# PRIMARY RESEARCH OF MINE WATERS FROM THE CHRUSTENICE IRON-ORE DEPOSIT

# PRVOTNÍ PRŮZKUM DŮLNÍCH VOD ŽELEZORUDNÉHO LOŽISKA CHRUSTENICE

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**Abstract**

This paper describes the primary research of mine waters in the Chrustenice Iron-ore Deposit. A particular attention is paid here to the research of microorganisms living in that environment. The goal of the research is to analyse mine waters in the area which was abandoned by people more than 45 years ago and to investigate microorganisms and representatives of species present there in the mine waters. The Chrustenice Mine ranked among the biggest and most important iron ore mines in Barrandien. This mine along with the mines in Nučice, Zdice, Nový Jáchymov and Mníšek pod Brdy contributed to the fame of the regional mining industry. Sedimentary oolitic iron ore in Chrustenice consists mostly of red iron ore based on Černín layers, siderite and, to a lesser extent, of haematite and chamosite. In exceptional cases, magnetite is present there. The Černín shale is black clay shale with sandy ingredients and many potash-mica scales. Now, the mine is flooded up to the 8th level. In the remaining area, there is a mining history museum with dozens of exhibits. In samples of the mining water taken on the site, mostly iron, manganese and sulphur microorganisms were identified. The primary study of the mine waters in the iron-ore deposit shows that, from the microbiological point of view, this site is very interesting and many chemolithotrophic species of bacteria are present there.

**Abstrakt**

Tento článek popisuje prvotní průzkum důlních vod železnorudného ložiska Chrustenice. Článek je zaměřen především na průzkum mikroorganismů žijících v tomto prostředí. Cílem průzkumu bylo analyzovat důlní vody těchto více než 45 let člověkem nevyužívaných prostor především na mikroorganismy a zjistit zástupce jednotlivých rodů, které se v těchto vodách za daných podmínek vyskytují. Důl Chrustenice patřil k největším a nejvýznamnějším železorudným dolům Barrandienu a spolu s doly v Nučicích, Zdicích, Novém Jáchymově a Míšku pod Brdy založil slávu zdejšího hornictví. Chrustenické sedimentární oolitické rudy jsou tvořeny převážně krevelem na bázi černínských vrstev, dále pak sideritem, méně pak hematitem a chamositem, výjimečně také magnetitem. Černínské břidlice jsou černé jílovité břidlice s písčitou příměsí a jsou bohaté na šupinky muskovitu. V současné době je důl zatopen až na úroveň 8. patra. Ve zbylých prostorách je vybudována veřejně přístupná expozice historického dolování s desítky exponátů. Ve vzorcích důlních vod odebraných na

místě byly identifikovány především nálezy železitých, manganových a sirných mikroorganismů. Prvotní studie důlních vod železorudného ložiska ukazuje na velmi zajímavou lokalitu z mikrobiologického hlediska s vysokým výskytem chemolitotrofních druhů bakterií.

**Key words:** mine waters; iron-ore deposit; microorganisms; chemolithotrophic species of bacteria

## 1 INTRODUCTION

The Chrustenice Mine ranked among the biggest and most important iron ore mines in Barrandien. This mine along with the mines in Nučice, Zdice, Nový Jáchymov and Mníšek pod Brdy contributed to the fame of the regional mining industry. There were 84 underground levels in the Chrustenice mine, reaching down to a depth of 426 m (i.e. 120 m below the level of sea). The length of roadways there was about 15 km and the underground levels were connected via 36 inclined shafts. The Chrustenice Mine is the only one in Barrandien where visits were possible even after closedown of the mine in 1965. Since 1995, this mine is open to the public and offers an exhibition with mining exhibits. The mine is flooded now up to the 8th level. In other spaces, there is the mining history museum with dozens of exhibits which can be put into operation – such as mine trucks, a pneumatic loader, or drilling rigs.

## 2 GEOMORPHOLOGIC CHARACTERISTICS OF THE DEPOSIT

The Chrustenice iron-ore deposit is a part of the Bohemicum geological unit. To be more precise, it is a part of the Teplá-Barrandien area. The Chrustenice Mine was located under a woody slope close to the Chrustenice–Loděnice road. The slope with trees forms a valley to the south. The valley is crossed there by a railroad and the Beroun–Praha road. The nearest surroundings of the iron ore deposit is almost exposed, the outcrop is located on the slope of the Blejskavá Hill. The hillslope is covered by rock waste and slope loam with rather big pieces of quartz rock which are scattered in the loam. Fragments of typically heavily limonitised ore is also found there [3, 5].

The subsoil consists of layers of clay and sand sediments with minor benches of quartz rock and sandstone in lower layers where they co-occur with shale. For the lower boundary, coarse and fine sediments alternate frequently and are bound to flysch sediments. Towards the overlaying formation, there are mostly benches of sandstone and grey to black fine-grain quartz in a rather high thickness [4]. Fig. 1 shows the Czech Republic divided into geological units.


**Fig. 1** Division of the Czech Republic into geological units [10]

The sedimentary oolitic iron ore in Chrustenice consists mostly of red iron ore based on Černín layers which are black clay shale with sandy ingredients and many potash-mica scales [2].

The Chrustenice deposit is the tectonic continuation of the Nučice lenticular mass of ore. It is separated from the Krahulovec deposit by means of a dip fault. The both parts are different in terms of tectonics as well as in terms of mineralogy and petrography. In the Chrustenice mine, the western part of the lenticular mass of ore was excavated along 1,800 m. From the tectonic point of view, this is a rather calm section. In the core of the lenticular mass of ore, there was the best ore which was frequently referred to as "skleněnka" – it contained up to 40 per cent of iron and was surrounded by "makovka" containing up to 30 per cent of iron. Towards edges of the lenticular mass, there was a not so rich pelocarbonate ore and the entire lenticular mass was wrapped with the ore containing 25 per cent of iron. The minerals occurring most often in the deposit include calcite and Epsom

salt which was frequently present on walls of the mine shafts. The ore in the deposit consists mainly from Fe, Si, Al, Ca and O compounds. The vital iron-carrying mineral is siderite, to a lesser extent haematite and chamosite, and, in exceptional cases, magnetite [6]. The deposit is located on a dry site without major water courses. There is a small river approx. 750 m to the west. It, however, does not affect the water system in the mine. The groundwater and its quantities depend mostly on rainfall. Irruption of water in the mine is seldom and occurs typically after heavy rains or heavy snow-melt.

## 3 CURRENT SITUATION

The mine is flooded now up to the 8th level. In other spaces, there is the mining history museum with dozens of exhibits which can be put into operation – such as mine trucks, a pneumatic loader, or drilling rigs. The route for those who visit the Chrustenice Mine is about 1 km long. The visitors may see unique spaces and exhibits showing the difficult work of miners and quarrymen in Barrandien. Fig. 2 shows the access to the mine.

**Fig. 2** Access to the mine (the photo taken by the authors)

The mine can be entered via a supply gate built in 1926. Behind the entrance adit, there is a former machine area where the first trailing shaft ends. The main adit in the 8th level in the "Old Shaft" is connected via a short shaft. In a branch shaft, there is a water reservoir – in past, the water reservoir received waters from the main dewatering pipe located in the depth of the 72nd level. Above the water reservoir, there is an auxiliary ventilation raise which maintains fresh air there. The Old Shaft in the deposit subsoil ends in a remote "Old Shaft". That part of the site was made available to public in 1998. It is interesting that there are dripstones in shafts and adits. Visitors can see the machinery used in the advance heading: a drill rig, pneumatic loader or a chargeman's station. During the visit, visitors enjoy a mine truck ride as well.

The mine is also used for in-depth diving and testing of breathing mixtures for divers. Those who dive in the mine include divers from mining rescue teams, fire rescue teams, police and speleologists.

## 4 RESULTS OF THE SURVEY OF FLOODED GALLERIES

### 4.1 Phenotypic characteristics of strains

Samples of mining water in flooded galleries were put in line with ČSN EN ISO 5667 [11] into sterile sample containers. The samples were properly identified and processed within 24 hours after the sampling. A basic microscopy analysis was carried out by means of native specimens in a direct light and by means of immersion lens.

Mining activities can be the reason for chemolithotrophic ferrous, manganese and sulphur bacteria found there: *Gallionella, Leptothrix, Ferribacterium, Crenothrix, Beggiatoa, Thiothrix* and *Sideromonas* [1, 7, 8].

*Gallionella ferruginea* (Fig. 3) is one of most typical iron bacteria which oxidises dissolved bivalent iron, creating insoluble ferric hydroxide which twists as a result of its metabolism, fibres formed into helical curves which are easily to identify. The fibres branch reaches 100–200 µm. In samples, fragments of the fibres were found. The bacteria are located at the end of the fibres where they rotate, creating a spiral-like swing of the entire fibre. In the samples of water, two well-known sub-species of these bacteria were found: *Gallionella ferruginea* sp. *minor* with thin fibres and *Gallionella ferruginea* sp. *major* with coarse fibres.

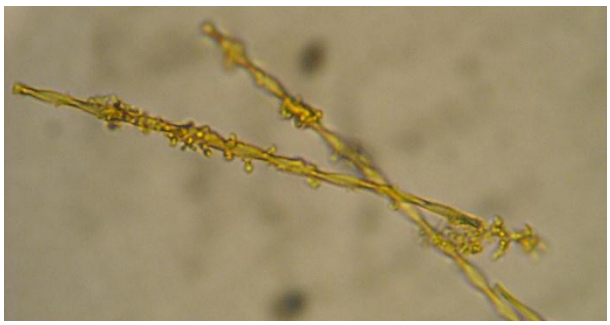

**Fig. 3** *Gallionella ferruginea* (1200x zoom, the photo taken by the authors)

An interesting finding was a very small iron rod-like bacterium which was described by Švorcová in 1975 as *Ferribacterium* sp. [9].

*Leptothrix ochracea* (Fig. 4) is a rod-like or fibre-like bacterium with a shell incrusted either with iron or manganese oxide. In the specimens, the identified bacteria occurred in a form of fibre-like colonies surrounded by frequent precipitates of trivalent iron or manganese.

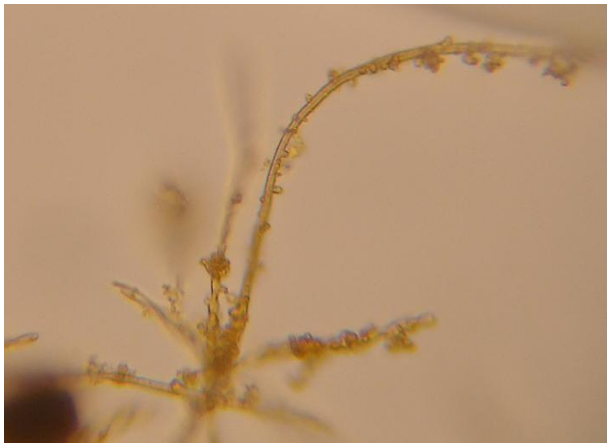

**Fig. 4** *Leptotrix ochracea* (1200x zoom, the photo taken by the authors)

*Crenothrix polyspora* is a metanotrophic bacterium with fibrous morphology consisting of several development levels of various morphologies. A detailed ultrastructural analysis of the gramengative bacteria showed that there was a multi-layer sheath on the surface of the fibres.

Sulphuric bacteria were represented mostly by *Beggiatoa* sp. a *Thiothrix* sp. which were oxidised by means of sulphan oxygen dissolved in water. These microorganisms were found on the border of the microaerobic and anaerobic systems in a thin layer next to the surface of the water. The both bacterial species were also found as a part of fine sludge which was present as a film on the bottom of shallow waters. In consequence of these activities, the bacteria were observed in microscopic specimens as crystals of sulphur and sulphur compounds because it is, in particular, the *Beggiatoa* bacteria which oxidises first sulphan to elemental sulphur which is visible as amorphous light-refraction drops in fibres – after sulphan from the environment is used up, the bacteria oxidises the accumulated sulphur creating sulphates which enter the surrounding environment.

## 5 CONCLUSIONS

In the samples of the mine waters taken on the site, mostly iron, manganese and sulphate microorganisms were found. There were 7 bacterial classes found in the specimen: *Gallionella, Leptothrix, Ferribacterium, Crenothrix, Beggiatoa, Thiothrix, Sideromonas*; for some classes, several types were found. The primary study of the mine waters in the iron-ore deposit shows that, from the microbiological point of view, this site is very interesting and many chemolithotrophic species of bacteria are present there. Because the site is rather attractive and easy to access, it is advisable to continue the microbiological survey of the site on the basis of the current chemical-biological condition of the mine waters in the worked-out Chrustenice Mine.

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## RESUMÉ

Důl Chrustenice patřil k největším a nejvýznamnějším železorudným dolům Barrandienu a spolu s doly v Nučicích, Zdicích, Novém Jáchymově a Míšku pod Brdy založil slávu zdejšího hornictví. Článek je zaměřen především na prvotní průzkum této lokality formou mikroskopické analýzy vodních mikroorganismů žijících v prostředí opuštěného dolu. Ve vzorcích důlních vod odebraných na místě byly identifikovány skupiny železitých, manganových a sirných bakterií rodů *Gallionella, Leptothrix, Ferribacterium, Crenothrix, Beggiatoa, Thiothrix* and *Sideromonas*, jejichž nálezy dokládají předchozí hornickou aktivitu v této oblasti. Studie je doplněna originálními a dosud nepublikovanými fotografickými snímky nativních preparátů dvou nejčetnějších bakteriálních druhů – *Gallionella ferruginea* a *Leptotrix ochracea,* které byly ve vzorcích identifikovány ve formě inkrustovaných vláknitých kolonií, tvořících četné sraženiny železa a manganu.

Prvotní studie důlních vod železorudného ložiska ukazuje na velmi zajímavou lokalitu z mikrobiologického hlediska s vysokým výskytem chemolitotrofních bakteriálních druhů.