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INFORMATION TECHNOLOGIES IN GEOLOGY

Abstract

The problems facing to geology give the soil for development of new methods for the analysis of geological information, which are able to promote the revelation of regularity describing the knowledge of researched objects. This is the direction for development of mathematical geology.

The mathematical geology is the reliable base to fruitful development of information technologies in geology. What information technologies are most widely used in geological researches? Among them it would be desirable to outline:

1. Application software;
2. Systems of automation of routine operations (chores);
3. Database management systems;
4. Network and internet technologies;
5. Systems of information safety;
6. Geoinformation systems (GIS-systems), 3D-modelling;
7. Systems for knowledge extraction (Data mining);
8. The systems, based on knowledge (Expert systems).

The feature of the present stage of development of information technologies is transition from the systems operating with data for the purpose of knowledge receiving, to the systems, using knowledge for solution of geological problems.

It is well-known, that the modern development of sciences has characterized by their mathematization - penetration of mathematical methods and mathematical style of thinking into them. The term «*the mathematical geology*» means the usage in geology of methods not only probability theories, but also many other mathematical sciences - geometry, algebra, the theory of sets, topology, etc. [Sharapov, 1995].

The geological problems give the soil for development of new methods for the analysis of the geological information, which promoting to the revealing of legitimacies for describing of knowledge about researched objects. This is the main direction for development of mathematical geology.

The mathematical geology is the reliable base for fruitful development of information technologies in geology.

The information technology is understood as a collection of methods, industrial and program-technological resources, united in a technological chain and providing collection, storage, processing, output and distribution of information.

Information technologies deal with usage of computers and the software for storage, conversion, protection, processing, transmission and reception of information. They are intended for reducing the laboriousness of usage processes of informational resources, rise of their reliability and efficiency. The art of information technologies consists of the current activity monitoring, They permit to perform different operations in time, to achieve result in a short period, to see an overall picture and to think of the strategy, changes of the researched object, new tendencies and the phenomena.

Among the information technologies, used in geological researches, it is possible to select a part which has promoted further progress of geological researches (fig.1). The most important ones are:

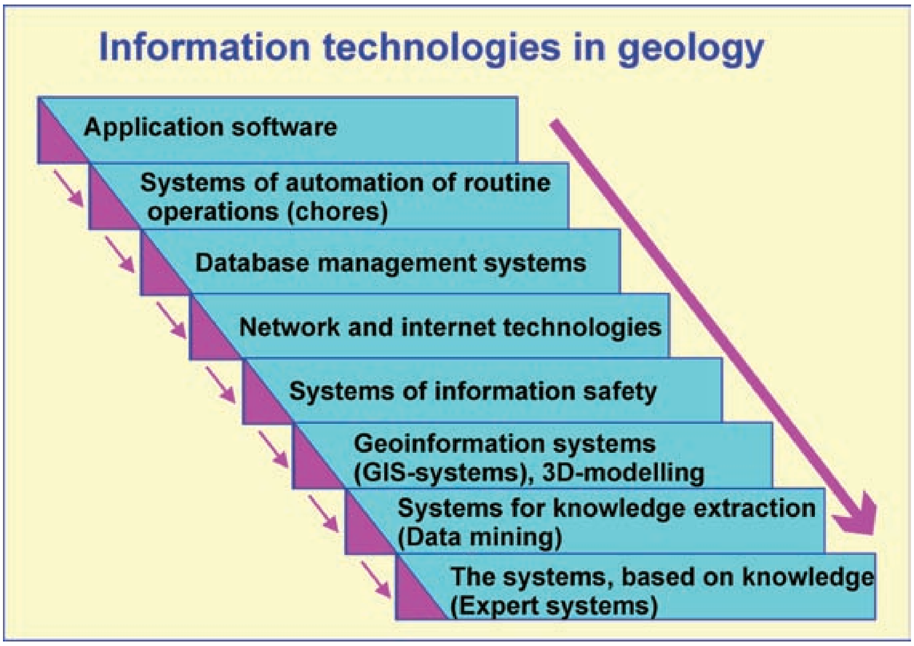


Fig. 1. The modern stages of development of information technologies in geology

1. Application software;
2. Systems of automation of routine operations (chores);
3. Database management systems;
4. Network and internet technologies;
5. Systems of information safety;
6. Geoinformation systems (GIS-systems), 3D-modelling;
7. Systems for knowledge extraction (Data mining);
8. The systems, based on knowledge (Expert systems).

The first steps have been linked to designing *of application software* - that has demanded from users of representation of the input information in a digital form. So the possibility of usage of complex algorithms for data processing and receiving of exact results has appeared.

Further the *systems of automation of routine operations* have spread wide, because the computers became accessible while carrying out the researches. As the result of using of software for text and graphics editors, text recognition, scanning of initial materials it became possible to image all information in electronic form. The specialized automated systems have solved the concrete geological problems. For example, the Automated control system of mining production, used in conditions of Muruntau open pit for monitoring of motor transport and ore sorting [Kantsel, Chervonenkic, 1990; Kantsel, et al., 1997]; System of automation of mining on the base of software MineScape **(**integrated 3-measured CAD system designed for geological models of coal and ore deposits, for planning and designing of the open and underground mining) [Bogdanov, 2005].

As geological researches are accompanied by great volume of actual material which needs the study, the following step in usage of information technologies has been made towards the development of databases and control systems of them. It has demanded considerable operations for structurization and standardization of input data [Gvishiani, 1995; Arsky, et al., 1998, 2007; Chesalov, 2005; Chesalov, et al., 2006; Laverov, et al., 2008]. The unification of description systems has allowed to spend further the comparison of researched objects.

The following step has been made to application of *network and internet technologies*, which have provided the possibility to access to various publications, operative data exchange between computers, realization of video conferences [Lavrik, Kaluzhnaya, 2000; Ryabinkov, 2006; Shogin, 2008].

For support of safety of digital data and confidentiality of their usage *the systems of information safety* were required. For example, the anti-virus programs, protected networks Secure Networks, system of detection of intrusions Dragon, the network scanner of safety “XSpider” designed by “Positive Technologies”, the network scanner of safety “Internet Scanner” designed by “Internet Security Systems”.

The Implantation of technologies for creation of *geoinformation systems*, has allowed to receive layer-by-layer and subject electronic maps. Such systems store in database the description of objects (view points) with a co-ordinate binding. Therefore by compilation of maps it became possible to make the analysis of space allocation of geological objects and to study allocation of space variability of samples. Now geological maps are made in the process of geological mapping. The important unit of modern mapping is a wide usage of toolkit based on geoinformation technologies and space images. Geological maps are the main source of the information for solution of problems of development of mineral-raw-material base and ecology. They form a basis at designing of retrieval and prospecting operations, carrying out of engineering-geological researches and other aspects of economic activities and regulation of using by bowels. The map compilation is not the final result of geoinformation system (GIS) operations. It is not a static unit. Further stages of GIS-operation consist in monitoring and operative change of information, and also in statistical processing, the analysis and possibility of forecasting of geographically linked information [Rundkvist, et al., 1996; Naumova, 2004; Cheremisina, Nikitin, 2006; Cheremisina, Sukhanov, 2008].

The use of *systems of extraction of knowledge (Data mining)* became the cardinal jump. They aimed to search the regularities in a huge set of fact data. Translation of the geological data into digital form becomes the integral and obligatory part of introduction of computer technologies, and the problems of the analysis of available data appear on the foreground. Term “Data Mining” designates not only concrete technology, but also the process of search of correlations, tendencies, interrelations and regularities by means of various mathematical and statistical algorithms: classification, regression and correlation analyses, neural networks, methods of fuzzy logic, pattern recognition. The algorithms of “Data Mining” are the basis for creation of models. These methods have allowed to make transition from the data (set of data) to knowledge (to regularities, significant for the user - geologist). Many researchers developed the special methods for the decision of geological problems [Kuklin, 1967; Vasil’ev, Dmitriev, 1972; Dmitriev, Krasavchikov, 1977; Lbov 1981; Voronin, 1983; Bekzhanov et al., 1987; Gvizhiani, Gyrvich, 1992; Voronin et al., 1996; Agayan et al., 2005; Tyapkin et al., 2006; Gvizhiani et al., 2008; Kulik, 2007; Materon, 1968 et al.].

The next step of application of information technology was linked with development of *systems, based on knowledge* - *expert systems.*

The system, based on knowledge - artificial intelligence system, is one, in which subject knowledge is presented in an explicit form and separated from other knowledge of system.

The geological information accumulated now is not used in a rational way. In overwhelming size it is intended for expert informing and only insignificant part of it is used for the purpose of receiving for forecasting and controlling solutions. Now there is the time of transition from the systems operating with data for the purpose of knowledge acquisition, to the systems, which use knowledge for solution of geological problems. The necessity of creation of ideology and methodology of development of expert systems (ES) of the modern level has ripened, for which the main purposes are in the procedures of the analysis of geological situations and the rise of efficiency of decision-making by users in the conditions of uncertainty.

Therefore now the expert systems are intensively developed and find practical application for solution of applied problems in the field of geology. The expert system is the computer program that can offer intelligent advice or make intelligent decisions using rule-based programs. The expert system is understood as a computer program using knowledge and the logic of expert reasoning for the purpose of framing of guidelines or making decision of considered problems. ES promote to receive the proved estimation of perspective areas and overestimation of deposits, discovered before, which are usually spent while the registration of gain of reserves.

The usage of ES is very convenient for the geologist. The user works with the system in dialog mode and, if necessary, can receive the needed explanations about the inference course.

In this direction the most effective are the *hybrid expert systems,* for which the knowledge base includes not only knowledge of experts, but also the regularities received as a result of the analysis of available databases.

For the first time the concept of hybrid expert systems has been entered by G.S.Pospelov in 1977 [www.ccas.ru]. Hybrid expert systems allow to use advantages of traditional resources and artificial intelligence methods, more effectively to connect formalizable and non-formalizable knowledge at the expense of integration of traditional artificial intelligence techniques.

The usage of knowledge of the qualified experts allows their transfer among the less qualified experts, providing the receiving of the proved solutions recommended by the expert system. The sequence of stages of process of decision-making can be observed during the analysis of operation of the decision block of system.

The forecasting problem was the first among the geological problems for which solution the expert system technology was used. In this case the basis of predicting systems are multifactor models of ore objects, in that sort as how they are represented by geologists. According to the principle of consecutive detailing as the main prognostic-metallogenic taxons of the researched objects there are considered: *metallogenic zone, ore area, ore cluster, ore field and deposit*.

The expert system allows on the basis of usage of various methods and techniques to solve a number of various tasks in the course of implementation of the common technological circuit at solution of forecasting problem. For the primary purpose of the forecast and estimation of ore deposits there are selected: *the definition of ore-formation type of deposits and an estimation of their scale*. The rules for carrying out the forecasting estimation of perspective areas are formulated by the expert-geologist or settle up on standard database objects. The second way raises the objectivity of result.

The geological information for characterizing researched objects is located in knowledge base of ES. ES imitates the process of acceptance of forecasting solutions by the expert-geologist, giving the needed explanations during the solution.

The technique of knowledge base acquisition from experts consists of the following procedures:

- gathering of the initial information, on the basis of the data of the diagnostic methods which have received a positive estimation of the expert while the result of practical activities;
- usage of experience and knowledge of experts for joint development and creation of situational model, and also the definition of the rules of research;
- joint estimation of the received results of research and expediency of development and usage of the system for making decisions.

The approach to construction of system on the basis of knowledge base acquisition from experts contains of such stages as *identification, conceptualization, formalization, realization, and testing.* Individuality of the approach consists in principles which are realized on each of the listed stages.

At the stage of *identification* for development of situational model problems the problems for decision are determined. The purposes consist in determination of the system of making decision for the analysis and estimation of situations in the researched problem. Computing resources and commissions of competent experts on solved problem have defined.

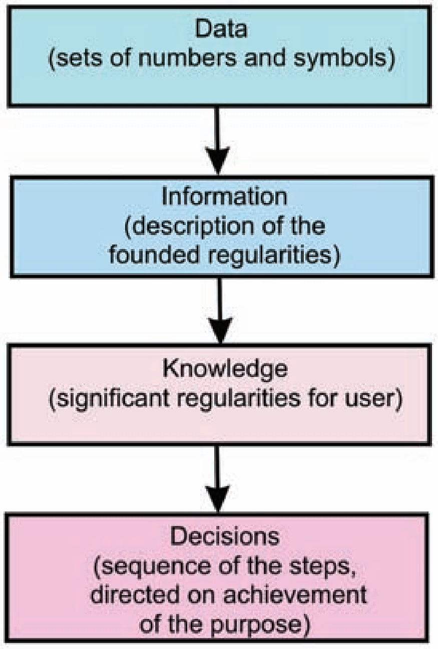
At a stage of *conceptualization* the analysis of problem area with participation of experts is made, the situational model is created; the method of the problem decision is defined, the structure of databases for storage of the available information is designed.

At a stage of *formalization* the model of the analysis and estimation of situations, database and algorithms for providing of needed calculations are created.

At a stage of *realization* the program environment for application development is determined. There is the transformation of formal knowledge into the working program under the analysis and estimation of situations, and also during the work with used structures of the data. The filling of knowledge base of system is carried out.

At a stage of *testing* together with expert the check of work of the created variant of system on specific targets will be carried out. During testing the probable sources of mistakes are analyzed.

Fig. 2. The circuit of process of transformation "data – information – knowledge - decision" (on Popov etc., 1996], with additions)



During gathering data intended for decision there is a process of their trans-formation to the knowledge needed for receiving result (fig. 2). The success in the problem decision put before expert system entirely depends on quality of knowledge base.

The direction on creation of expert systems in geology develops rather for a long time. Among ES, successfully used in geology, it is necessary to note ES for the decision of forecasting problems:

1. PROSPECTOR - for estimation of prospects of the search for various types of minerals [Duda et al., 1979];
2. DRILLING ADVISOR - at borehole drilling for geological prospecting [Hollander, Iwasaki, 1983].
3. GENESIS - for automation of technology of construction and use of prospecting-search complexes [Bugaets et al., 1986; Vostroknutov, 1999, 2006];
4. SERGE - for classification of geochemical anomalies by searches of firm minerals [Bonnefoy et al., 1989];
5. GEO - for the regional forecasting of lead-zinc deposits of Bulgaria [Gitis et al., 1989];
6. OLOVO - for an estimation of tin deposits [Rodionov, Cyrkin, 1995];
7. Expert system for statistical forecasting of average and large deposits [Zhao et al., 1996].
8. Forecasting block of system GIS-INTEGRO [Cheremisina, Finkelshtein, 1999];
9. Expert system for an estimation of scales tungsten ore deposit [Mitrofanov et al., 2009].

All expert systems, mentioned above, based on the knowledge base constructed by acquisition from the expert and their further structuralization. For acceptance of decisions there were used production rules (type if - then), formulated by expert. During the creation of the automated forecasting-search complexes for the first time in 1991 the author [Chizhova, 1991] offered to use databases for formulation of solving rules and the technology of construction of the hybrid expert systems. Such systems used the complex knowledge base, including not only knowledge of experts, but also the regularities, received as a result of the analysis of available databases on researched geological objects. And only since 1996 the question on using of calculated solving rules began to be discussed actively in the literature.

The process of extraction of knowledge is meant as the following procedure: acquisition from expert and database; the organization (structurization) of knowledge; representation of knowledge in form, clear to expert system. According to [Popov et al., 1996] the extraction of knowledge from database is meant as the following transformation: transition from the data (sets of numbers and symbols) to the information (description of the founded regularities), to knowledge (significant regularities for user), to decisions (sequence of the steps directed on achievement of the purpose) (fig. 2).

The *knowledge base* is understood as the organized set of knowledge submitted in the form which supposes their automated use in expert system. The base knowledge includes the set of the facts specific to solved problem, the purposes and procedures (deciding rules), needed to expert system for the decision of the problem. Hybrid expert systems are the systems which can use different methods of representation and processing of knowledge, and also means of data processing, including optimization algorithms and concepts of databases.

Hybrid expert systems in the best way corresponds to the decision of forecasting geological problems because they enable to use the knowledge of the qualified experts - geologists and the objective regularities received as the result of the mathematical analysis of available actual geological material on research objects at various hierarchical levels.

Hybrid expert systems for forecasting and estimation of ore deposits can be considered as the recognizing systems. So their construction can be carried out on the base of methodology of the theory of pattern recognition. According to [Tou, Gonzales, 1978] in the given theory the main principles for construction of recognizing systems are the principle of generality of properties and a principle of enumeration of objects. On the base of these principles the author has developed two technologies: ASTRA and ANALOG [Chizhova, 2010]). The features of construction of knowledge base by using these approaches are shown on fig. 3. The procedures of construction of knowledge base are designed for each approach. The distinctions of its elements consist in a choice of the ways of the description of research objects and their types, the form of calculating functions and solving rules (fig. 3).

The principle of generality of properties based on the assumption, that the objects forming one class have property of the similarity reflected in their characteristics. So in this case (ASTRA) it is necessary to allocate systems of the informative attributes describing group of objects as a whole (identifying attributes) and each type separately (dividing attributes), and on their basis to construct solving rule for reference the object under study to one of the allocated types of objects.

In the second case (ANALOG) some measure of similarity is used for definition of affinity degree of the object under study to one of standards. Thus there is possible the choice of the nearest analogue to the object under study from the reference objects contained in a database on any set of attributes. It enables the user to check various hypotheses and to compare an overall performance of the chosen criteria.

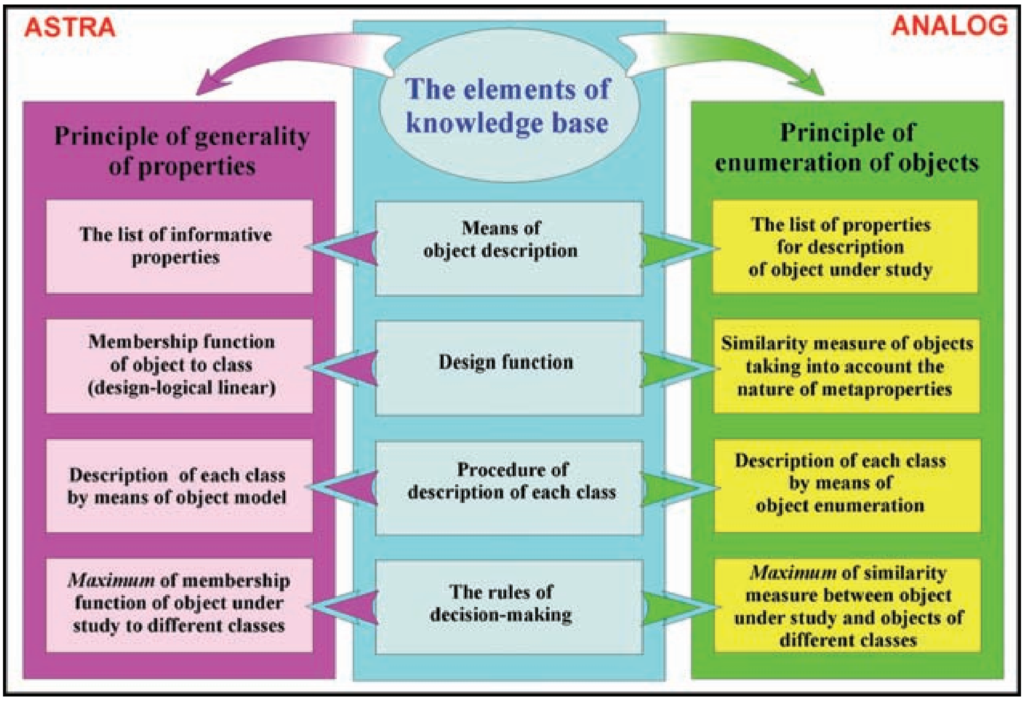


Fig. 3. The features of construction of knowledge base at the using of different approaches for its designing

Technologies are approved at designing of specialized expert system for the forecast and estimations of Epithermal Gold-Silver Deposit (Okhotsk-Chuckchee Volcanic Belt, Northeast Russia) [Struzhkov, Konstantinov, Chizhova, 1999], and for search of the nearest analogue of object among the world gold ore deposits and the solving of the forecasting metallogenic problems by the method of analogies [Chizhova, Konstantinov, Struzhkov, Pokrovsky, 2005].

Conclusion

New original decisions always were natural continuation of complex studying of the problem. Consistently analyzing development stages of information technologies in geology, it is possible to assume, that the further ways of their development, apparently, will be connected with:

1. Transition to 4D-modelling with the simple form of visualization which opens new opportunities at research of properties and conditions of natural objects.
2. Creation of the systems based on knowledge, on the most perspective hybrid technology.

It will demand complication of used mathematical methods, for maintenance of fast receiving of reliable results.

The work was supported by Russian Foundation for Basic Research (grant RFFI № 09-05-00423-a).

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