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CONTENS

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NEW APPROACH OF WORK AND BUSSINESS MODERNIZING IN MINES WITH UNDERGROUND EXPLOITATION IN SERBIA

Mirko Ivković , Jovo Miljanović , Zorica Ivković

Abstract

All analyzes and considering of labor and business in underground mines coal in Serbia, show that there is an extremely difficult economic situation, low level of mechanization of technological phases and work processes, a high share of hard physical labor and a continuous trend of deterioration of relation preparation-excavation in almost all pits, which leads directly to discontinuity of excavation. To get out of this position fundamental changes are inevitable, and they are treated in this paper.

Key words: mines, coal, underground exploitation

1. INTRODUCTION

In complex and varying conditions of coal mines in Serbia, a number of specific technical solutions are applying in underground mining of stone coal, brown coal and lignite with efforts to adapt to the conditions of each bearing, with mixed results. Mainly in the active mines there is mining of thick coal seams, which is the most versatile and the most difficult area in the field of underground mining.

In Serbia, now is active eight production mines with eleven pits and one mine whose main activity is the development of mining investment facilities. Production which is realized per year is unacceptably low, and the main cause is the low level of mechanization, high amortization of equipment and lack of investment.

Most active mines are in exploitation from 160 to 50 years and the majority of the coal reserves are running out except in deposits of “Soko” and “Štavalj”. On the other hand, there is a greater number of bearings, which its natural and geological conditions are predisposed to systems of underground mining, with significant reserves and long life exploitation, and nearby them can be build new thermal power plants.

Adequate to conditions, selected mining methods and technology, the best design of mechanism for extract and transport, the choice of type and ways of supporting and selection of appropriate technology of development and security (for support) of the premises of mining, as well as the organization of work present a series of potential opportunities to enhance the effects of mining and greater security work.

2. ALTERATION OF ACCESS OF MODERNIZATION AND WORK OF UNDERGROUND MINES

The current active mines with remaining small reserves of coal should be mined, and at the same time, the sooner possible, to start with opening new mines with large reserves and conditions in which can be applied modern machinery. The practice of the lack of investment in mining also needs to be changed and adapted to the needs.

As an illustration of the reduced investment in mining, in relation to the planned period 2010-2013. is presented in Table 1 and the lowest level is in the procurement of the technical, from only 14.1%, while mining production are exercised over 90%.

In Table 2, for the period 2010-2013., is presented a survey of investment in mining by each mine, which speaks about trends of lag mine development.

Table 1. Review of investment in mining by mines of PE UCE (2010-2013)

Mine	2010		2011		2012		2013		2010 2013	
	Done (m)	Value (din x 10 ³)	Done (m)	Value (din x 10 ³)	Done (m)	Value (din x 10 ³)	Done (m)	Value (din x 10 ³)	Done (m)	Value (din x 10 ³)
Vrška Čuka	0	0	0	0	0	0	0	0	0	0
Ibarski rudnici	0	0	0	0	0	0	0	0	0	0
Rembas	1.420	236.642	1.463	237.927	635,8	108.681	1.106	199.737	4.624,8	772.986
Bogovina	0	0	0	0	0	0	0	0	0	0
Soko	133	23.468	292	62.803	224,5	58.456	96	27.988	745,5	172.715
Jasenovac	367	65.939	198	40.486	222,2	50.021	109	30.108	896,2	186.554
Štavalj	293	47.895	419	57.376	1.081,1	100.219	407	54.792	2.200,2	260.282
Lubnica	46	3.316	119	15.116	70.8	21.708	797	146.975	1.032,8	187.115
TOTAL	2.259	377.260	2.491	413.708	2.234,5	339.085	2.515	459.600	9.499,5	1.589.653

Commentary:

- In mines “Vrška Čuka”, “Ibar Mines” and “Bogovina” no investment in mining as their reserves are running out,
- Average, yearly in all mines, 2.375 m of new mining facilities are done, which is very low and disrupts the continuity of excavation works, the largest volume of development of mining facilities is at the mine “Rembas”, while the lowest is in the mine “Soko”, which is a mine with the largest potentiality, which indicates that it must increase the volume of work at this mine,
- In the mine “Štavalj” investment mining works are works that provide current production and should not be regarded as a classic investment.

Table 2. Review of planned and realized value of investments in mines of PE UCE (2010-2013)

(din x 10^3)

Investment structure	2010		2011		2012		2013		2010 -2013		
	Plan	Realization	Plan	Realization	Plan	Realization	Plan	Realization	Plan	Realization	%
Geological works	75.706	19.172	81.190	17.475	72.000	24.485	87.600	13.432	316.496	74.564	23.5
Mining works	630.290	377.260	527.585	413.708	654.190	339.085	611.675	459.600	2.423.840	1.589.653	65.5
Construction	54.825	0	243.000	0	35.700	0	35.000	0	368.525	0	-
Technical and technological equipment	461.531	126.800	614.080	183.435	754.017	44.080	924.942	36.347	2.754.570	390.662	14.0
Organizational expenses	108.200	101.809	67.830	68.629	76.000	56.714	212.060	55.060	464.090	282.212	60.8
TOTAL	**1.330.552**	**625.041**	**1.533.685**	**683.247**	**1.591.907**	**464.364**	**1.871.277**	**564.439**	**6.327.421**	**2.337.091**	**36.9**
Realization rate (%)	**46,9**		**44,5**		**29,1**		**30,1**		**36.9**		

Commentary:

- Total realization of investments was achieved with 36.9%, where the highest achieving percentage is in “mining works”, and the lowest is in “technical and technological equipment”,
- Lack of investment in equipment has a direct impact on the production capacity and the development of mining operations,
- Low percentage of implementation of the investment in the “geological works” also affects the rational mining works in the pits,
- Decline in the size of investment per year is obvious for year 2012., and 2013..

3. PROBLEMS OF MINE PRIVATIZATION

Plans for the privatization of the mines and thermal power plants, as well as strategic partnerships with foreign investors are now absurd. No investor will buy a mine, build a power plant and at outmoded prices sell electricity and go into bankruptcy.

The social status of the Serbian population is now very bad and with difficult prospect in the near future to repair. Increasing in energy prices, particularly electricity and coal, would lead to a more severe impoverishment and very few people could settle obligations for energy consumption.

Coal is a resource of national interests and the state needs to invest in opening new mines with modern equipment. Approximate consideration of the opening of the mine coal in “Poljana” shows that it could achieve the level of production of one million tons, which is more than double what all active mines give now, and could be open, both directly and indirectly, around 1.000 job places.

For a decade and the half, employment in Serbia is falling down and is receiving an alarming rate, but no measures are taken for the development of mining and hiring people. Someone has to produce something and not all can just trade or engage in petty services.

4. PRICES OF ELECTRICITY AND COAL

The price of electricity in Serbia is at the bottom in relation to European pricing. Compared to kilowatt in Denmark or Norway, Serbian kilowatt is almost five times cheaper, but our electricity is lower than in the environment.

Table 3 shows the prices of electricity in some European countries and in Serbia, for comparison.

Table 3: Prices of electricity in some countries

PRICES OF	ELECTRICITY		(€ cent/KWh)
Country	No taxes and VAT	With tax and VAT	TOTAL
Germany	14,89	14,32	29,21
Slovenia	11,76	4,81	15,57
Croatia	10,60	2,90	13,50
Montenegro	8,59	1,95	10,54
Bulgaria	7,35	1,47	8,82
Bosnia	6,80	1,16	7,96
Macedonia	4,10	3,70	7,80
Serbia	5,17	1,07	6,24

Source: “Večernje novosti”, 14.06.2014.

Coal prices in Serbia are the lowest in the region. In order to illustrate, coal prices in Slovenia and Serbia are analyzed.

Underground coal mines in Serbia their small coal place to power plant “Morava” for the price of €1.65/GJ and coal for power plant “Šoštanj” from Velenje is priced €2.95/GJ. According to data taken from Slovenia (Price list of transportation “Velenje”, 2013.), the commercial range of brown coal imported from the Czech Republic will cost €260/t, while our same quality coal “Rembas” in Resavica with VAT costs 9.400 din. (€81).

That electricity produced from coal relative to other energy sources is cheaper, is evident from Table 4 (source of data AGGIO D.O.O. Novi Sad)

Table 4.Comparative heat and price-value of obtained energy from energy fuels used in Serbia (2010)

Ordinal	Name of fuel	Unit of issue	Calorific value MJ	Calorific value KWh	Price per unit of issue €	Market price	Price 1MJ/€	Price 1 Kwh/ €	The average degree of utilization of thermal energy%	Price Kwh of net, energy (dinar)	Type of fuel	Commentary
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Firewood	kg	14.81	4.11	0.060	1pm=500kg=30€	0.0041	0.0146	60	2.287	renewable	Positive balance CO_2
2	Energy briquete	kg	18.00	5.00	0.100	1 t =100 €	0.0056	0.0200	80	2.350	renewable	Positive balance CO_2
3	Energy pellets	kg	18.46	5.12	1.130	1 t = 130 €	0.0070	0.2540	91	2.622	renewable	Positive balance CO_2
4	Brown coal	kg	18.81	5.22	0.064	1 t = 64 €	0.0034	0.0123	60	1.927	fossil	Negative balance CO_2
5	Fuel oil	kg	41.20	11.44	0.789	1 kg = 0.77 €	0.0187	0.0672	94	6.720	fossil	Negative balance CO_2
6	Natural gas	Nm³	33.10	9.19	0.426	1Nm3= 0.426 €	0.0129	0.0464	96	4.543	fossil	Negative balance CO_2
7	Oil fuel	kg	39.27	10.90	0.437	1 kg = 0.437 €	0.0111	0.0401	90	4.188	fossil	Negative balance CO_2
8	Electrical energy	KWh	3.60	1.00	0.065	1 Kwh = 0.065 €	0.0181	0.0650	100	6.016	ren/fossil	50% - 50 %

Source: AGGIO D.O.O. Novi Sad 1€=94

Remark: Block 13 determines the balance of CO_2 as a product of CO_2 emissions in power generators, respectively the tax on CO_2 emissions, which was introduced by the Kyoto Protocol in developed European countries.

5. CONCLUSIONS

All analyzes indicate that over the next three decades, coal will be the main energy source for electricity generation. Accordingly, and Serbia should develop coal industry, and in addition to the modern open pit mines develops underground coal mining by opening new mines. Also, the technological processes of production, development of mining facilities and their security, transportation of raw materials and people transport must be modernized and mechanized.

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DEPOSITION OF LIMONITE AND CLAY IN "BUVAČ" DEPOSIT BY USING HYDROLIZED POLYACRYLAMIDE

Ljiljana S. Tankosić, Nadežda M. Ćalić; Milena R. Kostović

ABSTRACT

In mineral processing plant of the ArcelorMittal mine Prijedor, from mineral deposit "Buvač" the iron ore prepares by the classification of the coarse classes and magnetic concentration of the fine classes. Iron ore is abundant in large quantities of the smallest classes with a high iron content.

This paper presents a preliminary study to determine the possibility of limonite concentration from sludge by selective flocculation and by separation of the precipitated material - limonite, in the form of the concentrates. The positive results of these studies imply the possibility of increasing the efficiency of limonite ore to 30% , thereby the increasing of the total limonite reserves. It should be noted that this product contains about 30% natural ocher pigment, which is priced the much higher than limonite, and in addition to significant contribution of environmental protection have a significant economic benefit.

The presented tests in this study are related to the sample testing of limonite settling and separately the clays in the various conditions (pH and the type and flocculant concentration, the time of the settling) so that by the knowledge of the behavior of these minerals in the various conditions of settling can to predict the optimal parameters of settling for selective flocculation of limonite.

Key words: sludge, limonite, clay, recovery, flocculation, selective flocculation, flocculants.

1. INTRODUCTION

Mineral processing plant of the ArcelorMittal mine Prijedor prepares the iron ore from mineral deposit "Buvac" by the classification of the coarse classes and magnetic concentration of the sand hydrocyclone (-0,300+0,030 m). Class -0,030 mm represents mullock and sometimes it contains up to 30% mass with high content of iron. In depleted parts of ore the content of iron is in-between 42 – 48%, and in rich parts of ore the content of iron is often higher than demanded content in concentrate (52 – 54%).

Already upon excavation, the structural-texture characteristics of limonite ore from the mine "Buvac" cause to obtain major amount of smaller classes, with grit below 25 µm. Every further procedure enlages the part of there clases from which can not be excracted the concentrate of sufficient quality in the existing plant for preparation of mineral materals in Omarska, and as such it represents mullock. This mullock is not suitable for deposition because it represents more stabile suspension and with that, a problem for the protection of the environment. On the other hand, sludge extraction with approximately 50% Fe or over 75% limonite in the capacity of mullock, represents a major loss of limonite and increasing of economic effects in the mining business.

The basic problem for the successful sludge treatment, whether in the purpose of its disposition or deposition to the landfill, drainage of valorization of minerals from the sludge in the procedures of preparation of mineral materials, is the fact that all of these processes are taking place by action of the physical forces of attraction or reflection (gravity, centrifugal, magnetic, etc.) to particles individually.

When it comes to the suspension of small classes, which represent quasidisperse systems, the surface forces which act between the mineral grains are stronger than the forces of attraction and refusal of physical fields, or they significantly lessen their effect. In the stable suspensions the particles grit below 10 (30) µm remain dispersed for a long time. That's why the movement of the smallest grains through fluid are slown down which jeoperdizes the processes of preparation of mineral materials up to the non-applicability.

The simplest mechanism of particles dispersion is increasing the charge of their surfaces. The charge and change of charge can be an important fact in the action of flocculants, even though it is shown that the effective, specific absorption of flocculants can take place in the case when the surface of mineral particles and active ions of flocculants have the same charge sign. That is why one needs to have the data on charge of the particles' surface in the explanation of the flocculation mechanism.

One of the most perspective procedures for separation of minerals from sludge is selective flocculation (1,2,3,5). Great number of papers speaks of terms for successful selective flocculation, but they state only a few industrial applications. Understanding of the process and research is still in relatively early stage (1,2). For the time being the opinion which prevails is (4,7) that the formation of molecules is taking place in the possible three mechanisms: increasing the electrostatic refusal between particles, formation of polymer bridges between particles and ion exchange between polymer and surface of particles.

2. EXPERIMENTAL WORK

Mineral concentration by applying the selective flocculation by rule includes four stages:

- particles dispersion so that every particle could be exposed to the flocculants' effect
- selective absorption of flocculants
- formation and growth of flocculants
- separation of flocculants material.

In preliminary tests which were performed in the purpose of determining the possibility of limonite concentration from the sludge by selective flocculation and blow down, the conditions of flocculants dosage, dispersants, pH conditions, mixture and sedimentation are monitored.

2.1. TEST METHODS

In experimental studies in this paper, more than one test method was applied, as follows:

- test methods in order to characterize samples of limonite and clay (size, density, chemical and mineral composition);
- test methods of the mineral surface by determining electro kinetic potential;
- test methods of deposition, separate for limonite samples, separate for clay samples.

2.2. SAMPLES FOR TESTING

All tests of minerals in this work were carried out on samples of limonite and clay samples that are part of the ore deposit "Buvač". The samples were prepared by manually selecting, by hand trituration in a porcelain ball mill and sieved on a sieve with opening of 0.025 mm and 0.005 mm.

For measuring the electro kinetic potential were used the samples of size below 0.005 mm, and for the experiments of flocculation below 0.025 mm.

The chemical composition of samples of limonite is shown in table 1.

Table 1. The chemical composition of samples of limonite

Fe, %	**SiO_2, %**	**Al_2O_3, %**
57,23	**2,68**	**1,49**

The table 1 shows that the sample of limonite has a high Fe content which is the approximate to theoretical. Impurity content is relatively low, so we can say that this is a sample of pure mineral of limonite.

The chemical composition of clay is shown in table 2.

Table 2. The chemical composition of sample of clay

Fe, %	Mn, %	SiO_2, %	Al_2O_3, %
5,16	**1,98**	**58,44**	**17,68**

2.3.REAGENTS

In the studies presented in this paper were applied reagents of pro-analytical purity, as follows:

- as the pH value regulators are used sodium hydroxide (NaOH) and hydrochloric acid (HCl);
- as flocculants are used anionic and cationic polyacrylamides type SUPERFLOC, of Kemira company with different, increasing molecular weight and trademarks, as it is shown in Table 3.

Table 3. The flocculants used in the experimental tests

Name of the reagent	Tag
Anionic polyacrylamides	A100 A120 A130 A150
Cationic polyacrylamide	C496

2.3.1. Preparation of reagents

pH regulators (NaOH and HCl) were prepared as aqueous solutions of concentration 0.1 mol/dm^3, and the same are added to the solution as necessary to achieve the desired pH.

Flocculants are prepared immediately before the experiment as fresh solutions. All used reagents were prepared as solutions in distilled water. The concentration of the basic solution of polyacrylamide was 0.1% and 0.5% and they were added in needed amounts and the concentrations that were required by determined tests, expressed in g/t or g/l.

2.4. EXAMINATION OF MINERAL SURFACE

The electric charge of the mineral surface was determined by determining the electro kinetic potential on the basis of measurements of the electrophoretic mobility of particles using microelectricalforetical Zeta meter "Riddick". The process is repeatedly displayed in detail in the literature (13).

2.5. TESTS OF DEPOSITION

Tests of deposition of limonite and clay were conducted in a measuring cylinder of volume of 100 ml. The share of minerals in suspension subjected to an investigation corresponds to the share of solid hydro cyclone overflow in the industrial plant and is 12% Ch. The examinations were carried out under different conditions (pH and the type and concentration of flocculants, sedimentation times) in order to determine the behavior of these minerals in the different deposition conditions. The aim of this study is to predict flocculation conditions and types and consumption of flocculants for selective flocculation of limonite.

3. RESULTS AND DISCUSSION

The test results of the electro kinetic potential of limonite and clay are depicted graphically in Figure 1.

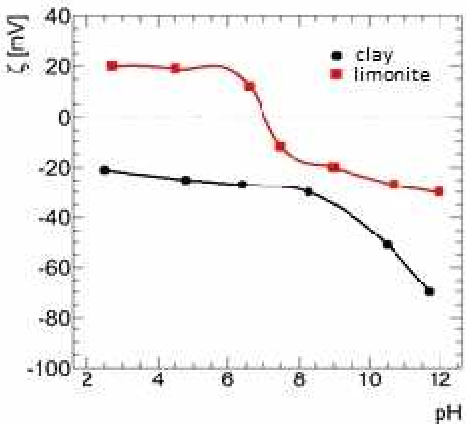

Figure 1. Electro kinetic potential of limonite (1) and clay (2) in function of pH.

Electro kinetic potential of limonite in the acidic environment is positive. The isoelectric point is achieved at pH close to 7, and above this point the pH electro kinetic potential of limonite is negative.

Electro kinetic potential of clay in the whole investigated range of pH is negative.

According to the values of electro kinetic potential of limonite and clay in water at different solution of pH, adsorption flocculants by action of electrostatic force does not occur, since on the negatively electrified surface and while there is negative charge, the active ions flocculate.

Test results of deposition of limonite and clay are presented graphically in Figures 2, 3 and 4 as the ratio of the mass of minerals in the sediment and flow pattern (distribution) and into the function:

- consumption of flocculants, during the sedimentation t=1 min;
- deposition time at the natural pH (6,3-6,5) when the consumption of flocculants is 5mg/l;
- deposition time at the natural pH (6,3-6,5) when the consumption of flocculants is 10mg/L.

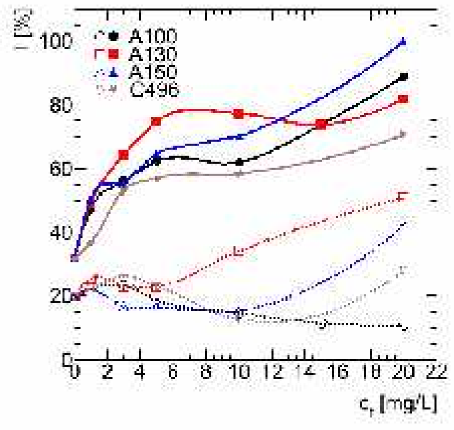

Figure 2. Distribution of limonite and clay in the slurry as a function of consumption flocculants, pH (6.3-6.5).

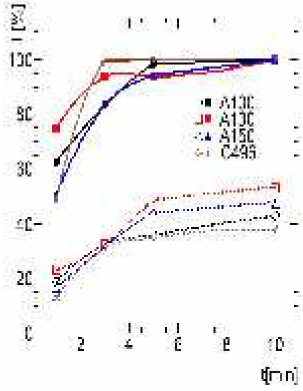

Figure 3. Distribution of limonite and clay in the slurry as a function of deposition time,of pH6.3-6.5; consuption of flocculants 5mg/l.

The analysis of the results shown in fig. 2 and 3 shows that the mass distribution of limonite in part precipitated sludge increases from a few to several tens of percent over the allocation achieved without flocculants when it is about~32% (Fig 2, the zero point on the abscissa) and reaches a value of 62-100%, at a concentration of 20 mg/l by the application of all flocculants, with the lengthening of the time of flocculating from 1 to 4 min. (Fig. 3). In the same conditions, the distribution of clay in the slurry, ranges from 10 (A100) to 40% at a concentration of flocculants of 20mg/l (A130).

The distribution of the limonite in slurry, at the concentrations of 5 and 10mg/l is from 60-80% (Figure 2). With anionic flocculants A130, the highest allocation was achieved. On the other hand, the distribution of the clay, at the same concentration, with the flocculants A100 and A150 is ~ 10-20%, and by using flocculants A130, same is 24-34%. It is interesting that at concentrations higher than 10 mg/l and more, the distribution of the clay is significantly increasing, and only with flocculants A100 is practically unchanged. To further study, the concentrations of flocculants of 5 and 10mg/l are adopted, with respect to deposition time of 1 min, and the appearance of a very large floccules with large amounts of "trapped water".

From the diagram in fig. 3, it can be seen that the use of all three anionic flocculants at a concentration of 5 mg/l, limonite allocation amount is 85-95% during the deposition time of 3 min. Interestingly, by the application of a cationic flocculants, at the same time of the precipitation (3 min), the distribution of limonite is 100%. Also, during the deposition of 3 min., allocation of clay amounts ~ 30%, regardless of the applied flocculants. With increasing deposition time, the distribution of limonite in the slurry is still high and is reaching 100%, while the distribution of clay increases, but does not exceed 50%. For these reasons, the deposition time of 3 min. was adopted. For this deposition time, the best results from the aspect of selectivity, showed flocculants A130.

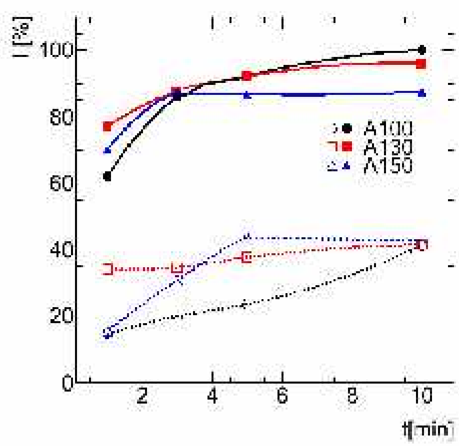

Figure 4. Distribution of limonite and clay in the slurry as a function of deposition time, pH6.3-6.5; consuption of flocculants 10mg/l.

With increasing concentration of applied flocculants to 10 mg/l in the diagram in fig. 4, it can be seen that the distribution of limonite is ~ 80% in the deposition time of 3 min. With the same concentration of flocculants, but with increasing of deposition time, significantly does not increase the distribution of limonite. Distribution of clay is still significantly lower than the distribution of limonite and is not greater than 45%, and during the deposition of 3 min., which was adopted, it amounts 20-35%. At these concentrations, and the deposition time of 3 min, A100 flocculants gives the best results of importance for the selectivity between the limonite clay.

4. CONCLUSION

As a general rule, the flocculation is more successful by increasing the number of hydrocarbon radicals, that is, with an increase in the molecular weight of the polymer (3,7,11 and 12). This is confirmed by our experiments.

Comparing the data of measurements of electro kinetic potential of limonite with the results of the deposition, it can be concluded that the flocculation limonite polymers is result of adsorption of the polymer on the surfaces of minerals powers stronger than the physical force of electrostatic effects. This is more noticeable when it comes to clay, where in the whole range of pH over the electro kinetic potential is negative. When it comes to limonite, it can be said that the good flocculation is achieved near the isoelectric point (pH 6-7) in terms of small values of positive charge.

On the basis of experiment of deposition of limonite and clay, can be concluded that the distribution of limonite in the obtained precipitates is significantly higher than the distribution of clay by using all flocculants, regardless of the time of deposition, type and concentration of applied reagents. Distribution of limonite for adopted deposition time of 3 minutes is in range from 80-100%, while the distribution of clays is in range from 20-50%.

The results show that it is possible to achieve selective flocculation limonite, because in the sludge, which is received in the industrial plant as a dressing hydro cyclone, the content of iron is often over 45% and sometimes over 50%. In order to obtain the conditional concentrate it is necessary to reduce the content of clay in the slurry from 2 to 15%. Distribution of limonite in laboratory experiments, in the optimal conditions in the sediment amounts from 80-100%. Distribution of clay in the overflow amounts from 20 to 50%, which translated to industrial conditions means that you can easily get the precipitated product with over 51-55% Fe, with mass utilization of over 80% compared to the initial sludge. According to the Fe content, such a product, after the consolidation, could be interesting for metallurgy.

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THE SELECTION OF OPENING AND DEVELOPMENT FOR THE GROUPED BAUXITE ORE BODIES BY USAGE OF MULTIPLE CRITERIA OPTIMIZATION

Slobodan Majstorovic, Drazana Tosic, Edin Fazlić

ABSTRACT

Selection of the optimal openings and development for the bauxite deposits with grouped ore bodies is a complex task and more variant. The complexity of the problem is caused by the large number of influencing factors that is need to mathematically formulated by method of mathematical modeling.

This article presents a mathematical method of more critea optimization by standard-vector method for determination of the optimal underground openings and development of bauxite deposit with the grouped ore bodies.

Key words**: **opening and development, mathematical method, criteria optimization,

1. INTRODUCTION

The process of mathematical modeling is carried out in the two stages by the methods of variants for the several different models of opening and development of deposit.

In the first stage, for each of the opening and development variants by objective function is determined the optimal dimension of underground field, horizon dimension and the size of the mining fields. The function describes the objectives of the technical system, i.e. it is considered that system completes its aims until the values of function is within the area that limited the allowed boundary values of objective function at a time. The mathematical model for optimization of the mentioned parameters are based on the technical description of opening and development system according to the following algorithm:

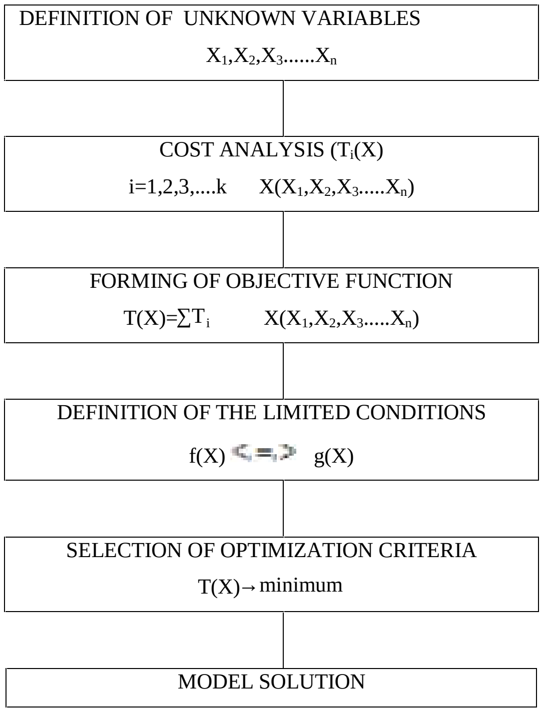


Figure 1. The algorithm of objective function

In the second phase of mathematical modeling, the optimal parameters values obtained from the first phase are observed and defined as a unified system and compared according to the criteria that the designed a system of opening and development of the grouped bauxite ore bodies should to satisfy. To solve the second phase of mathematical model, the method of criteria optimization-standard methods of vector can be successfully applied.

The standard method of vector is relatively a simple method of ranking and selection of the best solution of the offered variants which is carried out according to the following methodology.

1. For each variant which compares and whose efficiency is evaluated, the values of certain criteria K_1, K_2, K_3,.... are calculated.
2. Based on the obtained values of criteria the optimal value between the same critea is determined.
3. The vector X_{mn} is calculated according to the known values of criteria.
4. ”Standard vector” R_i is calculated, and
5. The minimum value of the vector X_{mn} determines.

The calculated vector shows the vector column of criterion (K_i), which gives the least deviation by all criteria. The minimum values of ”standard vector” is an optimal solution and the process is carried out according to the following algorithm:

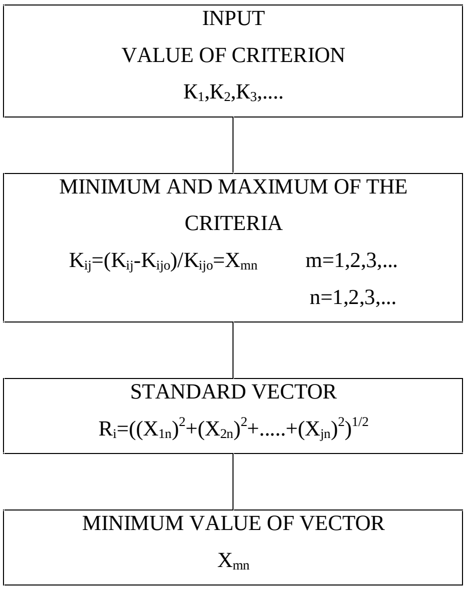


Figure 2. The algorithm of criteria optimization

2. DEFINITION OF THE CRITEA OPTIMALITY

Definition of the optimal system of opening and development of bauxite deposit with the grouped ore bodies by method of "standard vector" is carried out according to the following criteria of optimality:

K_1- the costs of opening and development of mine field.....$T_{odmf} \rightarrow$ minimum,

K_2- capacity of working field..$Q_g \rightarrow$ maximum,

K_3- the costs of ore bodies development...............................$T_{obp} \rightarrow$ minimum,

K_4- capacity on ore body excavation ....$Q_d \rightarrow$ maximum.

The values of listed criteria are defined for each variant of openig and development as follows:

<u>K_1 criterion:</u>

For the underground field which is subject of a problem, the several different variants of opening location is carried out, the development rooms, the transporting routes and amount of ore which remains in protective pillar near openings are defined and for each of the proposed variants were determined the all costs by analytical method. The total costs of opening and development of mine field are determined by the following summary of the individual costs:

1. The value of ore in a protective pillar: Protective pillar of ore is part of deposit which are not excavated in order to protect the openings as a capital stopes of great importance for the underground mine. Construction of protective pillar is carried out on the basis of angular parameters with the approximate values (Table 1.), whereby is necessary to predict the protective zone around the shaft of 10-15m width.

Table 1.

ROCK CATEGORY	VALUE OF ANGULAR PARAMETERS
Weak rocks	$55 - 65^0$
Medium hard rocks	$65 - 75^0$
Hard rocks	$75 - 85^0$

The value of ore in the protective pillar can be determined as:

$$T_{ZS} = Q_{ZS} \times C_r \quad \text{(BAM)}$$

Q_{ZS} - the amount of ore from a protective pillar of shaft (t),

c_r - the ore price (BAM/t).

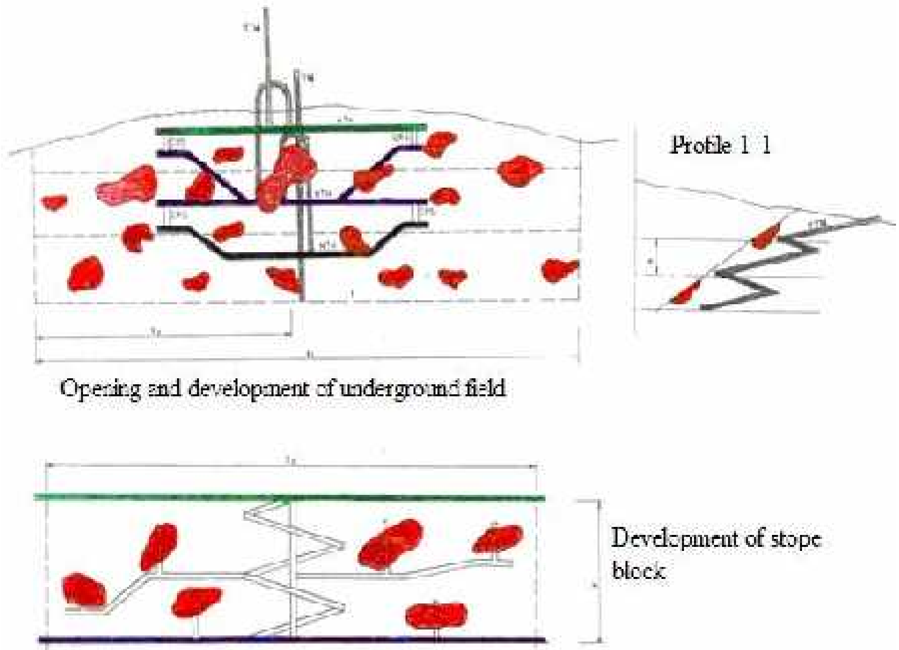


Figure 3. The variant of opening and development of mine field with the grouped bauxite ore bodies

2. The costs of underground stope of mine field opening: for each concrete mine field opening can be defines as:

$$T_{PO} = \sum_{i=1}^{n} L_i \cdot C_{PO} \quad \text{(BAM)}$$

L_i- length of development stope at the level of excavation field or horizon (m),

n - number of the stope fields or horizons in the boundary of mining field,

C_{PO}-the price of advance of opening (BAM/m).

3. The costs of development advance in the underground field: for the each concrete opening of underground field depending of kind of opening, the selected method of excavation, capacity and the natural conditions of deposit the costs of caving of development stope of mining field can be defined as:

$$T_{PR} = \sum_{i=1}^{n} L_i \cdot C_{PR} \qquad \text{(BAM)}$$

L_i- length of development at the level of excavation field or horizon (m),

n- number of the stope fields or horizons within of boundary of mine field,

C_{PR}- the cost of development stope (BAM/m).

4. The maintenance costs of the openings of underground field:

$$T_{PO}^{od} = \sum_{i=1}^{n} L_{ij} \cdot t \cdot C^{od}{}_{PO} \quad \text{(BAM)}$$

C_{PO}^{od} - the maintenance costs of development (BAM/t),

L_{ij}- length of supported portion of development stope (m),

t- the time of the opening maintenance which is equal to the time of excavation of underground field or underground mine.

5. The maintenance costs of underground field development:

$$T_{PR}^{od} = \sum_{i=1}^{n} L_{ij} \cdot t \cdot C^{od}{}_{PR} \quad \text{(BAM)}$$

C_{PR}^{od} - the maintenance costs of development (BAM/m),

L_{ij}- length of supported portion of development stope (m),

t- the time of development stope maintenance which is equal to the time of excavation of stope field or horizon.

6. The costs of haulage and hoist of ore: depend on the quantity of ore that is transported and transpost distance:

$$T_{tr} = \left(R_1 \cdot l_1 + R_2 \cdot l_2 + R_3 \cdot l_3 + R_n \cdot l_n\right) \cdot C_{tr} \quad \text{(BAM)}$$

$R_1,...R_n$- amount of transported ore (t),

$l_1,...l_n$- haulage distance (m),

C_{tr}- cost of haulage (BAM/tm).

7. The costs of energy for ventilation: expressed by the price of electricity necessary for airflow and ventilation of underground mine:

$$T_{pr} = 85{,}68 \frac{\sim \cdot C_{kwh} \cdot P \cdot L \cdot t \cdot Q^3}{S^3 \cdot \text{¦}} \quad \text{(BAM)}$$

L- total length of openings and development stope (m),

Q- total required amount of air for ventilation of mine (m^3/s),

C_{kwh}- cost of electricity (BAM/kWh).

8. The cost of the surface mining facilities and the acess roads: they can be reduced to the cost of arranging of location for the auxiliary and mining facilities and the costs of the acess roads.

$T_{ipro} = G \cdot C_{ul} + L_{ps} \cdot C_{ps}$

By summing up the all those costs for each variant is obtained the total value of costs for individual variant of opening.

K₂ criterion:

The maximum possible capacity of excavation field can be determined from the ratio of total reserves for exploitation and time of exploitation of stope field. These reserves of excavation field are:

$$Q_{op} = \sum_{i=1}^{n} Q = X_3 \cdot X_4 \cdot K_{OR} \cdot K_{ir} \quad \text{(t)}$$

X_3- size of stope field to strike (m),

X_4- size of stope field to dip (m),

K_{OR}- the coefficient of mineralization of functional surface of the stope field,

K_{ir}- coefficient of deposit recovery in the exploitation process,

i- number of ore body in stope area,

Q_i- the ore reserves in the ore body (t).

The time of exploitation of stope field can be defined as the time required for the development of stope field increased for additional period of 1 -2 months.

$$T_O = T_{pop} + T_r \quad \text{(god)}$$

$$T_{pop} = \frac{\sum L_{pp}^{op}}{V_{pop}} \quad \text{(god)}$$

$$\sum L_{pp}^{op} = L_{TH} + L_{VH} + L_{CRS} + L_{SPU} = 2(X_2 - X_4) + \frac{H_{OZ}}{\sin\sim} + \frac{H_{OZ}}{\sin} \quad \text{(t)}$$

L_{TH}- dinstance of haulage drift of stope field, (of block)(m),

L_{VH}- distance of ventilation drift of stope field, (of block) (m),

L_{CRS}- length of central ore raise of stope field, (of block) (m),

L_{SPU}- length of service ramp for stope field, (block) (m),

H_{OZ}- height of excavation block (m),

X_4- the optimal width of stope block (m),

~ -the angle of central ore raise (º),

- the angle of service drop hole (º),

V_{pop}- the average rate of development work on preparation room (m/year).

The maximum possible capacity of stope field can be determined as:

$$Q_g = \frac{X_3 \cdot X_4 \cdot K_{ir} \cdot v_{pr}}{0.16 \cdot v_{pr} + 2(X_2 - X_4) + \frac{H_{OZ}}{\sin \quad + \sin}} \quad \text{(t/year)}$$

X_3- length of stope field (m),

V_{pr}- advance of development rooms (m/year),

X_2- the width of underground field (m).

<u>K_3 Criterion:</u>

For the sublevel caving methods of excavation the preparation of ore bodies is adapted because this method is mainly used for bauxite deposits excavation so that from development stopes i.e. of the haulage and ventilation drifts develop the haulage and ventilation snicked gates (SpTH) (SpVH), with ore body with the development system of underground field. Direct to the floor contact of ore body, from (SpTH) the ore raise (Rs) is developed and ore-pass ramp (SVU) and connected to the (SpVH).

The ore body is divided to the benches in hight (h) and on the level of each bench are developed the short snicked gates where (RS) and ore-pass raise(SVU) connected with the ore body.

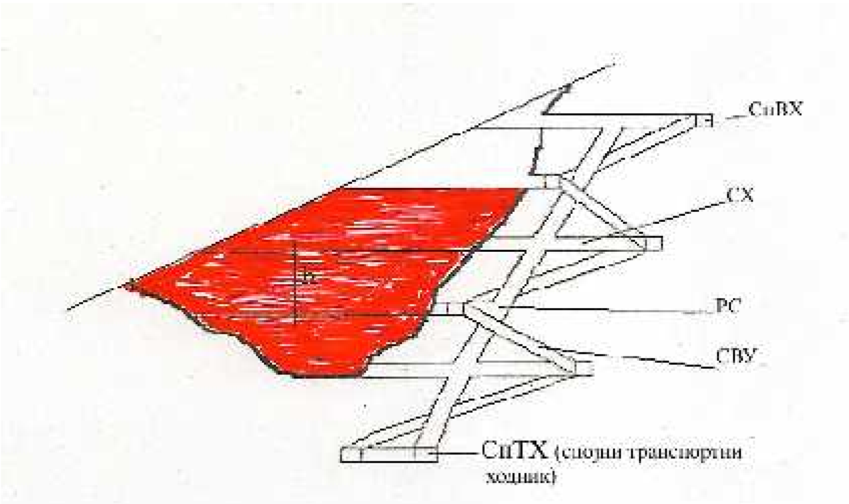


Figure 4. Ore body development

The total costs of preparation of the ore bodies foe excavation can be defined as:

1. The costs of haulage drift (T_{Sp} TH):

$$T_{SpTH} = \frac{X_5 \cdot C_{SpTH}}{R_t \cdot K_{ir}} \quad \text{(BAM/t)}$$

X_5- haulage drift lenght (m),

C_{SpTH}- cost of snicked gate advance (BAM/m),

R_t- total amount of ore in the ore body (t),

K_{ir}- coefficient of recovery at excavation of ore body .

2. The costs of ventilation drift (TCpVH):

$$T_{SpVH} = \frac{X_5 \cdot T_{SpTH}}{R_t \cdot K_{ir}} \quad \text{(BAM/t)}$$

X_5- haulage drift lenght (m),

C_{SpVH}- cost of ventilation drift advance (BAM/m),

R_t- total amount of ore in the ore body (t),

K_{ir}- coefficient of recovery at excavation of ore body .

3. The cost of ore raise advance (RS):

$$T_{RS} = \frac{X_6 \cdot C_{RS}}{R_t \cdot K_{ir} \cdot \sin} \quad \text{(BAM/t)}$$

X_6- vertical distance between haulage and ventilation drift (m),

C_{RS}- the cost of ore raise advance (BAM/m),

- angle of inclination of ore chute (º).

4. The costs of ore-pass ramp (SVU)

$$T_{svu} = \frac{X_6 \cdot C_{svu}}{R_t \cdot K_{ir} \cdot \sin \; {}_{svu}} \quad \text{(BAM/t)}$$

C_{svu}-cost of ore-pass ramp (BAM/t),

${}_{SVU}$- inclination angle of ore-pass ramp (º),

5. The costs of the snicked gates advance for bench (SH)

$$T_{SH} = \frac{L_{SH} \cdot C_{SH} \cdot N}{R_t \cdot K_{ir}} \quad \text{(BAM/t)}$$

L_{SH}- average length of snicked gate for bench (m),

N- number of bench on the ore body,

C_{SH}-the cost of izrade spojnog hodnika (BAM/t).

Summing up the all those cost of ore body development gets the total value of the costs of preparinf for the individual ore bodies.

K_4 Criterion:

The maximum possible stope capacity of the one ore body, based on the knowledge of the general exploitation conditions, the avaible equipment characteristics and knowledge of the other underground subsystems of production can be determined according to the duration of the production stope cycle and avaible work during the day:

$$Q_d = f\left(L, \mu, ¨, °\right) \quad \text{(t /day)}$$

Q_d- daily capacity of stope (t/day),

L- average length of loading from stope to the raise (m),

μ- factor of working environment,

¨- factor of available equipment,

°- factor of operation organization.

According that, stope capacity is determined on basis of production cycle, production and the technical characteristics of equipment and work organization:

$$Q_d = \frac{t_r}{t_c} \cdot Q_c \cdot K_{ir} = N_c \cdot Q_c \cdot K_{ir} \quad \text{(t /day)}$$

t_r- duration of working day (h/day),

t_c- duration of working cycle of excavation ore in the stope (h),

Q_c- stope capacity for one cycle (t),

N- number of the cycles in one working day.

According to the production organization with method of sublevel -crosscut stope for one working cycle at the one stope face by ore excavation must to develop the two crosscuts (stope) drifts. For one cycle the possible production is equal to:

$$Q_c = \left(\left(h \cdot b - h_{OH} \cdot b_{OH}\right) \cdot w + 2 \cdot h_{OH} \cdot b_{OH} \cdot l_b\right) \cdot ¥ \cdot K_{ir} \quad \text{(t /cycle)}$$

The previous established and defined criteria for further calculation is necessary to calculate by applying of some of the mathematical methods and the obtained values of criteria for each of analyzed variants show in tabular form:

$$K_{ij} = \frac{K_{ij} - K_{ijo}}{K_{ijo}}$$

Table 2.

	THE VALUES OF CRITERIA			
	K1	K2	K3	K4
VARIANT 1.	K_{11}	K_{12}	K_{13}	K_{14}
VARIANT 2.	K_{21}	K_{22}	K_{23}	K_{24}
VARIANT 3.	K_{31}	K_{32}	K_{33}	K_{34}

3. DETERMINATION OF STANDARD VECTOR

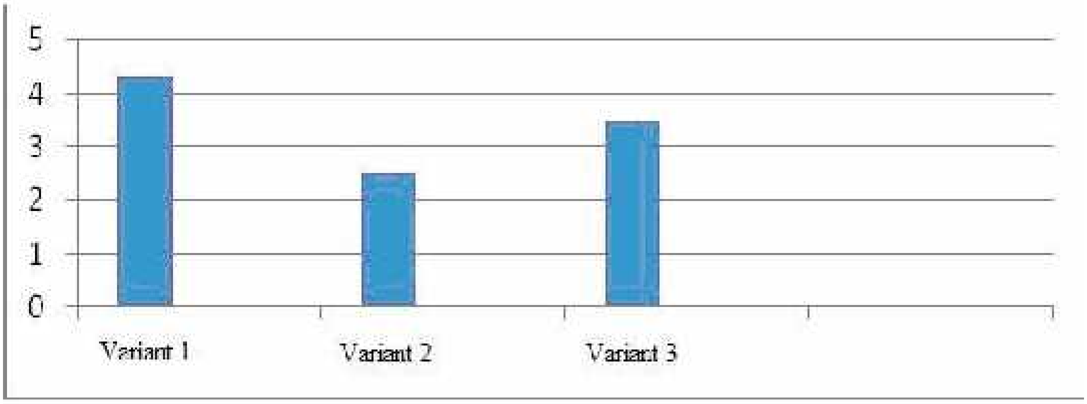
Calculation of standard vector is according to the form:

$$R_i = \sqrt{(X_{1n})^2 (X_2)^2 + ...(X_{jn})^2}$$

and the results are given in tables (Table 3) and graphic (Figure 1.).

Table 3.

$T_{ОПЈП}$	a_{1j} j=1,2,..n.	$T_{ПРТ}$	a_{2j} j=1,2,...n	Q_d	a_{3j} j=1,2,...n	Q_{god}	a_{4j} j=1,2,...n	R_{ij}
K_{11}		K_{13}		K_{14}		K_{12}		
K_{21}		K_{23}		K_{24}		K_{22}		
K_{31}		K_{33}		K_{34}		K_{32}		



Graph 1.

4. CONCLUSIONS

The method of vector norm is relatively simple method of ranking and choice of the best solution of the offered variants. The variant of opening and development of underground field that has the smallest vector norm represents the optimal solution of opening and basic preparation of bauxite deposit with the grouped ore bodies.

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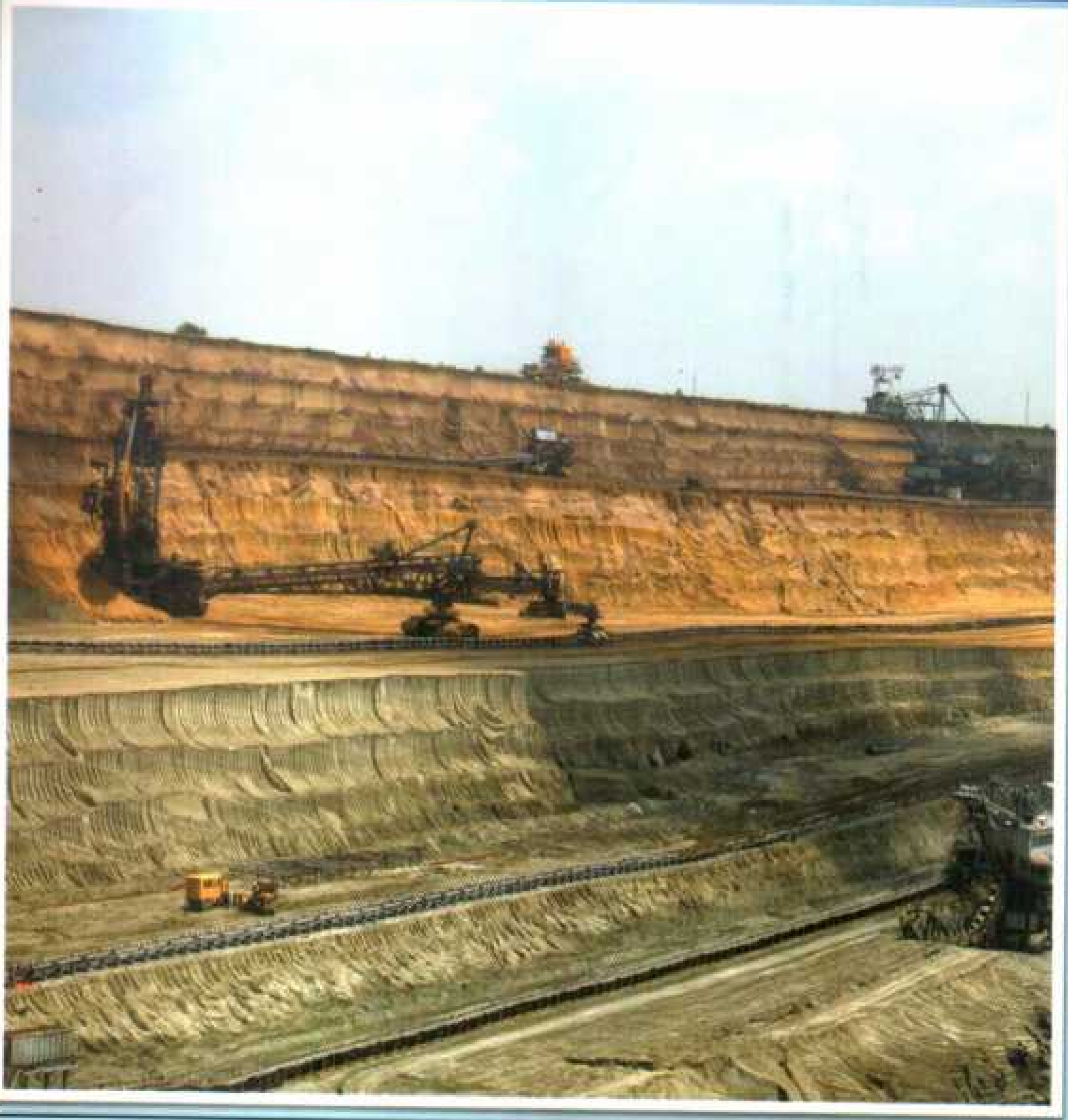

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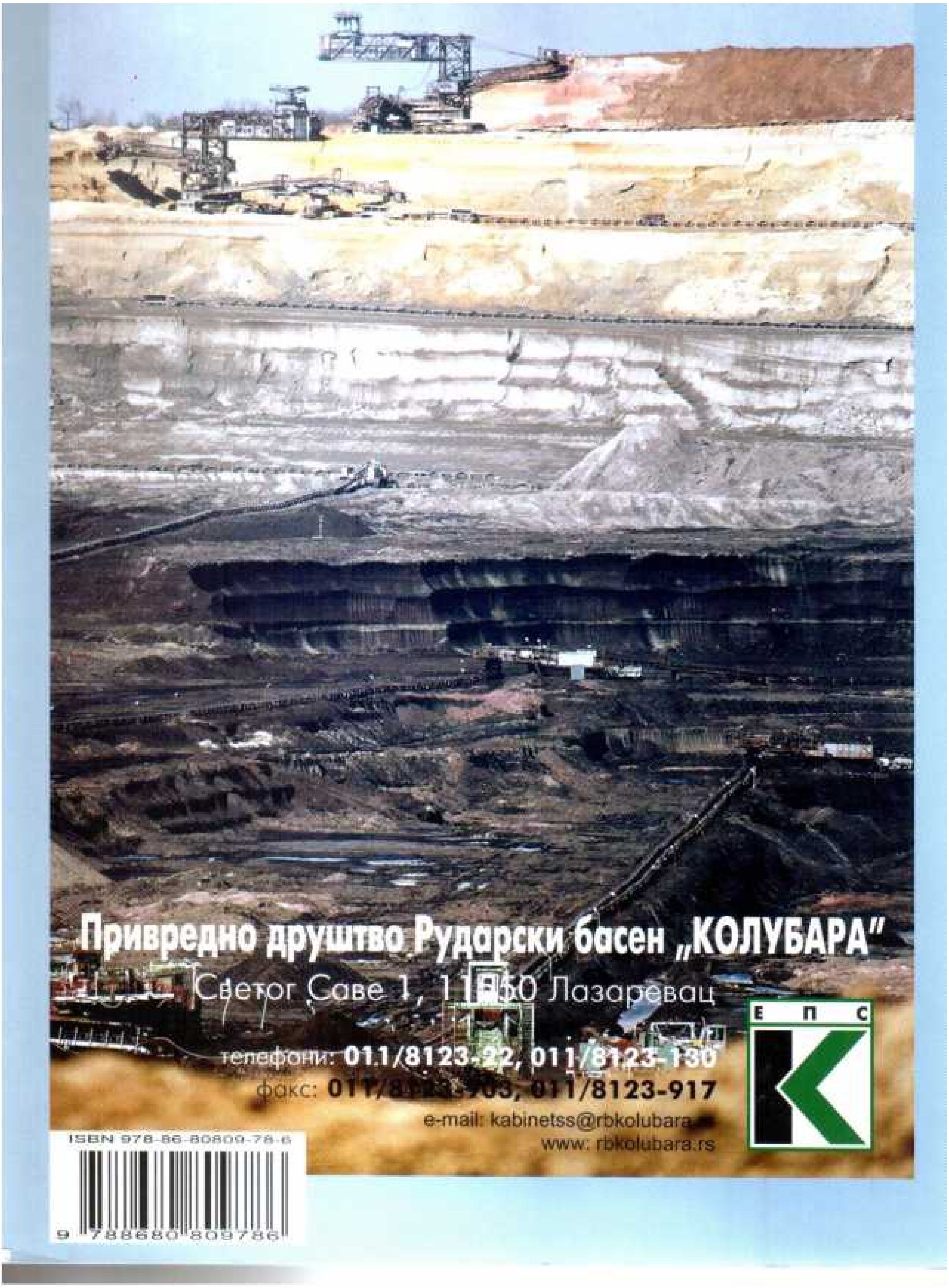
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