GROUNDWATERS IN MINE "TREPCA" AND DRAINAGE PROBLEMS

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ABSTRACT

Mine drainage frequently represents an essential factor for safe and profitable exploitation of a mineral material deposit. Increased deposit water-bearing capacity leads to significant aggrevation of mine operation techno-technological and economic indicators. Complexity of above problems is greatly emphasized when groundwaters are accumulated in karst chanels and caverns as is the case in Lead and Zinc Mine "Trepca" - Stari Trg. The volume of caverns for the level of a 60 m high horizon is about 1,500,000 m^3. The danger of sudden accumulated water inrush is exceptionally high in the stage of new horizons opening. The paper presents the deposit geological and hydrogeological properties, drainage flow-sheets and protective measures in the stage of 12th and 13^{th} horizons opening.

INTRODUCTORY REMARKS

Lead and Zinc Mine "Trepca" - Stari Trg pit with the depth of the lowest 11^{th} horizon of 815 m falls among deep pits. The program for further exploitation includes opening of two new horizons, i.e. the 12^{th} and 13^{th} one, 60 m deep each, i.e. totally. 120 m and thereafter the pit depth will be 935 m [1]. Exploratory drilling indicated mineralization to the 16^{th} horizon level, i.e. 300 m below the 11^{th} horizon. Deposit "Trepca" falls among the larger worldwide known lead and zinc deposits. In the course of to-date exploitation (67 years) 36,700,000 tons of high grade sulphidic ore have been mined out of it. Mineralization is related to limestone contact in the foot-wall and shale in the hanging-wall with scaterred occurrence of breccia. Limestone is associated with the presence of large groundwater accumulations. Over the long period of exploitation of the mine the danger from groundwaters varied and hence safety measures were adapted to existing conditions and requirements. Groundwater inflow increases with the increase of mine depth, and hence drainage problems became more and more complex and the costs ever increasing. The depressive area from which groundwater draines into the mine also increased and after opening of the 11^{th} horizon it reached 17,5 km^2. From this surface area about 3,2 x 10^6 m^3 of water infiltrates into the earth crust per year of which about 2,4 x 10^6 of water inflows into underground mine rooms per year [2].

Due to the presence of groundwater accumulations in the limestone, opening of new horizons is carried out through a waterimpervious environment - shale. Down to the 7th horizon opening was carried out from the direction of then active inclines it the pit no northern section, but also through shales. During 7th horizon opening and development in 1953 unpreciseness lead to horizon and pumping station flooding (water gates were not closed in time). Water rised 41 m above the 7th horizon. Only after gates closing the water level was lowered below the 7th horizon and the pumping station was liberated. Mine operation was interrupted for four months resulting in great damage in the mine [3].

During horizon opening from the hoist shaft towards central section hauledge roadways are driven through the shale and drainage facilities are constructed on the lower horizon and two horizons are opened simoultaneously so that the groundwater level is lowered by 120 m. In haulage roadways water bariers with water gates are constructed near the hoist shaft. Ahead of the water gates pump chambers are constructed on the lower horizon and further on towards the central section a water collection sump is made. Construction of drainage facilities and loverering of groundwater level upon accumulation opening for 120 m lasts about two years, having a substantial bearing on new horizons opening duration. Water accumulation opening and lowering to the lower horizon interrupts water inflow to the higher horizons. This method of opening and maintenance of pumps operative on higher horizons resulted in active pumping stations on the 11th, 9th and 5th horizons. According to the program for 12th and 13th horizons opening operation of pums on the 11th horizon will be terminated and pumps on 13th, 9th and 5th horizon will be operative.

DEPOSIT GEOLOGICAL AND HIRDROGEOLOGICAL PROPERTIES

"Trepca" deposit is of hydrotermal metasomatic, medium to high thermal origin created by inflow of solution during the Alpine orogenesis. Tectonic played a major role in deposit formation, spatial distribution, shape and orebody size. Orebody position depends on shale position (hanging-wall) and that of the limestone (foot-wall) so that the orebodies were formed on its contact or in the limestone itself. Do-date about 40 orebodies were opened in the deposit which have a tubelike irregular shape with an area between 100 end 10,000 m^2 with a substantial depthwise strike. The principal structural shape in the shales is of folded type, while in the limestones faults, fissures and cleavages prevail and this accelerated its karstification.

Hydrogeological explorations indicated that water aggrevating the mine flows out of the limestones. The water flows out of the fissures, cleavages, fault zones and particularly from karst chanals and caverns. The water also flows out of emptied boreholes intersecting fault zones in the limestones. Hence, total limestone masses in the deposit are classified as water permeous rocks - hydrological collectors because groundwater accumulates in them representing a potential hazard for miners safety and aggrevates exploitation. Haulage roadways are constructed in the limestones representing the productive zone foot-wall and here caverns containing more than a million m^3 of water with a hydraulic pressure of 12 bar represent a particular danger. To-date two zones have been recorded in which caverns are located, one near the central orebody towards the northern section, and one near the ending stopes in the pit north section. Fig. 1 shows the cross section of one cavern.

The remaining lithological members, primarily shale, are classified in the hidrogeological sense as water impervious rocks - insulators. Fissures in them are less frequent, and when they exist they are of smaller size and in these cases water volumes are insignificant, water regime is not constant so it does not represent an operation hazard.

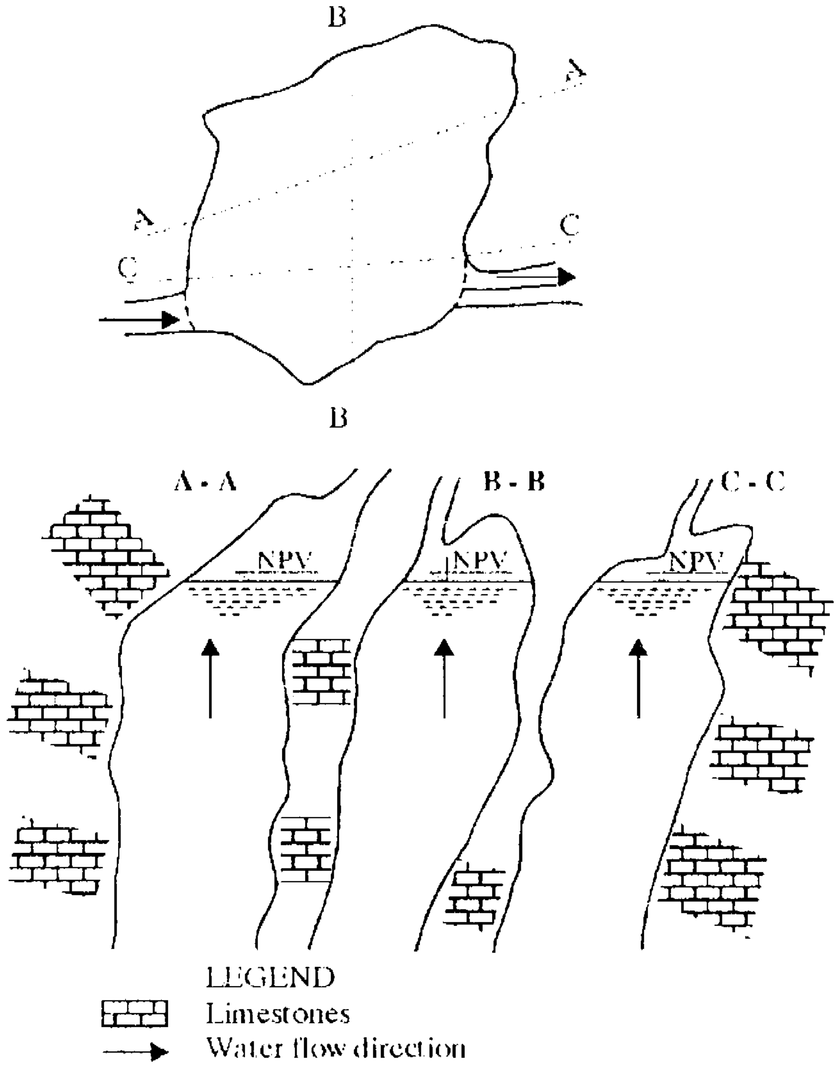

Fig. 1. Cavern - lake plan and profile

Currently, groundwater level is on the level of haulage roadway on the 9[th] horizon (+ 15.0 m) and hence all upper horizons are mainly dry being located in the depressive zone formed by groundwater level lowering. Fig. 2 shown the deposit predicted hydrogeological profile. Currently about 95 % of total groundwater preasure comes from the 11[th] horizon, so only a smaller amount originates from the free depth of the north service shaft on the 9[th] horizon and south section upper horizons.

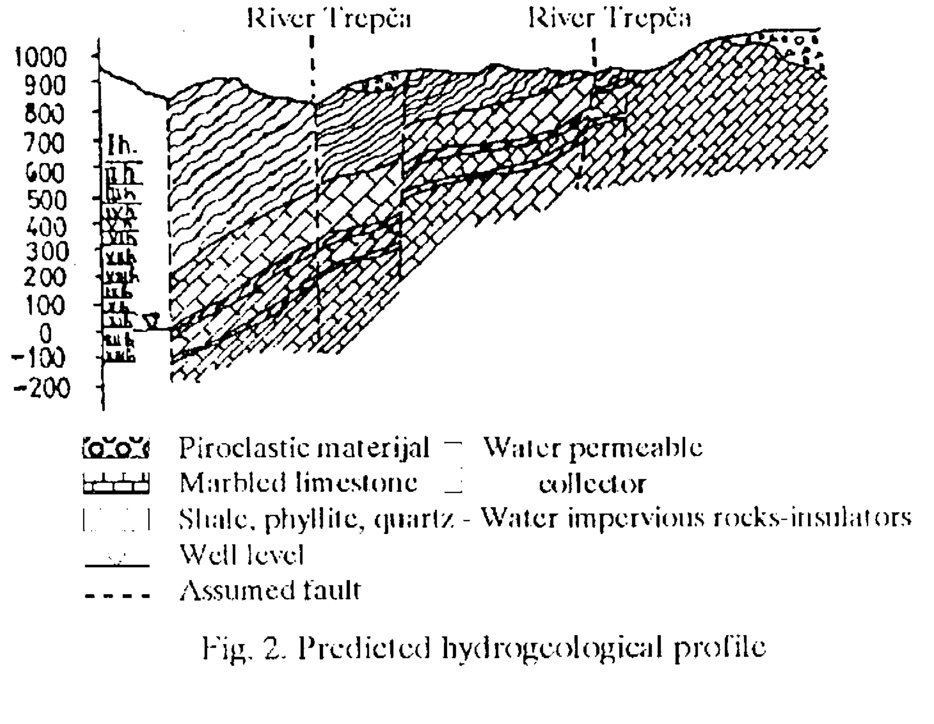

Fig. 2. Predicted hydrogeological profile

Water temperature increases with mine depth increase, i.e. groundwater level lowering. On the 9th horizon the main water volume temperature was 31° C and on the 11th horizon 33° C. Water temperature is maintained on the same level. Water opened by boreholes near the central orebody on the 9th horizon had a temperature of 38° C and on the 11th horizon 52° C. It is assumed that hot water is associated with the ore with pronounced oxidation and cold water with the limestones having in view that more serious investigations were not completed.

MINE DRAINAGE

Currently, mine drainage is carried out indirectly by water pumping from the 11th to the 9th horizon and from the 9th to the 5th horizon. and from the 5th to the 1st horizon from where the tunel leaves the pit through haulage adit I. All three pumping stations contain three centrofugal pumps each with below technical properties:

$Q = 4,8$ to $8,4\ m^3/min$
$H_{man} = 132$ to 250 mWC
$N = 280$ to 400 kW
$n = 1475$ and 2900 r/min,

Water inflow on the 11th horizon ranges between 4,0 and 4,8 m^3/min. Hydrostow water affects water inflow variations. There is only one steel pipeline with inner diameter of 350 mm for drainage from the 9th to the 1st horizon and two from the 11th to the 9th horizon (due to high deposition of matte from the water in the pipeline), shortage of a spare pipeline from the 9th to the 1st horizon is a major problem related to matte cleaning from the pipeline. The pipeline must be cleaned at least once a year. Pipeline diameter may decrease from 350 to 150 mm due to matte deposition, when due to increased resistance and decreased flow (pump outputs) two and occasionally all three pumps must be in operation.

According to the investment program opening of the 12th and 13th horizon is designed and groundwater level lowering by 120 m, i.e. to the level - 105 m. The pumping station will be located 5 m below 13th horizon level because it is easier to control pumps with a positive suction height, there are no pouring problems and pump efficiency is higher.

After start-up of the pumping station on the 13th horizon the pumping station on the 11th horizon will terminate operation and the water from the 13th horizon will be pumped to the 9th one and further in line with the existing flow sheet as seen on Fig. 3. which shows the designed drainaged facilities on the 13th horizon (pumping station, water gate and water collection sump).

The possibility of groundwater level lowering by well drilling and water pumping by submerged pumps was also considered in order to shorten the term of new horizons opening, but this alternative was abandoned due to technical reasons [4].

Pump sizing and properties selection were made in line with following conditions: pipeline dia 350 mm; 6 90° bends; two valves; water temperature t = 34° C and simoultaneous pumping of 12 m^3/min of water by permanent operation of two pumps with an output of 6 m^3/min each.

Upon groundwater level lowering to the 13th horizon a permanent drainage regime will be initiated with a flow rate ranging between 5.5 and 7.0 m^3/min.

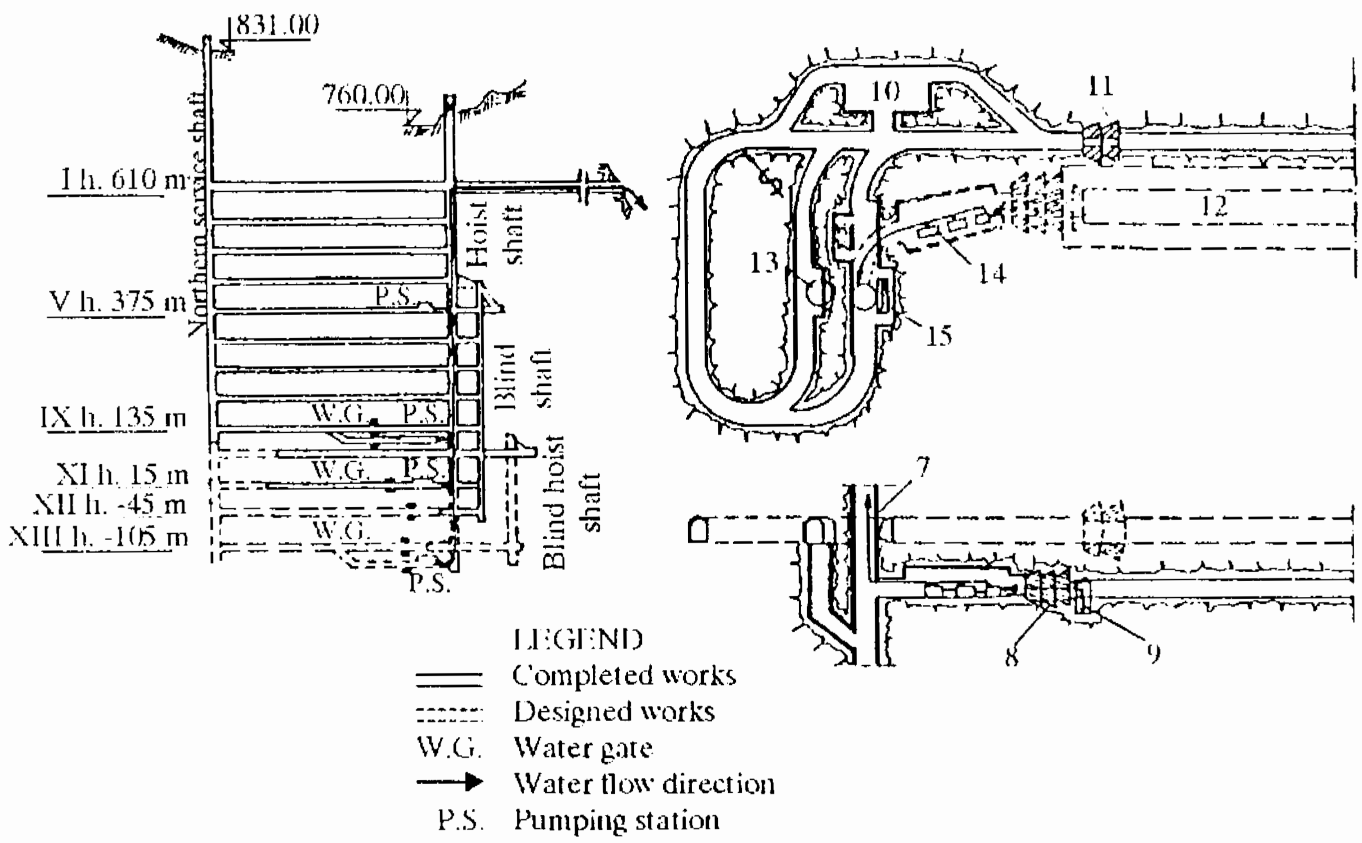

Fig. 3. Mine drainage flow-sheet upon opening of the 13th horizon with drainage facilities layout on the 13th horizon
(7-delivery pipeline, 8-barage tampon, 9-suction pipeline, 10-depot, 11-water gate, 12-water collection sump, 13-ore bunker, 14-pumping station,15-hoist shaft)

Manometric height calculations were made in line with formulae usually found in drainage literature [5], [6]:

$$H_{man} = H_g + \sum gub = H_g + \lambda b \frac{L}{d}\frac{w^2}{2g} + Z\lambda n \frac{\sum le}{d}\frac{w^2}{2g} \quad [m]$$

so calculations will not be given here because they are high time consuming but only the calculated manometric height:

$$H_{man} = 249{,}71 \ /mVS/ \sim 25x10^5 \ Pa = 25 \ bara$$

Centrifugal pumps of type CVRNL 8/6 were selected manufactured by "Jastrebac" - Nis with below technical properties:

$Q = 4.8$ to $8.4\ m^3/min$; $H_{man} = 330$ to 250 /m/;
$N = 560$ kW; $n = 145o$ r/min.

PROTECTIVE MEASURES DURING OPENING OF THE 12TH AND 13TH HORIZONS

Past practice indicated that major hazards of groundwater inrush take place during opening of new horizons. According to experience gained during opening of the 9th and 11th horizon the below protective measures are designed for opening of the 12th and 13th horizon:

- drilling of a series of deep boreholes from the chamber near the shaft defines the position of the contact shale - limestone, this being necessary for determination of water barage and drainage facilities location. The shale - limestone contact is becoming nearer to the hoist shaft. Upon contact definition barages are defined on the 12th and 13th horizon, and the barage on the 13th horizon should be located in such a way to allow suficient space for construction of the pumping station and part of the water collection sump capable to receive the water in case of possible inrush prior to construction of the whole collection sump.

- the concrete barage should be located in most compact shale. Injection of cement groute is designed into the shale at the barage in order to prevent water inrush through the rock massif and increase shale load bearing capacity. Construction of a two stage steel reinforced barages with a 2.40 x 1.95 m steel water gate is also designed to enable passing of self mobile hydraulic equipment as seen on Fig. 4. Water gates on upper horizons have a smaller opening so the equipment had to be disassembled and cut. The barage should contain tubes for water level control, cables, compressed air, technical water, air discharge and separate ventilation. The gates are calculated so as to withstand the pressure twice higher than water hydrostatic pressure of 12 bar for the 12[th] horizon and 24 bar for the 13[th] horizon. On gate location a track movable segment is installed to be removed for gate closing.

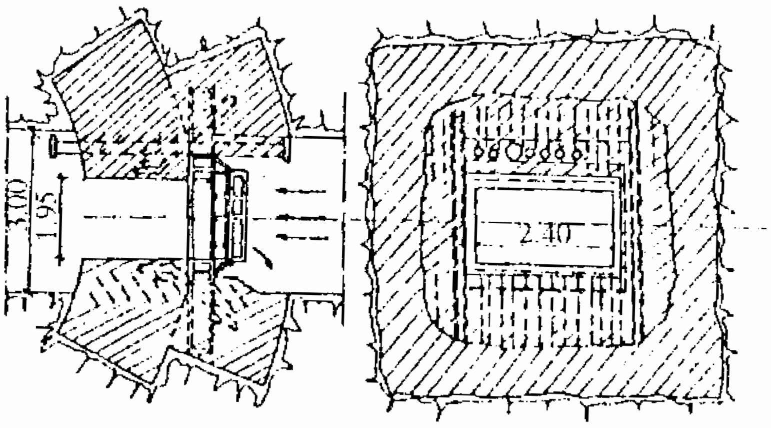

Fig. 4. Water gate diagram on the 13th horizon

- 5 m below 13[th] horizon level to the roght of the haulage roadway a pump chamber will be constructed connected with the hoist shaft and a water drift with the collection sump where a barage will be made with two suction pipes, on for each collection sump. The concrete tampon is shown on Fig. 5.

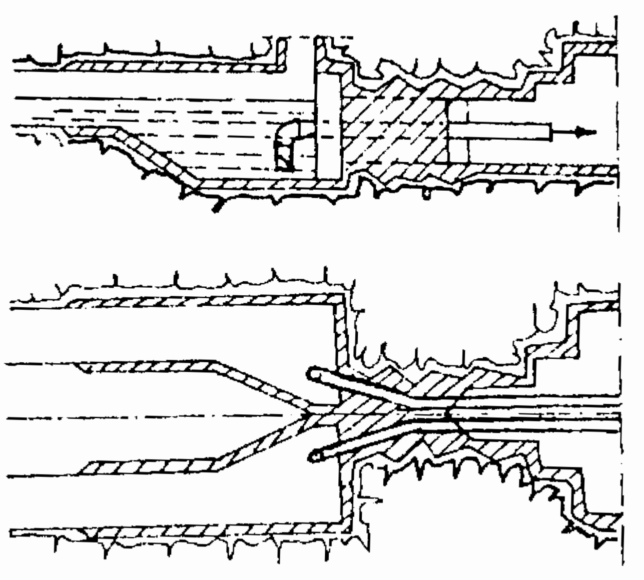

Fig. 5. Concrete tampon

- The water collection sump has two parallel drifts 173.5 m long and clear cross section area of 13.5 m^2 and with a volume of 4650 m^3. Ahead of the collection sumps will be constructed connected by short inclines with the haulage roadway and drainage chanal.

After construction of the barage with the gate it is necessary to check the throughput capacity by water injection behind the gate and the upper valve must be opened until complete air is evacuated behind the barage. The barage and water gate on the 12th horizon are constructed in the same way.

Upon installation of the pumps and construction on one collection sump part, construction of haulage roadways is continued and the roadway on the 13th horizon is 10 to 15 m ahead of that on the 12th horizon. Roadway is preceded by exploratory deep drilling usually with three boreholes of which the middle one is along the roadway axis. The objective of the drilling is to more closely define the direction of shale-limestone contact. When the roadway enters into the limestone deep exploratory drilling is continued so that the boreholes penetrate into the water in the caverns. In addition, prior to blasting predrilling by test boreholes 3.0 m deep is carried out as seen on Fig. 6. The depth of blastholes is 1.6 m so that the remaining limestone column of 1.4 m may withstand the 12 bar water pressure on the 12th horizon. When the depth of blastholes is increased the depth of test boreholes must be also increased so that the limestone column of 1.4 m is maintained.

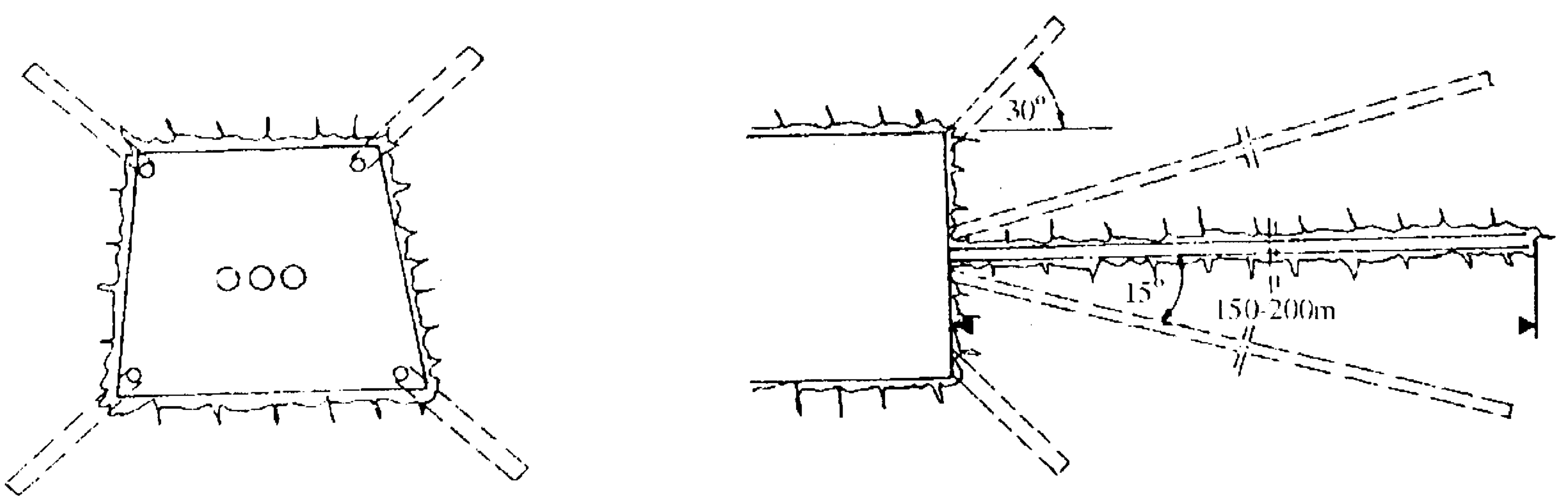

Fig. 6. Predrilling diagram

In addition to predrilling, having in view the marked potential hazard the following work regime is designed:

- Prior to blasting all persons are withdrawn behind the water gates and the gates are closed;
- All valves are opened in order to control possible water inflow after blasting and in the case of inflow the valves are closed in order to raise the water level behind the gates.
- Blasting must be initiated by electrical detonators with closed gates.
- All equipment and tools should be moved in front of the gates prior to blasting.
- Shift supervisor should check the fulfillment of all protective measure prior to blasting.
- All persons going through and out of the water gates are permanently recorded.
- For faster and more efficient manpower information audio and light signals should be installed at the faces and in front of water gates.
- At the water gates permanent duty mast be maintained and change of the persons is made on the spot.
- Water gate correctness should be controled daily and the contact sufaves on the frame must be clean and oiled.
- If there was no water inflow after blasting the gates may be opened after 15 to 30 min in dependence of roadway face distance from the gate. The gates are opened in the presence of shift supervisor.

- Upon gate opening a separate fan is switched on and after face ventilation the workings are controled in shift supervisor presence.
- In cases of electric power supply interruption all men must be withdrawn end the gates closed.
- When initial pressurized water emerges drainage start, i.e. water level lowering by increased pumping regime is carried out until the groundwater level reaches the 13th horizon level and a slower drainage regime is initiated.

Water opening is designed by deep boreholes but not by direct penetration into the caverns by blasting and flooding of the rooms behind the water gates, as was the case during opening of the 9th and partially 11th horizon. Upon opening increase in order to increase water inflow on the 9th horizon, 30 min upon blasting rooms were flooded behind the water gates with a volume of 2,5oo m^3 while water pressure on the gate was 12 bar.

Borehole water opening will enable guided water discharge proportionally with pump output, while a pipe containing a valve will be installed at the borehole collar. This will significantly increase manpower safety. It should be noted that irregular cavern shape will greatly aggrevate the use of deep boreholes. Cavern opening by short boreholes is much more risky. In both cases the drill must be secured against pushing, while the drill operator may not stand in the drill axis. Water flow through a borehole depends on its diameter, length and hydrostatic pressure (water level in the cavern) ranging for a 76.2 mm dia borehole 10 m long at $H = 120$ m, 4.7 m^3/min to 0.95 m^3/min at $H = 5{,}0$ m. Drilling of four boreholes is designed and upon water level lowering to 35 m above the 13th horizon, the opening should be widened to allow a flow of 12.0 m^3/min.

As already stated, groundwater in this mine contains a significant amount of carbonate which is deposited in the pipeline to form a matte which decreases pipe cross section even as high as 80 % resulting in pump output decrease and increase of already high drainage costs. This requires pipe cleaning in line with a specified schedule. Cleaning is made by an acid solution leading to water pumping delay so this was dificult to carry out and cost intensive. Matte cleaning by flow of flotation tailings through the pipeline was tested normally used for stope hydrostow resulting is somewhat improved effects. It should be noted that this method does not enable any pipe wear control. Information exists that Ukraine has patented a procedure for matte clean in pipelines by use of electric shocks and that the procedure is efficaceous without any consequences regarding the pipeline.

CONCLUSION

Increase of mine depths results in increased hazard related to groundwater inrush into underground rooms. This hazard was particularly pronounced in the stages of opening and development of new horizons in deposits where limestones are the accompanying rocks. Where water filled caverns exist hazard is even higher and drainage more complex, as is the case in Lead and Zink Mine "Trepca". Accumulated water volume in two 60 m high horizons when opened simoultaneously totals about 3,000,000 m^3. Opening of the 12th and 13th horizons is designed. The expected water inflow is about 7,0 m^3/min and the geodetic pumping height from the 13th to the 1st horizon will be 715 m. The paper outlines protective measures to be applied during opening of the 12th and 13th horizon which also may be favorably used in other mines when similar hydrogeological conditions are present.

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