Hydrogeological Aspects of the Open - pit Mine Slope Stability (Case Study)

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ABSTRACT

The development and use of machines of large capacities at open-pit mining requires also the solution of hydrogeological problems associated with it. The reduction of the negative influence of water is therefore considered as important from the start to the termination of coal mining and subsequent reclamation. The goal of this process is a safe exploitation which depends on the insurance of the geotechnical safety of the open-pit mine. Due to the face front advance, slope movements have developed in the debris on the area Jezerka in the forefield of "the Czechoslovak Army" open-pit mine since the beginning of the 80's. In 1988 movement of 7 million m^3 of debris occurred. The results of a detailed study of hydrogeological conditions were used for the reduction of slope movements by means of underground water drainage via borehole and shaft. The monitoring of drainage effects in the debris contributed to a more precise determination and gradual verification of conditions of flows in the area under study. The measures taken resulted in a substantial reduction of the slope movements including slope failure.

INTRODUCTION

The slope stability is influenced by a number of factors, the importance and effect of which should be evaluated according to the conditions of a given locality. The effect of water is beyond dispute and as a rule is of a decisive significance. This effect demonstrates itself even on the slopes of the rock massifs, where water pressure in the fissure environment evokes more accidents than do the other factors altogether(10). Similarly Hoek and Sharp(6) described the effect of water in the examples of a water-bearing rock slope a partially dewatered slope and a totally dewatered slope. It is possible to increase the angle of the 80 m high slope by 10 to 17 degrees by controlled dewatering, depending on the ground water level decrease, or by the ground water level decrease behind the slope heel. C.O. Brawner(1) considered the water pressure and water flow conditions to be among the decisive factors. The author also emphasized the continuous observation and evaluation of the structural and geological conditions of the open slopes as the principal prerequisite for the evaluation of hydrological and geotechnical conditions for the advance of mining. This approach is often not strictly exercised, which leads to false conclusions and false measures taken against the slope failure. The effect of water on the slope stability in anisotropic and non-homogeneous environment of rock massif was solved by N.R. Morgenstern(9). The author pointed out the complexity of calculations of water pressure distribution in fissure environment as a decisive factor of the

stability. Difficulty of input data determination restricted the calculation reliability. The direct pressure observation of ground water pressure in rock massifs was recommended.

The hydrogeological conditions of slope areas and their surrounding environs are characterized by relatively rapid changes, which significantly affect the slope area stability, in addition to other factors, e.g. temperature, weathering, etc. The reason of it is the direct supply to groundwater body by precipitation water, or by seepage of surface water. The ground water level shows a seasonal fluctuations in dependence on precipitation intensity (snow thaw). The inflow of fissure ground water from subjacent groundwater body to near-surface zone of a rock massif is not frequently fully appreciated.

The effect of ground water on the rock slope stability is manifested:

- by hydrostatic pressure, which lifts the rock blocks and works as a lateral pressure on the discontinuity planes. This pressure reduces the resistance against the slides on the planes and also the shear strength of massif by decrease of the normal stress on the discontinuity plane. The massif is more or less loosened. The effect of flow pressure is also significant, which can achieve high values due to the permeability change, particulary at the base of near-surface zone (the zone of surface disjunction of fissures and Quaternary sediments), although one of its frequent effects are the shifts of the slope deposits during winter time, when natural massif dewatering does not occur due to freezing of the slope surface;
- by physical and chemical effects of ground water in rocks and discontinuity fillings, when the processes occur of alteration, filling cavities with water, and the shear friction between filling and rock decreases;
- by an unsuitable intervention upon the slope stability, when its relieve occurs, which leads to the formation of tension cracks in the upper part of the slope and subsequent loosening of a slipping plane[8]. The changes of the slope configuration and rock deposition create the positive conditions for precipitation water infiltration, which is drained by a slipping plane. This plane then becomes the most permeable and a privileged flow of ground water.

The hydrogeological conditions and their changes represent the significant factor for ensuring the slope stability. Therefore, maximum information is necessary to be acquired, which should be continuously updated using the monitoring of hydrogeological changes. The reliability of the data determines the efficiency of measures taken against the slope movements.

THE HYDROGEOLOGICAL CHARACTERIZATION OF LOCALITY

The mining area of the open-pit coal mine "the Czechoslovak Army" in s part of the North Bohemian Brown Coal Basin, which was formed by filling of the trough oriented in the SW-NE direction. The basin in bordered by the morphologically significant slope of gneiss and granite massif of the Krušné hory Mts. in the North-West. These rocks form the bottom of the Miocene sediments of the basin. The wide fracture zone can be found in the direction of the basin axis at the junction of the basin sediments and the rock massif of the Krušné hory Mts. This zone is not uniform, it is faulted by cross faults in the NW-SE and W-E directions. The geomechanically weakened zone, created during the processes of alteration and mechanical fracturing of the crystalline complex rocks, is 750 to 1150 m wide and reaches high up to the Krušné hory Mts. slopes. The rock rupture forms a wide zone of discontinuous faults of a non-

uniform directions. The faults are impossible to be correlated among the structural units. The cross faults, which form the block structure of the massif, represent the preferential zones for ground water flow. The large loosening of the crystalline complex surface is also significant, which is heaps up below the slope debris.

The occurrence of the stability problems of the Quaternary sediments concerns the deluvial sediments at the base of slope of the Krušné hory Mts. Coarse grained debris and gravel overlap the subjacent Miocene sediments. In the studied locality they reach the thickness of up to 60 m. They are followed up by the talus cone at the outlet of the mountain brook "the Vesnicky potok" into the basin. The accumulation of rocks of the fossil slides also participates in the thickness of debris deposits.

The working face of the open-pit coal mine "the Czhechoslovak Army", which is located in the central part of the basin near the town of Most, has approached the apex of coal bed at the base of the mountain slopes. The morphology of the slope in the area "Jezerka" reaches up the angles as high as 35 degrees. The study of the hydrogeological conditions in the "Jezerka" region forms an integral part of the measures taken to secure the geotechnical safety of the mine, particulary that of the slope stability.

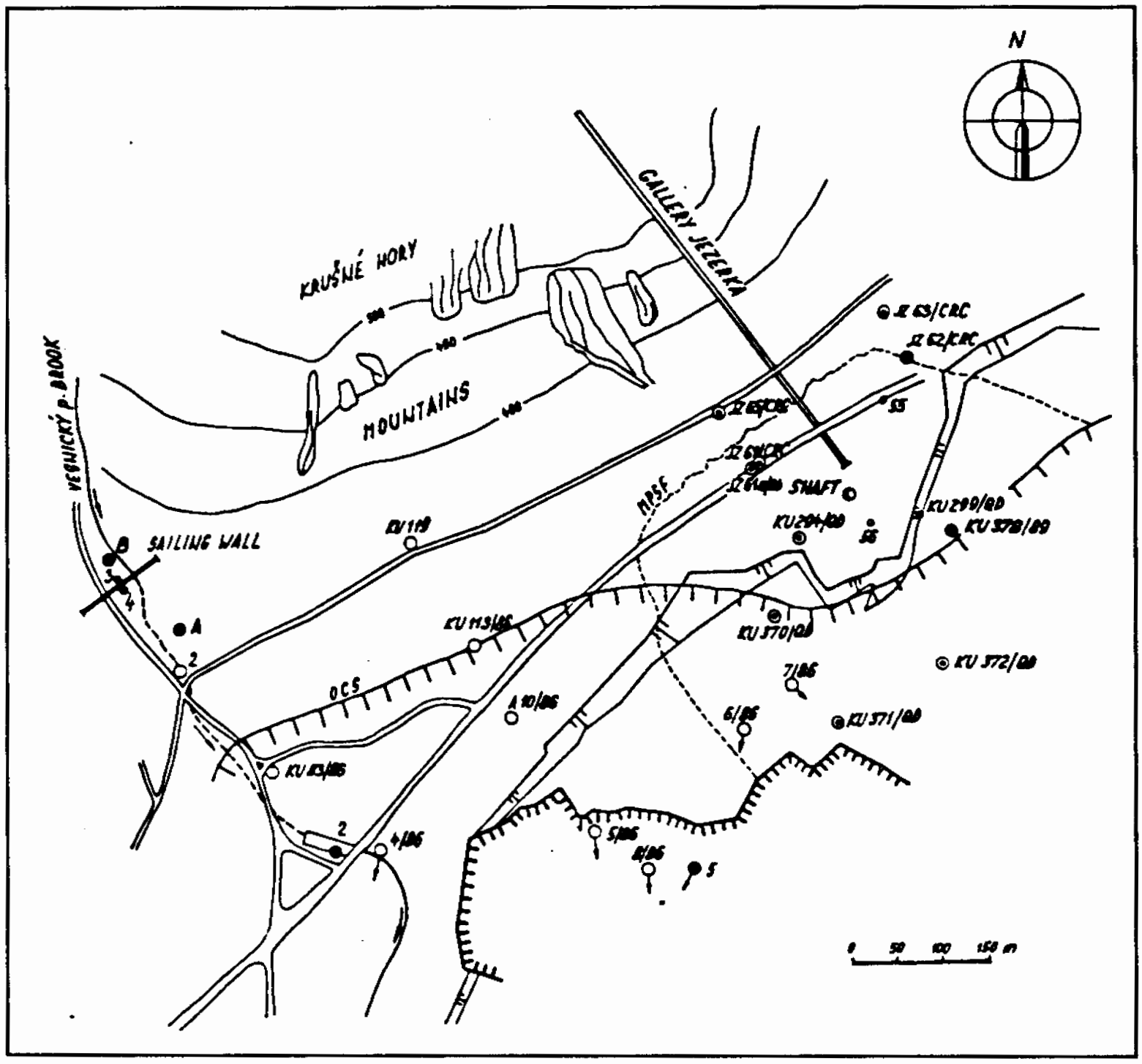
THE HYDROGEOLOGICAL ASPECTS OF TALUS SLOPE STABILITY

The talus pillar in the "Jezerka" area fills up the morphologically depressed area in the subjacent claystone of a bowl shape with an overall angle of taxis to the SE. Since early 1980's, there has been formed a slide area there as a result of a stripping. The unambiguous conclusion of effective dewatering followed up the analyses of conditions off slide formation, because the stripping sections cannot keep up on the overall slope angle of more than 8-10 degrees. The conditions for slope failures are also created even by small amounts of infiltrated water on the base of debris deposits[3].

The first talus movements were indicated in July 1983 on its base in the depth of 13 to 15 m. The further development of movements started in April 1985 and continued until November 1985, on the junction of talus and tertiary claystones. The movements were recorded also in the gallery "Jezerka" on the boundary of lithographic unit in the distance of 38 - 65 m from adit entrance. In 1987 the axis gallery started to wind up to the SE as a result of faster movements in the Eastern part of the talus pillar. The movement activity on the slide plane differed in 1988; in the Western part reached up to 2 - 6 mm per month, in the middle part 10 mm per month and in the Eastern part the movement was the fastest of 80 - 200 mm per month. The talus movements peaked in April and May 1988 and then declined.

To reduce the landslides, the dewatering of debris deposits was started in September 1986 by pumping water from the shaft "Jezerka" at an average rate od 1 $1.s.^{-1}$ (Fig.1). The main supply of water being pumped was bound on talus and partially also on the Miocene sandy sediments in the outcrop area. The larger amounts of pumped water during the spring months corresponded to the thawing period (Fig.2). The decreasing tendency of pumped water maxima was given by overall precipitation deficit, which was apparent starting in 1986, when compared with the long-termed average (Fig.3). The tritium content measurements evidenced the portion of "young" ground water in pumped water from talus, which gradually decreased[11]. The decrease of a recent water share proved the efficiency of draining of the talus pillar. The tritium content measurement results evidenced that with the exception of a

period of spring snow thaw dewatering occurred of either Miocene sandy sediments or inflows of fissure ground water from subjacent crystalline complex. The balance of hydrogeological evalution revealed that talus pillar is probably supplied by a larger source. The trace test with the use of nuclide ^{51}Cr confirmed the connection between the water-bearing dejection cone soaked with water from the Vesnicky potok brook, and water outflow in slide area in the year 1986 (Fig.1). The indicator was also detected in pumped water[7]. Although the pumping shaft was 760 m away from dejection cone, the mean flow rate was the third out of nine observation sites. The test proved the creation of flow paths and non-efficiency of performed diverting of stream bed, unless it was connected with construction of underground sealing wall.



(QD-Quaternary debris, CRC-Crystalline complex, OCS-outcrop of coal seam, MPSF-margin of a potential slope failure; A-the site of the marking tracer in the 1986, B-in 1989)

Figure 1. The situation of the dewatering objects-facilities and the observation boreholes within the slope debris on the area "Jezerka"

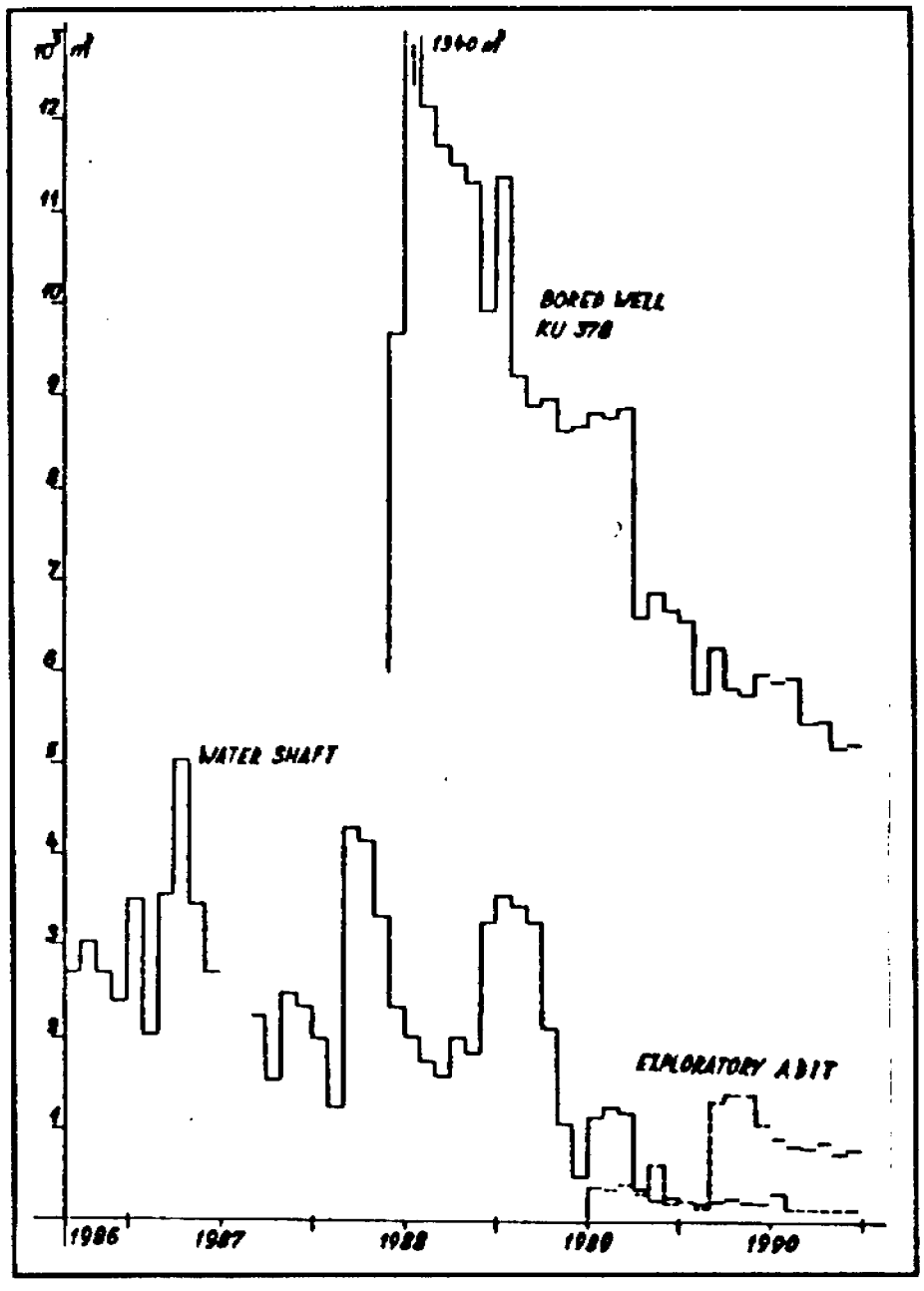


Figure 2. The groundwater pumping on the area Jezerka - monthly total

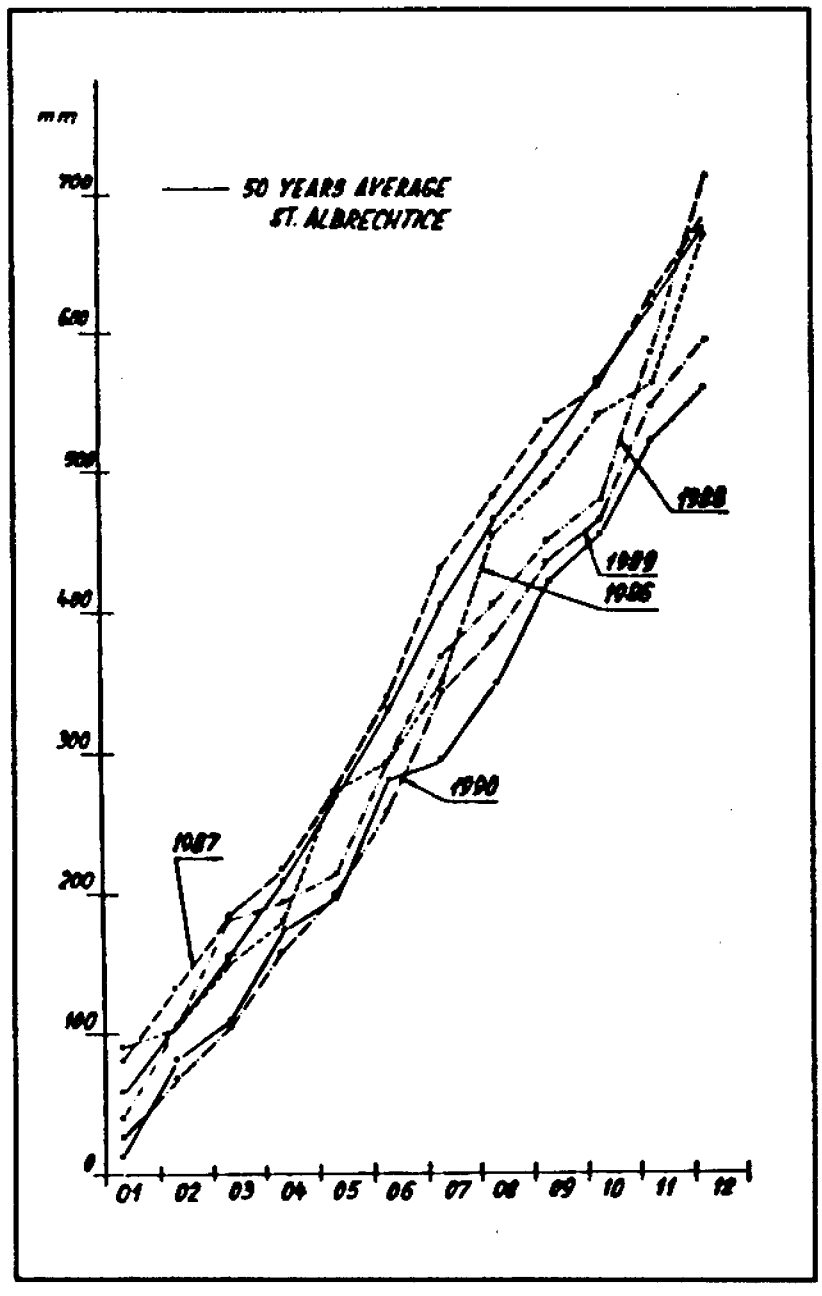


Figure 3. The monthly total mass curves of atmospheric precipitation from the station Jezeři, 365 m a.s.l.

To increase the draining efficiency of talus, there was deepened a pumping borehole KU 378 (Fig. 1). The objective was also to reduce the slope movements recorded in the early 1988. The borehole well was located in the axis of the talus pillar. By the end of the first quarter of a year 1988 there was found the significant downward tendency of the surface area in the reference points 55 and 56 (Fig.1). The intense pumping of ground water within the long-term pumping test showed their stabilization. In June of the same year the permanent water pumping from the borehole well was started as a part of talus dewatering. A positive draining effect was demonstrated by different decreases of ground water levels in all observed boreholes. In the borehole JZ 63, although it was located behind the basin boundary there was found the hydraulic connection with collector of a near-surface zone of the crystalline complex. On the contrary, this connection was demonstrated as inexpressive in the borehole JZ 62, even through the borehole was located in debris near the borehole well KU 378. In general, the conception of privileged paths of ground water circulation in debris was gained. The hydrogeological observations showed that the shear plane as a zone of increased permeability was not bound to the contact of debris and underlier only but reached as far as the fractured part of crystalline massif.

The interrupted pumping of ground water on both locations in December 1988 led a

to general increase of water levels in observation boreholes, however, with a different reaction again. The smallest ground water level changes were found in the boreholes JZ 62 and JZ 61, which followed up the hydrogeological changes in the crystalline massif. The significant changes were recorded in all observation boreholes in debris (QD) and in the borehole JZ 63 (Fig. 1). The renewed water pumping was reflected in the gradual decrease of water levels in the observation boreholes in agreement with the previous tendency. In Fig. 2 can be clearly seen the significant decrease in amount of pumped water from the watershaft Jezerka in the end of 1989. It was partly due to the precipitation deficit but the main reason was the effectivity of sealing underground wall in the Vesnicky potok brook valley. In the year 1989 the trace test verified good functioning of this wall, because indicator was detected in the borehole well KU 378 after a very long time[12].

The course of water pumping from gallery Jezerka showed the considerable changes in total amounts during the period March to May 1990. Dewatering of static storage of fissure underground water is assumed, however, short time of observation does not permit the detailed analysis. Nevertheless, the fact that dewatering of water-bearing fissure system of crystalline rocks occurred in the adit is significant. This finding changes the former opinions of negligible hydrogeological importance of fissure systems of crystalline complex. The evidence of presence of recent ground water in inflows from solid rocks, i.e. ground water of tritium age, suggests the formation of secondary circulation paths due to the draining effect of mine in the fracture zone.

CONCLUSIONS

The rational dewatering of talus deposits permitted to reduce and stabilize the slope movements into the quasi-stationary state, which assured a certain degree of mine geotechnical safety. It concerned the movement of 7 millions cubic meters of debris. The prerequisite for effective slope dewatering is the exact estimation of hydrogeological factors and evaluation of circulation paths. This information form a non-replaceable set for solution of geotechnical safety of mine, especially improvement of slope stability. Purposeful measurements of natural nuclide content was successfully applied as a working method not only in basin collectors but also in fissure water-bearing system.

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