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

# NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

№6
2025

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

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

# N E W S
## OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

**6 (474)**

**NOVEMBER – DECEMBER 2025**

**THE JOURNAL WAS FOUNDED IN 1940**

**PUBLISHED 6 TIMES A YEAR**

ALMATY, 2025

*«Central Asian Academic Research Center» LLP 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.*

*«Орталық Азия академиялық ғылыми орталығы» ЖШС «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. Web of 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.*

*ТОО «Центрально-азиатский академический научный центр» 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.*

---

**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: «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Communications of the Republic of Kazakhstan Nº KZ50VPY00121155, issued on 05.06.2025
Thematic scope: *geology, hydrogeology, geography, mining and chemical technologies of oil, gas and metals*
Periodicity: 6 times a year.
http://www.geolog-technical.kz/index.php/en/

---

**«ҚР ҰҒА» РҚБ Хабарлары. Геология және техникалық ғылымдар сериясы».**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**
Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).
Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген № KZ50VPY00121155 мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *Геология, гидрогеология, география, тау-кен ісі, мұнай, газ және металдардың химиялық технологиялары*
Мерзімділігі: жылына 6 рет.
http://www.geolog-technical.kz/index.php/en/

---

**«Известия РОО «НАН РК». Серия геологии и технических наук».**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**
Собственник: ТОО «Центрально-азиатский академический научный центр» (г. Алматы).
Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан № KZ50VPY00121155, выданное 05.06.2025 г.
Тематическая направленность: *геология, гидрогеология, география, горное дело и химические технологии нефти, газа и металлов*
Периодичность: 6 раз в год.
http://www.geolog-technical.kz/index.php/en/

## CONTENTS

**A.U. Abdullaev, I.N. Litovchenko, V.S. Lyutikova**
Swarm recognition algorithm as a promising artificial intelligence method in seismological research.....8

**E.T. Alsheriyev, K.S. Dossaliyev, A.S. Naukenova, A.M. Yegenova, L. Abdrasilov**
Mathematical modeling and computer calculation of the prediction of possible consequences of earthquakes.....22

**N. Amirgaliev, L. Ismukhanova, A. Madibekov, B. Sultanbekova, A. Sultanayeva**
Monitoring the level of polychlorated bipheniles pollution in the Ile River falls.....32

**A.B. Baibatsha, A. Nukhuly, A.Ye. Agmanova, E.S. Bashilova, B.B. Amralinova**
The legacy of Academician K.I. Satpayev in the study of uranium deposits of Kazakhstan.....47

**R. Bashirov, V. Abbasov, S. Zakenov, G. Bashirova, L. Nurshakhanova**
Effect of parameters on chip shrinkage in ultrasonic turning of oilfield parts.....63

**M.Zh. Bulenbayev, B.T. Altaibayev, D.R. Magomedov, A.K. Omirgali, A.N. Bakrayeva**
Investigation of the possibility of separate bio-leaching of uranium and vanadium from black shale raw materials.....76

**U.M. Jabıyeva, K.V. Jafarova, G.I.Malikov, S.Z.Abdullayeva**
Modeling the path to greener plastics through sustainable innovations in Low-Density Polyethylene.....92

**R.K. Zhanakova, N. Atalykova, G. Jangulova, E. Kakimzhanov, O. Kurmanbaev**
The near-pit wall rock mass state stability monitoring method.....102

**B.M. Zhurynov, A.F. Tsekhovoy**
Project-based approach to quantitative assessment of the EPN effectiveness on the example of Kazakhstan industrial holdings.....118

**G.B. Ilmalieva, D.M. Tursunbekov, E.B. Kenzhaliyev, O.V. Atanova, K.M. Smailov**
Evaluation of the efficiency of using fly ash in polymer composite materials.....135

**M. Leman, A. Tairov, I. Malkovskiy, L. Toleubaeva, A. Aldiyarova**
Dynamic-stochastic model of sustainable water resources management in Kazakhstan.....151

**A.V. Mazdubay, D.R. Absolyamova, A.Zh. Taskarina, A.D. Suleimenov, D.D. Alipbayev**
Tribotechnical analysis of energy-efficient mixers for mineral suspensions.....168

**Sh.M. Medetov**
Safe transportation of a drilling rig during rockfalls.....180

**B.T. Ratov, A.E. Kuttybayev, M.T. Tabylganov, V.L. Khomenko, A.S. Kainazarov**
An effective device for the development of shallow aquifers.....195

**S.S. Sayyidkosimov, A.T. Nizamova, A.N. Kazakov1, M.R. Hakberdiev, I.Y. Sohibov**
Methodology for forecasting dynamic rock pressure manifestations in underground gold mining.....209

**D.Kh. Sunakbaeva, D.Kh. Yuldashbek, K. Aitekova, Y.T. Ergashev**
Biologically active substances for reducing heavy metal migration in contaminated soils.....230

**V.M. Timokhin, V.V. Kondratiev, V.Yu. Konyukhov, I.S. Remezov, N.N. Bryukhanova**
Diagnostics of the structure of crystalline materials of rock formations by the method of thermally stimulated depolarization.....246

**J.B. Toshov, K.T. Sherov, U.R. Bainazov, B.N. Absadykov, M.R. Sikhimbayev**
Study and determination of the stress-strain state of conveyor belts.....265

**J.F. Shırıyev, G.R. Muradov, K.S. Mammadov, S.A. Musayeva, M.A. Azımov**
Prospectivity assessment of deep sediments in pirsaat, Lower Kura Depression.....280

**N.S. Faiz, Sh.K. Shapalov, K.Zh. Smagulov, N.P. Tokenov, B.K. Nauryz**
Creation of geoinformation maps for assessment of wind energy potential of local areas of Turkestan region.....294

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 6. Number 474 (2025), 102–117

***https://doi.org/10.32014/2025.2518-170X.574***

UDC 622.6

**© R.K. Zhanakova[1], N. Atalykova[2*], G. Jangulova[2], E. Kakimzhanov[2], O. Kurmanbaev[2], 2025.**
[1]Kazakh National Research Technical University named after K.I. Satpayev, Almaty, Kazakhstan;
[2]Al-Farabi Kazakh National University, Almaty, Kazakhstan.
E-mail: Nazym.96s@gmail.com

# THE NEAR-PIT WALL ROCK MASS STATE STABILITY MONITORING METHOD

**Zhanakova Raisa** — PhD, Kazakh National Technical University named after K.I. Satpaev, Professor of the Mining Department, Almaty, Kazakhstan,
E-mail: zhanakova_raisa@mail.ru, https://orcid.org/0000-0003-0845-8449;
**Atalikova Nazym —** PhD student, Al-Farabi Kazakh National University, Department of Cartography and Geoinformatics, Almaty, Kazakhstan,
E-mail: nazym.96s@gmail.com, https://orcid.org/0009-0002-4423-7117;
**Jangulova Gulnar —** Candidate of Technical Sciences, Al-Farabi Kazakh National University, Associate Professor of the Cartography and Geoinformatics Department, Almaty, Kazakhstan,
E-mail: gulnar_zan@mail.ru, https://orcid.org/0000-0002-7866-1031;
**Kakimzhanov Erkin —** PhD, Al-Farabi Kazakh National University, Associate Professor of the Cartography and Geoinformatics Department, Almaty, Kazakhstan,
E-mail: erkinkakimzhanov@gmail.com, https://orcid.org/0000-0002-1919-6459; **Kurmanbaev Olzhas —** PhD, Associate Professor, Al-Farabi Kazakh National University, Almaty, Kazakhstan,
E-mail: olzhas_ak@list.ru, https://orcid.org/0000-0002-4867-6910.

**Abstract.** The article presents information and results of assessing the stability of the near-pit wall rock mass of the Central Pit at the Akzhal deposit, as well as the technogenic risks arising from the interaction between open-pit and underground mining operations. Based on a developed step-by-step modeling algorithm consisting of six stages, a comprehensive analysis of the geomechanical conditions determining the probability of collapse of the southern pit wall was carried out. At the 1st stage, geomechanical risks in the active mining zones were assessed; the 2nd stage focused on identifying and locating potentially hazardous areas affecting transport communications and infrastructure. At the 3rd stage, the natural stress field of the rock mass was determined, allowing clarification of deformation zones; the 4th stage included the analysis of engineering-geological, geodetic, and

geomechanical investigation results. The 5th and 6th stages involve slope stability calculations and the assessment of how identified deformations influence the safety of underground mine workings. The study results showed that the southern wall of the Central Pit is in a state of limiting equilibrium and exhibits a high probability of sudden collapse. It was established that underground mining using a caving system contributed to the formation of zones with increased rock mass displacement, which is confirmed by modeling data. Additionally, specific geomechanical conditions were identified between the open-pit space and underground workings, creating an elevated collapse risk. The findings emphasize the need for comprehensive geomechanical monitoring and the improvement of technogenic risk management methods under combined mining conditions.

**Keywords:** slope stability, technogenic risk, geomechanics, rock mass deformation, pit wall

**© Р.К. Жанакова[1], Н. Аталыкова[2*], Г. Джангулова[2], Е. Какимжанов[2], О. Курманбаев[2], 2025.**

[1]Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Алматы, Қазақстан;

[2]Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан.

E-mail: Nazym.96s@gmail.com

## КАРЬЕР МАҢЫНДАҒЫ МАССИВТЕРДІҢ ТҰРАҚТЫЛЫҒЫН МОНИТОРИНГТЕУ ӘДІСТЕМЕСІ

**Жанакова Раиса** — PhD, «Тау-кен ісі» кафедрасының профессоры, Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Алматы, Қазақстан,
E-mail: zhanakova_raisa@mail.ru, https://orcid.org/0000-0003-0845-8449;
**Аталықова Назым** — PhD докторант, «Картография және геоинформатика» кафедрасы, әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail: nazym.96s@gmail.com, https://orcid.org/0009-0002-4423-7117;
**Жанғұлова Гүлнар** — техника ғылымдарының кандидаты, «Картография және геоинформатика» кафедрасының қауымдастырылған профессоры, әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail: gulnar_zan@mail.ru, https://orcid.org/0000-0002-7866-1031;
**Кәкімжанов Еркін** — PhD, «Картография және геоинформатика» кафедрасының қауымдастырылған профессоры, әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail: erkinkakimzhanov@gmail.com, https://orcid.org/0000-0002-1919-6459;
**Құрманбаев Олжас** — PhD, «Картография және геоинформатика» кафедрасының қауымдастырылған профессоры, әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail: olzhas_ak@list.ru, https://orcid.org/0000-0002-4867-6910.

**Аннотация.** Мақалада Акжал кен орнындағы Центральный карьер жыныс массивінің тұрақтылығын және ашық әрі жер астындағы тау-кен жұмыстарының өзара әрекеттесуі нәтижесінде қалыптасатын техногендік

аймақты бағалау бойынша алынған мәліметтер мен нәтижелер келтірілген. Алты кезеңнен тұратын кезең-кезеңімен модельдеу алгоритмі негізінде карьердің оңтүстік бортының опырылу ықтималдығын айқындайтын геомеханикалық жағдайларға кешенді талдау жүргізілді. Игеріліп жатқан аймақтардағы геомеханикалық жағдайы 1-кезеңде бағаланды; Көлік коммуникацияларына және инфрақұрылым нысандарына әсер етуі мүмкін қауіпті учаскелерді анықтауға және оларды локализациялауға 2-кезең бағытталды. Массивтің табиғи кернеулі күйі айқындалып, деформация аймақтарын нақтылауға 3-кезеңде мүмкіндік берді; Инженерлік-геологиялық, геодезиялық және геомеханикалық бақылаулар нәтижелерін талдауды 4-кезең қамтыды. Карьер беткейінің тұрақтылығын есептеуді және анықталған деформациялардың жер асты тау-кен қазбаларының қауіпсіздігіне әсерін бағалауды 5- және 6-кезеңдер қарастырады. Зерттеу нәтижелері Центральный карьерінің оңтүстік беткейі деформациялық тұрғыдан кенет опырылу ықтималдығы жоғары екенін көрсетті. Жер асты өндірудің опырылу жүйесі массивтің жоғары жылжымалылық аймақтарының қалыптасуына ықпал еткені, бұл модельдеу деректерімен расталатыны анықталды. Сонымен қатар, карьер кеңістігі мен жер асты қазбалары арасындағы геомеханикалық жағдайлар опырылу қаупін күшейтетіні белгіленді. Алынған нәтижелер кен орындарын біріктірілген әдіспен игеру жағдайында техногендік үдерістерді басқаруды жетілдіру және кешенді геомеханикалық мониторинг жүргізудің маңыздылығын айқындайды.

**Түйін сөздер:** еңіс тұрақтылығы, техногендік тәуекел, геомеханика, массив деформациясы, карьер беткейі

**© Р.К. Жанакова[1], Н. Аталыкова[2*], Г. Джангулова[2], Е. Какимжанов[2], О. Курманбаев[2], 2025.**

[1]Казахский национальный исследовательский технический университет имени К.И. Сатпаева, Алматы, Казахстан;

[2]Казахский национальный университет имени аль-Фараби, Алматы, Казахстан.

E-mail: Nazym.96s@gmail.com

## МЕТОДИКА МОНИТОРИНГА УСТОЙЧИВОСТИ ЗА СОСТОЯНИЕМ ПРИБОРТОВЫХ МАССИВОВ КАРЬЕРОВ

**Жанакова Раиса** — PhD, профессор кафедры «Горное дело», Казахский национальный технический университет имени К.И. Сатпаева, Алматы, Казахстан,
E-mail: zhanakova_raisa@mail.ru, https://orcid.org/0000-0003-0845-8449;
**Аталыкова Назым** — PhD докторант, кафедра «Картографии и геоинформатики», Казахский национальный университет имени аль-Фараби, Алматы, Казахстан,
E-mail: nazym.96s@gmail.com, https://orcid.org/0009-0002-4423-7117;
**Джангулова Гульнар** — кандидат технических наук, ассоциированный профессор кафедры «Картографии и геоинформатики», Казахский национальный университет имени аль-Фараби, Алматы, Казахстан,

E-mail: gulnar_zan@mail.ru, https://orcid.org/0000-0002-7866-1031;
**Какимжанов Еркин** — PhD, ассоциированный профессор кафедры «Картографии и геоинформатики», Казахский национальный университет имени аль-Фараби, Алматы, Казахстан,
E-mail: erkinkakimzhanov@gmail.com, https://orcid.org/0000-0002-1919-6459;
**Курманбаев Олжас** — PhD, ассоциированный профессор кафедры «Картографии и геоинформатики», Казахский национальный университет имени аль-Фараби, Алматы, Казахстан,
E-mail: olzhas_ak@list.ru, https://orcid.org/0000-0002-4867-6910.

**Аннотация**. В статье представлены результаты оценки устойчивости прибортового массива Центрального карьера месторождения Акжал и анализа техногенных рисков, возникающих при взаимодействии открытых и подземных горных работ. На основе разработанного поэтапного алгоритма моделирования, включающего шесть стадий, выполнен комплексный геомеханический анализ, позволивший определить вероятность обрушения южного борта карьера. На первом этапе проведена оценка геомеханических рисков активных зон разработки. Второй этап был направлен на выявление и локализацию потенциально опасных участков, влияющих на транспортные коммуникации и инфраструктуру. На третьем этапе определено естественное напряжённо-деформированное состояние массива, что позволило уточнить зоны повышенной деформации. Четвёртый этап включал анализ инженерно-геологических, геодезических и геомеханических наблюдений. Пятый и шестой этапы предусматривали расчёт устойчивости бортов и оценку влияния установленных деформаций на безопасность подземных выработок. Результаты исследования показали, что южный борт Центрального карьера находится в состоянии предельного равновесия и характеризуется высокой вероятностью внезапного обрушения. Установлено, что подземная отработка по системе обрушения способствовала формированию зон повышенной подвижности массива, что подтверждается данными моделирования. Дополнительно выявлены геомеханические условия между карьерным пространством и подземными выработками, создающие риск возникновения обрушения. Полученные результаты подчёркивают необходимость комплексного геомеханического мониторинга и совершенствования методов управления техногенными рисками при комбинированной разработке месторождений.

**Ключевые слова:** устойчивость откосов, техногенный риск, геомеханика, деформация массива, борт карьера

**Introduction**. Open pit mining is the Kazakhstan's resource sector foundation, enabling the development of valuable minerals such as uranium, copper, iron ore, coal and gold. Quarries are usually developed as a series of downward ledges with motor roads, that provide surface access to the quarry lower horizons (Figure 1).

Figure 1. Quarry general view

As a result, formed the quarries sides or slopes, which often have significant inclination angles, represent geotechnical complexity and are inherently at risk of deformations and landslide processes (Mikhaylov, 2011:23). During the period 2022-2025, several cases of slopes collapse in open pits were recorded in Kazakhstan, which led to significant damage to the mining infrastructure and a and temporary shutdown miming operations. In some cases, the slope collapses consequences were accompanied by workers injury and death, which emphasizes the critical importance of timely and high-quality geotechnical monitoring for quarries sides and slopes stability (Khabarova, 2018:18).

In conditions of Kazakhstan's open pits, slopes landslides and collapse can develop under the both internal and external factors influence. The internal ones include tectonic breaks, fracture zones, the weak presence or weathered rocks, which reduces the massif internal strength. External factors are heavy precipitation and fluctuations in the groundwater level, leading to an increase in pore pressure and a decrease in shear resistance; seismic activity typical for a number of country regions, which can cause destabilizing vibrations; as well as man-made impacts caused by mining operations, including drilling and blasting operations and massive excavations that upset the slopes balance (Sizov, 2012:441).

As shown in Figure 2, these factors can lead to four main mechanisms of slopes and quarries sides destruction:

- shear displacements along weakness zones or tectonic faults;
- rock blocks collapse;
- landslides;
- combined forms of destruction combining several mechanisms.

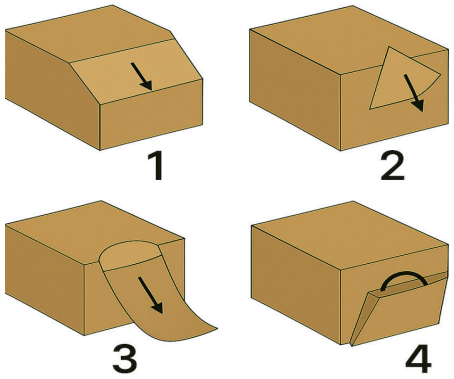



Figure 2. Slope destruction mechanisms in action

1- flat destruction, 2- wedge-shaped destruction, 3- circular destruction (bottom left) and 4 - overturning destruction

In open mining conditions, slope collapse's various mechanisms are observed, which is confirmed by modern researches:

Flat caving, quarry sides significant fragments can slide on flat surfaces formed along crusts, cracks or faults characteristic of the deposits geological structure (Smirnov, 2005:349, Kashkin, 2001).

Wedge-shaped collapse is the most common and potentially dangerous deformation type resulting from the two structural intersection planes that form a wedge, which, under the gravity influence or man-made loads, can separate and descend along the slope (Nurpeisova, 2012).

Circular destruction occurs on slopes composed of relatively homogeneous materials (weathered rocks, cohesive soils) and is characterized by displacement along a curved sliding surface (Nurpeisova, 2024:223). Overturning destruction is recorded in the presence of steeply falling rocks blocks or columns, which, under the gravity influence, washing by groundwater or seismic vibrations, tip over, disrupting the slope stability (Pisciotta, 2021:13, Kim, 2017:222).

Considering the high risks associated with slope collapses and deformations in open-pit rock masses, effective stability monitoring plays a crucial role in ensuring mining safety and maintaining the continuity of production processes (Kenzhekhan, 2022:36). The primary objective of slope stability monitoring is the timely detection and displacement rates analysis, as an increase in deformation often serves as an slope failure early indicator (Dosanov, 2019).

Slope and pit wall destructions rarely occur suddenly; instead, they typically develop gradually as a cumulative displacements result. Therefore, early identification of destabilization signs in pit slopes enables mining companies to implement preventive measures, reduce the emergency situations risks, and ensure mineral deposits the safe and sustainable operation (Fusco, 2023)

Monitoring methods for pit slope stability are generally classified into two main categories based on the data acquisition approach (Figure 3):

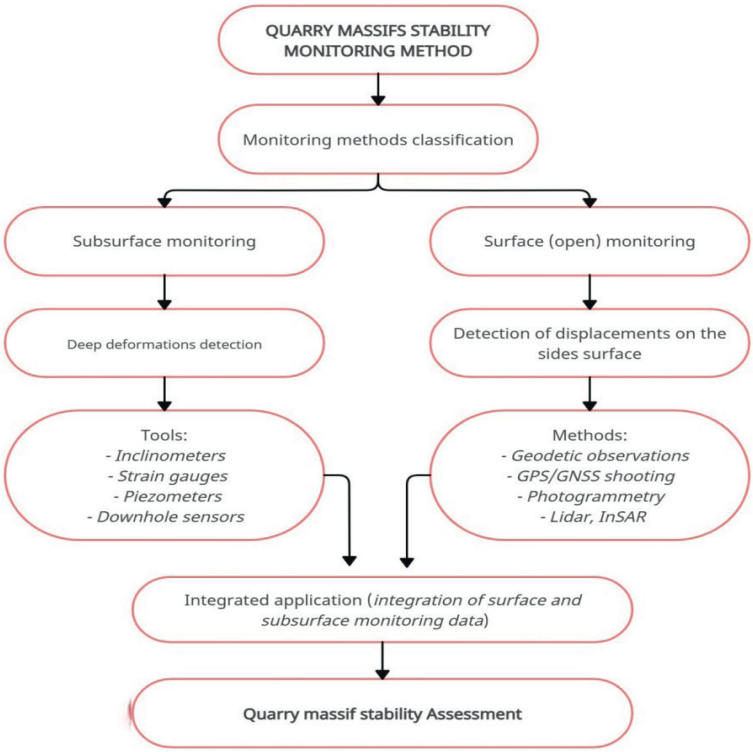



Figure 3. Monitoring methodology's structural diagram for the quarry massif stability

1. Subsurface monitoring focuses on detecting deformation processes within the rock massif, including deep-seated displacements occurring in zones of weathered or weakened rocks and near structural discontinuities. This approach utilizes borehole inclinometers, tensometers, piezometers, and other geotechnical instruments to record variations in the stress–strain state of slope materials.

2. Open mine workings monitoring is focused on identifying and measuring displacements occurring on the sides surface and quarry slopes. Geodetic methods (tacheometric observations, GPS/GNSS), photogrammetry, lidar surveys and satellite radar technologies (InSAR) are used as the main means of control, which make it possible to obtain data on the speed and direction of instrument massifs displacement.

The integrated application of both subsurface and surface monitoring methods provides a pit slope stability comprehensive assessment. This combined approach allows for the destabilization trends timely detection and the proactive measures implementation to prevent hazardous incidents and maintain safe mining operations (Almenoy, 2025:1241).

Traditional approaches to monitoring the condition of open-pit slope rock masses have long been based on the geotechnical instruments and geodetic measurements use, which make it possible to quantitatively assess slope displacements and

deformations (Almenoy, 2025:46). Although technological advancements have significantly improved these processes, a comprehensive understanding of pit slope stability monitoring methods remains fragmented. This is largely due to the absence of review studies that critically analyze both existing and emerging monitoring techniques. Consequently, there is a growing need for a systematic synthesis of accumulated practical experience and scientific findings, an effectiveness objective assessment of current monitoring methods, and the identification of unresolved challenges requiring further research. The ultimate goal is to develop and refine methodologies for pit slope stability monitoring that ensure the reliable real-time data acquisition and enhance the mining operations overall safety (Begalinoy, 2024:34).

Geological structure. A key priority for the mining industry in the Kazakhstan Republic is to improve the open-pit mining operations efficiency and safety. Global mining practice demonstrates that with the increasing depth of open pits, the slope rock massifs stability becomes one of the critical factors determining the resource extraction reliability and economic efficiency.

Thus, open pits annual deepening typically ranges from 20 to 40 meters, which significantly increases the deformation processes risks and landslide phenomena. At the largest mines in India and South Africa, pit depths exceed 1,000 meters; in the United States, Canada, and Australia they reach 800–1,000 meters; while in Russia, Sweden, and Finland, open-pit operations are carried out at depths greater than 500 meters. Under such conditions, the issues of monitoring and controlling slope stability gain particular importance, as they are essential for ensuring the mining operations safety and continuity (Begalinov, 2024:34; Bekbergenov, 2024:66).

Similar tasks are faced by the KazakhstanRepublic mining industry, where several large deposits are under development, including the Akzhal open-pit mine. This site is characterized by significant depth and complex engineering-geological conditions, which necessitate the advanced methods application for monitoring pit slope stability (see Figure 4).

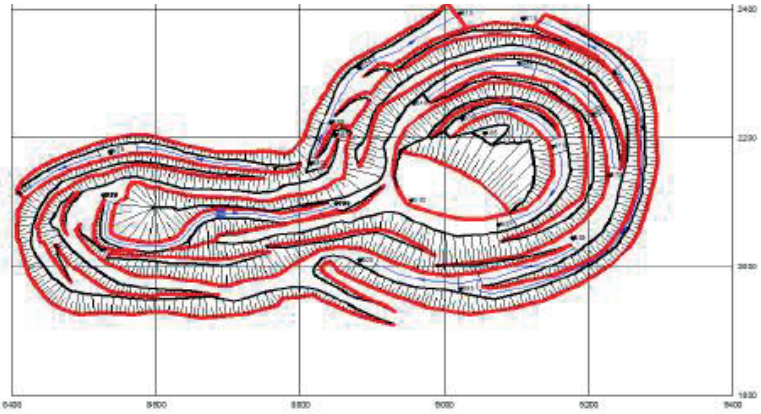


Figure 4. East Quarry Plan

The “Akzhal” deposit’s eastern section is characterized by difficult mining and geological conditions, since it is located on the three large structures junction of the Dzungarian-Balkhash geosynclinal region. In the northern part, the Zhaman-Sarysuysky synclinorium southern wing is observed, in the Aktau-Mointinsky anticlinorium southern and northern parts, and the central zone is confined to the Akzhal-Aksorinsky synclinorium eastern part (Bekbergenov, 2025:07). The field itself is located within the large anticlinal fold southern wing, which core is composed of effusive-pyroclastic rocks of Frasnian age, and the wings are terrigenous-carbonate Famen and Lower Tournai deposits. The most significant Akzhal anticline folded elements, the Central syncline and the Eastern anticline are distinguished in the structure of the area (Bekbergenov, 2024:66).

The deposit is administratively and territorially confined to the Shetsky district of the Karaganda region. At a distance about 90 km southwest from deposit located the Mointy railway station, and about 110 km northwest is the Agadyr station. 12 km north-east from deposit is the Karaganda-Almaty highway.

The nearest mining center is the Balkhash city, located at a distance about 130 km to the southeast. Geomorphologically, the area is characterized by a low, but pronounced in relief ridge, divided into a number of small hills with complex outlines and steep slopes (30-40°) (Duong Van Binh, 2024:268). The uplands are separated from each other by shallow trough-shaped logs, sometimes turning into narrow gorges. Relative elevations are 30-60 m. The Akzhalskoye deposit location coordinates are shown in Figure 5.

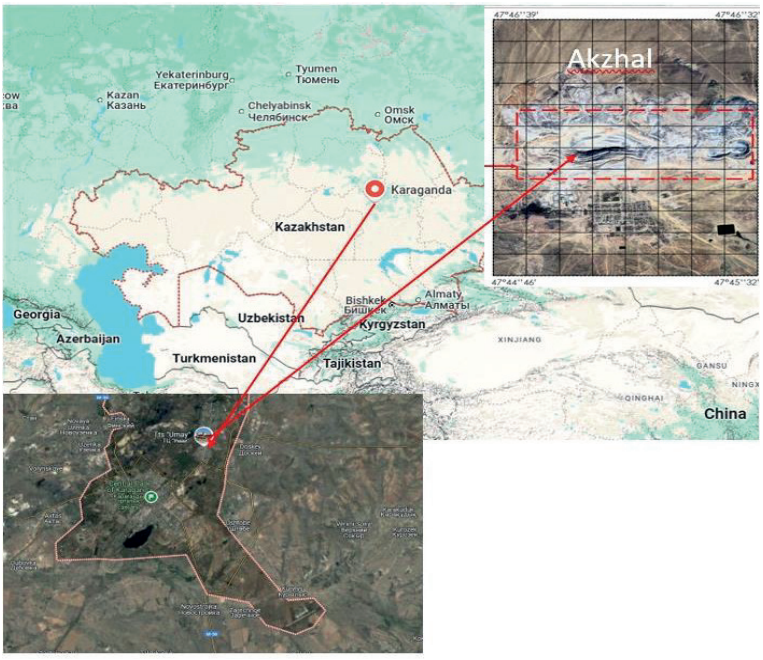
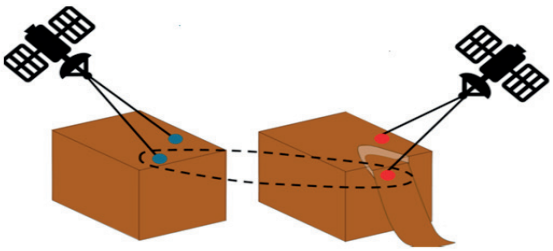



Figure 5. Akzhal field location with coordinates – 47°46’29’’N73°59’22” E

**Materials and methods of research**. For a quarries pit wall stability comprehensive assessment, a wide range of methods is used, which can be conditionally divided into several main groups: geodetic, geotechnical, geophysical, geomechanical, analytical and numerical, as well as visual observations. Each of these approaches has its own purpose: from displacements and deformations direct measurement to forecasting the processes development based on modeling. Their combination allows not only to record the slope rock massifs current state, but also to identify hidden hazardous areas, as well as to develop measures to prevent emergency situations.

One of the most accessible and widely applied techniques for monitoring the open-pit slope rock masses stability is tacheometric surveying. Tacheometers enable high-precision measurements of angular and linear variations between a stationary instrument and reflective prisms installed along the pit slopes. Repeated surveys allow to detect even rock mass minor displacements and facilitate the long-term deformation trends observation.

In addition to tacheometric surveying, modern geodetic monitoring employs other advanced technologies, notably the Global Positioning System (GPS) and pseudolite (PL) systems. These methods are based on the differential positioning principles and enable the determination of points relative displacements situated along pit slopes and benches (Keximov, 2024; Alimkuloy, 2023). Unlike traditional measurement approaches, GPS and PL systems provide autonomous, real-time monitoring with millimeter-level accuracy (Liu, 2025; Fusco, 2023), making them particularly effective for large-scale slope stability control. The tacheometric integrated application, GPS, and PL measurements ensures high data reliability and enables the potentially hazardous slope movements timely detection, thus representing a modern methodologies core component for open-pit slope stability monitoring (Lesnikoy, 2024:22).



- GPS-coordinates recorded during primary survey
- GPS-coordinates revealing circular destruction during second survey

Figure 6. Differential GPS positioning to detect circular landslide processes

The assessment of pit slope stability is a multi-stage process that combines instrumental, analytical, and modeling methods aimed at developing a rock mass condition comprehensive understanding and forecasting its temporal behavior. Figure 6 presents a schematic representation of the slope stability assessment

process, which is based on a comprehensive, iterative geomechanical control cycle (Zhumagalieva, 2023:96).

This integrated approach provides a systematic framework for combining various observation and analysis methods, thereby enhancing the predictions reliability and enabling the potentially hazardous zones early identification (Fig. 6).

The process begins with the geomechanical methods application, which determine the fundamental strength and rocks deformability parameters — serving as the foundation for subsequent modeling. The next phase involves dynamic monitoring, during which three principal groups of methods operate concurrently, forming a unified diagnostic complex:

- Geodetic methods, characterized by high precision, record even minimal surface displacements;
- Geotechnical methods monitor subsurface processes and groundwater levels;
- Geophysical methods perform mass probing, revealing concealed structural heterogeneities and potential failure zones.

The final stage is the stability evaluation, which serves as a critical decision-making point in ensuring operational safety and risk management during open-pit exploitation (Fig. 7).

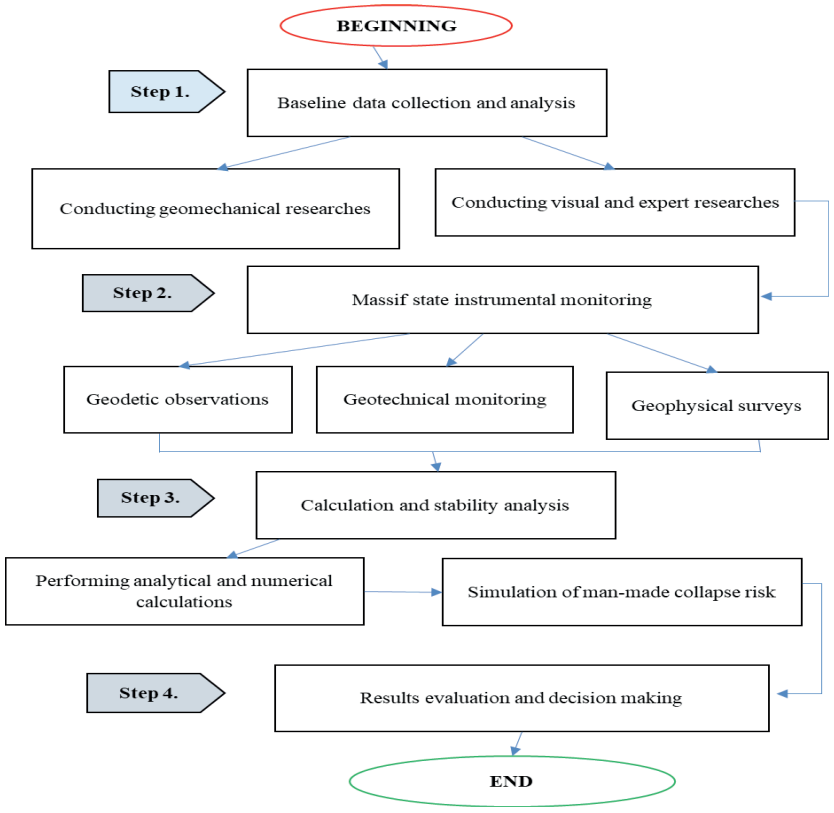



Figure 7. Implementation scheme of pit slopes stability assessment

**Results.** Для моделирования техногенного риска обрушения подземных горных выработок, обусловленного деформационными свойствами бортов Центрального карьера, предлагается следующий поэтапный алгоритм моделирования:

*1-ǔ stage* includes the geomechanical risks assessment typically for Akzhal deposit active production areas, using modern methods of geomechanical investigations.

*2-ǔ stage* is aimed to localizing potentially hazardous zones forming within the pit slopes and affecting transport communications, personnel movement, and the placement of infrastructure facilities within the potential collapse zone.

*3-ǔ stage* provides for the natural stress field determination, which makes it possible to more fully characterize deformation zones and establish their influence degree on the stability of pit slopes.

*4-ǔ stage* is related to the analysis of initial data obtained during previously conducted scientific research and engineering–geological works, including the geomechanical and geodetic observations results.

*5-ǔ and 6-ǔ stages* represent the pit slope stability calculation and their impact assessment on the underground mine workings safety, which makes it possible to identify critical areas and predict the deformation processes development.

At present, during the sub-pit reserves extraction in the Akzhal deposit's Central pit, the sudden collapse risks of the Central pit's southern slope have been identified.

**Discussion.** The stability assessment results along the southern slope's geological profiles indicate that it is in a limiting equilibrium state. A high potential for slope collapse is observed, which is associated with underground mining carried out using a caving system. This led to the formation of massif's increased movement zones. These conditions pose a risk to mining productivity, may cause equipment damage, and threaten the personnel life and health (Bekbergenov, 2025:07).

There is also an air shock waves risk occurring in underground workings: during the previously mined-out stopes inspection, a direct aerodynamic connection was identified between the underground workings and the open-pit space (Figure 8).

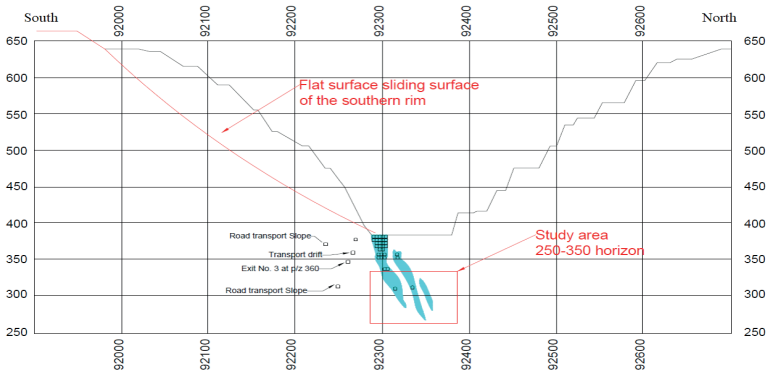



Figure 8. Geological cross-section of the Central area along profile V

On-site measurements of the natural stress fields at the Akzhal deposit have not been previously performed; therefore, their evaluation was carried out based on data from the international World Stress Map (WSM) project. According to the WSM database, the rock massif's natural stress state in the deposit area is characterized predominantly by a Strike–Slip (SS) tectonic deformation regime. Along the ore body strike, the magnitude of horizontal stress is approximately 1.9 MPa, and in the direction perpendicular to the strike — about 1.4 MPa (Figure 9) (Bekbergenov, 2024:66)

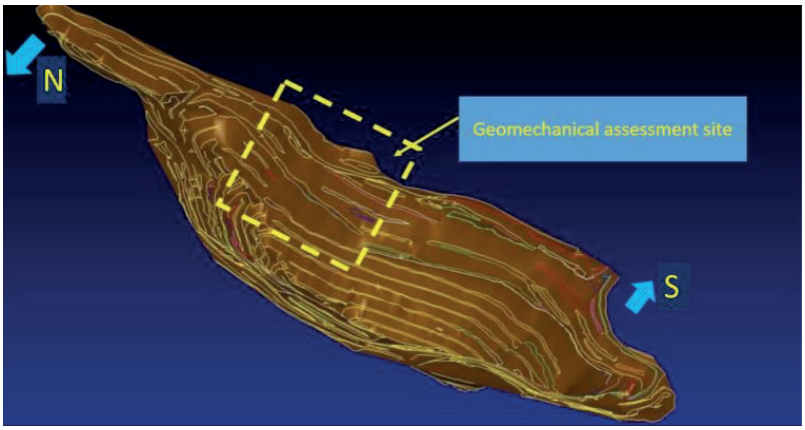



Figure 9. Geomechanical assessment site

Southern slope area modeling was performed along three profile lines (A, B, C). Since the available geological profiles have an inclined vector, profile lines with direct dip were constructed in the Micromine software, covering elevations from +660 m to +400 m (Figure 10).

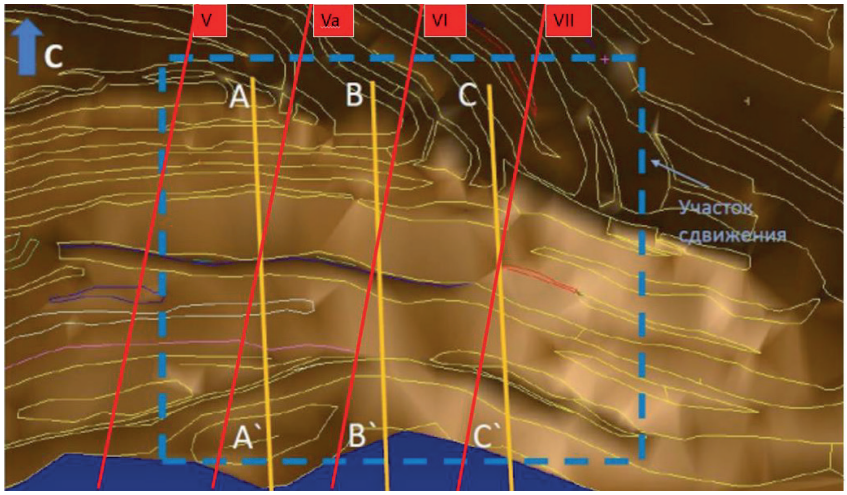



Figure 10. Geomechanical assessment site with cross-sections

Further, to assess the local slope section stability, the evaluation was carried out considering the key elements of the pit slope monitoring methodology. To obtain initial data, all influencing factors were thoroughly analyzed and taken into account, including rock massif's geological and hydrological conditions, physical–mechanical properties, and technological parameters. Based on these data, slope stability analysis was performed using Slide2 software (Figure 11).

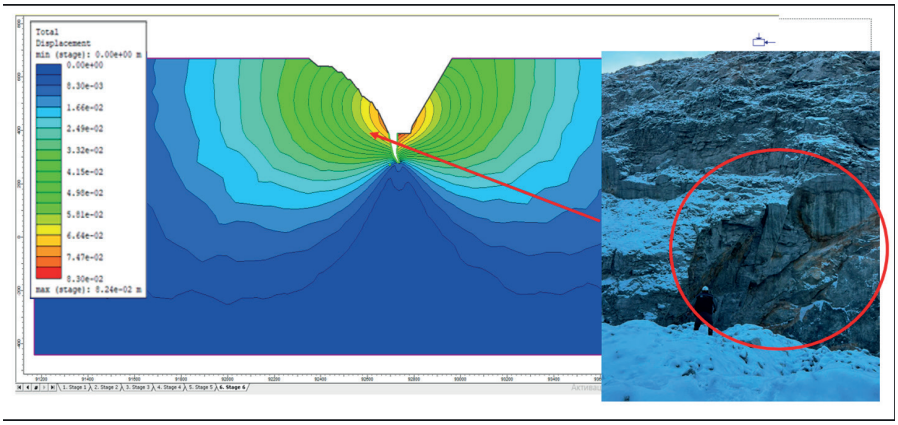



Figure 11. Pit slope massif's stability analysis results performed in the software environment Slide2

The model's computational boundary was established by extending the mining zone threefold relative to its actual dimensions. This model expansion allows to consider the mining operations influence on the rock massif stability within a broader area and enables prediction of possible changes in its geometry at different stages of development. Such an approach is an important condition for a correct risk assessment and for substantiating the optimal mining methods choice.

The conducted geomechanical modeling provides predictive data on the ground surface's behavior and condition above the mined-out space. This is critically important for assessing the technogenic disasters risk both during ore extraction and after mining operations are completed

For the Akzhal deposit, whose projected operational life is 25–30 years, systematic monitoring is required. It is considered essential to conduct regular researches of the geomechanical and geotechnical processes development within the rock mass, as well as ground surface behavior continuous instrumental monitoring. Such an approach will allow timely adjustments, hazardous zones refinement, and the preventive measures development to avoid technogenic disasters. Moreover, understanding the mining influence limits ensures the buildings safety, engineering and infrastructure facilities, as well as underground communications.

**Conclusions.** As a research result, an improved methodology for monitoring the pit slope rock masses stability has been developed and tested. The method is based on the differential GPS positioning integrated application, geomechanical modeling, and an automated data collection system. The high-precision communication

system use at the base station ensured data transmission stability and deformation process accuracy recording in real time. The obtained results confirm the integrated methodology effectiveness for the early slope failure detection mechanisms and for forecasting their development. The proposed approach improves the reliability of pit slope stability, enables timely hazardous zones identification, and allows for the preventive stabilization measures implementation. The research results can be used in geomechanical monitoring systems of existing and planned open-pit mines, as well as in engineering calculations for the underground and transport workings design.

**References**

Alessandro Pisciotta G., Dardanelli G., Maltese A., Pipitone C., & Lo Brutto M. (2021) NRTK, PPP or Static, That Is the Question. Testing Different Positioning Solutions for GNSS Survey. Remote Sensing, 13, 1406. https://doi.org/10.3390/rs13071406 (in English)

Alimenov T., Zhanakova R., Sarybayev M., & Shabaz D.-M. (2025) A Novel Approach to Selecting Rational Supports for Underground Mining Workings. Civil Engineering Journal, 11(3). — P. 1217–1241. https://doi.org/10.28991/CEJ-2025-011-03-022 (in English)

Almenov T.M., Zhanakova R.K., Askarova G.E., Shautenov M.R., & Amantayuly K. (2025) Comprehensive assessment of ore losses and dilution impacting Vasilkovsky gold deposit profitability. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, (4). — P. 27–46. https://doi.org/10.32014/2025.2518-170X.528 (in English)

Alimkulov S.K. (2023) Osnovnye gidrograficheskie svedeniya o rekakh i vremennykh vodotokakh Balkash-Alakol'skogo basseina. [Basic hydrographic information about rivers and temporary watercourses of the Balkash-Alakol basin]. Biology. Medicine. Geography. 1(109). — P. 195–205. (in Russian)

Begalinov A., Almenov T., Zhanakova R., & Bektur B. (2020) Analysis of the stress-deformed state of rocks around the haulage roadway of the Beskempir field (Kazakhstan). Mining of Mineral Deposits, 14(3). — P. 28–36. https://doi.org/10.33271/mining14.03.028 (in English)

Begalinov A., Shautenov M., Peregudov V., Almenov T., Bektur B., & Sakhipova K. (2024) Research of gravity concentration of the gold placer of Eastern Kazakhstan. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 3(465). — P. 17–34. https://doi.org/10.32014/2024.2518-170X.407 (in English)

Bekbergenov D.K., Jangulova G.K., Zhanakova R., & Bektur B. (2024) Investigation of the block caving geotechnology at deep horizons. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 6(468). — P. 49–66. https://doi.org/10.32014/2024.2518-170X.460 (in English)

Bekbergenov D.K., Jangulova G.K., Zeinullin A., Zhanakova R., Shagirova K., Atalykova N., & Kurmanbayev O. (2025) Modeling of Geomechanical Processes from Open Pit to Underground Mining with Complex Morphology. Civil Engineering Journal, 11(7). https://civilejournal.org/index.php/cej/article/view/6017/1882 (in English)

Fusco F., Magliulo P., Guerriero L., et al. (2023) A revised landslide inventory of the Campania region (Italy). Scientific Data, 10. (in English)

Kashkin V. B., & Sukhinin A. I. (2001) Distantsionnoe zondirovanie Zemli iz kosmosa. Tsifrovaya obrabotka izobrazheniy [Remote sensing of the Earth from space. Digital image processing]. Moscow: Logos. (in Russian)

Kenjezhan E.B., & Aben A. (2022) Geodeziyalyk zhosparly-biyiktik negizdemeni kuruda GPS tehnologiyasy [GPS technology in the construction of a geodetic plan-altitude framework]. In Proceedings of the International Scientific and Practical Conference "Innovative Technologies in Geospatial Digital Engineering". — P. 34–36. (in Kazakh)

Kerimov I.I., Gakaev A.A., & Adaev Kh.A. (2024) Primenenie geofizicheskikh metodov pri

izuchenii opolznevykh protsessov [Application of geophysical methods in the study of landslide processes]. GeoYug, 1. — P. 25–33. (in Russian)

Kim J., Song J., No H., Han D., Kim D., Park B., & Kee C. (2017) Accuracy Improvement of DGPS for Low-Cost Single-Frequency Receiver Using Modified Flächen Korrektur Parameter Correction. ISPRS Int. J. Geo-Inf., 6, 222. (in English)

Lesnikov V.G., Tkachev P.V., & Yushchuk I.V. (2024) Geodezicheskoe obespechenie monitoringa opolzney [Geodetic support for monitoring the use of]. Geomatika, 2(38). — P. 15–22. (in Russian)

Liu Y., Zhang M., & Wang S. (2025) When Time Prevails: The Perils of Overlooking Temporal Landscape Evolution in Landslide Susceptibility Predictions. Remote Sensing. (in English)

Mikhailov S.I. (2011) Primenenie dannykh distantsionnogo zondirovaniya Zemli dlya resheniya zadach v oblasti sel'skokhozyaistvennogo proizvodstva [The use of remote sensing data for solving problems in the field of agricultural production]. Earth from outer space, 9. — P. 17–23. (in Russian)

Nurpeisova M.B., Kyrgyzbaeva G.M., & Aitkazinova Sh. (2012) Perspektivy ispol'zovaniya sovremennykh priborov dlya geomekhanicheskogo monitoringa prirodno-tekhnicheskikh sistem [Prospects of using modern devices for geomechanical monitoring of natural engineering systems]. In Proceedings of the International Conference "Gornoe delo i metallurgiya v Kazakhstane. Sostoyanie i perspektivy." (in Russian)

Nurpeisova M.B., Kurmanbayev O.S., Jangulova G.K., Sarsembekova Z., Ormanbekova A., & Kakimzhanov E.Kh. (2024) Creation of Geodetic Reference Network for Monitoring Transport Interchanges in Seismic Areas. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 4(466). — P. 209–223. https://doi.org/10.32014/2024.2518-170X.436 (in English)

Sizov A.P., Khabarov D.A., & Khabarova I.A. (2018) Novye podkhody k razrabotke metodiki formirovaniya semanticheskoi informatsii monitoringa zemel' na osnove obrabotki i analiza kartograficheskoi informatsii [New approaches to the development of methods for the formation of semantic information on land monitoring based on the processing and analysis of cartographic information]. Geodesy and Aerial Photography, 4. — P. 434–441. (in Russian)

Smirnov L.E. (2005) Aerokosmicheskie metody geograficheskikh issledovanii [Aerocosmic methods of geographical research]. St. Petersburg: St. Petersburg University Press. (in Russian)

Khabarova I.A., Khabarov D.A., & Chugunov V.A. (2018) Razrabotka metodiki lesotaksatsionnogo deshifrirovaniya s ispol'zovaniem GIS-tekhnologii po kosmicheskim snimkam [Development of a method of forest taxonomy decryption using GIS technology based on satellite images]. Integral Journal of Applied Sciences and Technologies, 1. — 18 p. (in Russian)

Zhyong Van Binh, Fomenko I.K., Nguyen C.K., et al. (2024) Otsenka opolznevoi opasnosti s ispol'zovaniem metoda sootnosheniya chastot i kombinovannogo fraktal'no-chastotnogo metoda (na primere Tinh Tuck, Vietnam) [Screening of landslide hazards using the frequency ratio method and the combined fractal-frequency method (using the example of Tinkh Tutsk, Vietnam)]. Notes of the Mining Institute, 268. (in Russian)

Zhumagalieva A.K., & Turebaev Zh.K. (2023) Sozdanie tsifrovoi modeli rel'efa dlya otsenki opasnosti selevykh protsessov na primere reki Talgar [Creation of a digital relay model for screening out the danger of mudflow processes using the example of the Talgar River]. Geoecology. Engineering Geology, Hydrogeology, Geocryology, 2. — P. 88–96. (in Russian)

**Publication Ethics and Publication Malpractice**
**in the journals of the Central Asian Academic Research Center LLP**

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 journals of the Central Asian Academic Research Center LLP 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 Central Asian Academic Research Center LLP 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 Central Asian Academic Research Center LLP.

The Editorial Board of the Central Asian Academic Research Center LLP will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:
**www:nauka-nanrk.kz**
**http://www.geolog-technical.kz/index.php/en/**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**

Ответственный редактор *А. Ботанқызы*
Редакторы: *Д.С. Аленов, Т. Апендиев*
Верстка на компьютере: *Г.Д. Жадырановой*

Подписано в печать 15.12.2025.
Формат 70x90$^{1}/_{16}$. 20,5 п.л.
Заказ 6.

*«Central Asian Academic Research Center» LLP*
*Алматы, Қонаев к-сі, 142*