Tools for ranking objects of the mineral resource complex based on ontology

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Abstract. Mineral resources form the basis for the development of the vast majority of industries. At the same time, most of them are non-renewable. To determine promising exploration activities in conditions of limited human, financial, and sometimes technical resources, it is necessary to take into account a large number of factors when setting exploration tasks for the reproduction of mineral resources. To solve problems with relatively weak formalization, it is customary to use the mathematical apparatus of fuzzy logic in decision support systems. However, it must be based on an ontological model that will contain the interrelationships of the elements of the system and allow you to find implicit relationships between them. In this paper, based on the mathematical apparatus of fuzzy logic and the Mamdani method, it is proposed to form an ontology of geological and economic monitoring in relation to a mineral resource facility (MRF), an industrial raw materials hub (IRMH) and an administrative entity. As a result, using the Reasoner component built into Protege, indicators of geological and economic monitoring, taxonomic units and the frequency of information collection for designing a decision support system in the geological industry were determined. It is possible to create such a convergence, taking into account the heterogeneity of data storage systems, on the basis of an ontological model. The advantage of using ontology is the high level of this tool flexibility, taking the form of heterogeneous data integration within a single storage system. This article attempts to use ontological models framework together with artificial intelligence for the geological subject area in terms of solid minerals, particularly common ones, and ground waters.

1 Introduction

The object of the study, the system of subsurface management in terms of solid mineral deposits, including the most widespread ones, seems to be very specific primarily due to the fact that exploration has the occurrence in stages and the probabilistic nature of its results. In order to identify minerals on the territory, a large number of studies are required, the result of which is very difficult to predict in advance. At the same time, after conducted

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survey of a sufficiently large area, the share of inferred resources, valuable for further research, is very small. [1].

Then, in the process of geological- economic analysis, this small part of the resources attractive for further exploration and development is reduced due to the availability of more profitable sites. The concept of ranking subsurface resources by prospects is introduced, taking into account the current level of development of the material and technical base for solving problems of subsurface management, assessing infrastructure security, human resources potential of a future mining enterprise, etc. [2]

As a result, the volume of information concerning mineral resources increases significantly, and a unified system that could process some big data obtained after exploration has not been still developed. At the same time, research in the field of artificial intelligence systems in geology is very common, but they mainly concern oil and gas sector [3].

Nevertheless, such studies for solid minerals have not been conducted in practice, and especially for most popular ones [4, 5]. Perhaps because of their relatively low investment attractiveness. However, this object of research is of undoubted scientific and practical interest due to the large number of factors that are indispensable in the system for conducting a comprehensive analysis.

2 Theoretical

The ontology of geological and economic monitoring should be based on the use of the Mamdani method [6-10]. The application of the Mamdani method is based on the theory of fuzzy sets. The membership function in this case is represented as follows M : {A, (B, C)}.

Where is a geological object characterized by the matrix [Aij], where i is a geological object (mineral resource object) or a group of adjacent mineral resource objects included in the model, its name (number); j – characteristics of the object i – mineral, type of study (stage of work), geological and industrial type, volume of ore reserves and useful component(s) of categories A+B+C1; C is a mining facility characterized by the matrix [Bi,j], where i is the mining enterprise included in the model, company, number; j is the parameters of the mining facility. C is a mining and processing facility (processing plant – OF) described by the matrix [Cij], where: i is the OF included in the model, name is the number, company; j is the parameters of the object [11-12].

The following elements should be included in the ontological model of monitoring of subsurface management:

- Mineral resources supply (mineral resource facility - MRF) – (indicated in Model 1).
- Geological enterprises (industrial and raw materials hub - IRMH) – (indicated in Model 2).
- The potential of the subsurface resource – (indicated in model 3).

Each of the above-mentioned elements, in turn, consists of components. Thus, the block "Mineral resource supply" (MRS) contains the following blocks:

- Indicators of the state of mineral resources supply (indicated in the 1_1 model).
- MRS groups according to the level of knowledge and profitability (indicated in the 1_2 model).
- MRS movement indicators (indicated in model 1_1_3 (Figure 1).

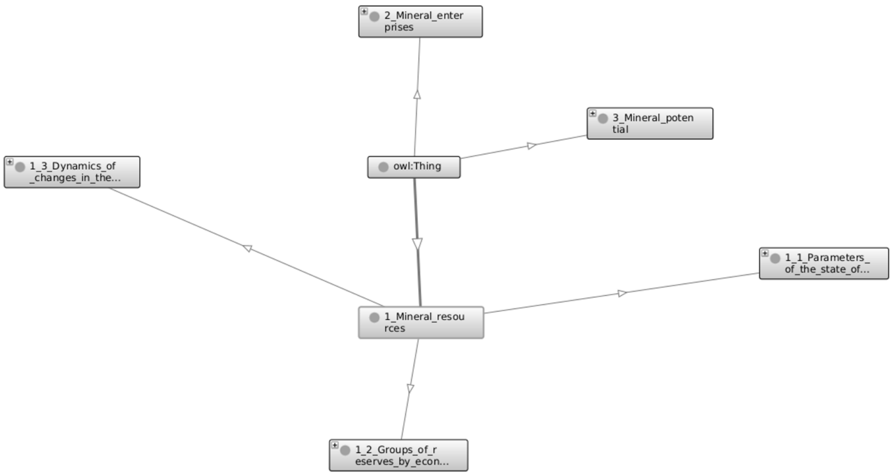

Fig. 1. Decomposition of an ontological graph according to a block "Mineral resource supply" (MRS).

In turn, each of the blocks includes a number of other parameters defining it [12-17]. For the block "Indicators of the state of mineral resources supplies" (Figure 2):

- The name of MRS (indicated in the model 1_1_1);_1_1).
- The total volume of MRS (indicated in the model 1_1_2).
- The volume of MRS of the distributed reserves (indicated in the 1_1_3 model).
- The volume of MRS of the undistributed reserves (indicated in the 1_1_4 model).
- The share of MRS of the distributed reserves (indicated in the 1_1_5 model).

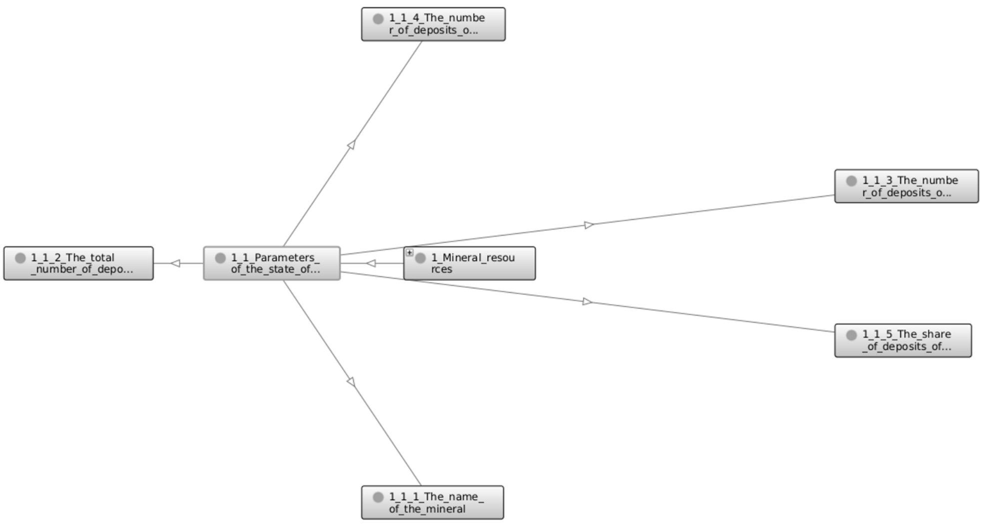

Fig. 2. Decomposition of the ontological graph according to the block "Indicators of the state of mineral resources supplies".

- MRS groups according to investment attractiveness (1_2_1).(1_2_1).
- Total reserves MRS (1_2_2).
- The volume of MRS for industrial categories in the State Register of Reserves (1_2_3_).

- The volume of MRS for category C2 in the State Register of Reserves (1_2_4_).
- The share of MRS for industrial categories in total reserves (1_2_5_).
- The volume of non-commercial reserves MRS (1_2_6).
- The volume of MRS for industrial categories in the distributed subsoil riches (1_2_7).
- The volume of MRS for category C2 in the distributed subsoil riches (1_2_8).
- The volume of the most widespread MRS in the distributed subsoil riches (1_2_9)

As part of the ontological model, along with model classes, objects are also represented (used as a system term Individuals). Objects are instances of the class they belong to (Figure 3).

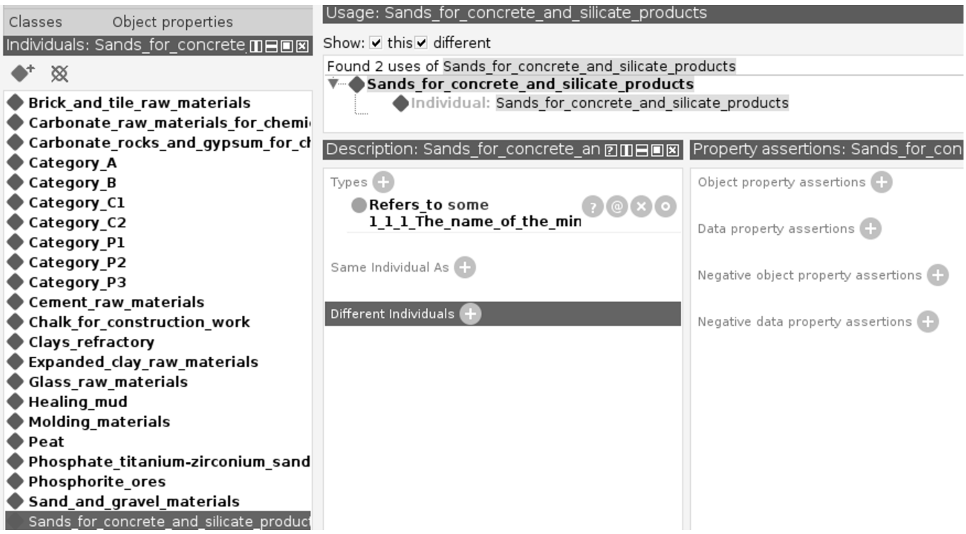

Fig. 3. Composition of objects for indicator 1_1_1.

Thus, within the framework of the ontological model, a description of the basic entities and their child (subordinate) instances is accomplished.

3 Practical

As a result, we have identified groups of indicators for which it is most appropriate to monitor geological and economic parameters with a given frequency. At the same time, the frequency of data collection and the taxonomic unit for which data collection should be carried out in a priority order are determined (Table 1).

The resulting ontological model with the structure and interrelations of indicators proposed by the authors makes it possible to search for dependencies in geological and economic data. In fact, it becomes possible to detect the cause-effect relation and indicators interconnections.

With the help of the automatic dependency explorer in the Protege - Reasoner program, it becomes possible to determine indicators interconnections. For example, there are ontological dependencies for the indicator of raw materials territory potential, that can affect its value.

Taking into account the loading of data on the mineral resources valuation base into the ontological model, the geological-economic map of the Bryansk region was coordinated according to the forecasted mineral resource potential of the territory.

Table 1. Composition of the group of monitoring indicators with the frequency of collection and monitoring.

No	The name of the indicator	The method of determination	Taxonomic unit
1	Repayment of mineral reserves for the initial year of forecasting, units.	Calculated	MRF, IRMH
2	Repayment of mineral reserves for the t-th year of forecasting, units.	Calculated	MRF, IRMH
3	Repayment of mineral reserves cat. A+B+C 1 for the forecast period, units.	Calculated	MRF, IRMH, the subject
4	Residual mineral reserves of cat. A+B+C1 at the forecast dates, units.	Calculated	MRF, IRMH
5	Availability of proven reserves for the initial year of forecasting, years	Calculated	MRF, IRMH
6	Availability of residual proven reserves at the forecast date, years	Calculated	MRF, IRMH
7	Recommended availability of proven reserves at the forecast date, years	Accepted	MRF, IRMH

In relation to the subject of the study, there are other approaches to building causal relationships between elements resulting in the output of real geological and economic data set. An example of such approach is the use of neural network programming [5-8].

4 Conclusions

The ontological approach consists in the development of a thesaurus of the subject area, the structure and composition of the knowledge base used in the process of geological and economic assessment of the results of exploration. The relevance of this approach lies not only in the content of the thesaurus and the knowledge base, but also in the search for patterns and rules that implicitly define the functional subsystem of the object of study in the process of modeling the structure and relationships in the ontological model. The latter in this case is a complex of geological exploration works aimed at prospecting, exploration and assessment of the state of the subsoil.

Thus, the authors considered the methodological aspects of assessing the prospects of subsurface areas through ontological engineering of geological exploration, taking into account their characteristics, based on the use of a knowledge base containing a thesaurus of geological and economic indicators for the stages of the exploration process. The links between geological and economic indicators as part of the thesaurus of the subject area are determined in order to build an ontological model that allows for subsequent analysis. The actual assessment of indicators within the framework of the thesaurus for evaluating the results of geological exploration allows us to characterize the condition of the research object and proceed to the assessment of the volume of mineral extraction in accordance with the requirements of a separate territory, region, state (taking into account the volume of exports and imports) of mineral raw materials.

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