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Digital technology in the control system of mining industry

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***Abstract* — The article presents the results of research related to the improvement of the mining industry management . Today, the information security of the mineral resource complex is not assessed, information flows are being decentralized. The introduction of innovative economic management mechanisms is impossible without a high-quality information resource. The need for the integration of information databases in the field of subsoil use was considered and justified . Digital (technological) platforms are the only possible for integration of information flows.**

***Key words* — subsoil use, mineral resources complex, geological information, territorial-regional information system, technological platform.**

I. INTRODUCTION

The importance of digital technology in the mining industry is undeniable. It is implemented at all stages of exploration and mining. Despite the fact that the demand for mining products continues to be steady, currently the mining industry is experiencing an increasing influence of constraints. This is due to the depletion of rich deposits, the transition to more complex technological schemes for the extraction and processing of ore, the development of deposits in remote areas with a completely missing or poorly developed infrastructure. In the current situation, development depends not only on investments aimed at modernizing production and developing new mining regions. These costs will increase as the mining enterprises go to more remote areas and develop deposits with low metal content. The use of modern information software systems in this case becomes necessary in the conduct of any production and management of mining activities.

Therefore, the development of the industry to a greater extent in such a situation is determined by the need to use innovative digital tools in the industry management system. The need for new economic mechanisms for managing the industry has ripened at least 15 years ago, but without a high-quality information resource and a systematic update, it is impossible to make an effective management decision in the field of industry management and in enterprise management. Ignoring the state of this need directly determines the threat to the state of Russian national economic security [1, 2].

The purpose of the study is to develop the main directions of improving the management system of the mining industry on the basis of modern information technologies in the context of accelerating informatization (digitalization) of the Russian economy.

II. RESEARCH METHODOLOGY

The main source of problems in subsoil use in Russia is the weakening of actions combined by the term “management”. Destructive changes in the control system began when the fundamental principles of dialectics, including the principle of the struggle of opposites, which the second law of thermodynamics is a vivid manifestation, were forgotten. The most important advantage of the dialectic approach is that the main negative factors of the analyzed systems are exposed.

As a result of the state of the mineral resource base analysis (MRB), it was found that for most of the major mineral resources (MR), Russia may face in the near future with the problem of a profitable reserves of mineral resources shortage. A problem can be prevented only by radical measures related to conducting a strategic study of the subsoil and creating effective economic mechanisms in management. However, practice shows that resource economies can be innovative [1,2,3]. Resource industries are able to move downstream industrial chains to related industries - consumers of these same resources [4]. This means that the mining industry always has the potential to integrate into the regional economy. The development of new resource industries depends on the ability of the economy and society to use technology and resources for the transformation of the natural environment and its involvement in economic production. And to organize this ability is one of the main management tasks facing the state.

Using the institutional, strategizing and comparison methods, it is shown that the informatization of the economic space puts forward new scientific, theoretical and practical problems of improving the organization of management, on the solution of which, ultimately, the competitiveness of the mineral resource complex (MRC) depends.

To achieve the goal of the research, a hypothesis was proposed that the management system in its operation should evolve, move away from the old methods in management and find fundamentally different, innovative ones. Management innovations or innovative management methods can represent both changes and changes in management methods themselves, as well as their elements, including through digital technologies, and the management mechanism should be adaptive, developing, and resistant to the negative effects of internal and external factors. Comprehensive application of information flows in the MSC is possible only on the basis of end-to-end integration. Integration of large information flows, inventories, databases, technologies used and created in the field of subsoil use can be implemented on the basis of a digital (technological) platform.

The rationale of the hypothesis is that at the present stage of development of management thought there is a search for a more sophisticated, temporal management model aimed at increasing the adaptive capabilities of the controlled system and adapting to the rapidly changing environmental conditions. In recent years, a new direction of scientific research has been formed and is developing, based on “chaos theory”. This trend is relevant, because social and economic processes do not always follow a strictly predictable path, and it is not always possible to compare the significance of a factor influencing a system, the degree of its influence and the scale of possible consequences [5].

To test the hypothesis, we based on the theory of multilateral platforms [6] have shown that digital (technological) platforms are the only possible ones to create a unified environment for the integration of all information flows in the subsoil use.

III. Results of the Research

For the management system in the sphere of subsoil use, it is peculiar to form large information flows that are associated with information files on natural resources, on the activities of nature users and the state of the environment. And the adoption of a management decision fully depends on the state of these information files.

Meanwhile, information security in the industry management system is not assessed today, the flow of information for making a management decision is decentralized. There is no uniform methodology for organizing information volumes and creating a single information space in the field of industrial management, creating a new technology for making management decisions. At the same time, the information flow should be created in accordance with the requirements and demands of the organizational and economic management mechanism (OEMM) by the industry, information arrays should be complex [7]. But information about the state of natural resources, including MRB, is dispersed in industry registers (cadastres) and data banks, in territorial cadastres of natural resources. This is due to the fact that information arrays, as a result of processing of which a management decision is taken, various reference systems and registers in the field of environmental management, are the sphere of interests of executive authorities that are completely different in their purpose. And the powers related to the controlling influence of the system on the objects of management are distributed over different subjects of management. Figure 1 shows the distribution of powers in the management of the mining industry.

We see that the reproduction of MRB, the sphere of mining activities, and the supervision of mining activities are concentrated in the Ministry of Natural Resources of the Russian Federation. In comparison, the terms of reference of the USSR Ministry of Geology concerned only geological and geological exploration works.

Thus, a single information base on the status of SRB does not exist. It should be noted that there is no single cadastre of natural resources in the country. Such an information system for monitoring anthropogenic changes is an integral part of the management system, since information on the current state of the environment and its trends should be used as a basis for developing conservation measures and be taken into account when planning the development of the economy. However, the actual decision-making on the basis of monitoring such an information system, which exists in a scattered manner, does not occur. The results of the assessment of the existing and predicted state of natural resources are also scattered or absent altogether.

Creating a single information base in the industry is possible only through the integration of existing inventories on the basis of a single information system. Formation of it should be carried out jointly by all interested departments. Its current distinction between the objects of the federal and republican levels and the maintenance of several system databases will inevitably lead to data conflict. One subsoil user can have objects of both federal and regional jurisdiction, which leads to loss of the integrity of the geological study of the subsurface and management of stock information, as well as other negative consequences.

Cadastre of deposits and occurrences of minerals and the state balance of mineral reserves	←	Federal Agency for Subsoil Use of the Ministry of Natural Resources and Ecology of the Russian Federation
Land Registry	←	Federal Service of State Registration of Cadastre and Cartography
Water cadastre	←	Federal Agency of the Ministry of Natural Resources and Ecology of the Russian Federation
Groundwater cadastre	←	
Cadastre of specially protected natural territories	←	Federal Forestry Agency of the Ministry of Agriculture of the Russian Federation
Forest Registry	←	
Register of fish stocks	←	Federal Agency for Fisheries of the Ministry of Agriculture of the Russian Federation
Register of hunting animals	←	Ministry of Natural Resources and Ecology of the Russian Federation
Register of environmental pollutants	←	

Fig. 1 Cadastres of natural resources and organizations and authorities, their leading (compiled by the author)

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Today, access to geological information obtained by subsoil users remains completely inaccessible, information created by different subsoil users is scattered, not structured, not informative, is not stored in proper conditions, and is lost in the future.

It is necessary to develop a normative concept of geological information, and this is possible only when such information will be recognized as intellectual property, the concept must be coordinated both legally and economically. In this regard, one of the main tasks in the revival of the geological industry should be the creation of a geo-information market, an inventory of information resources, since the available information resources do not meet the needs of the subsoil user and the state both in terms of quantity and quality, develop and create a territorial-regional information system (TRIS).

Consider our hypothesis on the example of the Far Eastern Federal District (FEFD). An analysis of the complex of materials reflecting the state of small and medium business and geological knowledge within the FEFD revealed that there is no geological-cartographic basis that meets modern requirements in the Far East, which hinders the implementation of advanced mineralogical research. Leading mining companies with a high level of current mining reserves transferred to licensed use refrain from financing the early stages of geological exploration due to the high level of geological and economic risks, since the current licensing system in the sphere of subsoil use does not provide the necessary conditions to increase the investment attractiveness of geological exploration, and in the unallocated subsoil fund, the share of reserves and deposits is large, the development of which is not economically feasible.

The databases of the state cadastre, balance of reserves, study, licenses are largely disconnected, and the information in them is partially duplicated. TRIS will solve the problem of database fragmentation.

The need to solve this problem is shown in Table 1.

TABLE 1. THE ACTUAL STATE OF INFORMATION RESOURCES OF THE MINING INDUSTRY MANAGEMENT SYSTEM BY FUNCTION (BASED ON ROSNEDRA [8])

		Regulatory functions				
		Accounting	Analysis	Plans construc tion	Admin istra tion	Regula tion
Regulatory mechanisms	State policy on the use of MRB					
	Coordination of MRB use					
	State control of subsoil use licenses					
	State control over rational use of mineral resources					
	Management of the state subsoil fund					
	State licensing of subsoil use					
	Regulation of revenues from the MRB use					
	Regulation of investment in the MRB use					

automated
partially automated
not automated
no subject to automation

We see that the information system for the regulation and use of mineral resources for individual blocks has been developed and is working, but the information is divided due to the lack of common approaches to its integration and unification. In order for TRIS to be successful, it is necessary to create conditions for effective interaction between participants, the possibility of obtaining access to a common bank of information on the current state and development trends of economic sectors in Russia and in the world in general, and on projects and programs implemented within the MRC , in particular. This is only possible in the technological platform (TP). The presence of TP-participants in a single industry information space, simplification of the communication procedures between them, an open exchange of ideas, needs and suggestions, should have a positive impact on the quantity and, subsequently, on the quality of projects produced within the TP [9]. In this case, the information space will not be limited to the traditional framework of sectoral interests. TRIS is not created from scratch. Basic architectural and technological solutions for creating geographically distributed information and analytical systems in the field of environmental management always contain the GIS-component of the information and analytical system [10].

The territorial-regional information system on the subsurface for the integrated development of mineral resources must be unified and integrated. However, in modern conditions the once unified system of geological and economic information, presented by relevant institutions and departments, was violated due to the absence of several components in it. These are the system of accounting and monitoring of common minerals (CM), geological information and its accounting system, and the completeness of the study of the territories of the regions. Thus, the requirement for a technological platform must be its universal ability to integrate, and, therefore, the metadata subsystem, which is intended for integrable properties, modules and functions, as well as interactions and interrelations between them and other platform elements, should become an indispensable element of the platform.

The proposed approach to the formation of TRIS based on a digital (technological) platform made it possible to identify an extremely negative point representing a risk to the economic security of the state. The main role in making management decisions in the MRC is played by information obtained in the course of regional geological and geological exploration works.

Large mining companies that have high availability in reserves under license agreements refrain from financing the initial stages of exploration, since such work is always accompanied by a high level of geological and economic risks.

TABLE II. GEOLOGICAL STUDY OF THE TERRITORY OF THE FAR-EASTERN FEDERAL DISTRICT ON JANUARY 1, 2012 (EXCLUDING OVERLAP) * (BASED ON MATERIALS BY N. KORENKOVA, 11])

Item administrative units	Square of administrative unit without large inland waters, km^2	The scale of filming						
		1:10 000	1:25 000	1:50 000	1: 100,000	1: 200,000	1: 500,000	1: 1 000 000
Far Eastern Federal District:	**6181838**	**9704** / **0.16**	**66330** / **1.07**	**1598784** / **25.86**	**530427** / **8.58**	**5241270** / **84.78**	**3275304** / **52.98**	**6181838** / **100.00**
1. Republic Sakha (Yakutia)	3103200	3883 / 0.13	15407 / 0.50	501796 / 16.17	195304 / 6.29	2315760 / 74.62	1389556 / 44.78	3103200 / 100.00
2. Primorsky Krai	163100	927 / 0.57	2063 / 1.26	131046 / 80.35	17403 / 10.67	163100 / 100.00	163100 / 100.00	163100 / 100.00
3. Khabarovsky Krai	786,345	825 / 0.10	1617 / 0.21	278,923 / 35.47	36,000 / 4.58	785,717 / 99.92	321,254 / 40.85	786,345 / 100.00
4. Amur region	361281	118 / 0.03	709 / 0.20	94958 / 26.28	10479 / 2.90	361281 / 100.00	181218 / 50.16	361281 / 100.00
5. Kamchatsky Krai	471,520	353 / 0.07	2522 / 0.53	114,976 / 24.38	37727 / 8.00	471,520 / 100.00	286,000 / 60.65	471,520 / 100.00
6. Magadan region	459880	1156 / 0.25	26,214 / 5.70	221,490 / 48.16	114,039 / 24.80	459880 / 100.00	316,975 / 68.93	459880 / 100.00
7. Sakhalin region	86,030	1820 / 2.12	10738 / 12.48	38,515 / 44.77	26,985 / 31.37	86,030 / 100.00	84,908 / 98.70	86,030 / 100.00
8. Jewish Autonomous region	36,000			12,422 / 34.51	45 / 0.13	36,000 / 100.00	33,850 / 94.03	36,000 / 100.00
9. Chukotka autonomous region	714,482	622 / 0.09	7060 / 0.99	204658 / 28.64	92445 / 12.94	561982 / 78.66	498443 / 69.76	714,482 / 100.00

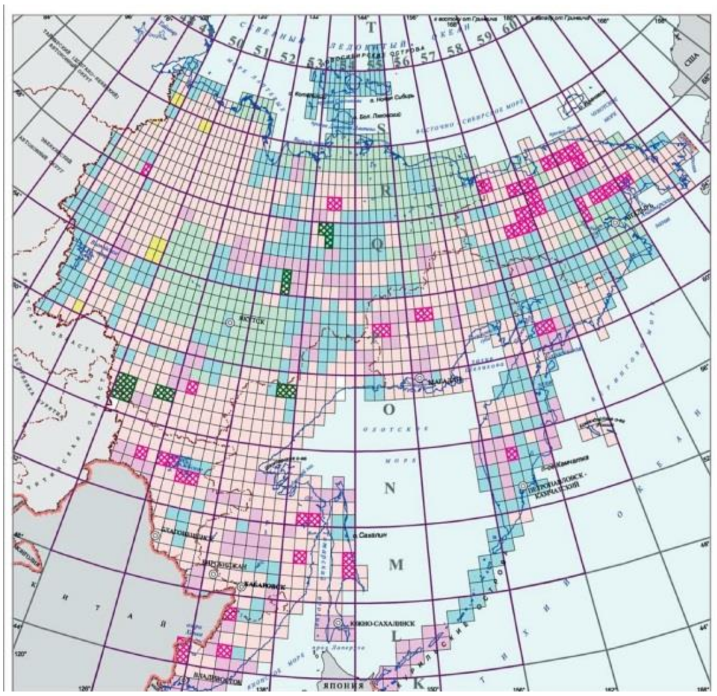
* In the numerator - area, km^2
In denominator -% to total area

And since the state licensing system does not contain preferences to increase the investment attractiveness of geological exploration, and in the unallocated subsoil fund, the share of reserves and deposits is large, the development of which is not economically feasible. And again, we will demonstrate our conclusion on the example of the FEFD, where a lengthy study was conducted to determine the degree of knowledge of geological survey, geophysical, hydrogeological, engineering and geological work in the district [11]. The result of this work allows you to determine the security of geological information without the use of special formulas. Table 1 shows the geological knowledge of the district as of 01/01/2012. Unfortunately, after 2013, such a study in the Far East was no longer conducted. However, the situation in 2019 has not chaned.

For example, in accordance with the table, the territory of the Khabarovsk Territory is covered by a geological survey of 1:50 000 scale - 35% of the territory; 1:100,000 scale - 4.5% of the territory. In Russia as a whole - 24% and 8.5%, respectively.

Figure 3 presents a map of the provision of the Far Eastern District with a geological basis of a scale of 1:200,000. Analyzing the information presented in Figure 2,

Fig. 2. Map of FEFD provision with geological basis of 1:200 000 scale (compiled by N. Korenkova [11])



we conclude that the geological basis for the Khabarovsk Territory is practically all represented by sheets published before 1979. The geological maps of 1:200 000 scale issued after 1998 make up no more than 10% of the territory of the region. A geological additional survey of the area was not actually carried out, most of the work on the aero-gamma spectrometric survey of 1:25000-1:50,000 scale was completed before 1990.

Conclusion - the study of the territory of the Far Eastern Federal District by deep geological and geophysical methods as a whole remains fairly low and extremely uneven, which, for example, for oil and gas, does not always allow an objective assessment of the prospects of both individual regions and oil and gas complexes. But in general, poor geophysical knowledge makes it necessary to continue magnetic prospecting, seismic exploration and other types of geological and geophysical studies [11, p. 3]. The situation with hydrogeological study is not the best. A hydrogeological map of 1:1 000 000 scale for the territory of Sakhalin Island is only available in 1972 (Hydrogeology of the USSR, vol. XXIV, 1972), for the whole territory of Primorsky Krai - published in 1964.

TABLE 3. ENGINEERING-GEOLOGICAL AND COMPLEX HYDROGEOLOGICAL ENGINEERING-GEOLOGICAL STUDY OF THE TERRITORY OF THE FAR-EASTERN FEDERAL DISTRICT WITHOUT TAKING INTO ACCOUNT THE OVERLAP AS OF 01/01/2012 (BASED ON MATERIALS BY KORENKOVA N.M. [11])

Administrative unit	Key indicators * on the scale of filming						Not captured square
	Total filmed	1:25 000	1:50 000	1: 100,000	1: 200,000	1:500 000 1:1 000 000	
FEFD (in general)	1420240 23.05	874 0.01	74884,7 1.22	3391.5 0.06	394054 6.39	947036 15.37	4741916 76.95
Primorsky Krai	163100 100	341 0.21	33,019 20.24	3391.5 2.08	22,217 13.62	163100 100	0 0
Khabarovsk region	786,345 100	228 0.03	10107 1.29	N. **	79,398 10.10	717,465 91.24	0 0
Amur region	81818 22.65	n.a.	3494 0.97	n.a.	78324 21.68	n.a.	279463 77.35
Jewish Autonomous Region	17110 47.53	n.a.	12910 35.86	n.a.	4200 11.67	n.a.	18890 52.47
The Republic of Sakha (Yakutia)	159857 5.18	n.a.	1172 0.36	n.a.	148685 4.82	n.a.	2923643 94.82

Chukotka Autonomous Region	16,100 2.25	200 0.03	n.a.	n.a.	15900 2.23	n.a.	698,400 97.75
Sakhalin region	75205 87.42	n.a.	1338.7 1.56	n.a.	7395 8.60	66,471 77.26	10,825 12.58
Magadan region	34,414 7.48	105 0.02	964 0.21	n.a.	33,345 7.25	n.a.	425466 92.52
Kamchatka Krai	6470 1.37	n.a.	1880 0.40	n.a.	4590 0.97	n.a.	465,050 98.63

* In the numerator is the area, km^2; in denominator - the share of the total area,%.
**No data

Published State Hydrogeological Maps of 1: 200,000 scale are available only for approximately 896630 km^2 of the FEFD territory, which is about 1.5%! [11, p.9].

Engineering and geological knowledge, an analysis of which is presented in Table 2, is 0.9 thousand km^2 (0.01%) for detailed work, 78.3 thousand km^2 (1.28%) for large-scale work, and 394.1 for medium-scale thousand km^2 (6.39%), small-scale - 947.0 thousand km^2 (15.37%)

[11, p. 13].

The degree of engineering and geological knowledge of the FEFD, as well as hydrogeological, is insufficient and extremely uneven. The overwhelming amount of work completed before 1990. Meanwhile, hydrogeological and complex hydrogeological and geotechnical exploration are very relevant for densely populated areas of the FEFD. This is due to the need to organize the rational use of water, monitor the quality of drinking and industrial waters, search for and explore new aquifers and ensure their safety. A geotechnical study is of particular importance because it is associated both with the increasing civil and industrial construction, and with the complexity of the geological and hydrogeological conditions in the district. Thus, at present, despite the massive development of administrative centers and large settlements, practically no engineering and geological surveys are carried out, or they are carried out by various non-specialized organizations, in whose archives all reporting materials are stored. There are also no survey materials for the construction of the pipeline route, roads and railways. This situation is typical for the whole country.

Thus, geological information is the main and only product of the geological study of the subsoil, the basis of any geological exploration. Geological, economic and geological and statistical information created on its basis plays an important role in the management decision-making process at the level of industry management.

Using the capabilities of technological platforms in the management system of the mining industry at the regional level will also solve such problems as the lack of information about the scale of the mineral and raw material potential of common minerals, the diversity of the minerals that form it, and their location in the depths. But the adjustment of the state balance is impossible without a geological-cartographic basis that meets modern requirements in a number of promising areas of the region, the absence of which hinders the conduct of leading forward-looking research. The development of exploration and mining industries of the economy involves the widespread use of modern computerized systems for collecting, processing, and promptly transmitting geological data [12].

It is necessary to develop and maintain an up-to-date information resource on mineral resources, including common minerals, and monitor changes in the dynamics, monitor the accuracy of the boundaries of license areas, identify inconsistencies between license coordinates and the actual location of mountain allotments on the ground. These tasks can be solved in terms of an integrated information system. At the federal level, a new information system in the form of developed software, called the Unified Fund of Geological Information, has begun to be used today in a test mode in a number of regions of Russia. However, in this system, geological information is not fully present, fragmentary and without updating its interpretation.

IV. Conclusion

The study revealed that the implementation of the territorial-regional information system is possible on the basis of the TA, which, on the one hand, is a way of information interaction of the platform participants, on the other hand - by a new innovative method of management system. The basis of TRIS should be basic technologies. The conceptual structure of TRIS needs to be built in such a way that it relates to the levels of government.

The main result of using the TP capabilities in the mining management system at the regional level will be the construction of a geo-information resource containing up-to-date and reliable information about the fields currently in operation, the reserve fund, which are not listed on the balance of the deposits, the subsoil use objects of past years, the description of the fields, with an orderly standard view with information on location, quantitative and qualitative characteristics of the field.

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