MINE WATER. GRANADA, SPAIN. 1985

STUDY OF FORMATION OF FISSURE-KARST WATER INFLOWS INTO MINE WORKINGS

N.V. Sokulina

All-Union Research Institute of Hydrogeology and Engineering Geology, Moscow region, Zeleny-village, USSR.

ABSTRACT

In exploring a deposit being flooded by fissure-karst water inflows from a river valley, hydrogeological studies for providing effective and safe mine works and predicted assessment of changes in hydrogeological conditions were carried out.

A complex of methods was used in studying water content of carbonate rocks. Geomorphological and hydrogeological data along with results of prospecting drilling obtained enabled to establish the valley of an old river, just which is associated with the most permeable carbonate rocks.

Hydrogeological importance of high-permeability limestone was studied through intensive pumping-out of a group of wells yielding more than 100 l/s, well-discharge measurements, regime observations of ground-water table, discharge and level of surface water. Anisotropy of filtration properties of the basement carbonate rocks was established in area and depth.

Forecasting of water inflows into mine workings and assessment of changes in hydrogeological environments during developing the deposit was made by simulation. Influence of deposit dewatering upon surface runoff and depression-cone widening was determined. It is noted that forecasting under such difficult hydrogeological conditions is of a preliminary character and needs correction in the course of development and construction of the deposit.

In last years hydrogeological studies of hard mineral deposits are being carried out along two lines: a traditional one directed toward providing effective and safe mine works, in particular prediction of water inflows into mine workings, and a new line oriented to predicted assessment of changes in hydrogeological conditions to decrease negative impact on

geoenvironment and to reach rational use of ground water. Both lines are based on studying water inflows into mine workings.

In hydrogeological studying the hard mineral deposit, surface- and underground runoff of the river valley is established to be the main source of its watering; the factors affecting water inflows are permeability and adjusting storage capacity of basement carbonate rocks in the near-river- bed part of the deposit.

DESCRIPTION OF THE DEPOSIT

The deposit under exploration is characterized by difficult hydrogeological conditions resulting from aquifer formation in irregular fissured and karstic basement limestone and dolomite with thickness of a few hundreds of metres. In the west of the area carbonate rocks are exposed while in the east and south they occur under Devonian ore-bearing sediments to the depth of 80-100 m. The deposit is overlain by a rock mass of different lithological composition not affecting significantly water inflows. In the west of the deposit (in the area of exposed karstic rocks) there is a river with the annual mean discharge of 3.0 m^3/s and flood discharge - over 30 m^3/s. The river is believed to be the main source for water inflows into the mine workings.

STUDY METHODS

A complex of methods was used in studying water content of carbonate rocks in the river valley. At the first stage geomorphological and hydrogeological studies were carried out followed, after a general nature of the river valley was determined, by more detailed and expensive works (well drilling, hydrogeological and geophysical well testing, regime observations).

As a starting point of the studies geomorphological structure of the river valley was described. Landscape-indicator researches involving interpretation of aerial photographs, aerovisual and field observations were carried out. The main attention was payed to investigating topography, karst manifestations and vegetative types (Sadov, 1978).

Basing on the researches made it was established that in between the current river bed and the deposit there was an old valley, entrenched into basement karstic rocks as well. To judge by research experience, old valleys are commonly associated with the most fissured, karstic and high-permeability rocks which may essentially affect water-inflow amounts into mine workings.

A local "key" site being a typical one in the river valley made more precise the determined general regularities. Watershed areas, interfluve sides composed by carbonate rocks with a great number of karst cones, a high structural-, an aggradation-, first-alluvial terraces and a flood-plain

were established here. Such features of a paleo-valley as transition moors, fluvial-streams of the pradolina and near-marsch uplands were observed in the east of the river valley. The results of geologic-geomorphological zoning showed that the "key" site of the river valley is placed on a relatively uplifted, highly fissured basement block. The old- and the current river beds are supposed to inherit within this block probable fractures of the basement. Studies performed enabled delineating the paleo-valley along the current river bed in sites neighbouring upon mine workings to be designed.

Isochronous measurements of the minimum discharge of the river were made with regard for its geomorphological structure. The results obtained enabled establishment of two absorbing zones of surface runoff. The first zone (1.1 km long) absorbed 11% of the minimum river discharge, the other one (0.9 km long) - 22%. The both zones were associated with high structural terraces, to the east of which the old river bed was located.

Down-stream, where the old valley joins current one and the old river bed approaches the present one, sharp increase in ground-water discharge occurs and the streamflow rises by 25-30% relative to discharge in the upstream cross-section. Additional analysis of data on geologic-prospecting drilling confirmed the occurrence of the old river valley, the entrenchment of which into bedrocks exceeded that of the current river bed by 5-7 m.

Basing on analysis of aerial photographs, geological small-scale and topographic maps, the formation of the old valley is supposed to take place before Moscow Glaciation. The subsequent advance of glacier and the most recent structural highs of the basement blocks changed surface-runoff direction in the river head with the result that the river bent to the north of the explored deposit. But the middle and lower river stream maintained the present-day direction. The further sinking of the basement blocks resulted in rising the erosive entrenchment and overlying the old river-bed by the younger sediments. The age of the old river-bed is supposed to be pre-Mesozoic.

In order to study hydrogeological role of high-permeability limestone in the old river valley, filtration tests, regime observations of ground-water table, surface-water discharge and level, hydrologging in test- and observation wells were carried out. The pumping out of a group of wells yielding up to 110 l/s, with water-table lowering by 4-5 m, showed that transmissivity in the old river valley amounted to 10 000 m^2/day, decreasing in the current valley to 3300 m^2/day and in watersheds - to 1800-200 m^2/day.

According to regime observations performed, the old river valley during dry-weather period was associated with the aquifer piezominimum of carbonate rocks involving seepage flow out of watershed area, as well as out of high structural terraces of the river bed. It confirms availability of a zone of high-permeability rocks through which ground water is discharged into rivers (Sokolov, 1962).

The hydrologging investigations of the developed territory made it possible to establish that rock permeability at watersheds and in the river valley was of different degree. At watersheds carbonate rock permeability decreases essentially with depth in exponential relation, dying down below the depth of 75-80 km. Most permeable are the upper 50 m of the profile below the carbonate-rock top; within this profile interval the upper 10 m are somewhat less permeable against the next 10-20 m depth-interval being of the highest permeability. It seems to be a result of colmatage of the upper profile part by fractions from overlying layers. The thickness of fissured rocks in the river valley exceeds 140 m; the dying out of fissure zone with depth is not established.

SIMULATION OF PREDICTED WATER INFLOWS

Basing on the determined regularities of the changes in filtration properties of carbonate rocks both in the river valley and deposit territory, a mathematical model was constructed for estimating the predicted water inflows into mine workings and studying possible changes in hydrogeological conditions with the dewatering of the deposit. Here, a great role belonged to establishment of character and distribution zone of high-permeability limestone which would be a passage for underground- and surface water inflow into mine workings during exploration and development of the deposit.

The simulated hydrogeological conditions were represented diagramatically in plane and cross-section (Luckner, Shestakov, 1976). The hydrogeological cross-section was restricted to single-layer rock mass, hydrodynamic parameters of which were given with regard for filtration properties of all aquifers contributing (with dependence on the degree of their interaction with aquiferous carbonate rocks and on filtration properties ratios) to watering mine workings. In case of lacking interconnection with overlying aquifers or their low water conductivity and yield, the parameters of the single-layer rock mass were accepted respectively as those of the carbonate aquifer. Providing that this interconnection is close and parameters of overlying layers and aquiferous carbonate rocks are comparable, the parameters of the single-layer rock mass are accepted as summary estimates of water-conductivity and yield of rocks. This has resulted in a certain overestimation of the accepted filtration properties of the rock massive. But considering intensification of interrelation between aquifers which will occur (during field development) as a consequence of the rock discontinuity induced by mine workings and connection of water-bearing strata through geologic-prospecting boreholes, this overestimation may be suitable.

According to results of filtration tests and regime observations, the river-bed resistance is equal to less than 200 m. However, due to the fact that under disturbed environments decrease in river-bed resistance is possible which is

resulted from growing flow gradients and suffosion processes; relation of aquiferous carbonate rocks with the river is accepted during simulation as ideal.

In simulating some models for annual mean river discharge were analysed. The annual mean river discharge being set in model was determined by summing up all mean monthly river discharges with allowance for transmissivity of river-bed sediments.

Before estimating predicted water inflows, the transmissivity of river-bed sediments was determined as a water-inflow amount into quarries, when the constant river head was given under steady conditions. This amount controled the further river-discharge amounts being given. If it exceeded the actual river discharge, the excess of the river water was assumed to be not absorbed by near-river-bed sediments but removed downstream.

During simulating, the annual mean river discharge or its seasonal variation was given (with allowance for transmissivity of near-bed sediments).

ANALYSES OF THE OBTAINED RESULTS

The simulation enables to establish that 75% of the predicted water inflow are produced at account for surface water, as well as solid and storage components. In this case carbonate sediments in the river valley due to their high storage capacity greatly level seasonal variations of water inflows as far as a portion of surface water during flood recharges the near-river-bed sediments and raises their water table. But during dry-weather period the water table decreases and carbonate rocks dewatering occurs. The results of regime observations of ground-water levels confirm the above statements and show, at the same time, that water-table falling in near-river-bed sediments after the flood rising is rather slow.

The simulation data demonstrated that while dewatering shallow quarries, located at the distance of 4-5 km from the river, the predicted water-inflow values were relatively not high amounting to the first thousands m^3/day. Any additional filtration preventive measures here are not required, except for drainage well system. Development of these quarries will not cause essential changes in hydrogeological environments of the region. The lowering of the water table will not exceed a few metres. The surface river runoff is kept during the major part of a year, desiccating only during winter dry-weather period. Removing of fresh drainage water may be carried out with no additional nature-conservancy measures.

The dewatering of deep quarries, located at the distance of 1,5-2 km from the river, will be followed by intensive water inflows into mine workings which exceed water inflows into shallow quarries by some times. The measures origionally proposed for decreasing water inflows during deposit development (river-bed concreting) may be of low efficiency, as

far as the main flow moves not through the current river-bed but through the underground bed of the old valley.

Water lowering during deposit developing will cause essential changes in hydrogeological environments. Ground-water levels will decrease throughout vast territory. The river flowing near the deposit will be desiccated during the major part of a year and it will keep surface runoff during flood period only.

Presently, the carbonate aquifer may be widely used for water supply but development of deep quarries will exhaust it, which will require either using the deeper carbonate aquifers of the river valley or searching new sources of water supply being not affected by water lowering in mine workings.

The deposit development is expected to cause essential activization of karst-forming processes, quantitative prediction of which is presently impossible.

Thus, a great complex of works was carried out while studying the developed site. These works enabled establishment the main sources for forming water inflows into mine workings and the factors affecting them. At the same time, it should be noted that under difficult hydrogeological conditions considered predicted values must be corrected in the course of exploration and development of the deposit.

REFERENCES

1. Luckner, L., Shestakov, V.M., 1976, Simulation of geofiltration, "Nedra" Publrs., 407 p., Moscow.

2. Sadov, A.V., 1978, Study of exogenous processes by aero-landscape methods, "Nedra" Publrs., 151 p., Moscow.

3. Sokolov, D.S., 1962, Main conditions for karst forming, Geogeoltekhizdat, 322 p., Moscow.