifting breaks exist in rear parts these volcanic belt and are formed zones powerful basalt volcanism type to Provinces Pools and ranges of North America. The Similar situation existed in Carboniferous period on Ili plate, allowing to speak of possible take-off in medium Visean stage her(its) south edge (Issykkul block) from the main part on rear North-Kungey high angled fault. The torning away block with large Sonkul and Sarydzhaz batolites belonged inland part of Ili plate - the zone overland volcanic outlying-continental type. With south she was limited North-Kungey fault, providing in contact volcanic belt and synchronous him terrigen-carbonate sequences of rear Karatau-Nothern Tien-Shan- basin.

Saur phase of tectogenezis has caused the manifestations basalt volkanizm (basalt Satin suite of Kungey-range Dalashik and calcareous-basalt-rhyolitic series along Kokpak-river. It was formed sublatitudinal graben, during Visean and beginning of Serpuhov stages of Carboniferous period, filled with basalt, lenses and horizon organic limestones, arcoz and quartz sandstones, which the source served the

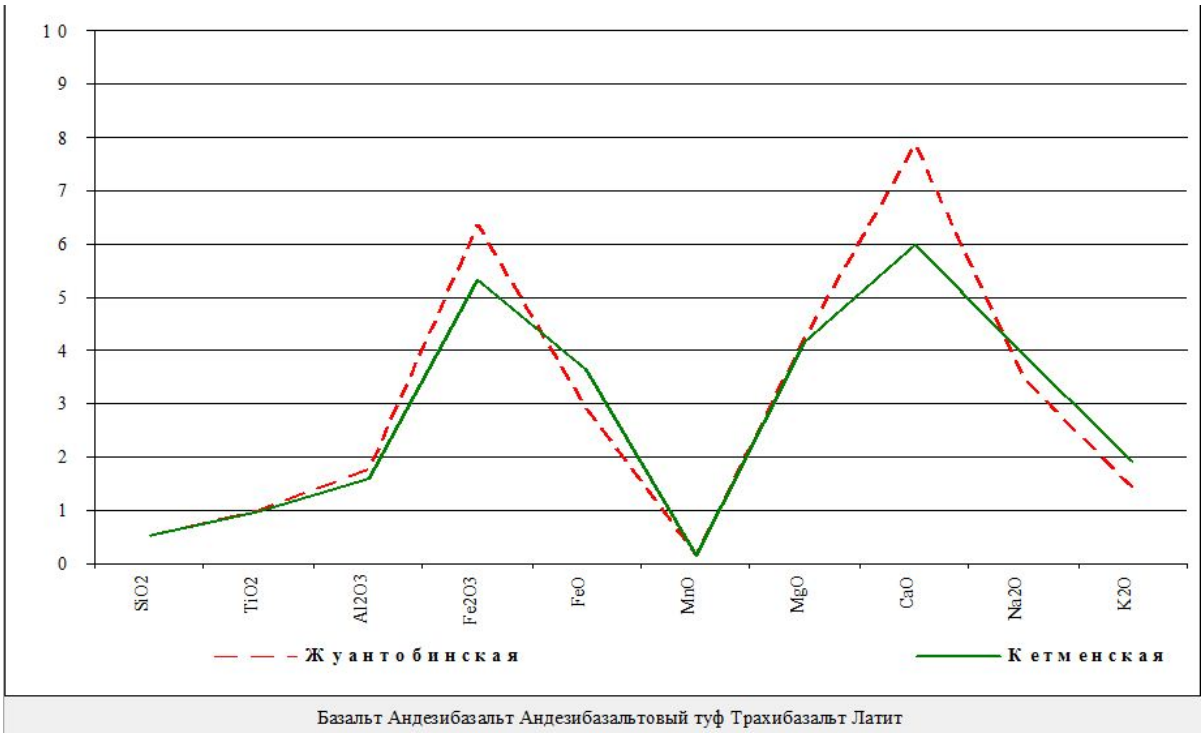


Figure 1 – Comparison of composition Tournaisian-low Visean basalts Dzhungar Alatau (Juantobe series,145 samples) and Ketmeni range (Ketmen series,161 samples)

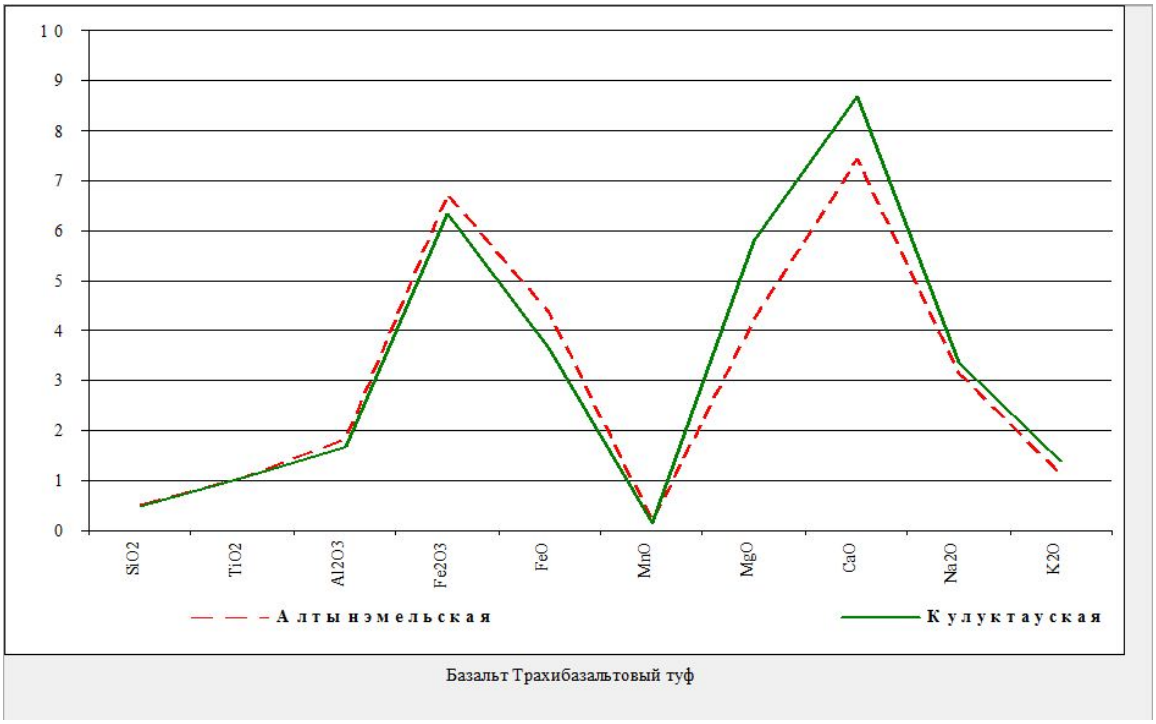


Figure 2 – The Comparison of composition Visean basalts Dzhungar Alatau (Altynemeli series,149 samples) and Ketmeni range (Kuluktau series,60 samples)

salients precambrin sediments and granites of Sarydzhas batolit. The Width of graben is more 10 km, visible extent is of the order 200 km. Southward from it wide-spread shallow calcareous sediments, including thin bedding/oncolitic limestones of Central Tien SHan, but here in after southward - a gneisses and eclogites,forming powerful zone of metamorphic rocks , belonged to South-Tien-Shan paleobasin.

Degradation of Karatau-North-Tyanishan rear basin was expressed in his(its) salting, appearance gypsum and shallowing By the end of Carboniferous period dominating his(its) sediments become the red coloured sandstones and siltstones with the remainder of overland flora (Tekes suite) and Late Cardoniferous complex spores and pollens. They formed outcrops in Kopyl range and along Karkara-river, where rumpled; creased in steep folds, places are pulled over on Low Carboniferous-bashkirian grey coloured complex [21].

Disappearance of the last sea basin and the beginning of accumulation continental the red coloured molass at the end of Asselian - the Sakmar century marks the beginning of a rigid collision on the Southern Tien Shan [11, 22]. Possibly, and for the North Tien Shan continent the beginning of a rigid collision with Tarim is necessary on Asselian-Sakmara centuries of Permian period.

Work is performed with assistance of Committee of Science of Ministry of education and science Republic Kazakhstan at the expense of resources of the agreement № 189 of 15.03.2018. "Scientific ensuring complication and expansion of mineral raw material resources of Republic Kazakhstan".

Л. И. Скринник, Р. Р. Гадеев

«Қ. І. Сәтбаев атындағы геологиялық ғылымдар институты» ЖСШ, Алматы, Қазақстан

ЖОНҒАР-БАЛҚАШ ПАЛЕОБАССЕЙНІН ЖАБУ УАҚЫТЫ ТУРАЛЫ СҰРАҚТАР

Аннотация. Оңтүстік-Шығыс Қазақстан және Қытаймен шекаралас облыстар бойынша материалдарды талдау арқылы Палеоазиаттық мұхиттың дамуы арал доғалары мен оқшауланған бассейндердің седиментациялық қалыптасу жолымен келип шыққандығы айқындалды. Жоңғар-Балхаш теңіз бассейндері ерте ордовик пен перм кезеңінің ортасына дейін қалыптасқан, оның шөгінділерінде теңіз фауналарының болуы

осыны дәлелдейді. Алакөл ауданымен шекаралас Қытай территориясы бойынша стратеграфиялық материалдар Жоңғар-Балхаш палеобассейнінің ең жас теңіздік терригенді шөгінділері фамен-ертетурней кезеңінде екендігін және шеткі вулкандық белдеудің турней-ерте башқырлық вулканиттері жауып жатқандығын айқындайды. Әрі қарай сәйкесті көтерілімді аудандарда үзілістер жалғасып, гжелдік дәуіріндегі соңғы жиналған жерүсті молассы, одан кейін контрасты төменгі перм вулканды сериясы жалғасуда.Бұл ауданның ең жас офиолиттері ерте девон дәуіріне жатады. Бұл деректер бассейндердің жатысы, құраушы палеомұхиттық және олардын жабылу уақыты (ерте перм болуы мумкін) туралы әртүрлі дәуірлерді айқындайды. Коллизия араласқан әдеттегі шөгінді материалдармен толтыру жабылу жолы болып табылады.

Жонғар-Балхаш бассейнінің белсенді шеті – оны Оңтүстік Тянь-Шань палеомұхитынан бөліп туратын Іле плитасы болып табылады. Девон, таскөмір және перм кезеңдерінің вулкандық жинақталуы Қазақстан континенті жағындағы Жоңғар-Балхаш теңіздік басссейні қоршап тұрған вулкандық белдемдің бөлігі болып табылады, бұл туралы геологиялық және петрохимиялық мәліметтерде айтылады.

Түін сөздер: палеомұхит, офиолиттер, аралдық доға, белсенді шеті, фауна, гжельдік ярус, петрохимиялық параметрлер.

Л. И. Скринник, Р. Р. Гадеев

Институт геологических наук им К. И. Сатпаева, Алматы, Казахстан

К ВОПРОСУ О ВРЕМЕНИ ЗАКРЫТИЯ ДЖУНГАРО-БАЛХАШСКОГО ПАЛЕОБАССЕЙНА

Аннотация. Анализ материалов по юго-востоку Казахстана и прилегающей области Китая показывает, что развитие Палеоазиатского океана происходило путем формирования островных дуг и обособленных бассейнов седиментации. Джунгаро-Балхашский морской бассейн существовал с раннего ордовика до середины пермского периода, о чем свидетельствует наличие морской фауны в его отложениях. Стратиграфические материалы по прилегающей к Алакольскому району территории Китая показывают, что наиболее молодые морские терригенные отложения Джунгаро-Балхашского палеобассейна имеют фамен-раннетурнейский возраст и перекрываются турнейско-раннебашкирскими вулканитами краевого вулканического пояса. Далее следует перерыв, соответствующий поднятию района, последующее накопление наземной молассы гжельского века, а затем контрастной нижнепермской вулканической серии. Наиболее молодые офиолиты этого района имеют раннедевонский возраст. Эти данные говорят о разном времени заложения бассейнов, составляющих палеоокеан и близком времени их закрытия (вероятно, ранняя пермь). Способ закрытия – коллизия в сочетании с простым заполнением осадочным материалом.

Активной окраиной Джунгаро-Балхашского бассейна является Илийская плита, отделяющая его от Южно-Тянь-Шанского палеоокеана. Вулканические накопления девонского, каменноугольного и пермского периодов являются частью вулканического пояса, обрамлявшего Джунгаро-Балхашский морской бассейн со стороны Казахстанского континента, о чем говорят геологические и петрохимические данные.

Ключевые слова: палеоокеан, офиолиты, островная дуга, активная окраина, фауна, гжельский ярус, петрохимические параметры.

Information about authors:

Skrinnik Lyudmila Ivanovna, candidate of geological-mineraligical Sciences, Chief researcher of LLP «Institute of geological Sciences named after K. I. Satpayev», Almaty, Kazakhstan; lisgeo@inbox.ru; https://orcid.org/0000-0001-6489-8065

Gadeev Ravil Ravilevich, master of applied Geology, researcher of LLP «Institute of geological Sciences named after K. I. Satpayev», Almaty, Kazakhstan; gadeev_ravil@mail.ru; https://orcid.org/0000-0002-9428-8142

REFERENCES

[1] Dobrecov N.L. The Evolution of the structures Ural, Kazakhstan, Tien-Shan and Altai-Sayan areas in Ural-Mongolian pleated belt(the Paleo-asiatic ocean) // Geology and geophysics. 2003. Vol. 44, 1-2. P 5-27 (in Rus.).

[2] Samygin S., Heraskova T.N., Kurchavov A.M. Tectonic development of Kazakhstan and Tien-Shan in Neoproterozoic and in early-middle Paleozoic // Geotectonic. 2015. N 6. P. 12-24 (in Rus.).

[3] Rjazancev A.V., Tolmacheva T.Yu., Nikitina O.I. Ophyolites, island-arcs and intracontinent rifts complexes in system of tectonic covers of Chu-Ili region Kazakhstan // Geodinamic evolution of the lithosphere Central-Asiatic fold belt (from ocean to continent): Material of the confer. N 4. Irkutsk, 2006. Vol. 2. P. 104-108 (in Rus.).

[4] Bogdanov A.A., Zaycev YU.A., Mazarovich O.A., Maksimov A.A., Tihomirov V.G., CHetverikova N.P. Tektonic районирование paleozoic array Central Kazakhstan // Bulletin Mosc. University. Series geol. 1963. N 5 (in Rus.).

[5] Geology construction of Kazakhstan / Bekzhanov G.R., Koshkin V.YA. and others. Almaty: AMR RK, 2000. 396 p. (in Rus.).

[6] Afonichev N.A. The Main line of the structured plan Dzhungar Alatau, Tarbagatay and North-East Pribalhash area // Mat-ly on geologies and useful fossilized Altay and Kazakhstan. VSEGEI. New series. 1960. Vol. 33. (in Rus.).

[7] Skrinnik L.I south-east Kazakhstan - active late Paleozoic border of the Paleo-Asiatic ocean // Geology and metallogeny Kazakhstan. Almaty, 2000. P. 99-108 (in Rus.).

[8] Buslov M.M., Cai K. Tectonics and geodynamics of the Altai-Junggar orogen in the Vendian-Paleozoic: implications for the continental evolution and growth of the Central Asian fold belt // Geodynamics and tectonophyzics. 2017. Vol. 8, N 3. P. 421-427 (in Eng.).

[9] Filippova I.B., Bush V.A., Didenko A.N. Middle Paleozoic subduction belts: The leading factor in the formation of the Central Asian fold-and-thrust belt // Russian Journal of Earth Sciences. 2001. 3(6). P. 405-426 (in Eng.).

[10] Buslov M.M., Safonova I.Y., Watanabe T., Obut O.T., Fujiwara Y., Iwata K., Semakov N.N., Sugai Y., Smirnova L.V., Kazansky A.Y. Evolution of the Paleo-Asian ocean (Altai-Sayan region, Central Asia) and collision of possible Gondwana-derived terranes with the southern marginal part of the Siberian continent // Geosciences Journal. 2001. N 5(3). P. 203-224 (in Eng.).

[11] Бискэ Yu.S., Alexeev D.V., Dzhenchuraeva A.V., Van B. History of the closing ocean basins in late Paleozoic between Tarim and Dzhungary: geodynamics and stratigraphic problems // Scientific notes Kazan university. The Series of natural sciences. 2016. Vol. 158, kn. 1. P. 75-93 (in Rus.).

[12] Bush B.A., Dmitrieva V.K., Iliina T. Sea Permian sediments in East Kazakhstan // Bulletin M. o-ва исп prirody. dept. geologies. 1967. Vol. HLII(6). P. 6-12 (in Rus.).

[13] Skrinnik L.I., Grishina T.S., Radchenko M.I. Stratigraphy and paleogeography of Carrbonifer of south-east Kazakhstan // Geology and prospecting of mineral wealth Kazahstana. 1998. 4. P. 9-14 (in Rus.).

[14] Radchenko I.I. First discovery of fossilized amphibian in South Kazakhstan // News of AS KazSSR. 1959. N 6 (in Rus.).

[15] Bo Liu, Bao-Fu Han, Jia-Fu Chen, Rong Ren, Bo Zheng, Zeng-Zhen Wang, Li-Xia Feng. Closure Time of the Junggar-Balkhash Ocean: Constraints From Late Paleozoic Volcano-Sedimentary Sequences in the Barleik Mountains, West Junggar, NW China // Тектonics. 2017. N 36. P. 1-23 (in Eng.).

[16] Gao X., Wei J.H., Fu L.B., Wang M., Zhang L., Yue P. Geochemical character and tectonic significance of the Kalagang Formation volcanic rocks in Tuoli area, West Junggar [in Chinese with English abstract] // Geological Science and Technology Information. 2014. 33. P. 16-24 (in Eng.).

[17] Van der Voo R., Levashova N.M., Skrinnik L.I., Kara T.V., Bazhenov M.L. Late orogenic, large-scale rotations in the Tien Shan and adjacent mobile belts in Kyrgyzstan and Kazakhstan // Tectonophysics. 2006. Vol. 426. P. 335-360 (in Eng.).

[18] Skrinnik L.I. To geodynamic of South-East Kazakhstan // Tectonic, geodynamic and processes of magmatism and metamorphism. M., 1999. P. 135-136 (in Rus.).

[19] Burtman V.S., Samygin S.G. Tectonic evolution to High Asia in Paleozoic and Mesozoic // Geotectonic. 2001. 4. P. 34-54 in Rus.).

[20] Skrinnik L.I. Petrochemical zone volcanic belt of South-East Kazakhstan // Geology Kazakhstan. Full-grown. Int. Geol. Congress. Almaty, 2008. P. 91-101 (in Rus.).

[21] Skrinnik L.I., Esmintctev A.N. Lateral rows of the Carboniferous deposits of North Tian-Shan // News of as RK. Ser. geol. 2008. N 3. P. 4-16 (in Rus.).

[22] Biske Ju.S. Paleozoic structure and history of South Tien-Shan. S-Peterburg, 1996. 192 p.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 223 – 230 **https://doi.org/10.32014/2019.2518-170X.27**

UDC 663

M. V. Gernet[1], I. N. Gribkova[1], K.V. Kobelev[1],
D.E. Nurmukhanbetova[2], E.K.Assembayeva[2]

[1]All-Russian Research Institute of Brewing, Non-Alcoholic and Wine Industry -
branch of the Gorbatov´s Federal Research Center of Food Systems of RAS, Moscow, Russia
[2]Almaty Technological University, Almaty, Kazakhstan.
E-mail: institut-beer@mail.ru, k.kobelev55@mail.ru, dinar2080@mail.ru, elmiraasembaeva@mail.ru

BIOTECHNOLOGICAL ASPECTS OF FERMENTED DRINKS PRODUCTION ON VEGETABLE RAW MATERIALS

Abstract. Fermented drinks are considered as the optimal form of a food product, used to enrich the diet with biologically active substances that have a beneficial effect on the metabolism and immunoresistance of the human body, which are provided not only by extraction, but also are formed as a result of the vital activity of various types of microorganisms. The latter, in turn, produce vitamins, amino acids, organic acids, etc., which gives fermented drinks a higher biological value. Drinks technology with the use of tea fungus (*Medusomyces gisevii*) is oriented for home cooking and it is not possible to apply it in an industrial environment. The relevance of this research work is to develop the technology of the drink, enriched with biologically active substances in the most accessible form to expand the range of functional beverages aimed at maintaining the health of various population groups. In order to solve this problem a combined yeast and lactic acid bacteria ferment was chosen, the optimal composition of the nutrient medium based on green tea and barley malt wort was determined, and the amino acid and vitamin activator was selected to reduce the fermentation process. The developed technology made it possible to obtain a drink with mixed leaven, harmonious in organoleptic characteristics, with a high content of amino acids, especially essential ones, which made it possible to recommend this functional drink for various groups of the population.

Keywords: tea, wort, microorganism cultures, yeast food, secondary fermentation products.

Introduction. Drinks are rightfully considered to be the most rational form of a food product for enriching the diet with biologically active substances and creating special-purpose products [1, 2]. The high popularity of beverages among the population suggests the constant development of technical, methodological, technological bases, including in the framework of the fight against fraud [3-7]. In recent years, the problem of their excessive consumption is actualized [8].

One of the priorities of the state policy of the Russian Federation in the field of healthy nutrition is the development of fermentation drink technologies, based on the use of plant raw materials and micro-organism cultures, that produce a complex of substances with significant potential of useful properties [1]. According to many scientists, the use of fermentation drinks contributes to the correct metabolism and strengthens the immunoresistance of the human body, which are formed as a result of microorganism vital activity [1, 2, 9-11, 26].

One of the urgent tasks in the production of fermented drinks is the search for fermentation micro-organisms, producing biologically active substances, which are necessary for the normal functioning of mankind during their life. The latter are most fully accumulated in the case of the symbiotic cultures use, which can be a single organism (for example, *Medusomyces gisevii*) or a cultures combination (for example, yeast and lactic acid bacteria) [1].

Literature review. The drink, obtained with use of *Medusomyces gisevii,* which consists of yeast cells and acetic acid bacteria, contains glucuronic, folic and citric acids, vitamins B_1, B_2, B_3, B_6, B_{12}, as well as difficult to determine substances with antibiotic action, including medusin. The viability of using

bacterial cellulose, obtained from *Medusomyces gisevii* as a hemostatic agent in veterinary medicine and humane medicine was confirmed [12]. A necessary condition for the life of this microorganism is the presence of tea in the raw materials composition.

Analysis of scientific and technical information suggests, that the creation of industrial technology, based on the use of cultures of microorganisms with known properties, that allow to control the process of drink production, is promising and relevant. At the same time, the conditions for obtaining a homemade drink described in the literature and patents for a method for producing a drink, based on tea fungus and attempts to create analogues with *Medusomyces gisevii* have not been continued [13-16].

Methods. To assess the effectiveness of technological methods, research methods used in the industry were used: determination of the volume fraction of alcohol - GOST 12787-81, the arbitration method, which is the separation of the alcohol fraction of a drink from extractive substances by distillation [17]; determination of titratable acidity - GOST 12788-87, which is a method for the titration of the acid content by neutralizing them with a 0.1 sodium hydroxide solution [18]; determination of the mass concentration of volatile components - a gas chromatography method with the Kristall 5000.1 flame ionization detector ("Khromatek", Russia) equipped with an automatic information collection and processing system [19]; determination of the mass concentration of organic acids – high-performance liquid chromatography with an "Agilent Technologies 1200" ("Agilent", USA) diode array detector [20]; determination of the mass concentration of sugars and glycerol - a method of high-performance liquid chromatography with a refractometric detector "Agilent Technologies 1200" ("Agilent", USA), equipped with an automatic system for collecting and processing information [21]; determination of the mass concentration of amino acids is a high performance liquid chromatography method with an "Agilent Technologies 1200" ("Agilent", USA) diode array detector, equipped with an automatic information collection and processing system [22].

The replication of experiments at all stages of the experiment - not less than 3. The results of experimental studies were processed by methods of mathematical statistics using Student's criterion.

In order to conduct a study on the production of fermented drinks, the following materials were used: barley malting brewing malt; brewing tricyclic malt light; black tea and green leaf; mixed ferment on the basis of dry brewing yeast S. cerevisiae and lactic acid bacteria *Betabacterium breve*.

Results. As part of the study, the following tasks were set: to investigate the possibility of using various plant raw materials and mixed cultures of microorganisms traditional for the brewing and non-alcoholic industries in the technology of fermented drink; select the optimal fermentation conditions; get a drink with stable performance over a long shelf life without loss of compounds, responsible for the functional orientation of the finished drink.

To identify the optimal composition of the nutrient medium, allowing to obtain a harmonious drink from the point of organoleptic and physicochemical parameters view, provided that yeast and lactobacilli are used, the following plant materials were used in the study: leaf tea (black and green), barley based wort and tritium-potassium malt brewing, as well as granulated sugar, in various ratios, and the fermentation was carried out by making mixed yeast brewer's yeast and lactic acid bacteria d at the rate of 4% by volume of the nutrient medium.

During the experiments, the duration of fermentation, controlled by loss of dry substances, using black and green tea coincided and amounted to 141 hours with barley malt wort and 114 hours with triticali wort, which is explained by the rich amino-acid composition of triticali malt wort, which accelerates enzymatic processes associated with the activity of yeast. However, the organoleptic evaluation of all analyzed samples using a 25-point system showed, that the most balanced indicators were fermented drink using a carbohydrate-tea base (based on green tea) and barley malt wort, in particular, a variant of the nutrient medium, based on green tea and wort from barley malt in a ratio of 75% and 25%, the data are presented in table 1.

In all other samples, the alcohol content and acidity were at 5–10% higher than the optimal sample, but an autolysis tone was present, which is unacceptable.

However, the duration of cultivation was quite long, so the next stage of our work was the use of various activators to shorten the process. For this purpose, the most productive amino acid-vitamin activator (AVA), obtained according to the technology [23] and containing 40–42% of soluble protein, including 13–15% of amine nitrogen, and vitamins (thiamine (B_1), pantothenic acid (B_3), pyridoxine (B_6), biotin (B_7), inoside (B_8) - 17 mg/kg. The share of AVA was 2.5–10 ml/hl or 0.5–2% by volume of the fermented wort (table 2).

Table 1 – Organoleptic and physicochemical indicators of the fermented wort optimal variant

Indicators	Characteristics of Fermented Green Tea and Barley Malt Wort
	Organoleptic Indicators
Taste	fermented drink with slightly sour
Colour	straw
Aroma	pleasant aroma of a well fermented fruit drink
	Physicochemical Indicators
Alcohol content, vol.%	3,30±0,2
Acidity, a.u.	11,00±0,3

Table 2 – Applied feedings doses for fermentation

Indicator name	Nutrient medium variant				
	Control	with Feedings of AVA, ±0,05			
	I	II	III	IV	V
Applied feedings doses, %	–	0,5	1	1,5	2,0

The dose of dressing with the use of selected nutrient medium (75% of tea and 25% of barley malt wort) is presented in table 2, the dynamics of acidity accumulation during fermentation - in figure 1, the content of secondary fermentation products – in the table 3. It should be noted that we previously studied other supplements, but they did not show any tangible effect [24].

Table 3 – The Content of Organic Acids (OA), Sugars and Glycerin in the Drink

Component	Content, mg/dm^3	Component	Content, mg/dm^3	Component	Content, mg/dm^3
OA±5,0%**		Amino Acids ± 5,0%**			
Oxalic acid	0,070	Aspartic	27,0	Tryptophan*	25,5
Wine acid	0,104	Glutamic	29,2	Isoleucine*	36,0
Malic acid	0,303	Asparagine	36,8	Phenylalanine*	17,5
Lactic acid	4,614	histidine*	20,0	Leucine*	65,0
Citric acid	0,147	Serine	48,0	Lysine*	5,0
Succinic acid	0,257	Glutamine	22,0	Alanine	22,0
The amount of volatile acids, in terms of acetic	0,18±2%	Arginine*	17,5	Tyrosine	16,8
		Threonine*	126,5	Valine*	41,0
		Glycine	40,0	Methionine*	49,0
Sugars and Glycerin ± 4,0%**					
Fructose	10,480	Glucose	5,310	Sucrose	2,7000
* - irreplaceable amino acids; ** - method reproducibility.					

The data in table 3 show, that the resulting drink had a wide range of functional compounds, responsible for functional orientation, and more significant accumulation of lactic acid occurs, as compared with the control, since the lactic acid bacteria Betabacter breve was used during fermentation. Sugar and glycerin in the finished drink is formed less than in the control, which is explained by a more intensive activity of microorganisms that consume sugar for reproduction. The composition of amino acids are also essential in 2 times more, than the control, which is explained by the most active metabolism of microorganisms.

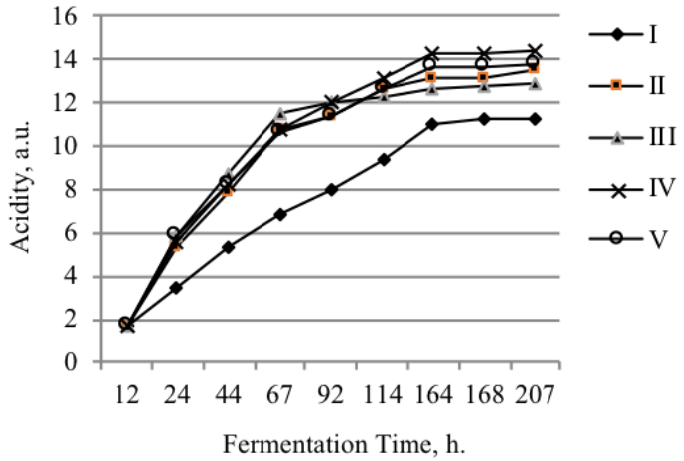


Figure 1 – Dynamics of acidity accumulation
in the samples when adding feedings to the nutrient medium during fermentation

Comparative studies have been carried out on fermented drink with use of tea fungus and mixed tea-based leaven.

The composition of volatile compounds and sugars are presented in tables 4, 5. It should be noted that the higher alcohols in the resulting drink, compared with the drink on the tea fungus, accumulate much more (except for l-propanol), and the content of esters is not so different.

Table 4 – Content of volatile compounds, organic acids and sugars
in drink with use of the microorganism medusomyces gisevii

Component	Content mg/dm^3	Component	Content mg/dm^3	Component	Content mg/dm^3
Ethers, mg/dm^3 ±10%**		Amino Acids ± 5,0%**			
Ethyl acetate	2,89	Aspartic	10,9	Valine*	1,44
Ethyl lactate	5,79	Glutamic	1,8	Methionine*	–
Organic Acids, g/dm^3 ± 5,0%**		Аспарагин	Asparagine	Трипто-фан*	Tryptophan*
Oxalic acid	–	histidine*	0,8	Isoleucine*	–
Wine acid	–	Serine	1,6	Phenylalanine*	2,0
Malic acid	0,021	Glutamine	–	Leucine*	0,9
Lactic acid	0,059	Arginine*	1,0	Lysine*	0,8
Citric acid	0,0083	Glycine	1,2	Tyrosine	–
Succinic acid	0,061	Threonine*	4,5	Totally Irreplaceable	11,4
		Alanine	1,3		
Sugars, mg/cm^3 ± 4,0%**					
Fructose	3,39	Glucose	2,74	Sucrose	17,33
* - irreplaceable amino acids; ** - method reproducibility.					

According to the content of amino acids, more intensive accumulation occurs in the drink with use of mixed yeast leaven and lactic acid bacteria, including irreplaceable bacteria, accumulates 36 times more compared to the drink on the tea fungus.

Table 5 – Content of volatile compounds, organic acids and sugars in the drink with use of mixed yeast leaven and lactic acid bacteria

Component	Content, mg/dm^3	Component	Content, mg/dm^3	Component	Content, mg/dm^3
Ethers, mg/dm^3 ±10%**		Amino Acids ± 5,0%**			
Ethyl acetate	1,3	Aspartic	27,0	Valine*	41,0
Ethyl lactate	3,3	Glutamic	29,2	Methionine*	49,0
Organic Acids, g/dm^3 ± 5,0%**		Asparagine	36,8	Tryptophan*	25,5
Oxalic acid	histidine*	histidine*	20,0	Isoleucine*	36,0
Wine acid	0,373	Serine	48,0	Phenylalanine*	17,5
Malic acid	4,83	Glutamine	22,0	Leucine*	65,0
Lactic acid	0,059	Arginine*	17,5	Lysine*	5,0
Citric acid	0,12	Glycine	40,0	Tyrosine	16,8
Succinic acid	0,331	Threonine*	126,5	Totally Irreplaceable	403
		Alanine	1,3		
Sugars, mg/cm^3 ± 4,0%**					
Fructose	19,9	Glucose	11,97	Sucrose	2,36
* - irreplaceable amino acids; ** - method reproducibility.					

Particular attention should be paid to the threonine amino acid, which accumulates 3 times more than in the drink with tea fungus (table 4, 5). From the point of view of the functional load, threonine is very useful for the body, since it is responsible for the protein metabolism in the body, is part of collagen, elastin and tooth enamel protein, positively affects the person's psycho-emotional state [25]. We assume that this drink, obtained by us with the help of a mixed leaven, can be recommended for a wide range of the population of Russia.

The third task to get a drink with stable performance over a long shelf life without losing the compounds, responsible for the functional orientation of the finished drink was solved using pasteurization techniques at a maximum processing temperature of 72 °C, due to which it was possible to extend the shelf life of the drink for 6 months.

Analysis of the secondary fermentation products in mixed leaven in a drink showed, that their concentration differs from that in a drink made on the basis of a tea fungus, which is explained by a different metabolic set of enzymes in two cases.

On the basis of the data, obtained in the study, the optimal organoleptic and physicochemical indicators of fermented drinks, prepared from pasteurized fermented bases were determined, which made it possible to develop a draft regulatory documentation for fermented drinks on plant raw materials.

Conclusions. Studies have allowed picking up planting materials and microbiological cultures, working out the technological parameters of the process, including fermentation modes - the optimal composition for the drink technology was the ratio of green tea extract and barley malt wort 3:1, as well as the use of an additive ava in the amount of 1%, which made it possible to reduce the fermentation time to 93 hours and to obtain a drink with high organoleptic and physicochemical parameters.

On the basis of a comparison of the drink we developed, with based on tea fungus drink, at the main functional components, it was concluded that the content of amino acids was 4 times higher than the total amount and 3 times threonine, which is probably the basis recommend a drink for food of various groups of the population of the Russian Federation.

Discussion. The conducted literary search on the studied problem revealed a diverse composition of vegetable raw materials in order to apply it in the drink technology. This type of raw material is traditionally used in fermented drinks, based on the microorganism *Medusomyces gisevii* [1-3, 18]. However, this microorganism did not find wide application in industry due to insufficient knowledge of catabolic reactions.

Therefore, we were faced with the task of developing a technology for a drink, that would be an analogue of the "Kombucha" drink. For this purpose, were used yeast and lactic acid bacteria, traditionally used in the production of kvass.

The use of plant materials, in particular tea, and barley malt wort and mixed microbiological cultures, made it possible to obtain a fermented drink enriched with functional compounds such as organic acids, amino acids, ethers and other volatile compounds in quantities exceeding drinks with use of tea fungus culture. This fact is explained by the difference in the metabolism and the set of enzymes of the two microorganism cultures, since the in technology were used lactic acid bacteria together with yeast, which is characterized by its own set of secondary products of metabolism compared to the culture of *Medusomyces gisevii* [19].

The obtained data on the composition and content of alcohols in the drink confirm the correctness of the choice of the malting wort as a source of nitrogenous nutrition for yeast, since it is known that it is the amino acids, that participate in the formation of higher alcohols as a result of catabolic reactions. The use of yeast and lactic acid bacteria, as well as a balanced plant substrate (tea and malt wort) made it possible to obtain a harmonious drink, rich in functional compounds. Accelerated fermentation metabolism was promoted by the use of an amino acid activator in the above-mentioned concentration, since the activator influenced the growth and reproduction of yeast. This is of great importance, since the duration of fermentation has decreased to 93 hours. The use of pasteurization techniques has made it possible to increase the shelf life without loss of useful compounds.

This fact allows to introduce this technology in the enterprises of the beer and non-alcoholic industry, since the microorganisms used are well studied and their livelihoods can be regulated, that is, they are technological.

М. В. Гернет[1], И. Н. Грибкова[1], К. В. Кобелев[1],
Д. Е. Нурмуханбетова[2], Э. К. Асембаева[2]

[1]Бүкілресейлік сыра қайнату, алкогольсіз және шарап өнеркәсібі ғылыми-зерттеу институты –
В. М. Горбатов атындағы «Азық-түлік өнімдерінің федералдық ғылыми орталығы»
Федералдық мемлекеттік бюджеттің ғылыми мекемесінің филиалы РҒА, Мәскеу, Ресей,
[2]Алматы технологиялық университеті, Алматы, Қазақстан

ӨСІМДІК ШИКІЗАТЫН ҚОЛДАНЫП АШЫТЫЛАТЫН СУСЫНДАР ӨНДІРІСІНІҢ БИОТЕХНОЛОГИЯЛЫҚ АСПЕКТІЛЕРІ

Аннотация. Ферменттелген сусындар биологиялық белсенді заттармен тағам рационын байыту үшін пайдаланылатын тамақ өнімдерінің оңтайлы түрі болып табылады, олар адам ағзасының зат алмасуына және иммундық тұрақтылығына оң әсерін тигізеді, олар экстракция арқылы ғана емес, сондай-ақ түрлі микроорганизмдердің өмірлік белсенділігі нәтижесінде пайда болады. Олар өз кезегінде витаминдерді, аминқышқылдарын, органикалық қышқылдар және тағы басқа заттарды түзеді, бұл ферменттелген сусындардың биологиялық құндылығын арттырады. Шай саңырауқұлағы (*Medusomyces gisevii*) қолданылған сусындар технологиясы үйде алуға арналған және оны өнеркәсіптік жағдайда қолдану мүмкін емес. Осы ғылыми-зерттеу жұмысының өзектілігі әртүрлі халық топтарының денсаулығын сақтауға бағытталған функционалдық сусындардың ауқымын кеңейту үшін барынша қолжетімді түрде биологиялық белсенді заттармен байытылған сусынның технологиясын жасау болып табылады. Бұл мәселені шешу үшін аралас ашытқылар мен сүт қышқылдары бактерияларының ұйытқысы таңдап алынды, көк шай және арпа уыты негізіндегі қоректік ортаның оңтайлы құрамы анықталды, аминқышқылы мен витаминді активатор ашыту үрдісін азайту үшін таңдалды. Алынған технология құрамында ауыстырылмайтын амин қышқылдарының көп мөлшері бар, органолептикалық көрсеткіштері үйлесімді аралас ашытқы негізіндегі сусын алуға мүмкіндік берді, бұл халықтың түрлі топтары үшін осы функционалдық сусындарды ұсынуға мүмкіндік берді.

Түйін сөздер: шай саңырауқұлағы, арпа уыты, ашытқылар мен сүтқышқылды бактериялардың біріктірілген ұйытқысы.

М. В. Гернет[1], И. Н. Грибкова[1], К. В. Кобелев[1],
Д. Е. Нурмуханбетова[2], Э. К. Асембаева[2]

[1]Всероссийский научно-исследовательский институт пивоваренной, безалкогольной и винодельческой промышленности – филиал Федерального государственного бюджетного научного учреждения «Федеральный научный центр пищевых систем им. В. М. Горбатова» РАН, Москва, Россия,
[2]Алматинский технологический университет, Алматы, Казахстан

БИОТЕХНОЛОГИЧЕСКИЕ АСПЕКТЫ ПРОИЗВОДСТВА НАПИТКОВ БРОЖЕНИЯ С ПРИМЕНЕНИЕМ РАСТИТЕЛЬНОГО СЫРЬЯ

Аннотация. Напитки брожения рассматриваются как оптимальная форма пищевого продукта, используемого для обогащения рациона питания биологически-активными веществами, благотворно влияющими на обмен веществ и иммунорезистентность организма человека, которые обеспечиваются не только за счет экстракции, но и формируются в результате жизнедеятельности различных видов микроорганизмов. Последние, в свою очередь, продуцируют витамины, аминокислоты, органические кислоты и др., что и придает ферментированным напиткам повышенную биологическую ценность. Технология напитков с применением чайного гриба (*Medusomyces gisevii*) предназначена для домашнего приготовления и не представляется возможным применить ее в промышленных условиях. Актуальность данной исследовательской работы заключается в разработке технологии напитка, обогащенного биологически активными веществами в наиболее доступной форме для расширения ассортимента функциональных напитков, направленных на поддержание здоровья различных групп населения. С целью решения данной задачи была выбрана комбинированная закваска дрожжей и молочнокислых бактерий, определен оптимальный состав питательной среды на основе зеленого чая и ячменного солодового сусла, для сокращения процесса брожения был подобран аминокислотно-витаминный активатор. Разработанная технология позволила получить напиток на смешанной закваске, гармоничный по органолептическим показателям, с повышенным содержанием аминокислот, особенно незаменимых, что позволило рекомендовать этот функциональный напиток для различных групп населения.

Ключевые слова: чайный гриб, сусло, комбинированная закваска дрожжей и молочнокислых бактерий.

Information about authors:

Gernet M. V., Head of Brewring department , Professor, Doctor of technical Science, All-Russian Research Institute of Brewing Non-Alcoholic and Wine Industry - branch of the Gorbatov´s Federal Research Center of Food Systems of RAS, Moscow, Russia; institut-beer@mail.ru; http://orcid.org/0000-0003-0277-7318.

Gribkova I. N., Researcher of Brewring department, Candidate of technical Sciences, All-Russian Research Institute of Brewing, Non-Alcoholic and Wine Industry - branch of the Gorbatov´s Federal Research Center of Food Systems of RAS, Moscow, Russia; institut-beer@mail.ru; http://orcid.org/0000-0002-4373-5387.

Kobelev K. V., Deputy directore of Scintific research institut of Brewring, Candidate of technical Sciences, All-Russian Research Institute of Brewing, Non-Alcoholic and Wine Industry - branch of the Gorbatov´s Federal Research Center of Food Systems of RAS, Moscow, Russia; k.kobelev55@mail.ru; http://orcid.org/0000-0002-3619-6282.

Nurmukhanbetova Dinara Erikovna, candidate of engineering sciences, acting associate professor, Almaty Technological University, Department of Food safety and quality; dinar2080@mail.ru; http://orcid.org/0000-0002-8939-6325.

Assembayeva Elmira Kuandykovna, Almaty Technological University, Department of Food Biotechnology, Master of Technical Sciences, Senior Lecturer; elmiraasembaeva@mail.ru; http://orcid.org/0000-0001-7964-7736.

REFEREVCES

[1] Shenderov B.A., Doronin A.F. (**2001**). Perspectives of Functional Drinks for Various Population Groups on the Tea and Coffee Basis. Materials of the 1st International Specialized Exhibition "Tea and Coffee Magic Aroma". Moscow. Russian Exhibition Center (VVC). P. 58-60 (in Rus.).

[2] Pilipenko T.V., Korotysheva L.B. (**2016**). Study of Tea-Based Drinks Quality and Functional Properties, South Ural State University Bulletin. Series "Food and Biotechnology", 4: 1. P. 87- 94 (in Rus.).

[3] Khanferyan R.A., Vybornaya K.V., Rajabkadiev R.M. (**2017**). Frequency of consumption of sugary carbonated drinks by the population of different age groups of the Russian Federation. Nutrition Issues, 3. P. 55-58 (in Rus.).

[4] Bessonov V.V., Khanferyan R.A., Galstyan A.G. (**2017**). Potential Side Effects of Caffeine Consumption in Healthy Adults, Pregnant Women, Adolescents and Children (A Review of Foreign Information). Nutrition Issues, 6. P. 21-28 (in Rus.).

[5] Khanferyan R.A., Rajabkadiev R.M., Evstratova V.S. et al. (**2018**). Consumption of Carbohydrate-Containing Drinks and their Contribution to the Total Caloric Intake. Nutrition Issues, 87: 2. P. 39-43 (in Rus.).

[6] Oganesyants L.A., Panasyuk A.L., Kuzmina E.I. (**2016**). Determination of the Carbon Isotope 13C/12C in Ethanol of Fruit Wines in Order to Identification Characteristics, Foods and Raw Materials, 4:1. P. 141-147. DOI: 10.21179/2308-4057-2016-1-141-147 (in Eng.).

[7] Zyakun A.M. et al. (**2012**). Mass Spectrometry Analysis of Prevalence of 13C/12C Isotopes Ratios in Grape Plants and Wine in Dependence on Climatic Factors (Krasnodar Territory and Rostov Region, Russia), Mass Spectrometry, 9:2. P. 16-22. DOI: 10.1134/S106193481313011X (in Eng.).

[8] Petrov A.N., Khanferyan R.A., Galstyan A.G. (**2016**). Current Aspects of Counteraction of Foodstuff's Falsification, Nutrition Issues, 85:5. P. 86-92 (in Rus.).

[9] Sergeeva I.Yu., Unschikova T.A., Rysina V.Yu. (**2014**). Improvement Directions of Kvass Fermentation Technology Based on the Analysis of Modern Scientific and Technical Developments, Equipment and Technology of Food Production, 3. P. 69-78 (in Rus.).

[10] Budaeva V.V., Gladysheva E.K., Skiba E.A., Sokovich E.V. (**2016**). The Method of Obtaining Bacterial Cellulose [Metod poluchenija bakterial´noj celulozi]. Patent of Russian Federation [Patent Rosijskoj Federacii] (in Rus.).

[11] Agbo F., Spradlin J.E. (**1995**). Enzymatic Clarification of Tea Extracts. Patent of USA (in Eng.).

[12] Khachatryan V. (**2012**). Tea Fungus: Sober Way Out. ISBN 978-5-88503-985-7. P. 99-101 (in Rus.).

[13] Shkitina E.N. (**2012**). Healing Fungi from All Diseases. ISBN 978-5-386-03870-0. P. 32-38 (in Rus.).

[14] Khachatryan V.Kh.,, Ivanova T.V. (**2000**). Drink, Method of Tea Fungus Liquid Culture Production and Method of Drink Production [Napitki. Metod proizvodstva I poluchenia kulturi chajnogo griba]. Patent of Russion Federation [Patent Rosujskoj Federacii] (in Rus.).

[15] GOST 12787-81 Beer. Methods for Alcohol Determination, Actual Extract and Calculation of Dry Substances in the Initial Wort (in Rus.).

[16] GOST 12788-87 Beer. Methods for Acidity Determining [GOST. Pivo. Obschie tehnicheskie uslovija] (in Rus.).

[17] Methods for Measuring the Mass Concentration of Volatile Components in Fermented Products by Gas Chromatography (Certificate of Measurement Method Attestation no. 01.00225/205-45-11) [Hromatograficheskie metodi izmerenija masovoj koncentracii letuchih komponentov] (in Rus.).

[18] Methods of Measuring the Mass Concentration of Organic Acids in Fermented Products by High Performance Liquid Chromatography (Certificate of Measurement Method Attestation no. 01.00225/205-49-12) [Hromatograficheskie metodi izmerenija masovoj koncentracii organiceskih kislot metodom visokoafektivnoj zhidkostnoj hromatografii] (in Rus.).

[19] Methods for Measuring the Mass Concentration of Sugars and Glycerin in Alcoholic and Non-Alcoholic Drinks by High Performance Liquid Chromatography (Certificate of Measurement Method Attestation no. 01.00225/205-54-12) [Hromatograficheskie metodi izmerenija masovoj koncentracii saharov I glicerina v alkogolnih I bezalkogolnih napitkah metodom visokoafektivnoj zhidkostnoj hromatografii] (in Rus.).

[20] Methods for Measuring the Mass Concentration of Amino Acids in Alcoholic and Non-Alcoholic Drinks by High Performance Liquid Chromatography (Certificate of Measurement Method Attestation no. 01.00225/205-48-12) [Hromatograficheskie metodi izmerenija masovoj koncentracii aminokislot v alkogolnih I bezalkogolnih napitkah metodom visokoafektivnoj zhidkostnoj hromatografii] (in Rus.).

[21] Shaburova L.N., Ilyashenko N.G., Sadova A.I. [et al.] (**2000**). Yeast Activation Method [Metod aktivacii drozhej]. Patent of Russion Federation [Patent Rosijskoj Federacii] (in Rus.).

[22] Gernet M.V., Kobelev K.V., Gribkova I.N., B.R. (**2016**). Development of Functional Fermented DrinksTechnology with Use of Tea. Part II. Formation of Main and By-Products of Fermentation during the Cultivation of Microorganisms [Issledovanie tehnologii funkcional´nih napitkov brozhenija na osnove chaja. Chast II. Obrazovanie osnovnih pobochnih produktov brozhenija v hode kul´tivirovanija mikroorganizmov]. Beer and Bevereges [Pivo I napitki], 2. P. 12-16.

[23] Shterman S.V. (**2017**). Sports Nutrition Products Moscow, Moscow. ISBN 978-5-906955-07-4(in Rus.).

[24] Fu C., Yan F., Cao Z. et al. (**2014**). Antioxidant Activities of Kombucha, Prepared from Three Different Substrates and Changes in Content of Probiotics during Storage, 34:1. P. 123-126. DOI.org/10.1590/S0101-20612014005000012 (in Eng.).

[25] Jayabalan R., Malini K., Sathishkumar M. (**2010**). Biochemical Characteristics of Tea Fungus, Produced during Kombucha Fermentation, Food Sci. Biotechnology, 19:3. P. 843-847. DOI/10.1007/s10068-010 (in Eng.).

[26] Oganesyants L.A., Khurshudyan S.A., Galstyan A.G., Semipyatny V.K., Ryabova A.E., Vafin R.R., Nurmukhanbetova D.E., Assembayeva E.K. (**2018**). Base matrices – invariant digital identifiers of food products News «Series of Geology and Technical Sciences». N 6. P. 6-15. ISSN 2224-5278 https://doi.org/10.32014/2018.2518-170X.30.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 231 – 241 **https://doi.org/10.32014/2019.2518-170X.28**

UDC 641.56:004.9

M. A. Nikitina[1], I. M. Chernukha[1], D. E. Nurmukhanbetova[2]

[1]V. M. Gorbatov Federal Research Center for Food Systems of Russian Academy of Sciences, Moscow, Russia,
[2]Almaty Technological University, Almaty, Kazakhstan.
E-mail: m.nikitina@fncps.ru, imcher@inbox.ru, dinar2080@mail.ru

PRINCIPAL APPROACHES TO DESIGN AND OPTIMIZATION OF A DIET FOR TARGETED CONSUMER GROUPS

Abstract. The nutritional status is one of the main factors determining health and preservation of the nation's gene pool. Experts consider 76% of people's deaths to be caused by noncommunicable diseases namely cardiac diseases (56,7%), different types of tumors (14,4%), lung diseases (3,7%) and diabetes (1,5%). Great part of the abovenamed diseases are associated with a deficiency or excess of certain components in the daily diet of a person. About half of the people deaths under the age of 70 linked to inadequate nutrition. One of the main prerequisites for the human health is its optimal diet, which should contain essential amino and fatty acids, vitamins and various trace elements. It is upon achievement of the optimal nutrition structure that high performance capabilities and primary prophylaxis of many diseases are ensured, immunoresistance is increased and organism defense against an impact of unfavorable environmental factors is strengthened. A solution to the problem of proper nutrition that corresponds to the requirements and possibilities of the human organism and is balanced by all indicators of nutritional and biological value is linked with the development and processing of big data and knowledge bases. They contain information that reflects the choice of individual (or personalized) diets and nutrition regimes with consideration for age factors, physiological status, medico-biological requirements, regional conditions, peculiarities in food consumption as well as for sources of disorders of the immune status. Difficulties in optimal decision-making solution is linked with many different factors. Firstly, with the probabilistic dispersion of characteristics and properties of biological raw material. Secondly, with individuality of the physiological peculiarities of the organism requiring in each case individual selection and correction of ration models taking into account structural relationships and restrictions at the component, elemental and monostructural levels. The paper shows the use of the information technologies realized by the methods of multi-criteria optimization and mathematical programming, which allow structuring the obtained set of alternatives, correct and/or construct an optimal diet.

Key words: diet, information technologies, computer programs, optimal diet, healthy nutrition.

Introduction. Nutrition is one of the main conditions of human existence. Quantity, quality and an assortment of consumed foods as well as timeliness and regularity of food intake decisively affect human life in all its manifestations.

Proper nutrition is the crucial factor of human health, performance capabilities and active life.

Among the environmental conditions that constantly affect the human body, nutrition, without doubt, has the highest specific weight. However, food has a principle difference from the other environmental factors as food is converted in the process of nutrition from the external factor into internal, and moreover, its elements are transformed into the energy of the physiological functions and structural elements of the human organs and tissues. That is why nutrition is the main factor in assurance of the normal growth and development of the human organism, its working capacity, adaptation to an exposure to different environmental agents and, finally, it can be considered that the nutrition factor has a determining effect on human longevity and activity [1].

It is well-known that the human organism is constantly negatively affected by different chemical, physical, social and other factors of a habitat, which leads to deterioration of a health condition on the individual level and an increase in morbidity, disability and mortality.

Diseases leading to high social costs, resulting in early deaths and depriving many people of full-value life, such as stroke, hypertension, cardiac ischemia, many types of cancer, diseases of oral cavity, anemia, goiter, liver cirrhosis, diabetes, presence of bile stones, obesity, diseases of the locomotor system in the elderly, can be prevented by proper nutrition, even if the detailed mechanism of the relationship between excessive or insufficient nutrition and these diseases is still unknown. According to the estimates of the WHO experts, the resources that are allocated to the treatment of these diseases significantly exceed the expenses necessary for their prevention [2].

According to the WHO data, in the Western European countries, noncommunicable diseases account for 77 % of all diseases, and they are the cause of deathin 86% cases with cardiovascular diseases occupying the first place [2]. The same trend is observed in Russia. For example, in 76% cases, the causes of death are noncommunicable diseases, among which are the circulatory system diseases (56.7%), neoplasms (14.4%), respiratory diseases (3.7%) and diabetes mellitus (DM) (1.5%).The main risk factors influencing mortality of the population of the Russian Federation are: arterial hypertension (35.5%), increased cholesterol level (23%), smoking (17.1%), insufficient intake of vegetables and fruit (12.9%), obesity (12.5%), excessive consumption of alcohol (11.9%), low physical activity (9%). It is obvious now that a decrease in mortality and an increase in life expectancy in Russia are possible, first of all, due to prevention of chronic noncommunicable diseases [3].

Several main noncommunicable diseases, including cardiovascular diseases, type 2 diabetes and certain cancer types, which accounts for more than half of deaths, diseases and disabilities, were identified as alimentary-dependent, that is, they can become more severe or be corrected by corresponding nutrition.

However, WHO identifies overweight (body mass index (BMI=25-29.9) and obesity (BMI=30 and higher) as the biggest unacknowledged problem of the public health in the world [2].

About half of deaths under the age of 70 are associated, to one extent or another, with malnutrition [4].

Several diseases are associated with deficiency or excess of certain components in human daily diets. The associations have been traced between fluorine and caries, iodine and goiter; essential fats and cardio-vascular diseases; dietary fibers and gastrointestinal diseases; calcium, fluorine, vitamin D and diseases of the locomotor system; iron, folic acid and anemia [5].

A degree of assimilability of diet components to a large extent depends on the accompanying sub-stances. For example, calcium is a substance that is hard to assimilate. Calcium is found in foods, mainly, in the form of poorly soluble salts (phosphates, carbonates, oxalates and others). Solubility of calcium salts increases in the acidic environment of the stomach; however, dissolved ions, to some extent, are again bound and precipitate in jejunum and ileum, where pH is closer to neutral. A deficiency of protein and an excess of dietary fibers and phytic acid negatively affect a degree of assimilability of calcium that is consumed with foods. Oxalic acid often prevents calcium absorption. Binding with oxalic acid, calcium gives water insoluble compounds, which are the components of kidney stones. These are dock, rhubarb, spinach and beet. Phytic acid (which is especially abundant in cereals) binds calcium to the insoluble form. An increase in the need for calcium upon increasing dietary fibers in a diet raises the risk of osteo-porosis [6, 7]; a growth in aggressiveness is possible upon decreasing fat consumption [8], which is necessary to consider when developing and adapting an individual diet (personalization in nutrition).

The human stomach at the age of 60 can produce only 25% of the gastric juice that it produces at the age of 20. With that, a proportion of consumption of cereals (rye, wheat, oat), which are rich in fibers, increases. Therefore, a need for calcium increases with age. Products with low content of oxalic acid (green head cabbage, broccoli, turnip) are good sources of calcium. Calcium assimilability from cabbage is as high as from milk.

A significant contribution to the mentioned problems can be made by the use of the modern infor-mation technologies, which allow prompt assessment of person's psycho-physiological peculiarities, including technological treatment and raw material preparation [9]; selection with consideration for this assessment of the individual full-value diets based on the optimized procedure; individual health nutrition education and dissemination of knowledge in this field using data (generalized and formalized in a form of databases/knowledge bases) about relationships between nutrition, health, age, individual characteristics of a person and ecological conditions; and control over the process of the diet use.

For human health, not only the full value of nutrition is important, but also its prophylactic, curative, detoxifying and geroprotective function. This, to a large extent, determines the modern requirements for

the structure of rational nutrition. At present, it is difficult to meet these requirements using the traditional approaches to formation of diets based on the dietitians' expert analysis as, when solving this problem, a person deals with quite a difficult combinatorial task of multi-parametric and multi-criteria optimization of a diet, which potentially can consist of many several hundreds of food products with different composition and properties. It is even physiologically difficult to a person to solve this task. In the general case, this task often does not have a solution and, therefore, there is a need for a step-wise iterative procedure of optimization in the course of the "human-computer" dialog [10].

The paper describes approaches to the development of the structural parametric models of adequate nutrition, formalization of the knowledge data and creation of the expert system of analysis and correction of the daily diet and nutrition regime for a certain group of people according to the scientifically substantiated norms and medico-biological requirements from available traditional food products in a particular region.

Principles for developing adequate human diet. It is known that human food should contain six hundred substances that are necessary for normal vital activities of the organism and occupy their place in the complex harmony of the biochemical processes. With that, 96% of the organic and inorganic compounds that come with food have certain curative properties [11]. Therefore, a human health condition ultimately depends on the quantity and ratios of these substances in a diet.

General approaches and methods for organization of nutrition are based on the principles of balance, individuality, rationality, functionality and adequacy [12].

The main tasks in organization of nutrition are:

- assurance of rational and balanced nutrition according to the age and physiological requirements in nutrients and energy;
- assurance of quality and safety of foods used in diets;
- prevention (prophylaxis) of communicable and noncommunicable diseases linked with the nutrition factor using enrichment of diets with main micronutrients (to prevent their deficiency).

Rational nutrition, which is adequate by quantitative and qualitative norms, as well as medico-biological requirements, is one of the main factors that predetermine health condition.

When formulating a diet, it is necessary to adhere to the principles of the rational, balanced adequate nutrition, which implies:

- satisfaction of the human needs for nutrients and energy, including macronutrients (proteins, fats, carbohydrates) and micronutrients (vitamins, microelements and others);
- balance of a diet by all nutrients, including amino acids, fatty acids, carbohydrates, vitamins, mineral substances;
- maximum variety in a diet, which is achieved by the use of a sufficient product assortment and different methods of cooking;
- adequate technological (culinary) processing of products that ensure high palatability of products and preservation of their nutritional value;
- consideration for the individual characteristics of a person (including intolerance to certain types of food products and meals);
- formation of a diet by qualitative and quantitative composition separately for different age groups in a population.

As was mentioned above, healthy food not only should be balanced by the content of proteins, fats and carbohydrates, but also should contain the whole complex of necessary minerals and vitamins. For creation of a proper diet, not only the presence of all nutrients is important, but also their compatibility, interrelatedness, synergism and so on.

Available variety of products leads to entropy of their choice. Among the main and most often used foods are bread, grits, pasta and sausages. Being mainly the suppliers of protein, they, at the same time, contain many co-occurring excessive ingredients that favor the development of obesity and alimentary-dependent diseases.

Difficulties in optimal decision-making are conditioned by the probabilistic dispersion of characteristics and properties of the initial components of the biological raw materials, individuality of the physiological peculiarities of the organism, which require in each case an individual choice and correction of diet models taking into account structural ratios and constraints on the component, element and monostructure levels. Therefore, the development of the computer technologies for the structural parametric modeling and optimization of the adequate nutrition system will allow knowledge-based selection of an optimal solution from a set of possible alternatives.

Intellectual component of the software. When developing software for assessment and optimization of a diet, it is necessary to take into account several requirements:

- addition of products and meals to a menu, and a possibility to edit a chemical composition;
- the use of the reference values for different population groups (healthy, curative, curative-prophylactic, dietetic nutrition and so on).

The functional structure of the developed system (figure 1) consists of the information database and a set of program modules that realize the control system of the information database, modeling and analysis of a diet, and the highly developed object-oriented user interface.

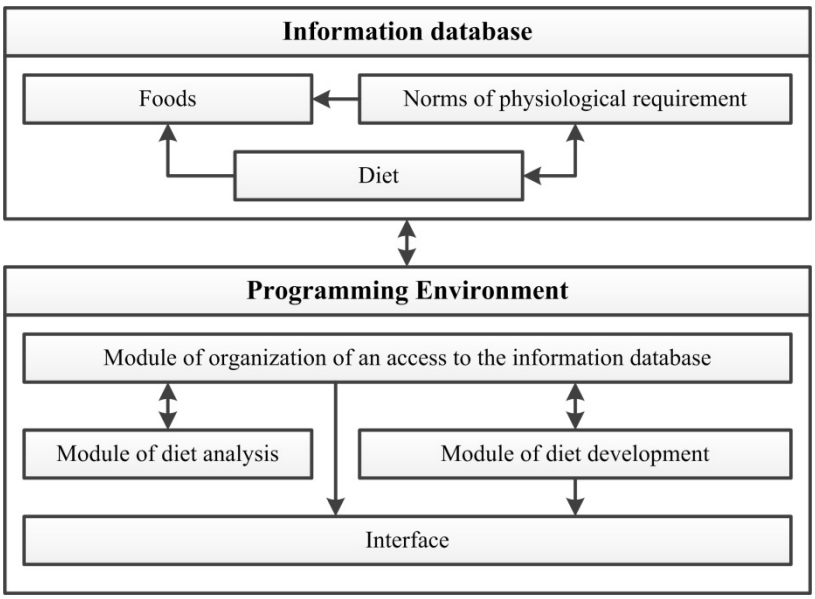
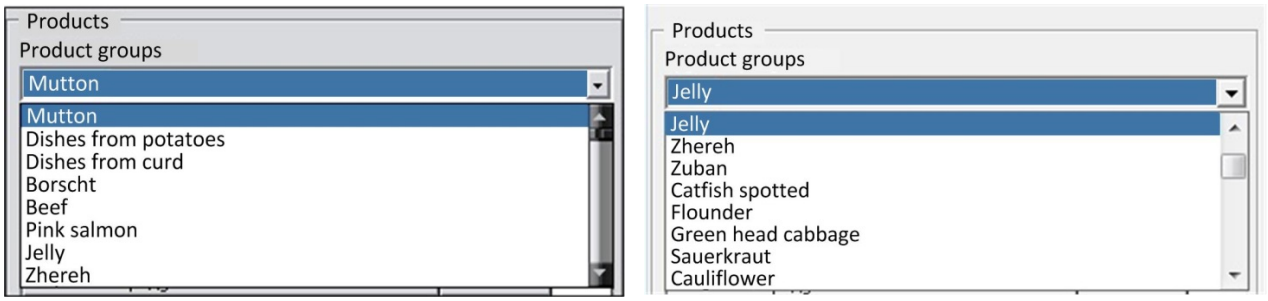


Figure 1 – The functional structure of the system

The information basis of the system is a database that reflects, in the structural manner, the physico-chemical indicators, functional-technological and structural-mechanical properties of products of animal and plant origin in a meal, atherogenic index of a food product, dietetic diets and menus, criteria of optimization and adequacy assessment, recommendations and norms of the physiological requirements in energy and nutrients for different population groups.

The main task of the system is the development and optimization of the nutrition menu for differentiated population groups according to the scientifically substantiated norms and medico-biological characteristics from available traditional products in a certain region of the Russian Federation. The decision is made in the module "Diet", which is intended to create new diets and correct the existing ones by addition of new meals and/or foods.

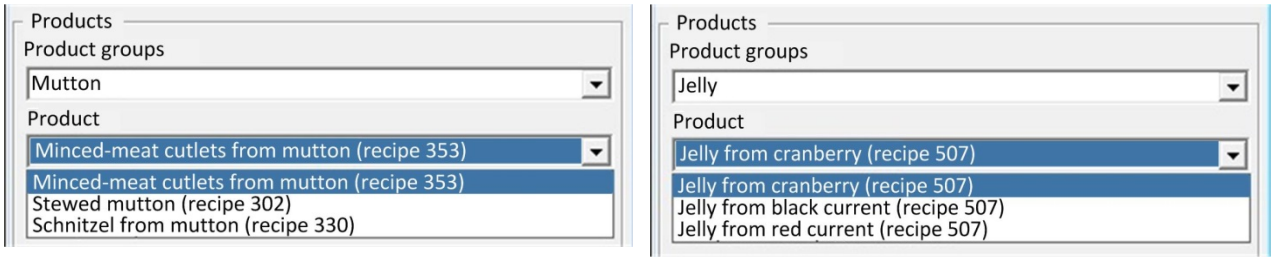
Figure 2 presents the dialog window of the database visually reflecting the group of products in the dropdown menu.



a) b)

Figure 2 – Window of the database with the list of the product groups:
a) "Mutton" group; b) "Jelly" group

When choosing the necessary group of products in the following box (text field), the products and meals of this group will be presented (figure 3).



a) b)

Figure 3 – Window of the database: choice of products (meals) from the chosen product category:
a) Choice of meals from the "Mutton" group; b) Choice of meals from the "Jelly" group

The development of an optimal diet comes down to the dialog algorithm (figure 4) [13] of detection of the product composition, their quantity and ratios by the set criteria and constraints. The first stage begins with entering information about existing daily diet of a patient with consideration for taste characteristics, ethical traditions, region of residence and so on.

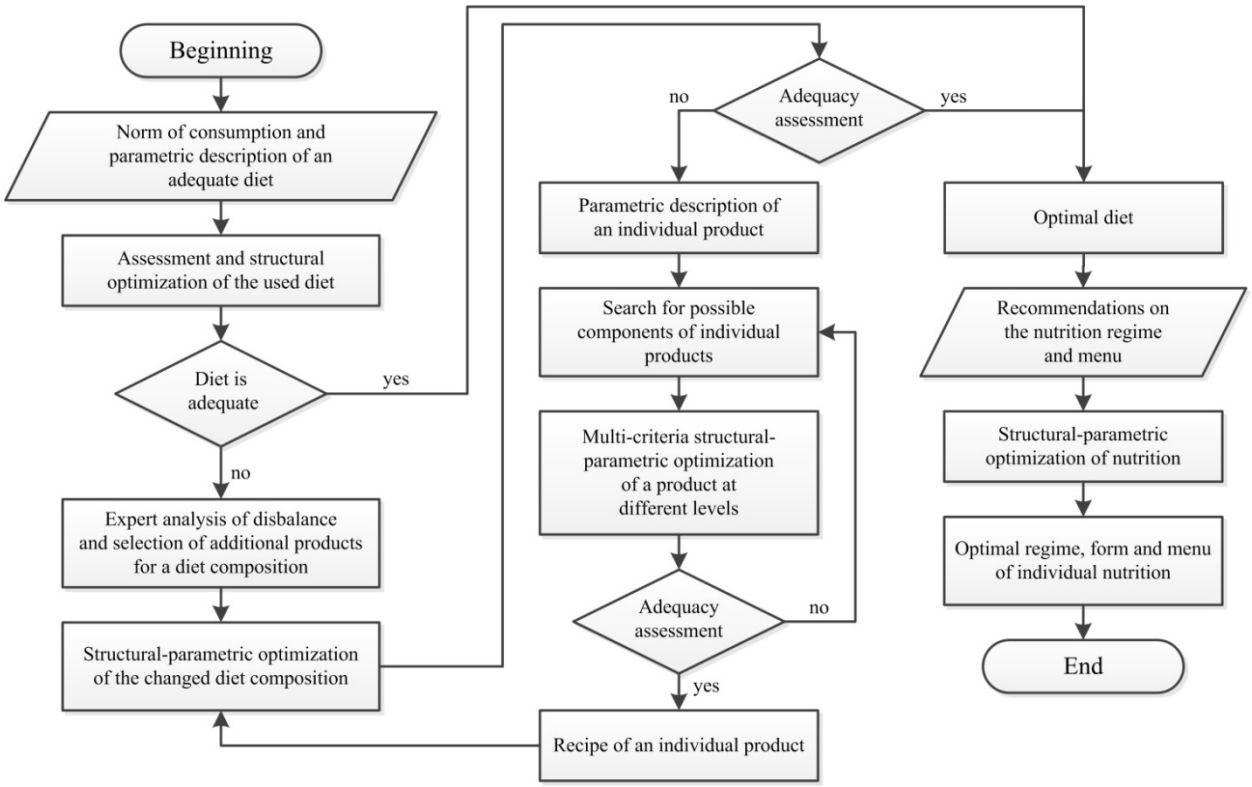


Figure 4 – Dialog algorithm of the structural-parametric optimization of the adequate nutrition

Using the described medico-biological status of a person, a parametric model of his/her adequate nutrition is formed in the expert system as specific parameters, norms and ratios of the nutrients and components that are required daily. On this basis, the assessment and structural optimization of the existing daily diet is carried out, which is linked with changes in the ratios and proportions of consumed foods by the criteria of the minimum deviation from the normative parametric structure of the indicators of the adequate nutrition.

The hierarchy of the quadratic criteria [14] of the minimal deviation from the reference structure of the set of indicators for nutritional, biological and/or energy values, as well as the criteria of the protein

digestibility, adequacy of protein intake, deficiency of albumin, transferrin, lymphocytes and others is used as a targeted function.

Minimization of the possible noncoincidence between parameters of the "standard" and proposed diets is linked with multi-criteria optimization and formation of the Pareto-optimal set of solutions by formalized criteria.

By the diagnostic algorithm for the medico-biological status of a person (figure 5), a vector of deviation of specific parameters of nutrients and components that are required daily is formed in the expert system relative to the established norms and ratios of adequate nutrition that allows to carry out the initial selection of products into the recommended diet that compensate existing deviations with consideration for individual characteristics of a person and social conditions (personal perception of one or another product, allergy, as well as availability of certain products due to a financial or geographical factor).

Upon insufficient compensation of deviations by selection of desired products and meals that are constituents of a diet, a search for their optimal qualitative ratios (structural optimization) is then carried out by possible incorporation of additional products and meals dependent on current deviations of

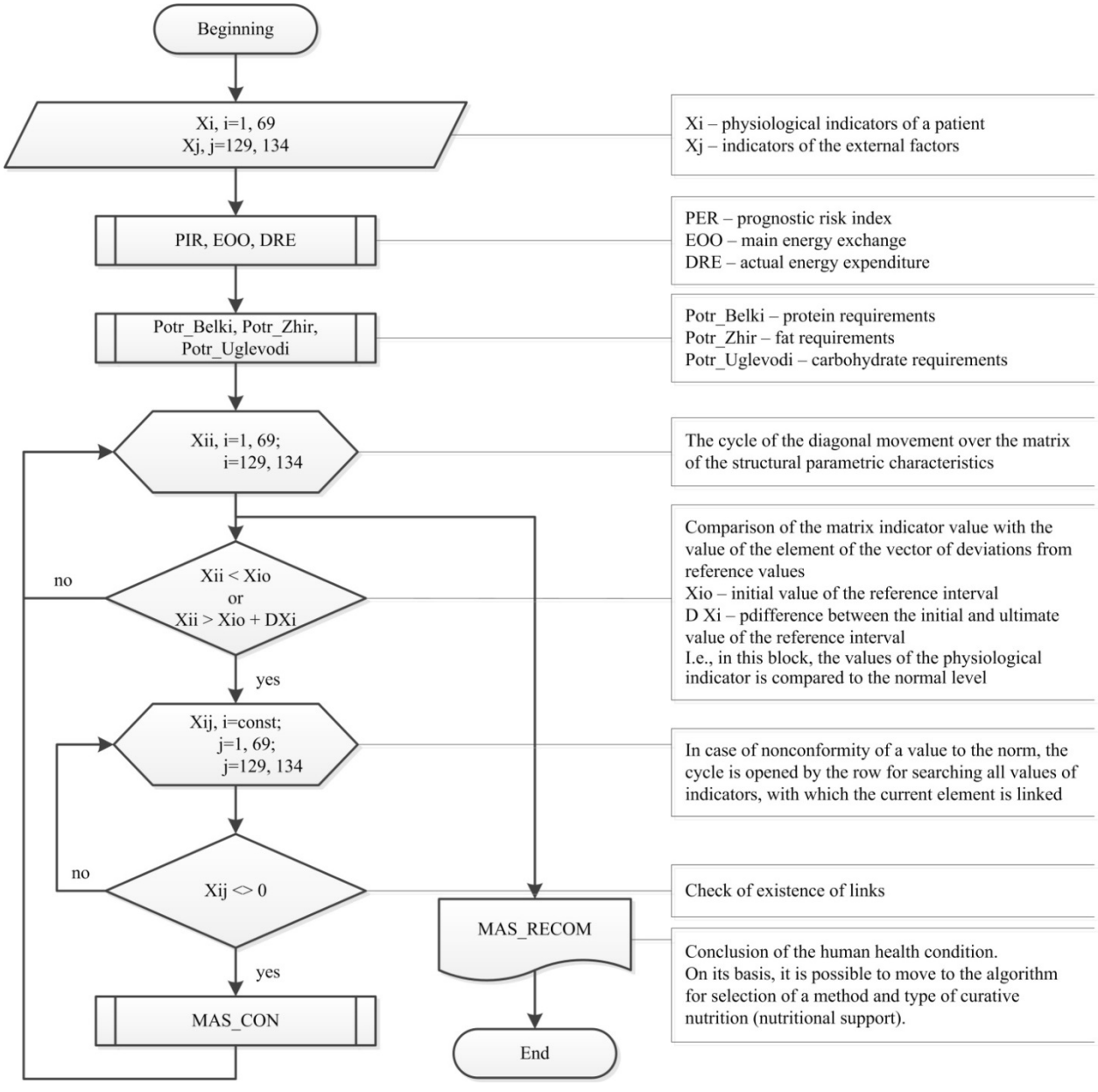


Figure 5 – Algorithm of diagnostics of human health condition

parameters from norms (the 3rd stage) or the development of the individual combined product (the 4th stage) that minimizes residual deviations.

To assess adequacy and quality of a diet, a functional [13] is proposed that reflects the average weighted total deviation of actual values of condition parameters from the norm. With consideration for weighted coefficients and selection of certain groups of factors, the quality functional has a form:

$$F(x) = 1 - \sqrt{\frac{1}{n}\sum_{i=1}^{n} a_i \sum_{j=1}^{n_i} b_{ij}\left(\frac{x_{ij} - x_{ij}^0}{\Delta x_{ij}^k}\right)} \to \max \quad (1)$$

where n – is the number of combined indicators; x_{ij}, x_{ij}^0 – the actual and desirable value; Δx_{ij}^k – the extreme deviation from the desirable value for the k[th] level of quality; b_{ij} – the weighted coefficient of the j[th] parameter in the i[th] group; a_i – the coefficient of group significance.

The value of quality coefficient changes from 1 in case of full coincidence of the obtained values with the recommended (the best quality) to 0 when reaching the boundary of the quality level (the ultimate value), so that at negative values of the functional, a diet does not correspond to the targeted quality level.

To detect the weighted coefficients, the method of the full factorial experiment can be used, at which the following values are entered into the columns of the response function y_{kr} of the r[th] replicate in the k[th] experiment: 1-0.7 – when assigning a product to a very good quality level; 0.7-0.3 – to good; 0.3-0 – to satisfactory; 0-(-0.2) –to bad; lower than (-0.2) – to a very bad quality level.

The mathematical model and algorithm for individual menu formation with consideration for taste preferences of people, their financial possibilities as well as individual physical and physiological characteristics come down to minimization of the discrepancy between taste preferences of a person and prescriptions of a dietitian by the criterion:

$$\sum_k (D_{KP} + D_{KD})\delta_k \to \max \quad (2)$$

where D_{KP} – the score value of the functional of patient's "taste" preferences of the k[th] meal; D_{KD} – the value of the functional of "curative" preference by the k[th] meal; $\delta_k = \begin{Bmatrix} 0 \\ 1 \end{Bmatrix}$ – logical variable of the component inclusion into the meal or diet composition upon constraints:

- for non-repeatability of meals in a daily diet
- for financial possibilities of a patient
- by mass of the k[th] meal
- for the ultimate caloricity at breakfast, dinner and supper
- for the ultimate volume of breakfast, dinner and supper
- by the upper and lower limits of the content of the i[th] chemical element

At the first stage, an assessment and analysis of the existing dietis carried out linked with calculation of the nutritional value (moisture, protein, fat, carbohydrates), vitamin and mineral composition (A, β-carotene, B_1, B_2, PP, C, Na, K, Ca, Mg, P, Fe) and the energy value of each i[th] meal/product in a diet.

After consecutive calculations for each component, all determined indicators for the first meal are obtained. Then, the value of the i variable is increased by one $i+1$; that is, we turn to the following meal in the menu. At each transition, the file is checked for its end.

After meeting this condition, we turn to the following stage linked with analysis and assessment of the existing diet.

At this stage, a gender and age group of a respondent (a person, patient, individual) is determined and the physical activity level is chosen. On the basis of the presented data, the norms of the physiological requirements in energy and nutrients for different groups of the population of the Russian Federation adopted by the Federal Service for Supervision of Consumer Protection and Welfare (Rospotrebnadzor) are uploaded.

The obtained calculated data on the physico-chemical indicators are compared with the regulatory indicators at two levels – minimum and maximum.

When there is a deficiency of one or more basic indicators (protein, fat, carbohydrates), the percent deviation from the norm is calculated and a product and/or meal that contain the lowest value of this indicator is found in a respondent's diet. In case of excess, a deviation from the limit for this indicator is calculated in a similar manner and a product and/or meal that contains the highest value of this indicator is found.

"Correction of a diet" is associated with replacement of an "undesirable" product by a similar one from this category of meals in order not to disrupt the balance of meals in a menu. A request to the database is made with the condition to display all meals in the same group category as a meal intended to be replaced. Among them, a meal with the maximum or minimum value of the targeted component is chosen.

Then, the other indicators of a diet are checked in terms of the correspondence to the minimum and maximum norms of consumption, and in case of misbalance, similar recalculation of products and meals in a diet is carried out.

As a result of the performed mathematical operations, the results are displayed showing the main physico-chemical indicators of a diet as well as the comparative analysis of deviations and options of their elimination.

Figure 6 presents the results of analysis of deviations from the reference norms and the proposed methods for diet improvement.

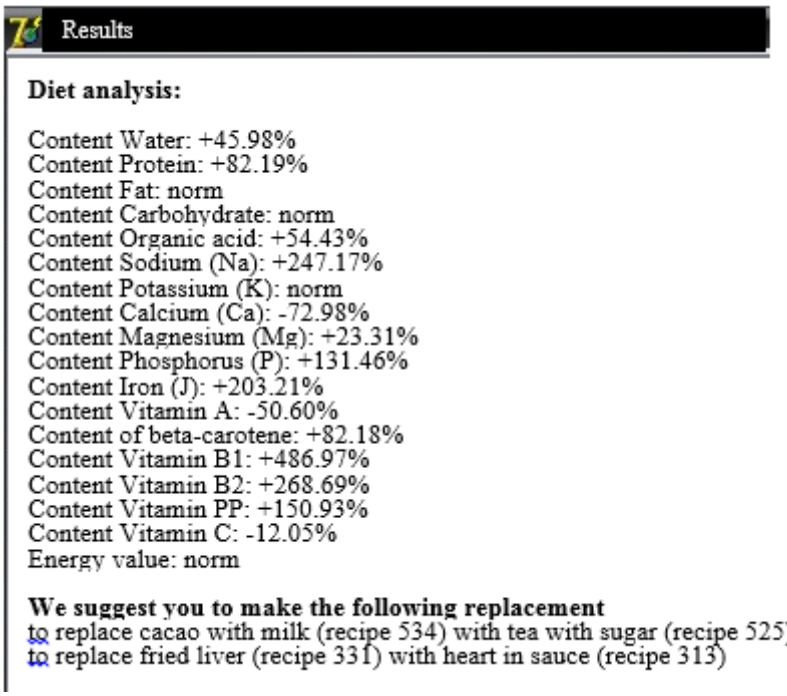


Figure 6 – Results of the program execution.

Analysis of IT solutions for human diet in the market. At present, several programs that are similar to the program under development are available on the market.

For example, the program "Assessment of actual nutrition by the Institute of Nutrition RAS" permits calculating a level of the main metabolism, giving recommendations on caloricity and the structure of nutritional value indicators by product groups, as well as visually reflecting nutritional value characteristics relative to norms. However, the proposed program does not allow taking into consideration a level of assimilability of food substances and a volume of actually consumed products, as well as product compatibility.

The apparatus-program complex "*Health Sources*" [15] (certificate of Rospatent No. 2004610012) consists of 4 modules (health assessment; analysis of factors influencing health; analysis of nutrition; dynamics) and allows screening a level of psychophysiological and somatic health, functional and adaptive reserves of the organism, assessing parameters of the physical development, making recom-

mendations on nutrition correction, physical activity, sport, sleeping regime, living, working and resting conditions. Analysis of the program complex showed that the main target audience is sportsmen, people having difficult professions (engine drivers, military personnel, shift workers). APC "Health Sources" allows giving a qualitative assessment of the health reserves that are taken into consideration upon development of the health improvement and training programs for correction of the revealed adaptation disorders. The system also allows assessing the actual diet by 27 nutrients and giving recommendations with consideration for gender and age groups. A diet is not corrected automatically by the program, but a dietitian makes changes in the current diet and nutrient composition of daily nutrition.

In the United Kingdom, the program *DietPlan* [16] was developed , which is integrated with the databases of McCance and Widdowson, USDA NDB, Australian NUTTAB, Danish, Canadian and New Zealand nutrient databases. In several databases, the nutrient composition exceeds a hundred of indicators. The developers of the software ensured harmonization of the nutritional value characteristics allowing the use of the initial data from significantly different sources. However, the English interface requires special learning and an unprepared user cannot use all options of the software without assistance. The program allows forming the individual and group reports, editing reference values for a category of patients under investigation.

The program *NutriSurvey*(Germany) [17] realizes the classical reference frequency method of consumption surveys, contains the database of products and nutritional value characteristics and normative values by different food categories. The program *NutriBase* (USA) [18] is intended for executing individual plans for clients of fitness centers or clinics and contains the nutrient databases USDA SR (USA) and CNF (Canada).

The output data of the program are graphs and tables about the condition and dynamics of consumption. The *NUT program* (USA) [19] contains the data about 8194 products and 146 nutrients, and enable execution of different nutrition plans, including ketogenic, low carb and other diets.

The principle disadvantages of the foreign computer programs are the following: they do not take into consideration the specifics of diseases, peculiarities of the organism and mentality of the Russians; there is no information about Russian foods and meals, they do not take into consideration the requirements of the Russian legislation for the composition, quality and safety of foods and meals. In additions, the interface in the Russian language is not envisaged in these programs.

Conclusions. At present, when constructing diets, it is necessary to take into account not only nutritional and biological values, but also other multiple factors: medical, technological, economic, social and so on. The solution to the problem of individual (personalized) adequate nutrition of a certain person should be considered trough many different factors. Status parameters, alternatives and criteria, different constraints and conditions should be taken into account. Information technologies for data and knowledge processing and formalization by optimal decision-making processes based on the complex models of multi-criteria structure-parametric optimization and objective assessment of the suggested options should be applied.

Information technologies can play a special role for representatives of different professions, population in the ecologically unfavorable regions, people with increased emotional and intellectual burden as they can not only present reliable and comprehensive information about peculiarities of nutrition, but also select an individual diet.

In contrast to the Russian and foreign analogues of computer programs for analysis of actual nutrition that are available on the market, the program under development enables simple and easy assessment and correction of a diet for a certain person with consideration for the physiological requirements, regional peculiarities of life and curative and prophylactic properties.

М. А. Никитина[1], И. М. Чернуха[1], Д. Е. Нурмуханбетова[2]

[1]«В. М. Горбатов атындағы тағамдық жүйелердің федералдық ғылыми орталығы» РҒА, Мәскеу, Ресей,
[2] Алматы технологиялық университеті, Алматы, Қазақстан

ТҰТЫНУШЫЛАРДЫҢ НЫСАНАЛЫ ТОПТАРЫ ҮШІН ТАҒАМ РАЦИОНЫН ЖАСАУ ЖӘНЕ ОҢТАЙЛАНДЫРУ ПРИНЦИПТЕРІ

Аннотация. Тамақтану жағдайы – денсаулықты анықтайтын және ұлт гендік қорын сақтайтын маңызды факторлардың бірі. Ресейде 76% жағдайда өлімнің себептері жұқпалы емес аурулар екені көрсетілген, олардың арасында қан айналымы жүйесінің аурулары (56,7%), ісіктер (14,4%), тыныс алу органдарының

аурулары (3,7%), қант диабеті (ҚД) (1,5%). Бірқатар аурулар күнделікті адамның тамақтану рационында белгілі бір компоненттердің жеткіліксіздігіне немесе артық мөлшерде болғанына байланысты. 70 жасқа дейінгі өлім жағдайларының жартысының жуығы белгілі бір дәрежеде дұрыс тамақтанбауға байланысты. Адам денсаулығын сақтау үшін басты алғышарттар болып құрамында ағзаға қажетті амин қышқылдар, май қышқылдар, витаминдер және әр түрлі микроэлементтер бар оның оңтайлы тамақтану рационы табылады. Тамақтанудың оңтайлы құрылымына дәл жеткен кезде, жоғары жұмыс қабілеттілігі қамтамасыз етіледі және алғашқы көптеген аурулардың алдын алады, иммундық резистенттілік жоғарылайды, ағзаны қоршаған ортаның қолайсыз факторларының әсер етуінен қорғау күшейеді. Адам ағзасының тиісті қажеттіліктеріне және мүмкіндіктеріне сәйкес, тағамдық және биологиялық құндылықтарды көрсеткіштер бойынша теңдестірілген адекватты тамақтану мәселесін шешу үлкен деректер мен білім базасын құрумен және өңдеумен байланысты. Оларда жеке (немесе арнайы) рациондарды және жас ерекшеліктері бойынша факторларды ескере отырып тамақтандыру режимдерін таңдауын көрсететін, сонымен қатар физиологиялық жай-күйіді, медициналық-биологиялық талаптарды, аймақтық талаптарды, тағамды тұтыну ерекшеліктерді және де иммундық жүйенің бұзылған көзін көрсететін ақпарат бар. Бірінші кезекте, сипаттамалардың шашылу ықтималдылығымен және биологиялық шикізаттың бастапқы компоненттерінің қасиеттерімен. Екіншіден, ағзаның өзіндік физиологиялық ерекшеліктерімен әрбір нақты жағдайда жеке таңдауды талап ететін және компонентті, элементті және моноқұрылымды деңгейде шектеулер мен құрылымдық қатынастарды ескере отырып рациондар үлгілерін түзетумен ерекшеленеді. Мақалада көпкритерияларды оңтайландыру әдістерімен және математикалық бағдарламалаумен асырылатын ақпараттық технологияларды қолдану көрсетілген, ол көптеген алынған баламаны құрылымдауға, тамақтанудың оңтайлы рационын түзету мен орнатуға мүмкіндік береді.

Түйінді сөздер: тамақтану рационы, ақпараттық технологиялар, компьютерлік бағдарламалар, нақты тамақтануды бағалау, деректер базасы, білім базасы.

М. А. Никитина[1], И. М. Чернуха[1], Д. Е. Нурмуханбетова[2]

[1]ФГБНУ «Федеральный научный центр пищевых систем им. В. М. Горбатова» РАН, Москва, Россия,
[2]Алматинский технологический университет, Алматы, Казахстан

ПРИНЦИПЫ РАЗРАБОТКИ И ОПТИМИЗАЦИЯ РАЦИОНОВ ПИТАНИЯ ДЛЯ ЦЕЛЕВЫХ ГРУПП ПОТРЕБИТЕЛЕЙ

Аннотация. Состояние питания – один из важнейших факторов, определяющих здоровье и сохранение генофонда нации. В России в 76% случаев причинами смерти оказываются неинфекционные заболевания, среди которых болезни системы кровообращения (56,7%), новообразования (14,4%), болезни органов дыхания (3,7%) и сахарный диабет (СД) (1,5%). Ряд заболеваний связаны с недостаточностью или избытком определенных компонентов в каждодневном рационе питания человека. Около половины случаев смертности в возрасте до 70 лет в той или степени связаны с неправильным питанием. Одной из главных предпосылок сохранения здоровья человека является его оптимальный рацион питания, содержащий необходимые для организма аминокислоты и жирные кислоты, витамины и различные микроэлементы. Именно при достижении оптимальной структуры питания обеспечиваются высокая работоспособность и первичная профилактика многих заболеваний, повышается иммунная резистентность и усиливается защита организма от воздействия неблагоприятных факторов окружающей среды. Решение вопроса адекватного питания, соответствующего потребностям и возможностям организма человека и сбалансированного по всем показателям пищевой и биологической ценности, связано с созданием и обработкой больших баз данных и знаний. В них содержится информация, отражающая выбор индивидуальных (или персонализированных) рационов и режимов питания с учетом возрастных факторов, физиологического состояния, медико-биологических требований, региональных условий, особенностей потребления пищи, а также источника нарушения иммунного статуса. Сложность принятия оптимальных решений обуславливается множеством факторов. В первую очередь, вероятностным разбросом характеристик и свойств исходных компонентов биологического сырья. Во-вторых, индивидуальностью физиологических особенностей организма, требующих в каждом конкретном случае индивидуального выбора и коррекции моделей рационов с учетом структурных соотношений и ограничений на компонентном, элементном и моноструктурном уровнях. В статье показано применение информационных технологий, реализуемых методами многокритериальной оптимизации и математического программирования, позволяющие структурировать полученное множество альтернатив, скорректировать и установить оптимальный вариант рациона питания.

Ключевые слова: рацион питания, информационные технологии, компьютерные программы, оценка фактического питания, база данных, база знаний.

Information about authors:

Nikitina Marina Aleksandrovna, Candidate of technical sciences, docent, leading scientific worker, the Head of the Direction of Information Technologies, V. M. Gorbatov Federal Research Center for Food Systems of Russian Academy of Sciences, Moscow, Russia; m.nikitina@fncps.ru; http://orcid.org/0000-0002-8313-410

Chernukha Irina Mikhailovna, **Doctor of technical sciences, professor,** member of Correspondence RAS, V. M. Gorbatov Federal Research Center for Food Systems of Russian Academy of Sciences, Moscow, Russia; imcher@inbox.ru; http://orcid.org/0000-0003-4298-0927

Nurmukhanbetova Dinara Erikovna, candidate of engineering sciences, acting associate professor, Almaty Technological University, Department of Food safety and quality, Almaty, Kazakhstan; dinar2080@mail.ru; http://orcid.org/0000-0002-8939-6325

REFERENCES

[1] Potemkina N.S., Krut'ko V.N., Mamikonova O.A., 2009.Nutrition as a factor of sustainable development. Proceeding of the Institute for Systems Analysis of the Russian Academy of Science, 42. P. 251-264.

[2] Gaining health. The European Strategy for the Prevention and Control of Noncommunicable Diseases. WHO/Europe (World Health Organization. Regional office for Europe) 2006. Copenhagen.

[3] Boitsov S.A., Oganov R.G., Maslennikova G. Ya., KalininaA.M., Ipatov P.V., 2012. Complex problem of non-communicable disease prevention: planning, realization, assessment // Prophylactic Medicine. Appendix, 15, 1. P. 3-18.

[4] Ulumbekova G.E., 2010. Health of population in the Russian Federation: risk factors and role of healthy nutrition // Problems of nutrition, 79, 2. P. 33-38.

[5] Shukesheva S.E., Uzakov Ya.M., Chernukha I.M., Nabiyeva Zh.S., Nurtaeva A.B., Nurmukhanbetova D.E. Research to improve the quality of food products // News of the academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Scopus ISSN 2224-5278. 2018. N 4(430). P. 37-45.

[6] Bolland M.J., Grey A., Avenell A., Gamble G.D., Reid I.R., 2011. Calcium supplements with or without vitamin D and risk of cardiovascular events: Reanalysis of the Women's Health Initiative limited access dataset and meta-analysis // British Medical Journal. 342 (7804). DOI 10.1136/bmj.d2040.

[7] Thorning T.K., Raziani F., Bendsen N.T., Astrup A., Tholstrup T., Raben A., 2015.Diets with high-fat cheese, high-fat meat, or carbohydrate on cardiovascular risk markers in overweight postmenopausal women: A randomized crossover trial // American Journal of Clinical Nutrition. 102 (3). P. 573-581. DOI 10.3945/ajcn.115.109116.

[8] Bergeron N., Williams P.T., Lamendella R., Faghihnia N., Grube A., Li X., Wang Z., Knight R., Jansson J.K., Hazen S.L., Krauss R.M., 2016. Diets high in resistant starch increase plasma levels of trimethylamine-N-oxide, a gut microbiome metabolite associated with CVD risk // British Journal of Nutrition. 116 (12). 2020-2029. DOI 10.1017/S0007114516004165.

[9] Ivashov V.I., Kapovsky B.R., Plyasheshnik P.I., Pchelkina V.A., Iskakova E.L., Nurmukhanbetova D.E. Mathe matical simulation of one-stage grinding of products frozen in blocks // News of the academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Scopus ISSN 2224-5278. 2018. Vol. 5, N 5(431). P. 48-65. https://doi.org/10.32014/2018.2518-170X.9

[10] Mamikonova O.A., Krut'ko V.N., Potemkina N.S., Chizhov A.Ya. Information structure and algorithms of the computer system "Nutrition for health and longevity" // Bulletin of Peoples' Friendship University. Series "Ecology and Life Safety". 2009. 1. P. 121-129.

[11] Nechaev A.P., Traubenberg S.E., Kochetkova A.A. Food chemistry. Publishing House Giord. 2015.

[12] Tsyganova T.B., Klassina S.Ya. Theory of functional systems as methodological basis for the concept of human functional nutrition // Tyumen Medical Journal. 2016. 18, 3. P. 3-9.

[13] Ivashkin Yu.A., Nikitina M.A. Information technologies for optimization of human adequate nutrition // Bulletin of the Institute for Systems Analysis of the Russian Academy of Science". 2016. 18, 1. P. 49-60.

[14] Ivashkin Yu.A. Multi-agent simulation modeling of large systems: textbook. Moscow: MGUPB, 2008.

[15] Apparatus-program complex "Health Sources". http://www.breath.ru/v.asp?articleid=100, access date 05.09.2018.

[16] DietPlan. www.fore-soft.com, access date 05.06.2018.

[17] Nutrition Surveys and Calculations.http://nutrisurvey.de/, access date 05.06.2018.

[18] The NutriBase 18 Professional Plus Software. http://www.nutribase.com/, access date 05.06.2018.

[19] NUT Nutrition Software. http://nut.sourceforge.net, access date 05.06.2018.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 242 – 247 **https://doi.org/10.32014/2019.2518-170X.29**

UDC 539.3 (043.3)

A. Almagambetova[1], S. Tileubay[1], L. Taimuratova[2], A. Seitmuratov[1], K. Kanibaikyzy[1]

[1]The Korkyt Ata Kyzylorda state University, Kyzylorda, Kazakhstan,
[2]The Sh. Esenov Caspian state University of technology and engineering. Aktau, Kazakhstan.
E-mail: aldajarovna_@mail.ru, sarsen-00@mail.ru, taimuratova@mail.ru, angisin_@mail.ru, VIP kundyz@mail.ru

PROBLEM ON THE DISTRIBUTION OF THE HARMONIC TYPE RELAY WAVE

Abstract. In this paper, we study the class of flat problems on the effect of moving loads on the surface of a laminated plate. The problems of this class are of great practical interest and in addition, can serve as a benchmark for the development of certain numerical algorithms for solving dynamic problems.

Among various periodic and non-periodic motions of deformable medium, plane waves of simple harmonic type, distributed along the surface of a body or half-plane, whose influence is limited by the vicinity of this surface, are of great importance. Therefore, we consider the problem of the distribution of the relay wave.

Key words: stratified plates, live-load, waves of Relay, wave equalization.

The equation of motion of a half-plane material in potentials φ, ψ is described by wave equations.

$$\frac{\partial^2\varphi}{\partial x^2}+\frac{\partial^2\varphi}{\partial z^2}=\frac{1}{a^2}\frac{\partial^2\varphi}{\partial t^2};$$

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial z^2}=\frac{1}{b^2}\frac{\partial^2\psi}{\partial t^2}, \qquad (1)$$

where a and b are the distribution speed of the longitudinal and transverse wave, respectively.

We assume that the boundary of the half-plane z=0 is stress-free, i.e.

$$\sigma_{zz}=\sigma_{xz}=0 \qquad (z=0) \qquad (2)$$

Let there be an elastic half-plane $z\le 0$.

Suppose that a flat harmonic wave propagates in the medium, i.e. potentials φ и ψ will be given in the form of [1]

$$\varphi(x,z,t)=\Phi_0(z)\exp[i(pt-qx)]; \qquad \psi(x,z,t)=\Psi_0(z)\exp[i(pt-qx)], \qquad (3)$$

Φ_0 and Ψ_0 satisfies the equations

$$\Phi_0''-\left(q^2-\frac{p^2}{a^2}\right)\Phi_0=0; \qquad \Psi_0''-\left(q^2-\frac{p^2}{b^2}\right)\Psi_0=0. \qquad (4)$$

Considering oscillations dacaying with depth $z\to-\infty$, there must be met condition

$$q^2-\frac{p^2}{a^2}>0; \qquad q^2-\frac{p^2}{b^2}>0; \qquad (5)$$

But since the speeds *a* and *b* satisfy the inequality $a > b$, it suffices to fulfill one condition instead of conditions (5)

$$\frac{p}{q} < b \tag{6}$$

Therefore, solutions of equations (4), dacayed at infinity $z \to -\infty$, have the form

$$\Phi_0(z) = A\exp\left(\sqrt{q^2 - \frac{p^2}{a^2}} \cdot z\right); \qquad \Psi_0(z) = B\exp\left(\sqrt{q^2 - \frac{p^2}{b^2}} \cdot z\right), \tag{7}$$

and for potentials φ и ψ we get expressions

$$\varphi = A\exp\left[i(pt - qx) + \sqrt{q^2 - \frac{p^2}{a^2}}z\right]; \qquad \psi = B\exp\left[i(pt - qx) + \sqrt{q^2 - \frac{p^2}{b^2}}z\right], \tag{8}$$

where A and B are arbitrary constants of integration.

Putting solutions (7) into the boundary conditions (2), we obtain

$$A\left[2 - \left(\frac{p}{qb}\right)^2\right] + 2iB\sqrt{1 - \left(\frac{p}{qb}\right)^2} = 0; \qquad -2iA\sqrt{1 - \left(\frac{p}{qa}\right)^2} + B\left[2 - \left(\frac{p}{qb}\right)^2\right] = 0. \tag{9}$$

In order for the solution of the problem to be non-zero, it is necessary that the determinant of system (9) be non-zero, i.e. to make the relation [2]

$$\left[2 - \left(\frac{p}{qb}\right)^2\right]^2 - 4\sqrt{1 - \left(\frac{p}{qb}\right)^2}\sqrt{1 - \left(\frac{p}{qa}\right)^2} = 0. \tag{10}$$

The ratio (p/q) is called the propagation velocity of the relay surface wave.

Denoting $\xi = \left(\frac{p}{qb}\right)^2$ and introducing the Poisson's ratio ν, from relation (10) we obtain the equation for the dimensionless velocity of the relay surface wave $\sqrt{\xi}$:

$$\xi^3 - 8\xi^2 + 8\xi\frac{2-\nu}{1-\nu} - 8\frac{1}{1-\nu} = 0. \tag{11}$$

Equation (11) has a single real positive root [1, 3,4].

If through z_1 и z_2 and designate the depth of penetration at which the amplitude of the voltage drops in e times due to the longitudinal and transverse wave, respectively, then for them we get the expression

$$z_1 = -\frac{l}{2\pi\sqrt{1 - a^{-2}b^2\xi}}; \qquad z_2 = -\frac{l}{2\pi\sqrt{1-\xi}},$$

at the same time $l = \frac{1}{q}$ - the wavelength. For example, with $\nu = 0{,}5$ we have

$$z_1 = -\frac{l}{2\pi}; \qquad z_2 \cong -\frac{l\sqrt{10}}{2\pi}.$$

Let the normal and tangential load intensity $-F_1(x+Dt)$ и $-F_2(x+Dt)$ be distributed on the surface $z = 0$ with constant speed D i.e. when $z = 0$ we have boundary conditions

$$\sigma_{zz} = -F_1(x+Dt);\ \ \sigma_{xz} = -F_2(x+Dt). \tag{12}$$

Initial conditions for such a problems are absent. [2, 47-50].
We introduce moving coordinates

$$x' = x + Dt;\ \ y' = y,$$

and the strokes in the future for simplicity will be omitted. Then for potentials φ and ψ we get the equations

$$\alpha^2 \frac{\partial^2 \varphi}{\partial x^2} - \frac{\partial^2 \varphi}{\partial z^2} = 0;$$

$$\beta^2 \frac{\partial^2 \psi}{\partial x^2} - \frac{\partial^2 \psi}{\partial z^2} = 0;$$

$$\alpha^2 = (D/a)^2 - 1;\ \ \beta^2 = (D/b)^2 - 1. \tag{13}$$

General solutions of equations (13) are d'Alembert method and have the form

$$\begin{aligned} \varphi(x,z) &= \varphi_1(x+\alpha z) + \varphi_2(x-\alpha z); \\ \psi(x,z) &= \psi_1(x+\beta z) + \psi_2(x-\beta z). \end{aligned} \tag{14}$$

By virtue of the absence of reflected waves from the lower infinitely distant boundary of the function φ_2 and ψ_2 should go to zero and for φ_1 and ψ_1 from the boundary conditions (12) we obtain the functional relations [5]

$$\begin{aligned} (\beta^2 - 1)\varphi_1''(x) - 2\beta\psi_1''(x) &= -\frac{F_1(x)}{\rho D^2}(\beta^2 + 1)H(x); \\ 2\alpha\varphi_1''(x) + (\beta^2 - 1)\psi_1''(x) &= -\frac{F_2(x)}{\rho D^2}(\beta^2 + 1)H(x). \end{aligned} \tag{15}$$

From relations (15) we get

$$\varphi_1''(x) = \frac{\beta^2 + 1}{\rho D^2}\left[(\beta^2 - 1)F_1(x) + 2\beta F_2(x)\right]H(x)\Delta^{-1};$$

$$\psi_1''(x) = \frac{\beta^2 + 1}{\rho D^2}\left[2\alpha F_1(x) - (\beta^2 - 1)F_2(x)\right]H(x)\Delta^{-1};$$

$$\Delta = 4\alpha\beta + (\beta^2 - 1)^2. \tag{16}$$

Using dependencies (16) for stress values, we obtain the expression

$$\Delta\cdot\sigma_{xx}=-\left(\beta^2-2\alpha^2+1\right)\left[\left(\beta^2-1\right)F_1\left(x+\alpha z\right)+2\beta F_2\left(x+\alpha z\right)\right]\times$$
$$\times H\left(x+\alpha z\right)+2\beta\left[2\alpha F_1\left(x+\beta z\right)-\left(\beta^2-1\right)F_2\left(x+\beta z\right)\right]H\left(x+\beta z\right);$$

$$\Delta\cdot\sigma_{zz}=-\left(\beta^2-1\right)\left[\left(\beta^2-1\right)F_1\left(x+\alpha z\right)+2\beta F_2\left(x+\alpha z\right)\right]H\left(x+\alpha z\right)-$$
$$-2\beta\left[2\alpha F_1\left(x+\beta z\right)-\left(\beta^2-1\right)F_2\left(x+\beta z\right)\right]H\left(x+\beta z\right); \qquad (17)$$

$$\Delta\cdot\sigma_{xz}=-2\alpha\left[\left(\beta^2-1\right)F_1\left(x+\alpha z\right)+2\beta F_2\left(x+\alpha z\right)\right]H\left(x+\alpha z\right)+$$
$$+\left(\beta^2-1\right)\left[2\alpha F_1\left(x+\beta z\right)-\left(\beta^2-1\right)F_2\left(x+\beta z\right)\right]H\left(x+\beta z\right);$$

$$H(\varsigma)=\begin{Bmatrix}1,\ \varsigma\ge 0\\ 0,\ \varsigma<0\end{Bmatrix},$$

and for shift u and w accordingly

$$u=-\frac{\beta^2+1}{\rho D^2\Delta}\left[\left(\beta^2-1\right)F_3\left(x+\alpha z\right)+2\beta F_4\left(x+\alpha z\right)\right]H\left(x+\alpha z\right)+$$
$$+\beta\frac{\beta^2+1}{\rho D^2\Delta}\left[2\alpha F_3\left(x+\beta z\right)-\left(\beta^2-1\right)F_4\left(x+\beta z\right)\right]H\left(x+\beta z\right);$$
$$w=-\alpha\frac{\beta^2+1}{\rho D^2\Delta}\left[\left(\beta^2-1\right)F_3\left(x+\alpha z\right)+2\beta F_4\left(x+\alpha z\right)\right]\times$$
$$\times H(x+\alpha z)-\frac{\beta^2+1}{\rho D^2\Delta}\left[2\alpha F_3\left(x+\beta z\right)-\left(\beta^2-1\right)F_4\left(x+\beta z\right)\right]H(x+\beta z) \qquad (18)$$

where $F_3(x)=\int_0^x F_1(\xi)d\xi;\ F_4(x)=\int_0^x F_2(\xi)d\xi.$

Let it be $F_2=0$ and consider the stress σ_{xx} on the boundary $z=0$. We obtain

$$\sigma_{xx}=F(v,D_0)F_1(x);\ D_0=D/a,$$

where $F(v,D_0)=\dfrac{A_1(v,D_0)-A_2(v,D_0)B(v,D_0)}{A_1(v,D_0)-A_2(v,D_0)};$

$$A_1=(1-2v)^{3/2}\sqrt{\left(D_0^2-1\right)(1-v)-(1-2v)};$$

$$A_2=\left[D_0^2(1-v)-(1-2v)\right];$$

$$B=\left[D_0^2(1-v)-\left(D_0^2-1\right)(1-2v)\right].$$

Let an elastic layer $0\ge z>-h\ \ |x|<\infty$ lie on the half-space $z\le -h$, over the surface of which the normal load is distributed, i.e. when $z=0$ we have boundary conditions

$$\sigma_{zz}^{(0)}=-F(x+Dt);\qquad \sigma_{xz}^{(0)}=0. \qquad (19)$$

The sizes and parameters of the layer will be denoted by the index "0", and the half-space - by the index "1".

At the contact boundary $z=-h$, you can set the conditions: hard contact

$$\sigma_{zz}^{(0)}=\sigma_{zz}^{(1)};\quad \sigma_{xz}^{(0)}=\sigma_{xz}^{(1)};\quad u_0=u_1;\quad w_0=w_1; \tag{20}$$

perfect contact

$$\sigma_{zz}^{(0)}=\sigma_{zz}^{(1)};\quad \sigma_{xz}^{(0)}=\sigma_{xz}^{(1)}=0;\quad w_0=w_1; \tag{21}$$

Can be set other conditions for $z=-h$.

In moving coordinates, solutions of equations for potentials in a layer and a half-plane have the form [3, 171-176].

$$\alpha_j^2\frac{\partial^2\varphi_j}{\partial x^2}-\frac{\partial^2\varphi_j}{\partial z^2}=0;\quad \beta_j^2\frac{\partial^2\psi_j}{\partial x^2}-\frac{\partial^2\psi_j}{\partial z^2}=0;$$

$$\left(x'=\frac{x+Dt}{h};\ y'=\frac{y}{h};\ \varphi_0=\frac{\varphi_0}{h^2};\ \psi_0=\frac{\psi_0}{h^2}\right). \tag{22}$$

Putting (22) into the boundary conditions (20), we obtain a system of functional equations which using in expressions for displacements u_j, w_j and stresses σ_{ij}, we obtain the solution of the problem.

А. А. Алмағамбетова[1], С. Ш. Тілеубай[1], Л. У. Таймуратова[2], А. Ж. Сейтмұратов[1], Қ. Қанибайқызы[1]

[1]Қорқыт Ата атындағы Қызылорда мемлекеттік университеті, Қызылорда, Қазақстан,
[2]Ш. Есенов атындағы Каспий мемлекеттік технология және инжиниринг университеті, Ақтау, Қазақстан

ГАРМОНИКАЛЫҚ ТИПТЕГІ РЕЛЕЙ ТОЛҚЫНДАРЫНЫҢ ТАРАЛУЫ ЖАЙЛЫ ЕСЕП

Аннотация. Жұмыста қатпарлы пластинкалардың бетіне қозғалмалы жүктемелердің әсері туралы бірнеше жазық есептер класы зерттеледі. Осы типтес динамикалық есептер проблемалары жайлы смәселелерді шешуге арналған белгілі сандық алгоритмдерді дамытудың негізгі бағыты бола алуымен қызығушылық тудырады. Деформацияланатын ортаның әртүрлі периодты және преиодтты емес қозғалыстарының арасында шектелген дененің бетіне немесе жарты жазықтыққа тарайтын қарапайым гармоникалық үлгідегі жазық толқындар әсер етеді. Сондықтан да Релей толқынының таралуын зерттейтін боламыз.

Түйін сөздер: қатпарлы пластинкалар, қозғалмалы жүктеме, Релей толқындары, толқындар теңлеуі.

А. А. Алмағамбетова[1], С. Ш. Тилеубай[1], Л. У. Таймуратова[2], А. Ж. Сейтмуратов[1], К. Канибайкызы[1]

[1]Кызылординский государственный университет им. Коркыт Ата, Кызылорда, Казахстан,
[2] Каспийский государственный университет технологий и инжиниринга им. Ш. Есенова, Актау, Казахстан

ЗАДАЧА О РАСПРОСТРАНЕНИИ ВОЛНЫ РЕЛЕЯ ГАРМОНИЧЕСКОГО ТИПА

Аннотация. В работе исследуем класс плоских задач о воздействии подвижных нагрузок на поверхность слоистой пластинки. Задачи данного класса представляют большой прикладной интерес и, кроме того, могут служить эталоном для разработки тех или иных численных алгоритмов для решения динамических задач. Среди различных периодических и непериодических движений деформируемых сред важное значение имеют плоские волны простого гармонического типа, распространяющиеся по поверхности тела или полуплоскости, влияние которых ограничивается окрестностью этой поверхности. Поэтому рассмотрим задачу о распространении волны Релея.

Ключевые слова: слоистые пластинки, подвижная нагрузка, волны Релея, волновые уравнение.

Information about authors:

Almagambetova Aigul Aldajarovna, Candidate of pedagogical sciences, Senior Lecturer The Korkyt Ata Kyzylorda State University, Kyzylorda, Kazakhstan; aldajarovna_@mail.ru; https://orcid.org/0000-0002-8790-8948

Tileubay Sarsenkul Shaykamalqız, Candidate of pedagogical sciences, The Korkyt Ata Kyzylorda State University, Kyzylorda, Kazakhstan; sarsen-00@mail.ru; https://orcid.org/0000-0001-6590-2097

Taimuratova Lidiya Ungarbaevna, Candidate of physical and mathematical sciences. Associate Professor of «Natural Sciences» Caspian state University of technology and engineering named after Sh. Esenov, Aktau, Kazakhstan; taimuratova@mail.ru; https://orcid.org/0000-0002-1692-4350

Seitmuratov Angisin, Doktor of Physical and Matematical Sciences, Professoz, The Korkyt Ata Kyzylorda State University, Kyzylorda, Kazakhstan; angisin_@mail.ru; https://orcid.org/0000-0002-9622-9584

Kanibaikyzy Kundyzay, Master degree of pedagogical sciences, The Korkyt Ata Kyzylorda State University, Kyzylorda, Kazakhstan; VIP kundyz@mail.ru; https://orcid.org/0000-0002-3713-1608

REFERENCES

[1] Filippov I.G., Filippov S.I. Dynamic stability theory of rods. Proceedings of the Russian-Polish seminar. Theoretical Foundations of construction. Warsaw, 1995. P. 63-69.

[2] Filippov I.G. An approximate method for solving dynamic viscoelastic media // PMM. 1979. 43(1). P. 133-137.

[3] Filippov I.G., Filippov S.I., Kostin V.I. Dynamics of two-dimensional composites // Proceedings of the International Conference on Mechanics and Materials, USA, Los Angeles, 1995. P. 75-79.

[4] Seitmuratov A., Medeubaev N., Yeshmurat G., Kudebayeva G. (2018) Approximate solution of the an elastic layer vibration task being exposed of moving load // News of the national academy of sciences of the Republic of Kazakhstan. Series physic-mathematical. 2 (318). P. 54-60 (in Eng.).

[5] Seitmuratov A.Z., Nurlanova BM., Medeubaev N. Equetions of vibration of a two-dimensionally layered plate strictly based on the decision of various boundaty-value problems // Bulletin of the Karaganda university-mathematics. 2017. 3(87). P. 109-116 (in Eng.).

[6] Seitmuratov A., Yergalauova Z., Makhambayeva, Bexeitova A. Axismetric problems of elastic layer oscillation limited by rigid or deformed boundries // News of the national academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. 1. P. 127-135 (in Eng.).

[7] Ashirbayev N., Ashirbayeva Zh., Sultanbek T., Shomanbayeva M. Waves of elastic stresses in the doublyconnected domain // Vestnik KarGU. Cerija matematika. 2018. 2(90). P. 18-25.

[8] Seytmuratov A.Z., Zharylgapova D.M., Medeubaev N.K., Ibraeva A.A. Applied tasks of plates fluctuation under more difficult boundary conditions // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2017. 3(423). P. 228-236 (in Eng.).

[9] Ashirbayev N.K., Banas J., Dubiel A. Solvability of an Integral Equation of Volterra-Wiener-Hopf Type // Abstract and Applied Analysis. Vol. 2014 (2014). Article ID 982079. 9 p. DOI 10.1155/2014/982079.

[10] Seitmuratov A., Ramazanov M., Medeubaev N., Kaliev B. Mathematical theory of vibration of elastic or viscoelastic plates, under non-stationary external influences // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2017. 4(320). P. 5-14. (in Eng.). https://doi.org/10.32014/2018.2518-170X; ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

[11] Seitmuratov A., Seylova Z.T., Kanibaikyzy K., Smakhanova A.K., Serikbol S.M. Approximate equation plate oscillation for transverse displacement of points of the median plane // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. 3(429). P. 258-266. (in Eng.). https://doi.org/10.32014/2018.2518-170X; ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 248 – 254 **https://doi.org/10.32014/2019.2518-170X.30**

UDC 556.3:556.11:574

M. K. Absametov[1], D. K. Adenova[1], A. B. Nusupova[2]

[1]Satbayev University, Institute of Hydrogeology and Environmental Geoscience named after U.M. Ahmedsafin, Almaty, Kazakhstan,
[2]The Institute of Geological Sciences named after K.I. Satpaev, Almaty, Kazakhstan.
E-mail: us.ign_satpaeva@mail.ru; dinara1982_82@mail.ru

ASSESSMENT OF THE IMPACT OF ANTHROPOGENIC FACTORS WATER RESOURCES OF KAZAKHSTAN

Abstract. Water is one of the most important natural resources that support the ecosystem and the daily lives of people. Water resources are considered renewable, how fast are they recovering and to what extent is their scarcity threatening the earth's ecosystem? The article describes the current state of water resources in the world in general and in the Republic of Kazakhstan in particular. Explicit reference was made to the challenges posed by recovering of fresh water. Main areas to increase the available of fresh water capacity with detailed description. The structure of the strategic management of the water resources presented.

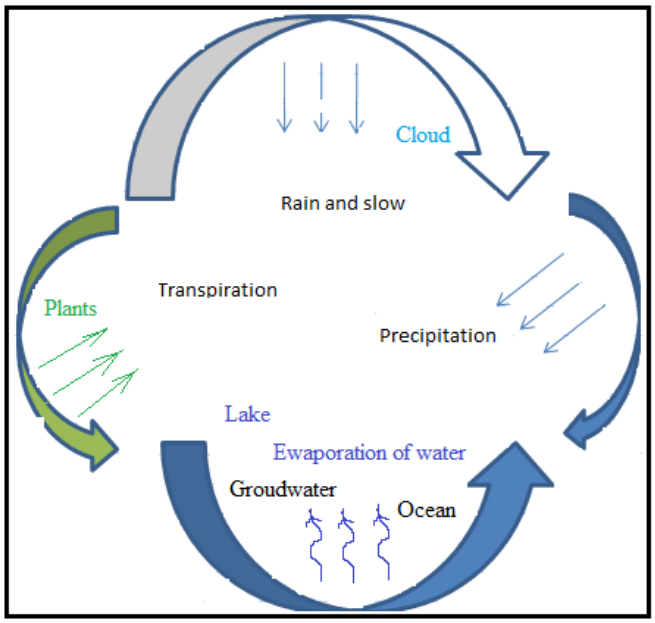
Key words: water resource, fresh water, groundwater, pollution, anthropogenic changes of environment, water resources management.

Introduction. Water is a tremendous value, a national treasure. The decision of all the most actual ecological and hydrogeoecological problems depends on the state of water resources. This is due to the unique properties of water, its presence in all spheres of the Earth, its important role in the physical, chemical, biological and geological processes that form these areas, and, finally, its irreplaceability in all kinds of human life. Any changes in the environment affect water resources [1], and, vice versa, changes in the quantity, regime and quality of water - one of the main factors of environmental transformation. To date, a number of complex and acute problems have accumulated in the use and protection of water resources of the Republic of Kazakhstan. The main reason for their occurrence is the mismatch of the economic mechanism, financial capacity and management system of water use and protection of the modern economic system.

Seas and oceans comprise over 96% of the hydrosphere, about 2% - groundwater, about 2% - of ice and snow, about 0,02% - surface water [2]. The largest part of the earth's fresh water is about 85-90%, contained in massifs of ice in polar regions and glaciers. Fresh water is also formed in rivers and streams, fresh lakes and clouds. In general, water, continuously moving on the globe in the global hydrological cycle under the influence of solar energy, as shown in the figure below, keeps its total amount unchanged, existing in three aggregate states [3].

There are about 85,000 rivers and temporary water courses in the territory of Kazakhstan; 8,000 of them are longer than 10 km. The average area of river basin is about 30 km^2.

Many rivers belong to the internal closed basins of the Caspian and Aral Seas and Balkhash, Alakol and Teniz lakes. Only the Yertys River belongs to the basin of the Arctic ocean (Kara Sea). The higher drainage network density is registered in highlands such as Altai, Zhetysu, Alatau and Ile, and less density is registered in the areas of sandy deserts of Pre-Aral and Pre-Caspi (less than 0.03 km per km^2). The largest rivers of the country are Yertys with a length (in Kazakhstan) of 1700 km, Syr-Darya – 1400 km and Zhaiyk –1082 km. Six larger rivers of Kazakhstan have water flow rates in the ranges from 30 to 900 m^3/sec (average annual values), 7 rivers – from 50 to 100 m^3/sec and 40 rivers – from 5 to 50 m^3/sec. [4].



Global hydrological cycle

Distribution of river runoff in the territory varies. Large runoff volumes are formed in the Yertys and Balkhash-Alakol basins (73-86% of the total resources). There is almost no local runoff in the Nura-Sarysu, Yessil and Tobyl-Torgai basins in the years of low water. The river runoff of the country is characterized by significant interannual variability: maximum and minimum values of an annual runoff three times the norm and two times below the norm, respectively. Alternation of groups (low water by 5-7 years and abounding in water by 1-3 years) is also common for the river runoff. Due to the climatic features of the country, up to 90% of the annual runoff accounts for spring, and up to 70% of the mountain river runoff accounts for summer periods [4].

In the formation of groundwater is of great significance climatic factors. The continentality and aridity of the climate and the extremely uneven distribution of water resources typical for the territory of Kazakhstan. The air masses coming from the Atlantic Ocean [5], from the Arctic, Siberia or Central Asia, which bring with them heat or cold, moisture or dryness, play a large role in formation the climate of the Republic.

Currently, the surface water of all rivers in Kazakhstan are estimated to total 102.3 km3/year [6], of which 57,6 km^3/year is formed in the territory of the Republic and in the neighboring countries 44,7 km^3/year.

Surface and underground waters are genetically interconnected and play an important role in economic and ecological relations of the Republic. Taking into account the high degree of vulnerability of the natural environment and industries of Kazakhstan's economy to possible changes in water supply, several factors need to be taken into account, including climatic changes in local runoff and anthropogenic reduction in runoff of transboundary. With these factors in the future, there are threats of a decrease in river flow resources in general throughout Kazakhstan and in the world as a whole [7].

To this end, there are, again, a lot of factors and environmental problems around the world, because every year, every day in large industrial areas not only surface water is polluted, but also underground [8-13]. Sources of groundwater pollution are very diverse. Pollutants can penetrate to groundwater in various ways: during the drainnage of industrial and domestic wastewater from storage, ponds, sedimentation tanks, borehole and karst funnel. The natural sources of pollution include highly mineralized (saline and brine) groundwater or sea water, which can be inserted later into fresh, uncontaminated water during the operation of water intake facilities and pumping water from wells.

For example, characteristic pollutants in water of the majority of water bodies of Russia are mineral oils, phenols, organic substances, copper, zinc, iron compounds, biogenic substances, mercury compounds, formaldehyde. The content of pesticides in surface waters, as well as polychlorinated biphenyls,

which are carcinogens that are not allowed to be dumped into water bodies is a cause and particular danger [14].

Water ecosystems are being degraded all over the world due to various environmental issues and factors. The change [15] in the geochemical cycles of elements in the system "watershed-reservoir" causes a widespread increase of mineralization and salinization of waters, increased turbidity, which entails the violation of metabolism in aquatic invertebrates and etc [14].

Every year since 1972, the United Nations has held conferences on environmental problems of the human environment [16]. One of the conference was devoted to the principles of water resources [17]. Special attention was paid to the problem of reducing the number of people with access to drinking water [18]. One [19-21] of the main subjects in the scenarios of the future was the aggravation of the shortage of fresh water. The World Bank estimates that, a significant change in the situation in the next 50 years could be no expectation: by mid-century of the XXI century already 40% of the world's population will experience increased water stress, 20% - to severely suffer from it. This bleak forecast does not take into account global climate change [22], which is likely to exacerbate the situation. Prophecies of water wars, the grand projects of the redistribution of river runoff. Measures to overcome water scarcity are actively discussed [23] not only within the borders of national economies, but also in the international aspect. Water more been a topic of debate in all the major forums of the world for the last 20 years.

We feel that anthropogenic change to the environment began since the post-industrial era, but [24] believes that it began 45 thousand years ago. Currently, worldwide attention is increasingly on increasing the greenhouse effect due to emissions of carbon dioxide, methane, nitrogen oxides and other greenhouse gases, which leads to a change in regional conditions of precipitation, an increase in the number of droughts [25], floods, storms and other adverse natural phenomena, an increase in the average global sea level, a reduction in freshwater resources and, as a consequence, an increase in economic and social costs to overcome them.

Changes in the climate system lead to uncertainty in water resources management. The intergovernmental Panel on Climate Change [19] forecasts an increase of 2-4 degrees over the next 100 years. Increased temperatures will interfere on the hydrological cycle, directly increasing the evaporation of surface water sources [26].

While the global demand for food and world population is mounting rapidly [27], land potential for agriculture is steadily declining due to various soil degradation processes, one of which is soil salination [15, 28-30]. And this trend is not just in one country, but in one area, the problem is all over the world.

Potential adverse environmental impacts of increased agricultural production include unsustainable depletion and pollution caused by nitrates in groundwater [31]. As well as the depletion of soil resources associated with the excessive use of nutrients and pesticides, which leads to health problems [32].

New approaches are needed to implement proper source management and remedial measures, thus [33] developed the methods for risk assessment of groundwater flow.

In different sources [34-36] believe that a methodology and model for the application of planning and integrated water resources management [37-40] in the use and conservation of groundwater is needed.

Denmark is taking made continuous efforts to ensure the sustainable management of groundwater [41-44].

[45] offers a comprehensive approach for assessing the vulnerability of groundwater to climate change to successfully address environmental and geo-economic challenges.

To reducing the impact and restore the function of natural ecosystems of these reservoirs requires a three-level approach [46]. Such activities are costly and therefore it is necessary to costly special attention to the comprehensive programs that offer many advantages.

Based on the review of the research carried out, it can be concluded that in many countries of the world are faced with environmental and economic problems in the field of water resources. Whose main goal is correct, purposeful management and groundwater resources planning.

Accordingly, it can be considered that the study of groundwater requires an ecosystem approach [47], reflecting the processes of their interaction with the environment.

Methods. Water supply shortages, humanity is familiar almost since its inception, but its current scale where a variety of water sources each year selected more than 4,000 km3 of water, by weight an order of magnitude more than other natural resources in the aggregate; in the process of economic activity uses

much more water-9000 km^3 [48], returning to the global hydrosphere annually 2000 km^3 of wastewater. No wonder that almost all the rivers of the world are polluted to some extent, not counting the upper layers of groundwater. According to [49], about 17 thousand km^3 of water is currently polluted, which is half of the maximum estimate of its available volume for use.

In the conditions of anthropocentrism, the depletion of fresh water resources has a dual nature, associated with both the intensive melting of glaciers of mountain countries in the conditions of global warming, and with global pollution of the environment and the hydrosphere as a whole.

The relationship between underground and surface runoff is based on a known water balance equation [50].

Consequently, the ratio of fresh and polluted water is determined by the balance equation reflecting the law of conservation,

$$Q_{(t=0)} = Q(t)_{\text{пв}} + Q(t)_{\text{зв}},$$

where $Q_{(t=0)}$ – initial the quantity of freshwater of the hydrosphere; $Q(t)_{\text{пв}}$, $Q(t)_{\text{зв}}$ – объемы пресной и загрязненной воды как функции времени антропоцентризма, located, in $Q_{(t=0)}$ = const, in the inverse relationship.

However, care for the environment is gaining, both around the world and in Kazakhstan. Sustainable water supply of the Republic implies harmonization of ecosystem approach to water use, dictated by environmental standards, providing both environmental protection and socio-economic development.

Taking into account the genetic relationship between surface and groundwater, it is extremely important to establish a normalized environmental potential for underground runoff in terms of its use in the exploitation of its natural resource. This is essential in the conditions of forced replacement of surface water resources with underground in the future, ensuring the preservation of biodiversity and sustainable development of Kazakhstan.

Conclusions. At the current level of study of the surface water, the standard of runoff of all the rivers of Kazakhstan is estimated at a value of 102.3 km^3/year. Consequently, the potential of the underground flow of the Republic is 51.15 km^3/year [51].

Optimization of using water resources in the sectors of economy should be based on the introduction of the water-saving technologies of the negotiable and closed water supply in all branches of industry, and a reduction in unproductive water losses during distribution.

As in other countries, and in the Republic of Kazakhstan is expected to increase the population (thousand people) [52]:

Projected population

Human settlements, people (%)	2020 year	2030 year
For the Republic, including:	18 698 400	20 585 800
Urban population	11 219 040 (60%)	13 380 770 (65%)
Rural population	7 479 360 (40%)	7 205 030 (35%)

Global climatic changes and intensification of technogenesis significantly affect the resource potential of groundwater and associated ecosystems, which leads to a deterioration of hydrogeoecological conditions in Kazakhstan. This is manifested, both in climate-driven and, above all, man-made depletion of groundwater resources, accompanied by the formation of depression pit and subterranean backwater zone, pollution of groundwater, significantly influences the natural environment and human habitat.

Climate change in arid conditions of Kazakhstan may cause a decrease in water resources, increases risks of droughts and a reduced agricultural yield, the increased incidence associated with the consumption of contaminated water, changes in the state of natural and climatic conditions of the territory of the Republic according to the degree of favorability for the population.

Groundwater depletion refers to the reduction of natural and artificial groundwater resources due to the excess of groundwater consumption over their groundwater recharge. The causes of such depletion may be deforestation, tilling of wild land, the straightening and river passing, groundwater sampling withdrawals, drainage system, etc. At the same time, depletion may be temporary (seasonal) and permanent

(due to economic activity). Technical replenishment of groundwater resources is carried out by the creation of dams, ponds, atmospheric runoff, by pumping water from pressure horizons, snowmelt delay, the use of biochemical treated wastewater, reducing evaporation, improving irrigation methods and irrigation of farmland.

Consequently, the natural resource of fresh water must be maintained, guaranteeing the necessary requirements for the sustainable functioning of the biosphere and its ecosystems, the services of mankind and its technosphere, which are provided by the resource of fresh water. Since water is needed for different purposes, functions and services, water management must therefore be ecosystem-based and integrated, taking into account both the demand for the resource and the threats to its conservation from pollution and depletion.

All this requires integrated management decisions [53] to prevent these negative phenomena through an ecosystem approach.

An integrated approach to water resources management, which many countries, including Kazakhstan, have introduced into their national policies, is the basis for groundwater management in the Republic.

REFERENCES

[1] Kath, J., Boulton, A.J., Harrison, E.T., Dyer, F.J. A conceptual framework for ecological responses to groundwater regime alteration (FERGRA). Ecohydrology. 2010. DOI 10.1002/eco.2010. (In Eng.).

[2] Lvovich M.I. World water resources and their future. M.: Science, 1974. 448 p. (In Russ.).

[3] Hydrogeology. A course of lectures at Stanford University. 2001. http://www.geohydrology.ru. (In Russ.).

[4] Pavlov A.N. Geological water cycle on Earth. L.: NEDRA, 1977. 143 p. (In Russ.).

[5] Absametov M.K., Mukhamedzhanov M.A., Sydykov Z.S., Murtazin E.Z. Groundwater of Kazakhstan – strategic resource of water security of the country. Almaty, 2017. 220 p. (In Russ.).

[6] Medeu A.R., Malkovskiy I.M., Toleubayeva L.S., Alimkulov S.K. Water security of the Republic of Kazakhstan: problems of sustainable water supply. Almaty, 2015. 582 p. (In Russ.).

[7] Danilov-Danilyan V.I., ets. Water consumption: environmental, economic, social and political aspects. M.: Science, 2006. 221 p. (In Russ.).

[8] Hua B., Yang J., etc., Groundwater Quality. Water Environment Research. 2009. DOI 10.2175/106143009X12445568400575. P. 1975-1995 (In Eng.).

[9] Gao D.W., Li Z, etc. An overview of phthalate acid ester pollution in China over the last decade: Environmental occurrence and human exposure. Science of the Total Environment, 2018, DOI: 10.1016/j.scitotenv.2018.07.093. P. 1400-1409. (In Eng.).

[10] Voros D., DiazSomoano M., etc. Mercury contamination of stream sediments in the North Bohemian Coal District (Czech Republic): Mercury speciation and the role of organic matter. Chemosphere, 2018, DOI 10.1016/j.chemosphere.2018.07.196. P. 664-673. (In Eng.).

[11] Tran T.H.M., Nguyen K.G., etc. Metal and metalloid concentrations in soil, surface water, and vegetables and the potential ecological and human health risks in the northeastern area of Hanoi, Vietnam. Environmental Monitoring and Assessment. 2018. DOI 10.1007/s10661-018-6994-7. (In Eng.).

[12] Masindi K., etc. Assessment of natural and anthropogenic influences on regional groundwater chemistry in a highly industrialized and urbanized region: a case study of the Vaal River Basin, South Africa. 2018. DOI 10.1007/s12665-018-7907-3. (In Eng.).

[13] Srinivas R., Singh A.P. Impact assessment of industrial wastewater discharge in a river basin using interval-valued fuzzy group decision-making and spatial approach. Environment Development and Sustainability. 2018. DOI 10.1007/s10668-017-9994-9. P. 2373-2397. (In Eng.).

[14] Popov S.V., Negrafontova O.G. State strategy of use, restoration and protection of water bodies of Russia. 2002. Ecology 2002 - the sea and man. (In Russ.).

[15] Nachshon U. Cropland Soil Salinization and Associated Hydrology: Trends, Processes and Examples. Water. 2018. DOI 10.3390/w10081030. (In Eng.).

[16] Declaration of the United Nations Conference on the human environment. Stockholm, 1972. (In Russ.).

[17] The International Conference on Water and the Environment. ACC/ISGWR. The Dublin Statement and Report on the Conference, Dublin, Ireland: WMO, 1992. 1.55. (In Eng.).

[18] United Nations Millennium Declaration. Approved by General Assembly resolution 55/2 of September 8, 2000. (In Russ.).

[19] IPCC., Climate Change and Water. IPCC Secretariat, Geneva. Technical Paper of the Intergovernmental Panel on Climate Change, 2008. 210 p. (In Eng.).

[20] Jayaswal K., etc. Water Pollution, Human Health and Remediation. Water Remediation. 2018. DOI 10.1007/978-981-10-7551-3_2. P. 11-27. (In Eng.).

[21] Shao D.G., Li X.D., etc. A Method for Temporary Water Scarcity Analysis in Humid Region Under Droughts Condition. Water Resources Management. 2015. DOI 10.1007/s11269-015-1031-x. P. 3823-3839. (In Eng.).

[22] Kokorin A.O. Climate change: review of the Fifth assessment report of the Intergovernmental Panel on Climate Change. M.: World wildlife Fund (WWF). 2014. ISBN 978-5-906599-07-0 80 p. (In Russ.).

[23] Kundzewicz Z.W., Gerten D. Grand Challenges Related to the Assessment of Climate Change Impacts on Freshwater Resources. Journal of Hydrologic Engineering. 2015. DOI 10.1061/(ASCE)HE.1943-5584.0001012. (In Eng.).

[24] Roberts P., Boivin N., Kaplan, J.O. Finding the Anthropocene in tropical forests. Anthropocene. 2018. DOI 10.1016/j.ancene.2018.07.002. (In Eng.).

[25] Wang L.X., Wei X.H., etc. Vegetation changes and water cycle in a changing environment. Hydrology and Earth System Sciences. 2018. DOI 10.5194/hess-22-1731-2018 P.**:** 1731-1734. (In Eng.).

[26] Jayakumar R., Lee E. Climate change and groundwater conditions in the Mekong Region-A review. Journal of Groundwater Science and Engineering. 2017. P. 14-30. (In Eng.).

[27] Wang Y.X., Zheng C.M. Review: Safe and sustainable groundwater supply in China. Hydrogeology Journal, 2018. DOI 10.1007/s10040-018-1795-1. P. 1301-1324. (In Eng.).

[28] Zuo R., Meng L., etc. Pollution risk assessment based on source apportionment in a groundwater resource area, NE China. Human and Ecological Risk Assessment. 2018. DOI 10.1080/10807039.2017.1410428. P. 1197-1215. (In Eng.).

[29] Singh A. Alternative management options for irrigation-induced salinization and waterlogging under different climatic conditions. Ecological Indicators. 2018. DOI: 10.1016/j.ecolind.2018.03.014. P. 184-192. (In Eng.).

[30] Nabiollahi K., Taghizadeh-Mehrjardi R., etc. Assessment of soil quality indices for salt-affected agricultural land in Kurdistan Province, Iran. Ecological Indicators. 2018. DOI 10.1016/j.ecolind.2017.08.001. P. 482-494. (In Eng.).

[31] Narany T.S., Sefie A. The long-term impacts of anthropogenic and natural processes on groundwater deterioration in a multilayered aquifer. Science of the Total Environment. 2018. DOI 10.1016/j.scitotenv.2018.02.190. P. 931-942. (In Eng.).

[32] McLaughlin D., Kinzelbach W., etc. Food security and sustainable resource management. Water Resources Research. 2015. DOI 10.1002/2015WR017053. (In Eng.).

[33] Sonne A.T., McKnight U.S., etc. Assessing the chemical contamination dynamics in a mixed land use stream system. Water Research. 2018. DOI 10.1016/j.watres.2017.08.031. P.141-151. (In Eng.).

[34] Fu Z.H., Zhao H.J., etc. Integrated planning for regional development planning and water resources management under uncertainty: A case study of Xining, China. Journal of Hydrology. 2017. DOI 10.1016/j.jhydrol.2017.08.022. P. 623-634. (In Eng.).

[35] Botero-Acosta A., Chu M.L.; Stumpf A.J. Impacts of environmental stressors on the water resources of intensively managed hydrologic systems. Hydrological Processes. 2018. DOI: 10.1002/hyp.13244. P. 2947-2962. (In Eng.).

[36] Smerdon B.D. A synopsis of climate change effects on groundwater recharge. Journal of Hydrology. 2017. DOI 10.1016/j.jhydrol.2017.09.047 (In Eng.).

[37] Chilikova-Lubomirova M. Water Resources for Everyone - an Approach for Sustainable Future Development. Grand Challenges Facing Hydrology in the 21st century. 2014. P. 83-92. (In Eng.).

[38] Han D.M., Currell M.J., etc. Alterations to groundwater recharge due to anthropogenic landscape change. Journal of Hydrology. 2018. DOI 10.1016/j.jhydrol.2017.09.018. P. 545-557 (In Eng.).

[39] Rodiger T., Magri F., etc. Assessing anthropogenic impacts on limited water resources under semi-arid conditions: three-dimensional transient regional modelling in Jordan. Hydrogeology Journal. 2017. DOI 10.1007/s10040-017-1601-5. P. 2139-2149. (In Eng.).

[40] Ashraf B., AghaKouchak A., etc. Quantifying Anthropogenic Stress on Groundwater Resources. Scientific Reports. 2017. DOI 10.1038/s41598-017-12877-4. (In Eng.).

[41] Absametov M.K., Shagarova L.V., Matushkina O.A. Library of legends of hydrogeological maps in ArcGIS. News of National Academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences ISSN 2224-5278. Vol. 5, N 431(2018). P. 9-11. (In Eng.). https://doi.org/10.32014/2018.2518-170X.2.

[42] Jorgensen L.F., etc. Groundwater management and protection in Denmark: a review of pre-conditions, advances and challenges. International Journal of Water Resources Development. 2017. DOI 10.1080/07900627.2016.1225569. P. 868-889. (In Eng.).

[43] Green T.R., Taniguchi M., etc. Beneath the surface of global change: Impacts of climate change on groundwater. Journal of Hydrology. 2011. DOI 10.1016/j.jhydrol.2011.05.002 P. 532-560. (In Eng.).

[44] Villholth K.G., etc. Groundwater Resources and Management Challenges in Sri Lanka-an Overview. Water Resources Management. 2010. DOI 10.1007/s11269-009-9510-6. P. 1489-1513. (In Eng.).

[45] Aslam R.A., Shrestha S., etc. Groundwater vulnerability to climate change: A review of the assessment methodology. Science of the Total Environment. 2018. DOI 10.1016/j.scitotenv.2017.08.237. P. 853-875. (In Eng.).

[46] Riley W.D., Potter E.C.E., Biggs J., etc. Small Water Bodies in Great Britain and Ireland: Ecosystem function, human-generated degradation, and options for restorative action. Science of the Total Environment. 2018. 645. DOI 10.1016/j.scitotenv.2018.07.243. (In Eng.).

[47] Poryadin V.I., Adenova D.K. Ecosystem function of underground flow in conditions of anthropogenesis of the environment Kazakhstan. Science magazine "CHRONOS ". UDC 082. M.: 2017. Vol. 3. P. 4-13. (In Russ.).

[48] Helmer R. Water Demand and Supply // Nucl. Desalinat. Sea Water: Proc. Int. Symp. Vienna, 1997. P. 15-24. (In Eng.).

[49] Rodda G. On the problems of assessing the World water resources. In: Geosci and water resource environment date model. 1997. P. 14-32. (In Eng.).

[50] Poryadin V.I., Akynbaeva M., Adenova D.K. Water balance method of assessing replenishment resource of groundwater in a river basin. Bulletin of National Academy of science of the Republic of Kazakhstan. ISSN 1991-3494. 2016. P. 78-83. (In Russ.).

[51] Sagin J., Adenova D.K., Poryadin V.I., etc. Underground water resources in Kazakhstan. International Journal of Environmental Studies. 2017. DOI 10.1080/00207233.2017.1288059. (In Eng.).

[52] General scheme of the organization of the territory of the Republic of Kazakhstan, approved by the government of the Republic of Kazakhstan dated December 30, 2013. N 1434. (In Russ.).

[53] Poryadin V.I., Absametov M.K., Adenova D.K. Management groundwater resources for solutions water supply of economy of Kazakhstan on the long-term period. News of the National Academy of sciences of the Republic of Kazakhstan. Series Geology and technical sciences. Almaty, 2017. P.93-102. (In Russ.).

М. К. Абсаметов[1], Д. К. Аденова[1], А. Б. Нусупова[2]

[1]У. М. Ахмедсафин атындағы гидрогеология және геоэкология институты, Алматы, Қазақстан,
[2]Қ. И. Сәтбаев атындағы геология ғылымдары институты, Алматы, Қазақстан

ҚАЗАҚСТАННЫҢ РЕСУРСТАРЫНА АНТРОПОГЕНДІК ФАКТОРЛАРДЫҢ ӘСЕРІН БАҒАЛАУ

Аннотация. Су экожүйені және адамдардың күнделікті өмірін сүйемелдейтін маңызды табиғи ресурстардың бірі болып табылады. Су ресурстары жаңартылатын болып табылады, дегенмен олар қаншалықты тез жаңартылады және олардың жетіспеушілігі жердің экожүйесіне қауіп төндіре ме? Мақалада су ресурстарының әлемдегі және атап айтқанда Қазақстан Республикасындағы жағдайына сипаттама берілген. Тұщы судың жетіспеушілігімен байланысты мәселелер қалыптастырылды. Тұщы судың қолжетімді қорларын ұлғайту бойынша негізгі бағыттар сипатталды. Су ресурстарын стратегиялық басқару құрылымы келтірілді.

Түйін сөздер: су ресурстары, тұщы су, жерасты сулары, ластану, қоршаған ортаның антропогендік өзгерістері, су ресурстарын басқару.

М. К. Абсаметов[1], Д. К. Аденова[1], А. Б. Нусупова[2]

[1]Институт гидрогеологии и геоэкологии им. У. М. Ахмедсафина, Алматы, Казахстан,
[2]Институт геологических наук им. К. И. Сатпаева, Алматы, Казахстан

ОЦЕНКА ВЛИЯНИЯ АНТРОПОГЕННЫХ ФАКТОРОВ НА ВОДНЫЕ РЕСУРСЫ КАЗАХСТАНА

Аннотация. Вода является одним из наиболее важных природных ресурсов, которые поддерживают экосистему и повседневную жизнь людей. Водные ресурсы считаются возобновляемыми, как быстро они восстанавливаются и насколько их нехватка угрожает экосистеме земли? В статье приведена характеристика современного состояния водных ресурсов в мире в целом и в Республике Казахстане в частности. Сформулированы проблемы, связанные с нехваткой пресной воды. Подробно описаны основные направления по увеличению доступных запасов пресной воды. Представлена структура стратегического управления водными ресурсами.

Ключевые слова: водные ресурсы, пресная вода, подземные воды, загрязнение, антропогенные изменения окружающей среды, управление водными ресурсами.

Information about authors:

Absametov M.K., doctor of Geological and Mineralogical Sciences, Director of the Institute, Satbayev University, Institute of Hydrogeology and Environmental Geoscience named after U. M. Ahmedsafin, Almaty, Kazakhstan; igg_gis-dzz@mail.ru; https://orcid.org/0000-0003-2520-6294

Adenova D.K., Researcher, Satbayev University, Institute of Hydrogeology and Environmental Geoscience named after U. M. Ahmedsafin, Almaty, Kazakhstan; dinara1982_82@mail.ru; https://orcid.org/0000-0001-7973-811X

Nusupova A.B., The Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan; us.ign_satpaeva@mail.ru; https://orcid.org/0000-0002-8318-7477

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 255 – 261 **https://doi.org/10.32014/2019.2518-170X.31**

UDC631.333.93

K. T. Zhantasov[1], B. A. Lavrov[2], D. M. Zhantasova[1],
K. S. Dossaliev[1], B. A. Ismailov[1], Zh. T. Zhumadilova[1]

[1]M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan,
[2]St. Petersburg state technological Institute (technical University), St.Petersburg, Russia.
E-mail: k_zhantasov@mail.ru, ba-lavrov@mail.ru,dm-zhantasova@mail.ru,
dosaliev_k@mail.ru,baxa-86_8@mail.ru,zh-zhumadilova@mail.ru

THE DEVELOPMENT OF A MINI WORKSHOP OF OBTAINING MIXED FERTILIZERS NEW RANGE BASED ON «ZHAMB-70»

Abstract. Analysis of data presented in the state program for the production and sale of agricultural products processing.The main reasons for the situation, determined the purpose and objectives of further research and implementation of the objections of improvement and production of new range of mixtures.

Provides technical information and materials on the way out of the situation by establishing mini workshops for production of ecologically pure and safe mixtures of the new range.The necessity of using modern means of labor protection and life safety in industrial conditions is shown.

The factors and risks of ensuring safety through the use of devices and equipment to reduce the psychophysical load of the personnel of the mini-workshop are considered.The production process is associated with many factors, the dominant of which is the lighting, climate and the dangers arising in the production environment.The kinds and types of risks are given, of which the most dangerous technogenic risk and emergency situations.Threats of dangers – professional, technical and ecological are shown. The factors of internal and external hazards, which are divided by the properties of their impact and potential threat.

Keywords: efficiency of fertilizer mixtures, mini shop, equipment, signaling and alerting means, illumination, temperature regime, microclimate, industrial sanitation, labor protection.

Introduction. At present, the composition of mineral fertilizers available on the market (nitroammophoski, sulphoammophos, etc.) does not fully satisfy the needs of crop producers in obtaining the right batteries. Using such mixtures, the farmer is forced to inseminate or reinforce one or another nutrient element of fertilizers, which affects the yield and quality of crops and products.

The way out of the situation is the use of environmentally friendly fertilizer blends - dry granular mineral fertilizers, made to order with the choice of the ratio of nutrient components. The main advantage of fertilizer is the ability to give the plant only those elements of nutrition that are necessary for it during development and fruiting. This excludes the possibility of overdosing on other components and besides, the constituent parts of the fertilizer are easier to store, since they are more resistant to caking and are not hygroscopic.

In modern conditions, partial and complete replacement of conventional fertilizers with mixtures is hardly possible because of the need to obtain them from different single fertilizers, obtained in most cases in the field [1-11].

Therefore, it is best to produce them in mini-shops of different regions of our country, which leads to the economy of material resources of agricultural producers and transport costs.

Properties of sorption substances. Based on the physico-chemical properties of glauconite according to the works of the authors [2-16], it was established that they reduce the content of heavy metals As, Pb, Mg and other elements from 64% to 99% and more, and radionuclides by 95-97% from aqueous solutions and are good feed additives for various animals.

The purpose of the first research direction is to develop the optimal technological compositions of fertilizer mixtures based on the difficult mixed fertilizer "ZHAMB-70" containing a moisture retaining substance, trace elements and humates[17-19].

This allows, along with the mechanochemically activated properties of the phosphate part of the fertilizer mixture, to produce a new range of mineral fertilizers that provide by the introduction of glauconitesorbing heavy metals and radionuclides, as well as zeolite.

Zeolite is permeated with a system of channels and has a well-developed surface for selective sorption of elements and molecules.This system of channels plays the role of a «molecular shield» for the sorption of nitrates, ammonium, alcohols and other substances. Therefore, the environmental safety of agricultural products is carried out due to the ability of glauconite and zeolite to adsorb radionuclides, heavy metals, alcohols and nitrates from aqueous solutions, and vermiculite to retain moisture and ensure its root system, leading to water savings for irrigation [18,19].

Ecologically mixtures "ZHAMB-70" of obtaining issues safe. Along with the above, the issues of obtaining environmentally friendly fertilizer, positively affecting the safety of life not only the surrounding animal and plant world, but also the development of technical bases of modern production of mixtures were raised.These issues include the organization of the enterprise in the form of a mini-workshop, equipped with modern devices and equipment, allowing compliance with the safety standards of the operating personnel of the production line.It is accompanied by the creation of not only sanitary and hygienic, but also other technical aspects of the temperature in the working mix, compliance with safety standards, ventilation, lighting and fire safety, requirements for the maximum permissible concentration and maximum permissible emissions of waste into the environment and their reuse in the process [20].

Therefore, in the second direction of research, research is being conducted on the development and creation of a small enterprise at the modern level with the comfort of the service personnel.

Speaking about the system "man – habitat – mechanical means", it is necessary to remember that here there is a mobilization of psychological and physiological functions of the personnel serving technological process.The speed of technological processes and their relationship with the human reaction in the current situation, associated with external sources of irritation, depending on the information received, requires more attention and reaction to the received signal information.

Human labor in any modern automated and mechanized production is the process of interaction between man and the production environment associated with the main and working capital, which include equipment and machines, raw materials and fuel and energy resources, etc.

A person who manages a certain technological process must quickly and accurately navigate in the current situation, ensure constant monitoring of actions to perform the cotrolling duties entrusted to him and ensure uninterrupted operation and the system and incoming signals, without forgetting self-control.

The foregoing requires increased attention to human security not only in production conditions, but also the culture of its provision. The safety of the workplace includes the organization of the workplace serving them and such working conditions that, if possible, affect the service personnel of hazardous and harmful production factors or their impact not exceeding the requirements of regulatory and technical documents and labor protection legislation.Therefore, the provision of safe working conditions is one of the most important requirements to the workplace to ensure the safety of the staff in its environment, affecting the level of industrial injuries and the safety of basic and auxiliary means of any enterprise.

Influence factors LS in the industrial cond. It is well known that a number of factors ensuring safety and smooth operation are necessary to create favorable working conditions for the personnel of the enterprises for the production of fertilizers and mixtures.

These factors include the following:

- lighting;
- ventilation;
- electrosecurity;
- fire safety;
- explosion safety;
- vibration and noise;
- the earthing and neutral earthing;
- health and safety;

- microclimate;
- firing;
- industrial sanitation, water and sanitation, other information and communication systems.

A threat to the safety of a production facility can be professional, including the protection of maintenance personnel, technical protection of buildings, structures, machines, equipment and devices, as well as environmental protection – including environmental protection.

In our case, which has all three threats to the safety of the production facility. The most important is the professional, since the object of protection is the service personnel, the individual who provides the output of certain products with certain qualitative and quantitative indicators.Therefore, the organization of safety of working conditions and the production cycle for the production of mixtures must comply with the current legislative and regulatory documents, with the use of modern means of automation and control of the process, devices, reactors, devices and auxiliary means of protection and support of the production process.

One of these production processes is the production of a fertilizer mixture, which is associated with the use of dust-releasing raw materials, such as man-made, phosphoric and carbon-containing raw materials, natural aluminosilicates, and fuel-energy resources.

To obtain products of appropriate quality, the danger of the production environment plays an important role, which depends on the degree of complexity of the work performed; exclusion from the process of traumatic equipment; timely and quality maintenance, repair, testing, inspections, technical inspection of equipment and machines, in the order and terms established by operational documents; state standards and specifications for equipment of specific groups, types, models, rules of arrangement and safe exploitation, and legislative acts; use equipment only as intended, in accordance with the requirements of the operational documentation, the organization of the manufacturer; the operation of machinery, apparatus and equipment by employees or service personnel having appropriate qualifications to the profession; having passed in the prescribed order training, training and testing of knowledge on labour protection; introduction and use of devices, machines and equipment of more advanced designs, brake devices of automatic control and alarm systems, remote control, warning signals of fire danger, stopping devices and equipment, etc.; the use of legal and regulatory documents in ensuring safety, assessment of the intensity of the labor process, assessment of occupational risk by classes of working conditions, assessment of occupational risk according to the formula Fayka-Kinna, etc. [21-30].

The implementation of all these provisions will ensure uninterrupted and high-quality production of target products and safe life of the entire production cycle, economic and ecological well-being of the population and the environment, including living organisms.

So, for example-the microclimate and lighting are one of the most important components of a comfortable environment of human work. Light has a strong impact on the human body, physiological and emotional state.Insufficient and uneven lighting, as well as pulsations affect the functioning of the visual apparatus, the performance and the psyche of the personnel serving the technological process.

Therefore, the design of lighting elements in industrial enterprises, including in mini-shops, in addition to meeting the requirements of various state Standards and rules of safe operation, must meet two basic requirements:

- provision of sufficient lighting (light);
- effective and safe performance of tasks by the service personnel in the conditions of the illuminated workplace and industrial stirring.

The choice of the types of lighting devices and installations providing the required illumination in the production room shall be made on the basis of the following factors:

- presence of dust, moisture, chemical aggressiveness, fire and explosion hazard of the operating environment and service areas;
- architecture and technological design of the production process, the presence of differences in heights, farms, technological bridges, reflecting the properties of walls, ceiling, floor, working surfaces of technological and auxiliary equipment, the size of building modules;
- requirements for the quality of lighting, including the rate of lighting, rational use of light flux, high efficiency and sufficient lighting power.

Therefore, on the basis of economic and aesthetic considerations, on the design, light distribution and limitation of blinding action, specific types of lamps will be selected, taking into account artificial and natural lighting, high-altitude differences of production facilities, their purpose and other factors.

The next aspect of sanitary standards is the temperature in the working space and the air circulation system with ventilation systems.

Speaking of light, don't forget about the main aspect of project and installation work- the device of individual protection of personnel from electric shock, in addition to the grounding and earthing devices.

The elements of the structure of technogenic risks. Any industrial, technological and technical object on which danger can arise is a direct object of danger. Therefore, the amount of damage caused by it can also serve as a potential threat even in normal operation and even more so in emergency situations.

Concerning to the industrial technological object, its danger can be determined by the following sign:

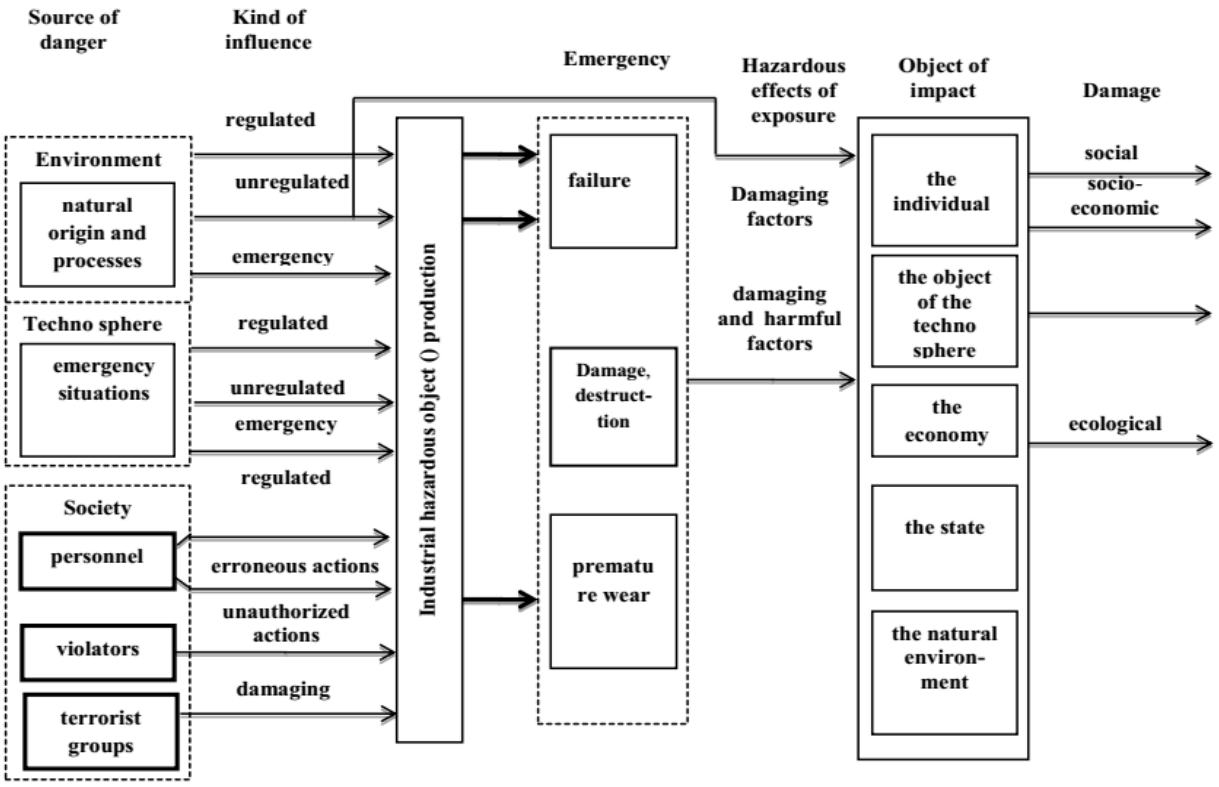
- the number of generated and accumulating hazardous and technogenic wastes and energy sources;
- the mechanism of damage in the normal conduct of the process and emergency situations;
- by type of danger-mechanical, thermal, electromagnetic, radiation and other;
- by the nature of possible emergencies.

Exposure to the above hazards may result in the following damages:

- health of the servicing device or equipment on which technological processes occur as mechanical damage in the form of risk, occupational diseases and possible death;
- violation of the state of the industrial enterprise of the technosphere in whole or in part resulting in damage or even destruction;
- environmental consequences and damage to the environment, which generally affects the economy of any state in which the industrial technological facility is located.

The qualitative and quantitative effects of hazards cause the above effects with a certain probability after exposure and are characterized by risk. Which are divided into radiation, technological, technical, environmental, economic, technogenic, social and others.

The main elements of the structure of man-made risk to human health and life of maintenance personnel in the performance of their professional duties, as well as the population living near the industrial facility are shown in figure.



The elemental composition of the man-made risk

Conclusions. Safety, this is the state of normal, uninterrupted and effective activity of an industrial technological facility in which vital interests of production personnel are launched from internal and external threats arising at the enterprise to external safety factors include man-made and environmental disasters, diversions and terrorist acts.In particular, by heavy metals through the assay the spectra of consumption of organic substances by bacterial communities [33].

The sources of the technogenic emergency include dangerous man-made accidents due to which an industrial emergency occurred on the industrial technological site or on its specific territory. Therefore, when it occurs, the probability of damaging effects of a particular kind of character associated with death, disability, moderate trauma and minor injuries is possible, with the realization of a certain hazard called individual risk. In many industrial plants, a technogenic emergency may arise, which is a violation of normal working conditions and the activities of the staff who serve, and entails a threat to human life and health.

Thanks. The research were carried out under the project of grant financing of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan for "The creation of technology and the development of scientific bases for the synthesis of multicomponent mineral fertilizers with specific features for gray soils", "Investigation of changes in the content of sanitary-epidemiological, toxicological and radiological compounds in tomatoes, carrots, maize and soya bean crops when using humate-containing complex-mixed NPK - prolonged-release fertilizer, to ensure environmental safety."

К. Т. Жантасов[1], Б. А. Лавров[3], Д. М. Жантасова[1],
К. С. Досалиев[1], Б. А. Исмаилов[1], Ж. Т. Жумадилова[1]

[1]М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті,
Шымкент, Қазақстан,
[2]Санкт-Петербург мемлекеттік технологиялық институты (техникалық университет),
Санкт-Петербург, Ресей

«ЖАМБ-70» НЕГІЗІНДЕ ЖАҢА АССОРТИМЕНТТІҢ ТУКОҚОСПАСЫН АЛУДЫҢ ШАҒЫН ЦЕХЫН ҚҰРУ ӘЗІРЛЕМЕСІ

Аннотация. АӨК қайта өңделген өнімдерін өндіру мен өткізу бойынша мемлекеттік бағдарламада ұсынылған деректерді талдау. Қалыптасқан жағдайдың негізгі себептері одан әрі зерттеулердің және жаңа ассортименттің тукоқоспаларын жетілдіру мен алуды жүзеге асырудың мақсаты мен міндеттерін алдын ала анықтады.

Жаңа ассортименттің экологиялық таза және қауіпсіз тукоқоспаларын алудың шағын цехтарын жасау арқылы пайда болған жағдайдан шығу бойынша техникалық мәліметтер мен материалдар келтірілді. Өндірістік жағдайларда еңбекті қорғау және қауіпсіздіктің қазіргі құралдарын пайдалану қажеттілігі көрсетілді.

Шағын цехтың қызмет көрсетуші персоналының психофизикалық жүктемесін азайтуға мүмкіндік беретін аппараттар мен жабдықтарды қолдану негізінде еңбек қауіпсіздігін қамтамасыз ететін факторлар мен тәуекелдер қарастырылды. Өндірістік үдеріс көптеген факторлармен байланысты, олардың ішінде ең бастысы жарықтандыру, микроклимат және өндірістік жағдайларда туындайтын қауіптер болып келеді. Тәуекелдердің үлгілері мен түрлері берілген, олардың ішінде ең қауіптілері техногендік тәуекел мен төтенше жағдайлар. Кәсіптік, техникалық және экологиялық қауіптердің қатерлері көрсетілген. Ішкі және сыртқы қауіптердің факторлары келтірілген, олар әсер ету қасиеттері мен әлеуетті қатері бойынша бөлінген.

Түйін сөздер: тукоқоспаның тиімділігі,шағын цех, жабдық, сигнал және хабарлау құралдары, жарық, температуралық режим, микроклимат, өнеркәсіптік санитария, еңбекті қорғау.

К. Т. Жантасов[1], Б. А. Лавров[3], Д. М. Жантасова[1],
К. С. Досалиев[1], Б. А. Исмаилов[1], Ж. Т. Жумадилова[1]

[1]Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,
[2]Санкт-Петербургский государственный технологический институт (технический университет),
Санкт-Петербург, Россия

РАЗРАБОТКА ПО СОЗДАНИЮ МИНИ ЦЕХА ПОЛУЧЕНИЯ ТУКОСМЕСИ НОВОГО АССОРТИМЕНТА НА ОСНОВЕ «ЖАМБ-70»

Аннотация. Анализ данных, представленных в государственной программе по производству и реализации продуктов переработки АПК. Основные причины сложившихся ситуации, предопределил цель и задачи дальнейших исследований и реализации в жизнь воспросов совершенствования и получения тукосмесей нового ассортимента.

Приведены технические сведения и материалы по выходу из создавшегося положения путем создания мини цехов получения экологически чистых и безопасных тукосмесей нового ассортимент. Показана необходимость использования современных средств охраны труда и безопасности жизнедеятельностив производственных условиях.

Рассмотрены факторы и риски обеспечивающие безопасность труда на основе применения аппаратов и оборудований, позволяющих снизить психофизическую нагрузку обслуживающего персонала миницеха. Производственный процесс связан со многими факторами, главенствующими из которых является освещение, микроклимат и опасности возникающие в производственных условиях. Даны типы и виды рисков, из которых наиболее опасны техногенный риск и чрезвычайные ситуации. Показаны угрозы опасностей – профессиональной, технической и экологической. Приведены факторы внутренних и внешних опасностей, которые разделены по свойствам их воздействия и потенциальной угрозе.

Ключевые слова: эффективность тукосмесей,мини цех, оборудование, средства сигнализации и оповещения, освещенность, температурный режим, микроклимат, промсанитария, охрана труда.

Information about the author

Zhantasov Kurmanbek Tazhmakhanbetovich, Doctor of Technical sciences, professor of the department "Chemical technology of inorganic substances" SKSU named after M. Auezov; k_zhantasov@mail.ru; https://orcid.org/0000-0003-1435-4873

Lavrov Boris Alexandrovich, Doctor of Technical Sciences, Professor of the Department "General Chemical Technology and Catalysis" of the St. Petersburg State Technological Institute (Technical University) of the Russian Federation, St. Petersburg; ba-lavrov@mail.ru;https://orcid.org/0000-0002-7362-4952

Zhantasova Dina Muratkhankyzy, Master of Economics, Senior Lecturer of the Department "Economics" SKSU named after M.Auezov; dm-zhantasova@mail.ru;

https://orcid.org/0000-0003-2041-5812

Dosaliev Kanat Serikovich, M. Auezov South Kazakhstan state University (SKSU), Shymkent, Kazakhstan; dosaliev_k@mail.ru; https://orcid.org/0000-0002-5423-9231

Ismailov Bakhytzhan Abdukhalikovich, PhD doctoral student of the department "Safety of life and environmental protection" SKSU named after M. Auezov; baxa-86_8@mail.ru; https://orcid.org/0000-0003-0925-5408

Zhumadilova Zhazira Tulzhanovna, PhD doctoral student of the department "Chemical technology of inorganic substances" SKSU named after M. Auezov; zh-zhumadilova@mail.ru; https://orcid.org/0000-0001-5892-1548

REFERENCES

[1] Koren'kov D.A. Spravochnik agrohimika. 2-oe izdanie pererabotannoe i dopolnennoe M.: Rossel'hozizdat. 1980. 286 p.

[2] Smirnov P.M., Muravin Je.A. Agrohimija. M.: Kolos, 1981. 319 p.

[3] Kuvshinnikov I.M. Mineral'nye udobrenija i soli: Svojstva i sposoby ih uluchshenija. M.: Himija, 1987. 250 p.

[4] Hlopkovodstvo / A.I. Avtonomov, M.Z. Kaiev, A.I.Shlejher i dr. 2-oe izdanie, pererabotannoe i dopolnennoe. M.: Kolos, 1983. 334 p.

[5] Umbetaev I., Bat'kaev Zh.Ja. Қазақстан Respublikasynyң oңtүstiginde қoza baptau zhүjesi. Almaty: Құs zholy, 2000. 204 p.

[6] Kustarnikov I.A., Gerasimov E.V., Fustochenko A.Ju., Isakov E.A. Porjadok prigotovlenie tukosmesi i sposoby ee vnesenija. Stavropol'skij gosudarstvennyj agrarnyj universitet UDK 631. 333, Perspective innovations in, education and transport 2013. Sworld – 17-26 December 2013.S.5. tehnicheskie nauki - Tehnika v sel'skohozjajstvennom proizvodstve.

[7] Ovsjanikov A.A. Tehnicheskij uroven' traktorov sel'skohozjajstvennogo naznachenija / Ovsjanikov A.A., Arkavenko A.A, Ovsjanikov S.A // Tehnika i oborudovanie dlja sela. 2012. N 1. P. 13-17.

[8] Ovsjanikov S.A. Proizvodstvennaja ocenka raboty posevnyh agregatov / Ovsjanikov S.A., Ridnyj S.D. // Sbornik nauchnyh trudov Sworld. 2013. Vol. 6, N 1. P. 64-67.

[9] Ridnyj S.D. Tukosmeshivanie v tehnologijah tochnogo zemledelija / Ridnyj S.D., Ovsjanikov S.A., Kustarnikov I.A. // Sbornik nauchnyh trudov Sworld. 2013. Vol. 6, N 1. P. 69-72.

[10] Ridnyj S.D. Tukosmeshivanie mineral'nyh udobrenij v tehnologijah tochnogo zemledelija / Ridnyj S.D., Kustarnikov I.A. // Sbornik nauchnyh dokladov VIM. 2012. Vol. 2. P. 456-463.

[11] Ridnyj S.D. Agregat dlja differencirovannogo vnesenija tverdyh granulirovannyh tukosmesej / Ridnyj S.D., Kustarnikov I.A. // V sbornike: Aktual'nye problemy nauchno-tehnicheskogo progressa v APK. 2013. P. 257-262.

[12] Andronov S.A., Bykov V.I. Glaukonit – mineral budushhego // Mat. pervoj Mezhdunarod. konf. Znachenie promyshlennyh mineralov v mirovoj jekonomike: mestorozhdenija, tehnologija, jekonomicheskaja ocenka. M.: GEOS, 2006. P. 79-83.

[13] Grigor'eva E.A. Sorbcionnye svojstva glaukonita Karinskogo mestorozhdenija / Sbornik dokladov NPK "Glaukonit – kalijnoe udobrenie i mineral, prigodnyj dlja reabilitacii zagrjaznennyh radionuklidami zemel'. (Cheljabinsk, Pravitel'stvo Cheljabinskoj oblasti, 3 ijulja 2003)". Cheljabinsk: Izd-vo ChDU, 2003. 55 p.

[14] Kuanysheva G.S., Balgysheva B.D., Asilov A.B., Urakaev F.H. Termo- i mehanohimicheskoe modificirovanie glaukonitov i ih sorbcionnye svojstva // Vestnik KazNU. Serija himicheskaja. 2014. N 1(73). P. 74-80.

[15] Kurbanijazov S.K., Әbdimүtәlip N.A., Zhanbaz M., Tojchibekova G.B. Obshhaja harakteristika polozhenija glaukonitov v razrezah Juzhnogo Kazahstana i ocenka ih resursov // Vestnik Nacional'noj akademii nauk Respubliki Kaahstan. 2014. N 4. P. 132-137.

[16] Zhantasov K.T., Dormeshkin O.B., Ajtbaev T.E., Bekaulova A.A., Ramatullaeva L.I., Rahmanberdieva Zh.N., Shapalov Sh.K., Mahambetov M.Zh. Rezul'taty predvaritel'nyh issledovanij po polucheniju i issledovaniju polikomponentnyh mineral'nyh udobrenij «ZhAMB-70» na sel'hozkul'turah // Izvesti Nacional'noj Akademija i nauk RK. Serija agrarnyh nauk. 2017. N 2. P. 266-273. UDK 631.4. ISSBN 2224-526X.

[17] Evrazijskij patent 023417. Fosfornoe organomineral'noe udobrenie ot 15.04.2014. vydan 30.06.2016.

[18] Otchet po teme «Sozdanie tehnologii i razrabotka nauchnyh osnov sinteza polikomponentnyh mineral'nyh udobrenij so specificheskimi osobennostjami dlja serozemnyh pochv» 2014. Shymkent JuKGU im. M. Aujezova. Gos. Registracii №0112 RK02590. Rukovoditel' temy - d.t.n., professor Zhantasov K.T.

[19] Otchet po teme «Issledovanie izmenenija soderzhanija sanitarno-jepidemiologicheskih, toksikologicheskih i radiologicheskih soedinenii v tomatah, morkovi, kukuruze i soe-bobovyh kul'turah pri primenenii gumatsoderzhashhih slozhno-smeshannyh NPK-udobrenij prolongirovannogo dejstvija, dlja obespechenija jekologicheskoj bezopasnosti» 2014. Shymkent JuKGU im. M.Aujezova. Gos. registracii №0115RK01485 Rukovoditel' temy - d.t.n., professor Zhantasov K.T.

[20] Metodologicheskie osnovy sovershenstvovanie avtomatizirovannyh sistem protivopozharnoj zashhity predprijatij neftepererabatyvajushhego kompleksa s primeneniem video tehnologij. Demehin F.V. doktor tehnicheskih nauk Sankt-Peterburg 2009. Kod spec. 05.26.03. spec: Pozharnaja i promyshlennaja bezopasnost' (po otrasljam). P. 383.

[21] Abrosimov A.A., Topol'skij N.G., Fedorov A.V. Avtomatizirovannye sistemy pozhar vzryvobezopasnosti neftepererabatyvajushhih proizvodstv. M.: AGPS MVD Rossii, 2000. 239 p.

[22] Legasov V.A., Chajvanov B.B., Chernoplekov A.N. Nauchnye problemy bezopasnosti sovremennoj promyshlennosti // Bezopasnost' truda v promyshlennosti. 1988. N 8. P. 44-51.

[23] Metodov funkcional'nogo kontrolja apparatury pozharnoj signalizacii i ih tehnicheskaja realizacija. Vasil'ev M.A. kandidat tehnicheskih nauk. Sankt-Peterburg kod spec 05.26.03. special'nost'. Pozharnaja bezopasnost'. 1999. P. 244.

[24] Sistemnyj analiz i problemy pozharnoj bezopasnosti narodnogo hozjajstva / Pod. red. N.N. Brushlinskogo M.: Strojizdat, 1988. 244 p.

[25] Enbekti korgau zhane tirshilik kauipsizdigi. Okulyk Zhantasov Қ.T., Kucherov E.N., Naukenova A.S., Zhantasov M.Қ. Almaty, 2012. 512 p. ISBN 978-601-272 331-4.

[26] Ohrana truda v jelektroustanovkah / Knjazevskij B.A., Marusova T.P., Chekalnn N.A., Shipunov N.V. / Pod pred. B.A. Knjazevskogo. 3-e nzd. M.: Jenergoatomizdat, 1983. 336 p.

[27] Korablev V.P. Mery jelektrobezopasnosti v himicheskoj promyshlennosti. M.: Himija, 1983. 176 p.

[28] Drugov Ju.S., Rodin A.A. Al'tshuller M.A. Analiz zagrjaznennoj vody: prakticheskoe rukovodstvo Binom. 2012. 678 p. ISBN 978-5-94774-762-1,

[29] Rodin A.A., Drugov Ju.S. Gazohromatograficheskaja identifikacija zagrjaznenij vozduha, vody i pochvy. SPb.: Teza, 1999. 486 p.

[30] Upravlenie bezopasnost'ju potencial'no opasnyh ob#ektov. 05.13.01 - sistemnyj analiz, upravlenie i obrabotka informacii (v mashinostroenii i vychislitel'noj tehnike): Dissertacija na soiskanie uchenoj stepeni kandidata tehnicheskih nauk. Tret#jakova Petr Andreevich. 61:06-5/1696. Izhevsk, 2006. P. 181.

[31] Rodionov A.I., Kuznecov Ju.P., Zen'kov V.V., Solov'ev G.S. Oborudovanie, sooruzhenie, osnovy proektirovanie himiko-tehnologicheskih processov zashhity biosfery ot promyshlennyh vybrosov. Dlja vysshej shkoly. M.: Himija, 1985. P. 351.

[32] Sistemy vlago-pyle podavlenija vodjanye pushki hennlich. Katalog RF. OOO «HENLIH» divisionhennlichengineering. 2017. P. 15.

[33] Mynbayeva B.N., Musdybayeva K.K., Tanybayeva A.K., Patsaeva S.V., Khundzhua D.A., Tlebaev K.B. Geological and morphological and fluorescent characteristics used in assessment of Almaty city soil contamination. 2018. Vol. 5, N 431. P. 153-160. https://doi.org/10.32014/2018.2518-170X.45. ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

МАЗМҰНЫ

СОДЕРЖАНИЕ

CONTENTS

Publication Ethics and Publication Malpractice
in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www:nauka-nanrk.kz

ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

http://www.geolog-technical.kz/index.php/en/

Верстка *Д. Н. Калкабековой*

Подписано в печать 06.02.2019.
Формат 70x881/8. Бумага офсетная. Печать – ризограф.
16,7 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко 28, т. 272-13-19, 272-13-18