Prace Naukowe Instytutu Górnictwa
Nr 135 Politechniki Wrocławskiej Nr 135
Studia i Materiały Nr 42 2012

Jeroným Mine,old mine workings, stability

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STABILITY OF OLD MINE WORKINGS OF JERONÝM MINE AT ČISTÁ, SOKOLOV DISTRICT

The Jeroným Mine, which is situated in the locality of Slavkovský les Protected Landscape Area, is a unique heritage site associated with mining in the 15th and 16th centuries. To make this mine working accessible to the public, it is necessary in the first place to stabilize underground voids and to ensure such internal microclimatic conditions that any degradation of the mine working and any hazard to workers performing restoration operations and later to visitors will not occur. The contribution deals with factors conditioning and affecting the stability of this system of mine workings.

1. INTRODUCTION

In the mine voids of the Jeroným Mine (Fig. 1), rooms after the extracted tin ore with traces of fire setting and passages with characteristic small cross-sections and with traces of work with a hammer and a pick are preserved. In the year 2008, the Ministry of Culture of the Czech Republic established the Jeroným Mine as a national historic landmark. In the future, the opening of this mine working in the form of a historical mining museum to the broad public is expected.

Mine workings in the Jeroným deposit represent a very spatially complicated system. In principle, they can be divided into flooded mine workings below the adit level and fully and partially accessible mine workings above the Jeroným adit level.

Manifestations of instability that are caused by the geological structure of the rock mass, previous mining activities and present-day influences (traffic along the road No.

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doi: 10.5277/gig121805

II/210 above the mine workings of the Jeroným Mine), can be, in principle, divided into factors following from [1]:

- the geological structure of the rock mass of the Jeroným Mine,
- geomechanical manifestations of the rock mass,
- anthropogenic activities.

Fig. 1. Jeroným Mine and road No. II/210

2. CRITICAL FACTORS FROM THE POINT OF VIEW OF GEOLOGY OF THE ROCK MASS

Geological monitoring focuses on the observation of discontinuities that may affect, from the engineering point of view, considerably the mechanical properties of rocks and may influence the total stability of the system of mine workings. From previous structural and tectonic measurements of disjunctive tectonics along 132 joints and in 25 documentation points, it follows that it is joint tectonics, represented by Cloos's joint systems that is the most important. As can be seen well in a contoured diagram in Fig. 2, the main systems of joints run in the NEE–SWW direction and in

the direction perpendicular to it, i.e. NNW-SSE direction Both the directions manifest themselves in high values of dips, namely from 70 to 90 degrees. The third type is represented by joints oriented roughly horizontally, with a gentle dip (5–35°). In relation to Cloos's joints, the discontinuities of NNW–SSE direction correspond to the joints of "Q" type (Querfläche), the NEE–SWW direction to the "S" joints and horizontal planes correspond to the "L" joints (Lagerfläche). These systems of joints are unambiguously endogenous discontinuities.

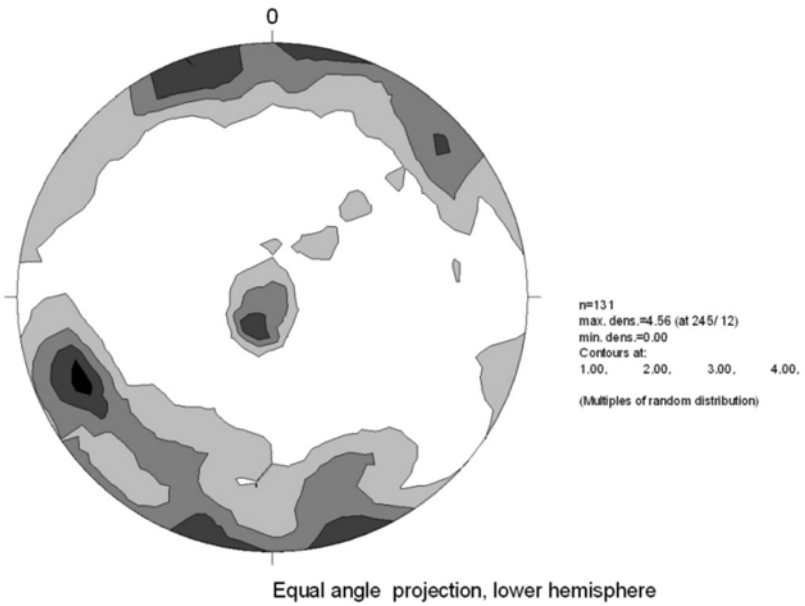

Fig. 2. Contour diagram

Another group of tectonics studied is represented by joint tectonics manifesting itself in residual pillars of room K 1; in this case already during the first in situ reconnaissance an assumption was stated that this tectonics is recent, induced probably by anthropogenic influences [4]. These, probably tension cracks copy roughly the directions of natural tectonics. In contrast to it, they are however prevailingly uneven, blind up to pinnate, and the abundance of them is higher (3–5/m); some are considerably open (1–5 cm) and fresh, without clay coating. This fact can be seen most clearly in the residual pillar of the diameter of about 1 m, situated at the toe of a cone of loose fallen rocks in a small room east of K1. Here a system of open (up to 5 cm) tension cracks occurs in the pillar as well as in the floor around the pillar, see Figure 3.

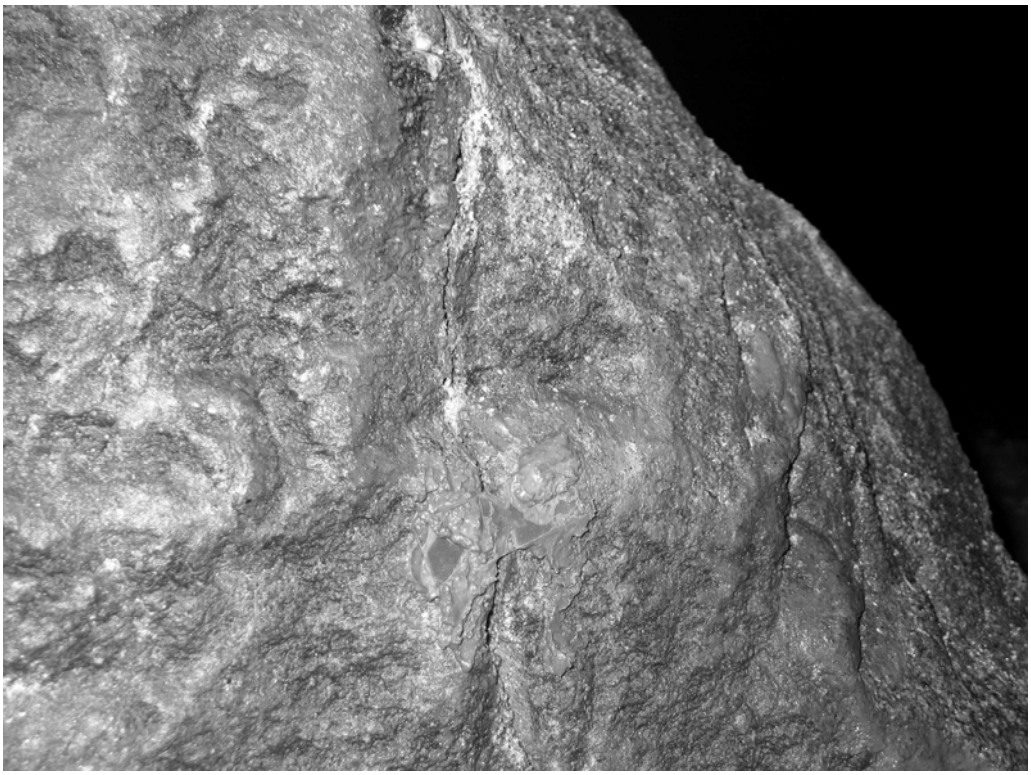

Fig. 3. Tension cracks in the surroundings of the pillar

The proper deposit of Sn-W ores is confined to the endocontact zone of granite of the Čistá type and is surrounded by surrounding rock materials with different (clearly lower) values of deformation and strength properties. In those parts of the deposit in which mine workings were there in the vicinity of associated rocks or in the vicinity of yet unknown mine workings, manifestations of geomechanical instability are evident. As an example can be given observed partial cave-ins, with which the character of caving materials correspond to that of rock material along the contact between the deposit itself and the eluvial rocks in the hanging wall of the deposit.

As well, tectonic elements in the rock material of the deposit and of the associated rocks should not be omitted in the assessment of geomechanical conditions of mine workings of the Jeroným Mine. They represent areas of the rock mass predisposed to weakening, i.e. the areas in which the strength and the bearing capacity of rock material are exhausted at first. Rocks flaked off from roofs and sidewalls of mine workings that cover the floors of passages and the bottoms of rooms can be observed as evidence. In some cases of flaked off pieces of rocks, even the plane of division can be seen in the roof. Although the proper flaking off of rocks and the sliding of rock blocks along the tectonic elements of the rock mass are only secondary manifestations of

mining operations and other processes (weathering, effects of groundwater flow, bursts and vibration, and others), they still exist.

3. CRITICAL FACTORS FROM THE POINT OF VIEW OF GEOMECHANICAL MANIFESTATION OF ROCK MASS

3.1. CRITICAL FACTORS RESULTING FROM A CHANGE IN STRESS-DEFORMATION STATE OF ROCK MASS DUE TO MINING AND DECOMMISSIONING OPERATIONS

Mining and other works have been performed in the Jeroným – Čistá deposit for about 500 years; during that time, the rock mass was affected by human activities differing in tools for rock disintegration.

The first stage, lasting till the first quarter of the 19th century, was characterised by the mining method of fire-setting and by classical mining by means of a hammer and a chisel. Traces of these methods are apparent in the whole of the Jeroným Mine.

The second stage is represented by modern exploratory operations, mining trials and research work. Of the stage, the application of drilling and blasting operations in rock disintegration, which are factors the negative effects of which on the stability of mine workings are evident, is typical.

The third stage took place in the sixties of the 20th century and concerned with the implementation of decommissioning of the Jeroným Mine, namely backfilling the Jeroným shaft with a loose rock material. The result of decommissioning operations is a cone of loose fallen rocks with the apex at the bottom of the Jeroným shaft that is accessible at present, at the depth of 27 m below the shaft mouth.

The fourth stage, which began in the year 1997 and will also continue for a rather long time in the future, is represented by works associated with the making the Jeroným Mine accessible in the framework of operations of securing the national historic landmark.

From the above-mentioned facts and facts known from the recent works in the deposit of Jeroným–Čistá, it follows that:

1. The initial state for the observation of geomechanical stability of mine workings in the course of securing works is the current state that is observed by a designed monitoring system [3,6].
2. The same is valid for the assessment of character and geomechanical condition of pillars and pillars between rooms (Fig. 4) and for the evaluation of origin and development of so-called “modern” fissures that have been evaluated so far merely on the basis of visual observation.
3. A strongly unfavourable factor that adversely affects the geomechanical stability of part of the Jeroným Mine is the uncompleted decommissioning of the mine, namely the partial backfilling of the Jeroným shaft. The created cone

of a loose fallen rock material applies an additional load to the bottom of the room below the Jeroným shaft in the vertical direction and simultaneously exerts lateral stress (preliminarily the soil pressure at rest) on the adjacent rock pillars.

Critical points in which monitoring instruments are installed can be divided into several groups.

3.2. CRITICAL FACTORS RESULTING FROM A CHANGE IN HYDROGEOLOGICAL CONDITIONS

Before commencing the mining operations, steady hydrogeological conditions existed. To changes in them, performed works associated directly with mining and works associated with exploration contributed. The existing system of mine workings represents a spatial reservoir [2], including workings not known yet and caved. According to cited data, water gets to the mine solely by surface water infiltration; it is a case of gravitational water. Mine drainage is ensured by the Jeroným adit. Part of mine workings below the adit level of the Jeroným Mine and some mine workings above the adit level (underground voids without outlet) are permanently flooded by trapped mine water (Fig. 4). In addition to the voids visibly without outlet, the voids may exist in the rock mass that could be closed by caving and that prevented mine water communication.

The negative influence of mine water on the geomechanical stability of mine workings can be seen in the following factors:

- Static pressure of mine water in the voids without outlet above the adit level. Although so far these voids have been designated as without outlet, mine water infiltration to the Jeroným drainage adit cannot be excluded reliably. The gravity movement of water may be, depending on the permeability of the rock mass, very slow
- Pressure of infiltration water flow. The result is suffusion, when fine particles are removed from the rock, and weakening the rock skeleton
- Lubricating effect of water on tectonic surfaces. Presence of water on tectonic surfaces decreases friction on these surfaces, which results in a decrease in shear strength along joints and fissures
- Chemical weathering of especially feldspars in an aqueous medium.

The evaluation of these factors according to the severity of negative influences is difficult. In all cases, what is meant is that the factors are long-term. The most severe factor is the water flow pressure and suffosion related. The factor of water flow pressure and suffosion was one of causes of cave-ins [3]observed in the Jeroným Mine.

3.3. CRITICAL FACTORS RESULTING FROM ANTHROPOGENIC ACTIVITY

From the geomechanical point of view [5], the monitoring of stability of the road II/210, which runs above the area of mine workings of the Jeroným Mine, is of paramount importance. The reason is the evaluation of mutual influences between traffic on the given road and the stability of mine workings in the area of mine workings of the Jeroným Mine.

The issue is solved by means of levelling measurement of heights of stable fixed points along both the sides of the road. The thickness of the rock pillar between the surface of the road and the roof of the known mine workings moves in the range from 25 to 40 m. The stability of the road II/210 in the Jeroným Mine area can also be influenced negatively by structures of rock mass weakening, namely old and yet unknown mine workings.

Fig. 4. Disturbed arch pillar

3.4. TIME FACTOR

The time factor is considered owing to weathering processes. We can reliably exclude gelivation and grinding action due to air movement. The following processes come into question:

- chemical processes based on the hydrolysis of feldspar minerals,
- mechanical processes associated with the pressure of water flow and subsequent suffosion,
- chemical processes related to the oxidation of rock environment.

The weathering processes and their influence on the stability of mine workings in the area concerned cannot be quantified reliably. In any case, the influence of them is negative. The weathering processes are a function of time and will continue taking place in the future regardless of human will.

4. CONCLUSION

Mine workings in the area of the historic landmark "Jeroným Mine" were developed in the course of several centuries. The present-day condition of mine workings has been affected by the above-described factors.

Instability problems manifest themselves only in a bridge caused by groundwater level fluctuations. In the case of passages and rooms, any changes exhibiting signs of instable behaviour have not been measured. With reference to the planned interconnection of both the systems with a connecting crosscut, which will run through verified, but unknown mine workings, instability manifestations can be expected above all in the Jeroným Mine surface area.

LITERATURE

[1] BERNARD J., SUČEK P.: *Studie zpřístupnění historického důlního díla Jeroným veřejnosti.* Rudné doly Příbram, Příbram 2000

[2] GRMELA A., ŽŮREK P., KUKUTSCH R., KOŘÍNEK R., *Hydrogeological and hydraulic relations of the old mine workings of the former Jeroným mine*. GeoScience Engineering, Volume LVII, Issue No.4, 2011.

[3] KUKUTSCH R., ŽŮREK P., STOLÁRIK M., *Monitoring and Documentation of Flaking-off Phenomena in the Historical Jeroným Mine*. Acta geodynamica et geomaterialia. Roč. 7, č. 3 (2010), s. 343–348.

[4] ŽŮREK P., KOŘÍNEK R., KALÁB Z., HRUBEŠOVÁ E., KNEJZLÍK J., DANĚK T., KUKUTSCH R., MICHALČÍK P., LEDNICKÁ M., RAMBOUSKÝ Z., *Historický Důl Jeroným v Čisté*. Monography, VŠB – Technická univerzita Ostrava a Ústav geoniky AVČR, v.v.i. Ostrava, 2008.

[5] ŽŮREK P, KOŘÍNEK R., MICHALČÍK P., DANĚK T., HUDEČEK V., KALÁB Z., KNEJZLÍK J, KUKUTSCH R., LEDNICKÁ M., *Odborné sledování geomechanické stability a seismického zatížení národní kulturní památky Důl Jeroným v Čisté*, Karlovarský kraj. Závěrečná zpráva HS č. 500 001, 2009

[6] ŽŮREK P, KOŘÍNEK R., MICHALČÍK P., DANĚK T., HUDEČEK V., KALÁB Z., KNEJZLÍK J, KUKUTSCH R., LEDNICKÁ M.: *Odborné sledování geomechanické stability a seismického zatížení národní kulturní památky Důl Jeroným v Čisté*, Karlovarský kraj. Závěrečná zpráva HS č. 500 102. 2010.