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URANIUM INDUSTRY AND RALSKO

T. Kafka: *Uranium industry and Ralsko.* – Geografie – Sborník ČGS, 103, 3, pp. 382 – 389 (1998). – The former Ralsko military training area is situated in close proximity to the region where uranium is mined. The paper deals with the history of uranium mining and with geological conditions of the territory and characterizes the methods of extraction used – deep mining of uranium ore and chemical extraction by in-situ lixiviation. Attention is paid to the present organization structure of the uranium industry and to the work of the state firm DIAMO with regard to the elimination of impacts of uranium ore extraction and processing.
KEY WORDS: uranium ore – deep mining – chemical extraction – elimination of impacts of mining.

Introduction

The uranium industry has a long tradition in the Czech Republic. As an institution, it was founded in 1945 based on an agreement between the former Czechoslovakia and the Soviet Union on prospecting and extraction of radioactive raw materials. It has progressively developed into a complex industrial branch providing, besides prospecting and extraction of uranium ore deposits and their processing, also other activities such as laboratory and technical research, chemical production, project-making and building activities, etc.Until the late 1980's, the production of extracted uranium concentrate corresponded to the planned economic system with regular annual volumes which were not influenced by oscillations of supply and demand on the world uranium market. Following a damping programme promulgated in 1989, the production was at first largely reduced, then individual mining plants were progressively closed and the organization restructured. In the second half of the 1990's, uranium concentrate has been produced from only two deposits, in Rožná, Southern Moravia, where ore is mined in the classical way, and in Stráž pod Ralskem, in the region of Česká Lípa, where the method of in-situ chemical lixiviation of uranium by sulphuric acid is used. The main activity of the DIAMO firm is now the liquidation of extraction and processing facilities and decontamination of the environment damaged by extraction and processing of uranium ore.

During its more than 50 year history, the uranium industry has developed a large know-how in the field of prospecting and extraction of uranium deposits, technologies of uranium ore processing, mining technologies, geology and hydrogeology, technology of deep in-situ lixiviation, mathematical modelling of technological, hydrochemical and hydrogeological processes, elimination and ecological decontamination of environmental impacts of uranium ore extraction and processing.

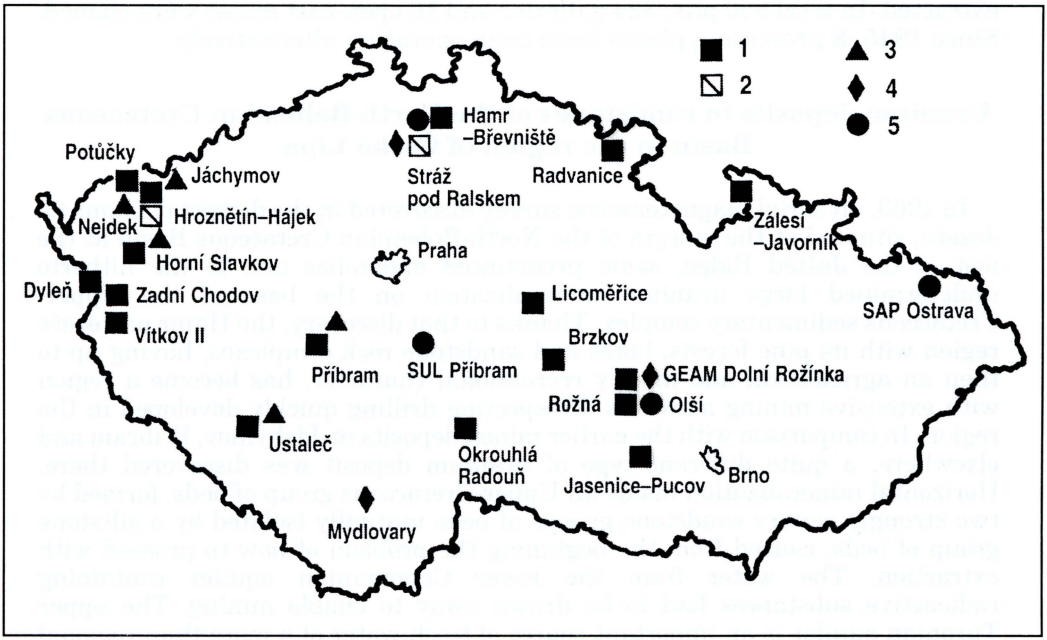

Fig. 1 – State firm DIAMO, Stráž pod Ralskem – mining and processing plants and seat of individual plants. 1 – deep mining, 2 – chemical extraction, 3 – radiometric processing plant, 4 – chemical processing plant, 5 – individual plant. Stráž pod Ralskem, Rožná = present producers of uranium.

The state firm DIAMO is the only organization in the Czech Republic involved in extraction and processing of uranium ore. Its present form dates from 1992 when it was declared successor organization to the former group Czechoslovak uranium industry. The DIAMO is exclusively owned by the state and directed by the Czech Ministry of Industry and Trade.

The present organization structure of the DIAMO firm corresponds to the character of the firm's activities and to the distribution of its activities in the territory of the Czech Republic (see Figure 1). DIAMO, Stráž pod Ralskem, is divided into a total of nine individual plants. Extraction and processing of uranium ore and production of uranium concentrate are now provided only by the plant GEAM, Dolní Rožínka, and the plant CHT, Stráž pod Ralskem. Two other important plants are the SUL, Příbram, involved in administration and elimination of historical mining localities, such as Příbram, Jáchymov region, Horní Slavkov, Okrouhlá Radouň, etc. and the plant TÚU, Stráž pod Ralskem, responsible for the elimination of the deep mining and processing plant in Hamr na Jezeře – Stráž pod Ralskem, region of Česká Lípa. From the historical viewpoint, it is worth mentioning the chemical ore processing plant in Mydlovary, Southern Bohemia, the liquidation and decontamination of which is done by the MAPE, Mydlovary. Outside the framework of uranium activities, we should mention the plant SAP, Ostrava, founded in 1997 to ensure decontamination of oil lagoons of the Ostramo concern.

The Czech Republic is an important uranium region with a number of deposits of vein and sandstone type. In total, 194 deposits and ore occurrence have been prospected on the territory of the Czech Republic, 74 of them being

extracted. In total 550 pits, 324 galleries and 16 open-cast mines were opened. Since 1945, 8 processing plants have been operating alternatively.

Uranium deposits in sandstones of the North-Bohemian Cretaceous Basin in the region of Česká Lípa

In 1963, an aerial magnetometric survey discovered in the district of Hamr na Jezeře, situated at the margin of the North-Bohemian Cretaceous Basin at the foot of the Ještěd Ridge, some pronounced anomalies due to the hitherto undetermined large uranium mineralization on the base of the Upper-Cretaceous sedimentary complex. Thanks to that discovery, the Hamr na Jezeře region with its pine forests, lakes and sandstone rock complexes, having up to then an agricultural and mainly recreational character, has become a region with extensive mining activities. Prospecting drilling quickly developed in the region. In comparison with the earlier mined deposits in Jáchymov, Příbram and elsewhere, a quite different type of uranium deposit was discovered there. Horizontal mineralization inside an Upper-Cretaceous group of beds, formed by two strongly watery sandstone groups of beds mutually isolated by a siltstone group of beds, caused from the beginning the problem of how to proceed with extraction. The water from the lower Cenomanian aquifer containing radioactive substances had to be drawn away to enable mining. The upper Turonian aquifer is an important source of fresh water of a more than regional significance. When orienting the mining it was thus necessary to prevent any communication between these two water-bearing horizons and damaging of the Turonian aquifer. From the beginning, the selection of an appropriate mining method went in two directions – to open the deposit in the classical mining way through pits or to use the method of underground lixiviation through drills from

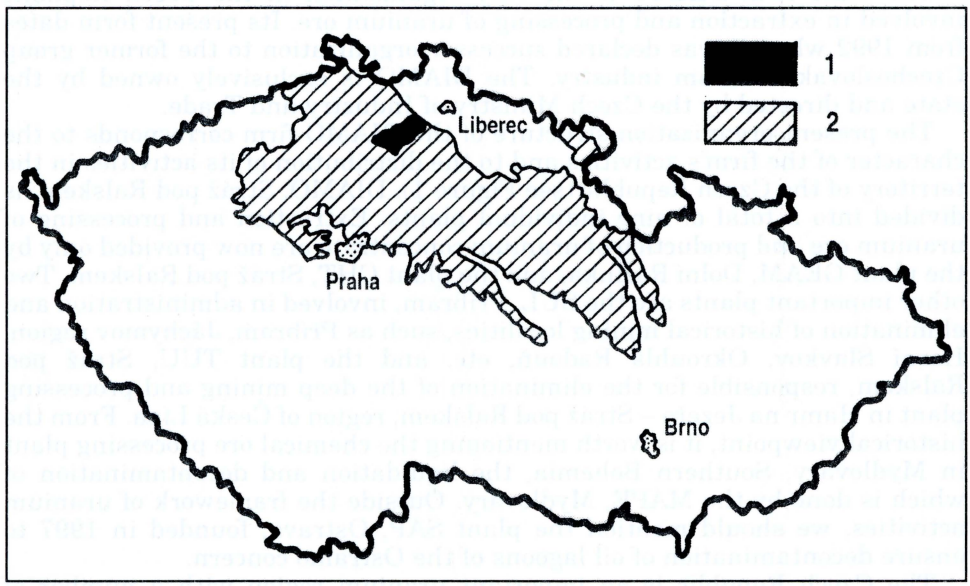

Fig. 2 – Position of the Stráž block within the Czech Republic. 1 – Stráž block, 2 – Bohemian Cretaceous Basin.

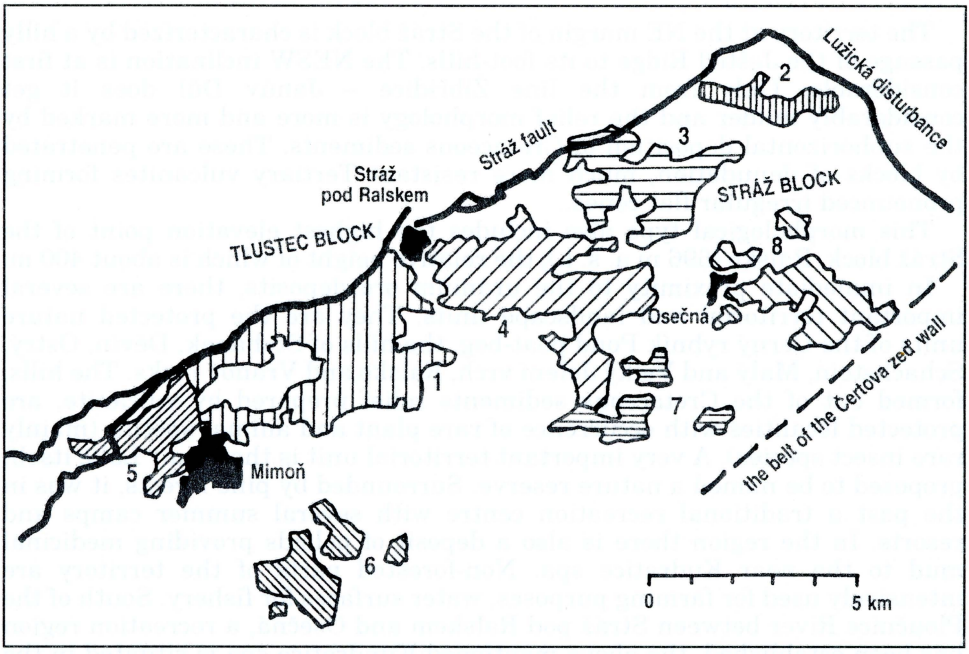

Fig. 3 – Uranium ores deposits in the region of the Stráž block. 1 – Stráž deposit, 2 – Křižany deposit, 3 – Břevniště deposit, 4 – Hamr deposit, 5 – Mimoň deposit, 6 – Hvězdov deposit, 7 – Holičky deposit, 8 – Osečná-Kotel deposit. a – Tlustec block, b – Stráž block, c – Stráž fault, d – Lužická disturbance, e – the belt of the Čertova zeď wall.

the surface. In total, 8 deposits were prospected (and their reserves determined) in the region and three of them – Hamr, Břevniště and Stráž – were consequently exploited. The total uranium production from this deposit agglomeration reached 25 000 t. The position of the Stráž block within the Czech Republic territory is visible in Figure 2. Figure 3 shows then the localization of individual deposits in the region of the Stráž block.

From the geological viewpoint, they are deposits situated on the base of the Upper-Cretaceous sedimentary complex of the Stráž block structural unit, in the underlayer of which there are metamorphosed rocks of the crystalline complex (mainly phylites), relics of filling of older sedimentary basins, granites and porphyries. The Cretaceous complex begins with a group of beds of fresh water Cenomanian sediments, and continues with a group of beds of Cenomanian sea disintegrating and fucoid sandstones covered by Lower Turonian siltstones. The highest part of the Stráž block Cretaceous complex consists of Middle Turonian ashlar sandstones protruding to the surface. The total thickness of the Cretaceous sediments reaches on average about 250 m. The Cretaceous complex is largely disturbed by tectonic activities and penetrated by veins and Tertiary vulcanite bodies.

In the Upper Cretaceous sediments two aquifers have developed – the Cenomanian one with extended underground water plan and the Middle Turonian one with a free underground water plan. Both aquifers are separated by an impermeable group of beds of Lower Turonian siltstones. The general direction of the underground water flow of both collectors is from the NE to the SW.

The territory at the NE margin of the Stráž block is characterized by a hilly passage of the Ještěd Ridge to its foot-hills. The NESW inclination is at first considerable. Only from the line Žibřidice – Janův Důl does it get considerably milder and the relief morphology is more and more marked by the subhorizontal deposition of Cretaceous sediments. These are penetrated by blocks of denudation, much more resistant Tertiary vulcanites forming pronounced irregular flat cones.

This morphological type also includes the highest elevation point of the Stráž block, Ralsko (696 m a. s. l.), the relative height of which is about 400 m.

In immediate proximity to the uranium ore deposits, there are several important territorial and landscape units. They are the protected nature units of the Černý rybník Pond peat-bog, the hills of Stohánek, Děvín, Ostrý, Schachstein, Malý and Velký Jelení vrch, Ralsko and Vranov rocks. The hills, formed out of the Cretaceous sediments relief prepared by vulcanite, are protected localities with occurrence of rare plant and animal species (mainly rare insect species). A very important territorial unit is the Hamr Lake itself, proposed to be named a nature reserve. Surrounded by pine forests, it was in the past a traditional recreation centre with several summer camps and resorts. In the region there is also a deposit of peloids providing medicinal mud to the near Kudratice spa. Non-forested parts of the territory are intensively used for farming purposes, water surfaces for fishery. South of the Ploučnice River between Stráž pod Ralskem and Osečná, a recreation region has been established, the above-mentioned Kundratice spa is situated in the immediate neighbourhood of Osečná.

To the SE of the region of lixiviation fields of the uranium chemical extraction there is the former Ralsko military land which was for many years administrated by the Soviet army. Although it is only hypothetical to consider any mutual influence of both differently used regions, they were connected by a statute of, in the time of communism, strongly watched and secret territorial units. Both territories are connected with purpose communications, mainly in the neighbourhood of the Svébořice Village directly situated at their limit. To the N and NW of Svébořice, there are lixiviation fields VP16, VP15, VP14B, VP14A and VP9B. To the S and SE there are forests of the military land with infantry and artillery shooting range. The protected deposit territory Ploužnice, connected with the radioactive matter deposits Hvězdov, is partly situated on the military land territory.

The territory of lixiviation fields of the Stráž pod Ralskem deposit is situated in the area of the protection zone of the Mimoň water resource. Because of the importance of this resource, high requirements on its protection against technological solutions pollution are laid.

Deep mining of uranium ore in the Hamr and Břevniště deposits

In the years 1965 – 1975 a large mining plant was built in Hamr na Jezeře and a chemical ore processing plant the near Stráž pod Ralskem. The chemical processing plant started to operate in 1975. Since the mid 1970s deep mining has extensively developed not only in the Hamr deposit (Hamr I mine), but also in the Břevniště deposit situated at 4 km to the NE of Hamr. Construction of the Křižany I mine started in 1973 and it was operated from the end of 1983. Because of changed needs for uranium ore, this mine has been liquidated since 1990. In 1980, the pits of the Hamr II mine – Lužice

started to be excavated. In June 1988, further mining activities in the prepared mine were abandoned for economic reasons and the whole plant started to be liquidated.

Simultaneously with the mine building, the first experiments with underground lixiviation of uranium through surface drills started. The first industrial quantity of uranium from the experimental lixiviation field VP3 was obtained in November 1967. This one as well as the later lixiviation experiments were unfortunately practised in the Hamr deposit in the proximity of the mine. Chemical extraction through in-situ uranium lixiviation has been, since the beginning of the 1970's, extensively applied in the neighbouring deposit Stráž, situated approximately at 3 km to the SW.

The coexistence of deep and chemical mining in two deposits of the same type and in the same lithostratigraphical environment caused many technological problems. The most important of them was the necessity to ensure the necessary level of Cenomanian waters for chemical extraction in the region of the Stráž deposit. This was done by the creation of an artificial hydraulic water-shed – a barrier between the region of deep mining and the region of lixiviation fields. The barrier is formed by a line of inset hydraulic drills which from the NE and E surround on the perimeter a part of the area of lixiviation fields of the Stráž deposit. The total length of the barrier is about 6 km. A smaller hydraulic barrier was later built between the communes of Svébořice and Mimoň at the SE margin of lixiviation fields with a view to preventing leakage of technological solutions. The system of hydraulic barriers is a sort of technical uniqueness of the region.

Chemical extraction by in-situ lixiviation in the Stráž deposit

Chemical lixiviation of uranium in situ, that is directly in the rock environment, is, under favourable geological and technological conditions, both an economically and ecologically acceptable mining method. This mining technology consists, put simply, in insetting a lixiviation agent (in the case of the Stráž deposit of dissolved sulphuric acid) into the ore-bearing rock layer through a system of surface drills. The solution passes through the rock environment, where uranium is lixiviated. Enriched by an effective component, it is drawn by a second drilling system up to the surface, where it is further chemically processed. After obtaining uranium, the solution is regenerated and again inset underground. Unfortunately, in the Hamr – Stráž locality both deep and chemical mining developed in close proximity which considerably complicated the running of both plants. In addition, chemical extraction quickly developed in the 1980's. The increase of lixiviation fields area and of the volume of inset solutions did not correspond to the level of knowledge about the possible negative impact of this method on the environment. The risk of contamination of the Turonian aquifer, which is a source of fresh water, was more and more evident with the development of knowledge about the geological structure of the territory.

The principle of the method of chemical extraction makes it clear that this technology mainly influences rock environment and underground waters by introduction of lixiviation solutions and other chemical substances. To a lesser extent, ecosystems are influenced as changes affect the landscape (deforestation of lixiviation fields, building of roads and open-cast mines), soil

conditions, soil chemism and water regime. These impacts are of a lesser extent than in classical deep or open-cast mining.

Underground waters were most affected in the ore-bearing Cenomanian group of beds. The insetting of technological solutions progressively contaminated 186 mil. m^3 of water. The region of contamination of Cenomanian waters covers an area of 24 km^2. The principal contaminants are sulphates, ammonia ions, aluminium ions and radionuclides, mainly uranium and thorium. The total quantity of dissolved matters in the Cenomanian collector is about 4,8 mil. t.

The contamination of water of the Turonian collector is an undesirable secondary impact of chemical extraction. It progressively occurred during the mining, that mainly through leaching of surface leaks of lixiviation solutions, by an impairing of drill equipment and by a passage of contamination from the Cenomanian aquifer into places of natural or artificial communication between the Turonian and the Cenomanian collectors. In total, 80 mil. m^3 of Turonian water in an area of 7.5 km^2 was contaminated, the principal contaminants being sulphates and ammonia ions. In total, there are in the Turonian horizon 25 to 30 thousand t of dissolved matters. The contamination of the Turonian collector is not of area character, but it forms "lens" clouds which correspond to the way of its formation. The contamination of Turonian waters is a serious problem because of the fact that the region of chemical extraction is situated within the protected region North-Bohemian Cretaceous.

Chemical extraction of uranium started in the region of the Stráž block in the second half of 1960's. During the 30 years of mining, about 4.100,000 t H_2SO_4, 300,000 t HNO_3, 113,000 t NH_3, 26,000 t HF and 1,000 t HCl were introduced into the rock environment. About 1,500 geological prospecting drills, 600 hydrological drills and 7,700 technological drills were done for mining purposes. A great majority of drills pass through the impermeable siltstone group of beds of Lower Turonian separating the Cenomanian and the Middle Turonian collectors. This artificial deterioration of the isolation character of the Lower Turonian siltstones represent, because of the hydrological regime, a great risk for the Turonian aquifer.

Liquidation of uranium ore mining and processing impacts in the Hamr – Stráž region

The aim of decontamination measures is a complex liquidation of mining works and surface equipments in the whole region, with the exception of surface buildings and equipments suitable for further usage, decontamination and recultivation of dumps and slime pits and their progressive incorporation into the landscape. The aim of liquidation activities and decontamination measures with regard to obliteration of impacts of chemical extraction of uranium is to bring the rock environment into a state which would prevent a deterioration of the fresh water contained in the North-Bohemian Cretaceous, and consequently to liquidate the drills and the non-usable equipment which were used for mining, and finally to recultivate the surface of lixiviation fields based on plans for the future usage of the territory.

On the time scale, liquidation of deep mining is divided into three basic stages, during which the mined underground spaces will be progressively stowed, the mining works reaching up to the surface and surface areas of

mining plants and drills will be liquidated and some dumps recultivated. Pits and drills must be liquidated in such a way as to prevent any communication between the Turonian and the Cenomanian aquifers. Further on, the chemical processing plant will be liquidated, waste rocks from dumps will be used for decontamination of slime pits. The slime pits of the chemical processing plant will be the last to be liquidated and decontaminated, and then biologically recultivated. Monitoring will be carried on in exposed places of the region.

The problems of further chemical extraction of uranium in the Stráž region were solved by the Government of the Czech and Slovak Federal Republic or of the Czech Republic in the period 1990 – 1996. Progressively a series of proposals of further steps to be taken were elaborated. Finally the chemical extraction of uranium in Stráž pod Ralskem was stopped on the 1st of April 1996 after ecological-economic evaluation of possible variants.

Decontamination of the rock environment is the most complicated liquidation activity in terms of both time and financial costs. It will be carried out in several stages during the next thirty years.

The first step in the decontamination of chemical extraction is the creation of hydraulic underbalance in the Cenomanian aquifer in the region of lixiviation fields in order to prevent a further extension of contamination in the as yet unaffected rock environment. Since 1996 the decontamination processing of solutions has been done by the technology of evaporation that allows the introduction of underbalance by leading out of about 5.5 m3/min of distilled water. After the setting up of linked up processing technologies, the Cenomanian solutions will be progressively cleared from the dissolved salts. The purified water will be discharged into water gauges or used for decontamination and the obtained salts will be processed to industrially usable products or materials. The final level of reduction of contamination in the Turonian and Cenomanian aquifers has not yet been determined and will be accurately discovered in the course of decontamination. The decontamination of rock environment will be completed by immobilization of residual contamination.

After the completion of rock environment decontamination, all the drills will be progressively liquidated with the exception of those used for monitoring after the completing of the total liquidation.

The surface of lixiviation fields was divided according to the way of its recultivation. The territory of the present chemical extraction will serve in future for recreation purposes with a particular stress put on forestry and nature protection.

The liquidation of chemical extraction is a complex problem, in its connections unique even at the international scale. The completion of liquidation should be achieved in approximately 2040 and its costs will reach tens of milliards CZK.

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