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RATIONAL USE OF SUBSOIL MINERAL RESOURCES

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Introduction. *Up to the present time neither of mining rent state mechanism changes has led to its radical perfection and rational use of deposit reserves.*
Methodology. *A method of determining the cost of valuable components reserves distinguishing the share of natural processes in the subsoil and materialized human labour in the creation of a mineral resources base.*
Results. *Consumable deposit reserves cost involvement in the creation of objective economic foundation for deposits rational exploitation tasks solution has been substantiated. The methods of assessing the effectiveness of deposits operation technology variants have been introduced, as well as the substantiation of deposits utilization acceptable completeness, and income distribution, observing harmonization between the economic interests of the state, the owner of the subsoil, and the economic interests of the mining enterprises, subsoil users.*
Results analysis. *Rational subsoil use crucial tasks solution results have been introduced and analyzed by the example of Kovdorsky phlogopite deposit.*
Conclusions. *The suggested principles and methods of solving crucial tasks of subsoil use with the involvement of deposit reserves cost contribute to subsoil mineral resources rational use.*

Key words: *reserves cost; harmonization of economic interests; subsoil use crucial tasks; solution methods.*

Introduction. Worldwide experience testifies that the development of human civilization is inseparably connected to the need in continuous growth of subsoil mineral resources consumption. For that reason by the present time the ownership of the subsoil has been completely moved to the state regardless of its political structure. In Russia the state's ownership of the subsoil is recognized in the Constitution, and its use, according to the Law of the Russian Federation "On the Subsoil" (article 9), is not conditional upon the form of the ownership of the subsoil user. Naturally, the presence of the owner raises the question for the subsoil users to pay for the subsoil mineral resources which have been used up by them. The Russian economy's move towards market relations has inflamed the situation of the subsoil users' payment for the utilized subsoil mineral resources, because certain previously existing inconsistency between the economic interests of the owner and the user of the subsoil has intensified. The former is interested in both effective and more economical, i. e. complete and integrated, use of deposit reserves, the latter is interested mainly in its own most profitable production economic performance, i. e. maximum profit regardless of deposit reserves utilization completeness. Existing mineral tax is incapable of respecting the interests of both parties.

There is a wealth of examples. Thus, at the turn of the 20th and the 21st centuries in the course of Norilsk polymetallic ore deposits operation the average content of copper in the extracted ore by 2–3 times exceeded the average one in the deposit reserves [1]. A that, high grade ore production reached 87% with reserves share of 32%. According to the data from the Central Committee for Solid Mineral Deposit Development of the

Federal Subsoil Resources Management Agency, the subsoil reserves losses during deposits exploitation reach from 5–6 to 12–15% on average according to the branches of ore mining industry; extracted mineral raw materials losses during processing reach from 2–25 to 15–55%. As a result, to produce their own marketable mineral products, mining enterprises use up significant reserves of the national mineral resources base. Thus, mining enterprises of Murmansk region, for 1 t of valuable components extracted in the marketable mineral products, use up from 1.1 to 3.7 t of all reserves at the operated deposits (table 1).

It follows from the above that deposit operation should provide, firstly, their utilization effectiveness, secondly, economically acceptable mineral extraction and losses, thirdly, harmonization between the economic interests of the state and subsoil users. These tree tasks meet the solution of the problem of subsoil mineral resources rational use. At that, the central key task without which the solution of other tasks seems impossible is the harmonization of the economic interests of all parties.

Table 1. Consumption of mineral raw resources of the Kola region deposits
Таблица 1. Расход запасов минерально-сырьевых ресурсов месторождений Кольского региона

Enterprise	Valuable component	Consumption of valuable component reserves for 1 t in products, t/t
OOO Kovdorsliuda	Phlogopite	3.7
	Vermikulite	2.2
OAO Kovdorsky GOK	Fe	1.1
	P_2O_5	1.6
OAO Olkon	Fe	1.2
OAO Apatit	P_2O_5	1.2
OOO Chalmozero	Pegmatite	1.5
JSC Kola MMC Pechenganickel Combine	Ni, Cu, Co	1.4
Lebedinsky GOK Karnasurt Mine	Loparite	2.6
Umbozero Mine	Loparite	2.2

Prominent scientists have been repeatedly indicating the need for the mining rent state mechanism development [2–4]. However, up to the present time neither of mining rent state mechanism changes and the amendments made has led to its radical perfection and rational use of deposit reserves.

Research methodology. Mining Institute of KSC RAS substantiated the solution concept for the crucial tasks of the subsoil use with direct involvement of the cost of consumable subsoil reserves, which provides the creation of an objective economic basis to solve the problem of deposits rational exploitation [5]. It has been suggested to approach the determination of deposits cost as goods representing original raw material for the production of marketable mineral products by the subsoil users.

The world practice have accepted the general principle of establishing the price of the produced marketable products Ц$_о$ which includes, firstly, recovery of all costs $C_к$, involved in manufacturing of products including those for original raw material acquisition, secondly, gaining profit for costs provided that it is not lower than the rates for costs accepted in the economy $C_к K_{пр}$, thirdly, tax payments according to the rates accepted in the taxation mechanism (Ц$_о \cdot$ 0.01Н):

$$Ц_о\left(1-0.01Н\right) \geq D_к\left(1+K_{пр}\right).$$

The same principle must be used when determining the cost of deposit reserves being utilized by mining enterprises. However, the distinctive features of subsoil mineral raw resources extraction should be taken into account.

The emergence and the location area of valuable components within the subsoil, their type, quality, quantity, as well as mining-geological conditions they are in, completely depend on the natural processes within the Earth's subsoil. Detection of valuable components in the subsoil, their examination and defining whether they meet the requirements applicable to mineral deposits is carried out with significant human input in the process of exploration and geologic prospecting works, which end up in the national mineral raw base formation.

For deposit reserves cost objective estimation and its application when solving the tasks of deposits rational exploitation, shares of natural processes and materialized human labour should be determined and distinguished. The suggested methodological approach is used when substantiating the operated deposit reserves cost determination [6–10].

The cost of 1 t of valuable component at a deposit:

$$C_{\text{н}} = C_{\text{р}}\left(1 + K_{\text{пр}}\right) + \frac{\Delta\Pi_{\text{р}}}{\text{Б}c}, \tag{1}$$

where $C_{\text{р}}$ – costs for geological prospecting works for 1 t of explored valuable component reserves; $K_{\text{пр}}$ – profit rate for costs accepted in the economy; Б – mineral reserves used up under deposit operation; c – the content of valuable component in reserves; $\Delta\Pi_{\text{р}}$ – excess profit or damage depending on natural conditions of deposit exploitation.

In formula (1), the share of human labour in the cost of deposit reserves is represented by human input for exploration and geological prospecting and a profit accounted for them $C_{\text{р}}(1 + K_{\text{пр}})$. Share of natural processes is represented by the excess profit or damage depending on them entirely. Its size is determined from the remainder of the income after all taxes have been withdrawn (excluding mineral tax), together with human labour inputs for the extracted reserves exploration and operation, and the profit accounted for these costs:

$$\Delta\Pi_{\text{р}} = \text{Д}_{\text{к}}\text{Ц}_{\text{о}}\left(1 - 0.01\text{Н}\right) - \text{Д}_{\text{к}}C_{\text{к}}\left(1 + K_{\text{пр}}\right) - \text{Б}cC_{\text{р}}\left(1 + K_{\text{пр}}\right), \tag{2}$$

where $\text{Д}_{\text{к}}$ – the quantity of the obtained marketable products; $\text{Ц}_{\text{о}}$ – the price of the marketable products; Н – the total of tax rates on the income; $K_{\text{пр}}$ – profit rate for costs; $C_{\text{к}}$ – prime cost of marketable products; $C_{\text{р}}$ – costs for geological prospecting works.

The cost of all reserves used up for the manufacture of marketable products:

$$\text{Б}cC_{\text{н}} = \text{Б}cC_{\text{р}}\left(1 + K_{\text{пр}}\right) + \Delta\Pi_{\text{р}} = \text{Д}_{\text{к}}\text{Ц}_{\text{о}}\left(1 - 0.01\text{Н}\right) - \text{Д}_{\text{к}}C_{\text{к}}\left(1 + K_{\text{пр}}\right).$$

Thus, the cost of valuable component reserves used up for the manufacture of marketable products can be defined from the fraction of income remained after payments for taxes as well as the costs of a mining enterprise for deposit operation and profit accounted for the costs.

Basic information required to calculate the cost of reserves is available at mining enterprises; it is regularly replenished by them, controlled by government compliance monitoring and oversight authorities, therefore being rather reliable. Profit rate for costs is a very particular case. In the world practice its size is not set at random at the subsoil user's will, but depending on the state of national economy and is usually distinguished by significant stability. At that, the type of marketable products

manufacture has scarce or little influence on the size of the profit rate. Thus, in a stable period of economy (1980–1990) in England, Germany, the USA, and South Korea fixed credit interest rates varied from 8.2 to 13.4%, and for deposits – from 11 to 12% per annum [11–14]. In mining industry profit rate for costs have been changing within a wider range, from 8 to 16%, because of various distances and costs for raw material transportation to the consumer [15–24]. So, in the world economy the size of profit rate for costs is sustained sensibly constant.

It follows from formulae (1) and (2) that the cost of deposit reserves depends on many factors. By the example of Kovdorsky phlogopite deposit [9], adequate variation of reserves cost under the variation of the content of a valuable component in the subsoil, prime cost and price for marketable products, and costs for exploration work have been shown. Unlike other types of marketable products, subsoil mineral raw materials cost may be found a negative value in case of unfavorable environmental conditions for deposits operation. The reasons for a negative cost of subsoil mineral reserves may also be other natural conditions of deposits, for example, their location at a significant depth. Adequate reaction of valuable components reserves cost to some changes in mining geological conditions of deposits and corresponding changes in the technology of extracted ore production and processing has been proved [25]. The possibility to use the cost of reserves which has been calculated using the suggested method in order to solve the tasks of rational subsoil use has been justified.

To assess the effectiveness of deposits exploitation, universally recognized indicator of profit from the sales of marketable products gained in the process of mineral raw material production and processing has been used.

Total profit from the operation of the deposit represents, firstly, share accounted for the human input on geological prospecting works and deposit operation, secondly, excess profit or damage depending on mining geological conditions of a deposit the state of which have been completely determined by natural processes within the subsoil:

$$П_р = Д_к C_к K_{пр} + Б c C_р K_{пр} + \Delta П_р.$$

Total profit from deposit operation can be determined from the remainder of the income after the sales of marketable products gained by a mining enterprise after all taxed (excluding mineral tax on ore) have been paid, and costs for exploration, prospecting and operation of a deposit have been offset:

$$П_р = Д_к Ц_о \left(1 - 0.01Н\right) - Д_к C_к - Б c C_р.$$

In order to get a fair view of the role of the subsoil owner, the state, and subsoil users it is desirable to determine their share in the total profit under the operation of a deposit.

Profit accounted for the share of the subsoil user:

$$П_{р.г} = Д_к Ц_о \left(1 - 0.01Н\right) - Д_к C_к - Б c C_н,$$

or

$$П_{р.г} = Д_к C_к K_{пр}.$$

Profit accounted for the share of the state:

$$П_{р.в} = Д_к Ц_о \left(1 - 0.01Н\right) - Д_к C_к \left(1 + K_{пр}\right) - Б c C_р,$$

or

$$П_{р.в} = Б c C_р K_{пр} + \Delta П_р.$$

Apparently, involvement of the cost of mineral raw reserves used up for the manufacture of marketable production by the subsoil users allows to ascertain and assess the share of natural factors and human labour in the profit gained in the course of deposit operation. Firstly, it allows assessing economic performances of deposit operation deeper and more objectively, secondly, contributes to make more economically profitable engineering solutions.

The choice of economically profitable variant of deposit operation gives reason to simultaneously accept losses of reserves under the operation and processing of extracted ore as economically acceptable, i. e. to solve the second crucial task of rational subsoil use.

In order to get a comprehensive view of the completeness of the operated deposit reserves utilization it is reasonable to use the coefficient of all losses of a valuable component in the process of extracted ore production and processing:

$$n_{з} = \frac{Бc - Д_{к}a_{к}}{Бc},$$

or

$$n_{з} = n + n_{об},$$

where $a_{к}$ – the content of a valuable component in marketable products (concentrate); n – valuable component reserves loss rate under ore production; $n_{об}$ – valuable component reserves loss rate under ore processing;

$$n_{об} = \frac{Да - Д_{к}a_{к}}{Бc},$$

or

$$n_{об} = \frac{Бc(1-n) - Д_{к}a_{к}}{Бc},$$

where Д – produced ore; a – the content of a valuable component in produced ore.

In practice, in order to assess the results of produced ore processing, the coefficient of a valuable component losses is commonly used, which is within the produced ore:

$$n_{хв} = \frac{Бc(1-n) - Д_{к}a_{к}}{Бc(1-n)},$$

or

$$n_{хв} = \frac{Да - Д_{к}a_{к}}{Да}.$$

Then the coefficient of the deposit valuable component reserves will be:

$$n_{об} = (1-n)n_{хв}.$$

The role of the third crucial task, which is the distribution of income gained at deposit operation with the harmonization of the economic interests of the state and subsoil users, should be admitted crucial in ensuring rational subsoil use. Consumable reserves cost involvement ensures objective foundation for the indicated problem solution for the first time.

The state as the owner of mineral raw base of the country must receive a sum from the income, which is equal to the accepted taxes and the cost of valuable component reserves used up for the manufacture of marketable products:

$$А_{в} = БсС_{н} + Д_{к}Ц_{о} \cdot 0.01Н. \quad (4)$$

Mining enterprise acquires its share from the income after all taxes have been paid (except for the mineral tax) excluding the cost of the used up reserves:

$$А_{г} = Д_{к}Ц_{о}(1 - 0.01Н) - БсС_{н}, \quad (5)$$

or

$$А_{г} = Д_{к}Ц_{о}\left(1 - 0.01Н\right) - БсС_{р}\left(1 + К_{пр}\right) - \Delta П_{р},$$

or income share equal to recovery of all costs for deposit operation and the profit on these costs corresponding to the rates accepted in the economy:

$$А_{г} = Д_{к}С_{к}\left(1 + К_{пр}\right).$$

As follows from the formulae above, in case of mining the deposit's sections with especially favorable mining and geological conditions (for example, with a high content of a valuable component in reserves) excess profit increases and, correspondingly, the state's income share increases. At that, the share of subsoil users may fall because their costs for the manufacture of the same quantity of marketable products are cut. It also follows from above that the involvement of reserves cost in income distribution allows the state to control selective development of deposits which is currently restricted by the Law of the Russian Federation "On the Subsoil".

Special situation occurs when the deterioration of environmental conditions of deposit's exploitation leads to the fact that its reserves cost is found a negative value. In this case the state's costs for exploration and the subsoil user's costs for deposit operation, as well as profit accounted for the costs, as can be seen from the formula (2), cannot be completely recovered from the income gained. Their general damage is equal to an absolute value of the cost of deposit's utilized reserves. It is unprofitable for the subsoil user to develop such deposits. If the state needs mineral raw material, it must undertake the recovery of all costs of the subsoil user. The said can be carried out by means of reducing the state's share in the income (formula (3)) by the cost of utilized reserves and corresponding increase in the subsoil user's share (formula (4)). Damage recovery will allow the subsoil user to justify operational costs and gain profit on them according to the rates accepted in economy.

Results of economic analysis. In table 2 by the example of Kovdorsky phlogopite deposit, the variants of its reserves utilization are considered.

Discussion. The assessment of effectiveness has been carried out for three typical situations most probable at deposit operation. Firstly, the choice of rational operation technology by the example of sections with valuable component content equal to the average for a deposit (variants 1 and 2). Secondly, operation effectiveness assessment for the sections with phlogopite content exceeding the average for a deposit (variant 3). Thirdly, operation effectiveness of the sections with low phlogopite content, verging towards the boundary content (variants 4 and 5).

Assessment of two first variants has shown that the best economic performances are provided by variant 1, which, at the settled marketable products output of 50 thousand t of crystal raw material, ensures the highest profit which is 21.4 million rub as compared

to the variant 2 (19.2 million rub). The main reason of the advantage of this variant of extracted ore production and primary processing consists in the lower quantity and cost of phlogopite reserves used for the manufacture of marketable products. It should be noted that under existing state tax mechanism which does not take into account the quantity and cost of consumable mineral resources, variant 2 has been considered more preferable, the marketable products prime cost of which is somewhat lower than that of the variant 1. Due to the fact that when assessing the variants with the account of the cost of consumed deposit reserves variant 1 has been chosen, valuable component losses under extracted ore production and processing corresponding to the chosen variant of technology should be considered economically acceptable or normative.

Table 2. Assessment of Kovdorsky phlogopite deposit operation variants effectiveness
Таблица 2. Оценка эффективности вариантов эксплуатации Ковдорского флогопитового месторождения

Indicator	Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
Initial data					
Phlogopite content in reserves c, kg/m^3	200	200	250	100	50
Marketable products $Д_к$, t	50 000	50 000	50 000	50 000	50 000
Price of marketable products $Ц_о$, rub/t	2500	2500	2500	2500	2500
Prime cost of marketable products $C_к$, rub/t	1250	1200	1050	1350	2200
Costs for exploration of 1 t of phlogopite $C_р$, rub/t	400	400	400	420	500
Losses of phlogopite in the course of production and processing of extracted ore $n_з$, unit fraction	0.3	0.4	0.3	0.3	0.3
Profit rate for costs $K_{пр}$, unit fraction	0.1	0.1	0.1	0.1	0.1
Tax rates for income Н, %	10	10	10	10	10
Results					
Consumption of mineral reserves Б, thousand m^3	357.1	416.7	285.7	714	1429
Consumption of phlogopite reserves Бc, t	71 429	83 333	71 429	71 429	71 429
Cost of utilized reserves of phlogopite Б$cC_н$, thousand rub	43 786	46 500	54 786	38 286	–8500
Excess profit or damage from environmental conditions $\Delta П_р$, thousand rub	12 321	9833	23 321	5250	–47 786
Total profit $П_р$, thousand rub	21 428	19 167	31 428	15 000	–33 214
Profit of the mining enterprise $П_{р.г}$, thousand rub	6250	6000	5250	6750	11 000
Profit of the state $П_{р.в}$, thousand rub	15 178	13 167	26 178	8250	–44 214
Share of the mining enterprise income $A_г$, thousand rub	68 714	65 000	57 714	74 214	121 000
Share of the state's income $A_в$, thousand rub	56 286	125 000	67 286	50 786	4000

In case of using the sections of the deposit with the higher content of valuable component in reserves (variant 3), there is a possibility of receiving higher profit (31.0 million rub) under the same settled marketable products output. It can testify to the advisability of deposit's best sections selective development, but only, as it will be revealed further, in case of taking into account the cost of consumable resources under income distribution. In fact, the main reason for a higher profit in this case is a significant increase in the excess profit (23.3 million rub as compared to variants 1 and 2) depending

exceptionally on particularly advantageous environmental conditions of such sections utilization. For this reason the share of the state, the owner of the subsoil, in the income increases when the share of the subsoil user is somehow decreased because the raise of the content of mined reserves somehow reduces the prime cost of ore production and processing. For the same reason within more advantageous environmental conditions the share of the owner of the subsoil in the income increases; the share of the subsoil user correspondingly decreases, which ensures the harmonization of the economic interests of both parties. Thus, when assessing the effectiveness of deposit operation with the account of the cost of consumable mineral reserves, selective development of the best sections of a deposit currently restricted by the Law of the Russian Federation "On the Subsoil" may be economically feasible especially if it is required to leave interchamber pillars l in the subsoil to ensure mining safety.

Operation of the sections of a deposit with the content of a valuable component in reserves being lower that the average (variant 4) is followed by reduction of profit (15 million rub) as a result of a significant reduction of excess profit, ore production and processing rate increase and, correspondingly, costs on the manufacture of the settled quantity of marketable products due to the deterioration of environmental conditions of operation. At the same time, due to the deterioration of environmental conditions of operation, the excess profit decreases and, correspondingly, costs of deposit consumable reserves. As a result of the indicated reasons the share of the state in the income decrease, whereas the share of a mining enterprise, incurring more substantial costs, increases which indicates the compliance with the harmonization of the economical interests of both parties.

In case of operating the sections with the content of phlogopite at the level of the boundary one for the deposit (variant 5), ore production and procession rates grow even more, and correspondingly, costs for marketable products manufacture increase. At the same time such rapid deterioration in the environmental conditions of deposit sections operation leads to significant damage instead of the excess profit and, as a result, negative value of phlogopite reserves cost. As a result deposit operation causes damage (–33 214 thousand rub) instead of the profit. While the only reason for this is disadvantageous environmental conditions of operation, the owner of the reserves, the state, if interested in mineral raw material, must recover the damage for the subsoil user equal to the absolute value of the cost of the used up reserves (8500 thousand rub). In this case the subsoil user is permitted to justify costs for operation and gain profit accounted for them according the rates $Д_к С_к(1 + K_{пр}) = 121\ 000$ thousand rub.

At that the share of the state in the income, which constitutes tax payments $Д_к Ц_о \cdot 0.01 \cdot 1 = 12\ 500$ thousand rub, reduces up to 4000 thousand rub.

Conclusion. Suggested principles and methods of solving key tasks of subsoil use involving the cost of deposit reserves contribute to rational utilization of mineral raw resourses of the subsoil, as well as the creation of objective economic foundation for radical perfection of the state mechanism of regular payments for the use of the national mineral raw base with the compliance with the economic interests of the owner of the subsoil, the state, and the subsoil users, which are distinguished by certain contradictoriness.

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РАЦИОНАЛЬНОЕ ИСПОЛЬЗОВАНИЕ МИНЕРАЛЬНО-СЫРЬЕВЫХ РЕСУРСОВ НЕДР

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Вступление. *До настоящего времени все изменения государственного механизма платы за недра не привели к радикальному его совершенствованию и рациональному использованию запасов месторождений.*
Методология. *Изложен метод определения стоимости запасов полезных компонентов с выделением долей участия в ней природных процессов в недрах и овеществленного труда человека в создании минерально-сырьевой базы.*
Результаты. *Обосновано привлечение стоимости расходуемых запасов месторождений для создания объективной экономической основы решения задач рационального освоения месторождений. Приведены методы оценки эффективности вариантов технологии эксплуатации месторождений, обоснования приемлемой полноты использования месторождений, распределения дохода с соблюдением сбалансированности экономических интересов государства – владельца недр и горных предприятий – недропользователей.*
Анализ результатов. *Приведены и проанализированы результаты решения ключевых задач рационального недропользования на примере Ковдорского флогопитового месторождения.*

Выводы. *Предложенные принципы и методы решения ключевых задач недропользования с привлечением стоимости запасов месторождений способствуют рациональному использованию минерально-сырьевых ресурсов недр.*

Ключевые слова: *стоимость запасов; сбалансированность экономических интересов; ключевые задачи недропользования; методы решения.*

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