For citation:
Izvestiya Ural'skogo gosudarstvennogo gornogo universiteta [News of the Ural State Mining University]. 2016. Issue 2. pp. 54-58.
УДК 622.553. 669.21(479.24) DOI 10.21440/2307-2091-2016-2-54-58

SELECTION OF OPTIMAL DEVELOPMENT SYSTEMS FOR “GOSHA” GOLD DEPOSIT IN THE REPUBLIC OF AZERBAIJAN

Z. J. Afandiyeva, M. B. Osmanov

Выбор эффективных систем разработки для Гошинского золоторудного месторождения (Азербайджанская республика)

З. Дж. Эфендиева, М. Б. Османов

В 1966 г. на Гошинском золоторудном месторождении были проведены первые геологоразведочные работы и выявлено 6 рудных зон. В последующие годы проводились детальные геологоразведочные работы, в результате которых выявлено и изучено 17 зон. С 2009 г. месторождение разрабатывается международной горнорудной компанией, которая доказала, что зоны 13 и 13а являются высокоперспективными, с богатым золоторудным оруденением. Проведенные исследования системы разработки подтвердили, что в условиях Гошинских золоторудных месторождений требуется применение конкретных систем разработки, которые наиболее полно отвечают природным и техногенным условиям месторождения. Для эксплуатации месторождений были рассмотрены различные системы разработки, большинство из которых являются традиционными, некоторые – новые. С учетом всех необходимых критериев и горнотехнических условий предлагается система разработки Гошинского месторождения, предполагающая скважины с открытыми забоями и отбойку руды глубокими шпурами сверху вниз. В статье даны результаты SWOT-анализа предложенной системы разработки. В настоящее время разработка с применением предложенного способа уже начинается. Предложенные варианты системы разработки имеют свои преимущества по сравнению с другими: они позволяют сэкономить начальные капитальные затраты и предусматривают снижение объема горных работ (не требуют заполнения разработанной пустоты). Предложенные авторами варианты систем разработки Гошинского золоторудного месторождения могут быть применены для других рудных месторождений Азербайджана и соседних республик с аналогичными горнотехническими и геологическими условиями.

Ключевые слова: золоторудное месторождение; подземные разработки; горные работы; системы разработки; рудная минерализация; капитальные затраты.

In 1966, “Gosha” gold mine hosted its first geological exploration works and six ore zones were found. In subsequent years, scientists carried out detailed exploration resulting in 17 known and studied zones. Since 2009, international mining company develops this deposit, and it proved that the areas 13 and 13a are mega-rich with gold ore mineralization.
Implemented investigation of the development system confirmed that Gosha gold mine requires concrete development system that can fully meet natural and technical conditions of the deposit.
We studied different development systems for the development of the deposit and gave their outcome in the article. Considering the main criterions and factors necessary for choosing development system, we propose the system “Wells with open face, breaking of ore by blast holes, from the top to bottom”. Strong and weak features, opportunities and dangers of the offered development system and the results of the SWOT analysis one can find in the article.
In comparison with others, the proposed variant of the development system has the following properties: it allows saving initial economic losses, and it decreases volume of mining works (filling the developed gaps is not required)
Our proposed options for development systems Goshinsky gold deposit fully meet the conditions of natural and technological fields and can be applied to other ore deposits of Azerbaijan and neighboring countries with similar mining and geological conditions.

Keywords: gold deposit; underground development; mining operations; development systems; mineralization; capital expenditures.

Introduction

“Gosha” gold mine is located in the northeastern part of the Lesser Caucasus between the rivers Asrikchay, Ahindzhachay and in the upper stream Gosha-su.

Ore field combines several promising deposits: Goshinsky, Itkyrylansky, Boyuk-Kishlaksky, Karavellyarsky, Safarlinsky, Perizamanlinsky, Oksyuzlinsky, Asrikchaysky, Gariblinsky, as well as some other deposits and occurrences.

Among these ore deposits and occurrences Goshinsky gold deposit is the most promising and has attracted the attention of foreign mining companies.

Ore deposits are represented by industrial veins of various shapes and sizes. Actually, vein formations are diabase dikes with capacity from 0.1 m to 3 m and a length of over 1 km.

Gold is the primary valuable component of industrial veins; silver and copper have secondary importance. In northeastern zones of the industrial veins, in some intervals, there is no gold and in others, it is unevenly distributed.

Ore deposits are characterized by a complex mineral composition. There are more than 30 minerals in these ore deposits.

Among ore minerals, zones of hydrothermal alterations were found in gold veins and silicified, it is possible to recall pyrite, chalcopyrite, chalcocite, barite, koveline, malachite, azurite, and (in rare cases) native gold. Capacity of the individual zones of hydrothermal altering rocks varies from one to tens of meters [1].

Material composition and intensity of mineralization in hydrothermally altered zones and gold ore veins is very volatile. Numerous intervals that contain gold reserves of industrial importance are located in range of the same zone.

In all of hydrothermally altered areas, occurrences of gold, silver and sulfides are in phenocrysts confined to veins, vein lets or other forms of congestions. It is also possible to observe ore mineralization in hydrothermally altered host rocks.

Hypogene minerals spread in the “Gosha” gold deposit are pyrite, pyrhotite, enargite, chalcopyrite, silver, gold, sphalerite, magnetite, rutile, anatase, faded ore, cinnabar, en-timonen, realgar, orpiment and chalcocite.

Non-metallic minerals available in Gosha deposit are quartz, calcite; and the minerals found in the oxidation zones are: malachite, azurite, goethite, limonite, hydrogoethite, hydrohematite, chalcocite, kovallin, cuprite and bornite.

The main ore-forming mineral of gold mineralization is pyrite, in some areas reaching 70 % of the total volume of ore. Copper minerals, mainly of chalcopyrite, make up 10 to 15 % of the ore. Along with chalcopyrite and pyrite, there also are rare tiny inclusions of sphalerite in the main ore mass [2].

Identified mineralized zones and auriferous veins contained in these zones are grouped in two systems of cracks: 1) Early – Northeast; 2) Later – Northwest.

Cracks in the northeastern region of the Gosha deposits are overwhelmingly filled with quartz veins, which are rich in gold reserves. In all mineralized zones, one can find quartz, rarely quartz-carbonate veins, with thin veins and phenocrysts of pyrite. Power quark lived from 0.2 m to 2.5 m, and the intensity of the proto from 20 m to 400 m. Conductor character forms a steep drop from 60° to 90°. Taking into account confinement of the ore deposits in quartz veins it becomes possible to predict the prospects of the detection of industrial concentrations of gold present even in the secondary quartzite.

Very significant wives from 700 to 800 m characterize this mineralized zones and ore bodies. A thickness of ore bodies varies from 15 m to 20 m, and in some cases, their capacity reaches up to 50 m from 30 m.

Materials and methods

Geological study and research have shown that gold ore deposits require the use of specific systems development under conditions of Goshinsky deposit.

At present, the stage is characterized by insufficient rates of the development of ore deposits and of reproduction of the mineral resource base, with a low probability of discovery and development of new fields.

Therefore, a large number of mining companies strives to maintain production capacity by selecting and applying the most effective systems for the development of ore deposits. In this context, increase in the depth of ore bodies leads to the complicated conditions for mining activities, which entails a significant increase in the specific capital expenditures. This in turn requires a search for new ore mining methods.

It is important to use efficient systems for the development of one of the promising areas of underground mining, ores of average capacity. Economic

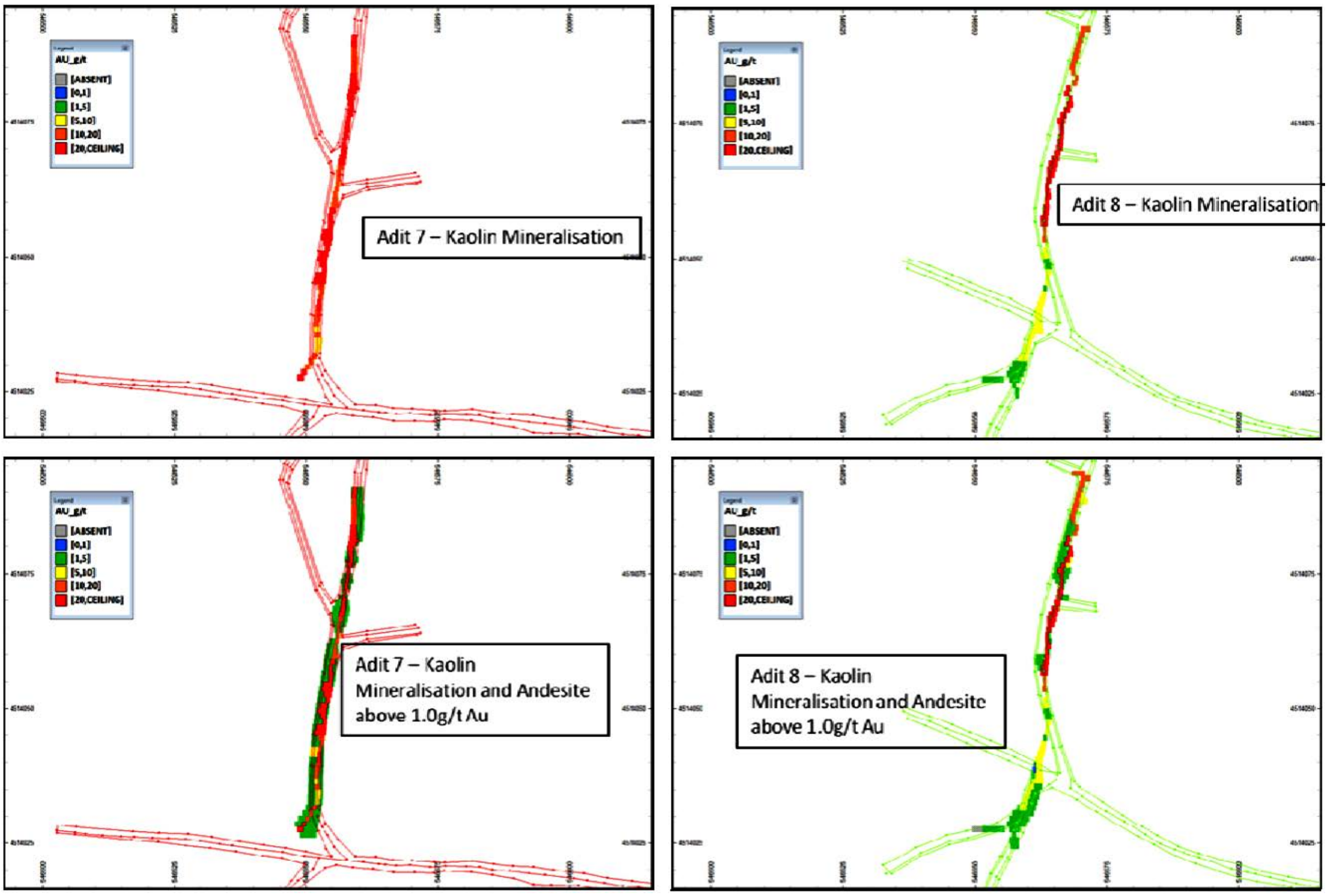

Figure 1. Conceptual model of the useful component amount.

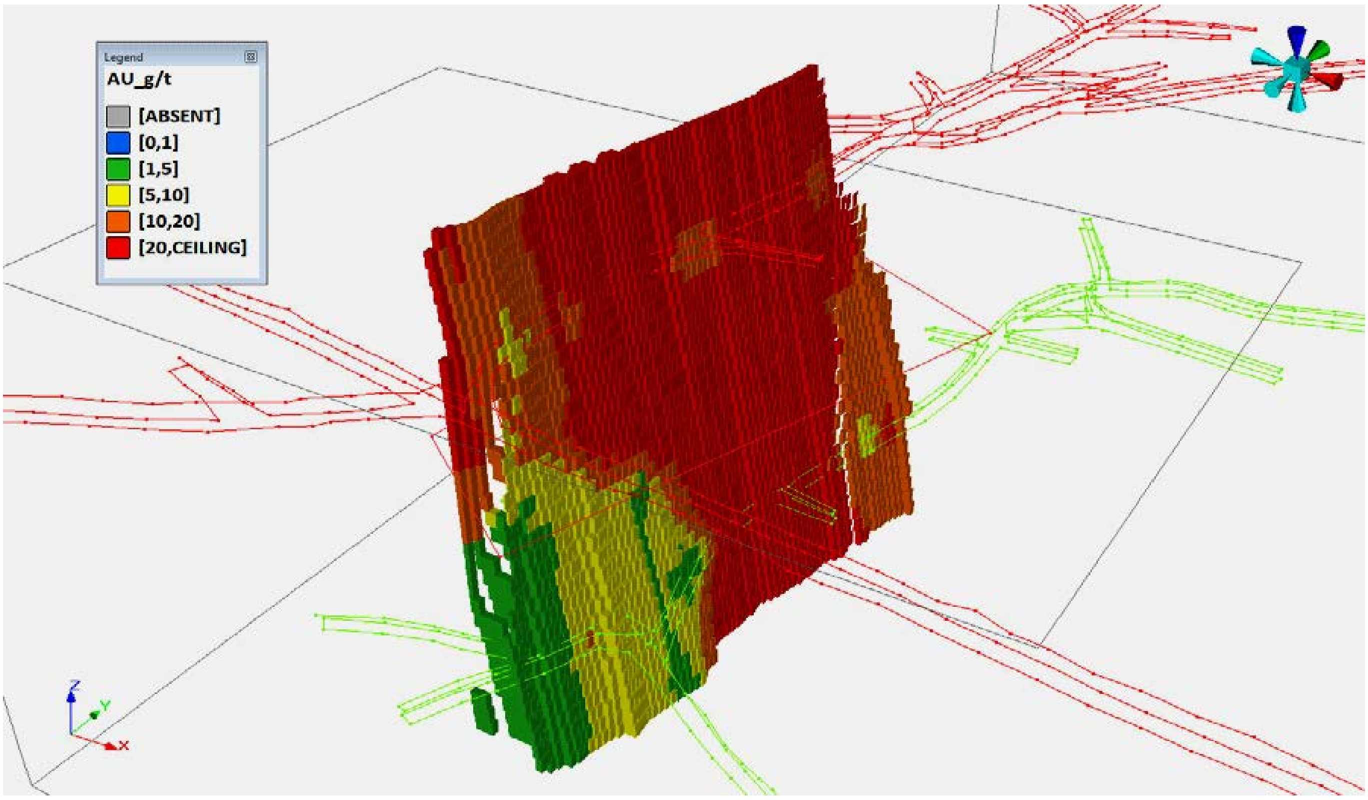

Figure 2. Kaolin isometric Projection Model.

Table 1. General characteristics of the considered development systems and their basic indicators.

Development system	Strengths	Weaknesses	Dangers	Grounding
Wells with open face, top-down or vice versa	High productivity, less prepartion strecks, less skill is requierd, less specialized system	Scarcity and ore loss, supplying of the sloping access is required, main equipment is not used effectively enough	Transportation of the filler material leads to ore loss in the columns, selection of the interval distance of the lower layer is important.	High based spendings and probability of high scarcity
Cutting and filling, from top to bottom	Removing of selective, garbage and empty rocks having less primary capital	High spendings, little productivity, ore loss, increasing of technical service problems	Kinds, source and transportation of the filler material	Few primary spendings, high selective opportuni-ty, exploitation quickness
Extracting of ore by collecting it in the clean- ing zone	Selecive, small sized open fields, having less primary capital, filling of the developed gap is not required	Spendings are high, little productivity, big amount of ore mass remains in the cleaning area of the development phase.	Obssession of the material in the cleaning area, probability of the gap creation under work area.	Creating of the problems closed with obssession of the material, serious tech- nical security problems.
Stepped development at the down direction along the lower layer	Productivity, selective, costs are few.	Labour capacious, ore loss is possible in the columns between the development fields.	Carrying out of the works under high gap, boring problem of the wells may be in the caolin situation.	Few primary spendings, high selective opportuni- ty, exploitation quickness.
Washing by high pressred water jet	Only caolanbized material is extracted, basic spendings and operation spendings are few, required skill level is low.	Loss of the collecing suspention, it may not surround all the ore zones, controling of the water regime.	Security problems while carrying out of the works under high pressured water, controling of water regime, exposing of the staff to the water, sudden spilling of the ore	Ore loss, technical sec- urity problems, high expenditure of technical water
Cutting by chained mechanism	Durable extraction, mechanized selectivity	Preparation of the special equipment	Loading, transportation, unloading of the material, security of the staff	Transportation problems of the material, serious technical problems, ore loss
Boring by mechanical method, cutting and filling by opening of ore in the side rocks	Not any well is bored in the caolin layer due to the opening of the ore in the side rocks, while the development is incresing filler material occurs	Development is slower because it has 2 steps, some ore loss, additional equipment is required.	Access is required for all the horizons, equipment can be exploitated inside the mine, ore loss, not all the caolined ore is extracted.	Carrying out of the test in the ore area

criteria for these systems focus on earning maximum profits at minimum costs spend at 1 tone of balance reserves. This requires technologies providing high efficiency of mining operations [3–5].

In the literature, there are more than 200 varieties of the main systems of underground mining of ore deposits.

There is a number of their classifications (N. I. Trushkov, R. P. Kaplunov, N. A. Starikov, V. R. Imenitov and so on). The most common is M. I. Agashkov classification based on symptom status of clearing space in the period [6, 7].

Since 2009, international mining company has been spending more detailed exploration works on Goshinsky gold deposit. These works has identified several rich ore zones and conducted repeated testing for known industrial horizons. In 2010, 5 wells were dug with more than 350 m of adits.

Reserves in the Gosha deposit consist of gold veins with little thickness, grouped into two sets, which lengthen to each other perpendicularly. In this research, attention was on one point. The vein consists of the mineralized quartz – pyrite – caolinite mass, which is located inside the weak mineralized andezites. Authors developed and prepared conceptual model according to the amount of ore and a useful component for the mineralized area section of area number 13 and around 7 and 8 stonlays on the base, which exists according to the deposit (Fig. 1).

According to the amount of ore and mineral components up model No. 7 to No. 8, mining passages were extrapolated on 15 m. The length of modeled productive layer reflects the length of productive layer in the crossings of both mining passages. The coverage of Kaolin model is presented in isometric projection shown in the Fig. 2.

Authors considered following development systems for exploitation of gold deposits, which have complex geological and finely kaolin mineralization [6–8]:

- Wells with open face, top-down or vice versa;
- Top-down cutting and filling;
- Development system based on shrinkage of ore in cleansed space;
- Benched development system along the dip;
- Washing of ore with high pressure water;
- Cutting of ore with chain mechanisms;
- Method of mechanical drilling with a notch in the side of ore rocks by cutting and filling.

Authors evaluated and conducted general characteristic studies, the results of which are in Table 1.

Following criteria were used for selection of optimal development systems of Goshinsky gold deposits:

1. The productivity rate of the mine throughout its operational life is 45,000 tons per year (120 tons per day).
2. Ores of industrial importance are located in kaolin veins. Particularly, in quartz-pyrite which is concentrated in kaolin mass.
3. Initial useful component of the ore lies close to the vertical slope of the ore zone with width from 0.25 meters to 2.5 meters, and angle of descent from 75º to 85º.
4. Suspended and lie foundation wall consist of silicified andesite.
5. Available sizes of galleries and distance between the horizons:
   a) Approximately 2.2 m (height) x 2.2 m (width).
   b) In galleries № 4, 7 and 8, the distance between the levels is 40 m;
6. Necessity for verifying possible contours of development of ore zone: Approximately 70 (length) x 70 (height).
7. According to the estimation, capacity in the area 13 is from 250 m to 400 m depth.
8. There are many other industrial potential mineralization zones in the Goshinsky system.

While selecting our proposed system of development for the mine, besides the criteria mentioned above, it is important to take into consideration such factors as: location, staff's skills, climate, topography, characteristics of a worked out ore, requirement for filling spaces left empty after exploitation, ore loss, impoverishment, maintenance expenditure, ventilation, drainage, flexibility, and so on.

A conducted research concluded, taking into account all necessary given criteria and mining conditions for Goshinsky deposit, that the most effective field development system is "Wells with open face, breaking of ore by blast holes, from the top to bottom." The most efficient version of the proposed system development is provided below. Main parameters and criteria for the effective variant of the proposed system design are given in Table 1.

The key factor in selection of excavation system for the development of the narrow ore veins is assurance of minimum impoverishment of the ore zone [9].

Upon considering the size of the equipment working area, their width should be greater than the width of ore. Otherwise, it may lead to the impoverishment of the ore zone. This is especially dangerous in the development of 13th ore zone as narrow ore bodies are richer with useful component.

Table 2. Characteristics of the proposed system "Wells with open face, breaking of ore by blast holes, from the top to bottom" SWOT analysis.

Strengths	Weaknesses	Expected	Expected dangers
High Productivity	Impoverishment and ore loss	Diversion of waste (underground)	Sort backfill material (source) and path of delivery
Small requirements of preparatory drifts	Requirement of ensuring of oblique entrance	Numerous land developments	in the scheme of the deve lopment of "top-down" ore loss in columns
Requires for low skill level	Ineffective use of basic equipment	When laying worked out spaces preservation of columns is unintended	Need to choose an intermediate distance in the lower layers
There is no need for the use of classified systems	Rational flexibility In tracing of ore		In kaolin environment "top down" a problem of deep drilling can appear
	High level of capital expenditure		
	Inside of backfill materials and potential loss of ore (bottom up)		

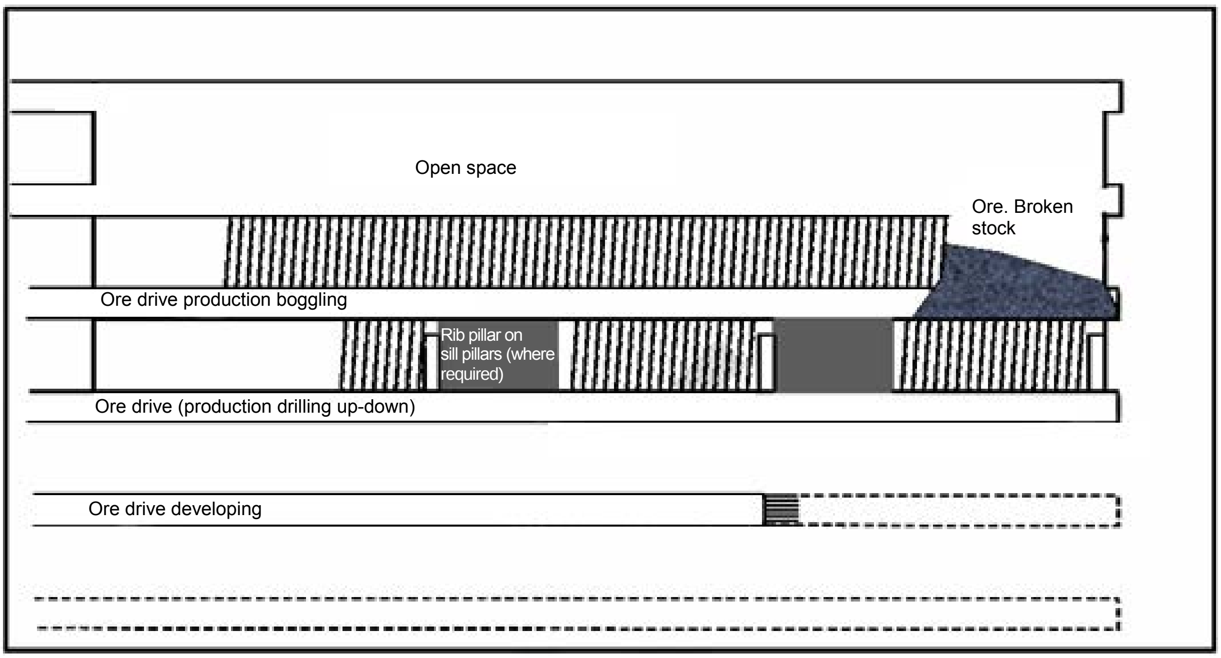

Figure 3. Proposed version of development systems – "Wells with open face, breaking of ore by blast holes, from the top to bottom."

Results

For Goshinsky gold deposit choosen development system is "Wells with open face, breaking of ore by blast holes, from the top to bottom" for Goshinsky gold deposit. Table 2. "Wells with open face, breaking of ore by blast holes, from the top to bottom"– SWOT analyze has been given.

In Fig. 3, a schematic diagram of the embodiment illustrates field development system, "Wells with open face, breaking of ore by blast holes, from the top to bottom."

The above-stated development system for the ore zones should be implemented in the following sequence:

1. Preparations of ore drifts. The distance between the developed drifts depends on the change in vertical position of the zone № 13. Intermediate distance between drifts can be changed based on experience; nevertheless, it will probably be no more than 5 m. First developed horizons will be based on the development of the first block. For conducting mining operations and providing sufficient width for penetration, drilling along the drift should remove rocks.

2. Downward drilling of deep wells between horizons;

3. Preparation of cutting holes;

4. Loading wells in stages; loading and blasting (usually 2–8 per explosion of the round);

5. Loading and unloading of exploded materials

6. The circuit design for each horizon provides takeaway materials from treatment areas from top to bottom. There are also possible options for loading and unloading at a distance. Alternatively unprocessed materials can be stored in the treatment areas. During the lower penetration of the treatment areas, the ore will be fed down. In this case, it will be possible to collect it from the subsurface. Only with the sole treatment units for cleaning horizons require loading in the distance.

Columns between the chambers or over drifts (over orts) provide leave in place.

7. Repeating of the process.

Discussion

Filling of the developed gap is not required in this proposed development system. Cleaning area progresses downward, trailing spaces that remain working in the field of cleaning may create a risk to people and equipment. If it is necessary to keep the columns between cameras and streck over (overlapped) for the geotechnical reasons, they can be placed in narrower mineralization zones being with less amount of the useful component.

Our proposed options for development systems Goshinsky gold deposit fully meet the conditions of natural and technological fields and can be applied to other ore deposits of Azerbaijan and neighboring countries with similar mining and geological conditions.

REFERENCES

1. 2003, *Geologiya Azerbaydzhana* [Azerbaijan Geology], Baku. vol. 6, 576 p.
2. 2005, *Mineral'no-syr'evye resursy Azerbaydzhana* [Mineral-raw material resources of Azerbaijan], Baku, 807 p.
3. Starikov N. A. 1947, *Sistemy razrabotki mestorozhdeniy* [Mining systems], Moscow, 326 p.
4. Trushkov N. I. 1947, *Razrabotka rudnykh mestorozhdeniy. Podzemnye raboty* [Development of ore deposits, Underground work], Moscow, vol. 2, 546 p.
5. Mamedov Sh. N., Mukhtarov G. G. 1966, *Effektivnye sistemy i tekhnologiya razrabotki zhil'nykh mestorozhdeniy Azerbaydzhana* [Effective systems and development technology of core fields in Azerbaijan], Baku, 205 p.
6. Agashkov M. I., Malakhov G. M. 1996, *Podzemnaya razrabotka rudnykh mestorozhdeniy* [Underground mining of ore deposits], Moscow, 636 p.
7. Afandiyeva Z. J., Osmanov M. B. 2012, *Povtornaya razrabotka Kedabekskogo zolotomedno-kolchedannogo mestorozhdeniya otkrytym sposobom* [Kedabek gold-copper-pyrite deposit open pit is in the redevelopment]. *Gornyy zhurnal*

[Mining Journal], Moscow, no. 4, pp. 36-37.
8. Afandiyeva Z. J. 2008, *Otsenka vliyaniya fizicheskikh svoystv gornykh porod na sistemu razrabotki samoobrusheniya rudy* [Assessing the impact of the physical properties of rocks on the development system caving ore]. *Gorno-geologicheskiy zhurnal* [Mining and Geological Journal], no. 1–2, pp.17–21.
9. 2000, *Instruktsiya po bezopasnomu vedeniyu gornykh rabot na rudnykh i nerudnykh mestorozhdeniyakh, ob'ektakh stroitel'stva podzemnykh sooruzheniy, sklonnykh i opasnykh po gornym udaram* [Instructions for safe mining operations on metallic and nonmetallic deposits of underground construction sites, dangerous and prone to rock burst], Moscow, 91 p.

Эфендиева Зарифа Джахангир,
кандидат технических наук, доцент
efendi2005@rambler.ru
Азербайджанский государственный университет нефти и промышленности
Азербайджан, Баку, пр-т Азадлыг, 20
Османов Мохаммад Баба
советник по горному делу
moqamed57@mail.ru
Горнодобывающая компания “АИМКЛ”
Азербайджан, Баку, st. H. Alasgerov, 16

Afandiyeva Zarifa Jahangir
Associate professor
efendi2005@rambler.ru
Azerbaijan State University of Oil and Industry
Baku, Azerbaijan Republic
Osmanov Mohammad Baba,
Advisor on mining companies
moqamed57@mail.ru
Mining Company AIMKL
Baku, Azerbaijan Republic