Environmental Aspects of the Mine-inundation of the Recsk Deep Copper Mine, Hungary

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ABSTRACT: The Recsk Copper mine was planned to operate in some 1.200 m depth from the surface in the Mátra Mountains in Northern Hungary. The site was investigated form 1970, using geophysical prospecting, by deep drillings and later two shafts and some investigation tunnels were made to control the quality of the ore. The operation of the mine was assured by intensive water excavation to keep the shafts and tunnels dry. Due to unfavorable changes on the world market of copper ore and the increasing production costs the excavation became unprospective, which lead to the decision of the termination of further investigations and the closure of the mine at the end of 1999. The shafts and tunnels were cleaned as much as possible and the pumps were also stopped. The filling up of the underground space started about three years ago and parallel to this fact the continuous monitoring of the system began. The previous geological investigations, new evaluation of the fracture pattern network of the different rock bodies, the data logged during the recovery process gave a unique opportunity of further investigation of GW hydraulics of the area. The practical aim of investigation is to model the recovery of the Recsk-system, but also to couple the fracture pattern simulation models with FD GW flow models in order to get a user-friendly numerical environment for further investigations.

1 INTRODUCTION

Mining in the Recsk area is known from the 2nd part of the XVIII. century when open pit and shallow copper mine was established at the village. Geological investigations of the XIX century showed that the bigger are bodies should be found not nearby the surface but in greater depth, The first drillings up to 396 an 495 m depth were unproductive, but in 1961 ore traces and in 1967 the chalcopyritic ore in the intrusion was found. Later the 500x500 m drilling network of 1.200 m deep boreholes was established and the whole magmatic intrusion with dominantly copper, but also zinc, lead, molybdenum, iron, gold and other rare metal deposits were discovered. In 1970 and 1977 two shafts of 8 m diameter and 1.200 m length was deepened. Until 1981 some horizontal exploration tunnels were made in –700 and –900 m bsl. Due to decrease of the price of copper, the investment was stopped in 1981 and only further maintenance works were performed (Szebényi – Földessy, 2002). In lack of foreign investors the owner of the mine decided the long-term abandonment of the mine, and the inundation of the subsurface cavities. After the termination of subsurface works the inundation started in November, 1999. Recovery of more then 1.000 m drawdown was measured at the first phase manually but from 2002 digital data-logger were settled into the shafts and in some other objects of the monitoring system. Simultaneously a continuous water quality control is also done (Szilágyi, 2002).

2 GEOLOGICAL CONDITIONS OF THE FRACTURED RESERVOIR

The investigated area is in the Mátra Mountains in N Hungary. The oldest formations of the basement are Permian shale and sandstone overlain by Triassic and Jurassic limestone and interbedded quartzite layers. Pre-neogene structural evolution of the region is rather complex. One of the most important tectonic lineaments of Hungary, the Darnó-zone, crosscuts the area on the east with a stripe of NNE-SSW. Along this tectonic zone andesite bodies could intrude the mentioned basement rocks in the Eocene. The andesite intrusion became stuck on the subvolcanic level having an extent of approx. 3 km length along the tectonic zone and a width of 600-800. Due to igneous fluids as well as heat effect of the intrusion the country rocks altered in a 100-150 m thickness; an even wider zone deformed significantly. During magma differentiation porphyric copper and molybdenum ore was formed (chalcopyrite, pyrite, molybdenite) first. Due to metasomathic effect copper, iron ore-bearing skarn formed (magnetite, pirrhotite, pyrite, chalcopyrite) 600-1.200 m depth beneath the surface. Locally the gold content of the ores is relatively high too. In fractures of the formations andesitic dykes were formed containing polymetallic (copper, zinc, lead) ores (sphalerite, galenite, pyrite). Following the main igneous phase, Oligocene and Miocene sediments deposited in the subsiding basin. Simultaneously both basement and intrusive rocks became highly fractured due to the extensional tectonic regime. During the Eocene, further andesite, dacite and their tuffs formed causing a large hydrothermal system with formation of a secondary polymetallic ore generation (pyrite, enargite, luzonite, native gold, tellurides, sphalenite and galenite). Ore deposits formed not only in the skarn, but also in sedimentary formations far from the magmatic contact zone. The map of the site and a geological section is shown on Fig. 1.

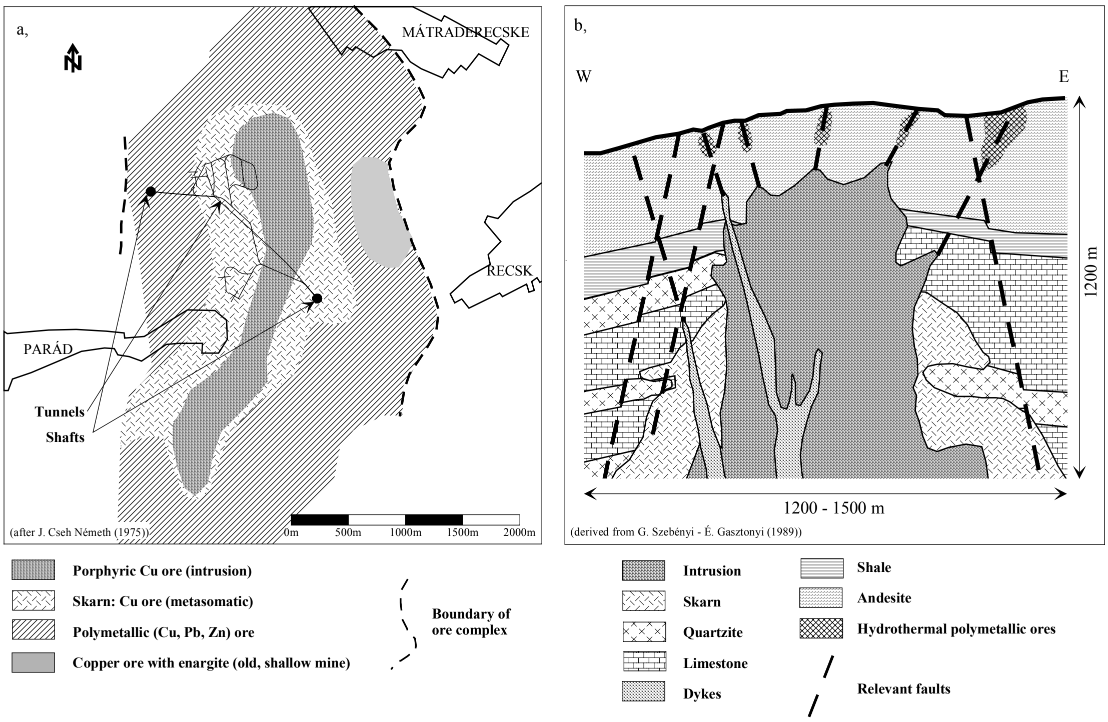

Fig.1.: Geological formations of the site (a) Location of different ore deposits (after Cseh Németh, 1975) (b) Geological sketch of the system (simplified from Szebényi – Gasztonyi, 1989)

Due to the complex petrological and structural evolution, the study area is at present a fractured reservoir consisting of rock types of different rheology. Because of the mineralization by reason of the hydrothermal activity, most early fracture generations are filled and/or sealed totally and cannot contribute present fluid migration. Numerous measurements show that the main pathways for fluid flow are the late NE-SW fault zones, while other investigations suggest the significant role of lithological contact surfaces as well. In case of the Triassic limestone bedding planes serve as the main discontinuity surfaces (Fig. 2a), which also exhibit evidence for a weak dissolution. There, however exist only a few fractures linking parallel strata making the fracture network highly anisotropic. Due to deformation effect of the Eocene intrusion bedding limestone is bended locally (Fig. 2b.). The rocks of the contact zone towards the intrusion show similar fracture geometry to limestone with deterministic role of bedding direction (Fig. 2c). Andesite and related igneous rocks show a well-developed cooling down bedding (Fig. 2d), but locally also is contains a dense network of steep faults and microfaults (Fig. 2e). Andesite contains much less fractures than limestone and as a result of lack of significant dissolution, fracture apertures are small as well. Although, sub-parallel to the Darnó zone several shear zones appear in the mine (Fig. 2f) and also in borecore material, none of these individual zones can be followed for a considerable distance. As a consequence of the variegated lithology and structures a highly anisotropic fracture network with significantly different fracture parameters (spatial density, direction, size and aperture distribution) can characterize the study area. On this basis direction depending local hydraulic parameters can be predicted as well.

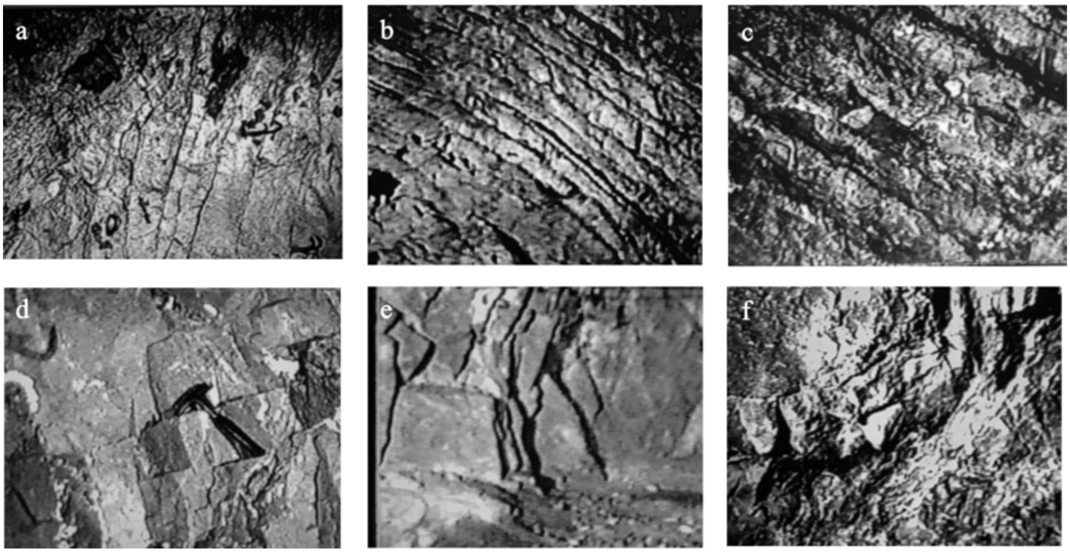

Fig.2. Typical discontinuity types for different lithologies in the Recsk mining area (for details see text) Photographs digitized from the documentation video of GEOKOM (2000)

3 DISCUSSION AND CONCLUSIONS: THE HYDRODINAMICAL MODEL

During geological prospecting hydrogeological investigations were performed both in case of several boreholes and during deepening the shafts. However, this information is rather local and the database gained can hardly be used for a real 3D characterization of the whole system. For building a conceptual hydrodynamic model of the site, fix data were used to characterize each formation, meanwhile each of them was considered as a hydraulically homogenous unit. From hydrogeological point of view there are five different rock types considered; limestone, quartzite, andesitic and dacitic pyroclasts, andesite and the skarn. Each of them is highly fractured because either of lithological (limestone bedding, andesite cooling) or structural reasons (Darnó zone, extension regime). In addition, hydrothermal and metasomathic activity caused an essential weathering of the igneous bodies resulting in some primary porosity of this unit. Even if most hydraulic parameters are highly oriented in small scale, as a consequence of the overlap of the processes mentioned above, a connected fracture network could have developed. Choosing high enough cell size (representative elementary volume), this kind of reservoir can be modeled as an isotropic porous system. For modeling Processing MODFLOW Pro was applied.

To avoid using anisometric elements, the whole system was built up from 100 m thick layers of 25 and 50 m wide cells. The applied layers were inhomogeneous, the actual hydrogeological parameter set characterizing the local formations was chosen based on the geological information derived from the stratigraphic study of more than 100 boreholes of 1.200 m depth. The model parameters were in part determined using the previous survey (permeability, porosity, etc.), in part they are based on literature data (specific yield, specific storage, etc., Table 1.).

The tunnels were modeled as drain cells, their volume and the volume of the shafts were added to the effective porosity of the relevant cells. Using the model 25 years of operation (1 period) and 11 years of recovery (2x0,5 year, 4x1 year, 3x 2 years, 9 periods) were simulated.

The model was validated using the measurements of water level elevations in the two shafts and in one more monitoring well. From 2003 monitoring of another well was stopped because of the loss of data-logger due to some operations in the well. The manually and quasicontinuously (data-logger) measured data are presented on Fig. 3a. The simulation results (Fig. 3b-3d) show that the fractured system can be modeled using porous model until the global behavior of the system is investigated. For smaller, local problems the anisotropy of permeability moreover and the directions and the closure of fractures should be taken into consideration. The suitability of the present monitoring system is limited, due to the fact that the measurements are performed in the shafts and not at the deepest point of the depression cone (Fig. 3a).

Tab. 1: The representative hydraulic parameters of the formations

Type	Transmissivity[1] [m^2d^{-1}]	Effective porosity [-]			Specific yield [-]	Specific storage [m^{-1}]
		rock	at shaft	at tunnel		
Intrusion	0,7	0,005	0,125	0,055	0,005	$5\cdot10^{-5}$
Skarn	1	0,01	0,13	0,06	0,01	$1\cdot10^{-4}$
Limestone	5	0,015	0,135	0,065	0,015	$1\cdot10^{-4}$
Quartzite	1,2	0,002	0,122	0,052	0,002	$5\cdot10^{-5}$
Andesite+Dacite	0,05	0,005	0,125	0,055	0,005	$1\cdot10^{-5}$

[1] Transmissivity of 100 m thick layer

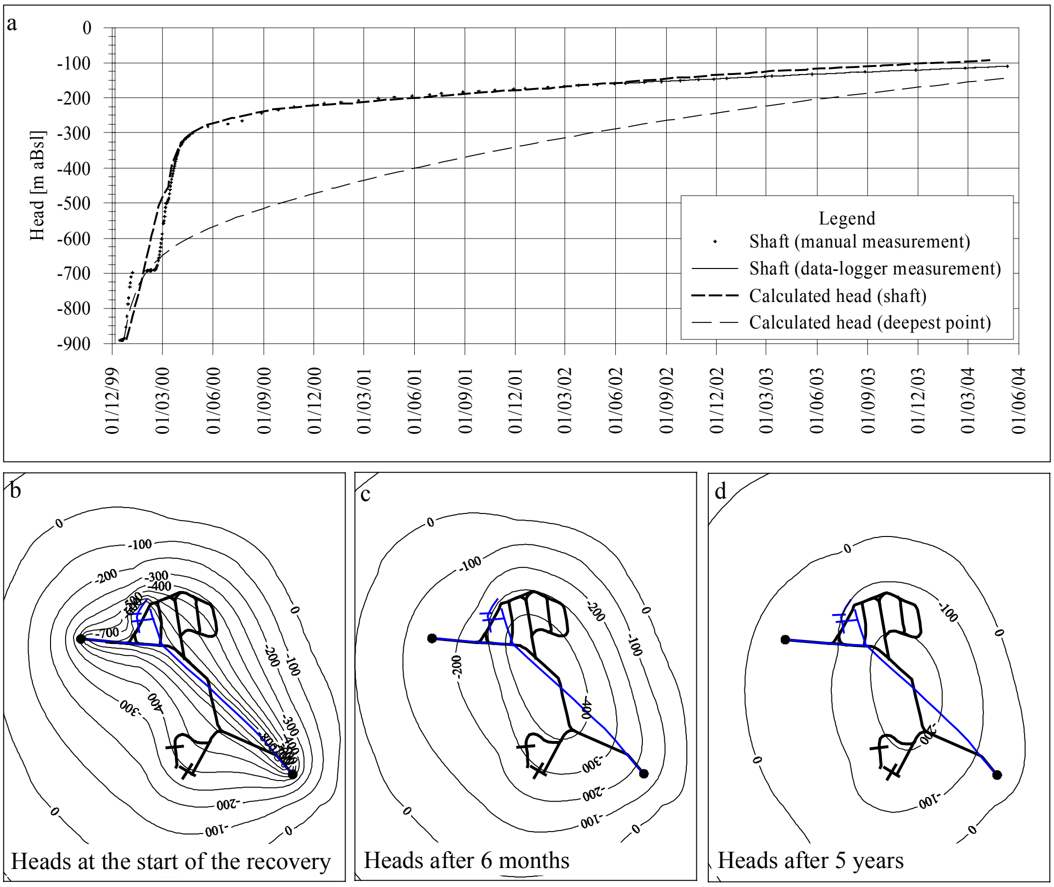

Fig.3.: Simulation results of the recovery of the Recsk copper mine

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