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Establishing Research Indicators of Quantity and Assessment Economic Values of Na Tum Pb-Zn mine in Bac Can Province, Vietnam

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Abstract: At present, there are many mines in Viet Nam that have been explored and exploited; however, useful accessory elements have not been explained regarding cutoff grade as well as value of mines in order to determine the charge for granting the mineral mining rights. This problem is not only reducing the mine's economic value and causing loss of mineral resources but also significantly draining the charge for granting the mineral mining rights, in addition to the unequality for mining investors. The results show that: Pb-Zn ore of Na Tum deposit, the cutoff grade should be used flexibly and depends on the type of natural ore as well as the ability of the useful accessory element recovery to select the official and suitable cutoff grade for each ore and ore bed. Beside that, If only the main elements (Pb-Zn) are calculated, the average content of ore beds in Na Tum deposit is lower than the cutoff grade; if the useful accessory elements (Fe, Mn, Ag) are calculated, the average content converted into (Pb - Zn) for the IVa ore bed is 1.55 times higher and the ore bed IVb is 1.8 times higher than the cutoff grade, the remaining ore beds are unsatisfactory for the cutoff grade at the time of assessment. The recoverable potential value (GTNth) and URV for the main elements (Pb + Zn) are much lower than the recovery of useful accessory elements (Fe, Mn, Ag); At the same time, the calculated value also indicates that the recoverable potential value and URV depend not only on the recoverable value of the main elements and the useful accessory elements, but also on the concentration and reliability of recoverable reserves/resources.

Key words: unit regional value (URV), Na Tum Pb-Zn mine, Bac Kan Province

1. Introduction

In geologic reconnaissance of mineral mines, to calculate the reserves, criteria of mining reserves or industrial mining criteria must be used, including criterion of quality and technology of mineral materials (quality of accessory components, most-allowed harmful components, types of natural ore or industrial ore grade). These criteria are ones used to circle and combine industrial ore beds, including: marginal content, and cutoff grade, etc., mining technology criteria, such as: maximum thickness of enclosing rock layers, and minimum thickness of industrial ore beds, etc. Among these criteria, cutoff grade is the most important criterion. In recent years, the interpretation of criteria for reserves of solid minerals in general and metallic minerals in particular in Viet Nam is not comprehensive. Especially, the cutoff grade is rarely calculated on the basis of geological and economical evaluation and there are just several mines that take into consideration of minerals and their useful accessory components. At the same time, during evaluation of economic value of mines, as well as of mineral resources, recoverable value of minerals or beneficial elements is not mentioned. Therefore, it is

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necessary to research on the determination of cutoff grade criteria and evaluation of the economic value of metallic mineral resources in recovery of useful accessory components for the development of the mining industry in integration and sustainability. This article introduces a part of results of the authors in the research on "Assessment of economic resources and economic value of some polymetalic mines in Northeast Viet Nam for sustainable development", Code: TNMT.2016.03.03, conducted by the Viet Nam Institute of Geosciences and Mineral Resources, Ministry of Natural Resources and Environment.

2. General Geology Properties of Mineral in Na Tum Mine

2.1 Mine Location

Na Tum Pb-Zn Mine is located in Ngoc Phai commune, Bang Lung town, Cho Don district, Bac Kan province. The mine is distributed on a low mountain range extending northeast - southwest called Pu Ngan Mountain. The mountain has a decreasing altitude from northeast to southwest, the northern side is steep, the southern side is gentler. The highest peak has an absolute height of 446 m, the lowest point at the bank of the stream with an absolute height of 326 m.

2.2 Stratigraphic Features

Participating in the geological structure of the area is the presence of stratigraphic units aged from Paleozoic to Cenozoic. The study area is located in Lo Gam structure zone and on the east-southeast side of Phia Khao anticline. The general structure of the area is single-inclined structure, extending in longitudinal direction, composed of continental-carbonate sediments of Phu Ngu formation (O-S *pn*), Phia Phuong formation (S_2-D_1 *pp*), Coc Xo Formation (D_1-D_{2e} *cx*) and the loose formations of the Quaternary system (Q).

2.3 Magma Functions Features

In the study area, small granite-biotite blocks of the Phia Bioc complex have been identified (γT_3n *pb*), the syenite blocks of Cho Don Complex (ξK_2-P *cđ*) and the unknown gabbro diaba belt are exposed in Na Khat area. Intrusive blocks come in small sizes, distributed in chains or stretched in a common structure

2.4 Tectonic Structural Features

The study area is in the area of Lo Gam structure zone, with the presence of two main structural units: Phia Khao - Yen Thinh anticline and linear single-inclined structure of the terrigenous - carbonate sediment of Coc Xo formation (D1-D2e*cx*). This structure is broken up into several blocks due to operation of faults systems in the northeast-southwest and meridian that move, compact, transform and form locally small folds stretching tens of meters.

Faults systems develop diversely in the zone, but mainly in the northeast-southwest and meridian direction. In addition to these two faults systems, there are other faults, accompanied by ones that develop in different directions (mainly northwest-southeast and northeast-southwest), developing in narrow spaces. They are branched faults (feather type) of larger ones. The small faults system acts as a conduit or a favorable location for mineralization, especially lead-zinc mineralization in the study area, including Na Tum mine.

2.5 Characteristics of Lead-Zinc Ore Beds in Na Tum Mine

Lead-zinc ore is distributed in the quartz-sericite shale, benthic limestone or thin-layer limestone of the Cok Xo formation. Popular circuit edge transformation are quartz, calcit, and dilomitization. In the mine, 5 ore bodies have been discovered and delimited, in the top order, denoted as TQ.IVa, TQ.IVb, TQ.IVc, TQ.IVd and TQ.IVe; in which IVa ore bed is the oxide one, the others are sulfur ore. The ore beds are lenticle. Minerals of primary ore include galenite, pyrite, sphalerite, arsenopyrite, and chalcopyrite, etc. Minerals of secondary ore include limonite, spilomelan, Fe hydroxide, Mn hydroxide, lepidocrocite, pyrolusite and goethite. Some basic characteristics of synthetic ore beds are mentioned in Table 1 [2].

Table 1 Size, morphology and content of elements in lead-zinc ore bodies.

Number of ore body	Type of ore	Size (m)		Formation of ore bodies	Average content (%)			
		Length	Thickness		Pb + Zn	Fe	Mn	Ag (g/ T)
TQ.IVa	Oxide	170	27.79	Big lentical	5.37	31.57	11.87	67.91
TQ.IVb	Sulphur	60	10.4	Big lentical	7.34			147.4
TQ.IVc	Sulphur	65	8.89	Big lentical	9.56			
TK.IVd	Sulphur	65	3.31	Small lentical	2.84			
TQ.IVe	Sulphur	65	11.06	Big lentical	10.08			

3. Research Methodology

3.1 Collecting and Synthesizing Documents

Collecting and synthesizing documents on exploration and mining projects and other documents related to research content in Na Tum mine and its adjacent areas [1, 2, 7, 8].

Synthesizing the results of calculation of reserves and natural resources according to geological reports that have been approved or recognized by authorities [2].

3.2 The Cutoff Grade Method with Recovery of Useful Accessory Components

Generally, in the process of establishing the reserve criteria, mining economic-technical parameters, including exploitation method, exploitation output, exploitation cost, loss and depletion of ore in exploitation, metallurgical technology, quality of ore concentration, recovery rate, cost of production, selling price of mineral materials and related environmental issues are evaluated. For countries of market economy, it is common for investors to choose a risk-taking solution, or to explore for feasibility study (or pre-feasibility study). In that case, the criteria for caculation of mineral reserves can not be properly implemented due to lack of information. Particularly, economic and technical information should be researched and established through exploration, and in calculating, the cutoff grade is considered the most important criterion, other criteria shall be considered as auxiliary criteria. In addition, from a market economy perspective, when evaluating the value of a mine to determine the price for ownership transfer, some researchers suggest that determination of the cutoff grade should be from analysing the balance of revenue and expenditure of the whole life of the project.

Although there are different perspectives, international researchers generally suggest that the cutoff grade in metallic mineral deposit report could be the formula [3, 5]:

$$\mathrm{C_{CN}} = \frac{\left(Z_{TD} + Z_{KT} + Z_{T} + Z_{mt}\right).C_{tq}.K_{l}}{G.K_{n}.K_{th}} \qquad (1)$$

In which: G - Price of goods per ton of product; ΣZ- Price (total cost) for a unit of product (1 ton of product) is defined by the formula:

$$\Sigma Z = (Z_{TD} + Z_{KT} + Z_{T} + Z_{L}).q \qquad (2)$$

q is the quantity of ore needed to get 1 ton of product, if the product is concentric ore, the coefficient q is calculated by the formula:

$$q = \frac{C_{tq}}{C_{q}.K_{n}.K_{th}} \qquad (3)$$

With: C_{tq}- Useful content of concentric ore (%); C_q - useful content in ore (%); K_{th} - ore recovery coefficient; K_n- The coefficient of ore depletion during mining (K_n= 1- r; r is the ore depletion in mining; K_l - The profit ratio required for the mining of minerals (usually choose K_1 = 1).

At present, the views about methods of defining the cutoff grade of mineral deposits with recovery of useful accessory components [4] are somewhat different. In fact, the determination of mineral reserve criteria is only approximate. For the approximate forecast of cutoff grade of main useful components in the mineral deposits calculated on the basis of synthetic ores, the formula derived from Khorusov (1973) and Kazahdan (1977) [3] can be applied as follows:

$$C_{CN} = \frac{(Z_{kt} + Z_t + Z_l + Z_T)}{G_c.H_c.K_n.(1 + \sum_{i=1}^{n} H_i)} C_{tqc} \quad (4)$$

In which: C_{CN} – cutoff grade of the main useful components in the mine calculated by synthetic ores (%); Z_{kt}, Z_t, Z_l, Z_t are the costs of exploration, exploitation, processing and metallurgy; Z_T- total fees and taxes and charge of mining grant in accordance with Decree No. 203/2013/NĐ-CP (now replaced by NĐ158/2019/NĐ - CP, dated November 29, 2016) for 1 ton of raw ore. G_C - price of main metal product unit (dong per ton). H_c - General recovery coefficient of the main component to the final product, including the recovery coefficient in the exploitation and concentration: $H_c = H_{kt}.H_t$; n - Number of additional components; K_n - Ore-poor factor in mining.

H_i- The coefficient of conversion of the value of the additional components to the main component, is determined by the formula:

$$H_i = K_{cdi} \frac{C_{pi}}{C_c} \quad (5)$$

With: K_{cdi} - Conversion factor of the ith accessory component on the main component; C_{pi}, C_c - In turn, the content of the ore in the geological document of the ith components and the main components.

Some methods of calculating the conversion factor of the accessory components are shown below:

* Method proposed by E.O. Pogrebitski:

Method proposed by E.O. Pogrebitski (1973) [5], conversion coefficient ($Kc_đ$) is determined by the formula:

$$K_{cd} = \frac{G_p.K_{thp}.C_{tc}}{G_c.K_{thc}.C_{tp}} \quad (6)$$

In which: G_c - Value of ore concentrates of main elements; G_P - The value of refined ores of accessory elements; K_{thc}- recovery coefficient of main element; K_{thp} - recovery coefficient of accessory elements; C_{tc}- Content of the main element in ore concentrates; C_{tp}- content of accessory elements in concentrates.

* Methods proposed by Chinese geologists

The cutoff grade is determined based on the principle of balance of payments and return on investment provides the formula when the accessory minerals are recovered, which is given by the following formula:

$$C_{CN} = \frac{C_{tq}\left[(C_x + C_1) + KR_2\right]}{(1 - K_n).H_t.G} \quad (7)$$

In which: C_{CN} is the cutoff grade (%, g/T); C_{tq}, C_l are the content of ore concentrates, metal (% or g/ton); C_x is the production cost of primary ore exploitation and processing (đ/ton); C_y is the total production cost of exploitation, processing and metallurgy of raw ore (đ/ton); C_1, C_2 is the recovered value of additional products for exploitation, processing and metallurgy (đ/ton); K_n is the coefficient of poverty in mining; H_t is the coefficient of recovery of the mineral selection process (%); K is the return rate in static state (%); R_1 is the investment cost for primary ore exploitation and concentration (đ/ton); R_2 is the investment cost for primary ore exploitation and concentration plus increased investmentin in additional products if any (đ/ton) và G is the price of ore concentrates or metal for final products (đ/ton).

In general, the methods or formulas for calculating the cutoff grade of international geo-economic researchers do not differ significantly.

The conversion content of reserves and resource (C_{Kqd}) is stated in the following formula:

$$C_{Kqd} = C_{tb} + \sum_{i=1}^{n} C_{qdi} \quad (8)$$

In which: n- number of useful components attached; C_{tb}- average content of the main component in the volume of reserves or resources (%); C_{qdi}- the ith additional component content converted by the main component of reserves and resource (%):

$$C_{qdi} = C_{pi}.K_{qdi} \quad (9)$$

C_{pi} is the average content of the i^th additional component of reserves in the mine as determined by the exploratory materials (%); K_{qdi} - the conversion coefficient of the i^th useful accessory component to the main one, depending on the input document to select one of the fourth, fifth, sixth or seventh formulas mentioned above.

For the project of lead-zinc ore exploitation of mine Na Tum, the author uses the formula 6 to calculate the conversion coefficient of the additional component into the main component.

After calculating C_{Kqd} (formula 8) compare C_{Kqd} with C_{CN} (calculated according to formula 1), if $C_{Kqd} \geq C_{CN}$, the reserve volume (resource) is considered to meet the requirements of the selected cutoff grade criteria (calculated for Pb + Zn) or not.

3.3 Assessment of the Economic Value of Resources and Deposits

3.3.1 Assessment of the Economic Value of Mineral Resources in the Region

Economic value of mineral resources in the region can be identified for each mineral, mineral group and all minerals in the research area. Economic value is estimated for areas with low or underdeveloped investigation levels which can be calculated according to the following formula [5]:

$$V = \frac{Q_{th}.G}{S} \quad (10)$$

The potential value for recovery of unit area calculated for each ore region, ore point or mineral deposit can be applied the following formula:

$$V = \frac{\sum_{i=1}^{k} D_i, k_t}{S} \quad (11)$$

In which: D_i - revenue from the production of i^th mineral forecasting in the research area; including the revenue from the actual production and the revenue for recoverable reserves and resources; k - dollar adjustment factor of assessment time (1USD = 23.260 VND on 28/08/2018); S - area of assessment.

Due to the uncertainty of geo-economic factors, the estimated data obtained by this method is only relative. However, this is an important basis for investors to compare and select areas to invest in deposit exploration. This assessment is mainly based on the value of commodity mineral recovery. During assessment, it is necessary to adequately assess the resources, reserves at different levels for each user, determine the recovery factor according to each field of use, the value of goods of the final product.

The potential value for recovery of the deposit and deposit areas can be calculated according to the proposal of N. A. Khrusov (1973):

$$GTN_{th} = Q_{th}.G \quad (12)$$

In which: Q_{th} - Recoverable resources (Q_{th} = Q.K; with: Q ore reserves/resources according to the exploration report; K - confidence factor based on reserve/resource level); G - Value of goods - products.

3.3.2 Assessment of Economic Value of Deposit

The assessment of economic value of deposit is essentially the valuation of the deposit through cost-benefit analysis methods to clarify the economic efficiency of deposit investment. The following is a summary of some targets used by the author to analyze the economic value of Na Tum lead - zinc deposit.

* Assessment of the economic efficiency of the deposit according to the gross profit standard

Assessment of the economic efficiency of the deposit according to the gross profit standard (GPS) is considered that the economic value of the deposit is equal to the total revenue obtained in the n years of future, discounted on the start year of deposit exploitation. There are many formulas including the formula of K. L. Porabitski (1975) [3] acknowledged and used by many economists geology of former Soviet Union and Viet Nam. According to him, GPS is determined by the formula:

$$LNT = \sum_{i=1}^{T} \frac{D_t - (Z_{tg} + K_n)_t}{(1+r)^t} \quad (13)$$

In which: D_t- Revenue in year t; $(Z_{tg} + K_n)_{t}$ - cost of production in year t; Z_{tg}- Exploitation and selection-metallurgy costs in year t; K_n- investment capital in year t; r- discount rate (usually selected by bank interest); T- existing project time.

* Assessment based on net present value

Net Present Value (NPV) [9] is a target reflecting the cost level of investment and net benefits of the project during the existing project time and defined by the formula:

$$NPV = \sum_{t=1}^{T} \frac{CI_t - CO_t}{(1+r)^t} \quad (14)$$

In which: CI_t - Revenues in the t^{th} year include taxes; CO_t - The costs spent in t^{th} years include taxes; (1/1+r)- discount factor.

* Assessment of the economic efficiency of the deposit according to the value added standards

Value added is the value difference between the output and the input of the project. Value added (NVA) [9] is presented in the following general form:

$$NVA = O - (MI + I) \quad (15)$$

or $NVA = O - (MI + I + R_P)$ (16)

In which: O- expected output value; MI- input value required to achieve output value (including production costs); I - Total investment; R_P- All foreign payments related to the project (Periodical amount, insurance, tax).

NVA [9] is the net value added of one year, the net value added of the project is determined by the formula:

$$\sum_{t=0}^{T} NVA = \sum_{t=0}^{T} [O_t - (MI_t + I_t] \quad (17);$$

or $$\sum_{t=0}^{T} NVA = \sum_{t=0}^{T} [O_t - (MI_t + I_t + R_{Pt}] \quad (18)$$

* Internal Rate of Return (IRR)

Assessment according to standard of internal interest rate or internal rate of interest (IRR) is the searching discount rate or possible internal rate of interest of IRR [9] and comparation to the limited interest I_{min}. Find the IRR value is to find the value r in the value NPV = 0, it means that the searching r is to satisfy the following conditions:

$$\sum_{t=1}^{T} \frac{CI_t}{(1+r)^t} = \sum_{t=1}^{T} \frac{CO_t}{(1+r)^t} \quad (19)$$

In which: T: the existing project time;

IRR can be determined by the approximate formula:

$$IRR = r_1 . \frac{PV(r_2 - r_1)}{PV + NV} \quad (20)$$

In which: PV - Positive value of NPV (corresponding to discount rate r_1); NP - Negative value of NPV (corresponding to discount rate r_2).

4. Results and Discussion

4.1 Determination Result of Cutoff Grade

As mentioned above, Na Tum lead – zinc deposit has the main useful elements that are Pb - Zn, ore also has useful accessory elements with certain economic value. In addition to the determination of Pb-Zn concentrates recovery ability, research results of technological samples also determine concentrates recovery ability of accessory elements (Fe, Mn, Ag) on a production line and almost no additional cost [1]. The economic and technical parameters of the deposit, such as: production costs, recovery factor, scarcity of ore, etc. are collected according to the documents in the IVa ore bed exploitation project of Bac Kan Mining Company Limited in 2012 [1, 2], selling cost of ores and concentrates is calculated according to the natural resource taxable price list in 2018 of Bac Can province [9].

The results are calculated in the following order:

Step 1: Determine the cutoff grade for the main elements (Pb + Zn) excluding the useful accessory elements. In this case, to determine the minimum industrial content, use formula (1). The results are summarized in Table 2.

Step 2: Determine the cutoff grade for the main element (Pb + Zn) when taking into account the useful accessory elements (Fe, Mn and Ag). For the calculation, the author applies formula (4). The results are summarized in Table 3.

Step 3: Convert the useful accessory elements into the main element. For calculation of the converted content of the useful accessory elements into the main element (Pb + Zn) when recovering them, we have formula (6), (7), (8) and (9). The results are summarized in Table 4 and Fig. 1.

Table 2 Determination result of cutoff grade excluding the accessory elements.

Element	Total cost for 1 ton of concentrates (Q)	Selling cost for 1 ton of concentrates (VND)	Useful element content (C_{tq})	Factor of scarcity of ore (K_n)	Factor of recovery (K_{th})	Cutoff grade (%)
Pb + Zn	1,213,115	9,082,569	62.16	0.89	0.84	11.12

Table 3 Determination result of cutoff gradewhen including the useful accessory elements.

Ore bed	Total cost (VND/T)	Selling cost (VND/T)	Factor K_{th}	Factor Kn	Factor of converted value (Hi)	Main element content (Pb + Zn) in concentrates	Cutoff grade (Pb+Zn) including the useful accessory elements (%)
TQ Iva	1,213,115	9,082,569	0.84	0.89	Pb+ Zn: 1	62.16	3.50
					Fe: 0.38		
					Mn: 0.74		
					Ag: 1.09		
TQ IVb	1,213,115	9,082,569	0.84	0.89	Pb + Zn: 1	62.16	4.10
					Ag: 1.73		

Table 4 Average content of ore beds converted into main element (Pb+Zn).

Natural ore	Ore bed	Element in concentrates	Selling cost - G (VND/ton)	Factor of recovery	Content in concentrates (%)	Converted factor (Kcd)	Content in ore (%)	Converted content according to Pb + Zn (%)
Oxide ore	TQIVa	Pb + Zn	9,082,569	0.84	62.16		5.37	5.37
		Fe	400,000	0.70	35.00	0.07	31.57	2.06
		Mn	700,000	0.70	12.00	0.33	11.87	3.95
		Ag	440,000	0.60	0.0025	861.37	0.0068	5.85
		Total						17.23
Sulfur ore	TQ IVb	Pb+Zn	9,082,569	0.84	62.16		7.34	7.34
		Ag	400,000	0.60	0.0025	861.37	0.0147	12.70
		Total						20.04
	TQIVc	Pb+Zn					9.56	9.56
	TQIVd	Pb+Zn					2.84	2.84
	TQIVe	Pb+Zn					10.08	10.08

From the results presented in Table 2, 3, 4, it can be concluded, that:

- According to the investment project documents for exploiting lead and zinc ore of Na Tum deposit of Bac Kan Mining Limited Company in 2012, the cutoff grade is calculated by C_{CN} = 11.12%) (Pb + Zn). With this content, most of the ore beds in the deposit are unsatisfactory. If the useful accessory elements are included, the cutoff grade depends on the recoverable content of the useful accessory elements in the ore; it is mainly based on the content of Ag, Mn and Fe gradually and there is a difference in each ore bed. For example the IVa ore bed, the cutoff grade with the useful accessory elements is C_{CN} = 3.5% (Pb + Zn); IVb ore bed, respectively is C_{CN} = 4.1%. Thus, when recovering the useful accessory elements (Fe, Mn, and Ag), the average content in Iva and IVb ore beds are higher than the cutoff grade. The remaining ore beds have no useful accessory elements and the average content (Pb + Zn) in the ore beds are smaller than the cutoff grade at the time of assessment.

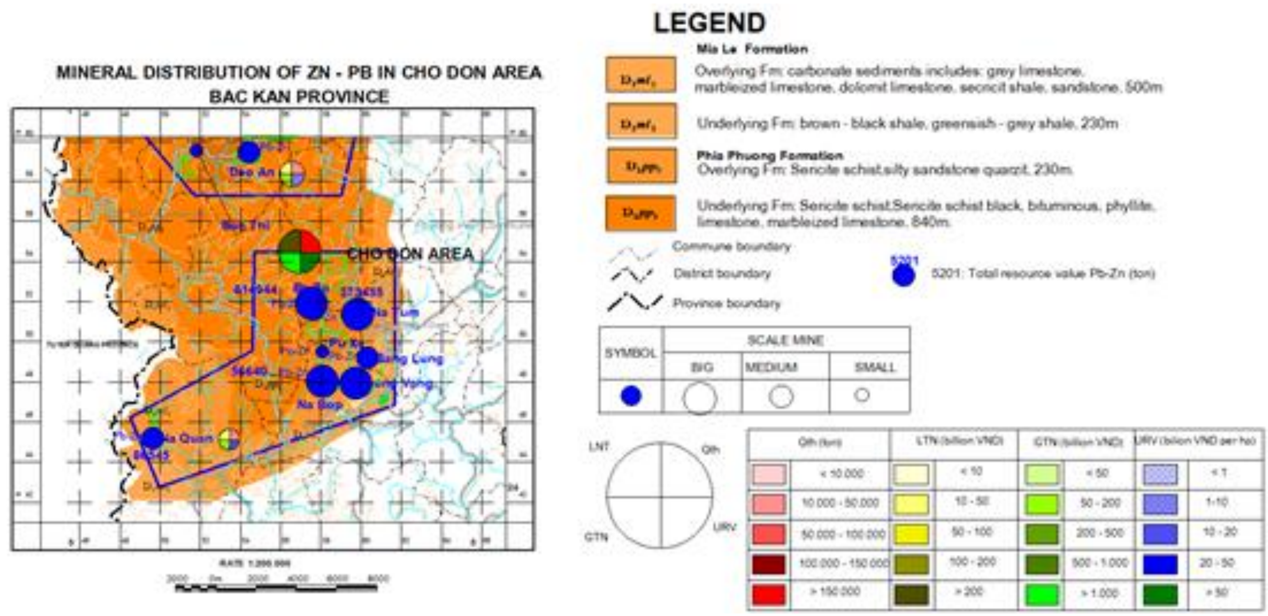

Fig. 1 Mineral distribution of Zn-Pb in CHO DON aera BAC KAN Province.

- For (Pb + Zn) content only, the average content in ore beds in Na Tum deposit is smaller than the cutoff grade (C_{TB} = 2.84 ÷ 10.08% < C_{CN} = 11.12 %). However, when calculating the useful accessory elements (Fe, Mn, and Ag), an average content for converting content (Pb + Zn) of ore bed IVa is 17.23% $(Pb + Zn)_{cd}$, which is 1.55 times higher than the cutoff grade (11.12%); ore bed TQ IVb is 20.04% $(Pb + Zn)_{cd}$, which is 1.8 times higher than the cutoff grade. The remaining ore beds do not have useful accessory elements and at the time of assessment the content is unsastified regarding the cutoff grade.

4.2 Assessment of Economic Value of Mineral Resources in the Region

In assessment of the potential value for ore recovery in the area, the authors use the method developed by N. A. Khrusov (1973), approved reserves/resources [2], and calculate Q_{th} according to formula (12). The results are summarized in Table 5.

Based on the calculation results of the Q_{th}, the unit price used according to the document collecting the average in the taxable price list of Bac Kan province [5], using formula (10), (11) to calculate economic value of mineral resources in the region. The results are summarized in Table 6.

Results in Table 6 shows that at the time of assessment, recoverable potential value (GTN_{th}) and URV of only the main elements (Pb + Zn) are much lower than the recovery of useful accessory elements (Fe, Mn, Ag); At the same time, it is also shown from the results that the recoverable potential value and URV depend not only on the recoverable value of the main elements and the useful accessory elements, but also on the concentrated distribution of the accessory elements with high economic value (Ag) in each bed.

Table 5 Recoverable potential resources (Q_{th}) Pb + Zn in Na Tum deposit.

Recovered object	Ore reserves (thousand tons)				Q_{th}
	121	122	333	334	
Pb - Zn sulfur		212,001	225,158		173,548
Pb - Zn oxide		1.206,717			603,358
Total					776,906

Table 6 Unit Regional Value (URV) and recoverable potential value of Na Tum deposit.

Recovered product	Area (ha)	Cost price (million VND)	Selling cost (million VND)	Selling cost - Cost price (million VND)	Q_{th} (thousand tons)	GTN_{th} million VND (USD)	URV, million VND /ha (USD/ha)
Pb – Zn sulfur ore	7.85	1.30	1.49	0.18	173.548	257,719 (11,080)	32,830 (1,411)
Pb – Zn oxide ore					603.358	895,987 (38,521)	114,139 (4,907)
Pb – Zn oxide ore recovering accessory elements: Fe, Mn, Ag		1.51	1.88	0.36	603.358	1,132,142 (48,673)	144,222 (6,200)
Total: Recovering Pb + Zn ores						1,153,706 (49,600)	146,969 (6,200)
Total: Recovering: Pb - Zn and accessory elements Fe, Mn, Ag						1,389,861 (59,753)	177,052 (7,612)

4.3 Analysis of Economic Efficiency of Lead and Zinc Ore Exploitation Project of Na Tum Deposit

Assessment of economic value of the deposit is to determine the value of the deposit through cost-benefit analysis methods to clarify the economic efficiency of mining investment. The document used for analysis is the investment project for exploiting lead and zinc ore of Na Tum deposit set up by Bac Kan Mining Company in 2012 [1, 2] with the selling cost of ore and concentrates is according to the taxable price list for natural resource in 2018 of Bac Can province [9]. Apply formulas 13, 14, 15, 20 to calculate GPS, NPV, NVA and IRR. The results are summarized in Table 7.

Table 7 Result synthesis of analyzing economic targets of lead-zinc ore exploitation project in Na Tum deposit.

Recovered product	GPS (million VND) (thousand USD)	NPV (million VND) (thousand USD)	NVA (million VND) (thousand USD)	IRR (%)
Recovering Pb – Zn	15,255 (656)	-1,165 (- 50)	25,933 (1,102)	9.36
Recovering Pb - Zn and and accessory elements Fe, Mn, Ag	48,554 (2,087)	32,133 (1,381)	87,710 (3,771)	24.25

From Table 7, some conclusions are drawn:

- The analysized results of the investment project of Bac Kan Mining Company Limited in 2012 show that at the time of the assessment, if only lead - zinc are recovered in exploitation, the investment of ore bed exploitation will not be effective. However, if the accessory elements (Fe, Mn, Ag) are recovered, the investment of exploitation can assure the economic efficiency. In other words, at the time of assessment, the investment of IVa ore bed exploitation at Na Tum deposit, apart from the lead-zinc elements, requests the recovery of useful accessory elements (Fe, Mn, Ag) to improve the investment efficiency and economic value of the deposit.

- The research results indicate that the recoverable value of deposit for Pb and Zn elements will be much lower than the recoverable value of useful accessory elements (Fe, Mn, Ag). At the same time, according to the calculation results of GPS, NPV and NVA, it is also stated that in the exploitation of lead and zinc ores in Na Tum deposit, if accessory elements (Fe, Mn and Ag) are recovered, economic value of deposit will increase significantly compared to Pb + Zn recovery. The results of IRR calculation show that if only Pb + Zn is recovered, the project to IVa ore bed exploitation investment has no economic efficiency (IRR = 9.36% < r = 10%). If accessory elements (Fe, Mn, Ag) are recovered, the investment project will bring economic efficiency to the enterprise (IRR = 24.5%> r = 10%).

5. Conclusions and Recommendations

5.1 Conclusion

1) Lead-zinc ore is distributed in the quartz-sericite shale, benthic limestone or thin-layer limestone of the Cok Xo formation. In the deposit, 5 ore beds have been discovered and circled and connected, in which, IVa and IVb ore beds, apart from Pb, Zn, have useful accessory elements that are highly recoverable and have high economic value as Fe, Mn, Ag (IVa ore bed) and Ag (IVb ore bead). From the point of view of exploiting and utilizing mineral resources, combining resource and environmental conservation, the current basic trend is to complete the method of defining target of the cutoff grade to ensure the principle of the full utilization of useful elements (minerals) in the ore beds of the deposit. Thus, for lead-zinc ore of Na Tum deposit, the cutoff grade should be used flexibly and depends on the type of natural ore as well as the ability of the useful accessory element recovery to select the official and suitable cutoff grade for each ore and ore bed.

2) The analysis results show that if only the main elements (Pb+Zn) are calculated, the average content of ore beds in Na Tum deposit is lower than the cutoff grade; if the useful accessory elements (Fe, Mn, Ag) are calculated, the average content converted into (Pb + Zn) for the IVa ore bed is 1.55 times higher and the ore bed IVb is 1.8 times higher than the cutoff grade, the remaining ore beds are unsatisfactory for the cutoff grade at the time of assessment.

3) The recoverable potential value (GTN_{th}) and URV for the main elements (Pb + Zn) are much lower than the recovery of useful accessory elements (Fe, Mn, Ag); At the same time, the calculated value also indicates that the recoverable potential value and URV depend not only on the recoverable value of the main elements and the useful accessory elements, but also on the concentration and reliability of recoverable reserves/resources.

4) At the time of the assessment, if lead-zinc is recovered only, the investment in exploiting lead - zinc ore of IVa ore bed in Na Tum deposit is not effective, but when the accessory elements (Fe, Mn, Ag) are recovered, the exploitation investment ensures economic efficiency. In other words, at the time of eassessment, the investment in exploiting lead-zinc ore in Na Tum deposit, apart from lead and zinc elements, needs to study the recovery of useful accessory elements (Fe, Mn, Ag) to improve the investment efficiency and economic value of the deposit. At the same time, the results show that the recovery value per unit area for main elements (Pb + Zn) is much smaller than the recovery value for the useful accessory elements (Fe, Mn, Ag).

5.2 Recommendation

1) When calculating fees and taxes, additional costs related to the issuance of mineral mining rights should be added in accordance with Article 69 of Decree No. 158/2016/ND-CP of the Government dated 29 November 2016 and the risk rate in the exploitation investment as well as the reliability of the reserves,

resources determined according to exploration results. When calculating charge for granting the mining rights, it is not only based on the value of the main minerals, but also the value of the recoverable useful accessory elements (minerals) from exploitation and ore selection process should be added.

2) At present, many deposits have been explored and processes. However, useful accessory elements have not been taken into consideration that reduces the economic value of the deposit and the loss of natural resources. This issue needs to be researched in order to improve the economic value of the mineral deposit, utilizing natural resources and protecting environment, reaching the objectives of sustainable development of the mining industry in Bac Kan Province.

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