REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation for the degree of Doctor of Science

CREATING THE CLASSIFICATION MODELS OF ROCKS FOR RATIONAL DEVELOPMENT OF MINERAL DEPOSITS OF AZERBAIJAN

Specialty: 2524.01 “Mining and oil-gas field geology, geophysics, surveying and earth surface geometry”

Field of science: Earth sciences

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GENERAL CHARACTER OF THE WORK

The topicality and development degree of the subject. Development of rich ore and non-ore mineral resources is of great economic importance for the social and economic development of the independent Republic of Azerbaijan. One of the disadvantages of the development of mineral deposits in Azerbaijan is the lack of reliable systematic physical data on the fields. Therefore, because of the lack of complete and reliable information on the physical and properties of rocks and minerals, it is practically impossible to conduct a comprehensive economic evaluation of the fields, as well as to select the method of their efficient development.

The current state of deficiencies in the registration, evaluation and efficient management of mineral resources, as well as the development level of software and hardware requires the creation of automated systems for the efficient development of mineral deposits.

There is a need to have reliable information on the physical properties of the mineral deposits to improve the technical and economic indicators of the mineral deposits and determine their reserves based on real data.

As it is known the lack of reliable data on the physical properties of mineral deposits often leads to erroneous calculation of reserves, leading to economic losses during designing, development and construction of associated facilities.

Reliable and fast access to data on the physical properties of rocks in the ore tract is a prerequisite to ensure safety in selection and justification of efficient development system of mineral deposits, as well as during mining operations and the exploitation of complex natural and technical facilities.

In general, the physical properties of rocks and minerals need to be thoroughly studied and their classification models must be created to ensure safe mining operations and efficient development of mineral deposits in Azerbaijan. This, in turn, ensures intensive development of the mining industry in Azerbaijan and minimization of environmental costs. The submitted dissertation solved all the above issues of the mining industry of Azerbaijan, including several economic and environmental aspects.

The object and subject of research are the rocks and side rocks that make up the mineral deposits of Azerbaijan

The purpose of the study. The main purpose of the dissertation is to determine the interaction between the physical properties of rocks and the regularity of changes in these properties for their efficient development in different stages of industrial appropriation of mineral deposits, predicting the physical properties of physical properties of rocks in closed areas and deep deposits, as well as development of economic and ecological aspects of the efficient use of a number of large ore deposits.

Taking the scale and importance of the problem into account, the solution of the following problems is intended to realize in order to achieve the goal having been set:

- determining the key changes in the distribution of physical properties of rocks and minerals for the efficient development of mineral deposits;
- studying the physical properties of rocks and minerals with further processing of the data obtained on the basis of computer technologies;
- studying the interaction between the physical properties of rocks using trend-analysis computer software;
- studying the tension-deformation state of the rocks under the manifestation of modern geodynamic processes;
- determining the impact of modern geodynamic processes on changes of the physical properties of rocks and minerals;
- preparation of cadastre according to physical properties of rocks and minerals;
- creation of computer database on physical properties of rocks in mineral deposits using GGT;
- application of cluster analysis to create classification models of mineral deposits;
- selecting the most favorable classification models of rocks,

taking into account their geological and mining-technical conditions for efficient development of mineral deposits;

- comparative analysis of economic and environmental aspects of Azerbaijan iron, aluminum and polymetallic fields in the national economy for their efficient development.

Research method. When solving the tasks set in the dissertation, complex methods: standard laboratory determination of physical properties of rocks and their processing on computer, solution of analytical and digital problems in rock mechanics, information methods, mathematical statistics, statistical analysis of experimental research data, modern technical means and computer programs were used.

Key provisions to be defended.

1.Carrying out analytical work for the effective development of mineral deposits in Azerbaijan and summarizing them, systematizing existing data on the physical properties of rocks.

2. Scientific justification of the classification of minerals and rocks of Azerbaijan according to their physical properties by the use of cluster analysis, the wide use of GGT and computer technologies to optimum design processes in the mining industry.

3.Creating a computer database for the physical properties of rocks and minerals in various fields of Azerbaijan and compiling a cadastre based on this.

4. Justification of economic and environmental aspects of efficient use of a number of large ore deposits in Azerbaijan.

Scientific novelty of the research. The following scientific innovations were obtained in the dissertation:

- physical properties of rocks and minerals on the main mineral deposits of Azerbaijan have been summarized and systematized.
- it has been established that there is a natural relationship between the physical properties of rocks on a number of mineral deposits in Azerbaijan.
- it has been established that there is interaction between modern geodynamic processes with changes in physical properties of rocks, so that it provides the parameters of the rocks being of great

importance for safety of mining operations in the construction and operation of complex natural and technical facilities.

- the identification system developed for the physical properties of rocks allows them to be systematized, classified and process the results using computer technology, and also significantly reduces the amount of mining work in the fields, in which case the data obtained on the rocks are considered reliable for many practical calculations.

- the cadastre of the rocks has been developed according to the physical properties of the rocks of the mineral deposits, enabling to quickly get acquainted with the mineral deposits and to evaluate the rocks as an object of development.

- computer database on the physical parameters of the rocks and minerals of various ore and non-ore deposits as a single data system controlling mining operations. The database, created according to the physical properties of the rocks, not only retains ready-made data, but also provides an opportunity to obtain operational data about any deposit and update it with new data.

- mineral deposits were classified using cluster analysis. The Euclidean distance was taken as size of the cluster, which is formed by comparing the values of physical quantities characterizing different physical properties of mineral deposits rocks. Their similarities and differences are given according to the calculated value of the Euclidean distance for each group of fields.

- classification models of rocks and minerals were created, which are able to classify mineral deposits located in the territory of the republic and allow to effectively arrange the development strategy of mining production.

- the Shuhart control map describing changing features of rocks’ characters has been created with the help of the trend model on the mineral deposits. The newly developed Shuhart control map enables to district the deposits according to the hardness, porosity, and other physical parameters of the rocks, which ensures long-term safe minning operations in quarries, mines and deposits.

- according to the proposals developed for the production andprocessing of ferrous and non-ferrous metals in Azerbaijan, along with base metals, the extraction of regulatory elements and the involvement of industrial waste, industrial gas and dust in production ensures reducing the cost of the final product, and thus minimizing the environmental pollution using spare protective technology.

Scientific and practical significance of the dissertation. The results obtained in the dissertation work can be used in the geological and technological departments of AETSN, the development of iron, polymetal, gold deposits of local and foreign mining companies, mining operations in new deposits, increasing the efficiency of the initial production cycle of mining companies, as well as in minimizing environmental protection costs during a full production cycle at a mining enterprise.

Approbation and application of the work. The results of the dissertation were reported and discussed at the following international scientific and technical conferences and congresses. eighth and ninth International Congress Baku (Baku, 2005, 2007), Proceedings of the 8^{th} International Conference: “New ideas in Earth sciences” (Moscow, 2007), International Conference: “Modern problems of mechanics” (Samarkand, 2007), All-Russian Youth Scientific and Practical Conference on the “Subsoil use problems” (Yekaterinburg, 2008, 2011); All-Russian Conference (Moscow, 2008), International Conference on Clays, Clay Minerals and Layered Materials (Moscow, 2009), International Scientific and Technical Conference “Aerospace Technologies in the Oil and Gas Complex” (Moscow, 2009), International scientific conference “Oil-gas, oil refining and petrochemicals” (Baku, 2010), Al-Azhar Engineering eleventh and thirteenth International Conference (Cairo, 2010, 2014), Geoinformatics 2010-9th EAGE International Conference on Theoretical and Applied Aspects of Geoinformatics. (Kiev, 2010), All-Russian Conference, with international participation “Geology and geochronology of rock-forming and ore processes in crystalline shields” (Apatite, 2013), All-Russian Scientific and Technical Conference “Geomechanics in Mining (Yekaterinburg, 2013, 2014), All-Russian Conference “Problems of

Geology of European Russia" (Saratov, 2013), V and VI Ural Mining Forum, All-Russian Scientific and Technial conferences with international participation "Solid Minerals"; technological and environmental problems of the development of natural and technogenic deposits "Subsoil use problems" (Yekaterinburg, 2013, 2015), I International Conference «Global Science and Innovation» (Chicago, 2013), VIII All-Russian Youth Scientific and Practical Conference (Ekaterinburg, 2014),XIII, XIV, XV and XVII international conferences "Resource-reproducing, lowwaste and environmentally friendly technologies for the development of mineral resources" (Moscow-Tbilisi, 2014, Moscow-Bishkek, 2015, Moscow-Homs, 2016, Moscow-Актau, 2018), IV and VI International Conference on Science, Technology and Higher Education (Westwood, 2014), 10th International Conference on Achievement of High School 2014 (Sofia, 2014), X international scientific-practical conference "Scientific prospects of the XXI century" (Novosibirsk, 2015), the 1st European Conference on Earth Sciences (Vienna, 2015), XIII International Conference on European Science and Technology (Munich, 2016), The VII International Conference on World Science problems and innovations. (Penza, 2017), the XXXIII International Scientific and Practical Conference on Innovation in Science and Technology (United Kingdom, 2017), the XX International scientific conference European conference European research. (Penza, 2019), as well as it was reported and discussed at a number of seminars of the department of "Geology and development of mineral deposits" of Azerbaijan State Oil and Industry University.

80 scientific works on the thesis of the dissertation, including 2 monographs, 48 articles, 27 international conference materials have been published, 3 patents have been obtained.

Personal contribution by the author. Determination, solution and implementation of the purpose of the dissertation, and the issues put forward were carried out independently by the author. Development, investigation of the obtained results, their interpretation in the form of reports, preparing and submitting them for publication in the form of scientific articles were directly realized by the author. The author's contribution to the preparation of some results to be interpreted (with co-authors) was greater.

The works, methods and justifications reflected in the dissertation were used in the teaching process of ASOIU and during its application in the facilities of Azerbaijan International Limited Mining Company .

Application of the research. Developments, new constructive solutions, methodologies and substantiations reflected in the dissertation were used in the educational process of ASOIU and in the facilities of Azerbaijan International Limited Mining Company. Relevant acts were taken in this regard. As a result of these applications, great economic benefits were achieved.

The organization where the dissertation has been carried out. The dissertation has been carried out at the department of "Geology and development of mineral deposits" of Azerbaijan State Oil and Industry University.

The volume and structure of the dissertation. The dissertation consists of an introduction and five chapters, results and the list of references. The volume of the work is 308 pages. The work consists of 68 figures, 60 tables and the list of 310 references. Introduction - 8 pages, Chapter I - 65 pages, Chapter II - 38 pages, Chapter III - 26 pages, Chapter IV - 30 pages, Chapter V - 92 pages, results - 3 pages, the list of references - 29 pages and 8 pages of appendix. It consists of 402846 characters without tables, graphs, pictures and the list of references.

The author expresses her deep gratitude to Ch.M.Khalifazade, scientific consultant, d.s.g.m, professor, prominent scientist, for his help and constant support in carrying out her dissertation.

MAIN CONTENT OF THE DISSERTATION

The **introduction** part interprets the topicality of the research, its purpose, the issues raised to achieve the goal, scientific innovation, the practical significance of the work, the provisions to be defended, the application of the work and some tasks.

The first chapter provides an overview of the available classifications of rocks and minerals for the development of mineral raw material deposits. The main directions of rock classification in different periods are shown.

The complexity of all the classifications used in mining, many of which do not comprehensively consider the physical properties of rocks, others (personal) enable to solve only specific small problems.

As it is known the gradual extraction of minerals from relatively shallow depths requires the design of exploration and prospecting for deeper minerals over the years. In this case, the investigation of well sections is allowed only if it is possible to realize the rocks by their physical properties in all the different natural conditions encountered.

Every year, the geophysics of exploration is posed with the problem of direct exploration of minerals. The problem cannot be solved successfully without a fundamental study of the dependence of the physical properties of rocks on their mineral composition and the crystalline structure of minerals.

The shortcomings in the development of this problem require the creation of a more reliable theory that determines the dependence of the physical properties of rocks and minerals on other parameters, as well as on the geological and technological conditions of the deposit and the technology of exploitation of mineral resources.

Therefore, there is a great demand for the creation of classification models according to the complex physical parameters of rocks of mineral deposits. In addition, a holistic approach to physical properties is very important for the creation of modern classification models of mineral deposits. The content of this problem is fully reflected in the first chapter of the dissertation.

The second chapter deals with the determination of the interaction between the physical properties of rocks of a large number of ore and non-ore deposits in Azerbaijan and the analysis of the impact of the physical properties of rocks on the development processes of mineral deposits using a computer program of trend analysis. Experimental investigations were conducted to clarify the nature of these properties and the character of the observed events. On the basis of the data obtained, interactions between the physical properties of the rocks were identified and a more perfect classification system was created based on the available data.

In the dissertation, the interaction between the physical properties of the rocks of the main mineral deposits of Azerbaijan including Dashkasan iron ore deposit was determined. Main physical parameters like porosity (P), density (ρ_0), tensile strength (σ_{com}), Jung modulus (E), specific heat capacity (C_m) and specific electrical resistance (ρ_e) were used for trend analysis of rocks of Dashkasan iron ore deposit (table 1) and the obtained results are presented (figure 1, 2,3).

Table 1

Key physical indicators for carrying out the trend analysis of the Dashkesan iron-ore deposit

Rocks	**P, %**	**σ_{com}, MPa**	**$E \cdot 10^{-5}$, kgs/cm^2**	**λ, Vt/K**	**ρ_υ, Om .m**	**C_m, Coul/кg K**
Marbled limestone	*2.81*	*37.0*	*4.70*	*1.15*	*$2.8 \cdot 10^3$*	*0.70*
Oxidized magnetite	6.00	146.0	5.40	4.20	$2 \cdot 10^3$	0.61
Tuff	3.62	134.0	2.50	2.49	$3.6 \cdot 10^3$	1.05
Tuff sandstone	3.65	118.0	7.70	2.40	$3.8 \cdot 10^2$	1.40
Hornstone	2.20	138.0	7.10	4.15	$3. \cdot 10^3$	1.52
Porphyrite with diabase	3.70	98.5	5.60	4.17	300,00	1.72
Garnet scarn	3.91	112.0	2.80	5.10	$8 \cdot 10^3$	0.72
Diorite	1.20	110.0	7.50	2.36	600,00	5.46
Quartz magnetite ore	7.75	152.0	8.50	3.90	$1.5 \cdot 10^3$	0.67

One of the main parameters of the rocks structure is the porosity, which greatly influences their physical properties. Therefore, numerous interactions have been discovered on the basis of porosity based on the physical properties of the rocks.

The strongest pore dependence is observed in the limit of compression strength (σ_{com}), the Jung module (E) and electrical resistance (ρ_e) is observed. Therefore, possible interactions between these parameters are reflected in the porosity parameter.

There is a direct proportionality between the values of E and σ_{com} of these parameters, as these parameters depend on the porosity in terms of the same probability value. With the help of Trend analysis, the interactions between the physical properties of the Dashkesan iron-ore deposit have been determined and are shown in figure1.

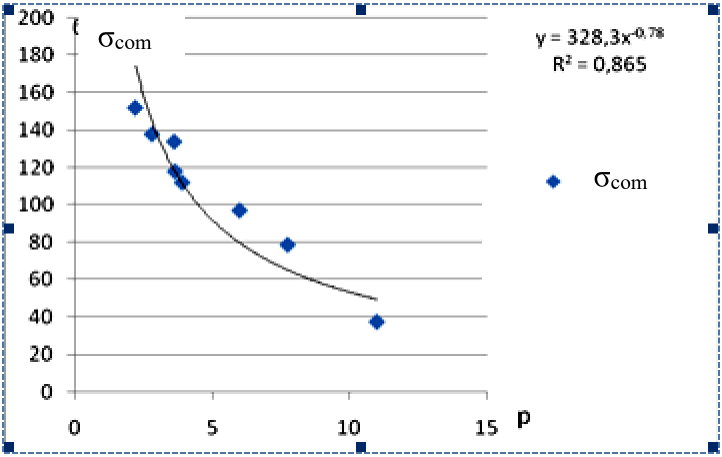

Figure 1. Dependence curve of compression strength limit (σ_{com}) on the porosity (P) of the Dashkesan iron-ore deposit

As it is known the approximation quality is determined by the reliability value of R^2 approximation. Its value ranges between 0 ÷ 1. The closer the value is to the unit, the more reliable the approximation function of the trend is. In this case, the equation will be as follows:

$$y = 328,3x^{-0.78}$$

here 328,3 and 0,78 are constants.

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here 328,3 and 0,78 are constants.

Here the value of approximation reliability is R = 0, 865, which corresponds to the experimental data, and the error is very small. Otherwise the equation would be as follows:

$$y = 17{,}32x^{-0.81}$$

here 17.32 and 0.81 are constants.These data are precisely evidenced by the trend line rate, the value of approximation reliability coefficient is $R^2 = 0.939$, which indicates the degree of correspondence with the basic data on the trend model (figure 2).

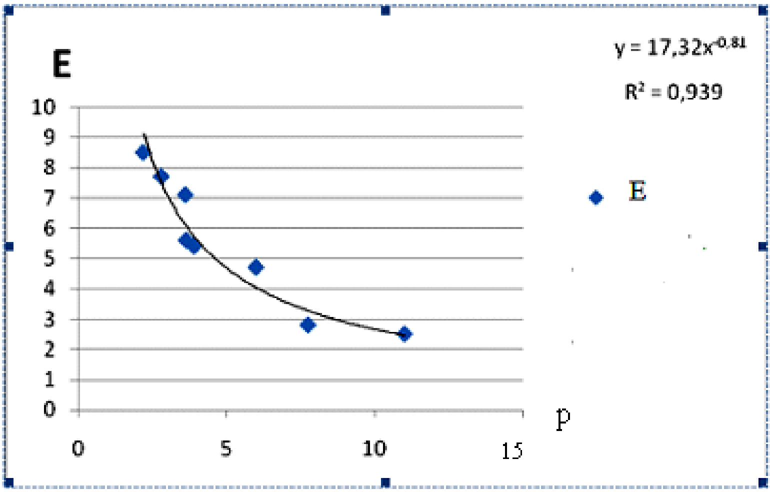

Figure 2. Dependence curve of Yung module (E) on the porosity (P) of the Dashkesan iron-ore deposit rocks

Figure 3 shows the relationship between electrical resistance (ρ_e) and porosity (P). Based on the mentioned above, the equation has the following form:

$$y = 17.47x\text{-}1.03$$

where 17.47 and 1.03 are constants.

Here, the conformity of the trend model to the initial data is proved by the value of the reliability level $R^2 = 0.964$

As it is seen from the diagram (figure 3), the value of the reliability level is nearly zero, which indicates the accuracy of the initial data obtained and the constructed diagram.

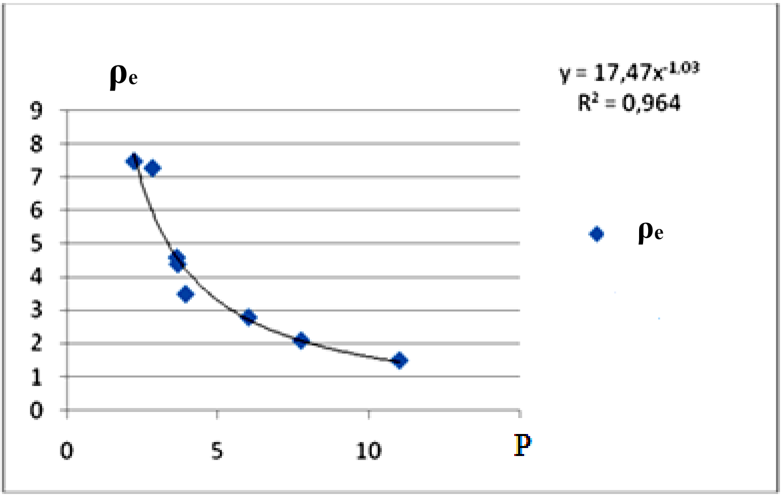

Figure 3. Porosity-dependent curve of electrical resistance (ρ_e) of Dashkasan iron ore deposit rocks

The data obtained on the reliability of the multinominal regression equation confirms the very qualitative structure of the interaction model between the physical properties of the rocks which was compiled by us.

By means of the trend analysis it was established that there is interaction between the physical properties of rocks on a number of ore and non-ore minerals in Azerbaijan.

The results of the research shown that there is a strong interaction between the physical and technical properties of the rocks. Both parameters depend on the mineral composition and structure of the rocks. The knowledge on the interactions of physical properties with the mineral composition and structure of rocks determines the general correlation dependence between the physical and technical properties of rocks.

The third chapter studies the role of geodynamic processes in the formation of tension-deformation conditions in rocks, the change in physical properties of rocks over time, and and the influence of hemodynamic factors on hazardous mining and oil and gas facilities Modern geodynamic processes are accompanied by vertical and horizontal movements of the earth, devastating earthquakes and volcanic activity, and massive landslides, which, in turn, they cause the formation of tension condition in the mountain massifs.

It was noted that the deformation-tension state of rocks and their deformation over time is primarily a sign of the emergence of modern geodynamic processes. Studying the interactions between modern geodynamic processes and the change in their physical properties of rocks is of great importance for the development of solid mineral deposits, oil and gas geology and geophysics, protection of the construction and natural and technical facilities, including underground maintaining of oil and gas.

From this, we can conclude that modern geodynamic processes occurring in the earth crust play a key role in the formation of tension-deformation conditions in the mineral deposits and are one of the major factors affecting the physical and mechanical properties of the rocks.

A prediction method is proposed to study the change in the physical properties depending on time. When the physical properties of the rocks in the area are studied, a time-dependent change in the rock mass is observed. The initial data for this are the results of the first repetitive observations.

The prediction method is implemented as follows. δh-amplitude of the modern geodynamic processes (MGP) is measured by repetitive monitoring in hazardous objects in seismic conditions, this time the average annual velocity (Δ ν) is defined and the occurrence time (Δt) of spatial variability in physical properties is calculated according to the following equation.

$$\Delta t = \frac{\delta h}{\Delta \upsilon}$$

δh is amplitude (MGP) mm; Δt is the occurence time, year of the change in the physical properties of rocks; Δυ is the velocity of MGP mm/years.

Studies determined that there is a strong correlation between the physical properties of rocks, accompanied by changes in modern geodynamic processes.

On the base of the results of the observations carried out repeatedly, the dependence of spatial variability (J) of the petrophysical properties of rocks on the modern geodynamic movement (δh) was determined by multiplying the average annual velocity (Δυ) by the duration period of the time (figure 4).

The main analysis of the repeated monitoring observations showed that the change in physical properties of the rocks in the mass occur in the places with the highest intensity of modern geodynamic movements of the earth's surface.

$$J = \delta h = \Delta t \cdot \Delta \upsilon$$

Here J_1, J_2, J_3, J_4, J_5 are the spatial variability of the properties of the rocks during the deformation of the earth's surface. As a result of repeated observation, when the rocks are in a state of tension-deformation, the physical properties change occur in them depending on the time.

These data enable to predict the occurrence of a hazardous situation in seperate areas and take action to prevent it in advance.

The proposed method for predicting spatial variability of physical properties of rocks is the basis for geophysical monitoring of natural and technical facilities, improving the quality of geological and geophysical data and ensuring safe, economical use.

This chapter also examines the effect of geodynamic factors on hazardous objects of mining and oil and gas complexes..

Until recently, the vast majority of emergencies and damage to oil and gas facilities were supposed to be due to technological reasons

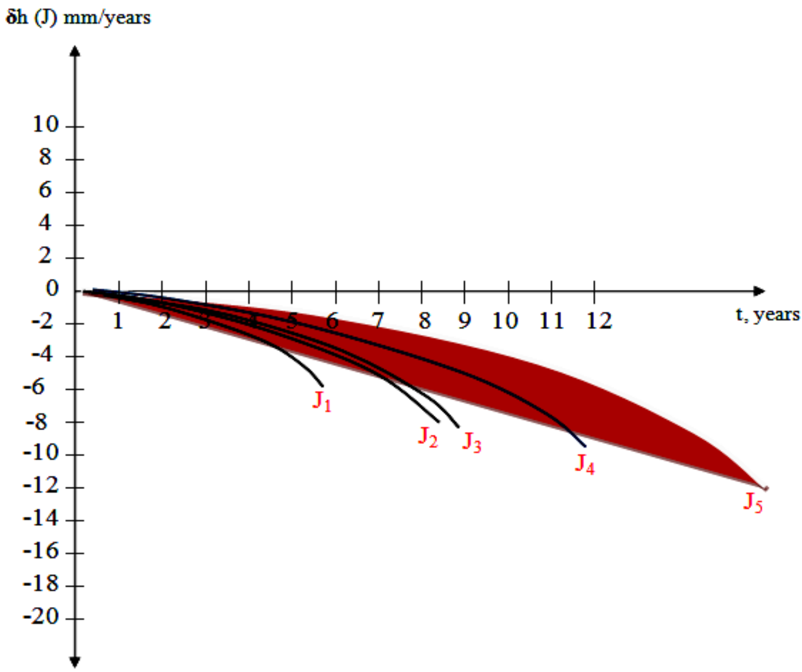

Figure 4. Dependence diagram of modern geodynamic processes (MGP) amplitude δh, (J) on time t of occurrence of changes in the physical properties of rocks

rarely, such accidents were associated with human-made (techno-genic) geodynamic processes. In general, the modern geodynamic factor of the geological environment (especially of natural origin) was not taken into account during the analysis of emergencies, especially at critical and environmentally hazardous facilities. However, the accidents occurring directly in the central zones of strong earthquakes were an exception.

There was also an opinion in science that the rocks are affected mostly by cyclic shocks of earthquakes. This kind of shocks is manifested in the form of unequal pulses. Thus, this opinion extremely limits the activity scope of the pressure and deformation created by the forces affecting the rocks. Cyclic shocks of earthquakes are also a characteristic feature concerning the appearance form of modern tectonic movements. More precisely, it is a kind of periodicity of movement, and is characterized by this.

It should be noted that both cyclic and periodicity are also evident in ancient geological cross sections. Lithophases accumulated in both geosyncline and platform of oil and gas basins have a cyclic structure. However, earthquakes are also recorded on the platform areas.

Despite the fact that flat platform areas are considered relatively stable compared to mountainous areas, the maximum intensity of geodynamic anomalies is also observed in the platform zones

However, in recent years, new substantial information about the earth's interior state has been obtained. It was found that modern super intense deformations (SD) limited by tectonic disturbed zones at a rate of 50-70 mm per year occur on the earth's surface.[1]

Given the predominance of human life on the platform areas, and the presence of the SD factor on the platform significantly increases the level of eco-geodynamic risk in these areas.

Chapter four is dedicated to the detailed study of the physical properties of rocks, the experimental data on cadastrization of rocks and minerals according to their physical properties, as well as on the creation of a database on the physical properties of rocks using GGT.

Generally, since there is not a dependence between the properties of rocks in the known classification according to the mineral composition and genetic characteristics of rocks, they do not meet the requirements of mining. Therefore, mining operations need a generalized classification of the physical properties of rocks. In the generalized classification, the rocks must be grouped in such a way that each rock group has the same physical parameter.

In the developed classification models that define the physical

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Kuzmin, Y.O. Modern geodynamics and assessment of geodynamic risk in subsoil use, 1999. - p 220 the basic properties of the rocks are separated (table 2). The rocks are then divided into three groups, taking into account their structure and are given in table.

Table 2

The main rock forming minerals that determine the physical properties of the rocks

Minerals	Code	Minerals	Code
Quartz	01	Nepheline	10
Feldspar	02	gypsum	11
Olivine	03	Holloids	12
Pyroxenes	04	Clay minerals	13
Dolomite	05	Mica	14
Hornstone	06	Sulfur	15
Apatite	07	Chlorite, talc	16
Serpentine	08	Carbonic minerals	17
Calcite	09	Maqnetite	18

properties of rocks, the rocks are grouped together in accordance with their mineral composition and structure. Within the proposed classification, 18 rock forming (sedimentary) minerals that determine

The proposed classification allows researchers to predict the physical properties of rocks and to reveal the nature of physical processes in rocks without doing any specific research. Registration on certain rules: the code of the main mineral, then the additional mineral code and the code of the rock structure, and thus the numerical characteristics of the rocks that determine its properties can be obtained.

This classification contains a calculation formula of the physical parameters of each group of rocks enabling to predict the physical properties of the rocks within any deposit (table 3).

The dissertation presents the fragments from the classification according to the physical properties of the rocks most commonly encountered in Azerbaijan. Thus, for instance, in the classification, the area which is occupied by diorite is recorded as follows:

Table 3

The classification models for the physical properties of the rocks of Azerbaijan

The composition of the group		The structure of the group											
		1				2				3			
		The structure of the semi-group											
		1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4
01	02	Quartzite	Sandstone	Granulite	Pegmatite	Plagiaporphir	Phexstein			Shist	Gravelite		
	14		Derivative Quartzite	Hornstone	Listvenite			Chlorite-hematite tuffs		Silislum shist	Clay-covered shist		
	16									Chlorite schist			
	18			Quartzite of iron									
02	01	Granite Adamellite Granocenite Quartz porphyry	Placiogranite Granodiorite Tonolite Dasit	Gneiss Banatite with biotite	Aplit Liparite Albitit Riadasite	Andesite-dasit	Tuff sandstone	Tuffit	Trachili-parit	Sand of arzoce			
	03				Olivine gabbro								
	04	Gabbro Labrodiorite	Gabbrosionite Gabbronorite	Forellenstein Anartozite	Gabbro - porphyrite	Basalt Andesite basalt Diabase	Biotite Tesshenite		Dolerite Micro-gabbro	Tuff - glomerate	Tuff		
	06	Sienite Diorite Porphyrite		Porphyry with diorite	Hornstone andesite	Andesite	Breccia	Trachit	Odinite Malachite Vogesite		Conglo-merate Tufobreccia		
	14				Kersantit	Monsonit							
03	04	Peridodite Dunite	Olivine norite		Picrite Saxonite Carsburgite	Verlite							
	18		Olvinite										

the area which is occupied by diorite is recorded as follows: 02.06.1.1 and the andesite also has the same composition 02.06.2.1, as a result of this recording, common and distinctive features of the rocks are clearly revealed. For example, these rocks differ only by the contact degree of their particles. At the same time, the records of 01.02.1.4 of pegmatite and apatite 02.01.1.4 prove that they differ primarily according to the minerals they contain.

The developed identification system allows the systematization, classification and processing of the results using the algorithms and computer technologies based on the physical properties of the rocks. The data obtained on the rocks is sufficient to provide a large number of practical reports.

The base properties of the rocks allow calculating the derivative indicators including technological properties by the known formula.

Efficient management of mineral resources requires information on mineral deposits, such as the use of the earth bottom. The cadastre is the main tool providing the necessary information about mineral deposits.The main property of the mineral resources of the deposit is its potential economic efficiency reflected in the cadastral data.It primarily depends on the bedding conditions, quality of the deposit and location of the mineral resources. An important source of such information is the preparation of a cadastre for the physical properties of mineral deposits.

At present, extensive material on the physical properties of rocks of the Republic of Azerbaijan has been collected. However, their use by experts is not possible, and the degree of detail of their data collection varies for individual researcher. Therefore, there is a great demand to prepare a scientifically based cadastre for the physical properties of a large number of rocks existing in the territory of Azerbaijan.

The first cadastre of rocks and mineral deposits in Azerbaijan is based on the physical properties of rocks and associated technological parameters of mining processes. In the cadastre, rocks must be regarded as objects of production and exploitation.Thus, the cadastre of the rocks of Azerbaijan's mineral deposits covers most of the ore and non-ore mineral deposits (table 4, 5).

Table 4

Cadastre of physical properties of rocks of Dashkasan iron deposit

Cadaster	Deposit		Location				Minerals	
	Dashkasan		Dashkasan				Iron ore	
Physical properties of rocks									
Rocks	γ_{0}, t/m^3	f	P, %	σ_{six} *MPa*	$E\cdot10^{-5}$, кqs/sm^2	υ_p, кm/s	υ_s кm/s	λ, Vt/K	ρ_υ, Om .m
Marbled limestone	2,75	1,60	2,81	37,0	4,70	4,88	2,64	1,15	$2{,}8\cdot10^3$
Magnetite	4,43	7,50	6,00	146,0	5,40	5,18	2,12	4,20	$2\cdot10^3$
Tuff	2,74	9,00	3,62	134,0	2,50	5,35	2,10	2,49	$3{,}6\cdot10^3$
Tuff sandstone	2,54	8,30	3,65	118,0	7,70	5,42	3,48	2,40	$3{,}8\cdot10^2$
Hornstone	2,82	9,70	2,20	138,0	7,10	5,39	3,18	4,15	$3{,}\cdot10^3$
Diabase porphyty	2,93	7,40	3,70	98,5	5,60	4,60	2,80	4,17	300,00
Granite scarn	3,39	4,10	3,91	112,0	2,80	4,81	1,87	5,10	$8\cdot10^3$
Diorite	2,74	3,20	1,20	110,0	7,50	5,83	2,90	2,36	600,00
Quartz magnetite ore	4,72	7,40	7,75	152,0	8,50	4,48	2,72	3,90	$1{,}5\cdot10^3$

Table 5

Cadastre of travertine deposits rocks according to their physical properties

Cadaster №	Deposit	Region				Minerals		
	Shakhtakht	Sadarak				Travertine		
	Garabaghlar	Sharur						
	Buzov	Babak						
	Salam-Malik	Ordubad						
	Istisu	Kalbajar						
	Hajivalli	Gubadli						
Physical properties of rocks								
Rocks	Deposit	ρ, t/m^3	p, %	σ_{sis}, MPa	$E\cdot10^{-5}$, kqs/sm^2	ν_s, km/s	ω_0, %	κ_x, %
Travertine	Shakhtakht	2,71	12,3	40,0	3,80	4100	5,50	0,85
	Garabaghlar	2,19	5,50	23,3	4,90	4094	2,74	2,90
	Buzov	2,58	6,85	37,5	4,60	4096	4,11	4,60
	Salam-Malik	2,10	12,0	9,66	4,75	4090	7,10	1,95
	Istisu	2,66	4,90	37,7	4,20	4098	0,75	3,50
	Hajivalli	2,39	8,00	35,0	4,40	4095	2,50	2,60

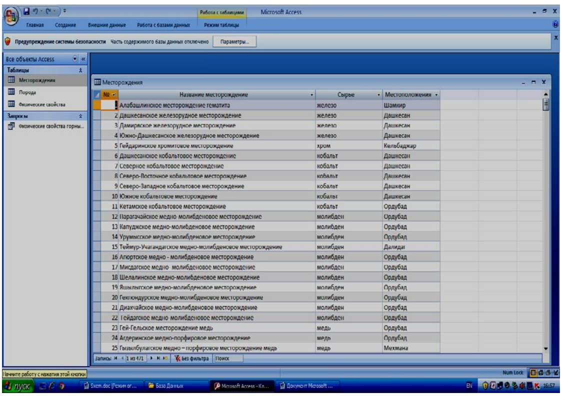
The mentioned cadastre is a source of information for quick acquaintance with physical parameters of rocks and the main properties of mineral deposits of Azerbaijan.

At present, the question of creating a database for the physical properties of rocks is raised, while the automated system enables flexible access to the information needed to ensure longterm safe and efficient development of mineral deposits at all stages of field development.

For this purpose, an automated system tool has beendeveloped to record about 800 ore, non-ore and solid-fuel deposits in Azerbaijan using modern computer technology.

According to the physical properties of rocks, the application of GGT technology in the creation of database allows not only the storage of field information, but also the adjustment of various changes, and also performs the control function.

In order to create a GGT bank database of various deposits, we have collected information about the area where the minerals are located and physical properties of rocks (figure 5, 6, 7).



№	Название месторождение	Сырье	Местоположения
	Алабашлинское месторождение гематита	железо	Шамкир
2	Дашкесанское железорудное месторождение	железо	Дашкесан
3	Дамирвское железорудное месторождение	железо	Дашкесан
4	Южно-Дашкесанское железорудное месторождение	железо	Дашкесан
5	Гейдаринское хромитовое месторождение	хром	Кельбаджар
6	Дашкесанское кобальтовое месторождение	кобальт	Дашкесан
7	Северное кобальтовое месторождение	кобальт	Дашкесан
8	Северо-Восточное кобальтовое месторождение	кобальт	Дашкесан
9	Северо-Западное кобальтовое месторождение	кобальт	Дашкесан
10	Южное кобальтовое месторождение	кобальт	Дашкесан
11	Кетамское кобальтовое месторождение	кобальт	Ордубад
12	Парагачайское медно-молибденовое месторождение	молибден	Ордубад
13	Капуджское медно-молибденовое месторождение	молибден	Ордубад
14	Урумысское медно-молибденовое месторождение	молибден	Ордубад
15	Теймур-Учагандагское медно-молибденовое месторождение	молибден	Далидаг
16	Агюртское медно - молибденовое месторождение	молибден	Ордубад
17	Мисдагское медно-молибденовое месторождение	молибден	Ордубад
18	Шелалинское медно-молибденовое месторождение	молибден	Ордубад
19	Яшылыгское медно-молибденовое месторождение	молибден	Ордубад
20	Гекгюндурское медно-молибденовое месторождение	молибден	Ордубад
21	Диахчайское медно-молибденовое месторождение	молибден	Ордубад
22	Гейдагское медно-молибденовое месторождение	молибден	Ордубад
23	Гей-Гельское месторождение медь	медь	Ордубад
24	Агдеринское медно-порфировое месторождение	медь	Ордубад
25	Гызылбулагское медно – порфировое месторождение медь	медь	Мехмана

Figure 5. Database of mineral deposits of Azerbaijan

All information is stored digitally, which allows to update data without much difficulty and obtain full information about rocks.

In general, we recommend using a GGT technology database together with the cadastre system to arrange the mining operations effectively according to the physical properties of rocks and minerals.

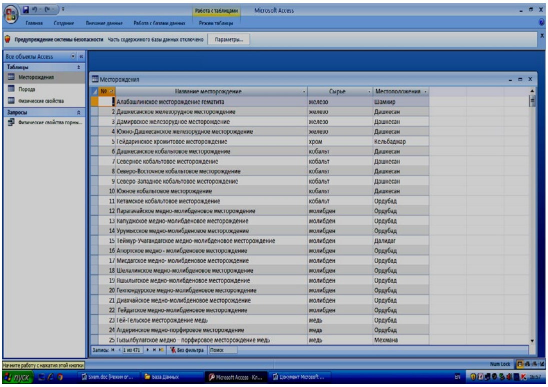


Figure 6. Database of rocks on mineral deposit

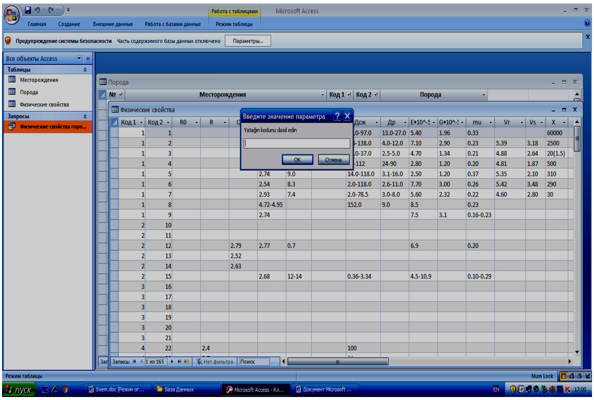


Figure 7. Database of physical properties of rocks for the main mineral deposits of Azerbaijan

The computer database created by us allows to obtain flexible information about the physical properties of the rocks of various fields in Azerbaijan, to continuously update and modify the database, taking into account the development of mining.

The created data bank is not only the storage of ready data, but also their creation is an effective tool corresponds to the change in the state of production.In addition, the flexible structure of the bank allows you to fill it with new information and ensure to change the service program.

Chapter five is dedicated to the creation of a model capable of classifying mineral deposits in the territory of the Republic of Azerbaijan, as the development strategy for mining production depends on the similarities and differences of existing fields.

One of the most realistic ways to effectively utilize mineral resources is a comprehensive approach to the extraction and processing of mineral raw materials, which ensures full utilization of mineral resources, recycling of waste, as well as secondary raw materials and other resources. Based on the model of complex use of mineral raw materials we propose, there are reserves at all stages of mining development, represented by alunite and bentonite clay deposits (figure 8, 9).

Successful implementation of any technological process of mining production depends, to a certain extent, on the necessary knowledge about the physical and technical properties of the rocks that constitute the mineral deposits.

Therefore, it is important to pay close attention to a comprehensive study of the physical properties of rocks of the mineral deposits. Namely taking into account the physical properties of the rocks of mineral deposits will enable to arrange the mining production effectively and obtain final product of high-quality.

In order to obtain reliable data on the physical parameters of the rocks, numerous measurements are required to be carried out on each rock type. All of this is accompanied by a large amount of work and requires significant material costs. In this case, the application of mathematical statistical methods will yield reliable results and makes it possible to save some material resources.

Cluster analysis is one of the multidimensional methods for the

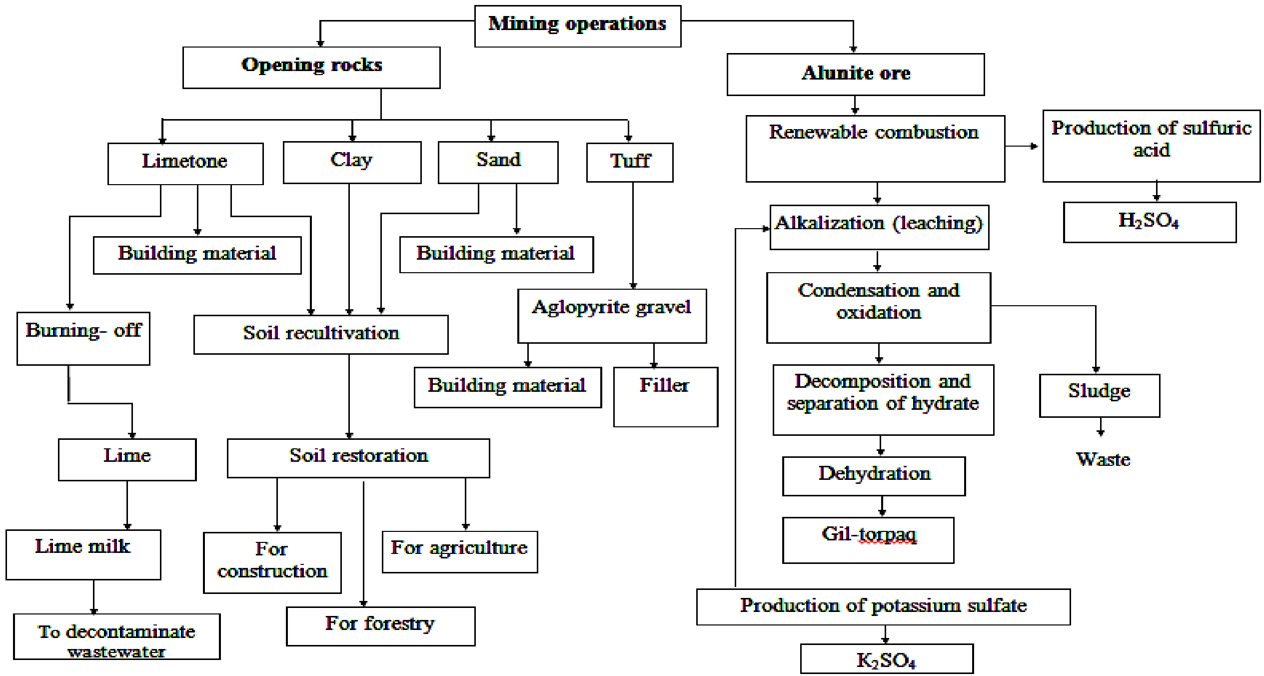


Figure 8. Special scheme for complex waste-free use in the alunite deposit (alunite ore production)

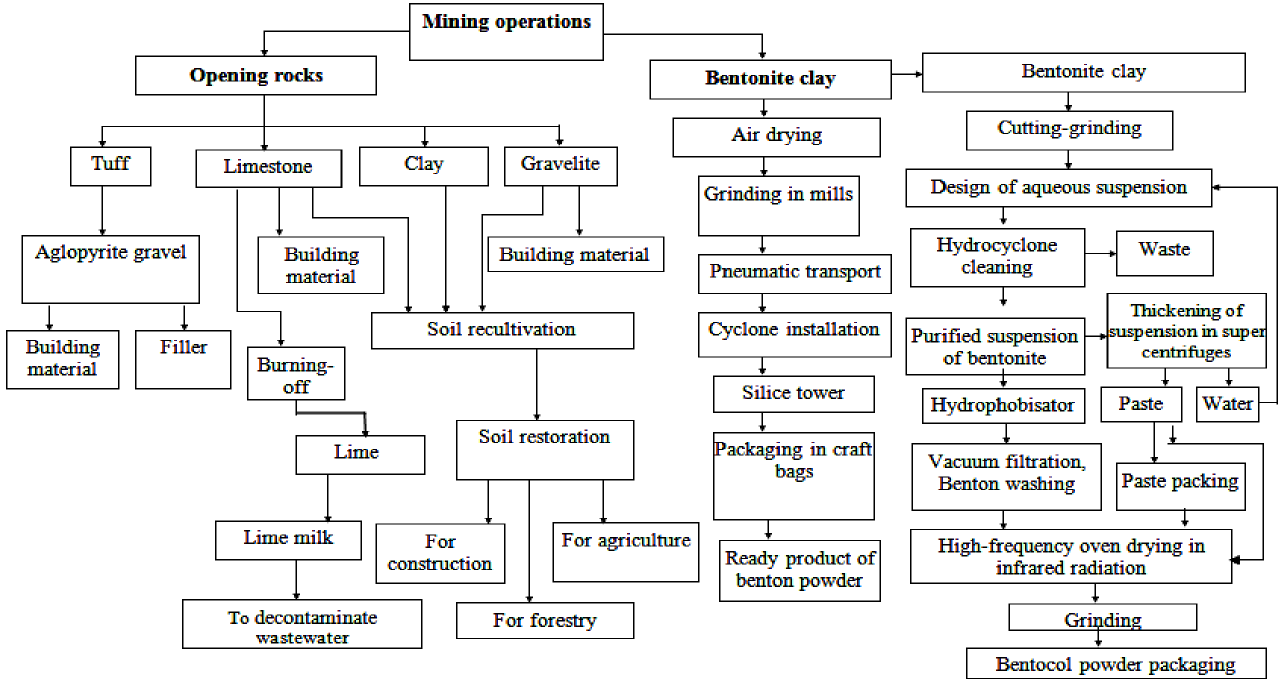


Figure 9. Special scheme of complex waste-free use on Dashsalahli bentonite clay deposit (bentonite clay production)

classification of rocks. Each of the groups contains many attributes and algorithms.

Currently, there are numerous clustering algorithms. Two main types of cluster analysis are commonly used: hierarchical and non-hierarchical.

We chose a hierarchical method for creating classification models of rocks. The grouping of observations is based on the similarity of measurements. As one of such dimensions Euclidean distance is often used, the essence of which is explained by the following formula:

$$d_{xy} = \sqrt{\sum_{i=1}^{m}(x_i - y_i)^2},$$

here m is the number of properties; x_i, y_i are the distance between objects;d_{xy}- i are the value of the properties of x and y objects. This is a straight line connecting two or three-dimensional points.

Based on the classification models of rocks and minerals, the effective development of mineral deposits as a number of non-ore raw materials of Azerbaijan is reviewed.

For this purpose, we carried out 10 major limestone deposits, each of which is characterized by 8 physical parameters, and revealed their similarities using cluster analysis (table 6).

In solving this problem, we used special statistical processing data packages STATISTICS. STATISTICS system is the best known statistical processing package in the Windows environment in the world practice. With the help of the STATISTICS program, a dendrogram was created to graphically represent the deposits in a cluster (figure 10).

Figure 10 shows that all deposits are divided into 3 clusters, and the first separate cluster consists of 6 deposits: Shahbulag, Guzdak, Gayali-Yatag, Dovlatyarli, Dilagardin, Aghdara. Of these deposits, the closest ones according to Euclidean distance are the Dilagardin and Aghdara deposits (d_{iy}=2.4). As it is seen from the dendrograms Dilagerdin and Aghdara are combined in one cluster, and the Dovlatyarli deposit has entered them with close indicators.

Other suitable chain: Guzdak and Gayali-Yatag are combined in one cluster, and according to the similarity of Euclidean distances,

Table 6

Rocks of limestone deposits physical properties

Deposit	$\gamma 0$ t/m^3	γ t/m^3	P, %	σ_{com} МПа	$E \cdot 10^{-5}$, кqs/sm	$G \cdot 10^{-5}$, кгс/см^2	λ, Вт/К	ω, %
Shahbulag	2.71	2.02	22.5	20.1	2.60	0.96	1.02	10.2
Gulbakht	2.68	1.96	33.5	14.8	2.60	0.96	1.42	2.56
Guzdak	2.66	1.88	23.5	14.9	2.60	0.96	1.20	4.85
Dovlatyarli	2.64	2.14	10.5	18.5	3.10	1.24	1.60	7.50
Dilagardin	2.66	2.04	21.5	24.5	2.80	1.16	1.36	8.34
Dashsalahli	2.65	2.09	29.5	33.6	5.82	2.80	1.40	13.5
Garadagh	2.58	2.01	32.5	21.9	3.60	2.20	0.88	13.3
Aghdara	2.59	2.05	21.5	22.1	3.10	1.90	1.10	6.21
Aghdagh	2.64	2.01	27.5	14.0	3.30	1.80	1.80	9.95
Gayali-Yatag	2.64	2.10	14.4	15.4	3.10	1.70	1.70	4.83

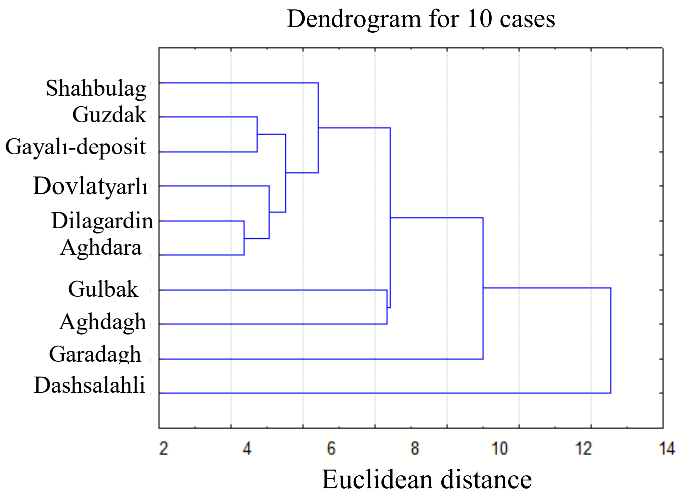


Figure 10. Dendroqram 10 explored limestone deposits according to their physical parameters

Shahbulag deposit is also included in this cluster. All deposits are then combined in a single cluster at the value of Euclidean distance (d_{iy} = 4.5). Thus, 6 limestone deposits are combined in one cluster because of their similarity d_{iy}. The second cluster includes two deposits: Gulbakht and Agdagh. The combination of the first group with the second one occurs at the value (d_{iy} = 6.2) of Euclidean distance.

The third group includes Garadagh and Dashsalahli deposits, which differ from the previous clusters at different values. In fact, Garadagh and Dashsalahli deposits form a free group at the value of (d_{iy}=12.5) Euclidean distance.

Almost their grouping is conventional. This difference should be taken into account in the development of limestone deposits.

There are many clustering algorithms. Let's use the agglomerative hierarchical clustering algorithms. Here 8 basic physical parameters of the limestone are taken (table 7).Then according to the formula:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

$$d_{xy} = \sqrt{d_{\rho_0}^2 + d_P^2 + d_{\sigma_{сж}}^2 + d_\lambda^2 + d_E^2 + d_{C_m}^2}$$

The distance between objects depends on the size of the coordinate axes.

Table 7

Original values

ρ_0	P	σ_{com}	λ	E	C	ω_0	k_f
2.48	14.4	11.0	2.60	2.70	0.50	2.86	0.52
2.71	31.0	45.6	5.82	5.42	1.05	13.2	1.43

Division of the initial values into average square value according to variables (table 8).

Table 8

Standardized values

ρ_0	P	σ_{com}	λ	E	C	ω_0	k_f
2.48	14.4	11.0	2.60	2.70	0.50	2.86	0.52
2.71	31.0	45.6	5.82	5.42	1.05	13.2	1.43
2.59	22.7	28.3	4.21	4.06	0.77	8.03	0.97

Calculate the Euclidean distance of the 10 limestone deposit groups we investigated and evaluate their similarities and differences. Then according to the formula:

$$d_{xy} = \sqrt{d^2_{\rho_0} + d^2_P + d^2_{\sigma_{сж}} + d^2_{\lambda} + d^2_E + d^2_{C_m} + d^2_{\omega_0} + d^2_{k_x}}$$

$$d_{xy} = \sqrt{\begin{aligned}&(\rho_{0_x} - \rho_{0_y})^2 + (P_x - P_y)^2 + (\sigma_{сж_x} - \sigma_{сж_y})^2 + (E_x - E_y)^2 + \\ &+ (\lambda_x - \lambda_y)^2 + (C_{m_x} - C_{m_y})^2 + (\omega_{0_x} - \omega_{0_y})^2 + (k_{x_x} - k_{x_y})^2\end{aligned}}$$

$$d_{xy} = \sqrt{0{,}053 + 275.6 + 1197.2 + 10{,}368 + 7.398 + 0{,}302 + 106.92 + 0{,}828} = 39.9$$

According to Euclidean measurement formula, the variable having great value is completely dominant over the variable having a small value. Then, according to the calculated value of Euclidean distance, the similarities and differences of these deposits depend mainly on the strength parameters of limestone (75%).

Based on the discriminant analysis, in these examples, the distance between the objects will be determined mainly by the strength of limestone. Since the values of other parameters are smaller than $\sigma_{sıx}$, they will not be practically considered in cluster separation.In this case, variable $\sigma_{sıx}$ is dominant over other variables. Therefore, we need a comprehensive system approach to the analytical structure to solve this problem.

In cluster analysis, clustering is significantly dependent on the absolute value of initial indicators. This problem can be solved by using the following formula with the help of normalization (standardization).

$$x_{\text{norm}} = \frac{x}{\bar{x}}$$

If the scales between coordinate axes are the same, then the initial values should be normalized before clustering. The results of the rationing are given in table 9.

Thus, the application of the statistical cluster analysis method

Table 9

Normalized values

ρ_0	P	σ_{com}	λ	E	C	ω_0	k_f
0.95	0.63	0.38	0.61	0.66	0.64	0.35	0.53
1.04	1.36	1.61	1.38	1.33	1.36	1.69	1.47

Normalized value

$$d_{xy} = \sqrt{0{,}081 + 0.5329 + 1.519 + 0{,}5925 + 0.4485 + 0{,}5184 + 1.6125 + 0{,}8836} = 2.48$$

Original value

$$d_{xy} = \sqrt{0{,}053 + 275.6 + 1197.2 + 10{,}368 + 7.398 + 0{,}302 + 106.92 + 0{,}828} = 39.9$$

allows us to group the deposits according to their physical parameters while studying a large number of deposits with different physical and technical parameters. Based on the grouping of deposits according to similarity rates, selection of optimum development method of this or that mineral can be ensured.

Using our method to determine group similarity according to the physical parameters of the deposits, it is possible to reduce the operating costs of the field, increase efficiency, and significantly reduce the cost of the final product by applying the same development technology for all group deposits in Azerbaijan.

Cluster analysis was used to classify a number of Azerbaijan's mineral deposits, including the Dashkesan iron-ore, Zaylik alunite, Gadabay gold, and Dashsalahli bentonite clay deposits, and "Shuhart control map" was compiled to observe the changes in their properties during the processing of the deposits.

Cluster analysis was used to determine the similarity degree of the rocks of a number of mineral deposits in Azerbaijan, including Dashkasan iron ore, Zaylik alunite, Gadabay gold, Dashsalahli bentonite clay deposits, and "Shukhart control map" was compiled to observe the changes in the properties of fields during their development. In addition, the values of the physical and technical parameters of the rocks belonging to the Dashkesan field were used.

The diagrams were developed using data obtained from table 1 and belonging to the additional Dashkesen iron deposits, as well as similarity rates of the physical properties of the rocks (figure 11). Hus, the rocks here are divided into two groups according to their physical values. The first group includes only seven rocks: marbled limestone, tuffs, tuffsandstone, diorite, diabase porphyrite, hornstone and garnet scarn, and the second group is characterized by two minerals: oxidized magnetite and quartz magnetite ore.

Despite their low level of similarity, their combination can be included into one group. According to Euclidean distance, the closest among them are tuffs and tuff sandstone ($d_{iy} < 2$). Then diorite and diabase porphyrites are grouped here ($d_{iy} > 2$).

These rocks are grouped according to their mineral composition and similarity in the kinds of structure, while garnet scarn combine with them indirectly.

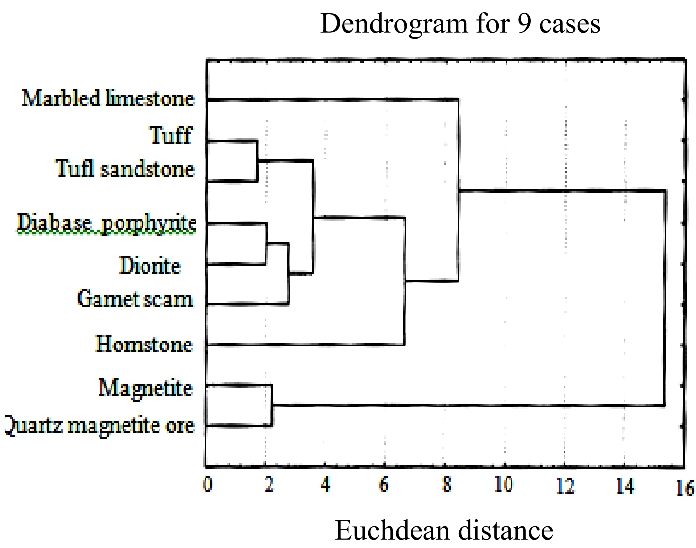


Figure 11. Dendrogram the rocks of Dashkasan iron field according to its physical parameters

These rocks are grouped according to Euclidean distance

(d_{iy} = 3.6). The marbled limestone and hornstone appear to becombined to this cluster at different values of Euclidean distance. In the next stages of the grouping, their similarity gradually diminishes. The second group (oxidized magnetite and quartz magnetite ore) has a weak degree of similarity to the first group. The similarity between these rocks is d_{iy} = 2.3.Combination between the first and second groups occurs at a value of d_{iy} = 15.5 of Euclidean distance and forms a cluster.

Data analysis of the deposit we investigated shows that all the rocks here are grouped according to mineral composition and kind of structure, as well as similarity rate of their physical composition.

Describing phase changes of the parameters in the form of graphics, map, profile, etc. is one of the most widely used methods in geological experiments.

The complex distribution of geological features often makes it difficult for the map to accurately describe the changing characteristics of these parameters. This problem can be solved by using trend analysis with the help of the following formula.

$$d = \frac{\sum x_{trend}^2 - \frac{\left(\sum x_{trend}\right)^2}{n}}{\sum x_m^2 - \frac{\left(\sum x_m\right)^2}{n}}$$

After calculating the unknown coefficient based on factual data with the help of software (computer programs) using an average square, a map of the trend surface was compiled, which allows observing the natural and random changes in the parameters of deposit rocks. This is confirmed by the values of statistical indicators. Here the values of kernel analysis obtained from 9 wells were used (table 10).

Figure 12 illustrates the trend data recordings, where the porosity of the rocks gradually decreases from the center of the deposit to the periphery, and this is either due to the weathering zone or side compression 9 samples taken from different areas of the

Table 10

Distribution and statistical indexes of porosity and strength of rocks according to the wells

Rocks	The number of the well №	Coordinates		Rocks porosity P, %	Rocks strength, σ_{com}, MPa
		X	Y		
Marbled limestone	1	7.5	6.0	2.81	37
Oxidized magnetite	2	14.5	12.5	6.0	146.0
Tuff	3	21.0	19.7	3.62	134.0
Tuflsandstone	4	23.5	19.0	3.65	118.0
Hornstone	5	28.5	26.5	2.20	138.0
Diabase porphyrite	6	32.0	30.5	3.70	98.5
Garnet scarn	7	34.7	32.1	3.91	112.0
Diorite	8	36.5	34.0	1.20	110.0
Quartz magnetite ore	9	38.0	36.6		152.0

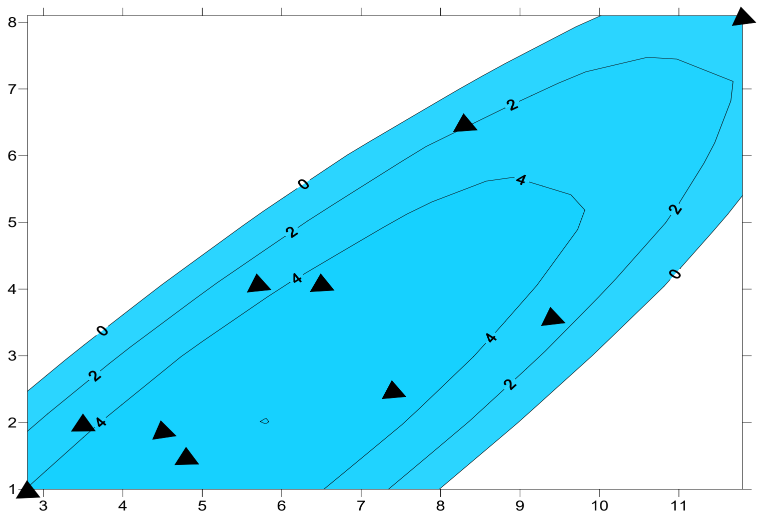


Figure 12. The map of the changes in the porosity of rocks on the Dashkesan iron ore deposit

deposit were used to establish the hardness map of the rocks on the Dashkesan iron ore deposit.

As it can be seen from figure 13, the strength of the rocks forming the deposit gradually increases from the periphery to the center. This is explained by the replacement of porous rocks in the northern part of the deposit with relatively solid rocks (marbled limestone, diabase porphyrities, diorite, tuffsandstone, tuffs, garnet scarn, hornstone, quartz magnetite ore and oxidized magnetite).

The control map, designed to control the changes in the properties of rocks within a particular area of the deposit, allows to district the rocks covering their areas according to the rate of hardness and porosity and ensure safe and effective mining operations.

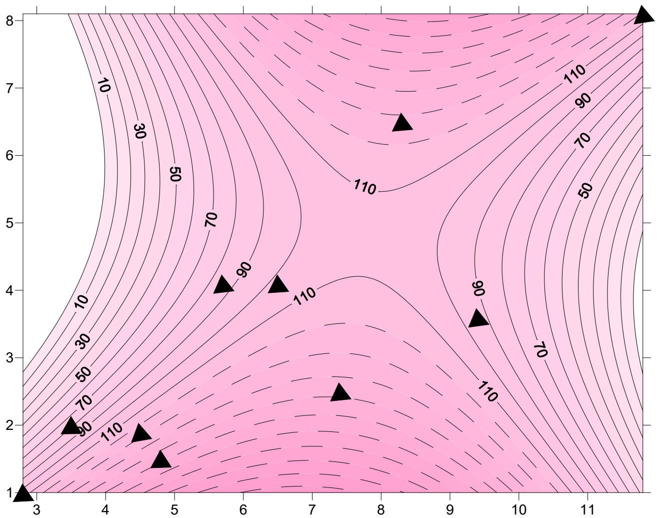


Figure 13. The map of the changes in the strength of rocks on the Dashkesan iron ore deposit

For the first time since Azerbaijan gained independence, the application of mineral resources to industrial development has been very slow due to the difficult socio-economic situation in the country. Meanwhile, in the context of the socio-economic and financial crisis in the world economy after 2008 and the sharp decline in the price of black gold on the international market, the commissioning of ferrous and non-ferrous metal deposits is the most pressing issue for Azerbaijan's socio-economic development.

After 2008-2010, sustainable economic development and diversification of the industrial and agricultural sectors, the promising construction of the international oil and gas main (transanodollu and transadriatic), as well as the development of international railways to the West- East and North-South in the near future will have a significant impact on the development of Azerbaijan’s mining industry.

At present, the Dashkasan magnetite deposit has been put into operation and supplying enrichment factory with new equipment has been performed in Dashkesan by means of the application of new technique and technologies.Starting from 2010, Zaylik alunite deposit was put into operation again and a new aluminum plant was built and put into operation on the basis of this deposit in Ganja based on innovative technologies and taking into account the rules of environmental protection.

At present, aluminum research institute has been established in Ganja in order to realize modernization of aluminum production in Azerbaijan. In addition, the construction of a large metallurgical plant on the basis of Dashkasan magnetite ore in Ganja is being completed.

Recently, processing Gadabay gold deposit being significantly localized in the copper-porphyry deposits in the development of ore resources in our country, belongs to the International Mining Company.

At the initiative of the new state mining company “Azergold” and the active position of Azerbaijan’s geological service, a large Chovdar gold deposit in the Dashkesan region has been involved in exploration and industrial development. Exploration and prospecting of the gold ore deposit in Nakhchivan AR is planned as well.

It should be noted that Azerbaijan has a large amount of various ore and non-ore mineral resources. Due to ore and non-ore resources, Azerbaijan occupies the first place not only in the Caucasus, but also among the countries of Asia Minor and the Middle East. As it is known, the development of mineral deposits requires large capital investments and investments by large international mining companies, depending on the mining technical conditions.With the development of the country's industrial potential and the socio-economic development of Azerbaijan, there will be a need to invest in the development of unique pyrite-polymetallic deposits on the southern slope of the Caucasus. Attracting investments from European Union countries and international mining companies of Canada is of great importance in solving this problem.

Recently, Strategic Roadmap concerning the socio-economic development of Azerbaijan until 2030 has been developed in which the development of the industrial sector and the exploitation of the country's mineral resources have been reflected.

At present, the dynamic growth and socio-economic development of Azerbaijan prove that ensuring the industry with the necessary mineral raw materials is acute and urgent issue. This, in turn, requires to enhance the use of metals and ores, as well as complex redevelopment of waste and previously developed deposit remains (Dashkesen iron, Zaylik aluinite, Paragachay molybdenum, Gumushluk lead-zinc deposits, etc.) using new technique and technology.

As it is known, the main raw materials in the development of ferrous metallurgy are iron ore, chromite and manganese ore, coke coal, flux and refractory materials.Studies show that a sufficient resource base of ferrous metallurgy in Azerbaijan will provide not only the efficient development of Ganja metallurgical plant, but also the export of its products.

Economic and environmental aspects of the efficient use of ferrous and non-ferrous metals have currently been poorly studied in Azerbaijan, although these methods of exploitation and processing are widely used by Western countries (USA, Canada, England) in relation to resource saving (conservation) and environmental protection.

Significant reserves of polymetallic ores (Cu, Pb and Zn) Nakhchivan ore group deposits are located in the southern slope of the Greater Caucasus, Filizchay, and Mehmanli copper and polymetallic deposits in Nagorno-Karabakh.

The first of these is unique in terms of its reserves and ore concentrate content. In addition to the main ore-bearing metals in these ore deposits, there are dozens of industrial elements (Ag, Au, Ni, Co, Ga, Ge, Ti, Sc), which can be exploited using technology capabilities, taking into account environmental protection of the region and a number of economic factors.

As it is known, the production, processing and consumption of mineral raw materials is closely connected with the extraction of many other limited natural resources and is accompanied by large amounts of waste in water and air basins.

At the same time, the development of ferrous and non-ferrous metal ore resources excludes large areas of land from agricultural use. Leasing the areas of land by mining companies is temporary, however, there is a direct damage to the surface of the earth, and it is impossible to restore this layer without special land-recultivation work.

The activities of mining and processing enterprises are also associated with the disruption of groundwater flows and the discharge of acid water, which significantly complicates to supply industrial areas of the country with fresh water. Atmospheric air is intensively polluted, especially by the wastes of enterprises producing and processing ferrous and non-ferrous metal ores.

At present, iron ore base of ferrous metallurgy in Azerbaijan are magnetite ore deposits of Dashkesan, South Dashkesan and Demirov. Mineral-raw material resources of these deposits, concentrated in a limited area, can be redeveloped by a single technology.

Development of the Dashkasan deposit was suspended because of the socio-economic crisis in Azerbaijan after the collapse of the USSR. Developed industrial infrastructure, availability of transport connections and experienced specialists, proximity of Dashkasan to Ganja determine the economic expediency of construction and implementation of large-scale mining and technological projects.

At present, some necessary works have been carried out with the involvement of foreign companies and foreign investments in order to reconstruct the mining and processing plant and quarries on the basis of new technologies and equipment. In the future, it is planned to put new deposits into operation in Dashkasan increasing the production of marketable ore to 2 million tons per year.

Moreover, in connection with putting new rich areas of Dashkasan deposits into operation in the future and the gradual depletion of existing mines being in the operation, in our opinion, it seems expedient to maintain iron ore production at 2 million tons per year. This will significantly extend the duration of Dashkasan deposit operation.

In our opinion, the increase in ore production may reduce the duration of the mining and processing plant operation, which will lead to limited employment of the able-bodied population due to the natural conditions and production characteristics in the region, and, consequently, will be unfavorable for the able-bodied population.In Dashkesan region, except for small enterprises related to the life conditions needs of the population, the main and only area of application of labor resources is the mining industry.

There is a need for improved technological development with the use of more advanced methods of enrichment related to the reserves of the rich areas of the deposits and corresponding reduction of iron amount in ores. One of these methods is obtaining granules for sponge iron production.Apparently, in connection with the increase in the capacity of factories by new enrichment, total yield of waste will increase so that it requires the construction of new waste facilities. With the full transfer of the factories to the agglomerate concentrate, the fresh water consumed in excess of the prescribed norm for the production of a single product would be saved.

Once the magnetite ore has been enriched, the contaminated water is discharged into the Goshgarchay river basin without treatment. Currently, the river’s source contains about 40 mln.t wastes with metal capacity of 5,0 mln.t. up to 5,2 mln.t.

The gravel sorted from waste (size 25 mm to 26 mm) is a valuable building material in high demand in the intensively developing Ganja region. The sorted gravel can be transported by cableway to the Poultry Bridge station, and from there to consumers by railway.

The use of wastes as gravel and sand increases the efficiency of deposit development and frees up a part of the capital investment for the development of appropriate raw material bases. In fact, the wastes of processing plants and quarries form an additional raw material base, which does not require capital investment for the development of production and construction of mines. It is also possible to create joint ventures for the production of products from the slags of the tube-rolling mill and the wastes of the mining and processing plant as well as slag, solid, gas and dust wastes from Ganja aluminum plant.

When preparing a long-term production development plan, it is expedient to include products made from wastes along with primary mineral raw materials. In this case, the prices of wastes and products made from them must be determined accurately.

These prices should ensure full use of wastes as musch as possible and the sale of products, the interest of public or private enterprises. At the same time, it is necessary to take into account the categories and quality of wastes, adding the value of waste and using the calculation coefficient in relation to rich ores. For example, a coefficient can be defined between 0.7 and 0.8 for the first category of waste, between 0.4 and 0.7 for the second category, and between 0.1 and 0.3 for the third category.

It is important and necessary to develop a cadastre of industrial wastes that reflect the quality of wastes and the physical and chemical properties of regulating metals, their derived volume and standard on different types of mining facilities.

Thus, along with the allocation of additional investments, the widespread use of wastes generated by mining companies in production requires the establishment of a special government agency. The activity of such a government agency is mainly the solution of a full range of issues related to scientific research and the creation of a production process aimed at the comprehensive use of wastes in the country's economy.

The use of waste, secondary resources, recultivation of contaminated lands is still not mandatory for mining enterprises. As for the level of extraction of useful components from mineral raw materials, this is due to the lack of more modern technology for processing, insufficient capital investment for the purchase of modern enrichment equipment and technologies. One of the reasons for the inefficient use of these resources is the lack of economic evaluation of waste during mining.

Thus, millions of tons of waste extracted from mining enterprises are stored in landfills in Sumgait, Dashkasan, Ganja, Paragachay Valley and Gumushlu settlement (Nakhchivan Autonomous Republic), effectively contain the costs of exploration, exploitation, transport and storage in fact.

Mining waste in these areas of the republic is not economically evaluated, remains unregistered and turns into invaluable resource. Further development of the mining industry and improvement of primary mineral raw materials and processing of subsidiary reserves in the Republic should be implemented in Dashkesan complex, including promising ore deposits in South-Dashkesan and Demirov fields, using labor resources of Dashkesan and adjacent areas.

At present, the main facilities of non-ferrous metallurgical raw materials in Azerbaijan are Zaylik alunite deposit, Paragachay molybdenum deposit and Filizchay sulfide-polymetallic ore deposit group. After the collapse of the USSR and Azerbaijan gaining independence, the development of the first two non-ferrous ore deposits was completely suspended due to unfavorable socio-economic conditions. However, it should be noted that the mineral resource base of non-ferrous metallurgy in Azerbaijan is not limited to these deposits.Significant polymetallic ore resources in the country include Filizchay and Nakhchivan groups and Mehmani deposit. The composition of ores in these deposits consists of dozens of useful components, the main part of which can be extracted from the group of Filizchay sulfide-polymetallic ore deposits, which are unique in the Caucasus and the Middle East in terms of favorable mining conditions, resources and concentration of accompanying elements according to the current level of modern technology.

This group is located on the southern slope of the Caucasus, in Balakan and Zagatala regions of Azerbaijan. This group includes four deposits of sulfide-polymetallic ores: Filizchay, Katekhchay, Kasdagh and Tenros.The mentioned deposits are located in the picturesque mountain-forest areas of Balakan and Zagatala regions. During the development of these deposits, the green cover of the mountain range, settlements and mountain rivers may be in danger of destruction due to the mass pollution of the environment with sulfur dioxide and other macro and microelements in the ore concentrate.

In addition, it contradicts the principle of complex processing, as the processing of concentrates in foreign countries plants after having been extracted excludes the use of wastes and the production of pyrite concentrate.

Processing of polymetallic ores in conditions of imperfect technology can lead to the loss of a large amount of useful component from 1 ton of raw material, which is unacceptable in the conditions of strong demand for polymetallic resources of Azerbaijan in the international market.

Taking into account environmental protection and a number of economic factors, we offer Dashduz plain of Sheki economic complex as the most profitable place, having no settlements, green areas, and agricultural plants, for the dislocation of the Filizchay mining and metallurgical complex. The area is located close to the Yevlakh Railway, Mingachevir, Sheki, Zakatala and Gakh, where a large part of the laborforce can be involved in this production. Here we also propose the construction of a mineral and raw material complex corresponding to the infrastructure, along with a metallurgical plant, a mechanical repair plant repairing machinery and mining equipment, as well as the construciton of a facility for the production of agricultural machinery and vehicles.

This area is also useful as it possesses irrigation, technological and drinking water resources, as well as a natural closed “landfill” area (Lake Ajinohur saltwatery lake), which turns into a dead valley in the summer. It can be used as a natural waste storage for a metallurgical plant with a full production process. In addition to the mining plant, this includes a chemical plant for the production of elemental sulfur and sulfuric acid from pyrite concentrate and copper powder (or copper sulfate) from copper concentrate.

The main importance of complex use of mineral raw materials is that recycling is used in environmental protection, polymetallic ores are used in complex use of recycled wastes, which doubles the specific weight of recycled components in comparison with other methods.

Recycling of waste, sludge and slags, sulfur-containing and other gases, dust and waste materials is the most important factor for scientifically substantiated mining and metallurgical production process, expansion and efficient use of raw materials (resources saving). Such an approach to the development of mineral resources provides obtaining additional non-ferrous metal, chemical, agrochemical, construction and glass raw materials.

Reducing metal losses, obtaining chemical and construction raw materials, significantly increases the rate of obtaining useful components and contributes to improve the environment. The higher the coefficient of complex use of ore raw materials, the less industrial waste and, as a result, the environment is less polluted.

Later in the dissertation, the ways of complex using Zaylik alunite ore deposit both in the quarry development area and the industrial waste and remnants of Ganja aluminum plant were investigated. Also, a number of practical suggestions have been made in the dissertation to improve the economic efficiency of Zaylik alunite and Dashkesan group magnetite deposits.

The main raw material for aluminum production in Azerbaijan is alunite ore of Zaylik deposit. It is a complex raw material for the production of aluminum, sulfuric acid, potassium sulfate, vanadium, agrochemical and construction raw materials. In addition to the main component alunite, alunite ore contains a significant amount of other useful components.

Aluminum plant was put into operation in Ganja in 1965 on the basis of alunite ore obtained from Zaylik deposit, and in 1991 the operation of the plant was suspended because of socio-economic and environmental reasons. The calculations based on data from other enterprises show that if the cost of the initial ore is zero, the capital costs per tonne of ore is on average $ 5.05. Accordingly, the total cost of enriching a certain amount of alunite is $ 15 million.

Enrichment of ore in the mine reduces the volume of raw ore by almost half and provides significant saving during transportation and processing.

High economic efficiency of such a process is that, along with high amounts of extractable aluminum (from 75% to 78%), it can provide the improvement of high alunite containing enriched alunite (from 88% to 93%), production and technological operations, as well as it can minimize wastes and eliminate the causes of environmental pollution. Wastes, generated from the enrichment process, such as quartz sand, glass, construction and agrochemical raw materials can be successfully used in relevant industries.

The initial enrichment of alunite ore is mainly aimed at the complex use of raw materials, reducing the transport from the deposit to the plant. Improving the ore processing prevents pollution around the city of Ganja.

Alunite ore also contains large amounts of sulfur. In the process of converting alunite to aluminum, sulfur and its compounds turn into a volatile gases, most of which are removed from the plant pipes. Sulfur in the form of anhydride is present in the plant's exhaust gases.

Extraction of sulfur and sulfur-containing elements from volatile gases will significantly meet the country's demand for sulfuric acid. In the production of sulfuric acid, sulfur has many advantages over other sulfur-containing components in terms of both transportation and processing technology. The process of burning sulfur is much more efficient than the burning of pyrite, and the transportation of sulfur is 2.5 times cheaper than the transportation of pyrite, and 3 times cheaper than the transportation of sulfuric acid.

The experience of many companies in the United States, Canada and Mexico confirms that it is more expedient to extract sulfur from sulfur-containing gases. In non-ferrous metallurgy enterprises of the republic, wastes are divided into solid, liquid and gaseous products. These wastes cause great damage to the environment. Dust and gases associated with production in mining enterprises are non-renewable wastes. Being dissolved in air, they cause air pollution and thus cause serious damage to the atmosphere. In this regard, special attention should be paid to the processing of gaseous powders, which will increase the production of minerals and lead to the complex use of mineral resources.

Installation of modern dust collectors and electric filters at Ganja Aluminum Plant will enable to additionally obtain hundreds of tons of aluminum, sulfuric acid, calcium sulfate, etc.

Production of sulfuric acid from furnace gases significantly shortens the technological cycle and reduces operating costs compared to the process of obtaining mineral raw materials from initial pyrite. Sulfur gases generated from Ganja plant are also a valuable raw material for the production of elemental sulfur and liquid sulfur dioxide, and they are easier to be transported than sulfuric acid.

In order to increase the economic efficiency of the development of Zaylik alunite deposit, it is recommended to establish a processing (enrichment) plant near Zaylik deposit, due to the fact that half of the crushed ore consists of non-alunite minerals (kaolinite, pyrophyllite and quartz) and their transportation leads to high transport costs, complicating the production technology used at the plant, in addition, the construction of a processing plant near the quarry will allow on-site enrichment of alunite ore. When obtaining alunite concentrate, it is advisable to allocate approximately half of the processing volume to the processing of wastes, including refractory materials, natural building materials and related minerals such as kaolinite for the production of raw materials for the faience industry in Ganja.

In general, as a result of the solution of the issues which the dissertation is dedicated to, the following theoretical results were obtained and practical recommendations were given for the improvement of mining production processes and the effective arrangement of the development of mineral deposits in Azerbaijan.

RESULTS

1. Knowing the interactions between the physical properties of rocks enables to determine other parameters according to the known parameters. This, in turn, allows the selection of effective methods for the development of mineral deposits and the optimal solution of existing scientific and practical problems of mining.

2. It has been established that there is a mutual regularity (interaction) between modern geodynamic processes and the changes in physical properties of mineral deposits, which is the basis for improving the quality of mining and geological data and safe long-term exploitation of the earth's crust.

Mutual regularity between the changes in the physical properties of mineral rocks and modern geodynamic processes was determined so that it forms the basis for geophysical monitoring of hazardous facilities, improving the quality of mining and geological data and long-term safe operation of the earth bottom (subsoil).

3. Classification of rocks according to their physical properties allows researchers to predict the physical properties of rocks and to reveal the essence of the physical processes taking place in them without any special research.

4. For the first time, we have developed a cadastre based on the physical properties of rocks of mineral deposits in Azerbaijan and related technological parameters. This cadastre enables to quickly get acquainted with the basic properties of mineral deposits for the efficient arrangement of their processing and exploitation.

5. The bank data we have created is the basis for designing mining processes. It ensures comprehensive integrated computer-based procedures, software for the physical properties of rocks of

various fields, including: evaluation of the distributed properties parameters, investigation of the mineralogical-structural and identical groups of rocks according to physical data.

The created database is a single database for designing the organization of mining operations. It is a collection of databases on the physical properties of rocks of different deposits, and it is a complex computer procedure, including programs that take into account the evaluation of the distribution parameters of properties, ensure the classification of the rocks into similar groups according to mineral composition, structure and physical data.

6. A classification model of the rocks evaluating statistical processing and changes in their physical properties has been created on the basis of bank data as a single data storage system. This model will allow for efficient development of the deposits and safe management of mining processes.

As a single data storage system based on bank data, a classification model of rocks that evaluates the variability of statistical processing and their physical properties has been developed. This model allows arranging the selection of efficient field development methods and reliably managing mining processes.

7. Cluster analysis has been used for the determination of the similarities and differences of dozens of ore and non-ore deposits in Azerbaijan, as well as for their single group.Using the Euclidean distance parameter (d_{iy}) for identifying similar groups of deposits ensure to choose the optimum development technology and significantly reduce the volume of capital expenditures for mining.

8. A control map has been created to monitor the variability of rock properties within the field, so that it will allow zoning the rocks that make up the field according to the degree of porosity and stability, and ensures safe and efficient mining operations in the fields.

9. The proposals, developed by us for the use and processing of ferrous and non-ferrous metals in Azerbaijan, implement complex methods and resource saving technologies. It is proposed to extract regulatory elements along with precious metals and involve industrial

waste and remnants of mining facilities into production. This, in the end, will ensure a significant reduction in the cost of the closed technological cycle and the final product and minimize the negative impact of mining facilities on the environment.

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