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THE STATE AND PROSPECTS OF HYDROGEOLOGICAL DEVELOPMENT OF HARD MINERAL DEPOSITS IN THE USSR

G. N. Kashkovsky, Z. P. Lebedyanskaya

All-Union Research Institute of Hydrogeology and Engineering Geology, I42452 Moscow region, Noginsk district, pos. Zelenyi, USSR.

ABSTRACT

The present day problems of studying the hydrogeological conditions of mineral deposits undergoing geological prospection have been formulated.

Poorly developed solutions to the problem of the prediction of the chemical composition of the mine water, rock consolidation, degassing of the subsurface brines, water seepage through clays and the impact of mine workings on the hydrogeological environment are reflected.

The necessity for a greater reliability in hydrogeological predictions at the sites of mineral deposits to be achieved through a complex use of various methods of field studies, including stationary regime observations, as well as an application of mathematical simulation is shown.

The results of methodical scientific studies and long term hydrogeological predictions for mining regions with various hydrogeological conditions (development of karst water, confined water complexes, water-bearing layers dipping at angle) are illustrated. The characteristics of the variations in the hydrogeological conditions of these regions are given.

INTRODUCTION

The hydrogeology of hard mineral deposits represents a separate systematic and applied branch of the science of hydrogeology in the USSR.

Studying the hydrogeological conditions of hard mineral deposits, beginning with the prospecting stage, is extremely important. The aims of hydrogeological studies during the geological prospecting of deposits have been considerably widened and complicated. This is accounted for by the nature of the procedures which should be applied with the development of deposits in new regions and at greater depths, as well as by the increased requirements on the control and rational use of the environment (bowels, water resources, etc.).

AIMS OF HYDROGEOLOGICAL STUDIES

The present day aims of studying the hydrogeological conditions of deposits undergoing geological prospecting can be formulated in the following way :

(a) assessment of the hydrogeological conditions of the development of the deposits;

(b) determination of the predicted water inflows into the systems of mine workings;

(c) hydrogeological substantiation of the measures providing for the protection of the mine from ground-water inflows;

(d) prediction of the possible development of cones of depression (piezometric) of ground-water and fundamental variations in the hydrogeological conditions, considering an interaction between the water withdrawal from mines and large water intakes;

(e) estimation of the chemical composition of mine drainage;

(f) hydrogeological substantiation of the measures providing for the protection of water resources and rational use of water during dewatering of deposits.

PROBLEMS OF MINE WATER STUDY

Hydrochemistry of Mine Water

The problem of the prediction of the chemical composition of mine water is complicated and poorly developed. Special experimental studies at a series of deposits should be carried out under typical conditions in order to develop a reliable method of prediction. This is particularly applicable to physical-chemical processes, occurring at several complex mineral deposits which are in the process of an intensive dewatering and mining development. In such situations, complex hydrochemical and hydrodynamic studies will be required.

Dewatering and Subsidence

It is known, that a deep water drawdown is followed by considerable rock subsidence and ground surface deformation. The procedure for prediction of these phenomena and calculation of the deformations is being developed, but the studies are at the initial stage. An extension of these investigations will be necessary in the near future.

Ground Water Problems during Deep Level Prospecting

Geological prospecting of mineral deposits at deep levels is associated with a series of new problems, including the necessity of studying highly mineralised water and brines which can be characterised by an increase in temperature and a content of dissolved gases. The processes of gas emanation under the conditions of intensive water drawdown have not been seriously studied.

Ground Water Problem of Clays and Superficial Deposits

The study of the regularity of water seepage in clays becomes extremely urgent when considering that a significant water drawdown regionally affects the ground-water regime, and that the prediction of a disturbed regime of ground-water involves the study of aquifer interaction. Based on the results of the studies performed in the regions of the deposits of Kursk Magnetic Anomaly and at other sites (V. M. Goldberg, B. V. Borevsky), one can suggest that the clays of the old deposits are fractured, thus affecting the process of water seepage. An initial seepage gradient in these clays is not so important as the one in highly elastic clays of the recent superficial deposits.

In studying the seepage of water, mineralisation and temperature are very important, as this type of filtration differs considerably from that of cold (fresh) water. These studies should be extended.

The studies of clay consolidation and the elastic release of water from clays due to the effects of a deep drainage require further studies. The contribution of the water released from clays to the ground-water recharge under these conditions is measurable, this contribution must affect the chemical composition of the sampled water.

PREDICTION OF GROUND WATER INFLOW

Improving the reliability of hydrogeological predictions is one of the most serious problems. Previously, the total water inflows were predicted with somewhat overestimation of the design parameters. One must not confine to this method, as the use of overestimated water inflows is inadmissible when assessing the possibility of use of drainage water for water supply and purification of mine water during the process of pumping water to the ground surface. Often a reliable prediction of formation of cone of depression should be given including an estimation of the effects of debris cones on ground-water intakes.

With the benefit of wide regime observations of water inflows into the mine workings and of ground-water levels during the process of development of mineral deposits, it is reasonable to perform the studies of complex hydrogeological conditions with analogue and digital computers. This enables an assessment of the efficiency of works carried out at the stage of geological prospecting to be given as well as the variations in hydrogeological conditions due to the influence of human activity to be studied. In addition, the techniques for carrying out hydrogeological works during geological prospecting are improved as a result of such studies.

To obtain valuable hydrogeological information, it is necessary to develop the principles of selection of well drilling methods. The following measures are considered to be essential : (a) application of layer testers, (b) flowmetering of wells, (c) purposeful use of geophysical methods. Further methodical scientific developments should define the role of each of the field methods, within the single complex of hydrogeological works, during geological prospecting, according to the stages of study.

The present day purposes of hydrogeological studies at the sites of mineral deposits especially in large mining regions require their wide statement on geotectonic, hydrogeochemical and paleogeographical grounds.

Hydrogeological studies at the sites of mineral deposits are combined with studies on the problem of a rational use and control of the environment. The processes, which should be investigated, vary with time, so regime observations are of primary importance for their understanding and prediction. In this connection a development of the principles of formation and location of the well network for a detailed study of the ground water regime in the areas of mine workings is urgent.

A large complex of studies on the following problems has been carried out by VSEGINGEO together with territorial geological organisations over the last decade :

(a) development and substantiation of the procedure for studying the hydrogeological conditions of mineral deposits at various stages of their prospection;

(b) estimation of the variations in these conditions during production of minerals;

(c) prediction of water inflows into the systems of mine workings;

(d) study of the effect of mine workings on the variations in hydrogeological conditions and development of the subject of hydrogeological substantiation of measures for water resources control in production areas.

A series of theoretical and methodical developments has been performed on the basis of investigations carried out on a regional plan with a wide use of analogue simulation.

A typification of the hydrogeological conditions of mineral deposits has been proposed and prediction methods for determining water inflows into mine workings have been recommended or developed relative to each type. For the mineral deposits confined to water-bearing stratified sediments, analytical methods for the determination of water inflows into the systems of mine workings have been developed. A technique of hydrogeological predictions using analogue simulation and a complex use of simulation with statistical probability methods has been worked out for the development of karst-fractured rocks.

Experience has shown that the process of simulation should consist of two stages. At the first stage, the main regional hydrogeological characteristics are defined and hydrogeological parameters are refined through the solution of a series of reverse problems.

Multi-variant predictions of the changes in the hydrogeological conditions of mineral deposits during their development with allowances for the deepening of mine workings, their extension in area and the application of various methods of drainage and techniques of development

of the deposits are developed on the basis of the results obtained and the substantiation of analogue models at the second stage of simulation.

GROUND WATER PROBLEMS IN VARIOUS MINING REGIONS

Some results of the studies and hydrogeological predictions in various mining regions will be discussed below.

In the early stages of the studies reverse problems were solved in karst regions of the Urals featuring an inclined occurrence of a mass of carbonaceous rocks characterised by an extremely large heterogeneity according to their filtration properties.

These reverse problems were solved for the determination of water conductivity and water yield of the rocks with subsequent predictions of water inflows into drainage nodes and productive mine workings. As a result of mapping the water conductivity of rocks on the simulation data, the high anisotropy of the filtration properties of karst massif rocks (accounted for by the zones of tectonic disturbances) and the weathering zone of crushed and fractured rocks are established.

The amount of water yield from karst mass rock have been determined using the data of water conductivity when solving reverse problems under the conditions of a seepage regime. These values have amounted to 1-2% over the largest part of the rock mass observed, and 2-4% in the areas of development of highly permeable rocks,

Subsequently, the correlations between jointing and karsting and seepage coefficients of water-bearing rocks have been defined (Plotnikov) on the results of the mass sampling of prospecting wells through zonal pourings, water injection and by the method of flow-metering as well as by studying the core of each well. Seepage parameters have been calculated over the whole area of karst rocks to a depth of 1200 m using these correlations. Average characteristics of the defined vertical zones of the massif have been obtained as a result of a statistical analysis. A stochastic geostructural model of the karst massif reflecting the variations in its hydrogeological parameters in area and depth has been constructed on these grounds.

Revision of the part of this model devoted to seepage properties, chiefly in the zones of tectonic disturbances, has been performed using the method of analogue simulation of geofiltration. The coincidence of the estimated water inflows and natural water inflows into mine workings as well as those for average flow gradients for the region show the reliability of the analogue model and the possibility of its use for predictions.

The following number of practical tasks have been solved :

(a) assessment of the efficiency of river course isolation over re-routing the river outside the boundaries of the karst area;

(b) construction of a rational scheme of the drainage of deep levels;

(c) estimation of the hydrogeological efficiency of developing mineral deposits at depths below 500 m with the flooding of

worked out zones;

(d) evaluation of the possible average water inflows into the system of mine workings at designed levels to the depths of 1000 m.

Mineral deposits in the Krivorozhskii iron ore basin are confined to a mass of rocks dipping at a steep angle which comprises strata of vastly different permeabilities, the hydrogeological nature of which varies from impervious beds to highly pervious ones.

Studying deep levels has proved to be effective due to the complex use of various field methods which supplement each other, for example, the use of logging and experimental tools. This enabled information on the seepage properties of rocks in deep levels to be obtained and an initial analogue model of the filtration medium to be produced.

Prediction of water inflows in the deep levels of mines has been performed by the method of analogue simulation. A specific technique has been used which embraces the following : the reverse tasks have been solved according to the Libman scheme and their solutions resolved so as to provide the model with the water inflows into particular mines at certain locations and the magnitudes of the current active levels in mine workings through selection of the water permeability of the rocks.

A model of a longitudinal section of a dipping mass of water bearing rocks with their permeability characteristics at various levels of development has been constructed by applying the reverse tasks solution. Prediction of the general water inflows into the mines for a period of further exploitation of the mineral deposits of the basin has been carried out using this model.

Studies in the region of the Kursk Magnetic Anomaly, characterised by a wide development of highly confined ground water aquifers in interbedded sandy clay and carbonaceous rocks, consisted of evaluating the degree of water exchange of the main ground water aquifers and complexes under natural and intensely disturbed hydrogeological conditions and of long term predictions of the ground water regime during the drainage of iron ore deposits and the wide production of ground water for water supply.

The seepage data obtained from semi-permeable chalk and marl enabled the determination of the value of ground water leakage recharging lower ground water aquifers as well as the value of ground water discharge into rivers through underlying semi-permeable chalk and marl rocks to be made. Then, a prediction of the level of ground water as it varies due to the effects of ground water withdrawal during draining of mineral deposits and at centralised water intakes may be performed. The results of the simulation show that a single piezometric cone will have been formed under the influence of water intakes and drainage systems in mineral deposits in the region of the Kursk Magnetic Anaomaly by the year 2000. Its length in a north-south direction will be 200-250 km.

Predicted balance constituents of ground water for the year 2000 determined on the model with an allowance for the interaction between ground

water aquifers and complexes enabled estimations of the contribution of precipitation seepage, ground water discharge into rivers, water withdrawal by mines and water intakes to the water balance to be made.

A new important trend in the study and development of methods of prediction of variations in the hydrogeological conditions of mining regions has been followed in recent years.

Generalisation of the information from these regions and the predictions made enabled trends in the processes leading to variations in the natural conditions of the regions to be analysed.

According to the predictions performed on analogue models, a significant change in the structure of the ground water balance will have occurred by the year 2000 in the Kursk Magnetic Anomaly. Ground water discharge into rivers will reduce by 60%. Leakage from the maestricht-turonian ground water aquifer into the cenoman-albian one will increase by a factor of 4 and that from the cenoman-albian ground water aquifer into the callovian-bathian one will increase by a factor of 30. Forty-five percent of the generalised ground water withdrawal will be accounted for by the infiltration of precipitation, 35% by elastic and static storages and 20% by water inflow from rivers.

In the Central coal mining region characterised by mine water pumping and surface drainage amounting to approximately 65000 m^3/h as well as subsidence of rocks over the worked out zone, the surface run off has considerably decreased and an increase in the infiltration of precipitation has been observed.

The modulus of sub-surface run off has increased by a factor of approximately 2. Large cones of depression have formed in practically all the ground water aquifers of the Lower Carboniferous. In these cases, the iron content of the ground water is changed.

Some environmental changes are observed in the region of operating mines of the Western Donbass. Ground surface subsidence due to mine workings results in flood plain submersion. Discharge of mineralised mine water causes an increase in mineralisation of river water.

Production from mineral deposits in the Karst regions leads to a several fold increase in the sub-surface run off. An additional recharge of ground water results from an increase in the infiltration of precipitation and due to the occurrence of new Karst forms. The flood run off becomes 3-5 times as large as the initial one and the winter dry weather discharge decreases by a factor of 5-15.

Thus, the control of fresh ground water resources becomes a very important task. Solutions to the complex problems of draining mineral deposits and water supply from ground water are required.

CONCLUSIONS

There are a lot of methods of studying the present day hydrogeology of hard mineral deposits. Modern techniques of drilling and test-filtration works geophysical investigations are used toward this end.

The works are based on the high degree of development of ground water dynamics and the regional hydrogeological investigations in many areas of the country. The methods of analogue simulation on analogue computers and calculations on digital computers are applied.

At the same time there is a necessity for a further development in the methods of study and hydrogeological prediction in the regions of mineral deposits, a complex use of modern techniques and an improvement in the methods of processing data. Further a wider application of the achievements of applied sciences results in the enlargement of a number of the problems related to the prospecting of deep mineral deposits, studying problems of environmental control, etc.

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