MINERALOGICAL SOCIETY OF GEORGIA
G. TSULUKIDZE MINING INSTITUTE
GEORGIAN TECHNICAL UNIVERSITY
INSTITUTE OF HYDROGEOLOGY AND ENGINEERING GEOLOGY

# THE DEVELOPMENT OF MINING AND GEOLOGY IS THE PRECONDITION FOR THE REVIVAL OF ECONOMY

## BOOK OF ABSTRACTS

11th International Scientific-Practical Conference on Up-to-date Problems of Mining and Geology

**25-26 September, 2025**

**Tbilisi**

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RMG

RICH METALS GROUP

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# GEOMECHANICAL STUDY OF OPEN-PIT MINES (RMG GOLD/COPPER OPERATIONAL SITE)

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Rich Metals Group operates the Bolnisi open-pit mines in the Kvemo Kartli region of southern Georgia, with primary operational deposits located at Madneuli, Sakdrisi, Bneli-Khevi, and Mushevani. The operational history of RMG Copper began in 1975 and has continued successfully to the present day. The mine produces copper-gold concentrate, silver, and other polymetallic ores. RMG Gold focuses on the heap leaching of gold from secondary quartzite ore.

It should be noted that the active open-pit mines operated by the RMG Group exhibit significant variability in the structural-lithological composition and geotechnical properties of the host rock formations. Consequently, each site necessitates a site-specific geomechanical assessment approach to ensure accurate analysis and appropriate mine design.

The Madneuli deposit is situated within the Upper Cretaceous volcanogenic and volcanogenic-sedimentary sequence, commonly referred to as the Mashavera sequence [1]. This sequence comprises intermediate to acidic tuffs, tuff breccias, ignimbrites, and various types of cross-cutting dacites, along with rhyodacites and andesitic-basaltic dikes.

The Sakdrisi deposit is located near Kazreti, in Dmanisi municipality. The Sakdrisi deposit consists of 5 ore nodules stretching along a northeast-trending fault. The structural setting also includes several northwest-trending transverse faults intersecting the main fault zone.

The Sakdrisi deposit belongs to the epithermal type of deposits in terms of mineral composition and the nature of hydrothermal alterations. There are versions that it is connected to the southern peripheral part of the complex Late Cretaceous Darbazi-Abulmulk caldera [2].

The Bektakari epithermal prospect consists of two distinct ore zones: one silicified zone exposed on surface with local barite and enriched in gold devoid of base metals, and a second zone crosscut by drilling, consisting of a lithologically controlled, folded breccia sequence mineralized with base and precious metals. The main opaque minerals in the latter ore zone are sphalerite, chalcopyrite, pyrite, barite, and galena and tennantite-tetrahedrite, cementing the clasts of the breccia [3]

The Mushevani 2 gold-copper polymetallic deposit is located between the Madneuli and Lower Bolnisi deposits and occupies the southeastern slope of the mountain at 1026.6 m. The rocks containing the deposit are represented by volcanics of the Mashavera Formation of Upper Cretaceous and Cenomanian age and volcanogenic-sedimentary rocks.

The Bneli-Khevi deposit is located in the Tetritskaro Municipality. The deposit is localized within upper cretaceous Santonian stage rhyodacite tuffs, which are subdivided into two main horizons: crystal-lithostatic, aerolitic, psammitic, and psephitic tuffs and agglomerate and pelitic, occasionally interbedded with lenses and intermediate layers [4].

Geotechnical investigation and assessment of the open-pit mines conduct using modern geotechnical methodologies. Parameterization of the rock mass and fault zones used for geotechnical modeling is based on detailed field and laboratory investigations.

Field activities include structural mapping of pit benches, geotechnical logging of core samples from vertical boreholes, and sample collection for subsequent laboratory testing.

Geotechnical modeling performs using Rocscience software tools: Dips, RocPlane, RS2, Slide2, Slide3 and Swedge. Geotechnical domains defines based on the structural interpretation of pit exposures and core logs. The modeling results provids key input on pit geometry optimization, particularly the determination of bench design parameters.

Kinematic slope analysis carry out using Dips, identifying potential planar and wedge failures related to dominant joint sets. Bench design parameters and safety factors determine using Swedge and RocPlane.

For the principal lithological units forming each deposit, dominant structural discontinuities identifies. Kinematic analysis applies to each sector to identify segments potentially prone to planar or wedge failures, along with their controlling structural features. For sectors vulnerable to such instabilities, bench design and factor of safety (FoS) calculations performes using Swedge and RocPlane.

In the assessment of slope stability for certain open-pit mines, we apply the Q-slope method. Q-slope offers a rapid and efficient empirical approach for preliminary design of reinforcement-free rock slopes. The method incorporates the main components of the original Q-system (RQD, Jn, Jr, Ja), along with environmental (Jwice) and stress-related (SRF_slope) factors, enabling real-time evaluation of slope stability under field conditions.

The study is based on comprehensive geotechnical fieldwork and laboratory investigations. Using the collected data, Q-slope indices were calculated for different geotechnical domains within the open pit, and recommended slope angles were derived using the Q-slope empirical formula. The predicted values were then compared against observed stable slope geometries, demonstrating a high degree of correlation and validating the effectiveness of the method for preliminary and optimization-stage open-pit design. The results confirm the applicability and reliability of the Q-slope method under conditions of lithological and structural heterogeneity

Geotechnical modeling of open-pit mining operations is essential for ensuring the safe operation of the pits and for the accurate economic evaluation of mine planning.

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# STUDY OF THE EXPLOSIVE PROPERTIES OF METHANE AND COAL DUST MIXTURE

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Methane and coal dust are two of the most significant contributors to underground coal mine explosions. Their combined presence creates a hybrid mixture with enhanced explosive potential, posing serious safety risks in mining operations. The first recorded information about a coal mine explosion dates back to 1621, when 30 miners died as a result of an explosion in Gateshead, England, UK [1]. Since then, mining engineers have been developing methods and protective measures to prevent explosions in coal mines. Despite the implementation of these methods and measures, several hundred miners still die or are injured annually due to explosions.

During the recent 20 years, more, than 50 serious accidents were occurred in the mines of USA, Peoples Republic of China, Russian Federation, Ukraine, Turkey, Poland, Czech Republic, Georgia and other countries, which were caused by explosion of methane and coal dust [1, 2].

The experts expect to increase the threat of explosion of methane and coal dust in Coal mines in future. It is related to much deeper mining of coal, where the mining-geological and mining-technical conditions are much complicated and these coal layers are characterized with higher content of methane [1, 2, 3].

According the normative documents acting currently in the different countries, the explosive and flammable material`s concentrations in the working environment shouldn`t exceed the applicable concentrations. The applicable concentration of methane in the mines of different countries varied from 0.5% to 2% and the flammable admixtures in the coal dust shouldn`t exceed 20-35%; the specific percentage indicators are defined for non-flammable admixture compositions, which is given according the distances from the spots of coalface cleaning areas in the tunnels [1, 2, 3].

The explosions present a serious problem in Georgia as well, for the "Tkibul– Shaori" coal ore shafts. In last 20 years (2010, 2011, 2013, 2014, 2015, 2016, 2018, 2022) 29 miners died and 24 injured from Explosion accidents in Georgia [3].

The paper presents the results of experimental work in the shock tube, in which was explored in Georgia being "Tkibul-Shaori" coal ore's mines detonation, deflagration and ignition characteristics conditions of coal dust and methane containing mixtures.

Investigation of flammability and explosion characteristics were performed in Shock Tube. General view of the Shock tube is shown on (Fig. 1). The shock tube consists of a blast chamber, tubes sections, computer system for the dosed supply of methane and coal dust, sensors, data recording equipment and a process control module. The shock tube is located in a tunnel. The data recording equipment and the control module are located in the monitoring station located at a 6m distance from the tunnel entrance. Key technical characteristics of the blast chamber and separate tubes are as follows: diameter of blast chamber and tubes – 50 cm; length of blast chamber – 50 cm; length of separate tubes – 1 m; wall thickness – 8mm; number of separate tubes– 10, total length of shock tube – 10.5 m [4].

fig 1. Shock tube in underground experimental base of the Mining Institute

Injection of Methane gas (94% purity) was performed from high pressure gas container. Dosed injection of coal dust of different fraction was provided from dust chamber. The fire work electric igniter ware used for explosion initiation. PCB pressure sensors were installed in blasting chamber Distance from initiating point to sensor was 5.5m. The signals were recorded by digital oscilloscope Tektronix DPO 4034. Besides, high speed video camera" Motion BLITZ" was installed on window of shock tube for in situ monitoring of ignition and explosion of hybrid mixture. Drager x-am 5000, with external pump was used for determination of methane gas concentration in chamber (fig. 2).

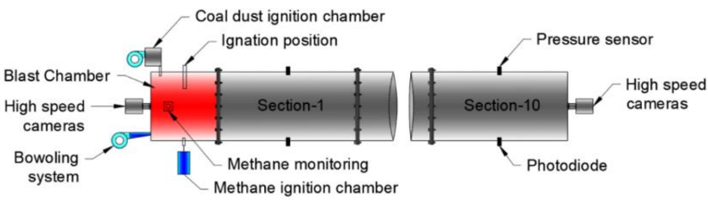


Fig. 2. Schematic circuit of experimental set-up

Experiments on explosion initiation was performed in two modes: a) Pure methane of different concentration (varied between 5-13 vol.%) were injected in shock tube and initiated; b) Hybrid mixture composed from methane (5%) and coal dust of different fraction (0,5-0,2mm; 0,2-0,1mm; ≤0,1mm) and concentration (50gr/m³, 25gr/m³ 10gr/m³) were injected in chamber and initiated.Series of experiments were performed to determine the impact of coal dust concentration and fraction of coal particles on explosion initiation and propagation in Hybrid mixture of Methane and Coal Dust. Experimentally recorded the overpressure histories for difference concentration of methane in shock tube, as well as for hybrid mixture of Methane and Coal Dust, with various dust concentration and particle sizes. Coefficient of maximum rise overpressure were calculated by experimentally obtained results. The flame propagation in shock tube for different composition of ignition system were monitored and high-speed video images were recorded.

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# RELATIONSHIP BETWEEN UNIAXIAL COMPRESSIVE STRENGTH (UCS) AND POROSITY IN BASALT

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The objective of this study is to establish a correlational relationship between the porosity of basalt and its uniaxial compressive strength (UCS).

Due to the mass demand for construction materials for infrastructure in Georgia, there is a need for detailed information on various hard rocks like basalt.

Therefore, we carried out intensive field and laboratory works to determine the impact of porosity in basalt on uniaxial compressive strength.

Basalt, a widespread extrusive volcanic rock, is commonly used in constructions, basalt fiber production, and as aggregate in concrete, as well as in infrastructure projects that require durable materials due to its outstanding physical and mechanical properties. The main physical-mechanical properties of basalt is its Uniaxial Compressive Strength (UCS), and porosity.

Identifying the relationship between porosity and UCS allows for more efficient selection of basalt materials, saving both time and financial resources. Thus the topic represents a relevant scientific and technical challenge.

To explore the UCS-Porosity relationship, a series of basalt rock samples were collected from Kvemo Kartli region, which had different depths from the surface and most importantly, varying degrees of porosity.

The samples underwent combination of laboratory tests to measure their UCS, specific gravity and bulk density [1]. The

UCS was measured using a standard uniaxial compression test, where a rock specimen is compressed along a single axis until failure occurs [2]. The porosity of each sample was estimated by the porosity coefficient, determined with the help of specific gravity and bulk density of rocks [3, 4].

The experimental results from basalt samples show a clear trend of decreasing UCS with increasing porosity (Fig.1). As expected, basalt with lower porosity exhibited higher compressive strength, suggesting that the intact rock structure is more capable of bearing loads.

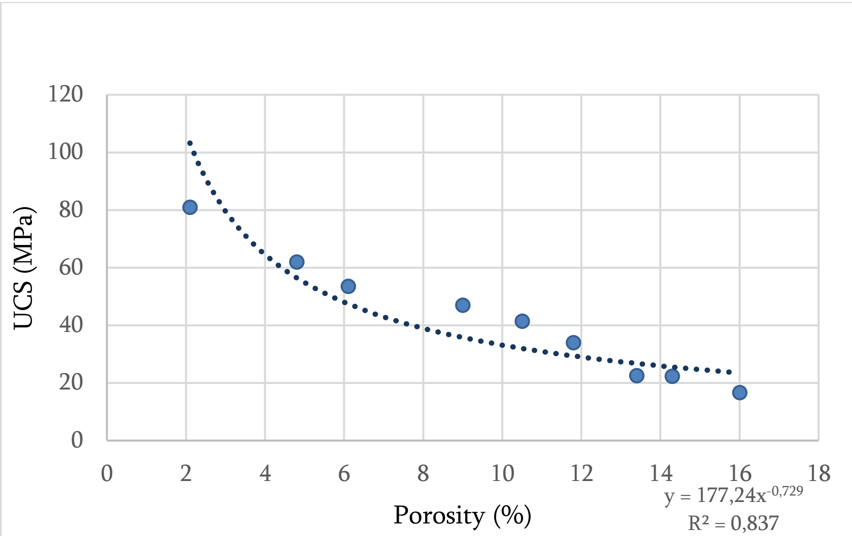


Fig.1. Relationship of Porosity and UCS for Basalt

Interestingly, the relationship between UCS and porosity was not strictly linear. At 2% to 6% porosity levels, the decrease in UCS was more pronounced, than samples with higher porosity.

The study confirms that there is a strong inverse relationship between the Uniaxial Compressive Strength (UCS) and porosity in basalt rocks. As the porosity increases, the UCS decreases, largely due to the weakening of the rock's structure by the voids and fractures. This relationship is crucial for engineering and construction projects that involve basalt, since the porosity of the material is relatively easy parameter to determine and needs less time and financial resources.

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# POTENTIAL OF CRITICAL ELEMENTS IN GEORGIA: EXISTING RESOURCES AND GEOSTRATEGIC IMPORTANCE

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The global economy is currently undergoing a crucial phase of transition, where energy transformation, technological innovations, and environmental challenges are sharply increasing the focus on a country's natural resources and their sustainable management. In this context, special attention is paid to critical elements and metals that play an essential role in the development of high-tech devices, renewable energy systems, and the defense industry.

Currently, according to a joint assessment by Geoscience Australia and its international partners including the United States, Japan, South Korea, the United Kingdom, and the European Union those resources are considered critical which are essential for the production of high-tech, energy-related, and military products. Critical elements are classified as minerals and raw materials for which global demand remains consistently high, while supply is limited due to factors such as geological scarcity, geopolitical tensions, and trade barriers. As a result, diversifying access to these elements has become one of the most pressing challenges in today's geopolitical context. The most critically assessed elements include: Rare Earth Elements (REE), Gallium (Ga), Indium (In), Tungsten (W), Platinum Group Elements (PGE) including Platinum (Pt) and Palladium (Pd), Cobalt (Co), Niobium (Nb), Magnesium (Mg), Molybdenum (Mo), Antimony (Sb), Lithium (Li), Vanadium (V), Nickel (Ni), Tantalum (Ta), Tellurium (Te), Chromium (Cr), and Manganese

(Mn).

Georgia, as a geostrategic hub located between Europe and Asia, has the potential to significantly contribute to global access to critical elements. The country's geological structure and diversity of metallogenic zones indicate the potential presence of important elements such as: Antimony (Sb), Manganese (Mn), Nickel (Ni), Vanadium (V), Molybdenum (Mo), Cobalt (Co), Lithium (Li), and Rare Earth Elements (REE). Identifying and efficiently exploiting these resources could become a key direction for Georgia's economic development and its integration into the glbal resource supply chain.

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# GEOLOGICAL AND TECHNOLOGICAL STUDY OF CLAY ORE OCCURRENCE IN GURIA

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A geological and technological study was conducted of 17 little-known and unlicensed clay occurrences in the Guria region.

The region is rich in deposits and occurrences of various types of clays, with diverse distributions and compositions. Clays, and in particular bentonites, are an important and main mineral resource in the territory of Guria.

Given the wide distribution of these formations, their genesis and formation conditions are of great interest, as they are related to important issues in the geological structure and development history of the given region.

This territory is an important province of Georgia in terms of the distribution of volcanic rocks. Intensive effusive volcanism was observed here in the Paleogene era, the main phase of which manifested itself in the Middle Eocene.

The result is a powerful volcanogenic-sedimentary formation, where two stages of volcanism development are distinguished: early-alkaline and late, alkaline or subalkaline in nature. The changing nature of volcanism is expressed in the diversity of widespread formations.

In general, the territory, distinguished by a complex tectonic structure, is composed of Upper Cretaceous limestones and marls, Paleocene-Lower Eocene coloured marls, Middle

Eocene powerful volcanogenic-sedimentary strata, as well as magmatic bodies of various forms of occurrence and composition, Upper Eocene foraminiferal marls and lyrolepis horizon, Oligocene-Lower Miocene rocks of the Maikop formation, Middle and Upper Miocene limestones and marls, Pliocene conglomerates, clays, sands and Quaternary deposits.

Clay occurrences, despite the differences in the causes of the clay formation process, are mainly related to the region's sediments, rocks of various composition and origin. Most often, they are the product of their gradual transformation over time and are mainly located in them (eluvial-sedimentary clays).

The formation of some clay deposits was associated with climatic conditions and, accordingly, surface silt processes. In such natural outcrops to the surface, zoning is visible - the transition of pelitic material into coarse-grained, semi-eroded, and then into the parent rock.

Complex spatial (Mtispiri, Bzhuzhi, etc.) zoning of the useful body and a detailed study of hydrothermal-metasomatic changes showed and made more or less acceptable the hydrothermal origin of bentonite and kaolin clays of this region.

There is an opinion about their appearance as a product of halmyrolytic weathering.

A significant part of the manifestations is associated with marine or river conglomerates and are found in the form of primary, and mainly secondary (sedimented) deposits.

Some of the clay outcrops are associated with the laterite-like weathering crust, which is widespread in the region. These clays are mainly red or yellow. They are characterized by different granulometric and mineral compositions, and are alluvial or eluvial depending on their origin.

The clays are mainly of polymineral composition with a predominant content of certain clay minerals. In this regard, montmorillonite (Sameba, Buknari, Aketi, Askana, Mshvidoburi, Nasakirali, etc.), halloysite (Fartskhnisi, Mamati, etc.), or kaolin (Makvaneti, Gonebis kari, etc.) clays are distinguished. Such clays usually contain Ca–Na feldspar, quartz, hydromicas, etc.

They also differ in chemical composition, depending on the clay deposit, the main oxide components vary within the range: $SiO_2$ content 37 - 61%, $Al_2O_3$ content 13.4 - 25%; clays of all manifestations contain iron oxide in the amount of 2.2 - 14%. Increased iron content is typical for clays associated with laterite (Mamati, Nasakirali, Mshvidoburi).

The material composition of 19 technological samples, compiled from surface samples of various clay deposits and ore occurrences of the Guria region, was studied. X-ray phase and silicate analyses were carried out. According to the results of X-ray phase analysis, clay minerals are represented mainly by halloysite, Ca-montmorillonite, hydromica, and rarely kaolinite, and silt material is represented by feldspar and quartz. The results of silicate analysis are given in Table 1.

Table 1

**Results of silicate analysis, %**

| Name of villages, Location | Content, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Moisture | loss on ignition | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ |
| Shua Fartskhisi | 4,22 | 10,20 | 44,6 | 3,3 | 21,9 | 11,3 | 0,5 | 1,92 | 0,24 | 1,24 |
| Shua Amagleba | 8,10 | 7,44 | 51,2 | 1,04 | 17,8 | 8,8 | 0,5 | 1,44 | 0,62 | 1,78 |
| Sameba | 1,50 | 3,40 | 57,3 | 0,76 | 17,7 | 3,6 | 0,81 | 4,1 | 2,7 | 2,0 |
| Sameba, upper section | 8,50 | 5,60 | 52,1 | 0,37 | 16,7 | 6,8 | 1,9 | 2,69 | 1,3 | 2,5 |
| Beginnings Sameba | 6,60 | 12,74 | 50,6 | 1,12 | 16,8 | 9,5 | 1,5 | 2,5 | 1,0 | 1,78 |
| Vani, upper part | 6.22 | 16.41 | 37.1 | 1.02 | 13.4 | 5.6 | 14.8 | 2,0 | 0.4 | 2 |
| Buknari | 3.91 | 6.03 | 47,0 | 1.52 | 15.1 | 9.8 | 12.3 | 0.2 | 1.5 | 2.2 |
| Kveda Aketi | 5.53 | 7.51 | 51.2 | 1.52 | 18.0 | 9.4 | 2.9 | 0.5 | 1.2 | 1.4 |
| Dzimiti | 4.33 | 7.70 | 50.5 | 1.14 | 20.4 | 7.7 | 2.5 | 0.4 | 1.2 | 3.3 |
| Mamati | 6,00 | 11,72 | 40,0 | 1,20 | 25,0 | 14,0 | 0,2 | 1,0 | 0,1 | 0,4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Askana, Gulufa river gorge | 10,20 | 7,60 | 53,7 | 0,80 | 16,0 | 5,6 | 0,2 | 2,7 | 0,6 | 1,8 |
| Mshvidobauri | 7,00 | 8,70 | 48,5 | 1,30 | 17,4 | 12,0 | 0,7 | 2,8 | 0,4 | 1,3 |
| Nasakirali | 6,50 | 8,80 | 47,7 | 0,80 | 21,1 | 10,0 | 0,4 | 2,1 | 0,4 | 1,8 |
| Gonebis kari | 1.2 | 6.26 | 61.5 | 0.6 | 21.5 | 2.1 | 1.4 | 0.2 | 1,0 | 2.4 |
| Makvaneti,beginning of Shataul section | 0.72 | 3.56 | 61.9 | 0.84 | 17.3 | 2.2 | 1.2 | 0.2 | 0.4 | 8.8 |
| Makvaneti, end of Shataul section | 3.9 | 11.63 | 44.1 | 0.47 | 24.7 | 9.6 | 0.9 | 0.2 | 0.1 | 0.6 |
| Makvaneti, Gogieti section | 4.76 | 11.01 | 46.7 | 1.92 | 20.9 | 12.2 | 0.8 | 0.1 | 0.2 | 0.7 |
| Tsiteli mountain, shore of the river Bzhuzha | 3.18 | 8.53 | 50.3 | 0.33 | 22.4 | 5.1 | 1.9 | 0.2 | 0.2 | 3.3 |
| At the top of the of Kveda Shukhuti | 4.52 | 7.86 | 51.7 | 1.98 | 17.5 | 11.8 | 1.2 | 0.5 | 0.2 | 1.5 |

According to the results of silicate analysis, the amount of colouring oxides in the samples is high, except for two samples, the content of $Fe_2O_3$ varies from 5 to 12%, and $TiO_2$ from 0,4 to 2%. In the technological samples collected at the beginning and end of the Shataul district of the village of Makvaneti, a very high difference is observed between the content of $Fe_2O_3$ (2,2 and 9,6%) and $Al_2O_3$ (17,3 and 24,7%).

The ceramic properties of the technological samples were studied by plasticity, melting point, water absorption, total shrinkage, average density, porosity, mechanical strength in bending, frost resistance, and the optimal firing temperature for ceramic slabs was determined.

According to ceramic characteristics, clays from only six villages (Shua Fartskhnisi, Sameba, Buknari, Kveda Aketi, Dzimiti, and the Makvaneti-Shataula section) were suitable without additives. The slabs made from these samples, fired at a temperature of 1150–1200 $^0$C, meet the regulatory conditions of the standard. For the remaining samples, it was necessary to prepare clay mixtures in which natural additives were used in various proportions - quartz, trachyte, perlite dust, and obsidian. The ceramic properties of tiles made from mixtures are presented in Table 2.

Table 2

**Mechanical-ceramic properties of tiles made from Gurian clay mixture**

| Name of villages, Location | Optimum firing temperature, T $^0$C | Total Shrinkage, % | Water Absorption % | Average density kg/m$^3$ | Porosity % |
|---|---|---|---|---|---|
| Shua Amagleba | 1150 | 10,6 | 0,04 | 2405 | 0,1 |

| | | | | | |
|---|---|---|---|---|---|
| Sameba | 1150 | 10,3 | 0 | 2426 | 0 |
| Vani | 1150 | 9,1 | 0,02 | 2237 | 0,04 |
| Mamati | 1200 | 12,0 | 0,07 | 2524 | 0,2 |
| Askana, Gulufa river gorge | 1150 | 10,2 | 0,3 | 2405 | 0,7 |
| Mshvidobauri | 1200 | 11,3 | 0,2 | 2450 | 0,5 |
| Gonebis kari | 1200 | 8,4 | 0,1 | 2440 | 0,2 |
| Makvaneti, Shataula section | 1150 | 11,0 | 0,4 | 2422 | 0,9 |
| Makvaneti, Gogieti section | 1200 | 12,0 | 0,1 | 2440 | 0,2 |
| Tsiteli Mta, River Bank Bzhuzha | 1200 | 12,2 | 0,1 | 2450 | 0,2 |
| KvedaShukhuti | 1200 | 12,7 | 0,01 | 2470 | 0,04 |
| Nasakirali | 1150 | 11,0 | 0,04 | 2430 | 0,1 |
| Buknari | 1150 | 10,9 | 0,07 | 2510 | 0,2 |
| Kveda Aketi | 1150 | 10,6 | 0 | 2520 | 0 |

According to the data in Table 2, the optimal temperature for firing tiles is 1150 – 1200 $^0$C. The water absorption of fired tiles ranges from 0-0.4% and, accordingly, the porosity of the tiles is very low.

After frost resistance tests (25 cycles), the fired slabs did not disintegrate or split, and no cracks or chips appeared, which indicates the frost resistance of the tested slabs.

As a result of the research it was established that the slabs prepared from the mixture of ceramic clay of the Guria region meet the requirements of the standards: 13996-93 Ceramic tiles for external facade cladding; 6787-2001 Ceramic floor tiles; 6141-91 Glazed ceramic tiles for internal wall cladding, technical conditions.

Of all the technological samples, only the samples from Vaniskedi and Tsikhisubani show themselves as bentonite clays. In these samples, such physicochemical indicators as the content of the mineral montmorillonite, porosity, colloidality, bentonite number, and water absorption were determined. Based on the results obtained, a fairly high content of montmorillonite was established in them. Tsikhisubani bentonite exhibits high colloidality, average water absorption, and is characterized by a very high value of the bentonite number. The presented samples in their natural form are characterized by low swelling, which can be improved by modifying them with optimal combinations of chemical reagents.

The adsorption capacity of bentonite clays for methylene blue, dispersion, and exchange capacity were determined, and high values were obtained.

Thus, taking into account the technological features, reserves, and mining and geological conditions of processing, it is possible to consider the feasibility of industrial use of Gurian ceramic clays.

# FLOTATION OF SOLID PRODUCTS OF ACID WASTEWATERTREATMENT COPPER-PYRITE DEPOSITS

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Acid wastewater generated at sulphide ore deposits is one of the important sources of toxic pollution of the environment. On the other hand, over the years, tons of non-ferrous and heavy metals enter rivers with wastewater and are lost as valuable raw materials for further technological processing. Therefore, it is advisable to carry out purification with the utilization of wastewater, which implies a solution to two problems at once - wastewater treatment and the return of lost heavy metals to production through simple technological transformations. The acidic wastewater of the Madneul copper-pyrite deposit is typical in composition for wastewater from similar deposits around the world. Barium sulfide was used for its purification and processing, which ensures complete purification of wastewater from metal sulfates. As a result of purification, sulfides of heavy and non-ferrous metals, calcium and barium sulfates are precipitated. It is possible to return tons of metal to production in the form of sulfides, which will ultimately significantly affect the growth of the production economy Depending on the composition of the sediment, it can be used as an additive in metallurgical processes. Also, it is also possible, after conducting research, to include the sediment in the technological scheme of copper pyrite ore enrichment. However, due to the high content of barium sulfate, it is obvious that further processing of the sediment will be much more profitable after its separation into selective concentrates, namely, in the form of sulfide concentrate of heavy and non-ferrous metals and sulfate barium concentrate. To separate the solid product of cleaning the acidic wastewater of copper-pyrite deposits into selective concentrates, a flotation enrichment method was selected - foam flotation. Preliminary enrichment results are satisfactory. Sulfide flotation concentrate contains more than 50% copper and more than 95% zinc, almost 90% of barium sulfate precipitates in the tailings. Work continues on obtaining collective sulfide and sulfate-barium conditioned concentrates.

# APPLICATION OF STRUCTURAL-GEOLOGICAL AND ENGINEERING GEOLOGICAL METHODS TO REAL CONSTRUCTION SITES

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In our daily lives, it is often necessary to drawing up large and small construction projects of various types and purposes. Once the functionality and dimensions of the projects are determined it becomes necessary to carry out research works of various profiles, the list of which is quite large and involves overcoming various difficulties in order to implementing them. One of the most important of them is the engineering-geological survey of the object site, which in turn includes many narrow specializations.

These include: searching for geological planning data for a specific region in the National Geological Funds, identifying seismic activity zones using the Atlas of Seismic Zoning of Georgia, reviewing geomorphological and hydrogeological characteristics. The second stage is to conduct detailed field-geological surveys. Their list and detail should be determined according to the need: determining the type of Quaternary cover, indicating all mandatory characteristics, including a full description of pits and wells and displaying the results of laboratory research; It is necessary to compile a detailed stratigraphic-lithological section of the area, measure the fracture systems at selected observation points according to the project specifications and standards, and determine statistical graphs and attach photographic material for better understanding.

The report presented at the conference will present the structural and engineering geological features of all types of objects, graphic and photographic material. It should be noted once again that modern research methods of both structural geology and engineering geology have been used in the research works.

These projects once again emphasize the need for interdisciplinary research for the effective implementation of high-level research. In this short annotation, we will list the types of construction objects that have been completed with the participation of various Georgian design companies. Ninotsminda-Kartsakhi 30 km section - Marabda-Akhalkalaki railway. Preparation of a full project;Abastumani resort access road.

Separation of rockfall areas from slopes and rock walls;Khulo - Khulo-Batumi highway. Separation of rockfall and landslide-prone areas; Bakhvi 1, 2 HPPs – Chokhatauri. Preparation of a full project;Dariali HPP - Kazbegi. Preparation of a full project;Jonauli HPP - Tsageri. Preparation of a full project;Khrami 5 HPP - Tetri-Tskaro. Preparation of a full project;seismic hazard;Mestia 1, 2 HPPs. Preparation of a full project;Rioni 2 HPP - Ambrolauri. Preparation of a full project; Sadmeli HPP - Ambrolauri. Preparation of a full project; Mtkvari 1 HPP (Rustavi-Sakuneti) - Akhalqalaqi. Preparation of a full project;Preparation of a preliminary project for the Namokhvani HPP cascade (Zhoneti, Namokhvani, Tvishi);Kasleti 1 HPP - Khaishi. Arrangement of a landfill for inert material removed from the tunnel; Mleta-Kobi access highway - Khadas-Tskali river - Kvesheti, Bedoni, Khada and Kobi 1, 3 districts. Landfills for inert material removed from the tunnels;Rustavi metallurgical plant. Arrangement of slag dump; Samkuris-Tskali

2 HPP – Akhmeta. Arrangement of camp and concrete node areas;Study of the territory of Tkibuli coal enrichment plant for the purpose of renovation and expansion;Mtkvari 1 HPP (Rustavi-Sakuneti) - Akhalqalaqi. Arrangement of camp areas;Oni section - Kutaisi-Ghebi highway. Arrangement of inert material removed from the tunnel;Chocheti – Kaspi. Arrangement of humus soil dump;New Surami-Zestafoni highway. Arrangement of camps and concrete junction areas and landfills for inert material removed from tunnels - a total of 22 sites, #5 is rejected; Khobi 2 HPP - Khobi. Arrangement of the main power distribution line;Akhalqalaqi-Zekari-Baghdad - Trialeti Ridge. Inspection of sites for installing towers on the high-voltage power transmission line;Tskaltubo-Akhaltsikhe - Trialeti Ridge - Arrangement of the high-voltage power transmission line;Tbilisi Sea area - restoration of ecology;Temkis-khevi – Tbilisi. Restoration of the territory; Shindisi – Tbilisi. Study of the territory with a development perspective; Khulo Center - Renovation of the recreation park.

# INVESTUGATION OF THE USE OF UTILIZED GUNPOWDER TO REDUCE THE HIGROSCOPICITY OF AMMONIUM NITRATE

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Energetic materials are important class of functional compounds, development of energetic materials is a challenging process that require the best of computational, chemical synthesis, and material design techniques.

As is known, ammonium nitrate is used as an oxidizer in the production of explosive mixtures. Using ammonium nitrate as a propellant oxidizer is limited due to its hygroscopicity.

Surface modification of AN with several coating methods was applied in order to reduce hygroscopicity.

The physical coating method - In this method the interaction between the surface of AN particles and the coating agents occurs by physical absorption. The chemical coating - In this method the adsorption of coating materials on the surface of the AN particles causes a chemical reaction resulting in the formation of a coating layer on the particles. Encapsulation is a new coating method. The capsule-like coating layer is formed on the surface of AN particles, which are homogeneous and of a certain thickness. The coating experiments were conducted using a solvent/non solvent method based on the coacervation principle.

The chemical structure of the coated ammonium nitrate has been investigated by Fourier transform infrared spectroscopy.

# PETRROLOGY AND GEOCHEMICCAL STUDY OF THE BEKTAKARI-BNELIKHEVI ORE KNOTE

G. IOBIDZE

The study focuses on the petrological and geochemical characteristics of the Bekthakari-Bnelikhevi plutonic rocks, encompassing both intrusive and sub-intrusive bodies.

The samples were analyzed using XRF analysis and evaluated through Middlemost's TAS classification along with other geochemical diagrams.

The results reveal that the plutonic rocks are predominantly associated with a subduction-related geodynamic setting, as evidenced by microelement and rare earth element (REE) spider diagrams, as well as AFM and Ti-Zr-Sr plots.

A dominance of tholeiitic and calc-alkaline series is observed, indicating diverse mechanisms of magmatic differentiation and highlighting the significant contribution of mantle components.

This research offers an integrated perspective on the interplay between magmatic processes and the tectonic environment, elucidating not only the genesis of the rocks but also highlighting the metallogenic potential of the region, which is crucial for both fundamental and mineral resource investigations.

# NON-CARBONATED MINERAL WATERS OF SHIDA KARTLI AND PERSPECTIVES OF THEIR USE

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The study area is located on the right bank of the Mtkvari River, on the border of the Kartli Molasses subzone and the Kavtiskhevi subzone of the central zone of the Adjara-Trialeti folded system (Fig. 1).

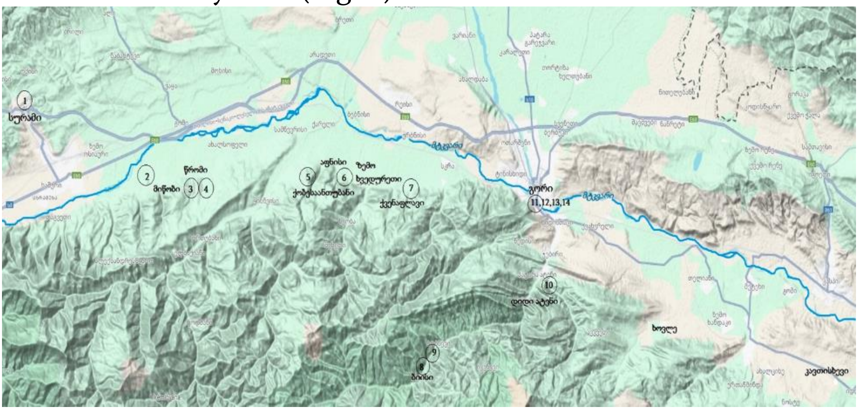


Fig. 1. Schematic map of the location of the study mineral waters

Shallow and deep circulation groundwaters are developed here. The former are associated with modern Quaternary and Miopleocene sediments, while the deep circulation groundwaters are associated with pre-Quaternary sediments [1].

Field works were carried out in the Khashuri, Kareli, Gori, Kaspi districts, in the Tana River valley. 14 groundwater sources were investigated on site. Most of them are geological exploration wells. They have almost the same geochemical nature: weakly or low-mineralized (M ranges from 0.1 g/l to 2.7 g/l), mainly subthermal (from 20°C to 37 °C); sometimes thermal (> 37°C), for example, Kvenaplavi, Biisi, Tsromi.

These mineral waters are mainly chloride-sodium (saline), sometimes hydrocarbonate-chloride-sodium (alkaline-saline) or calcium in ionic composition. The sulfate ion content is insignificant in most wells.

According to the gas composition, the waters are mainly hydrogen sulfide, often with methane and nitrogen content. The free titrated sulfur content is from 4 mg/l to 20 mg/l: Gorijvari, Biisi, Biisi Tourist Camp, Mitsobi, Tsromi Bath. Their classification as mineral waters is due to the presence of hydrogen sulfide as a specific component [2].

It should be noted the increased iron content in some wells (Gorijvari - well No. 2 - 143 mg/l, Biisi camp - 50.4 mg/l, Kveenaplavi - 20 mg/l. Tsromi bath - 19.9 mg/l). Iron water baths are used for cardiovascular diseases and anemia.

As for microelements, most of them are within the limits accepted for balneological use. The arsenic content in all studied samples ranges from 0.7 mg/l to 0.9 mg/l. Such arsenic content allows us to attribute these waters to the group of weakly arsenic-containing mineral waters (As 0.7 mg/l — 5.0 mg/l). It is believed that the enrichment of underground mineral waters with arsenic occurs during the process of enhanced leaching under conditions of increased temperature and pressure. Arsenic-containing mineral waters are used for therapeutic baths. In this case, arsenic ions penetrate the body through intact skin. These waters are used for diseases of the cardiovascular system and metabolism [3].

Studies have shown that resorts and public baths, which were popular not only among the local population, but also outside the region, need renovation, and in some cases, restoration. For example, the boarding house in the village of Khovle is completely destroyed, the spring area is swamped.

The well to the east of the village of Tsromi, which was previously used as a bath, is now gradually swamped and does not function, and due to the increased temperature, the water in question can be used not only for balneological purposes, but also in greenhouse farming.

The flow rate of Gorijvari and Mitsoba wells has dropped significantly. Depending on the reasons, it is necessary to either clean the well and filter, or, in case of depletion of the water level in the aquifer, drill deeper.

Shida Kartli region is favorable for the development of medical and health tourism. There are all the conditions for creating balneological resorts and resort complexes: the presence of healing water sources, diverse natural landscapes, warm climate, unique historical sights. Hot water (over 35 degrees) can be used to heat houses and create greenhouses.

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RESEARCH ON LANDSLIDE AREAS DEVELOPED ON THE RIGHT SLOPE OF THE ZHINVALI RESERVOIR OF THE GEORGIAN MILITARY ROAD

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Landslides developed on the right slope of the Zhinvali Reservoir are mainly associated with the headwaters of erosion ravines and their adjacent slopes, which adjoins to the transport corridor of the Natakhtari-Mleti section of the Georgian Military Road [1].

As a result of the field and laboratory work, 9 main landslide areas (bodies) were identified within the study area, which attract attention with their size, development dynamics and the perspective of possible hazards (Fig. 1.).

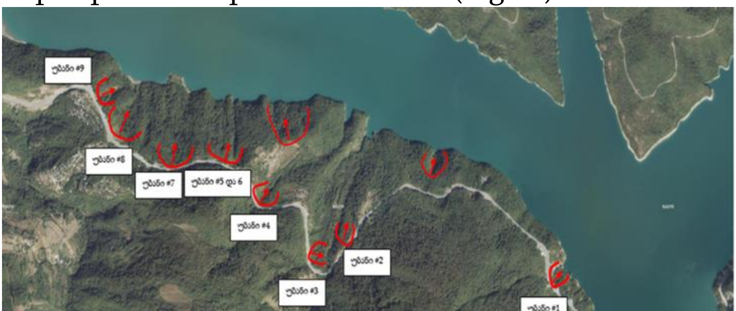


Fig. 1. Landslide areas on the right slope of the Zhinvali reservoir

Field and laboratory studies were conducted in two of the nine identified landslide sites (№ 4 and № 7), the data of which were used to determine numerical indicators of the stability of landslide slopes. The work carried out clearly showed that landslide bodies become activated when certain factors coincide, and if we take into account their location in relation to the road, we may get undesirable results (Photos 1, 2) [2].

Factors such as the increase in the moisture content of the surrounding rocks and seismic events have a significant impact on the development of these landslides [3].

Photo 1. Main cut off area of the № 4 landslide body

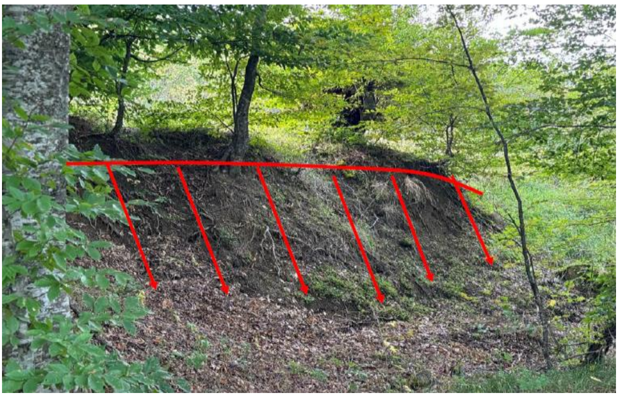

Photo 2. Main cut off fragment of the № 7 landslide body

Anthropogenic factors contribute significantly to the development of these events: vibrations caused by continuous flows of heavy-duty vehicles and unregulated surface water flows, that flow freely onto landslide slopes.

The study found that in order to stabilize landslides, it is first necessary to clean and restore existing culverts and drainage channels to prevent the flow of water drained from the roadway onto landslide slopes. Light-weight slope retaining supports should be constructed, especially on damaged sections.

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# SCHEMES FOR PROTECTING STEEL PIPES OF UNDERGRAUND GAS PIPELINES FROM ELECTROCHEMICAL CORROSION UNDER CONDITIONS OF DIFFERENT SOIL RESISTIVITY VALUES

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Currently, road and railway crossings are considered potentially dangerous sections of the linear part of underground gas pipelines. Accidents in these sections, as a rule, have a higher specific frequency (per unit length) than on average in the linear part of the main pipeline. Such accidents have more severe consequences with significant socio-economic damage [1].

The arrangement of a section of the highway at the intersections of highways and railways requires the use of an additional structure - a protective casing (Fig. 1). Casings reduce the load on the pipeline, protect the pipe from vibration, friction and mechanical damage. In such places, the soil often becomes mobile, and this can lead to a dangerous situation - a pipeline rupture. In addition, casings additionally protect the pipe from stray currents and serve to detect and eliminate gas leaks in the event of damage to the gas pipeline.

The most common casing pipe material is carbon steel, which is used due to its strength, availability, high load and pressure resistance. The electrochemical corrosion process on the surface of a metal structure placed in the soil proceeds in a manner similar to a galvanic corrosion element. Soils with a specific electrical resistance $R_s$ less than 20 Ohm · m have high corrosive activity, and low if $R_s$ >50 Ohm · m.

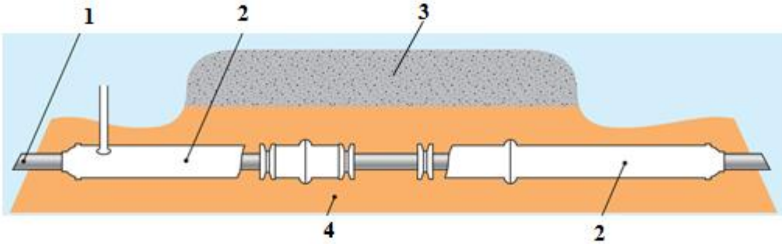


Fig. 1. Scheme of laying the main gas pipeline under the highway: 1 - gas pipeline; 2 - protective casing; 3 - roadway; 4 – soil

The diameter of the protective casing (Fig. 1) exceeds the corresponding parameter of the main pipeline by twenty centimeters. It is worth noting that the pipe placed in the casing has reinforced insulation. All welded joints are carefully checked using non-destructive methods, and only pipes that have passed strength and tightness tests are installed in the casing. During the installation process, the ends of the steel casing are equipped with sealing devices made of dielectric material. At one end of the protective casing, it is necessary to arrange a vent plug to release gas into the atmosphere. Not only the installation process of the pipes themselves is standardized, but also the length of the protective casing. In particular, if we are talking about railway tracks, then the protective casing passing under the tracks must extend at least 50 meters from the axes of the outer tracks. Such a long length of the casing is justified by the following considerations: natural gas is very explosive under high pressure, and railway trains have a very high mass. As for roads, the protective casing must extend at least 25 meters from the edge of the road. In addition, the regulations also impose strict guidelines regarding the depth of installation of the casing [2].

The electrochemical corrosion process of steel casing placed in the soil, as well as on the surface of a metal structure, proceeds in a manner similar to a galvanic corrosion element, which is discussed in detail in the works [3, 4, 5]. The process is accompanied by the passage of electric charge current in two directions: minus - cathodic and plus - anodic. An electrically conductive medium - electrolyte is formed in the soil, through which a certain electrochemical potential appears on the surface of the pipeline - cathodic and anodic areas. During iron corrosion, an insoluble product - hydrogen oxide is formed. The variable composition of iron hydroxide (rust), in general terms, is described by the formula:

$$nFe(OH)_2 \cdot mFe(OH)_3 \cdot qH_2O, \tag{1}$$

where *n, m, q* are integers.

Steel casing pipe protection from electrochemical corrosion can be carried out by cathodic or protective protection. Cathodic protection is used when the metal does not have a tendency to pass into a passive state. In this case, in the cathodic electrochemical corrosion protection system, the negative pole of a constant current source is connected to the metal casing, and the positive pole is connected to an anode grounding conductor, as a result of which the potential of the pipeline is shifted to the negative side. The anode grounding conductor is destroyed during electrochemical corrosion, but the metal structure does not corrode.

In the case of electrochemical protection of a metal casing, a protector with a low electronegative potential is connected to it. As a result, it is not the metal casing that is destroyed, but the protector. Each protector has its own maximum radius of action - this is the distance at which its protective effect is satisfactory.

Employees of the G. Tsulukidze Mining Institute have developed schemes for cathodic or protective protection devices against electrochemical corrosion of the steel casing of underground gas pipelines.

The presented results can be taken into account in the practice of designing protective steel casing elements at individual sections (railway and road crossings) during the underground construction of gas pipelines in the territory of Georgia.

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# SURFACE STRUCTURAL ANALYSIS WESTERN PART OF THE KAZRETI GOLD-POLIMETALLIC DEPOZIT

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The Upper Cretaceous Kazreti gold-polymetallic deposit is located in the vicinity of town Kazreti (Bolnisi district), approximately 4 km, due west, from the Madneuli deposit. The host rocks of the deposit are represented by Upper Cretaceous rhyolitic and rhyodacitic pyroclastic tuffs and ignimbrites, as well as feeder dikes of andesitic, andesite-basaltic, and rhyolitic composition [1]. Hypsometrically, the uppermost part of the deposit is represented by a barite horizon (barite cap), which reaches a thickness of up to 150 m.

Fracture measurements were conducted using the Field Move Clino mobile application, which allowed for digital data collection and integration with a coordinated geological map. The geographic position and azimuth of each measured point were determined with high accuracy using GPS and a digital clinometer. In order to study the spatial orientation of fracture planes present on the surface of the Kazreti gold- polymetallic deposit, research was conducted in stages, in accordance with the standards of structural-geological investigation.

In the first stage, a preliminary assessment of the study area was carried out based on visual observation and analysis of aerophotogrammetric materials. This assessment preceded the fieldwork and guided the design of the field route, aiming to identify representative and informative sites for the study.

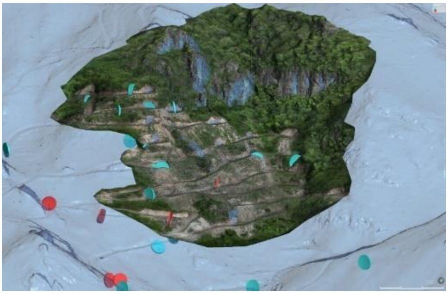

Fig.1. Aero photogrammetric image with observation points

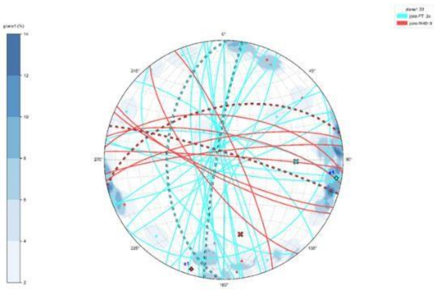

Fig. 2 - The distribution of the measured fracture planes on a polar stereone

The western slope of the deposit was selected for fieldwork, where volcanic-sedimentary and volcaniclastic rocks are well exposed along with rhyolitic and andesitic dikes(Fig.1). Of particular interest were the fracture planes developed within the host rocks and dykes, as well as their spatial orientation characteristics. the measured fracture orientation data are presented in the corresponding table

Table 1

Fracture measurement data

| ID | unitId | x | y | z | dip | dipAzimuth | strike |
|---|---|---|---|---|---|---|---|
| 1 | joint-PT | 452922.15 | 4583941.70 | 890.00 | 87.21 | 188.08 | 98.08 |
| 2 | joint-PT | 452928.43 | 4583996.88 | 872.00 | 81.75 | 189.59 | 99.59 |
| 3 | joint-RHD | 452942.45 | 4583897.29 | 873.00 | 59.42 | 6.03 | 276.03 |
| 4 | joint-PT | 452854.03 | 4583906.35 | 836.00 | 73.79 | 9.98 | 279.98 |
| 5 | joint-PT | 452921.19 | 4583890.03 | 873.00 | 83.53 | 158.46 | 68.46 |
| 6 | joint-PT | 451778.42 | 4582960.24 | 873.00 | 80.56 | 336.44 | 246.44 |
| 7 | joint-PT | 452912.15 | 4583918.85 | 872.00 | 89.00 | 90.23 | 0.23 |
| 8 | joint-PT | 452892.47 | 4583950.88 | 871.00 | 81.38 | 325.10 | 235.10 |
| 9 | joint-PT | 452839.06 | 4584070.25 | 830.00 | 86.06 | 141.13 | 51.13 |
| 10 | joint-RHD | 452807.12 | 4584114.83 | 848.00 | 80.26 | 203.47 | 113.47 |
| 11 | joint-PT | 452368.31 | 4583497.94 | 830.00 | 86.47 | 287.45 | 197.45 |
| 12 | joint-PT | 452861.75 | 4583926.22 | 845.00 | 83.23 | 279.90 | 189.90 |
| 13 | joint-PT | 452706.44 | 4583731.96 | 716.00 | 81.67 | 281.75 | 191.75 |
| 14 | joint-PT | 452833.81 | 4583889.90 | 817.00 | 88.56 | 260.63 | 170.63 |
| 15 | joint-PT | 452835.71 | 4583879.84 | 820.00 | 88.74 | 262.07 | 172.07 |
| 16 | joint-RHD | 452714.00 | 4583981.89 | 798.00 | 80.17 | 65.78 | 335.78 |
| 17 | joint-PT | 452940.18 | 4583748.26 | 815.00 | 74.03 | 41.42 | 311.42 |
| 18 | joint-PT | 452912.82 | 4584228.73 | 790.00 | 23.61 | 145.03 | 55.03 |
| 19 | joint-PT | 452937.47 | 4583795.15 | 815.00 | 88.59 | 71.73 | 341.73 |
| 20 | joint-RHD | 452858.71 | 4583819.75 | 800.00 | 74.93 | 349.77 | 259.77 |
| 21 | joint-PT | 452781.31 | 4583880.29 | 800.00 | 80.55 | 298.85 | 208.85 |
| 22 | joint-RHD | 452745.08 | 4583927.51 | 780.00 | 72.17 | 11.28 | 281.28 |
| 23 | joint-RHD | 452745.06 | 4583926.84 | 780.00 | 87.36 | 4.05 | 274.05 |
| 24 | joint-RHD | 452753.19 | 4583846.07 | 780.00 | 83.85 | 353.23 | 263.23 |
| 25 | joint-PT | 452748.39 | 4583841.33 | 760.00 | 79.80 | 116.36 | 26.36 |
| 26 | joint-PT | 452727.07 | 4583852.84 | 752.00 | 47.87 | 231.03 | 141.03 |
| 27 | joint-RHD | 452569.40 | 4583853.23 | 745.00 | 72.53 | 231.86 | 141.86 |
| 28 | joint-RHD | 452589.43 | 4583872.25 | 740.00 | 77.77 | 206.59 | 116.59 |
| 29 | joint-PT | 452560.82 | 4583847.79 | 738.00 | 80.44 | 292.02 | 202.02 |
| 30 | joint-PT | 452544.55 | 4583812.54 | 720.00 | 81.18 | 270.56 | 180.56 |
| 31 | joint-PT | 452571.55 | 4583802.61 | 720.00 | 74.83 | 264.66 | 174.66 |
| 32 | joint-PT | 452570.93 | 4583809.46 | 720.00 | 70.26 | 260.44 | 170.44 |
| 33 | joint-PT | 452570.93 | 4583809.46 | 720.00 | 86.46 | 69.10 | 339.10 |

After the fieldwork, the study proceeded to the office stage, which involved exporting the data collected in the field application and processing it in specialized spatial software (Leapfrog Geo). The data were plotted onto the existing aerophotogrammetric file (Fig. 1), followed by stereographic analysis using the same program (Fig. 2). The results of the stereographic analysis are presented in the corresponding graphical materials, which illustrate the spatial distribution of measured points and the main trends in fracture plane orientation.

A surface measurement and stereographic analysis of fractures were conducted in the western part of the Kazreti deposit, on exposures of host rocks and intrusive bodies along the western slope of the deposit. As a result, two distinct fracture systems were identified: one associated with mineralization, characterized by northeast and southeast-trending fractures (blue), and the other comprising a network of non-mineralized fractures related to late volcanic activity. The latter, which intersects older mineralized horizons obliquely, reflects a later/post-mineralization deformation stage, indicating multiphase structural-tectonic processes in the deposit's evolutionary history. In this direction, future research is planned in the western area of the deposit, which will correlate with deep structural data.

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# GLOBAL CHALLENGES, TRENDS AND PROSPECTS FOR SUSTAINABLE DEVELOPMENT OF THE OIL AND GAS INDUSTRY

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1. The paper discusses the global role of the oil and gas industry, new trends, environmental impacts, technological innovations, geopolitical influences and long-term strategies to ensure sustainable development.

Sustainability in the oil and gas industry involves maintaining a balance between economic growth and environmental protection, dealing with social responsibility and industry challenges. Where greenhouse gas emissions are reduced, natural resources are conserved, and the environmental impact of oil and gas extraction and production is minimized, a focus on reducing greenhouse gas emissions, protecting biodiversity and minimizing water use and pollution, a combination of technological innovation, efficient operations, and responsible management, a commitment to responsible management of natural resources and compliance with environmental regulations, and collaboration with communities to solve problems and ensure that the benefits of economic development are equitably distributed.

As is known, in 2015, the UN General Assembly identified 17 global goals, or so-called The Sustainable Development Goals, as part of the universal 2030 Agenda for Sustainable Development, aim to address some of the world's most fundamental economic, social and environmental challenges, where private sector engagement is essential. This is particularly relevant for the broader energy sector, and in particular the oil and gas sector, as the industry has a direct or indirect impact on each of the 17 Sustainable Development Goals. It is a sector with significant potential, poised to change the global landscape by making exciting and productive contributions to the Sustainable Development Goals, and from a social, environmental and economic perspective [1].

Figure 1 below provides a high-level view of how the oil and gas industry can make a significant contribution to each of the 17 Sustainable Development Goals, either by increasing positive contributions or by avoiding or mitigating negative impacts, through sound planning and implementation of processes and operations; Overall, oil and gas production can contribute to the socio-economic development of individual countries by providing access to energy, decent employment opportunities, business and skills development, increased fiscal revenues, and improved infrastructure. However, the development of the oil and gas industry has historically contributed to some challenges - climate change and environmental degradation, population displacement, economic and social inequality, armed conflict, gender-based violence, tax evasion and corruption, increased risk of certain health problems, and human rights violations - which can be addressed by promoting the Sustainable Development Goals. Accordingly, in recent decades, the industry has made significant progress in preventing, reducing, and managing such impacts and risks.

2. In this regard, following the United Nations (UN) Global Climate Change Conference (COP26), it is noteworthy that the UN Sustainable Development Goals (SDGs) provide a framework for how the oil and gas industry can not only adapt in a way that does not make it vulnerable and devastated, but also actively contribute to the betterment of humanity – both people and

planet.

In this spirit, a new public-private consortium called the ,,Global Energy Alliance for People and Planet“ was launched at COP26, which continues the drive for global decarbonization and aims to allocate US$100 billion in both public and private financing to:

- Avoid and stop generation a total of 4 billion tons of carbon emissions;
- Provide one billion underserved people with access to clean and reliable power;
- Create, enable and improve 150 million jobs.

Notably, oil and gas still account for nearly 60 % of global fuel consumption and are expected to remain the leading global energy sources through the end of the forecast period to 2035. Meanwhile, natural gas supplies, which are growing faster than either oil or coal, will overtake coal as the second most important fuel source by 2035. Renewable energy is also growing rapidly and is expected to reach 10 % of global primary energy supply by 2035.

In addition, to meet global energy demand, the oil and gas industry is expected to invest up to US$700 billion per year through 2040, the vast majority of which will be in non-oil exporting countries. Including investments in oil refining and transportation, this figure reaches almost US$23 trillion [1].

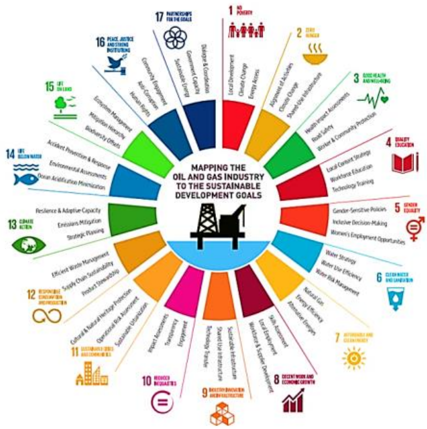


Fig. 1. Mapping the oil and gas industry to the sustainable developments goals

3. In the context of sustainable development, the main goal of businesses should be to conduct business responsibly, taking into account the contribution to society, minimization of risks and non-harm. It is important here to align companies with and orient them towards sustainable development goals in terms of conducting their own individual analysis to understand how their business can make an impact. The specific roles and contributions of the company will depend on the local social, political and economic context, the resource itself, the phase of the oil and gas activity (exploration, development, production, closure or decommissioning) and the information received from local communities and other stakeholders through formal dialogue and engagement [2].

4. Oil and gas companies are striving to align their operations with the Sustainable Development Goals and make a significant contribution to them, particularly in areas such as affordable and reliable energy (SDG7), climate action and life on land and water (SDGs 13, 14 and 15), economic development and innovation

(SDGs 8 and 9), and health and access to clean water (SDGs 3 and 6). [3] Accordingly, there are opportunities for the SDGs to be integrated into the core business activities of oil and gas companies. Integration requires a shared understanding by all stakeholders of how the SDGs can create value and align with the company's business objectives. Companies can operationalize the SDGs by embedding them into their core business practices, corporate systems, policies, standards and processes, where they can drive greater efficiency, cost savings, competitiveness and strengthen the social license to operate in the oil and gas industry. Companies can also benefit from engaging with stakeholders to expand their impact and leverage additional resources to achieve the Sustainable Development Goals, which require multi-sectoral and multi-disciplinary approaches, as many of the challenges of the Sustainable Development Goals are beyond the capabilities or control of a single company.

5. To realize their full potential to contribute to the interrelated and indivisible goals of sustainable development, oil and gas companies should engage in a multi-stakeholder dialogue with relevant actors at local, national and international levels to identify shared priorities and potential coordinated responses in local contexts, which requires approaches that ensure synergies and manage trade-offs.

The oil and gas industry, on the cusp of 2025, is at a significant crossroads. The interplay of global energy needs, climate change imperatives and rapid technological innovation is transforming the sector as never before.

However, the trends in the oil and gas industry remain a cornerstone of the global energy supply, even as it faces increasing evolutionary pressures. In 2025, economic factors such as changing demand, geopolitical tensions, and investment patterns will shape the industry's trajectory.

In such circumstances, sustainability is now at the center of the industry's agenda, as stakeholders call for greener practices and reduced carbon footprints. The future will be determined by the industry's ability to adapt to renewable energy trends while addressing environmental challenges. [4] In response to the current urgency, governments, societies, businesses, and all stakeholders must adopt a sensible approach to climate change.

6. Sustainability in the oil and gas industry is challenging, but there are opportunities for innovative ideas to achieve sustainable development while minimizing environmental impacts.

Innovative ideas in the oil and gas industry are constantly looking for new ways to reduce environmental impacts while maintaining profitability and promoting sustainable development. Here are some of the innovative ideas that are being implemented in the industry: carbon capture, utilization and storage (CCUS), renewable energy, digitalization, circular economy, environmental consulting, energy efficiency, carbon trading, sustainable transport [5].

Thus, the oil and gas industry is a complex sector and remains an important driver of the world economy, with a significant impact on meeting the energy needs of the global economy and on the security, environmental and development outcomes. Achieving sustainability in the oil and gas industry requires constructive engagement among stakeholders, including governments, companies, communities, and civil society organizations, who, working together in a coordinated manner, can identify common goals and solutions and build a more sustainable future.

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# ORIGIN OF THE RED COLOR OF THE UPPER CRETACEOUS RED LIMESTONES AND THEIR BIOSTRATIGRAPHY OF WESTERN GEORGIA

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Oceanic Anoxic Events (OAEs) represent brief periods of burial of large amounts of organic carbon in the oceans during Cretaceous time. Burial of organic carbon, which preferentially sequestered isotopically lighter carbon during OAEs, resulted in positive δ13C excursions of 2–3‰ recognizable in the global ocean.These deposits are typically dark–grey to black shales, considered to be the result of interaction between extreme warm climate, ocean circulation, high bioproductivity and organic carbon preservation. Little attention has been paid to periods between OAEs, when oxic deep sea deposits such as red marls and red shales were deposited during mid- and Late Cretaceous [1].

The Cretaceous oceanic red bed (CORB) a newly opened window into global oceanic and climatic changes during the Cretaceous greenhouse world.

Red limestones from the Cretaceous period are a distinct type of sedimentary rock found in various locations worldwide. These red limestones, often fine-grained and pelagic, are characterized by the presence of hematite, which gives them their characteristic red color. The formation of these red limestones is linked to specific geological and environmental conditions, including the availability of iron and oxygen levels during their deposition [2].

Upper Cretaceous red limestones are often found in marine sediments, particularly in the Tethys Ocean, and are distinct from continental red beds.

Many red limestones are pelagic, meaning they were deposited in the open ocean, often far from land.

These limestones often contain microfossils like radiolarians and foraminifera, which can help determine their age and depositional environment.

Many Upper Cretaceous red limestones are dated to the Cenomanian-Santonian stages of the Upper Cretaceous.

The presence of hematite suggests that the limestones were deposited under well-oxygenated (oxic) or moderately oxygenated (sub-oxic) conditions at the sediment-water interface. The transition from white (anoxic) to red (oxic) limestones can be related to the end of major anoxic events, like the Bonarelli event in the Late Cenomanian. Microbial activity may have played a role in the formation of red coloration in some cases, through the precipitation or oxidation of iron. Marine red beds (MRBs) are significant in sedimentology, paleoceanography, paleontology, paleoecology, and paleoclimatology, offering insights into Earth s redox history and climatic shifts. First identified in the 19th century in the Mediterranean, Europe, and North Africa, MRBs were initially described lithologically. Mid-20th century advances linked their red coloration to hematite (Fe2O3) and oxidizing conditions. The late 20th century saw MRBs integrated into studies of oceanic anoxic events (OAEs), carbon cycling, and mass extinctions.

Since the 21st century, high-resolution geochemical techniques and numerical modeling have advanced MRB research, revealing their roles in paleoenvironmental reconstruction, plate tectonics, and biological evolution. MRBs are categorized into oceanic (basin), deeper water (slope), and shallow water (shelf) types based on depositional environments [3].Cretaceous oceanic red beds (CORBs), first identified in the Carpathians and eastern Alps, are globally distributed in the Atlantic, Pacific, Indian, and Tethyan Oceans. Their formation is linked to Late Cretaceous oceanic oxidation, iron cycle changes, global cooling, and sea-level fluctuations. CORBs mark the transition from anoxic to oxic marine conditions [4].

Biostratigraphic analysis primarily relied on planktonic foraminifera, which were extracted from marlstones and limestones using the grinding method, which involved cutting rock samples into thin sections. Sections of foraminiferal tests, were subjected to detailed taxonomic examination. The majority of specimens retain sufficient morphological integrity to permit reliable identification at both genus and species levels [5]. Planktic foraminifera constitute the dominant elements of the analyzed assemblages, with the section s biostratigraphic framework primarily established through detailed foraminiferal analysis. Key diagnostic species were reliably determined through examination of fossil axial sections and rotary profiles.

Thus, this paper presents a comprehensive analysis of the biostratigraphy and microfacies of foraminifers from the Cretaceous oceanic red beds (CORB) exposed in the sections of Western Georgia.

Different hypotheses explain the origin of red pigmentation of limestones and shales including: 1. Detrital origin of iron derived from continental weathering; 2. Iron-bacterial mediation at the time of sedimentation; 3. Iron oxidation in oligotrophic, highly oxic environment. Additional research on the Cretaceous oceanic red beds is needed in order to better document their origin and palaeoceanographic and palaeoclimatic significance.

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# PURIFICATION OF EXPIRED TROTYL FROM IMPURITIES BU CRYSTALLIZATION

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Solutions play a major role in human practical activity. In chemistry, dissolving and crystallization are significant methods of scientific research and technological processes.

Due to the recent socio-political situations in Georgia, the development of utilization methods of explosives released from ammunition, including expired TNT, become of great importance. The matter is relevant, both from an ecological and economic point of view.

The aim of our research is to use crystallization method for purification of expired trotyl (u-TNT) from impurities and its recycling.

In general, crystallization, is the process by which a solid substance is transferred to a solution by heating it in some solvent, and after cooling it is released back into solid form [1,2]. Often, for this purpose, a mixture of two or several solvents is used.

For purification of u-TNT, we use two types of crystallization method. The first involves dissolving u-TNT in a heated solvent (toluene, ethanol, etc.) to form a saturated solution. As a result of gradual or rapid cooling of the solution, crystallization occurs. The second type is to dissolve u-TNT in one solvent and crystallize it in the other solvent that dissolves the first solvent and crystals do not. Several variations of this method can be processed.

In both cases, from brownish u-TNT, whitish, purified crystals are obtained which are visually quite different from the initial crystals (Photo 1, 2).

The above methods are based on a well-known rule of chemistry: during the growth of crystals, impurity molecules practically do not get into the growing crystal lattice. They mix with the solvent and remove the purified crystals by filtering.

For initial inspection, we detonated expired and purified TNT in low-carbon steel tubes. The experiment shows that in the case of u-TNT, the steel tube breaks down into several pieces (photo 4), while, the purified TNT explode leads to complete fragmentation of the tube (photo 3). In other words, in the latter case, the explosion power is significantly increased:

Fig.1.

Fig.2.

Fig.3.

Fig.4.

The degree of crystal purity is determined by TLC or thin-layer chromatography [3,4].

Based on our experiments, we consider to offer the crystallization method as one of the cheapest possibility of utilization of expired TNT.

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# ROPEWAY PROTECTIVE BARRIERS ON GEORGIAN ROADS AND THEIR DEVELOPMENT PROSPECTS

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Motorways are the most developed sector of Georgia's transport infrastructure. Currently, 1594 km. of international importance and 5451 km. of domestic importance are in operation in Georgia. Their improvement and increasing safety are the subject of constant concern of the state.

One of the main components of ensuring the safety of roads are the constructions of protective barriers, which are located both on the dividing strip of traffic directions, and along the peripheral strip of the carriageway.

Several types of protective barrier systems are common on Georgian roads, which fall into two main categories - non-deformable and deformable road barriers.

Road rope barriers belong to the type of deformable road barriers.

Rope protective barriers appeared in Georgia in the 1980s. The first design documentation for rope barriers dates back to this period. [1]

Rope barriers are relatively inexpensive, easy to install, easy to maintain and repair after a collision. They reduce snow accumulation and do not complicate snow removal from the road surface, compared to steel or concrete barriers.

In addition, they slightly restrict visibility from the road and provide a good "transparent" view behind the barrier. Rope barriers are generally useful structures in terms of vehicle occupant safety, as they significantly reduce the acceleration developed during a collision, unlike steel or concrete barriers.

The report discusses the history of the development of rope barriers from the beginning of the 20th century to the present day - in the world and in Georgia. [2]

Engineering approaches to the calculation of rope barriers are analyzed. [3] An energy method for calculating the structure of rope barriers is proposed, which is based on the absorption of the energy of a vehicle impact by the barrier.

Opinions are expressed on the prospects for the placement of rope barriers on Georgian roads.

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# DISTRIBUTION OF HEAVY METALS ON THE TBILISI-SADAKHLO SECTION (EUROPEAN ROUTE E001 (E117)

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In 2024, the volume of road transport in Georgia reached 14.8 million tons. Of these, 19%, i.e., more than 2.8 million tons, falls on the Armenia-Russia route, which, according to TBC Capital [1], amounts to approximately 200,600 units of freight transport recorded at the Daryal border checkpoint (the Georgian-Russian border).

Since 2024, we have begun studying the degree of pollution with heavy metals and toxic elements of the E001 and E117 roads, between the Sadakhlo (Armenian-Georgian border) and Daryal (Georgian-Russian border) customs points.

At the first stage, we studied the first section of the specified road (Sadakhlo-Tbilisi). Fig. 1 shows the sampling points, and their coordinates are given in Table 1.


Fig. 1 Sampling Points

Table 1

**Coordinates of Sampling Points**

| Sample | Coordinates | | Sample | Coordinates | |
|---|---|---|---|---|---|
| | N | E | | N | E |
| S_500 | 41°39’25” | 44°53’38” | S_508 | 41°24’16” | 44°49’50” |
| S_501 | 41°38’31” | 44°51’33” | S_509 | 41°22’39” | 44°50’60” |
| S_502 | 41°37’40” | 44°48’25” | S_510 | 41°21’46” | 44°49’42” |
| S_503 | 41°36’25” | 44°46’60” | S_511 | 41°19’48” | 44°47’40” |
| S_504 | 41°32’17” | 44°46’25” | S_512 | 41°16’26” | 44°47’25” |
| S_505 | 41°30’56” | 44°47’82” | S_513 | 41°15’14” | 44°47’60” |
| S_506 | 41°29’40” | 44°48’65” | S_514 | 41°14’24” | 4°48’45” |
| S_507 | 41°28’38” | 44°47’59” | S_510 is a Control Sample | | |

All samples were collected using the standard geochemical envelope method from a depth of 15 cm. Based on the results of chemical analyses of these samples, the contamination factor (CF) of the studied chemical elements was calculated (Table 2). The data obtained are shown in Fig. 2.

Table 2

**Contents of the Heavy Metals and Toxic Elements in the Soil Samples**

| Indicator | Content, mg/kg | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cu | Pb | Zn | Ni | Co | Cd | Mn |
| Maximum | 120,0 | 300,0 | 300,0 | 100,0 | 20,0 | 2,0 | 1400,0 |
| Minimum | 50,0 | 250,0 | 110,0 | 30,0 | 8,0 | 1,0 | 350,0 |
| Average | 82,9 | 278,6 | 170,4 | 54,3 | 11,1 | 1,9 | 746,4 |
| CF | 1,38 | 1,11 | 1,31 | 0,68 | 1,38 | 0,96 | 1,87 |

The contamination factor (CF) is a ratio used to assess the degree of contamination, particularly in environmental studies, by comparing the measured concentration of a contaminant to a background or reference value. It helps determine the extent of pollution in soil or sediment. The CF is calculated by dividing the measured concentration of a contaminant (e.g., a heavy metal) in the sample (like soil or sediment) by a background or baseline value, which represents the concentration of that contaminant in unpolluted areas [2].

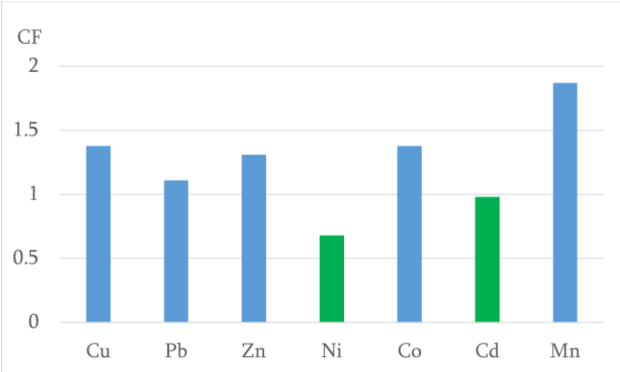


Fig. 2 Pollution assessment: Contamination Factor (CF)

A CF value less than 1 indicates low contamination, while values between 1 and 3 suggest moderate contamination, and values greater than 3 indicate considerable to very high contamination.

As can be seen from this figure, none of the values of the pollution factor of the heavy metals we studied indicate severe pollution. At the same time, the lowest pollution is noted for nickel and cadmium.

At the same time, based on absolute values, the highest concentrations of the chemical elements in question were found at sampling point S_514, which is located directly on the border crossing. Thus, the most polluted area was found at the temporary parking place and the customs control of trucks. This is due to driving in low gears, which results in the highest emissions of pollutants.

The pollution factors shown in Fig. 2, calculated at a distance of more than 60 km, are an average value that shows trends in changes in the concentrations of polluting elements in the soil.

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# GLOBAL CRITICAL MINERALS TRENDS, CHALLENGS AND PROSPECTS

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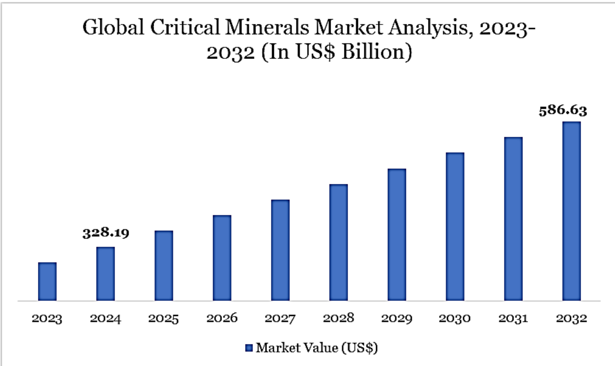
Critical minerals are a group of essential elements and mineral resources that are vital for the development and advancement of a wide range of modern economies and technologies, as well as being crucial for the global energy transition, economic prosperity, strategic importance and national security, playing a significant role in modern technologies such as defense, manufacturing, electronics, renewable energy and electric vehicles. However, their supplies may be limited or at risk of supply disruption, and the scarcity and limited supply chains of these minerals make them critical for ensuring a sustainable and secure future, as their supply chains are often concentrated in a few countries, making them vulnerable to geopolitical risks and supply disruptions.

Critical minerals such as lithium, cobalt, nickel, rare earth elements, and others are essential for the production of a wide range of products, including batteries, electronics, solar panels, wind turbines, and more, including:

- Lithium: Used in electric vehicle batteries.
- Cobalt: Essential for batteries and alloys.
- Nickel: Used in Lithium stainless steel and batteries.
- Rare earth elements: Used in magnets, catalysts, and electronics.
- Graphite: Important for batteries and lubricants, among others.

It is worth noting that the global critical minerals market size was US$320.43 billion in 2022 and is projected to reach US$494.23

billion by 2030, growing at a CAGR of 5.69 % from 2023 to 2030. The report covers products offered by companies such as Rio Tinto, Vale, Glencore, Freeport-McMoRan, Anglo American plc, Albemarle Corporation, Lynas Rare Earths Ltd, Barrick Gold Corporation, BHP, SQM S.A. and others. Meanwhile, the global critical minerals market size reached US$328.19 billion in 2024 and is expected to reach US$586.63 billion by 2032, growing at a CAGR of 7.53 % during the forecast period 2025-2032 (See Fig. 1) [1].




The global critical minerals market is experiencing unprecedented growth, largely driven by the accelerated transition to clean energy technologies. According to the International Energy Agency (IEA), the market size of key minerals for the energy transition has doubled in the past five years, closely matching the size of the iron ore mining market. This growth is mainly driven by a tripling of lithium demand, a 70% increase in cobalt demand, and a 40% increase in nickel demand between 2017 and 2022, with clean energy use accounting for a significant portion of this demand.

The global critical minerals market is segmented by mineral type, extraction method, application, and region (see Table 1).

Table 1. Critical Minerals Market Size [1]

| Metrics | Details |
|---|---|
| By Mineral Type | Lithium, Cobalt, Rare Earth Elements (REEs), Nickel, Graphite, Manganese, Tungsten, Cooper, Others |
| By Extraction Method | PRIMARY Mining, Secondary (Urban/end-of-life product) Recycling, Brine Extraction, Ore Processing, Others |
| By Application | Electric Vehicles (EVs), Revenable Energy (e. g. With turbines, solar panels), Consumer Electronics, Aerospace & Defense, Industrial Machinery, Energy Storage System, Others |
| By Region | North America, South America, Europe, Asia-Pacific and Middle East and Africa |
| Report Insights Covered | Competitive Landscape Analysis, Company Profile Analysis, Market Size, Share, Growth |

A notable trend in the critical minerals market is the increase in investment in mineral development, which increased by 30% in 2022 after a 20% increase in 2021. Lithium saw the sharpest increase in investment by 50%, followed by copper and nickel.

Copper is emerging as a key player in the global critical minerals market, largely due to its indispensable role in the clean energy transition. Globally, copper demand is expected to grow significantly. According to a study by S&P Global, global demand for copper is expected to grow from 25 million metric tons in 2022 to 53 million metric tons by 2050, driven by its widespread use in renewable energy systems and electric vehicles. These initiatives underscore the central role of copper in achieving global sustainable development goals and the importance of securing its supply chain [1].

The growing demand for energy transition technologies, such as electric vehicles and renewable energy systems, is significantly increasing the market for critical minerals. By 2030, demand for minerals critical to the energy transition will nearly triple as the world shifts to renewable energy sources to reduce global carbon emissions to zero by 2050.

According to the International Energy Agency (IEA), the demand for minerals for clean energy technologies is expected to almost double by 2040. will quadruple to nearly 40 million tonnes per year. In this scenario, lithium demand is expected to increase ninefold, with copper seeing the largest absolute growth due to its essential role in electrification. Currently, clean energy use accounts for more than 40 % of total demand for copper and rare earths, 60-70 % for nickel and cobalt, and almost 90 % for lithium [2].It is known that geopolitical risks and supply chain concentration are significant constraints on the critical minerals market. China dominates the processing of key minerals, processing 70 % of the world's cobalt and nearly 60 % of lithium and manganese, while the Democratic Republic of the Congo supplies 70 % of global cobalt. This heavy reliance on a few countries makes the supply chain vulnerable Export restrictions, political instability, and market manipulation are hampering the global energy transition [3]. The sustainability of the global critical minerals market is increasingly being driven by government initiatives aimed at reducing environmental impacts and increasing resource efficiency in several key ways:

Advancing the UN Sustainable Development Goals (SDGs): Critical minerals are vital to advancing global efforts to combat shared challenges, particularly in areas related to clean energy, economic growth, and responsible consumption. These minerals enable the development of technologies crucial to achieving a number of the UN SDGs, including those focused on climate change mitigation, responsible industry, and innovation:

- Clean Water and Sanitation (SDG 6): Enabling reliable water treatment systems through copper-intensive infrastructure.
- Affordable and Clean Energy (SDG 7): Supporting the access to, and advancement of, mineral-intensive low-carbon energy technologies.
- Industry, Innovation, and Infrastructure (SDG 9): Minerals and metals serving as the backbone of industrial development.
- Responsible Consumption and Production (SDG 12): Promoting recycling to limit waste and reduce resource extraction [4].

Responsible sourcing and supply of critical minerals is fundamental to the realization of this and many other Sustainable Development Goals. It is necessary to ensure that the benefits of mineral extraction reach all stakeholders and that negative impacts on people and the environment are minimized, taking into account the promotion of climate protection, support for a just transition and the promotion of a circular economy. While critical minerals are vital for a sustainable future, several challenges need to be addressed to ensure their responsible sourcing and equitable distribution, including supply instability, environmental and social impacts, market failures, policy inconsistencies, risk management, and security. To address these challenges and maximize the benefits of critical minerals, a coordinated approach is needed, including the development and effective implementation of the following:

- Mainstreaming of Responsible Practices: Ensuring that all (critical) minerals supply is mined in line with responsible mining practices and standards would be transformative; however, it is still far from normative at a global level.

- Streamlined Regulations: Streamlininig, and where appropriate, simplifying processes to advance new mining projects responsibly.
- Harmonised Standards: Ensuring ethical sourcing, protecting human rights, and fairly distributing benefits.
- Collaboration and involvement with relevant international processes: Ensuring our work is aligned with international processes and that ICMM is an active participant in these processes (where appropriate), for example the UN Secretary General's Panel on Critical Energy Transition Minerals and UNEA 7 [4].

It is worth noting that, price volatility is a major concern in the critical minerals market. Factors such as supply-demand imbalances, geopolitical tensions, market speculation and economic conditions can contribute to price fluctuations. The clean energy sector, which is heavily dependent on critical minerals, is particularly vulnerable to these price fluctuations. Addressing price volatility requires diversifying supply sources, promoting responsible sourcing practices, investing in alternative technologies and fostering international cooperation. These measures will help ensure a stable and sustainable supply of critical minerals, reduce the risks associated with price volatility and support the clean energy transition.The rapid adoption of clean energy technologies such as solar photovoltaics and batteries is increasing demand for critical minerals, creating significant growth opportunities in the market. As demand for these technologies continues to grow, it is imperative for businesses in the critical minerals industry to prioritize sustainable and responsible practices. Implementing responsible practices ensures the well-being and safety of workers, local communities, and local populations. This includes fair labor practices, respect for human rights, and engaging in transparent and ethical business operations. By implementing sustainable practices, businesses can minimize their environmental impact, including reducing energy consumption, minimizing waste generation, and protecting ecosystems [5].

Given the risks outlined above, shortages of critical minerals could lead to supply chain disruptions, price increases, and economic slowdowns. Accordingly, many countries are developing strategies to ensure access to critical minerals, including diversifying sources, investing in new extraction and processing technologies, and recycling waste.

It is clear that the growing demand for critical minerals threatens resource dependence and exacerbates geopolitical tensions, environmental and social problems. These developments can be avoided, but to do so we must ensure that the countries and communities that own these resources benefit the most, as this represents a huge opportunity for resource-rich developing countries to achieve prosperity, achieve sustainable development goals and eradicate poverty. However, all too often, this is not the case, as the search for resources has led to the exploitation of local communities, human rights abuses and environmental destruction. In such circumstances, we see developing countries sinking to the bottom of value chains while others become rich from their resources. In such a sad reality, it is important to introduce principles and recommendations for justice and equity in the production and distribution of natural resources, and to implement effective mechanisms that take into account the strengthening of communities and accountability, and to ensure that clean energy contributes to equitable and sustainable growth.

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# CHEMICAL AND MINERALOGICAL STUDY OF QVEVRI CLAY AND THE NEED FOR STANDARDIZATION

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The tradition of making qvevri in Georgia dates back more than 8,000 years and is a unique element of Georgian cultural identity. Georgia is recognized by the international community as the birthplace of wine, where winemaking in qvevri represents a unique heritage and a brand with economic potential.

Traditional methods are still used to produce qvevri, including the use of local clay-based raw materials, special processing, and firing. The quality of qvevri largely depends on the mineral and chemical composition of the raw material (clay), the proper processing technology, and the firing conditions in the kiln.

Both archaeological (4th–3rd centuries BCE to 4th–5th centuries CE) and modern qvevri have been made in regions such as Armaztsikhe-Bagineti, Kavtiskhevi, Dedoplis Gora, Samadlo, Gostibe, Imereti, Kakheti, and Guria. Clay samples used in the production of qvevri were taken from various deposits, including Tkemlovana, Shrosha, Atsana, Vardisubani, and others.

The clay used to make qvevri is a polymineral mass consisting mainly of kaolinite, halloysite, montmorillonite, quartz, feldspars, and other minerals. The presence of quartz and other mechanical impurities affects the plasticity, drying process, and final properties of the qvevri.

Research has shown that both old and some modern qvevri are made using incorrect technology (insufficient firing temperature), which leads to defects and negatively affects the quality of the wine. It is important and necessary to develop standards for the raw materials used in qvevri production and to control the manufacturing process.

The properties of the raw materials and qvevri were studied using microscopic, X-ray diffraction (XRD), X-ray fluorescence (XRF), and physico-mechanical methods. The analysis of the obtained data allows for assessing the impact of qvevri on wine suitability.

The demand for high-quality qvevri is growing in parallel with the production of export-oriented wine. Therefore, it is necessary to study local raw material deposits, select and standardize them, which will ensure the preservation and development of qvevri as an object of cultural heritage and an economic resource.

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# RESEARCH ON THE POSSIBILITY OF EXTRACTING GOLD FROM THE FLOTATION TAILS OF GOLD-BEARING SULFIDE ORE

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The rising price and demand for gold, as well as the reduction in reserves, have made the processing of the so-called tails of the enrichment product extremely important (current). This has led to the development of a new technological process and the improvement of the existing technological scheme. Meanwhile, the depletion of reserves of rich deposits of precious and non-ferrous metals is pushing producers to develop poor, difficult-to-enrich deposits. The effective processing of minerals depends on a number of factors, such as: the cost and the quality of the resulting product, the product good condition, the complex and complete recovery of useful component from the ore. The research work aimed to investigate the possibility of extracting additional gold from the flotation tails of gold-bearing sulfide ore. In addition, gravitational, flotation, magnetic and hydrometallurgical ("column" test) enrichment methods were used. To study the possibility of extracting gold from the flotation tails of gold-bearing sulfide ores, the flotation tails of the Madneuli enrichment plant have been tested for enrichment. Its material composition and technological properties have been studied, and a recommended enrichment scheme has been developed. This scheme includes gravitational enrichment of the flotation tails on a centrifugal concentrator, grinding (90% -74 mm), and collective flotation. According to the scheme, the gold content is 37 g/t and the copper content is 9.8%

## KEY ASPECTS OF SAFE UTILIZATION AND TRANSPORTATION OF INNDUSTRIAL AND MEDICAL WASTE

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Industrial and medical waste represents and creates a significant problem, as waste is a product obtained as a result of industrial processes and also represents a strategic raw material that contains many useful, usable components: organic and Inorganic acids, polymeric materials, solvents, salts, alkalis, metallurgical, construction, food production, oil refining products, mercury, lead, acetone, semi-finished products and radioactive waste of special hazard.

All of the above-mentioned compounds and substances have lost their consumer properties and require their high-quality and safe recycling and utilization, which is realized using various methods.

A much greater threat to the environment and working personnel is posed by radiation-containing expired medical devices, equipment, and parts of diagnostic equipment that belong to class D medical waste.

20-30 % of the total waste generated in medical institutions is infectious, toxic, carcinogenic, corrosive, explosive, and radioactive materials.

The collection, storage, and disposal of Class D waste is carried out in strict compliance with the requirements for working with radioactive waste.

# U-Th MINERALIZATION AND NATURAL RADIOMETRIC ANOMALIES OF THE KHRAMI MASSIF (SOUTHERN GEORGIA)

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The pre-Alpine Khrami Massif includes the following units: Late Proterozoic autochthonous gneiss-migmatite complex, Late Variscan granitoids, Upper Paleozoic (Lower Visean-Bashkirian) volcanogenic-sedimentary units ("Lower Tuffites"), and minor occurrences of allochthonous serpentinites and anchimetamorphic sandstones.

The granitoid complex comprises biotite-, garnet-and hornblende–allanite-bearing granites, as well as aliaskites, quartz porphyries and granite porphyries. By the late 1980s, the presence of a range of accessory minerals, several of which are known to host radioactive elements, including allanite, thorite, zircon, xenotime, bastnäsite, molybdenite and cyrtolite, had been confirmed within the garnet- and hornblende–allanite-bearing granites [2,3,4]. Initial investigations also included background radiation measurements associated with these mineral phases [1]. Subsequent electron microprobe analyses of allanite from biotite–hornblende–allanite-bearing granites revealed significant concentrations of Ce, U and Th. However, the precise lithological association of these elements with specific rock types remained unresolved.

The present study aims to investigate the spatial distribution of U- and Th-bearing minerals and related natural radioactivity across the various lithological units of the Khrami Massif. Field measurements were conducted using a compact portable gamma-spectrometer equipped with a GAGG(Ce) scintillation detector (energy resolution ~7.4% at 662 keV), which integrates radiometer, dosimeter, and spectrometer functionalities.

The fieldwork covered both central and peripheral parts of the massif (including the Khrami HPP area, Bediani Ridge, Chochiani Gorge, and tributaries of the Khrami River). Systematic radiometric profiling, geological descriptions, rock sampling, and GPS-based georeferencing of observation points were carried out.

Allanite-bearing granites exhibited radioactivity levels of 13-20 μR/h, with local maxima reaching up to 28 μR/h. Quartz porphyries displayed the highest activity, up to 54 μR/h, indicating significant enrichment in U and Th. Migmatites and gneisses showed relatively stable activity in the range of 10-40 μR/h, with localized increases likely related to recrystallization processes and radionuclide remobilization. Basalts and other mafic rocks showed the lowest values of 6.5-7.5 μR/h. In certain exposures of metamorphic rocks (e.g., the Tkemliani area), background radiation levels of approximately 11.7 μR/h were recorded.

These findings provide a robust basis for future mineralogical, geochemical, and environmental radiological studies of the Khrami Massif. The high density of radiometric data enables confident correlation of observed anomalies with specific rock types, contributing to the reconstruction of the massif's geological history and the assessment of its potential for rare-metal mineralization.

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# THEORETICAL AND MATHEMATICAL MODELING OF SHOCK WAVE LOADS IN VARIOUS ENVIRONMENTS

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Fundamental research of fast processes is of great importance for developing space and aviation technology, energetics, chemistry and modern mechanical engineering, as well as shock wave physics. Theoretical and experimental research in this field enable the development of methods to solve various dynamic load problems related to shock wave loads in homogeneous, heterogeneous, gaseous, liquid and solid media. These studies also allows us to study and practically apply the processes of shock wave propagation arising from explosions and/or impacts in various environments. Shock wave loading is caused by the propagation of a shock wave, which is most often associated with explosions or supersonic processes.

Shock wave loads require different approaches to modeling.

The basic theoretical model and its associated equations are presented below. The theoretical model of shock wave loading is a modeling of gas dynamics and wave propagation. The typical situation is an explosion in an environment > shock wave > impact on the structure.

Shock wave model:

- Rankine-Hugoniot equations (comparison of the state of the environment before and after a shock wave)

$$\frac{P_2-P_1}{\rho_1(U_s-u_1)} = U_s - u_2 \quad ; \qquad \frac{\rho_2}{\rho_1} = \frac{(+1)M^2}{(-1)M^2+2} \quad .$$

Where: $P_1$; $P_2$ - Pressures before and after the shock wave;

$\rho_1$; $\rho_2$ - Density of the environment;
$u_1$ ; $u_2$ - Speeds;
$U_s$ - Shock wave velocity;
$M$ - Mach number.

Shock pressure wave profile: (ideal model)

$$P(t) = P_s\left(1 - \frac{t}{t_a}\right)e^{-\beta t/t_a} .$$

Where: $P_s$ - Pressure peak;
$t_a$ - Duration of pressure;
$\beta$ - Form factor.

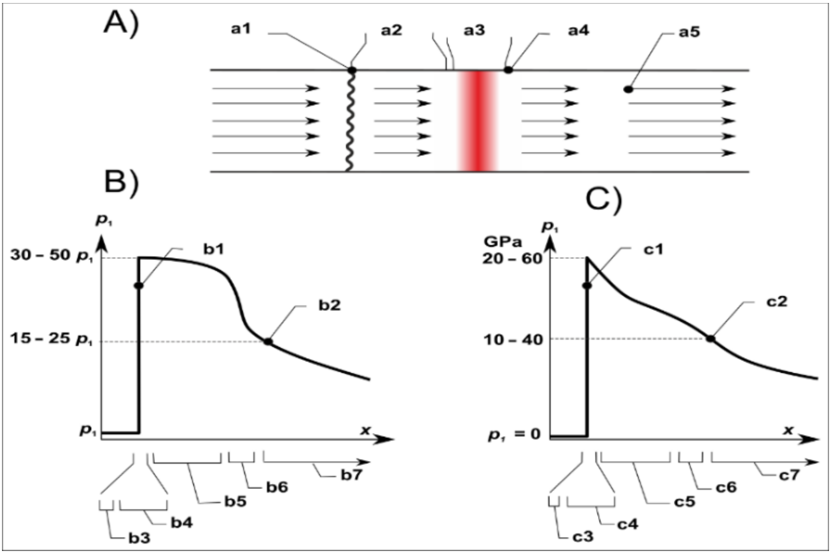


Fig. 1. Detonation wave diagram.

From a macroscopic point of view, a shock wave is an imaginary surface at which the thermodynamic quantities of the medium undergo a sudden increase (Fig. 1). After passing through the shock wave front, the medium's pressure, temperature, and density change. The velocity of the medium relative to the shock wave front also changes. These parameters do not change independently; they are related to the only characteristic quantity of the shock wave - the Mach number. It is a mathematical equation that relates the thermodynamic quantities of the environment before and after the shock wave passes. The Mach number is not constant and changes with changes in thermodynamic parameters, especially when exposed to shock waves. A relative measure of speed in a medium, Mach number is a crucial parameter in supersonic and hypersonic dynamics.

Sound is the propagation of density fluctuations in the medium through space. According to the equation of state of the ordinary medium, an increase in the pressure of the medium causes an increase in the speed of sound. Based on this mechanism, a shock wave in an ordinary medium always transforms into a compression wave. However, a shock wave is not additive. The thermodynamic state of the medium after a shock wave passes is not the sum of the thermodynamic states resulting from two shock waves of lesser intensity passing through the medium.

This paper studies the instantaneous rise, high speed and momentum of an air shock wave, which determine the wave's destructive nature. In order to reduce its environmental impact, the study takes into account physical, mathematical, and engineering analyses, which require the accurate determination of shock wave parameters. The main goal of the paper is to study, analyze and discuss the ways to practically apply methods for calculating the main parameters of shock wave loads in various environments. This research is based on theoretical knowledge, as well as empirical formulas and mathematical models obtained through many years of experiments and analytical studies.

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# STUDING THE POSSIBILITY OF OBTAINING LECA BASED ON A NUMBER OF GEORGIAN BREEDS

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It is known that various types, but especially artificial, (LECA – lightweit expanded clay aggreqete) are widely used in technology and many industries. The traditional technology of their production is based on the thermal treatment of clay rocks of various nature or man-made raw materials and their expansion. The porous materials obtained by this method are characterized by a closed-pore structure, lightness, environmental friendliness, heat and sound insulation properties, as well as other, often unique, physical and chemical characteristics [1] [2].

The most commonly used products made from lightweight porous inorganic materials are of two types: the so-called "expanded clay" and foam glass. Their identity is determined by the method of production – high-temperature, but different foaming process regime, high porosity of structures and low bulk/specific density, while the main areas of their application differ significantly. In particular, expanded clay is known as a granular filler for lightweight concrete or an invariable component of thermal insulation, water- and frost-resistant coatings, when expanded clay is used to make thermal insulation products of various shapes and purposes [3] [4].

In order to expand the acceptable resource base of two types of multifunctional (expanded clay: foam glass) LECA – lightweit expanded clay aggreqete and to comprehensively address environmental and technological issues within the framework of research related to their implementation, an alternative resource base was selected: mineral-bearing rocks available on the territory of Georgia. In particular, silicate rocks were selected for the study: zeolite, obsidian, clay slate, argillite, volcanic ash and trachyte (the main raw material). As a result of studying and analyzing their chemical composition, it was established that these materials are promising for use in the technological process of obtaining LECA [5].

Based on the results obtained for all six materials, the following general conclusion can be drawn:

- Trachyte and volcanic ash are less prone to swelling. However, an increase in temperature causes: a change in the color of trachyte fragments, and at 1250$^0$C their slight porosity is observed, while volcanic ash is calcined only at 1200 and 1250$^0$C;
- Argolite remains practically unchanged up to 1200$^0$C, and at 1250$^0$C it melts completely, forming a black glassy mass;
- The transformation of zeolite is manifested in a gradual change of color: 1000$^0$C – pink; 1200$^0$C – milky. Melting of its grains, with the formation of a heterogeneous melt (a combination of black and milky parts), occurs at 1250$^0$C;
- In the case of clay slate, swelling of raw material fragments was clearly observed in the temperature range of 1100 – 1200$^0$C; at 1250$^0$C, melting and “shrinkage” of the swelling material already occurs;
- Thermal treatment of obsidian fragments at a temperature of 1100$^0$C already causes their swelling. A further increase in temperature (1100-1250$^0$C) proportionally increases the degree of their swelling.

The swelling coefficient ($K_\alpha$) was determined for materials processed at temperatures corresponding to maximum swelling, which was calculated using the formula $K_{\alpha} = \gamma/\gamma'$ (kg/m3), where γ and $\gamma'$ respectively, are the bulk densities of the initial raw materials (shale and obsidian) with a fraction of 10-15 mm and materials obtained by swelling (temperatures corresponding to the maximum). It has been experimentally established that $K_{\alpha}$the value for obsidian is 4.1, and for slate - 3.9. That is, obsidian is characterized by a greater tendency to swelling than slate.

Based on the experimental results, it was confirmed that of the six types of raw materials studied, two types clearly showed a tendency to swell (transform into a porous material): the temperature range for clay swells is 1100-1200$^{0}$C (maximum 1200$^{0}$C), and for obsidian - 1100-1250$^{0}$C (maximum 1250$^{0}$C). The difference between them, which is noticeable visually, is in color and texture. Expanded slate is a brownish-brown layered material, while expanded obsidian is a milky-gray, completely glassy, homogeneous material. The first of them is similar to expanded clay, the second to foam glass. This assumption was confirmed by establishing the required characteristics in the relevant standards (GOST 32496-2013 for expanded clay and GOST 33949-2016 for foam glass).

A comprehensive comparative analysis of the properties of two main types of artificially obtained porous materials (expanded clay and foam glass), required by the standard and obtained from the raw materials taken for research, showed that by high-temperature firing of clay shale and obsidian, it is possible to obtain two different types and grades of porous expanded clay materials - expanded clay grade M700 from clay slate and expanded clay grade D200 from foam glass.

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# GEOCHEMICAL ANOMALY AT THE ZVARETI GOLD-LOW-SULFIDE MINERAL OCCURRENCE (GEORGIA, BOLNISI ORE DISTRICT

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The Zvareti gold-low sulfide ore occurrence is located between the Mushevani 3 gold-minor sulfide and West Lower Bolnisi gold-polymetallic deposits of the Bolnisi ore district.

The ore-bearing rocks are coarse-fractured crystal-lithoclastic tuffs of Senonian age of rhyodacite composition. These rocks are interbedded with subvolcanic bodies of rhyodacites, rarely andesites.

In the wells drilled in the central area of the Zvareti ore occurrence, single signs of gold content are noted. On its eastern flank, the smelting is much larger in terms of both volume and content. As for polymetallics, the Zvareti object, as well as most other deposits and ore occurrences in the ore region, is characterized by a tendency for the predominant content of zinc compared to lead. It is interesting that high silver contents are recorded in Zvareti. This fact is observed for a number of ore objects in the Bolnisi ore region, but in terms of silver content, the Zvareti ores are one of the most outstanding; for example, in the MSHDDH116 well in the interval 92 - 93 m, the silver content is 2.3 kg / t.

In addition to the above, there is a tendency for the Zvareti and Western Lower Bolnisi ores to continue each other.

Geochemical testing conducted by Caucasus Mining Company LLC at the Zvareti site and its northern flank identified secondary anomaly of gold, copper, lead, and zinc.

Despite the generally high background of gold, copper, lead, and zinc contents in the region (compared to Clark for these elements), the obtained anomaly are distinguished by anomalous concentrations.

The location and forms of the aforementioned anomaly here and at other sites in the Bolnisi ore district were, as a rule, significantly determined by the functioning of the east-northeast and north-northwest trending fault structures characteristic of the region.

The spatial distribution of geochemical anomaly of useful components and the geochemical profile quite clearly indicate a high positive correlation of gold and sulfides (mainly lead and zinc, to a lesser extent copper); as well as low migration of these metals, despite the rather fragmented relief of the region.

The obtained geochemical anomaly, in combination with geophysical anomalies, can be used to search for gold-sulfide ores at depth.

# FABRICATION OF METAL-POLYMER COMPOSITS BASED ON ALUMINUM WITH ANDESITE ULTRADRISPERSE POWDERREINFORCED MATRIX

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This study focuses on the fabrication and mechanical characterization of impact-resistant metal-polymer composites, whose structure is based on basalt fabric, an intermediate aluminum sheet (0.5 mm thickness), and a polymer resin matrix modified with natural volcanic-origin andesite micro-nano powder. The powder was produced by planetary milling (PULVERISETTE 7), with a fractional composition not exceeding 350 microns. In the composite structure, the aluminum layer is positioned between the basalt fabric layers and serves as an internal reinforcing element.

The material was fabricated using vacuum infusion technology. In this process, the polymer resin is transferred under vacuum conditions ($10^{-3}$ torr) into a vacuum bag containing the reinforcing components (basalt fabric and aluminum layer), ensuring uniform resin distribution and effective interfacial integration. This technological approach guarantees close bonding and a homogeneous structure of the composite layers, which is critical for mechanical impact resistance.

The impact resistance of the composite was evaluated using a dart-type impact test conducted in accordance with the ISO 6603-1 standard. Disk-shaped specimens with a diameter of 60 mm and a thickness of 4 mm were prepared for testing. The experiment was performed by free-falling a mass from a defined height, which strikes the specimen at its geometric center. During the test, the absorbed energy, type of damage, and crack propagation patterns were recorded. This method allows for assessing the material's capacity to absorb localized impact energy, thereby determining its impact resistance.

Results demonstrated that composites modified with andesite powder exhibit enhanced impact resistance, characterized by reduced damage, lower crack propagation intensity, and increased energy absorption capacity. Structural stability was preserved in the specimen's central region, indicating that the rigid phase integrated into the resin matrix acts as an effective reinforcing factor. The deformation behavior showed increased plasticity and uniform energy dissipation, which is especially important for response under impact loading.

Comparative analysis revealed that composites without andesite in the resin exhibited pronounced brittle fracture and rapid crack development. Their deformation was mostly fragmentary, with internal micro-layer separation occurring easily. In contrast, composites containing andesite maintained surface integrity and displayed deformation behavior oriented towards plasticity.

The obtained results indicate that integrating natural micro-nano components into the polymer matrix represents a promising approach to improving the mechanical and energetic properties of metal-polymer composites. Andesite powder, being an economically accessible and environmentally safe material, provides structural reinforcement without the need for additional additives, making it particularly attractive compared to standard polymer systems.

Beyond academic significance, such composites have practical potential in transportation, structural protective elements, and other applications where impact resistance is a critical requirement.

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