Methodological Aspects of Managing a Geological Study of Subsoil and Forming a Database for a Geological and Economic Map of the Mineral Resource Potential of Sakha Republic (Yakutia)

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Abstract. Managing the process of geological exploration of subsoil has now undergone significant changes. Over the period of applying information technologies in the geological industry, notable changes have occurred in the structure of the subsoil management system, which were expressed in solving organizational issues of the system design, choosing the structure of methodological tools, selecting a software and hardware platform, etc. At present, a significant difficulty is to solve the issue of creating a control system for the geological study process of subsoil and to reproduce mineral resources at the regional level, where the reserve disposal should be compensated by their growth. This is the idea of a simple reproduction of the raw materials base. For a number of raw materials, even such an increase is currently not achievable; regional programmes for a geological exploration of subsoil are formed by extrapolating last year's indicators or there are no such programmes at all. The authors have developed a control system model for the geological exploration process of subsoil and formed a system of indicators in the form of a database for a geological and economic map of the mineral resource potential (using the example of the Republic of Sakha (Yakutia)). This work was supported by the grant No. MD-2409.2020.5 given by the President of the Russian Federation.

1. Introduction
Applying information technologies in the geological exploration and subsoil use over the past years has made it possible to solve the problems of modelling and designing mining facilities, calculating the parameters of their operation, creating “digital twins” and using automated and robotic systems in carrying out geological exploration. In the subsoil use, applying geographic information systems is gaining popularity when planning exploration work. At the same time, the issue of constructing geological and economic maps within the framework of a geographic information system remains insufficiently studied. The issue of applying geographic information systems and technologies in geology was considered in the works [1-21].

The purpose of this work is to study the process of assessing the mineral resource potential of the territory, to decompose the results of a geological and economic assessment into an electronic map.
within the framework of the geographic information system and to develop the management decisions based on it.

To achieve the goal of assessing the mineral resource potential and modelling in the geographic information system, the following main areas of work are used:

1. data processing of scientific research and exploration works using the methods of probability theory and mathematical statistics, mathematical analysis, game theory, geometric methods;
2. determining the qualitative characteristics of geological objects and processes using the apparatus of mathematical logic and applied informatics;
3. modelling geological processes and, on this basis, predicting the identification of mineral deposits, while applying various mathematical methods;
4. unifying the processes of collection, processing, storage and interpretation of geological information using the information theory, mathematical methods and other scientific and technical documentation.

Assessing the mineral resource potential will make it possible to prepare information and analytical materials on the effective management of the subsoil fund for the executive authorities in the constituent entities of Russia, and will also allow subsoil users, other potential investors and consumers of geological information to have access to data for their subsequent processing and developing cartographic and geoinformation systems.

2. Theoretical part
During the previous stages of computerizing the geological industry, the following tasks have been solved:

- the structure of the State Bank of Digital Geological Information (SBDGI) has been formed;
- maintenance of SBDGI has been ensured on a unified software, technical, information technology and legal basis;
- applied information technologies and systems have been developed and are used in practice, including an automated system for licensing the subsoil use and state geological control, information systems for modelling fields, presenting information on the Internet;
- work has begun on forming digital atlases of natural resources for various regions of Russia;
- communication resources of the SBDGI provide information services to the heads and employees of the central office of the Ministry of Natural Resources of Russia, its territorial bodies and subordinate organizations working with primary and interpreted geological information.

SBDGI currently functions as an integrated distributed storage system for digital cartographic information of geological content, based on the digital models of maps of various scales and associated with them factual information on the territory of Russia. Alongside with SBDGI, the Unified Information System for Subsoil Use (UISSU) operates, the task of which is to organize effective information interaction between geological and mining organizations.

It should be noted that the SBDGI and UISSU projects have not been completed in full due to financial and organizational reasons. Therefore, forming digital geological and economic maps as elements of these large federal projects would make it possible to fully realize the potential subsoil users and investors’ necessity for up-to-date geological and economic information coming in real time from executive authorities in the constituent entities of Russia and operating enterprises-subsoil users who are responsible for forming and filling the structures. Considering the significant number of participants in the subsoil use process, it should be stated that the control system for this process is inherently active, since each enterprise in the structure may have its own particular tasks, and each element in the system is free to choose its state. The generalized model of a geological exploration management system is shown in Figure 1.
The following elements are distinguished as part of the geological exploration management system model: II is influencing impact; CD is control device represented by the decision support system “Geological exploration of subsoil and reproduction of mineral resources” (DSS “GES and RMR”); ED is executive device; CO is control object; CD 1 is control device 1, CD 2 is control device 2, MD is measuring device.

The control problem in this case is the synthesis problem, i.e. determining the algorithm of the functional structure of the control system that meets the requirements of quality and accuracy. From the viewpoint of determining the system type, it can be attributed to adaptive systems in connection with the possibility of changing the managing impact under the influence of environmental factors controlled by a measuring device.

The problem of optimal control in this case is expressed by selecting the matrix of control action $U$ to achieve the possibility of transition of the control object to a new state, considering the achievement of the target indicators of the Strategy for the geological industry development until 2030 and subordinate programmes.

3. Practical part

With regard to the territory of the Republic of Sakha (Yakutia), creating a geological and economic map has certain features associated with the specifics of studying the region's territory. The database of the territory knowledge of the Republic consists of several tables, one of which is the main one and contains the necessary data on various geological and economic indicators, and the rest tables are mostly used for reference. The structure of the main table is shown in table 1.

Based on analytical and statistical data, nine block maps have been prepared on the conjuncture of certain types of mineral raw materials (iron ores, oil, natural gas, antimony, tungsten, coal, tin, zinc and lead). Block maps present summarized information in the form of inset maps, diagrams, graphs and charts showing the main indicators of the mineral markets. In terms of general content, the cartographic material is divided into the informative blocks: in general for the Russian Federation and the Republic of Sakha (Yakutia). The block “The Russian Federation” contains schemes of export-import supplies of mineral raw materials and marketable products indicating the world largest importers and exporters.
Table 1. The structure of the main database table of the geological and economic map of the Republic of Sakha (Yakutia).

| Field name                          | Comments                                                                                          |
|------------------------------------|---------------------------------------------------------------------------------------------------|
| Index                              | Key field that specifies the uniqueness of records in the database                                  |
| Name of raw material               | Name of mineral                                                                                    |
| Administrative ulus (settlement)   | The name of the ulus on the territory of Sakha Republic (Yakutia)                                  |
| Geological and economic region     | Name of the geological and economic region                                                          |
| Geological-industrial type of ores | Geological-industrial type of the selected mineral. When filling in the table, it is selected automatically depending on the selected name of the mineral. The value is taken from the lookup table. |
| Group                              | The group to which the selected mineral belongs. When filling in the table, it is selected automatically depending on the selected name of the mineral. The value is taken from the lookup table. |
| Subgroup                           | The subgroup to which the selected mineral belongs. When filling in the table, it is selected automatically depending on the selected name of the mineral. The value is taken from the lookup table. |
| Unit of measurement                | The unit of measurement for this selected mineral. When filling in the table, it is selected automatically depending on the selected name of the mineral. The value is taken from the lookup table. Some types of minerals can have several different units of measurement. |
| Year                               | The year for which information is provided on a specific indicator                                   |
| Location                           | This field corresponds to the region for which this or that indicator is given                       |
| Stock type of raw materials        | This field defines the type of stock (ABC1 or C2)                                                   |
| Value of reserves                  | Value of mineral reserves                                                                           |
| Extraction volume                  | Mineral extraction volume                                                                           |
| Nomenclature                       | Nomenclature of output                                                                             |
| Production volume                  | Mineral production volume                                                                           |
| Imports volume                     | Mineral imports volume                                                                              |
| Exports volume                     | Mineral exports volume                                                                              |
| Demand volume                      | Mineral demand volume                                                                               |
| Supply volume                      | Mineral supply volume                                                                               |
| Consumption volume                 | Mineral consumption volume                                                                          |

The following information is provided in tabular and graphical form:
- reserves and forecast resources of minerals;
- volumes of extraction and production of mineral raw materials;
- volumes of import and export of mineral raw materials;
- prices for raw materials and commercial products.

The block “The Republic of Sakha (Yakutia)” contains reference data on mineral reserves; volumes of extraction and production of mineral raw materials; information about the largest and most promising mineral deposits.

4. Conclusion
Thus, the goal of this work, which is to study the process of assessing the mineral resource potential of the territory, to decompose the results of the geological and economic assessment into an electronic map within the framework of the geographic information system and to develop the management decisions on its basis, is achieved. It is fulfilled by developing a model of a geological exploration management system and forming on its basis a database having an interface containing the geological knowledge of the territory of Sakha Republic (Yakutia).

5. References
[1] Ahmet V Kh 2014 *Exploration and Conservation of Subsoil* 7 59-64
[2] Ahmet V Kh 2011 *Exploration and protection of mineral resources* 11 49-54
[3] Roy L V, Tretyak V P 2009 *Analysis of the industrial markets* (M.: INFA) p 442
[4] Dadykin V S 2013 Mineral resources of Russia. Economy and management 4 68-71
[5] Dadykin V S 2013 Bulletin of Moscow state regional University. Series: Economics 1 18-23
[6] Dadykina O V 2015 Bulletin of Belgorod University of cooperation, Economics and law 3(55) 291-298
[7] Dadykina O V 2016 Application of geographic information systems in geological-economic monitoring Mineral resources of Russia. Economy and management 1-2 pp 64-67
[8] Kazakov O D 2007 Quality. Innovation. Education 7(26) 64-67
[9] Kulagina N A 2013 The news of the Orenburg state agrarian University 2(40) 189-192
[10] Panasyugina E V 2016 Innovation and industrial development potential of the regional economy 1 352-355
[11] Geraschenkova T M 2014 Scientific notes of Petrozavodsk State University 1(138) 94-99
[12] Gorbachev B F, Chuprina N S 1998 Mineral raw materials Kaolinum Reference book (M.: Geoinformmark)
[13] Ryazanov M A 2011 Issues of innovative economics 9(9) 3-12
[14] Tyapushova E V 2012 Herald of BFU name of I.Kant 3 119-124
[15] Merkumov J S 2002 The organization and financing of investments (INFRA-M, Moscow, 2002)
[16] Novikov V 1992 The Economist 8 46-52
[17] Leybert T B 2008 Economics 9(46)
[18] Geraschenkova T M 2017 Approaches to the evaluation of the effectiveness of innovative development of the machine-building enterprise strategy SHS Web of Conferences 35 01119 ICIE-2017
[19] Bryantseva I V 2003 The economic stability of the enterprise: essence, evaluation, management Publishing house KHGTU (Khabarovsk)
[20] Gilyarovskaya L T, Lysenko D V, Endovitsky D 2008 Comprehensive economic analysis of economic activity (Prospect, Moscow)
[21] Lazhentsev V N 2013 Proceedings of Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences (RAS) 13 107-113