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INNOVATIVE INTELLECTUAL MANAGEMENT TECHNOLOGY OF URANIUM MINING BY THE ISL METHOD

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INTRODUCTION

In recent decades, there has been an intensive expansion of the information technology application in mining. From the tool of geometrical modeling of deposits and calculation of reserves they have turned into a tool of mining optimization and enterprise management. This is due to the multidimensionality and multivariance of the mining tasks, the need to make the right investment, design and management decisions under numerous constraints, risks and uncertainties. At present, the information technologies are applied to problems of geological and hydrogeological modeling, designing mining enterprises and their feasibility studies, production scheduling, assessment of geoecological consequences, transportation, etc. Mining companies implement complex information systems that are constantly used by engineering and technical services for monitoring mining operations, preparing reports, analyzing and optimizing of the deposit development, operational and strategic managing a mining company.

However, the use of information systems designed for traditional mining methods is difficult for the development of infiltration uranium deposits by in situ leaching (ISL) process. Since ISL process does not involve ore excavation, it is based on a useful component transfer to a solution and surfacing from production horizon by means of a technological wells system. In connection with this, Seversk Technological Institute of the NRNU "MEPhI" has developed a specialized software package for informational support of the uranium mining by the ISL method [1-6]. The coordinated work of the information systems of the software package makes it possible to implement the intellectual technology for managing the uranium deposit development by the ISL process. The intellectual technology is based on a comprehensive analysis of geological and geotechnological data at all stages of the enterprise's life cycle, multivariate geological, geotechnological, technical-economic modeling of the operating procedures, application of intelligent expert systems for decision support. The present report is devoted to the systems of the software package and its application for increasing the uranium mining efficiency by the ISL method.The use of information systems designed for traditional mining methods for the development of infiltration uranium deposits by in situ leaching (ISL) process is difficult. Since ISL process does not involve excavation of ore, it is based on a useful component transfer to a solution and surfacing from production horizon using a system of technological wells. In connection with this, the Seversky Technological Institute of the NNIU "MEPhI" has developed a specialized software package for informational support of the uranium mining by the ISL method [1-6]. The coordinated work of the information systems of the software package makes it possible to implement the intellectual technology for managing of the uranium deposit development by the ISL process. The intellectual technology is based on a comprehensive analysis of geological and geotechnological data at all stages of the enterprise's life cycle, multivariate geological, geotechnological, technical-economic modeling of the operating procedures, application of intelligent expert systems for decision support . The present report is devoted to the systems of the software package and its application for increasing of the uranium mining efficiency by the ISL method.

METHODS AND RESULTS

The software package consists of seven interconnected information systems: mining-geological, technological, geotechnological modeling, geoinformation expert-analytical, technical-economic, computer-aided design, mining planning. In addition, the software package includes a data warehouse that provides consistent storage of the information of any information system. The program code is developed in the programming language C ++ using the object-oriented approach. The operation of the software package is based on client-server technology. The interaction of client programs with the data store is performed by means of SQL queries.

Mining and geological information system (MGIS) allows to collect, process primary geological data, create two and three-dimensional geological and mathematical models of the productive horizon, to calculate uranium reserves and other geotechnological indicators of geological and operational units in various ways, and also visualize information on the production horizon condition by means of geological columns, sections, maps, etc. [2]. The entire amount of geological information received during the MGIS operation is stored in the geological data base included in the data warehouse of the software package. In addition to storage, the geological data base ensures the integrity and consistency of various information types.

The technological information system (TIS) is designed to form a model of the structure of the geotechnological enterprise mining complex (MC), to collect and handle technological data on the operation process, to coordinate data and prepare reports on the MC operation [3, 4]. The model of the MC structure includes a set of technological objects models and relations between them. TIS allows you to import geological data related to on technological wells and production units from the geological database, to create and edit the process object models, to define assign their relationships, to carry out the expert assessment of the data to identify any contradictions and logical errors, and to visualize the model in the form of plans, structured lists and tables. Collection of primary actual data on the process parameters and the condition of MC objects is performed from various sources using client programs. On the base of the MC structure model and the agreed data coordinated, the values of geotechnological indicators of the operational units are determined, and shifts, daily and monthly technical reports are formed. The initial data and the MC structure model are stored in the database of technological data, taking into account all the interrelations, which ensures their integrity and consistency.

The geotechnological modeling system (GMS) makes it possible to carry out simulation of the underground uranium ISL process and the pollutants migration within groundwater [5]. The calculations are performed on the basis of the geological and mathematical model of the productive horizon and the digital model of the mining complex imported from geological and technological data bases, correspondingly. Geotechnological simulation is based on a mathematical model of a multicomponent non-equilibrium filtration of reacting solutions. The hydrodynamic part of the model includes calculating the distribution of underground water heads, the filtration velocity, the convective mass transfer and hydrodynamic dispersion. In the physical-chemical part, homogeneous and heterogeneous processes occurring at ISL in the system of working solution - groundwater - the host rock (acid-base and redox processes, complexation, etc.) are considered.

Geoinformation expert-analytical system (GEAS) is used to optimize the operating modes of technological objects, to evaluate and analyze the efficiency of the geotechnological process. GEAS allows to visualize the entire amount of information about the MC operation, stored in the data warehouse. All MC objects are displayed on the interactive plan for the date specified by the user. For any MC object, it is possible to obtain all the information available from the data warehouse in the form of graphs, tables, maps of geological columns, sections, etc. In addition, the simulation results of the productive horizon condition, performed by the GMA, can be shown on the plan. The system has built-in tools for investigating correlations between geological, geotechnological parameters and indicators for different MC of objects. With the help of the GEAS, it is possible to analyze the hydrodynamic flows in the productive horizon and optimize them, in order to improve the quality of the productive solutions and reduce the reagents expenditures during the ISL process.

The technical-economic system (TES) includes an economic-mathematical model for calculating the economic performance of the operation units. The model describes capital costs and operating costs for the construction and development of units. On the basis of the economic-mathematical model, the uranium mining unit base cost and other economic indicators of unit development can be calculated.

The computer-aided design (CAD) system is used to design and optimize the system of uranium deposit development [6]. The initial datum for the design is the geological and mathematical model of the deposit. The design of the mining development pattern can be carried out in automatic or manual mode. In automatic mode, the pattern of holes is designed using the specially developed algorithms. Algorithms make it possible to create in-line and cellular mesh patterns adapted to the deposit morphology. The optimization of the hole patterns is carried out by searching for the extremum of objective functions by the gradient descent method. The objective functions are: time, the ratio of L/S (the ratio of the volume of working solutions to the solid lode rock mass) for a given degree of unit development, the formation exposure degree, the uranium mining unit cost, and also their combination.

The mining planning system (MPS) is used to predict the performance of existing and planned operational unit and to form the mining plans of an enterprise on the basis of the predicted data, which guarantee the planned production level of the uranium mining. The system operation is based on multifactorial statistical models of the operational units productivity. The input data for making mining plans are the geological and technological parameters of the planned operation units and geotechnological retrospective data of the operating units.

DISCUSSION AND CONCLUSIONS

The software package is applied practically at all stages of the mining enterprise life cycle. At the stage of exploration work, the geological data obtained during the core survey and geophysical studies of the wells are collected with the help of MGIS. Based on the received information, a digital model of the productive horizon is constructed, and the geotechnological parameters of the geological units are calculated. The deposit estimation and the feasibility study are carried out on the basis of the digital model of the deposit created at the previous stage. The optimal parameters of the field development system (the distances between the technological wells, the distances between the row wells, etc.) are determined by carrying out a series of geotechnological modeling using GMS. The modeling parameters are determined on the base of the results of laboratory studies, geotechnological investigation and pilot-industrial geotechnological test work at the field. With the help of the MPS, the prediction of geotechnological indicators of the operation units development is carried out (production rate, uranium content in productive solutions, specific acid consumption, etc.) based on a certain set of geological and geotechnological parameters (ore mass, metal content in the rock, well production, acid concentration in working solutions, etc.). On the basis of medium and long-term prediction, the mining plans of the enterprise, which provide planned production level, are carried out. Based on the results obtained, using the TES, the analysis and evaluation of the technical and economic performance of the enterprise are carried out, which are used to prepare the feasibility study for the enterprise construction.

Design of operational units is carried out using CAD, GMS and GEAS. Based on the geologic-mathematical model of productive horizon, an adapted well pattern is created and a unit design is formed. For the proposed draft operational units, multivariate geotechnological modeling is carried out, the cost price of uranium mining and other economic indicators for different variants of the unit development are calculated. Based on the results obtained, the best unit design is selected, which is the most appropriate for the tasks facing the enterprise.

At the stage of field development with the help of TIS, a digital MC model is created and maintained, the coordinated values of geotechnological indicators are calculated, and shift, daily and monthly reports on the enterprise work are prepared. GMS is used for epignostic and predictive geotechnological simulations to determine the current state of the productive horizon, to optimize the ISL processing of technological units, short-term development planning of the deposit development, to predict the propagation of the technological solutions within aquifer. The modeling parameters are constantly adjusted by comparing data of the MC control and the productive horizon state monitoring with the results of epignostic geotechnological simulations. Based on the results of the epignostic simulations, the unit part are identified where the ISL process is not effective enough and proposals are being prepared to change the operating modes of the technological wells. The verification of the proposals effectiveness is carried out by means of multivariate modeling. With the help of the GEAS, the analysis and assessment of the efficiency of individual operational units and the enterprise as a whole, preparation of proposals for uranium extraction intensification and reducing of the reagents consumption are carried out. The analysis of geological data for wells and sections is carried out using MGIS. The MPS is used for multifactor analysis and prediction of geotechnological indicators of unit development. The TES is used for calculating the economic performance of the MC (the cost of operational uranium mining, capital and operating costs, the cost changes dynamics with time, etc.) and the selection of the most effective operating modes for the operational units.

At the stage of the completion of the field development, the software package is used to determine the optimal procedure for decommissioning technological cells and units, to prepare activities for the additional recovery of uranium from the cranch, to forecast and assess the geoecological consequences of the ISL process, to determine the duration and depth of groundwater self-purification, and to prepare the aquifers plan recultivation.

The advantages of the developed software package are: modular architecture, scalability and the possibility of development; optimal database structure, ensuring the integrity and consistency of information; availability of mechanisms for integration with existing information systems at the enterprise; the inclusion of new modern decision support tools; compliance with information security requirements. The use of the software package for managing the field development makes it possible to create an integrated information and production environment for a mining enterprise; it also provides consolidation of information for the purposes of operational management, production accounting, planning and forecasting; increases the productivity of and technical, engineering and administrative personnel (automation of data processing and preparation of reporting documents, efficiency and availability of any information at various levels, etc.); improves the quality of management decisions (completeness, accuracy, reliability and relevance of data, automated analysis of sizable data, support for decision-making, etc.). All these contribute to the increasing of the field development efficiency and reducing the cost of mining uranium, by choosing the optimal development systems, monitoring technological regimes and optimizing the ISL process.

An important factor in the effectiveness of the software package application is the completeness of the line of software products that provide solving the tasks facing an enterprise for the entire life cycle, from exploration to the completion. Joint application of various systems of the software package gives a synergetic effect and allows us to talk about the creation of an intelligent technology for geotechnological enterprise managment based on a comprehensive analysis of geological and geotechnological data, multi-variant modeling of the geotechnological process, and the use of intelligent systems to support decision-making.

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