FIELD EXPLORATION GEOLOGY VOL. X

ENERGY RAW MATERIALS OF THE CZECH REPUBLIC

SEPTEMBER 4 – 13, 2023

MASARYK UNIVERSITY
BRNO SEG STUDENT CHAPTER

MUNI SCI Department of Geological Sciences

GUIDEBOOK

Masaryk University Brno
SEG Student Chapter

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Masaryk University Brno

Field Exploration Geology Vol. X

Energy Raw Materials of the Czech Republic

September 4th - September 13th 2023
Czech Republic

Editors
Kateřina Musilová
Jakub Vácha

MUNI SCI

SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

Masaryk University Brno SEG Student Chapter
Society of Economic Geologists (SEG)
Department of Geological Sciences - Masaryk University Brno

Cover: Photo of wood engraving from Georgius Agricola masterpiece De re metallica libri XII (issued 1556, Basel). Design by Kamil Sobek.

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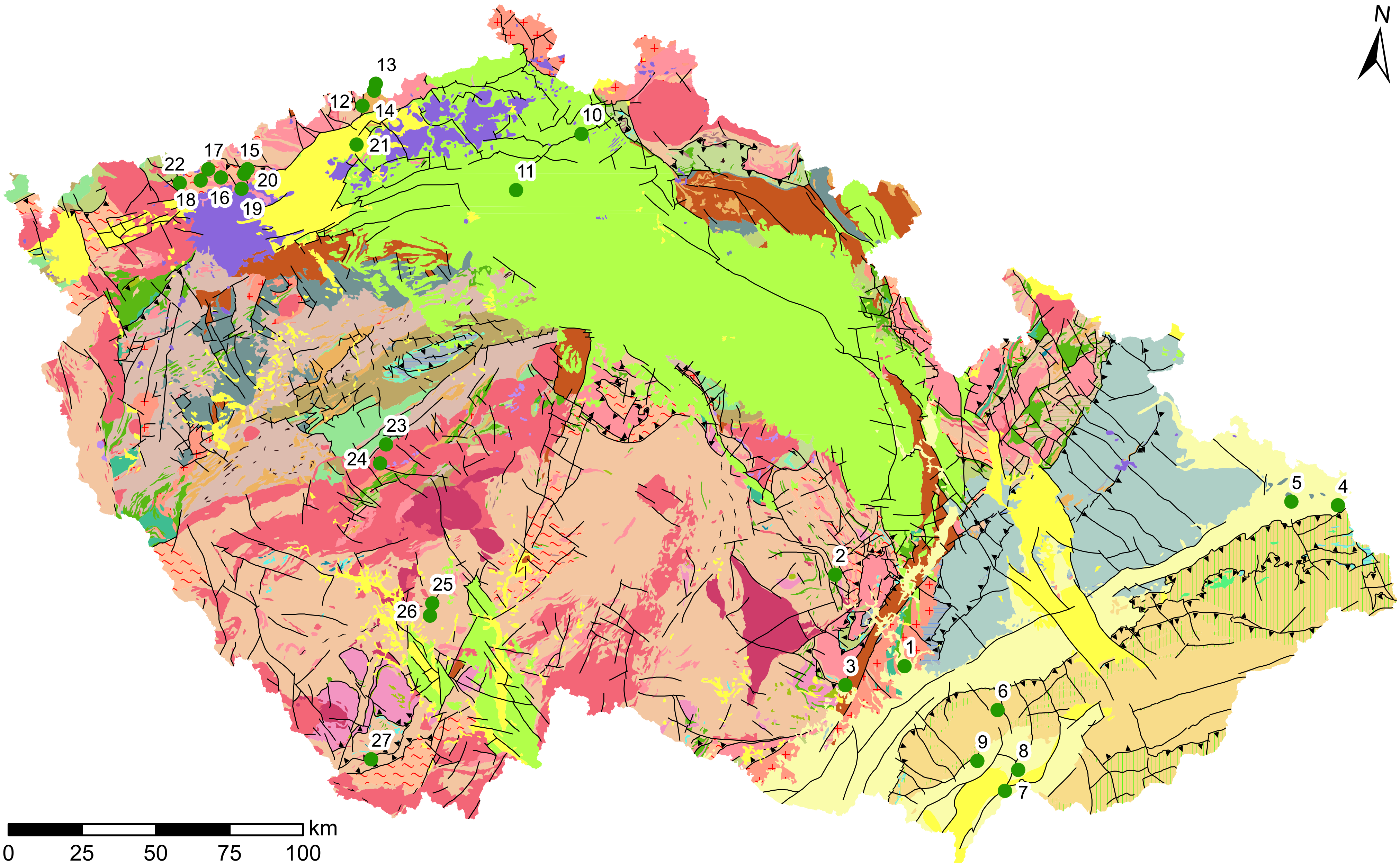

Simplified geological map of the Czech Republic.
Modified after Czech Geological Survey: Geoscience maps 1 : 500,000.

Tertiary of the Bohemian Massif

- clays, sands, gravel, minor coal and lignite beds, diatomaceous earth
- basalts, basanites, tephrites, foidites, trachybasalts, trachyandesites, trachytes, phonolites, basaltic volcanoclastics

Mesozoic of the Bohemian Massif

- predominantly Cretaceous marine claystones, marlstones, siltstones, sandstones and conglomerates

Mesozoic and Tertiary of the Carpathians

Late Paleogene and Neogene of the Alpine-Carpathian Foredeep

- clays, marls, sands, gravel, limestones, locally tuffites, lignite and gypsum

Marine Mesozoic, Paleogene and Neogene

- teschenites, picrites
- Jurassic variegated marlstones and limestones
- Cretaceous variegated claystones, marlstones, sandstones, minor conglomerates, locally cherts and limestones
- Paleogene–Neogene variegated claystones, marlstones, cherts, sandstones, conglomerates, limestones, locally andesites and tuffites

Paleozoic

Permian

- predominantly terrestrial claystones, mudstones, sandstones, arkoses, conglomerates, locally coal beds

Upper Carboniferous of synorogenic and postorogenic basins

- predominantly terrestrial mudstones, sandstones, arkoses, conglomerates, coal beds

Carboniferous of the Foredeep (flysch Culm)

- shales, greywackes, conglomerates

Devonian

- phyllites, quartzites, metaconglomerates, marbles and various metavolcanics
- limestones, locally shales, siltstones, sandstones

Ordovician

- shales, siltstones, sandstones, quartzites, cherts, basalts, locally slightly metamorphosed

Silurian

- shales, limestones, basalt intercalations

Cambrian

- shales, sandstones, conglomerates, quartzites

?Cambrian – Lower Carboniferous (undifferentiated)

- slightly metamorphosed siliciclastic sediments, locally intercalated with marbles and metavolcanics

Precambrian and/or Paleozoic (undifferentiated)

- variegated gneisses and migmatites intercalated with quartzites, calc-silicate rocks, marbles, eclogites, skarns, peridotites
- mica schists intercalated with quartzites, skarns, calc-silicate rocks, eclogites, marbles
- phyllites

Precambrian and Paleozoic Volcanics and Metavolcanics

- rhyolites, dacites, trachytes, andesites, basalts and associated tuffs, usually slightly metamorphosed
- greenschists, amphibolites

Intercalations in Precambrian and Paleozoic

- calc-silicate rocks
- marbles
- quartzites
- cherts

Lower Crust and Mantle Rocks

- granulites
- peridotites, serpentinites

Neoproterozoic

- siliciclastic sediments (mainly shales, greywackes, olistostromes, conglomerates), slightly to highly metamorphosed

Intrusives

Variscan intrusives

- variegated granitoids
- melanocratic syenites (durbachites)
- diorites, gabbros

Intrusives of Prevariscan or unknown age

- variegated granitoids, locally deformed and metamorphosed
- variegated metagranitoids and orthogneisses
- (meta)diorites, (meta)gabbros

Tectonic lines

- overthrust fault
- shear zone
- fault

Localities: 1 - Brno: Masaryk University; 2 - Dolní Rožínka: Bukov mine; 3 - Oslavany: museum of coal, mining heritage; 4 - Karviná: ČSM-North mine; 5 - Ostrava: Main mine rescue services; 6 - MND: Ždánice; 7 - Hodonín: museum of oil and gas; 8 - Ratíškovice: museum of lignite; 9 - Čejč: lignite seam; 10 - Stráž pod Ralskem: uranium leaching; 11 - Medonosy: sandstone formation; 12 - Mikulov: coal addit, medieval mine; 13 - Altenberg: old mine; 14 - Zinnwald: old mine; 15 - Výsluní: scheelite occurence; 16 - Mýtinka: old mines; 17 - Kovářská: former mine; 18 - Meluzína hill: rutile occurences; 19 - Klášterec nad Ohří: zeolite occurence; 20 - Hradiště u Kadaně: old mine dump; 21 - Bílina: brown coal mine, coal powerplant Ledvice; 22 - Jáchymov: Svornost mine; 23 - Příbram: sorting facility - uranium mine dump; 24 - Vrančice: old mines; 25 - Bohunice near Týn n. Vlt.: brickery, clay mining, lignite seam; 26 - Temelín: nuclear powerplant; 27 - Světlík: peat mine

Basic topographic map of the Czech Republic; State Administration of Land Surveying and Cadastre

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Introduction

Zuzana Bartošová

This guidebook was created for the purpose of "Field Exploration Geology" organized by SEG Student Chapter Masaryk University Brno. We are happy to announce that this year we are celebrating the 10th anniversary of our big field trips and therefore it will be full of interesting localities and visits. The event will be focused on energy raw materials found in the Czech Republic and in our guidebook, you can find a summary of knowledge related to the localities we are going to visit during our trip. Previous field trips took place mainly in localities in metallogenetic provinces of the Variscan part of the Bohemian Massif and also few localities in Slovakia, Poland, Germany and Hungary: Gold deposits in the Central Bohemia (2012), Erzgebirge (2013), Gold deposits of the Bohemian Massif (2014), Oberpfalz region (2015), Erzgebirge (2016), Slovak Ore Mountains (2017), Poland (2018), Eger Graben (2019) and Western Carpathians (2022). During 2020 and 2021, all chapter activities were on hold due to the Covid. Beginning in 2022, chapter members organize field trips and various activities, again.

The 10th volume – Energy Raw Materials of the Czech Republic is mainly focused on deposits of energetic raw materials in the Czech territory – coal, oil, natural gas (known as fossil fuels) and uranium. Coal has huge reserves and the black coal was mined in many locations in the country, but nowadays mining still works only in the Upper Silesian Basin. The open pit mining of brown coal (lignite) is still widespread. The oil is found especially in the South Moravian region but the total amount is not significant. Uranium mining has a long tradition in the Czech Republic and the mine in Rožná was the longest and last active uranium mine in Central Europe (terminated in 2017).

During this field trip we are going to visit and look at several interesting locations, such as underground research facility in the former Rožná uranium mine, underground active black coal mining near Ostrava, active oil and gas mining in Hodonín, active uranium leaching site under decommissioning in Stráž pod Ralskem, active open pit brown coal mining Bílina, former uranium mine in Jáchymov, uranium mine dumps in Příbram, Temelín nuclear power plant, and many more. We also will not miss several museums.

Lastly, we would like to thank to the Department of Geological Sciences at Masaryk University Brno (ÚGV MU) and the Society of Economic Geologists (SEG) for the financial and material support. We are also very grateful to our industry (P. Reichl) and academic (J. Leichmann) advisors for planning during the initial stages and help with funding proposal. For consulting several aspects of the fieldtrip organization, we thank to R. Škoda. We would like to express our gratitude to the lecturers of our short course – D. Drábová, J. Franců a J. Leichmann. Thanks also go to other colleagues from the university for technical support and help with the short course preparation. We would like to thank following companies and individuals: DIAMO, odštěpný závod GEAM (P. Vinkler and his coworkers), SÚRAO (L. Vondrovic, J. Smutek), OKD (R. Sikora, D. Hájek, K. Blahut and local geologists), DIAMO, odštěpný závod HBZS – Ostrava (V. Tesarčík and coworkers), MND (V. Opletal), DIAMO, odštěpný závod TÚU (M. Kroupa and coworkers), Severočeské doly (K. Mach), ČEZ – ELE (P. Jirava), Lázně Jáchymov (M. Přibil), ECOINVEST Příbram (J. Bětík), Wienerberger, závod Týn n. Vlt. (V. Fajtl), ČEZ – ETE (J. Kaňkovský, P. Šimák and coworkers), Rašelina – závod Světlík (P. Prokůpek) and all visited museums and visitor mines. Many thanks also belong to our colleagues, SEG members and friends for help with preparations, acquiring contacts and contributions for this guide book.

Zdař Bůh!

General geology of the Czech Republic

Sára Kozáková

The Czech Republic is located in the centre of Europe and consists of complex geological evolution and structure. It is divided into 2 major geological units: Bohemian Massif, which contains most of the Czechia, and Western Carpathians, which is a much smaller unit, located at the most eastern part of the country.

Western Carpathians

Western Carpathians are divided into: the Carpathian Foredeep, the Flysch and Klippen Belts, the Central and Inner Carpathians, the interior Paleogene and Neogene depressions and the Tertiary neovolcanites (Fig. 1; Blizkovsky et al. 1994). Western Carpathians of Czech Republic consist of Carpathian Foredeep and small part of the Flysch belt.

On the slope of the Bohemian Massif is located the Carpathian Foredeep. It is filled with around 1000 m thick molasse of a Neogene age. The Flysch zone is folded and laying on top of the Foredeep and partly also on the Bohemian Massif (Blizkovsky et al. 1994).

Bohemian Massif

Bohemian Massif is a part of the Variscan belt, occurring at its eastern side. The unit consists of metamorphosed Precambrian to Early Paleozoic crystalline basement which is covered by Paleozoic sediments (Blizkovsky et al. 1994). The belt forming the Massif can be divided into different major units: The Saxothuringian domain, The Moldanubian domain, The Teplá-Barrandien (Bohemian) domain and The Brunovistulicum domain. By some authors, The Lugian domain and The Platform cover of Bohemian Massif are also classified as major units (Schulmann et al. 2009).

The Saxothuringian domain is located in the western part of Czechia and is represented by Proterozoic metamorphed rocks, which were formed by intruded migmatites and paragneisses and variscan granitoid plutons. They are uncomformably covered by Cambrian and Ordovician rift sequences and are overlain by Ordovician and Late Devonian sediments and Carboniferous Flysch (Schulmann et al. 2009).

The Teplá-Barrandien (the Bohemicum) domain lays in the centre of Czech Republic. It consists of Neoproterozoic basement, uncomformably overlain by Upper Cambrian volcanic sediments, followed by siliceous black shales and flyshoid sequence (CGS 2022).

The Moldanubian domain is in the southern and south-western part of Czechia and can be divided into 3 defining units: the Monotonous Group, the Varied Group and the Gfohl Unit. The Monotonous Group is the biggest and deepest tectonic unit and is represented by Proterozoic sediments and Late Proterozoic to Early Palaeozoic orthogneisses, quartzites and amphibolites. The Varied Group is above the Monotonous Group and can be found on 3 independent locations in the domain. This group consists of gneisses and migmatites, quartzites and crystalline limestones (Svoboda et al. 1964). The highest Gfohl Unit is composed of orthogneisses, amphibolized eclogites, granulites and peridotites which are surrounded by felsic migmatites (Schulmann et al. 2009).

The Brunovistulicum domain, also called the Brunia continent, lays in the south-eastern part of the Czech Republic. It represents a Cadomian unit, formed during the Cadomian orogeny and then incorporated into the Variscan Bohemian Massif (Kalvoda et al. 2008). The continent consists of migmatites and schists from Neoproterozoic, in which were intruded younger granites. This hard basement is overlain by Cambrian and Ordovician rocks, later by Devonian conglomerates and quartzites and later carbonate platform sediments. In late Carboniferous, in foreland environment developed deposition of thick Variscan flysch (CGS 2022).

Platform cover of Bohemian Massif

Small units of Platform cover are mostly subhorizontaly deposited sedimentary complexes of Mesozoic, Tertiary and Quaternary age. We can date the start of the Platform cover development to the end of Triassic sedimentation.

Jurassic sediments can be found in small relics only in some places in the Czech Republic. In the north-western part of the country, the sediments are focused along the fault line, under the Cretaceous sediments. Bigger deposits are around and in the Moravian karst, having thickness around 50 m. Most common are basements of sandstones and sandy limestones which are transforming into micritic limestone. They are sediments of thin sea channel connecting the Tethys Ocean to the epicontinental sea. The biggest deposits of Jurassic sediments are laying on the rocks of Brunovistulicum and its Palaeozoic cover. One of the most famous beds in the Czech Republic are in Hády quarry, where they are overlaying the Carboniferous sediments (Chlupáč et al. 2002).

Cretaceous sediments are mostly concentrated in the central and southern parts of the Bohemian Massif. Mostly known is the Czech Cretaceous Basin, created after the Cenomanian transgression. It is the biggest and thickest part of the Platform cover. The oldest parts of the basin are Peruc-Korycany sediments or layers, which are divided into two parts based on the sedimentation environment. Peruc sediments were deposited first, in multiple cycles as lacustrine and fluvial sediments, mostly sandy conglomerate and sandstones. Korycany sediments were deposited later, as sea-transgression sediments, being mostly glauconitic sandstones. Next sea transgression, in the Early Turonian, deposited calcareous marlstones and limestones (Bělohorská formation), followed by sandstones of Jizerské formation and finished by siltstone, sandstones and limestones of Teplice formation and fine-grained sandstones of Merbolice formation (Chlupáč et al. 2002).

Cretaceous basins on the south part of the Czech Republic are deposited from both marine and fresh-water sediments, consisting mainly of sandstones, claystones and marlstones (Chlupáč et al. 2002).

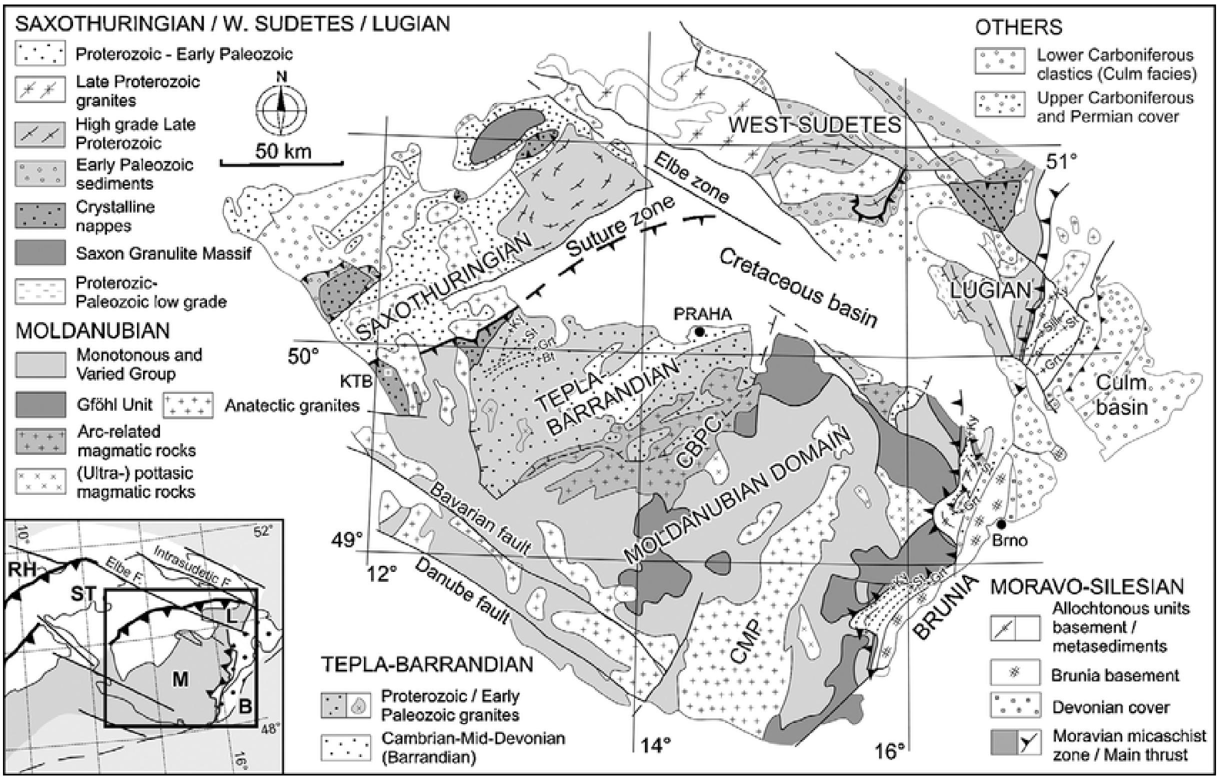

Fig.1: Simplified geological map of the Bohemian Massif (Schulmann et al. 2009).

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Energy raw materials of the Czech Republic in the past and the present

Terézia Babirádová

The mining and usage of energy raw materials is important for the prosperity and independence of every state. Since each economic sector of current society is dependent on electric energy, its production is the centerpiece of the world's interest. There is a wide range of energy raw material reserves in the Czech Republic: black and brown coal, peat, oil, natural gas and uranium.

Black coal

Black coal is a raw material used mostly for production of electricity. The higher-grade black coal processed into coke is used in metallurgy. Both types occur in Hornoslezská Basin at the north-eastern of the Czech Republic. ČSM Mine in Louky mining area is the last exploited black coal deposit in this area and in the Czech Republic. Kladensko-rakovnická Basin in central Bohemia was the second most important mining area until its termination in 2002. Other smaller occurrences were mined in Vnitrosudetská Basin, Boskovická ridge, Plzeňská and Radnická Basin and were all terminated in the 1990s. Other reserves in evidence which weren't mined are in Mšensko-roudnická Basin and Podkrkonošská Basin (Fig. 1).

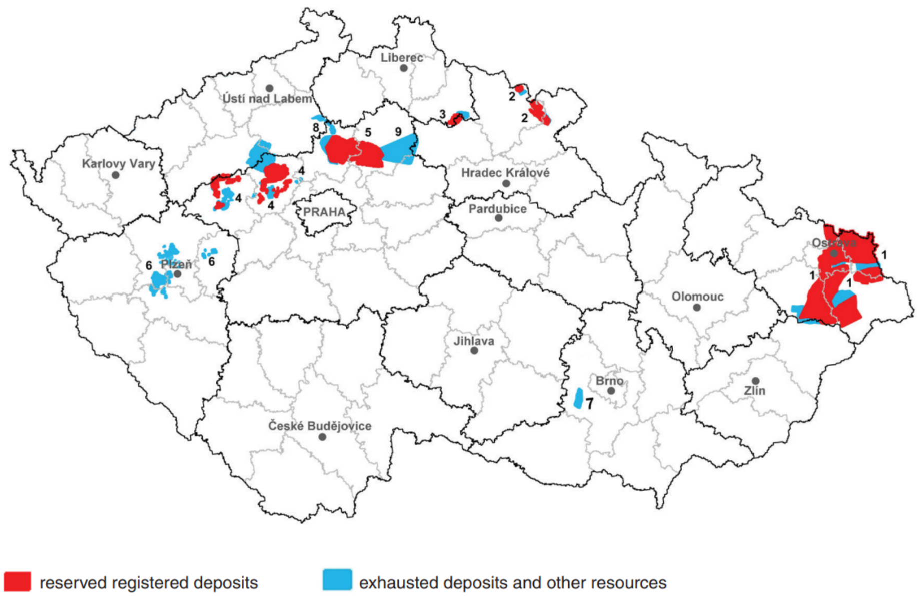

Fig. 1: Black coal deposits in Czech Republic. 1 – Upper-Silesian Basin, 2 – Intra-Sudetic Basin, 3 – Krkonoše Mts. Piedmont Basin, 4 – Kladno-Rakovník Basin, 5 – Mšeno Part of Mšeno-Roudnice Basin, 6 – Plzeň and Radnice Basin, 7 – Boskovice Graben, 8 – Roudnice Part of Mšeno-Roudnice Basin, 9 – Mnichovo Hradiště Basin (Starý et al. 2022).

Brown Coal

Brown coal is used mainly in electricity and heat production but also in the chemical industry. It is the main source of electricity in Czech Republic. The deposits – brown coal basins are in the west of Czech Republic and are parallel to the Krušné Hory Mountains. The extraction is almost exclusively carried out as an opencast mining. There are 3 main basins in this area (from NE to SW): Severočeská, Sokolovská and Chebsk, while Severočeská Basin accounts for approximately 80 % of production and Sokolovská Basin for the remaining 20 %. There are 5 active quarries in Severočeská Basin: Tušimice-Libouš, Bílina, Ervěnice, Holešice and Komořany near Most. Vršany and Slatinice quarries are reserved and planned for continuation of mining. In the Sokolovská Basin the mining is conducted in 3 mining areas: Alberov, Lomnice and Královské Poříčí, and is expected to continue until 2030. The Chebská Basin deposits are bound mostly by resource protection of the mineral waters of Františkovy Lázně and are not expected to be mined even though it was mined in the past (Fig. 2). There are also occurrences of low-quality brown coal in Česká křídová Basin that were mined in the past as an auxiliary raw material in the mining of refractory clays near Moravská Třebová and Svitavy. Production of brown coal declines gradually.

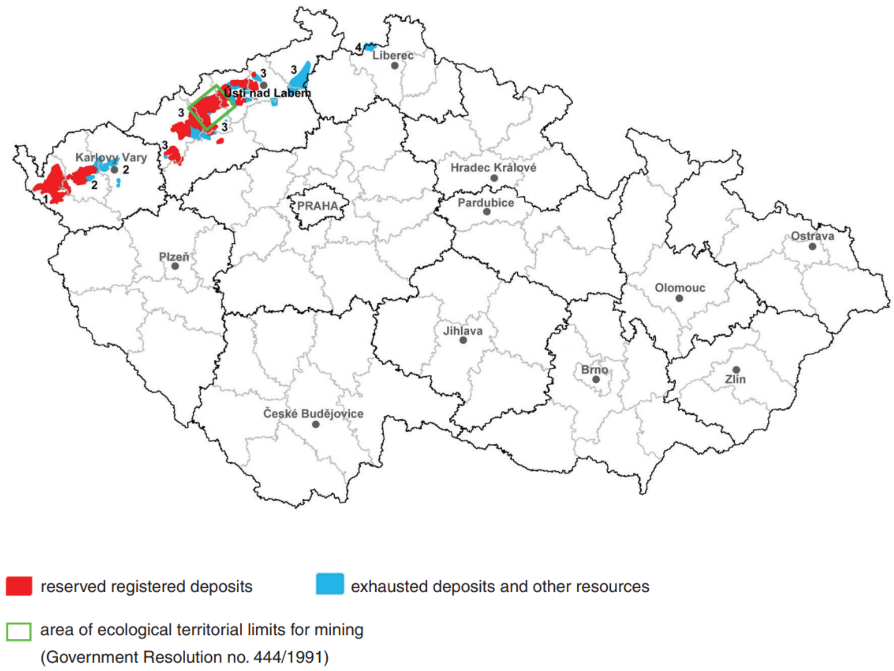

Fig. 2: Brown coal deposits in the Czech Republic. 1 – Cheb Basin, 2 – Sokolov Basin, 3 – North-Bohemian Basin, 4 – Žitava Basin (Starý et al. 2022).

Oil

The use of oil is versatile but most common in energy industry, petrochemical and chemical industry. It can be refined to gasoline, petrol, kerosene, diesel, lubricating oil and asphalt. Czech Republic doesn´t have industrially significant reserves of oil. Deposits are located in the area of Western Carpathians in Southern Moravia. The extraction of oil in Czechia is dated to 1914 and has been growing until 2003 when it started to decline. Today it is stabilized and covers approximately 2–3 % of domestic needs. The largest deposits are in the area of Carpathian foredeep (namely Dambořice, Borkovany, Žarošice, Uhřice and Ždánice) and are extensively extracted (Fig. 3).

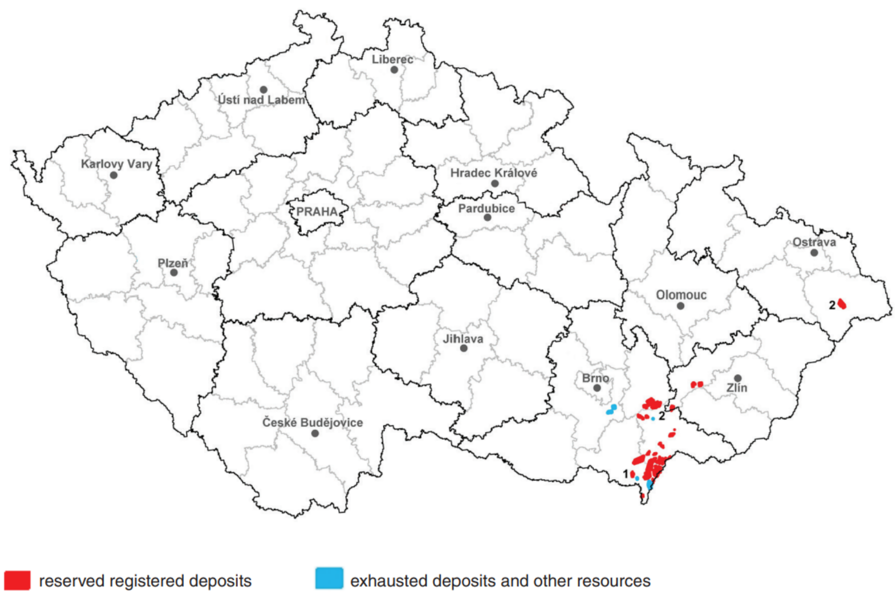

Fig. 3: Oil reserves in the Czech Republic. 1 – Vienna Basin, 2 – Carpathian foredeep (Starý et al. 2022).

Natural gas

Natural gas reserves are not economically significant in the Czech Republic. Deposits are in southern Moravia – in the Western Carpathians associated with oil, and in northern Moravia associated with the coal seams of Hornoslezská Basin (Fig. 4). Production covers for 1–2 % of domestic consumption.

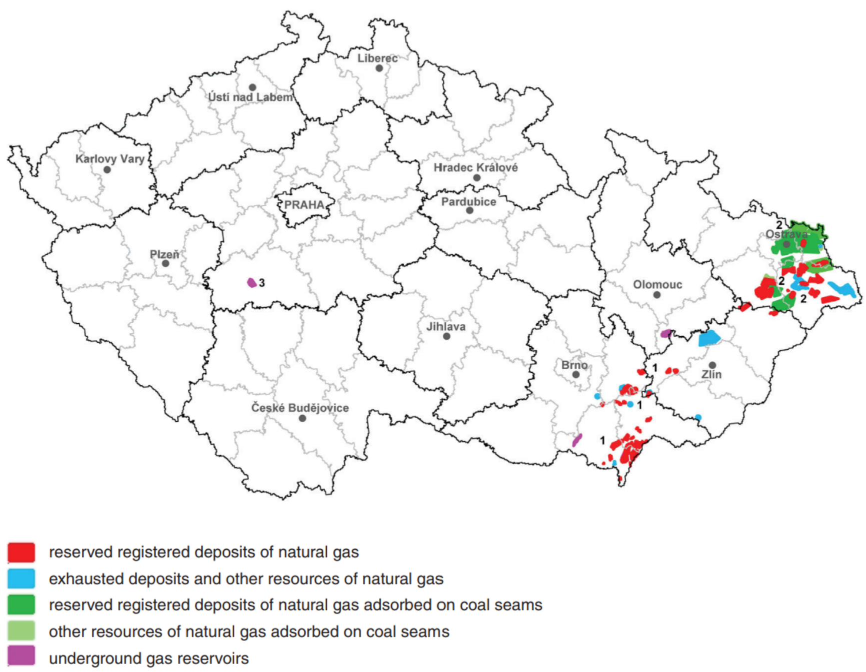

Fig. 4: Natural gas reserves in the Czech Republic. 1 – South-Moravian region, 2 – North-Moravian region, 3 – underground natural gas reservoir Háje (Starý et al. 2022).

Uranium

Uranium is not only an energy raw material but it's also used in medicine, ceramics or military industry. In the past Czech Republic was the world's top producer of uranium with 112 thousand tons from 1946 to 2019. In the 1990s the mines were terminated gradually due to economic losses and ecological reasons (Stráž pod Ralskem), except from Rožná mine which closed in 2017 (Fig. 5). In the following years the production represents the remediation of closed mines. Today production is approximately 30t of U per year.

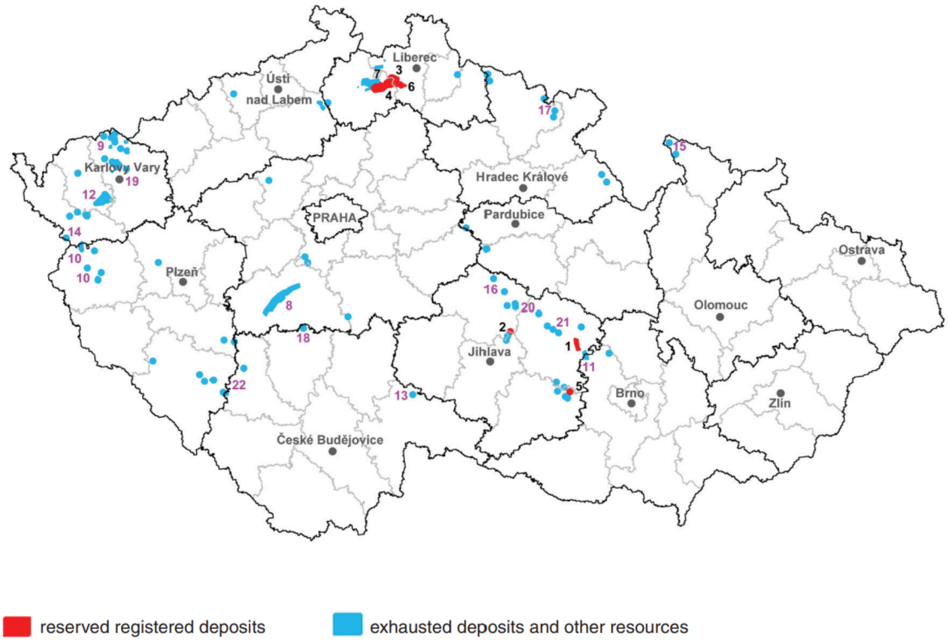

Fig. 5: Uranium reserves in Czech Republic. 1 – Rožná, 2 – Brzkov, 3 – Břevniště pod Ralskem, 4 – Hamr pod Ralskem, 5 – Jasenice-Pucov, 6 – Osečná-Kotel, 7 – Stráž pod Ralskem, 8 – Příbram, 9 – Jáchymov, 10 – Zadní Chodov + Vítkov 2, 11 – Olší, 12 – Horní Slavkov, 13 – Okrouhlá Radouň, 14 – Dyleň, 15 – Javorník, 16 – Licoměrice-Březinka, 17 – Radvanice + Rybníček + Svatoňovice, 18 – Předbořice, 19 – Hájek + Ruprechtov, 20 – Chotěboř, 21 – Slavkovice, 22 – Mečichov-Nahošín (Starý et al. 2022).

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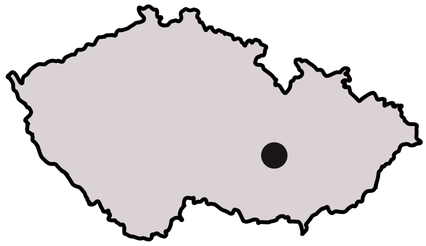
Uranium mining at Dolní Rožínka deposit

Kateřina Musilová



Localization

Dolní Rožínka is a village situated about 20 km northwest from town Tišnov in Vysočina region. The main part of the uranium deposit is situated between villages Dolní Rožínka, Rožná, Olší and Slavkovice-Petrovice.

Geological characteristics

Uranium deposits around Dolní Rožínka are formed in metamorphic and strongly migmatitic rocks and are classified as hydrothermal deposits. These deposits are situated in the NW part of the Moldanubicum in Strážecká unit. The Strážecká unit is formed by paragneisses, orthogneisses, migmatites, granulites and amphibolites. Less common are bodies of marbles, quartzites, pegmatites and aplites (Křibek 2009). Origin of Strážecká unit and NW part of Moldanubicum is connected with variscan orogeny.

Uranium mineralization of uranium deposits in Vysočina is connected with mylonite and cataclasite zones and feathered structures and shear zones from early variscan orogeny era about 380 Ma (Fig. 1). The main uranium-bearing minerals are uraninite and coffinite (Křibek & Hájek 2005).

History of uranium mining

History of uranium mining was closely related to the political situation. In the area of Dolní Rožínka, Slavkovice and Olší, intensive walking and car gama exploration for radioactive raw materials took place in the 1950s. The Rožná deposit was discovered in 1954, the Olší deposit in 1956, and the Slavkovice-Petrovice deposit in the early 1970s. It meant the biggest boom of uranium mining in the 60th and 80th, when production of uranium was between 2500 to 3000 t per year (Vondra 2012). Uranium mineralization was already 2–2.5 m below the surface in these localities (Křibek et al. 2005). Since the 1980s, ore research has been carried out by geophysical and radiometric methods (Navrátil 2023).

In 1968 a chemical treatment plant for uranium ore was founded in Dolní Rožínka. Before that the uranium ore was transported and treated in Mydlovary (Jež 2010). In Dolní Rožínka alkaline leaching technology was used for extracting uranium. In the ore, uranium is commonly in U^{6+} oxidation state, which is an easily leachable form. The final product was ammonium diuranate $(NH_4)_2U_2O_7$ which is also known as a powdery “yellowcake”. This compound is a chemical concentrate of uranium and the Czech republic held a foremost position in the world's production. It contains more than 70 wt. % of uranium. Altogether about 109 000 t of uranium has been mined in the Czech Republic since 1945 (Rapantová et al. 2023).

Rožná I

At the Rožná I deposit, mining lasted from 1957 to 2017. Rožná I was the main deposit of this area and was the last active uranium deposit in Europe. Between 1957 and 1980, foundation pits were dug to a depth of 600 m. In 1963, the opening was already made up to the level of the 12th to 14th floor with pits R1, R2, R4 and Bukov. Between 1980 and 1988, mining reached a depth of 800–900 m. Pit R3 was originally drilled to verify reserves up to the level of the 24th floor, as well as blind pit R7S between the 12th and 24th floors (DIAMO 2007).

After 2000, mining took place at depths of 950–1 100 m. Since 1988, mining has been in the regime of the attenuation program of uranium ore mining (DIAMO 2007). During 40 years of active mining in Rožná, the mine produced about 50 000 t of uranium (Vondra 2012).

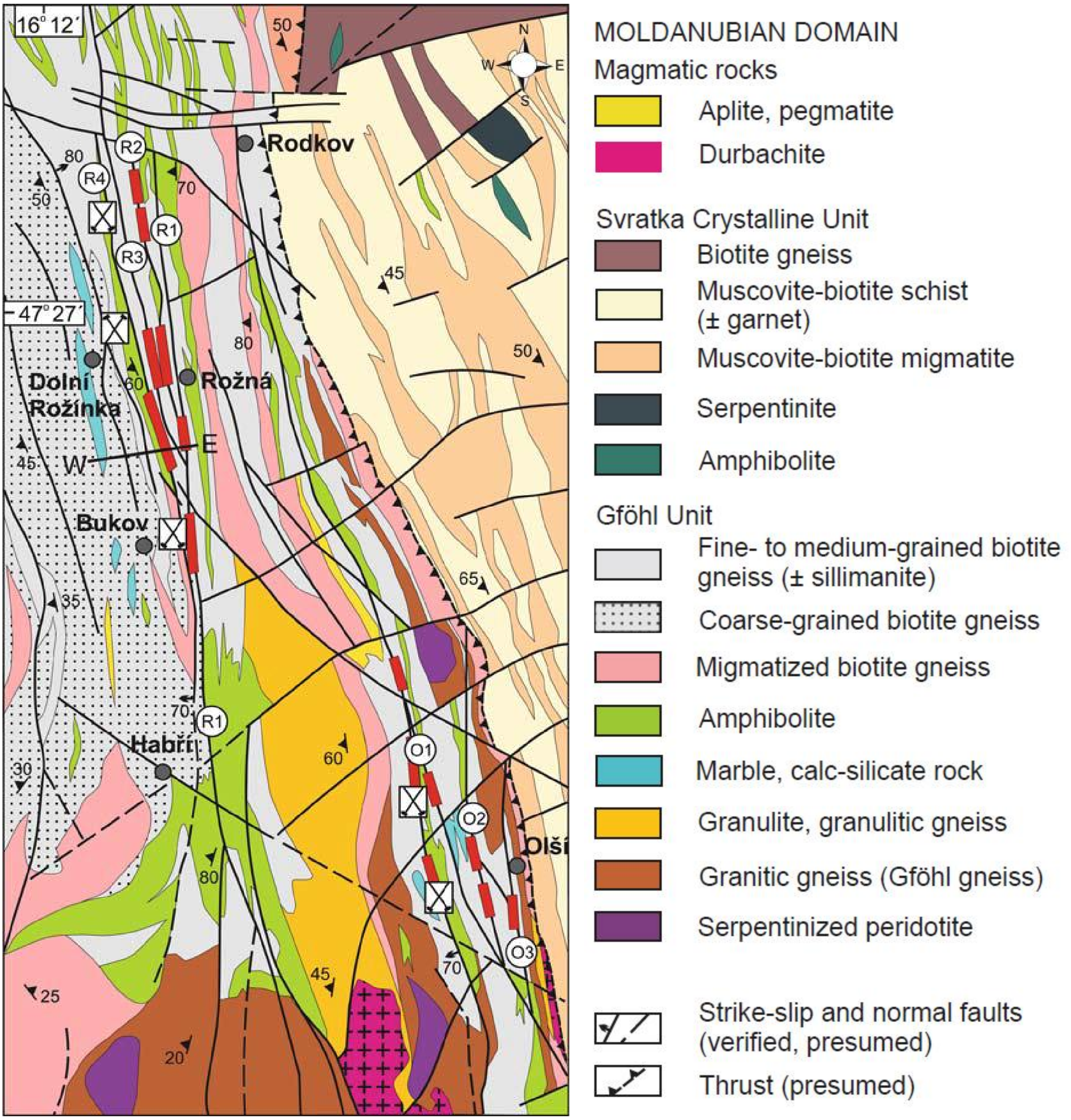


Fig. 1: Schematic geological map of the Rožná-Olší uranium deposit (Křibek 2009).

Olší-Drahonín

In the nearby Olší-Drahonín deposit, mining took place only between the years of 1959 and 1989. The main mining operations achieved a depth of 500 m, while the largest reserves were found at the depth of 300 m. The exploitation was finished here in 1989 and since 1996, excess waters have been discharged from the deposit and subsequently purified. Hydrogeological steady-state (Rapantová 2023).

Slavkovice-Petrovice

The Slavkovice-Petrovice deposit was mined in the years 1962–1970. In total 175 t of uranium was extracted (Jež 2010). Since 1970 the process of liquidation, flooding and remediation has been initiated.

Recent situation

The liquidation of the Rožná I uranium mine in Dolní Rožínka is a current problem, as the uranium ore mining was terminated in 2017. At present, the mine is no longer used for mining activities, but mine areas are still used for non-mining activities, mostly of a research nature. As soon as the mine areas cease to be used, the mine will be liquidated (Vokurka 2019).

The liquidation will start with the stopping of the mine water pumping, which will cause gradual flooding of the mine. The uranium mine, as a non-gassing mine, will be liquidated by a complete, non-strengthened backfill of the initial mine workings opening to the surface. After filling up the initial mine workings, a closure sinking platform will be built at their mouth. The next part is devoted to the problems of mine water during gradual flooding. As soon as the water contamination no longer exceeds the permitted limits, the water will be discharged freely to the local watercourse without prior cleaning (Vokurka 2019).

Abandoned uranium deposits Olší and Slavkovice-Petrovice are already flooded, but monitoring of water contaminants still continues. The total costs of the liquidation of the deposit in the period 1989-2000 amounted to a total of 182.4 mil. CZK. For the completion of liquidation works and long-term water purification and environmental monitoring, an amount of approximately 150 million CZK is expected to be spent by 2021 (of which CZK 117 million for operation of decontamination station; GEAM 2021).

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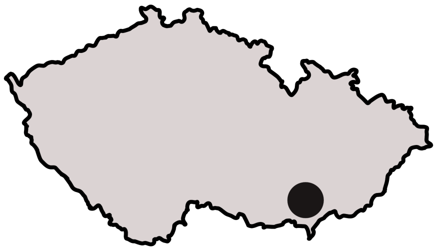
Oil and natural gas deposits of Southern Moravia



Kateřina Streitová, Monika Kubernátová

Localization

Gas and oil deposits are situated in an area from Břeclav, around Hodonín to Kyjov.

Geological characteristic

The Vienna Basin, also known as the Vienna Basin-Moravia, is a geological and topographical region in Central Europe. It is a low-lying, Middle-Upper Miocene and Pliocene sediment-filled basin located in the area of several countries, including Austria, Slovakia, Hungary, and the Czech Republic. The depression of the Vienna Basin is almost 200 km long and approximately 50–60 km wide (Hruban 2014).

The deposits are located in the northern part of the Vienna Basin. The largest amount of oil and gas was discovered within the Lower Baden clastic sediments (Muzeum naftového dobývání a geologie 2023).

The fundamental condition for the formation of deposits in the Vienna Basin was the vertical migration of hydrocarbons through the flysch nappe. This was facilitated by long-term tectonic activity along major faults, particularly during the middle Miocene, when the basin was opening through left-lateral horizontal displacements (Muzeum naftového dobývání a geologie 2023).

The majority of deposits is associated with the trapping of hydrocarbons along significant fault systems (Fig. 2a). Oil deposits are more common in older sediments and deeper structural traps, while gas is often trapped in younger sediments and shallower traps. Numerous structural and stratigraphic traps formed gradually during the geological evolution of the Vienna Basin (Fig. 2b). Deposits were found in Miocene sediments (Eggenburg, Ottnang, and Karpatian), but the most significant ones were discovered in Badenian and Sarmatian sediments. The best reservoirs consist of littoral sands (shallow marine and beach sands) of the Middle Badenian and Sarmatian (beach sands, infill of shallow submarine channels, or deltaic sediments; Muzeum naftového dobývání a geologie 2023).

History

Early oil exploration in the present-day Czech Republic occurred in the late 19th century in eastern and southeastern Moravia. Areas with natural oil springs were recognized in Halenkov, Malenovice, Nový Jičín, and others along the Carpathian arc extensions. Julius May, a sugar factory owner, conducted unsuccessful exploratory drilling between 1899 and 1902 in Bohuslavice nad Vlárou and Uherský Brod. The first deep well named Helena reached 450.7 meters. In 1900, another significant well was drilled near the Nesyt farmstead in Hodonín, leading to the region's scientific interest but financial uncertainty. Exploration paused until the Gbely oil discovery in Slovakia spurred renewed efforts in Moravia. In 1916, the Vienna-based firm OPTEG began exploration, and by 1917, the Moravian Mining Company (Moravská těžařská společnost) was established. It started mining in 1919 near the Morava River in Hodonín. Subsequent years saw acquisitions of drilling rights and field expansions. The company merged with Apollo in 1925 (Hruban 2015).

Apollo had numerous leases, including sites in Ratíškovice, Kroměříž, Bzenec, and Vranovice. During WWII, Apollo was part of the German conglomerate I. G. Farben. War efforts heightened oil exploration. New oil and gas reserves were found in Hodonín, Velké Bílovice, Lužice, Břeclav, Podivín, and Moravský Žižkov. Post-war, most German oil companies were nationalized via Beneš decrees. In 1945, Československé naftové doly emerged, becoming a state enterprise. Separate entities like Hlubinná vrtba, Těžba, and Geologický průzkum were later established. In the 1950s, oil and gas reserves were discovered at Hodonín, Kostice, Lanžhot, Lednice, Lužice, Ratíškovice, Vacenovice, Velké Bílovice, and Poddvorov. Peak oil production occurred in 1958 with 45 drilling rigs. The largest Czechoslovak oil field in Hrušky began production in 1959. After 1968, Moravské naftové doly Hodonín (MND) and Slovenské naftové závody emerged. In 1971, drilling started in Kobylí, and in 1972, a significant reservoir was discovered near Ždánice. Additional discoveries occurred in the 70s and 80s, including Dambořice, one of the largest oil reserves in Czechia. After 1989, the companies became independent. MND is transformed into a joint-stock company. The 2000s saw increased oil production, peaking in 2003. The significant Dambořice oilfield contributed over 70% of total production. Collection centres were established in Žarošice and Poštorná. Since its start at Nesyt, South Moravia has extracted around 6.5 million tons of oil (Hruban 2015).

Recent situation

The oil and gas mining is still active on many localities in Vienna basin - Břeclav, Hrušky, Lužice, Nový Poddvorov, Prušánky, Poštorná, Vracov – Vlkoš, Mutěnice, Valtice, Charvátská Nová Ves (all mined by MND, in detail in Appendix 1 and Fig. 1). Mined-our reservoirs are used as UGS in Tvrdonice-Hrušky and Dolní Bojanovice (Appendix 1; Česká geologická služba 2023). Another localities where with active mining are Podivín, Moravská Nová Ves, Lanžhot, Žarošice, Dambořice, Uhřice, Heršpice, Kloboučky, Ždánice, Nevojice, Koryčany etc. (Česká geologická služba 2023).

Editor's note: *Detailed individual deposit descriptions are given by Streitová and Kubernátová (2023) in Appendix I of this Guidebook.*

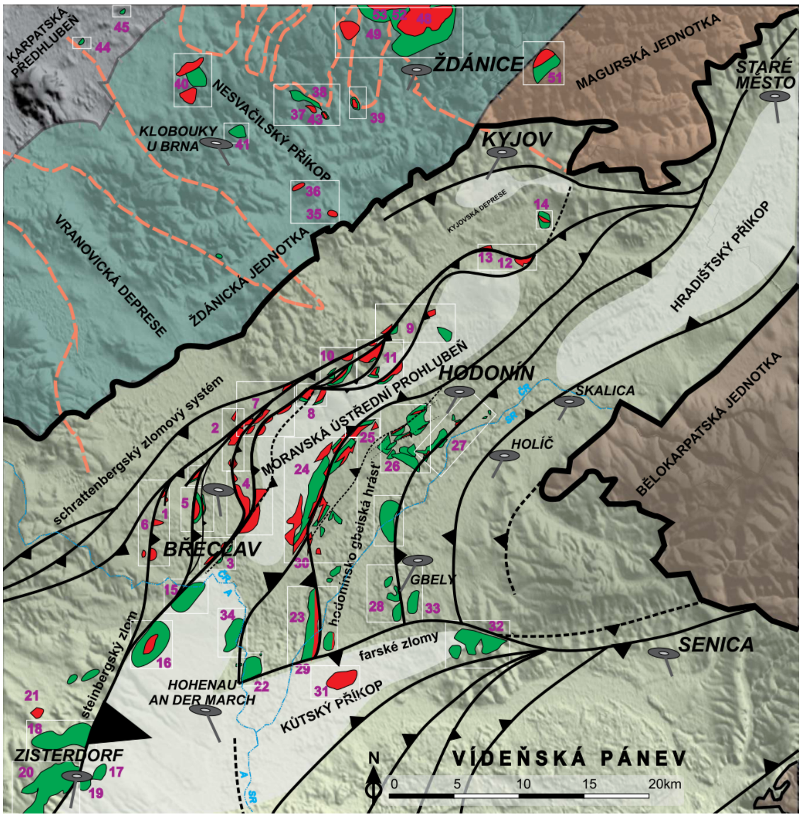


Fig. 1: Map of Vienna Basin with based tectonic and deposits of oil and natural gas. (Muzeum naftového dobývání a geologie 2023).

Deposits in Schattenberg-Steinberg Fault System zone

	Name	Year of discovery	
1	Lednice	1978, 1993	
2	Podivín	1941, 1996	
3	Břeclav (Stará)	1944	
4	Břeclav I. a II.	2008, 2009	
5	Poštorná	2002, 2004	
6	Valtice	1979	
7	Bílovice - Žižkov	1944	🟢
8	Prušánky	2001, 2006	
9	Mutěnice	1948, 1997	
10	Poddvorov	1952	🔵
11	Dolní Bojanovice	1989	🟢
12	Vacenovice	1929	
13	Skoronice		
14	Vracov	1986	
15	Bernhardsthal	1950	
16	Muhleberg	1942	🔵 🟢
17	Sickle - Plattwlad	1939	
18	Zistersdorf	1937	🔵
19	Goesting	1932	🔵 🟢
20	Maustrenk - Kreuzfeld	1941	🔵
21	Hauskirchen	1938	

Deposits in Lanžhot-Hrušky Fault and Hodonín-Gbely Horst zone

22	Lanžhot	1957	
23	Týnec - Cunín	1944, 1976	🔵
24	Hrušky	1959	🔵 🟢
25	Josefov	1962	
26	Lužice	1944	🔵
27	Hodonín	1920	🔵
28	Gbely	1913	
29	Brodské	1951	
30	Kostice	1953	
31	Kůty	1943	
32	Štefanov	1950	
33	Petrova ves	1953	
34	Rabensburg	1594, 1976	

Deposits in Nesvačilka Paleovalley and Carpathian Foredeep zone

35	Karlín	1993	
36	Krumvíř	1998	
37	Uhřice	1984	
38	Dambořice	1986	🔵
39	Žarošice	2001	🟢
40	Bošovice	1995, 2011	
41	Borkovany - Klobouky	2013, 2018	🔵
42	Uhřice (paleozoikum)	1978	
43	Uhřice - Jih	2001	🟢
44	Měnín	1946	
45	Otnice	1930	
46	Sokolnice - Žatčany	1994	
47	Slavkov (cukrovar)	1908	
48	Ždánice (krystalinikum)	1974	
49	Ždánice - Západ	1983	
50	Ždánice (miocen)	1977	
51	Koryčany	1983	
52	Mouřínov	1999	
53	Kloboučky	1984	🔵 🟢
Off the map	Dunajovice	1974	🟢

Oil reservers over 500 000 m^3 🔵

Natural gas reservers over 500 000 000 m^3 🟢

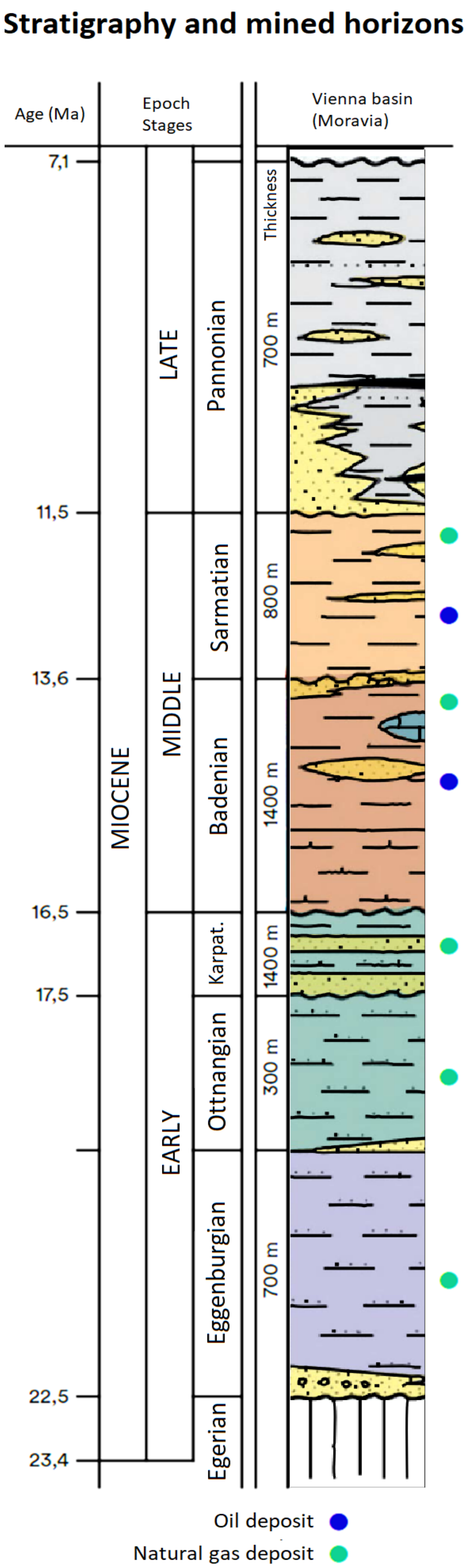


Fig. 2: a) Deposits in Southern Moravia (Muzeum naftového dobývání a geologie 2023) b) Stratigraphic scheme of Vienna Basin (Chlupáč et al. 2011).

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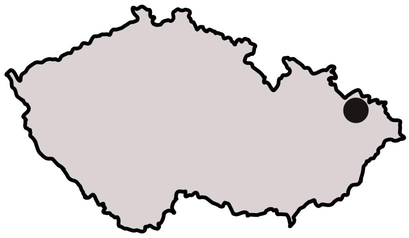
Black coal deposits in the Ostravsko-karvinská coal basin



Petr Nečas

Localization

The Upper Silesian Coal Basin (USCB) is one of the most important bituminous coal basins in Central Europe and even in the whole of Europe. It is located at the eastern edge of the Variscan Bohemian Massif, representing the eastern extension of the Moravo-Silesian Basin (Fig. 1). The NW part of the hard coal basin is covered by the Miocene Carpathian Foredeep. The southeast part is buried below nappes of the Carpathian overthrust belt (Silesian and Sub-silesian units). The Upper Silesian Coal Basin occupies a known area of more than 7000 km^2, the bigger part is located in Poland, whereas the southern part of the basin, the Ostrava-Karviná coalfield (OKC), with a known area of 1550 km^2, is situated in NE Czech Republic (Sivek et al. 2003). Coal mining has been practiced in this area for more than 200 years. There are economically significant hard coal deposits inside Upper Carboniferous siliciclastic, molasse-type sediments of the Ostrava Formation (paralic facies) and Karviná Formation (limnic facies; Wenniger et al. 2012).

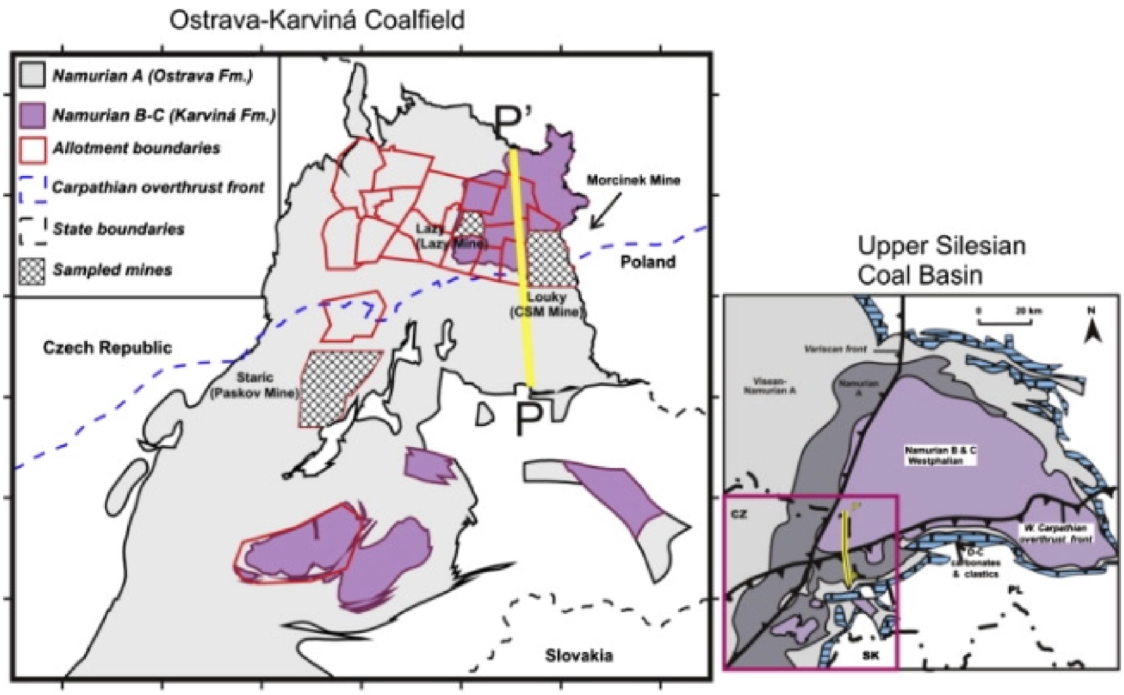


Fig.1: Location of the SW Upper Silesian Coal Basin, Czech Republic (Wenniger et al, 2012).

Geological characteristic

In this respect, the USCB occupies an analogous structural position to other European locations, stretching from the British Isles through Germany and Poland to the eastern part of Europe. The beginning of the sedimentary record in this locality began with a deposition of Cambrian siliciclastics on the Cadomian metamorphic and igneous rocks of the Brunovistulicum. The crystalline complex lies at depths of 1–12 km below the surface and forms the basement underlying the coal-bearing formations.

The Devonian transgression of basal clastics reached a significant regional extent. These layers are composed of shelf carbonates, slates. Later, layers of sandstones, siltstones, siltstones and slates were deposited in the Hradec Kyjovice Fm. These deposits are referred to in other parts of Europe as the "Culm" or "Variscan flysch" facies (Geršlová et al. 2016). The upper boundary of the culm layers smoothly transitions into carbonaceous coal-bearing molasses forming the filling of the HSP. The productive coal-bearing Carboniferous is classified into the paralic (cyclic) Ostrava formation and the limnic (continental) Karviná formation. The Ostrava formation is further divided into Petřkovice, Hrušovice, Jaklové and Poruba members (Fig. 2). The member sequence is built by its cyclic structure (transgression and regression of the Carboniferous Sea). The lithological composition is mainly fine-grained to medium-grained sandstones with a share of claystones, siltstones and coal of up to anthracite quality (Dopita et al. 1997). The paralic Ostrava Formation is up to 3000 m thick, with individual cycles varying from 6 to 20 m in thickness. It contains more than 170 coal seams, with an average thickness of 73 cm. About 80 marine and brackish horizons, more than 100 freshwater horizons, 16 coal tonsteins and 30 layers of "whetstone" rocks serve for correlation (Dopita & Kumpera 1993). The Karviná Formation is divided into Sadlová, Suchá and Doubrava members (Žampachová 2012). The continental Karviná Formation, deposited after tectonic inversion, is up to 1000 m thick. It contains up to 90 coal seams, 180 cm thick on average (maximum up to 16 m). The cycles are thicker and laterally less stable than those in the Ostrava Formation and contain frequent layers of conglomerates and coarse-grained sandstones. Only 25 freshwater horizons are known. The typical feature of both formations is the frequent occurrence of tuffogenous layers (whetstone rocks and tonsteins) which are important horizons (Dopita & Kumpera 1993). Most of the area above the coal-bearing layers in the Upper Silesian Basin (Fig. 1) in Poland and the Czech Republic is covered by the lower and middle Miocene claystones and sandstones of the Carpathian foredeep and the outcrop of the West Carpathian flysch belt (Picha et al. 2006).

Mining History

Ostrava hard coal has been used by people since prehistoric times, but organized mining has a shorter history and dates back to 1776 (Martinec & Schejbalová 2004). The germ of the later OKD company arose after World War II, when the then six mining companies were placed under national administration. Enterprises owned by them, i.e. a total of 32 mines, 9 coking plants, 10 mine power plants, ironworks in Třinec and Vítkovice and several other industrial enterprises, were incorporated into the national enterprise Ostravsko-Karvinské kamenouhelné doly Ostrava. In 1952, the OKD Combine (later the OKD state enterprise) was retroactively abolished and created. Another reorganization took place on July 1, 1965. The expansion of powers also resulted in a change of name to Ostravsko-Karvinské doly. At the head of this enterprise trust was the branch directorate, to which all the economic organizations of the former OKD Association were subordinated. Subsequently, in 1977, the state economic organization OKD, a concern based in Ostrava, was established. It was canceled on December 31, 1988, so that the state enterprise OKD could be established on January 1 of the following year (OKD 2023). After the period from 1992 to 2000, it was characterized by the privatization of state-owned enterprises and was accompanied by the liquidation of coal mining due to a decrease in demand for coal. During this period, all deep mines in Ostrava and Petřvald OKR were closed (Martinec & Schejbalová 2004). At the end of 2022, the only and last Czech hard coal company OKD presented a medium-term outlook in response to the current energy situation in the Czech Republic. It expects to mine it until the end of 2025 to help secure coal supplies for heat and electricity production. After that, the ČSM Mine is planned to be definitively closed (OKD 2023).

Recent situation

At present, mining activity is gradually terminated and the landscape is recultivated.

Current mining takes place in the last open mines ČSM-sever and ČSM-jih, which are the last active hard coal mines in the Karviná coalfield region. The mining activities are supposed to be stopped in 2025. Presumed amount of extracted coal is 1.2 MT per year.

Moreover the current problem is discharging of mine water. Water pits in closed mines General Jeremenko and Žofie are used for pumping of mine water for protection against flooding of mines in Karviná.

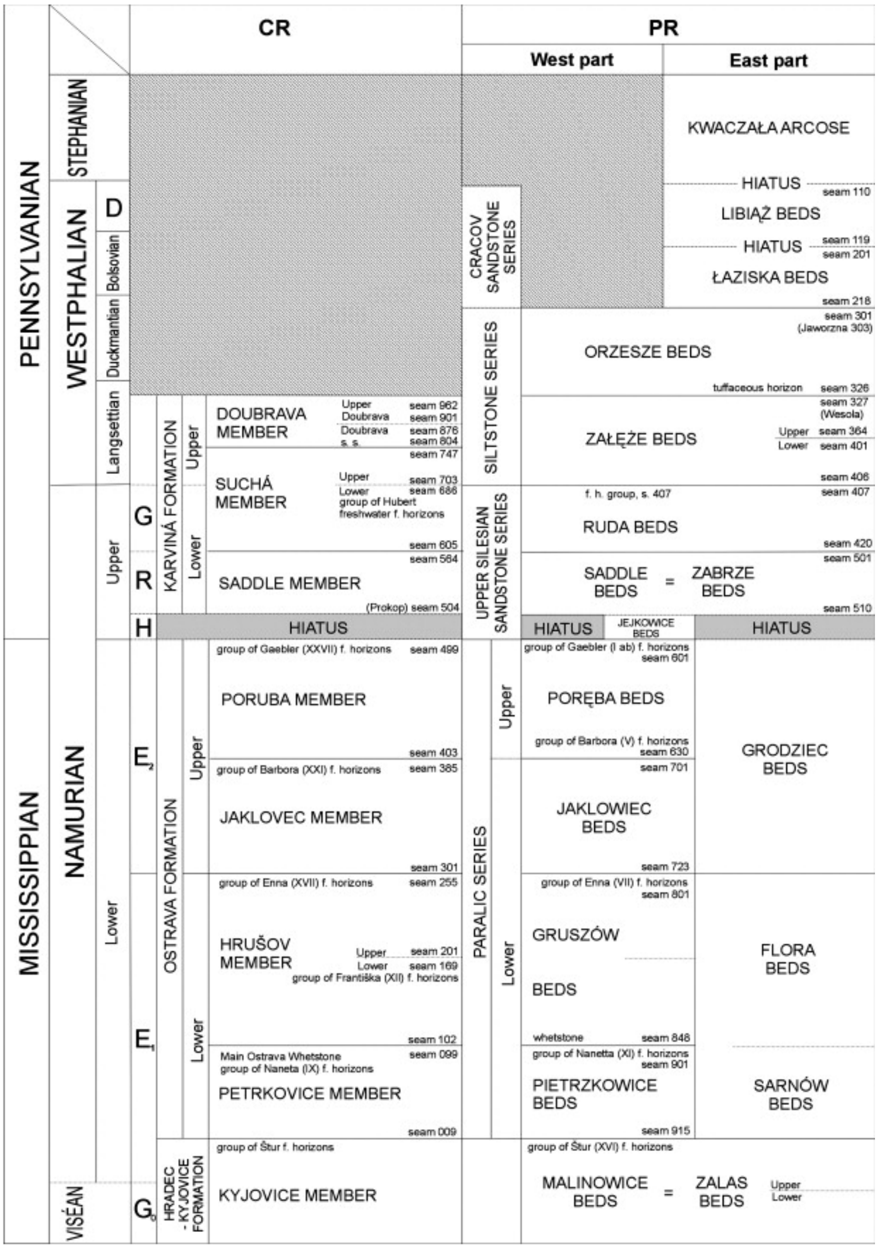


Fig. 2: Stratigraphy of Upper Silesian Coal Basin, Czech Republic (Sivek et al. 2003).

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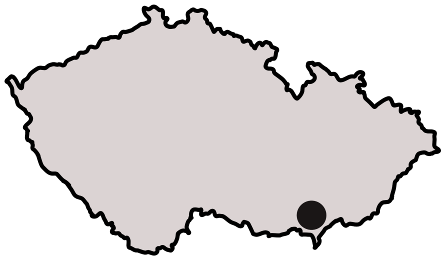
Lignite mining in South Moravia

Milan Hrouda



Localization

The deposit of lignite is located in the South Moravian Region in the districts of Hodonín and Břeclav, covering approximately 350 km^2 of productive area.

Geological characteristics

The South Moravian Lignite Basin belongs to the Dolní Morava (Lower Morava) Depression, a northern extension of the Neogene Vienna Basin, and contains the South Moravian Lignite Basin. The older sub-Pannonian Kyjov Layer and upper Pannonian Dubňany Layer are the two different regions where lignite layers have formed. The Kyjov Layer is developed in a strip along the northwestern and the Vienna Basin's northern and western edges, starting at Čejč and Hovorany and extending through Šardice, Svatobořice, and Kyjov, where the Kyjov Layer is produced. A much wider areal distribution can be found in the Dubňany Layer. It occurs in the so-called Moravian Central Depression, which is bordered by peripheral faults roughly along the lines of Mutěnice-Břeclav, Ratíškovice-Lanžhot, in the smaller lignite basin Rohatec-Bzenec-Strážnice, and in a Slovakian extension of the Moravian Depression (Kúty Trench) in the Gbely location.

History of mining

The first surface lignite mines were established in the early 19th century, marking the start of lignite mining. These mines connected to peasant adits and possibly even surface wild mining, making use of the fact that the coal seam either outcropped at the surface or was slightly below it.

The closest source of energy for Vienna's expanding industry was the nearby lignite. Wood was totally replaced by lignite in industry and railroad transportation due to lignite's high demand. Even the locomotives used lignite as fuel up to 1860, which made it possible to distribute coal over a vast area (Vienna, Bratislava, Olomouc). Along with noble landowners, local businessmen were responsible for the first mining since lignite was also used as fuel in industrial factories like brickworks and sugar refineries (Muzeum naftového dobývání a geologie 2023).

Numerous smaller mines extracted lignite during the first part of the 19th century. The Baťa Company, a commercial conglomerate, began operating in the South Moravian mining industry after 1932. In Ratíškovice, it opened the Tomáš Mine after purchasing mining rights from previous operators, ushering in a new phase in the growth of the area. Modern transportation and extraction techniques allowed for the annual extraction of about 200 000 tons at the 1934. A navigable canal and waterway from Rohatec to Otrokovice for the transportation of lignite were built concurrently with the development of the Tomáš Mine.

Mines at Dubňany (1. Máj Mine), Hovorany (Obránců míru Mine), and Šardice (Dukla Mine) functioned and were progressively shut down during the socialist state era. The Mír Mine in Mikulčice was established in 1983. Here mining eventually deteriorated and lost its profitability, which caused the enterprise to fail. The mining industry was shut down in 2009, and its liquidation is still under operation (Muzeum naftového dobývání a geologie 2023).

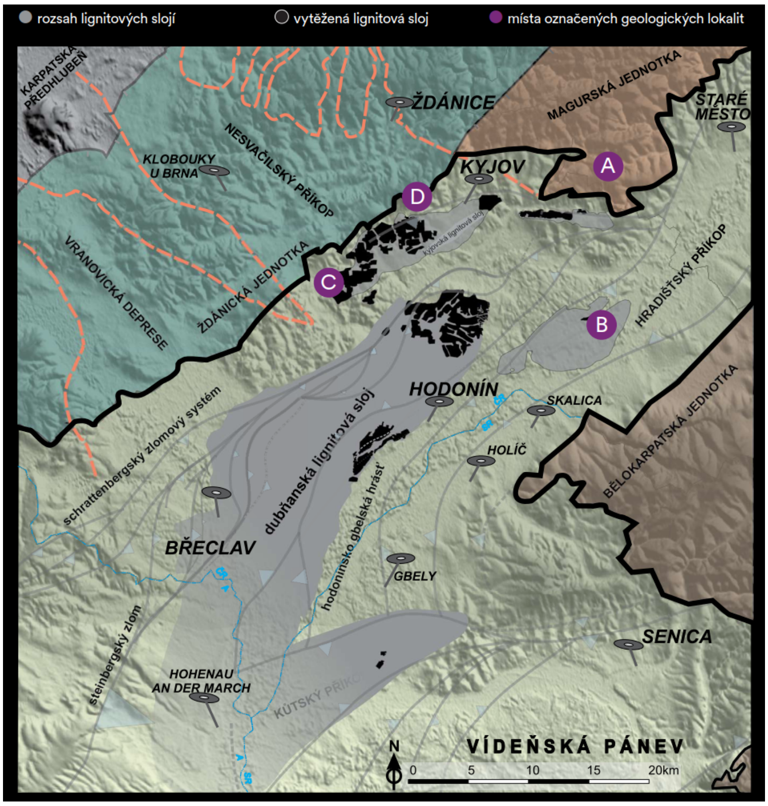


Fig. 1: Map of the Vienna basin with lignite layers and geological locations marked. Grey - range of lignite occurrence, black - exploated lignite deposits, purple - geological localities
(Muzeum naftového dobývání a geologie 2023).

Recent situation

In South Moravia there are few relics of lignite mining activities - Medlovice quarry, Čejč outcrop and Babí quarry. Medlovice quarry was used for mining of lignite and porcelanite. The Čejč outcrop can be viewed as a geological and geomorphological formation that has been modified by human activities; a small lignite seam is visible there. Different plant and animal fossils were found in abandoned quarries in the area.

In 2015, five deposits of lignite were registered in the Czech Republic in total. Balance explored reserves are 619.7 Mt, balance explored reserves are 229.9 million t and off-balance sheet reserves are 147.7 Mt of lignite. Extractable reserves are 1.9 Mt. No registered deposits are mined nowadays (Jirásek et al. 2017).

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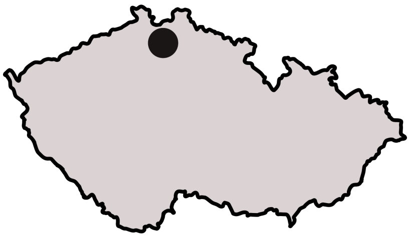
Uranium deposits of the Czech Cretaceous basin



Veronika Zetková

Localization

The Czech cretaceous basin is located in the lowlands of the Czech Central Highlands. The uranium deposits are found in the Liberec region in the north-east part of Bohemia. The reserves of uranium are spread in an area of the Stráž block which is bounded by the towns Stráž pod Ralskem on the west and Mimoň on the east (Surán & Veselý 2001).

Geological characteristics

The cretaceous basin is the largest sedimentary basin in the Czech Republic. It was formed in between the Moldanubian zone, Barrandien zone and northern margin of the Bohemian massif during one sedimentary cycle from Cenomanian to Santon. The fluviomarine sedimentation was followed by the marine sedimentation.

The Czech uranium deposits can be divided by their geological setting into two ore types: vein deposits and sandstone deposits. The sandstone deposits are the Upper Cretaceous type and this type occurs in the Stráž block.

The Stráž block consists of the Cenomanian aquifer that is defined by fine sandstone and the Late Turonian aquifer which serves as a reservoir of drinking water. The two aquifers are isolated by impermeable layer of sandstone. The Stráž block is interlaced by tectonic faults that were filled with volcanic veins that appear on the surface as the Devil walls that create the border line of the Stráž block.

The uranium rich layers appear in the Cenomanian aquifer in depths of 150 m. The uranium mineralization is fixed on surrounding sedimentary complexes and often occurs on boundaries between different rock types alongside with pyrite and organic substances. Uranium mineralization of the sandstone type is distinctive for the assemblage elements as U, Zr, Nb, Th and Ta and they appear in form of minerals like uraninite, zircon, clay minerals, etc. (Chlupáč et al. 2002).

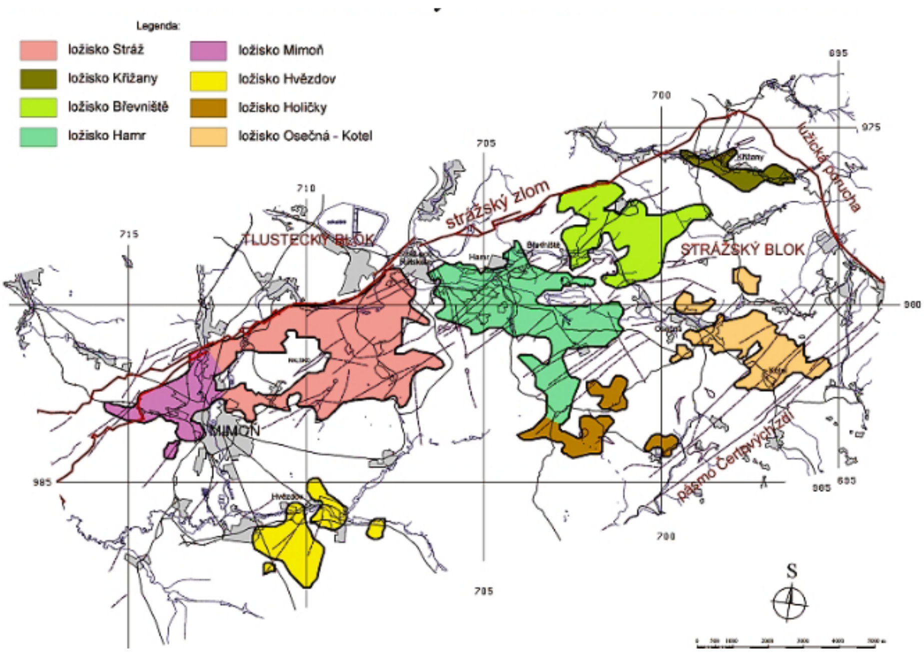


Fig. 1: Schematic map of the uranium ore deposits in Stráž block. (DIAMO 2023, edited).

Mining history

The uranium deposits in Northern Bohemia were discovered thanks to an anomaly encountered in 1963. Uranium reserves were found in eight sites but only three were extracted:

1. mine Hamr I and Hamr II - the mining took place between years 1965 and 1993. The mining site was spread at 12 km^2 and the amount of extracted uranium was 10 680 t.
2. Křížany mine – The mining took place between 1983 and 1990. There was 1060 t of uranium extracted on 13.7 km^2 site.
3. Stráž pod Ralskem deposit – The mining took place between 1968 and 1996, the mining has been followed by many years of remediation from the chemicals used on the site in order to transfer the areas into land for public use. The amount of extracted uranium was total of 15 862 t.

Two different mining methods were used in the Stráž block. The classical underground mining which was used in the mines Hamr I and Křížany and the chemical in situ leaching method. This type of mining uses a chemical solution that dissolves the material and is later pumped out and isolated. In case of siliceous rocks as sandstone, various acids have to be used during the process which leads to a long process of remediation by draining out the contaminated acidic water (DIAMO 2023).

Recent situation

The Stráž pod Ralskem deposit is the only deposit in Stráž block that is open to this day. Uranium is extracted from the mine water as the secondary product of remediation (Schrimpelová 2018).

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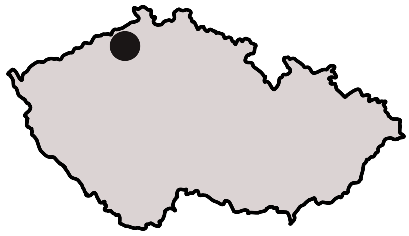
Cínovec-Zinnwald lithium deposit

Ľubomír Kyrc



Localization

The Cínovec village as well as deposit itself is situated in in Krušné Hore (Erzgebirge) in the northern part of the Czechia, on a border with Germany, approximately 90 kilometers NW from Prague. Deposit extends under both Czechia and Germany.

Geological characteristic

Cínovec or Zinnwald deposit can be divided into two main parts – North and South and minor Cínovec West part. Deposit itself is hosted in late-Variscan intrusive granite cupola (Fig. 1) formed by post collision A-type Cínovec granite, intruding through Teplice rhyolite (Breiter et al. 2017). Contact of granite and rhyolite is formed by so called "stockscheider" – pegmatitic coarse grained rock formed by orthoclase and quartz, with fine grained matrix. This rock indicates fast crystallization of granite magma on the contact with relatively cold rhyolite. In general, Cínovec granite is strongly fractionated, enriched by F, Li, Rb, Sn, W, Nb and Ta, with decreased content of P, Mg, Ti, Sr and Ba. Biggest part of the deposit is formed by fine grained albite-zinnwaldite granite reaching depth from surface up to 250 meters (drillhole CS-1) in the central part of the cupola. It is formed by quartz, albite, zinnwaldite and potassium feldspar (mostly altered to sericite), accessories are represented by fluorite, topaz, cassiterite, zircon and columbite (Breiter et al. 2016).

In the upper parts of the granite cupola presence slightly inclined quartz-zinnwaldite veins (called Flöze) had significant importance for historical mining. These veins are coarse grained, with thickness up to 2 meters. They are formed by dominant quartz, ore minerals are represented by zinnwaldite, cassiterite, wolframite, lesser by scheelite. These veins are parallel with granite – rhyolite contact. Less important were steeper veins (called Morgänge), their thickness is reaching up to 50 centimeters, with similar mineral assemblage as "Flöze" veins, however with lesser amount of the ore minerals. For both veins types it is typical to be accompanied by strong greissenisation of the surrounding granite rock, forming rims up to 20 centimeters thick (Müller et al. 2018; Breiter et al. 2019).

Massive greisen are flat zones with significant overprint of the formed granite. In Cínovec North this mineralization is less present, forming small bodies with thickness up to 20 meters and thin rims of massive zinnwaldite around quartz-zinnwaldite veins, with thickness around 50 cm, occasionally up to 2 meters. On the other hand, in Cínovec South greissenisation forming massive greisen is more often present, forming bigger bodies distributed within albite-zinnwaldite granite. Massive greisen is formed by zinnwaldite, quartz and lesser amount of fluorite and topaz (Breiter et al. 2016).

The Cínovec deposit is a world class deposit of Li, Sn and W, with significant amount of Sc, Nb, Ta, and REE+Y. Main ore mineral of Sn is cassiterite, for W it is wolframite and younger scheelite, both hosted primarily in Flöze and Morgänge veins. For Li, zinnwaldite is most important with Li_2O content between 2.4–4.4 wt. %. Worth mentioning is younger hydrothermal alteration (muscovitization) of zinnwaldite, resulting in decreasing content of Li and increasing content of Sn (Breiter et al. 2019). Sc is primarily hosted in zinnwaldite and muscovite with content up to 169 ppm, with average of 57 ppm, these micas form 93 % of Sc content in whole deposit. Sc is also present in wolframite, columbite and ixiolite and also in accessories such as zircon and xenotime. REEs are hosted in late magmatic minerals like xenotime, chernovite, monazite later remobilized to younger REEs enriched fluorite and fluorcarbonates for example synchysite and bastnäsite. Significant enshrinement in REEs was observed on the contact between granite cupola and Teplice rhyolite, in stockscheider zone (Hreus 2021).

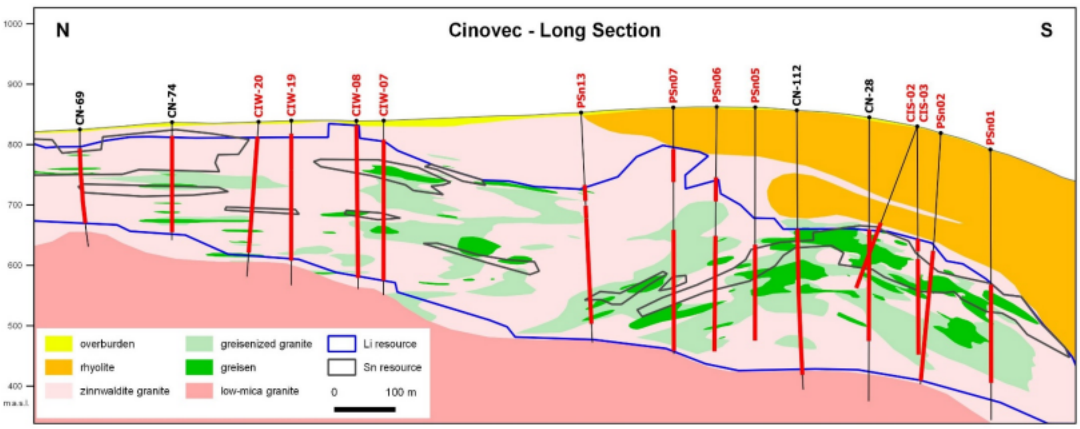
History

First mining of the Cínovec/Zinnwald deposit was focused on tin and it dates back to 1378. In second half of 19th century extraction of tungsten took place as well. Importance of the deposit increased during World Wars. During WWI, Cínovec I shaft was reconstructed to a bigger profile, enabling more intensive mining. After the WWII, the Czechoslovakian state company (Rudní Doly Příbram) continued in mining activity on the Czech side of the deposit (the German part was abandoned). Also, extensive drilling exploration was carried out at the same time leading to a discovery of the Cínovec South deposit in 1961. In this year excavation of the Cínovec II shaft began, and in 1980 exploitation of this part of the deposit started. In 1979 Cínovec north opened by Cínovec I shaft was exhausted and mining continued until 1990 in the area of the Cínovec South (Urban et al. 2015; Breiter et al. 2016).

Recent situation

Recently the Cínovec deposit is one of the biggest exploration projects carried out in Central Europe with main interest in Li, Sn, W and potentially Sc, Nb, Ta, Rb, Cs and REEs. Both Czech and German parts of the deposit are under exploration. In the Czech part it is exploration company Geomet and in Germany it is company Bacanora and SolarWorld.

The Geomet company is owned 49% by EMH (European Metals Holdings) and 51% by ČEZ a. s. (České energetické závody) through its wholly owned subsidiary, SDAS (Severočeské doly, a.s.). According to the ASX announcement published by EHM on 13th of October 2021, 22 drillholes with a total length of 6 622 meters were completed in the area of the Cínovec South. By this drilling campaign measured and indicated resources has increased to 413.4 MT with grade of 0.47% Li_2O and 0.05% Sn and total measured, indicated and inferred resources have increased to 708.2MT with grade of 0.43% Li_2O and 0.05 % Sn (0.1 % Li or 0.22 % Li_2O cut-off).



Hole	From	To	Width (m)	Li_2O (%)	Hole	From	To	Width (m)	Li_2O (%)
CN-17	22	224	202	0.62	CIW-25	9.5	373	361.5	0.43
CIW-22	123	387.5	264.5	0.54	CIW-26	173.75	410	236.25	0.49
CN-81	1	224	223	0.52	CN-86	81.8	230.9	149.1	0.48

Fig. 1: Cross section of the Cínovec South deposit, with selected lithium drill intercepts (EHM Investor presentation, published 20. 11. 2018).

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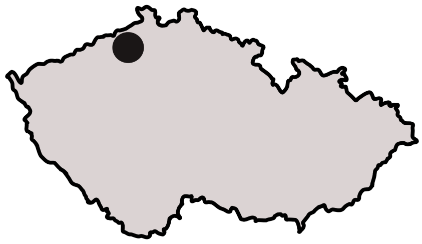
Brown coal mining in the Podkrušnohorská basin

Tomáš Turek



Localization

The Podkrušnohorská basin (approximately 1400 km^2) is divided into three separate units, which are located to the southeast of the Krušné hory mountain ridge.

The Most Basin (formerly the North Bohemian Coal Basin) is the largest (approx. 870 km^2) and the most important basin, and the highest quality brown coal is found here. It lies between the Doupovské hory mountains in the west and the České středohoří mountains in the southeast.

The Sokolov Basin is smaller. Its area is approximately 312 km^2. In the east, it is separated from the Mostecká Basin by the Doupovské hory mountains. In the west it is separated from the Cheb Basin by the Chlum Svaté Maří crystalline ridge.

The Cheb Basin is the smallest (approx. 270 km^2). The Chlum Svaté Máří crystalline ridge is separated Cheb Basin from the Sokolovká Basin (Chlupáč 2011; Sakala 2000).

Geological characteristic

There are several hypotheses about the origin of the basin. They interpret the basin as a synclinal part of a megafold, a simple tectonic graben or a rift structure in terms of the plate tectonics. One of the possible explanations is also vulcanotectonic subsidence. According to this theory, there is a subsidence in the basin area due to emptying places in the upper mantle, due to the production of volcanic material (Kopecky 1976; Malkovsky 1980; Sakala 2000).

Most of the Podkrušnohorská basin, the basement is formed of Krušné hory mountains crystalline rock, partly Permocarboniferous and Cretaceous sedimentary complex (Sakala 2000).

The Podorušnohorská basin is deposited mainly with sediments and volcanoclastic rocks. Brown coal seams were formed during the Tertiary period. In the Tertiary, there were massive lakes and wetlands in this area, into which two ancient rivers flowed. Their delta flows into the area near the towns of Žatec and Bílina (Chlupáč 2011).

First sedimentation in this area probably started in the Middle Eocene and continued in the Late Eocene with deposition of basal fluvial-lacustrine sandy layers (Fig. 1). Second sedimentation started during the Early Oligocene and continued to Oligocene - Miocene boundary and mostly of volcanic bodies, tuffites and reworked pyroclastic rocks, were deposited in this area. The third and main phase of sedimentation took place during the Miocene period (Late Egerian - Eggenburgian) and the main brown coal layer (up to 60 m thick) was deposited here (Sakala 2000).

Mining History

Mining in the Podkrušnohorská basins began already in the Middle Ages. Original mining took place by underground mining in adits and less by using open pit quarries. During the last century, there was a change in mining and large open pit coal quarries were created for the extraction of brown coal.

Due to mining, more than 100 villages were destroyed, and Most lost its original historical center from which only the church was saved and moved.

First records of coal mining in Most Basin are from the mid 16th century, but some indications point to the beginning of mining as early as the 14th century. The first mining was done from outcrops and shallow adits. Coal was used for the production of chemical compounds, heating and fertilizing with ash from burnt coal. Thanks to the development of transport and mining machinery, mining was expanded during the 19th century and a large number of adits and open pit mines were created. During the 20th century, mining was expanded and coal production steadily increased. Production increased until 1984, when it exceeded 82 Mt. (Pešek 2014).

Recent situation

Current mining takes place in an open pit mines:

1. Nástup – Tušimice Open Pit (Libouš): Probable termination without breaking the limits is 2029.
2. Vršany Open Pit: This open pit was interconnected with the Jan Šverma Open Pit in 2012. Probable termination of mining without breaking the limits is 2052.
3. ČSA Open Pit: Probable termination of mining without breaking the limits is 2025.
4. Bílina Open Pit (formerly Maxim Gorkij Super Pit): Thickness of the lignite seam is 25 to 35 m. Currently, the Bílina Open Pit is the deepest open pit in the Czechia with deepest open place in the Czech Republic. The limits in this open pit were broken this year and open pit can mine until 2035.

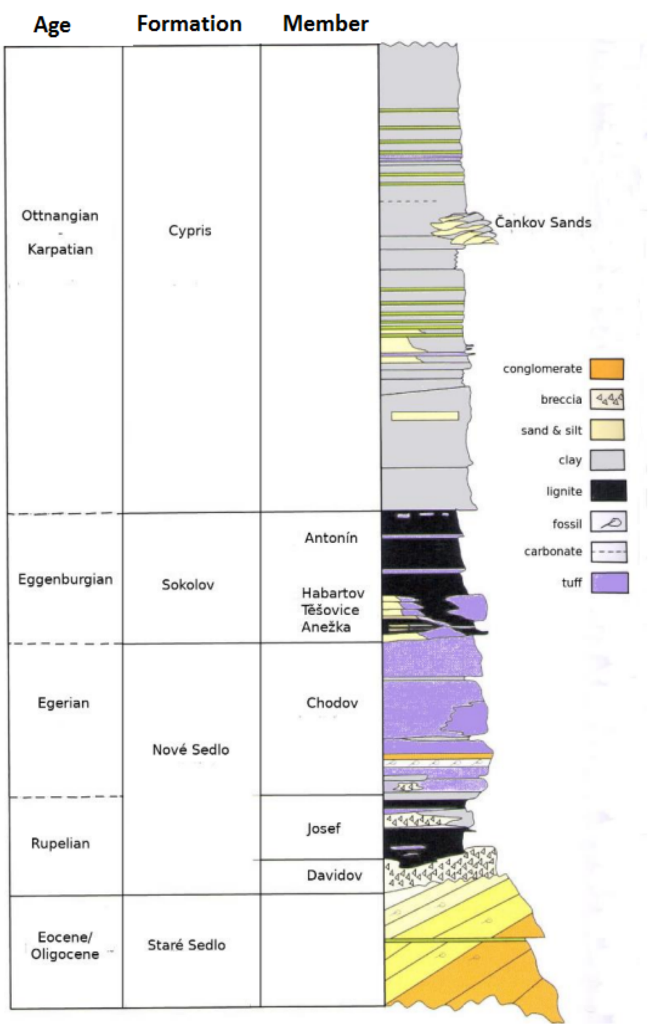


Fig. 1: Lithostratigraphic scheme of the Sokolov Basin (Pešek 2016).

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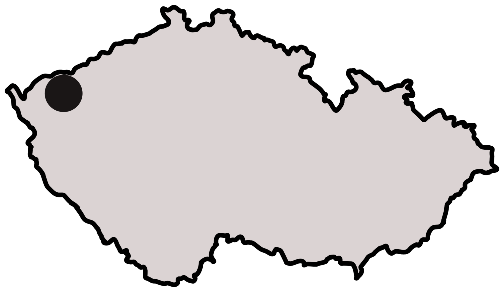
Uranium mining at Jáchymov

Jan Plachý



Localization

Jáchymov is a town located in the Karlovy Vary Region, 20 kilometers north from Karlovy Vary. The town is located in the Ore Mountains, a mountainous region known for its rich ore deposits and its historical connection to mining.

Geological characterization

Jáchymov and its surroundings belong to the group of the Krušné hory (Ore Mountains) crystalline rocks, which are adjacent to the Karlovy Vary pluton from the southeast. From the east, the Vogtland-Saxon Paleozoic region with deeper metamorphosed crystalline rocks of the Krušné hory extends into the area. All rocks of the Krušné hory crystalline complex are likely to have undergone two phases of regional metamorphism and intense folding (Mísař 1983).

The Jáchymov Group is composed of biotite gneisses, biotite schists, quartzite schists and quartzites, paragneisses, graphitic shales, carbonate shales, and amphibolites. Due to metamorphic processes, the Jáchymov Group does not exhibit a clear stratigraphy (Mísař 1983). According to Zoubek (1959), the established term "transitional complex" places the group in the upper Proterozoic to Cambrian period. Alpine cycle which brought tectonic pressure caused fracturing of the granite massifs. During this stage both ore veins and ore free minerals were formed. This process resulted in formation of iron, manganese, cobalt, silver, bismuth, nickel, and uranium mineralization (Ondruš 2003).

Jáchymov ore district is known for its five elements mineralization. The process is in fact divided into two stages. Ag–Bi–Co–Ni–As formation and U formation. The formation depends on different sources of ore bearing fluids. For this formation is characteristic superposition of minerals from both stages and remobilization of mineralization (Ondruš 2003).

History of mining

Richer deposits were discovered in the surrounding mining villages such as Svatá Kateřina (1528), Albertany (1529), and Boží Dar (1533). Thanks to these findings, Jáchymov and its surroundings prospered. The mined ore was not rich in silver (Ag) - it contained only 0.7 % Ag that could be used. Silver mining continued until the mid-19th century when there was a rising demand for uraninite. Uraninite was used for coloring glass products. In the mid-19th century, the demand for uranium surpassed the demand for silver (Veselovský 1997).

The discovery of radioactivity in 1896 by Becquerel, and the subsequent isolation of polonium and radium by Marie Curie-Sklodowska and Pierre Curie from ore in Jáchymov, marked a new phase. Initially, uraninite was mined for the needs of the glass industry. The therapeutic effects of the springs in the vicinity of Jáchymov were discovered and during the 19th century, many facilities were built in Jáchymov for therapeutic purposes.

After World War II, the Jáchymov region experienced its final and most extensive period of uranium mining. In 1945, the mines came under the control of the Czechoslovak Republic, although they had a limited number of employees and outdated equipment at that time. Subsequently, exploration led to the discovery of new veins of uranium ore, which resulted in increased mining activities (Fig. 1). By the early 1950s, nine mines were in operation, and uranium production reached its peak in 1955–57, when a significant amount of uranium was extracted. Many political prisoners were sent to work in mines for their unfavorable attitude towards the state. Uranium mining in this area lasted for over 100 years, but after 1964, all mines were closed, marking the end of this long history of ore mining in Jáchymov. The total uranium production in the period from 1853 to 1964 was estimated at 8 500 tons. In addition to mining, radioactive springs were used for therapeutic purposes, both natural springs in the mines and artificially prepared radioactive waters for the treatment of various illnesses. Overall, Jáchymov played a pivotal role as a center for uranium mining and the utilization of radioactivity in Czechoslovakia (Veselovský 1997).

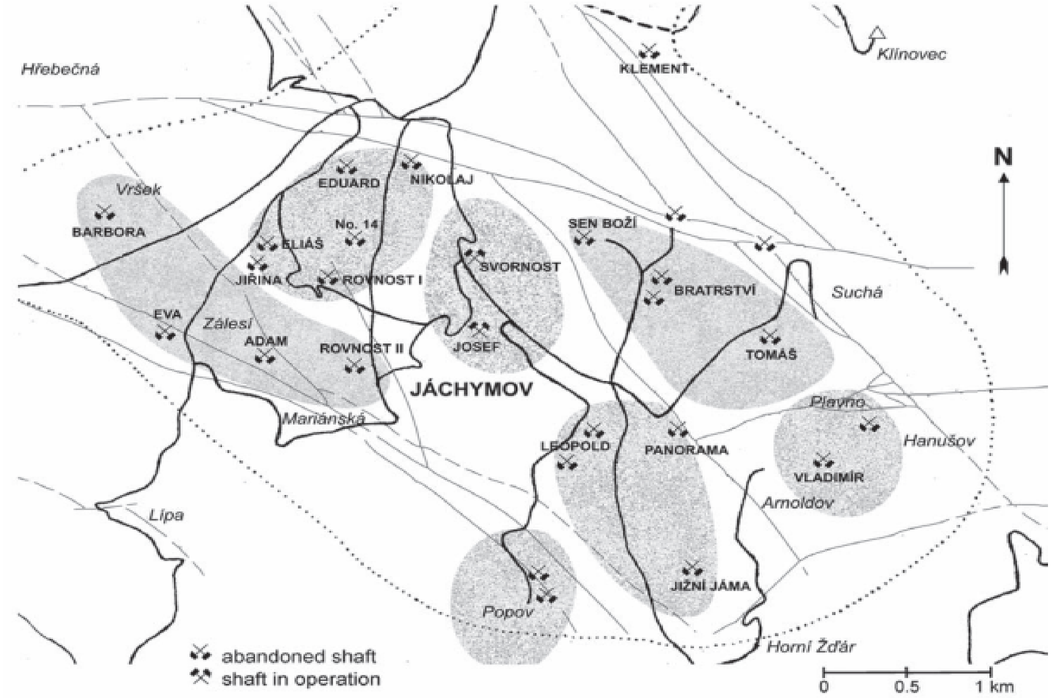


Fig. 1: Simplified map of locations of the six main ore clusters in Jáchymov district (Ondruš 2003).

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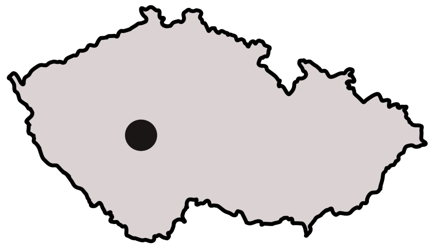
Uranium mining at Příbram

Tomáš Havran, Adriana Mašová



Localization

The town of Příbram is situated in the central Bohemian region about 20 km south from Prague and 30 km east from Plzeň.

Geological characteristic

Příbram town is situated in the Bohemian massif in the Barrandien region in the Příbramskojinecká basin. This basin is filled with Cambrian sediments which are usually very irregularly distributed in Barrandien. Those sediments fill depressions formed after the Cadomian mountain-forming processes on the underlying folded Proterozoic units and always lay discordantly. The main sedimentation area was the Příbramskojinecká basin, whose preserved and certainly very incomplete remains are found, in particular in Brdy between Rokycany, Příbram and the surroundings of Dobříš. The basin lays in a depression between the ranges of the Cadomian Mountains and was rapidly filled, especially in the Lower Cambrian, with detrital material brought by watercourses and torrential mudflows from nearby land. The bottom of the basin sank significantly due to tectonic activity, so that the brought material accumulated mainly in the L. Cambrian up to several thousand meters thick (Chlupáč et al. 2002).

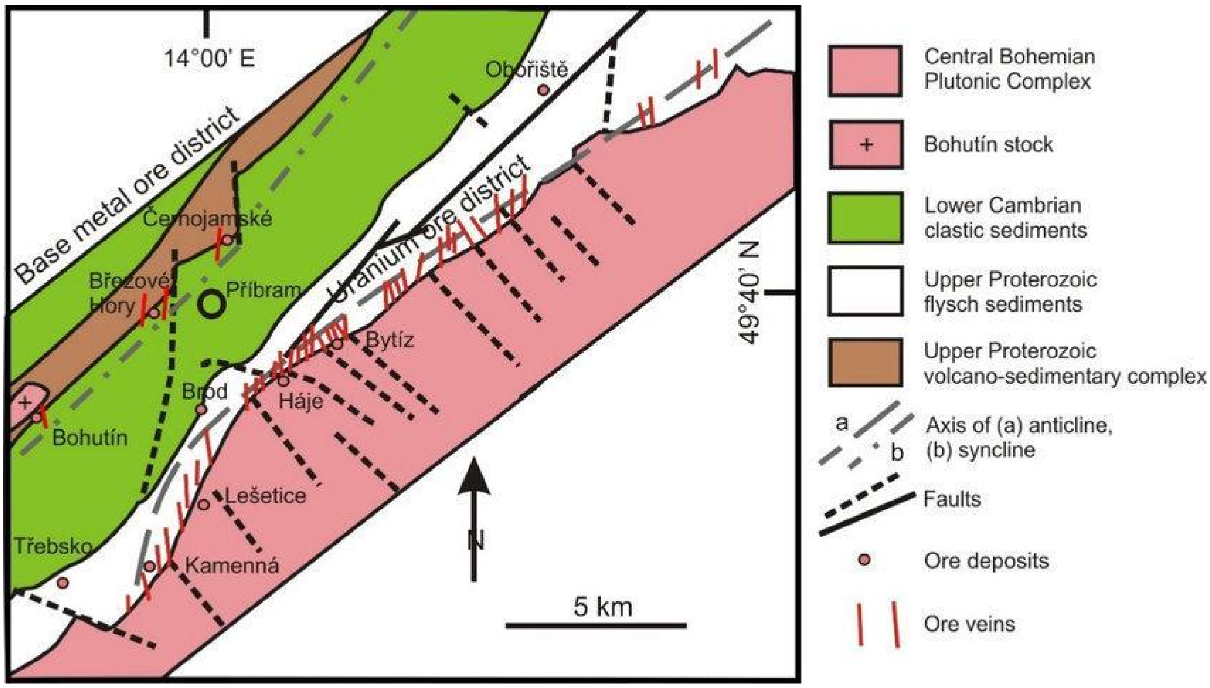


Fig. 1: Geological map of uranium district in Příbram and surroundings (René et al. 2019).

The Příbram uranium deposit is developed in a 1 to 2 km wide area and a 25 km long strip of exocontact of the Central Bohemia pluton. The most widespread rocks are variously intensively in contact with very weak regionally metamorphosed sediments. They are made up of variously represented claystones, siltstones, and sandstones with also a layer of Dobříš conglomerates. Intensely denuded, the rocks were overlain by Cambrian conglomerates and debris that forms a strip on the deposit, called the Dubenec-Druhlice Cambrian (Petroš 1964).

Polymetallic Pb-Zn-Cu ore can be dated to the cooling era of plutonic masses and post-orogenic hydrothermal activity. The mineralization is bound to fault zones and in some cases follows the course of vein volcanics. The classic example is Příbram, with its mineralogy, the composition of ore veins and the amount of secondary minerals (around 220 types of minerals are known). Veins with U mineralization are typically younger. Most common mineral is uraninite, “U-anthraxolite” and arsenates. Uranium minerals provided radiometric data and are dated between 250–290 Ma.

Mining history

The oldest silver mining in the Příbram mines is attributed to the ancient Celts. However, the first preserved report on mining activity in the Příbram region dates back to April 21, 1311. On this day, according to an ancient charter, Kondrád of Příbram and his sons Henry and Nicholas donated a foundry to Bishop John IV. The foundry had been established on the Příbram estate at their own expense.

Historical documents from the 14th century already describe mining activities in the Příbram area, although they lack specific locations of the mines and, more importantly, the foundries. In the 15th century, there is an increasing number of historical records about mining, and it is known that the largest silver reserves were located in the mines on Březové hory (Birch Mountains). However, mining was not continuous during this period - it occurred intermittently and gradually declined.

The salvation of the Příbram mines from a certain decline was achieved upon the arrival of Jan Antonín Alis, who proposed and implemented the concept of vertical shaft mining and deeper excavations. A significant milestone in the global mining industry was reached when the Vojtěch mine reached a depth of 1000 meters. Over time, in addition to silver, other ores such as lead and iron began to be extracted.

After World War II, the first uranium deposit in the Czech Republic was opened, with the Vojna I and II shafts. Mining took place between 1948 and 1991, during which time the Příbram region became one of the most significant hydrothermal deposits not only in Europe. Since the beginning of mining in 1948, political prisoners were enslaved for work in challenging conditions. A total of 48 432 tons of uranium were extracted. Unfortunately, all of it had to be sold to the USSR at practically operational costs. In addition to uranium, 6 200 tons of lead, 2 400 tons of zinc, and 28 900 tons of silver were extracted. The last cart was ceremoniously extracted on September 30, 1991.

Recent situation

Currently, the Mining Museum Příbram manages the majority of the facilities that have remained here after mining activities. One of the highlights of this museum's tours is a ride on a mining train. One route takes visitors underground from the Anna mine to the Prokop shaft, while another connects the Ševčín and Vojtěch mines. However, not all of the facilities have been preserved in their original condition. The former engine house of the Prokop mine, owned by the company Diamo, has been deteriorating for several years. The state company Diamo operates one of its branch facilities in Příbram – the Management of Uranium Deposits Příbram.

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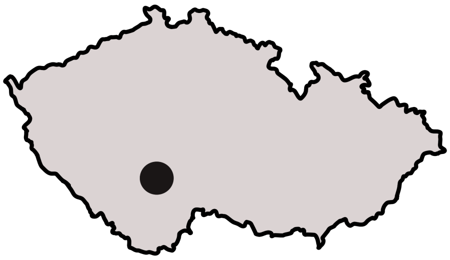
Lignite seams in the South Bohemian basins

Šárka Kučerová



Localization

The lignite seams are situated in the South Bohemian region, approximately 20 kilometres NW from the city of České Budějovice, in the českobudějovická basin.

Geological characteristic

Českobudějovická and Třeboňská basins are two large depressions, which are surrounded by the moldanubian rocks and variscan granitoids. The basins had been formed during the Saxony faulting tectonics. This process took place during the Cretaceous era and Tertiary era as a reaction to the Alpine orogeny. The main faults during the filling of those basins had orientation NW-SE. Nowadays the basins are separated by the lišovský hřbet, however, the two basins did relate to each other during some period (Chlupáč et al. 2011).

Cretaceous lignite and clay deposits of the depressions of the South Bohemian basins differentiate by their filling, which is made of fresh water or brackish water sedimentary regime (Chlupáč et al. 2011).

The most important tertiary lithostratigraphic unit of the South Bohemian basins is Mydlovary formation. The sedimentary rocks are layered throughout ¼ of the area of the basins. They are layered on top of the metamorphic rocks of moldanubian unit or on top of the granitoid (Pešek et al. 2010).

The complex of Mydlovary formation begins with clay sand and with locally layered basal conglomerates. Those clastics gradually cross to the overlaying cover to arenaceous greenish and then greyish clay. Locally in the českobudějovická basin had been formed layers of weakly charred coal, known as lignite (Pešek et al. 2010).

History

First attempts of mining of lignite date to the 19th century. In 1860 the dynasty of Schwarzenbergs tried to mine lignite in the Mydlovary municipality, however, those were only attempts. The first lignite mine was opened about 50 years later in the years of 1910–1917. More specifically in the years 1917 and 1918 the mine Svatopluk was established, thus surface mining began. The mining is concentrated near the intersection of Zahájí – Mydlovary – Zliv municipalities (Dufek et al. 2008).

In 1921 the South Bohemian power plants became owners of the lignite mines. The reserves, which have been proved by 359 geological boreholes, were approximated to last for 100 years. In 1922 a new power plant was built (Elektrárna Mydlovary) to make use of the low-quality coal. The power plant was enlarged for the next 2 decades. Back in the 1940‘s it was the most important source of energy in south Bohemia (Dufek et al. 2008).

In the late 1950‘s the lignite mines were shut down, and the Mydlovary powerplant transitioned to the higher-quality coal, which is transported to Mydlovary from Sokolov (Dufek et al. 2008).

Since the shutdown of the lignite mines, the large old extracted mine area became an uranium ore processing plant MAPE (from Magnesium Perchlorate) in 1962. In total about 16,7 MT of uranium ore was processed there. The power plant started to be used as a heating plant. First, it was only for the enterprise, and in the following years (1967) also for Zliv municipality. In 1974 a steampipe was built in Mydlovary, which helped to heat the city of České Budějovice (Dufek et al. 2008).

The leaching of uranium ore in MAPE ended in 1991, and the area is supposed to be recultivated. The processes of reclamation and remediation is still ongoing today. In 1998 the production of electricity in Mydlovary finally ended its duty, and for the first time since 1974, České Budějovice stopped consuming steam supplies from Mydlovary steampipe (Dufek et al. 2008).

Recent situation

The leaching of the uranium ore in MAPE ended in 1991, and the area is being recultivated. The reclamation should be finished in 2024. Since 2001 the heating plant has been suited to natural gas (Dufek et al. 2008).

Today the heating plant provides heat sources for nearby surroundings. There is also a possibility that the area could become a waste incineration plant (Dufek et al. 2008).

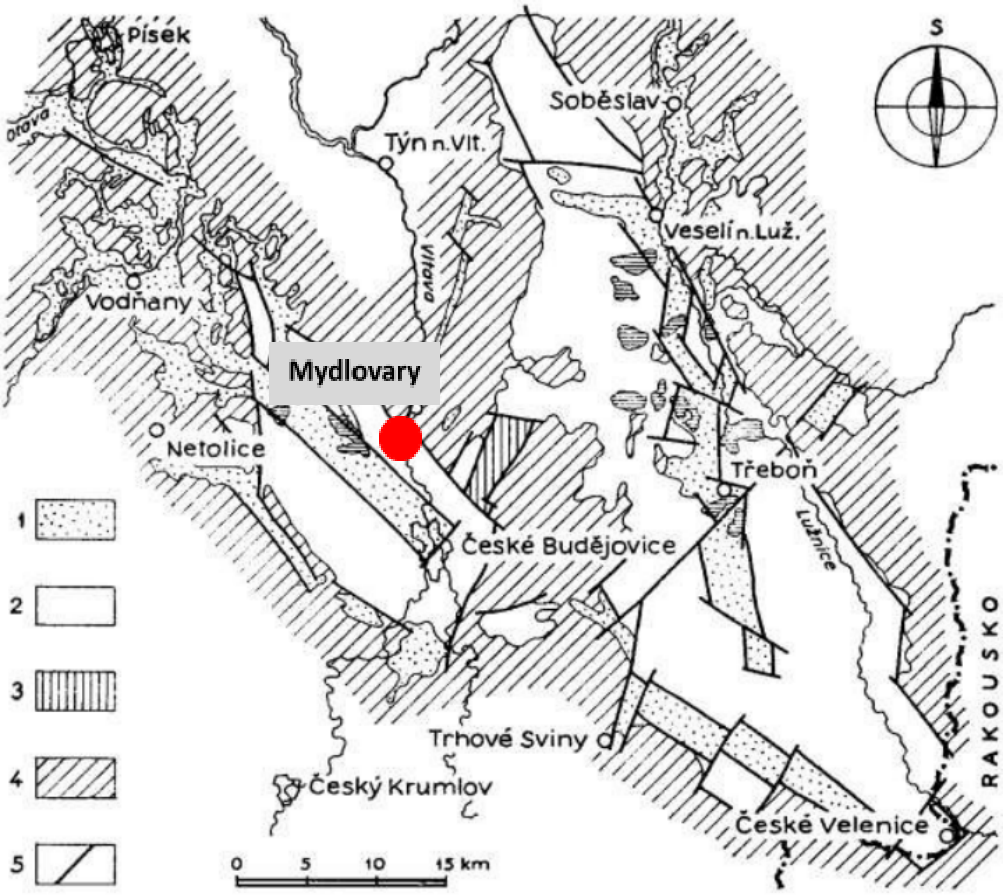


Fig. 1: Geological map of South Bohemian basins, explanatory notes: 1 – lipnické, zlivské, mydlovarské, domanínské, ledenické and moldavite-bearing gravel sand formations – Oligocene to Pliocene; 2 – klikovské formation – Senonian; 3 – Permo-Carboniferous; 4 – basement and magmatic rocks of Moldanubicum (Malecha et al. 1964, edited).

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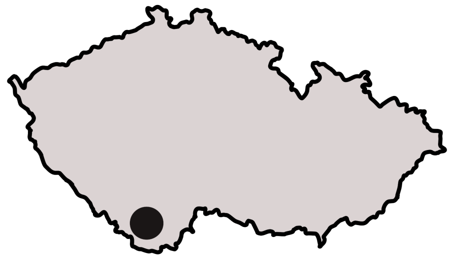
Peat mining at the Czech Republic

Jan Loun



Localization

In the Czech Republic, only the company Rašelina a. s. (formerly Rašelina Soběslav) and some spa facilities can mine peat. Currently, industrially mined peatbogs are Branná, Hranice, Světlík, Člunek, Hora sv. Šebestiána and Krásno-Čistá (only for spa purposes; Placková 2020).

Peat deposits cover large areas of the world's landmass, mostly in the northern hemisphere. In the Czech Republic peat mining is traditionally associated with peatlands in Šumava, Třeboň basin, Ore Mountains, Slavkovský forest and historically also with other peatlands.

Geological characteristics and genesis of deposits

Peat is a naturally existing sedimentary material, an accumulation of partially decayed vegetation or organic matter. It is the first phase of coal formation. A complete transformation would require more pressure, higher temperature and especially a very long time.

Peatbogs are wetland biotopes with a high production of plant biomass. Remains of plants decompose incompletely due to excessive waterlogging and unfavorable conditions for the life of decomposing organisms. Plant organic matter therefore accumulates in the bog. The layers of dead plant parts gradually grow and in the lower parts without access to air, they turn into peat in a process called peating. The conditions for the formation of peat bogs are waterlogging, low pH, low nutrient availability, low oxygen supply and reduced decomposition rate (IPS 2023).

In natural peatbogs the annual rate of biomass production is greater than the rate of decomposition. A peatbog takes a very long time to form, so it is almost impossible to create it artificially. Only a 1–2 mm thick layer of peat is formed per year so it takes thousands of years for peatbogs to develop the average depth of deposit which is 1.5 to 2.3 m. Peatbogs in the Czech Republic are usually up to 8 meters thick (Ministry of the Environment 2023).

History

The oldest use of peat in the form of dried bricks was for heating. Peat also served as a cheap, available litter for livestock, as it well holds water and smell and also has mild antibacterial effects. It had a very limited use as an insulating material (pressed Solomit boards; Placková 2020).

Extraction of this raw material was a very difficult work, as it was dug with a spade to a depth of up to 3 meters. The excavated peat was then transported on wheelbarrows to be dried and stored for use (Rašelina a.s. 2023).

Recent situation

The largest volume of peat is currently consumed in agriculture, in professional use (fields or forests) or in gardens. Peat well holds water and loosens and lightens the soil. However, it has to be adjusted before use, in particular, it is necessary to supply nutrients and reduce acidity by adding limestone.

Due to its antibacterial and healing effects, peat has been used for poultices or baths where it mainly relieves rheumatism, helps with movement difficulties and skin ailments. This is because peat has a good ability to hold heat, so a bath or a wrap with a heated peat solution intensively warms the body. This property has been used in spas for centuries. Most spas have their own natural source, or they arose at just such a source. Examples in the Czech Republic are Františkovy Lázně, Třebon spa, Bohdaneč spa and others. However, the consumption of peat for spa use is very small.

Besides heating, another use is drying of barley malt for the production of whiskey over a fire fueled by peat, which gives the drink a typical swampy smoky aroma. This method of use has remained the same for hundreds of years (Placková 2020).

Localities

Borkovická Blata in South Bohemia

The peatbog Borkovická Blata is located in the northern part of the Třeboň basin near the Borkovice village and covers an area of over 100 ha. It was formed in the postglacial period more than 10 000 years ago. The peatbog was created by the springs of underground water above the impermeable bedrock of the deposits of the Klikovské formation, the organic parts were gradually deposited and the layer of peat reached an average of 2–6 meters, in some places even 8 meters.

Peat extraction dates back to 1854. In the past, peat 'bricks' were dug out by hand, dried and used for heating and subsequently as fertilizer. Industrial peat extraction began in 1953 and ended in 1980. Since then, the Borkovická Blata has been established as a nature reservation. During mining a deposit of the organic mineral fichtelite was found here (Chroustová 2018).

Světlík in South Bohemia

The most important currently mined deposit is Světlík, Šumava. This is one of the last industrially mined deposits of peat in the Czech Republic. Peat has been mined here since time immemorial, but its use for horticultural and agricultural purposes only began in the 1930s. The turning point was 1948, when all private enterprises and organizations were incorporated into the national enterprise Rašelina. Thanks to the introduction of a new extraction method – milling, Rašelina became the exclusive supplier of peat and a producer of compost for agriculture. In 1988, Rašelina already had a total of 17 separate plants, employing 453 workers, when its mining amounted to 303 thousand m^3 of peat per year and compost production 794 thousand m^3. Through gradual transformation and privatization, the joint-stock company Rašelina was established on 1 January 1994. The current majority owner is the company CiMS, a.s. (Kolářová 2022).

Rašelina a.s. extracts peat for agricultural purposes (production of substrates for forest nurseries, vegetable growing, fruit growing, floriculture or horticulture), but also focuses on its medicinal effects. The humic acids and minerals contained in bog peat help relieve stress, fatigue and muscle stiffness, and stimulate the body's defenses. Different types of peat soaps are helpful in reducing the symptoms of acne, psoriasis and atopic eczema, they act against fungi, for healing wounds and burns, balance the function of the sebaceous glands, thereby slowing down the aging of the skin, has an anti-fatigue and soothing effect, relieves inflammations and acts against microbes. All these soaps are made by hand. This year, the company commemorates 75 years since the national company Rašelina Soběslav was founded in 1948 (Zahradnictví 2003).

Nearby, in the neighboring village of Blatná, is a small deposit of high-quality medicinal peat, which is owned by the municipality of Frymburk, which received a decision that this deposit has become a therapeutic spa resource. Part of the permit procedure is subsequent technical reclamation, which includes restoration of the drainage system, leveling of the surface and pH adjustment, and other works, such as seeding or planting (Zahradnictví 2003).

Přebuz in Krušné Hory

The Přebuz peatbog is located on a plateau in the extended valley of the Rolava river in the Přebuz highlands geological district, approximately 1.5 km northwest of Přebuz village.

The bedrock consists of autometamorphosed granites of the Karlovy Vary pluton, which are covered by a layer of peat up to thickness of 3 meters. Peat has long been mined here, mostly on a small scale. Mainly hand mined peat was used for heating households and also as insulation material for residential buildings. Peat has been mined on the Přebuz bog since the 18th century, significant development of peat mining took place here after 1812, when the price of firewood increased. Peat mining continued until the middle of the 20th century. Remains of mining activities are visible in the mountain landscape to this day (Žižka 2023).

In 1992, a natural monument on the site of a previously mined peatbog was established. It covers an area of 90 ha. The main reason for the establishment of this natural reserve is protection of the complex of semi-natural biotopes created after the extraction of peat (Žižka 2023).

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Appendix I

Oil and natural gas deposits of Southern Moravia - Main Deposits

Kateřina Streitová, Monika Kubernátová

Main deposits and important technical facilities

1. *Břeclav*

There are several oil and natural gas deposits located in the vicinity of the town of Břeclav (Fig. 1). Small deposits were discovered to the south of the town as early as the 1940s, and they were extracted within a few years. After the year 2000, Lama Gas & Oil conducted a 3D seismic survey over a significant part of the area. This survey led to the discovery of new significant gas deposits to the east of the town, which are still being exploited through 9 wells. In the extraction centre in Břeclav, gas is extracted from two wells, processed, and injected into the distributing gas pipeline. Additional extraction wells and the extraction centre are located behind the railway track, about a kilometre away (Muzeum naftového dobývání a geologie 2023).

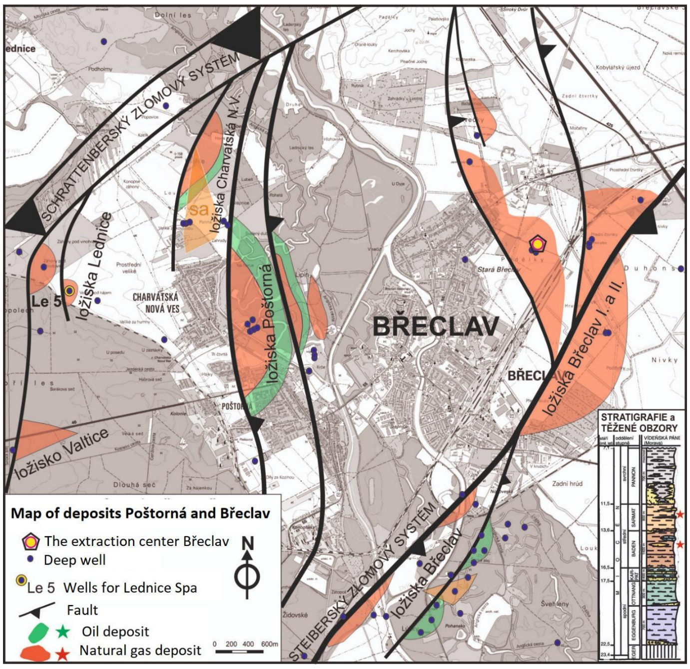

Fig. 1: Map of oil and gas deposits Břeclav and Poštorná (Muzeum naftového dobývání a geologie 2023)

2. *Poštorná*

The Poštorná extraction centre is the location where Lama Gas & Oil Company processes and dispatches the extracted oil and natural gas. The oil reservoir has a gas cap, from which oil is currently extracted from two wells and gas from three. The sandstone reservoirs beneath the hydrocarbon accumulations are saturated with ancient seawater, and for the Lednice Spa, a brine (with a temperature of 44°C, total mineralization of 10 g/l, and iodine content of 30 mg/l) is extracted not far from here through the Le-5 well, from a previously depleted small deposit (Muzeum naftového dobývání a geologie 2023).

3. *Hrušky*

Hrušky is the largest oil and gas field in the Czech Republic. Individual oil and natural gas deposits have been identified on an industrial scale in all Neogene formations present here. The exploitable reserves amounted to 1.5 million tons of oil and 1.6 billion m^3 of natural gas (Muzeum naftového dobývání a geologie 2023).

Since 1972, mining has been discontinued on a portion of the deposit horizons, and the construction of the Tvrdonice underground gas storage facility with four storage horizons was initiated (Muzeum naftového dobývání a geologie 2023).

4. *Tvrdonice – Underground gas storage*

The Tvrdonice underground gas storage is located in southeastern Moravia (Fig. 2), representing a unique complex for storing natural gas. Its uniqueness is in its utilization of original, partially exploited deposits of gaseous hydrocarbons, situated in layers at depths of 1 to 1.6 km (Molíková et al. 2022).

The history of this storage dates before 1968, when the idea emerged to use these underground deposits for storing gas during the summer and releasing it into the network during periods of increased consumption. The actual construction began as early as 1971. Pilot operation commenced in 1973, with the commissioning of the first compressor and the initiation of gas injection into the storage system. The first construction phase was completed in 1975. The second phase started in 1980 and concluded three years later. The objective of the second phase was to increase daily capacity, operational reliability, and optimize storage space (Muzeum naftového dobývání a geologie 2023; RWE Gas Storage CZ, s.r.o. 2023).

The last phase of modernization and construction took place between 2004 and 2005 (Muzeum naftového dobývání a geologie, 2023). Its focus was on enhancing safety and operational reliability (RWE Gas Storage CZ, s.r.o. 2023). A control system was implemented, and selected technological processes were fully automated (Muzeum naftového dobývání a geologie 2023).

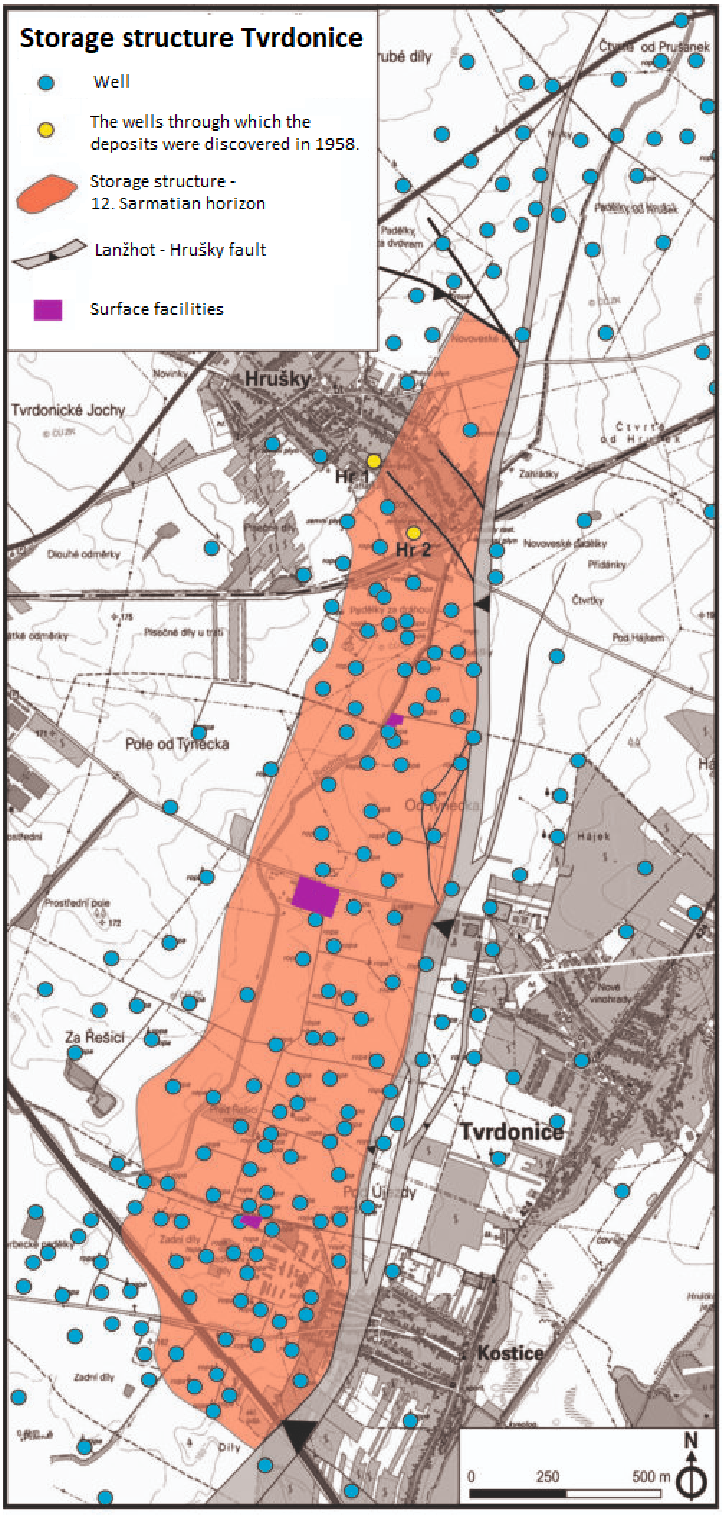

Fig. 2: Storage structure Tvrdonice and oil and gas field Hrušky (Muzeum naftového dobývání a geologie, 2023)

The underground gas storage is situated in a region that was once among the richest areas for oil and gas deposits in Central Europe. It is located in the eastern part of the Moravian depression and follows an elongated semi-vault structure along the Lanžhot-Hrušky fault system. The storage utilizes several layers of sandstone, with the most significant storage capacities existing between the 8^{th} and 14^{th} Sarmatian horizons and the 9th Baden horizon at depths ranging from 1 050 to 1 600 meters (Muzeum naftového dobývání a geologie 2023; RWE Gas Storage CZ, s.r.o. 2023).

In comparison to other underground gas storages, the Tvrdonice gas storage is characterized by greater storage depths and resulting higher pressure values. Due to the complex geological structure and numerous storage facilities, a relatively high number of production and observation wells exist, including special wells for injecting mine water (Molíková et al. 2022; Ryba et al. 2019).

Originally operated by the state-owned Český plynárenský podnik, the storage was subsequently privatized, with the operations taken over by RWE Gas Storage (renamed Innogy Gas Storage in 2016). Total gas reserves in the storage areas exceed 1 100 million m^3 (Muzeum naftového dobývání a geologie 2023), while the stored gas quantity reaches around 540 million m^3. The maximum extraction capacity of the storage exceeds 8 million m^3 per day (RWE Gas Storage CZ, s.r.o. 2023).

The process of gas storage involves gas injection through ČKD type 4 JBK 240 compressors with electric drives (RWE Gas Storage CZ, s.r.o. 2023). Gas purification from impurities occurs through multicyclones and dust filters. Gas is separated and dried at the collection centers to achieve the desired parameters for gas transport to end customers (Muzeum naftového dobývání a geologie 2023).

The Tvrdonice Underground Gas Storage stands as a significant component of energy infrastructure, offering valuable insights for the construction and operation of similar facilities (RWE Gas Storage CZ, s.r.o. 2023).

5. *Prušánky*

The collection centre in Prušánky is the location where connections from the Hrušky-sever field and Prušánky deposit wells are brought together. Oil and natural gas from the Bílovice-Žižkov and Poddvorov deposits were also processed here before further distribution. Despite some deposits in the vicinity of the Prušánky village being in the final phase of extraction, the potential of this area still exists, as evidenced by the discovery of deposit structures a few years ago (Muzeum naftového dobývání a geologie 2023).

6. *Lužice – Mikulčice*

The Lužice – Mikulčice region, located in the Czech Republic, has a rich history of oil extraction (Fig. 3) that dates back to 1919. Over the years, the oil deposits in this area were extensively mined, leading to the extraction of significant quantities of oil. By 1951, the region expanded its operations to include the extraction of natural gas. The 1960s marked a significant development for Mikulčice when an oil refinery was established. This facility processed the oil extracted from the local deposits. The refinery remained operational until the 1990s, after which the oil extraction activities in the region came to a halt.

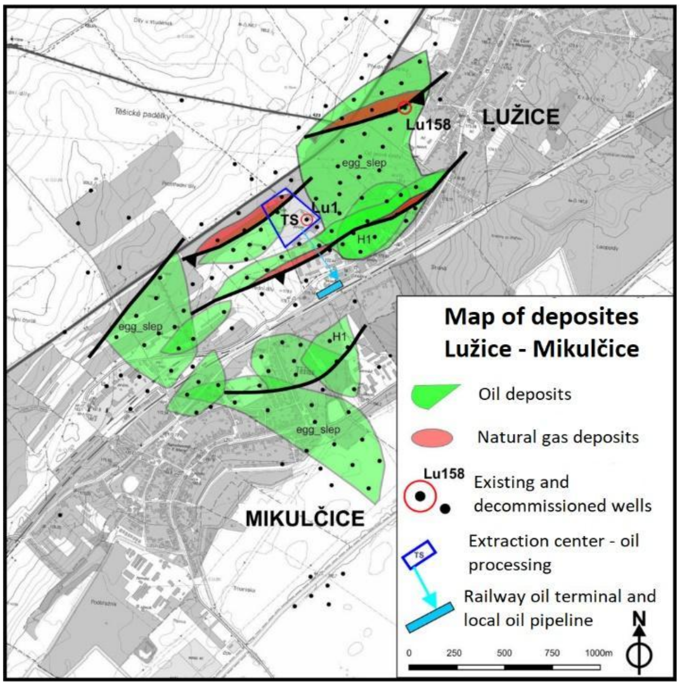

Fig. 3: Deposits area Lužice – Mikulčice (Muzeum naftového dobývání a geologie 2023).

The extracted oil typically contains dissolved hydrocarbon gases, water, and sometimes solid substances (such as sand). Due to increased transportation costs, vehicle corrosion, or higher processing expenses, these components must be removed before the oil is transported to refineries (Muzeum naftového dobývání a geologie 2023).

7. *Nesyt*

The oldest oil field is the vicinity of Hodonín (Fig. 4). In the year 1900, the first exploration well was drilled near the Nesyt farmstead in the Hodonín area. Over the following years, a series of wells were drilled, including unsuccessful attempts. In 1917, L. Odstrčil leased his exclusive rights to the Vienna-based Vulkan company, which later transferred the rights to the Moravian Mining Company. In 1919, a well was drilled in the Nesyt farmstead area, where the first oil deposit in Moravia was discovered. Since then, exploration and oil production have continued. The merger of the Moravian Mining Company with the Apollo company in 1925 was a significant step. A total of around 870 wells were drilled on the field, and oil was extracted from more than 20 Tertiary sandstone layers. The original reserves of oil and gas were 560 840 tons and 1 195 000 m^3. Production ceased due to declining output and environmental concerns. Between 2005 and 2015, the dismantling of wells and the reclamation of previously decommissioned ones, including the remediation of the area, took place (Muzeum naftového dobývání a geologie 2023).

Fig. 4:. Historical drilling at Nesyt (Muzeum naftového dobývání a geologie 2023).

8. *Poddvorov*

The Poddvorov deposit, situated in the Vienna Basin, has been a focal point of deep exploration since its initiation in 1952 with the drilling of Poddvorov 4 well. Despite encountering challenges such as accidents and gas eruptions, the deposit's importance remained steadfast. A pivotal discovery was made in 1958 with the identification of well P23, situated 150 m from its predecessor. This well tapped into oil-rich horizons at depths ranging from approximately 1 205 to 1 250 m. Subsequent incidents, like gas eruptions and oil spills, did not deter exploration efforts. Notably, Poddvorov 62 well's exploration in 1974 led to the discovery of a significant gas reservoir within the 1st and 2nd sands of the Badenian horizon. This gas field's remarkable geological attributes, such as elevated structures and porous formations, have contributed to its continuous extraction since 1955 (Muzeum naftového dobývání a geologie 2023).

9. *Mutěnice*

The Mutěnice deposit, situated in the closure of the Moravian Central Depression within the Vienna Basin, has been a site of interest since exploration activities began in 1944. This region has yielded several smaller oil and gas deposits. The most recent oil deposit was discovered in 2012 with the drilling of well Mu21, extracting oil from the 5th Badenian horizon. The exploration efforts have also identified gas-bearing horizons in the Sarmatian layers. The eastern part of the deposit, adjacent to the Brno-Hodonín Road (No. 380), showcases an active drilling rig. Additionally, the northeast portion of the Mutěnice deposit has been repurposed into an underground gas storage facility since 1999. Covering an area of over 7 km^2, the Dolní Bojanovice Underground Gas Storage facility was established in 2001 (Muzeum naftového dobývání a geologie 2023).

10. *Bojanovice - Underground Gas Storage (UGS)*

The Dolní Bojanovice Underground Gas Storage facility, situated in the northeast part of the Mutěnice deposit, has been operational since 2001. This storage complex spans an area of more than 7 km^2 and is owned by SPP Storage. The storage facility utilizes geological formations from previously exploited oil and gas fields, allowing for the storage of natural gas in the depth range of 700 to 2 100 m. The storage reservoir consists of four layers, each serving as a storage horizon: the main storage horizon with a depth of around 1 600 m and 15 wells, the "lenses" layer at approximately 1 800 m with 5 wells, the southeastern Laba horizon at about 2 000 m with 3 wells, and the 16th Sarmatian horizon with 4 wells at an average depth of 750 m. The total active gas volume stored in the facility is 576 million m^3, with a maximum injection rate of 7 million m^3 per day and a maximum withdrawal rate of 9 million m^3 per day. Gas injection and withdrawal are facilitated by vertical and horizontal wells equipped with gas-tight pipes and compressors. To ensure gas quality, the facility employs separation techniques to remove unwanted impurities such as water, hydrocarbons, and fine sand. Gas is dried using adsorption methods, with drying agents based on silica gels. The Dolní Bojanovice Underground Gas Storage facility is interconnected with the international gas network, being connected to the Slovak gas network operated by Eustream a.s. The facility plays a crucial role in ensuring a stable and reliable gas supply, particularly during peak demand periods and emergencies (Muzeum naftového dobývání a geologie 2023).

11. *Ratíškovice*

Oil and natural gas extraction in Ratíškovice began in 1919. The first well, drilled near the railway station, reached a depth of 315 meters. Over the subsequent years, several more wells were established in the area. Two pumping stations were constructed and remained operational until the 1960s. A refinery was also built to process the locally extracted oil. Notably, Ratíškovice was not only rich in oil but also in natural gas. By the 1950s, the region boasted the first Czechoslovak gas pipeline. Today, the Oil Museum in Ratíškovice offers visitors insights into the historical artifacts and the rich history of both oil and natural gas extraction in the area.

12. *Vracov – Vlkoš*

The Vracov – Vlkoš oil deposit, discovered in 1986, is located at the northern termination of the Vienna Basin and spans an area of approximately 1 km^2 within the cadastral territories of Vracov and Vlkoš. Oil is extracted from 7 wells using piston deep-well pumps and is characterized by a high content of asphaltic-resinous substances, indicating a probable biogenic degradation of the original oils. To date, more than 38 000 m^3 of oil has been extracted, with more than half being extracted by the Vracov 4 well. Oil and gas deposits were found in the overlying sediments of the Sarmatian and underlying flysch layers of the Paleogene. Oil exploration was conducted in several locations here, with the area between Vacenovice and Milotice being examined first due to natural gas occurrences. Drilling exploration near

Vracov then revealed several smaller oil accumulations. The Vracov deposit formed in layers of sandstone from the Middle Miocene age (Sarmatian). During this period, a marine flood expanded from the central Vienna Basin, and sands were deposited on the northern slope of the Vacenovice elevation. Oil and gas are found in a clayey-sandy complex in the lower part of the Sarmatian sequence, which reaches a thickness of up to 100 meters. A total of 12 sandy horizons were identified, with 9 of them being saturated with hydrocarbons. The oil is extracted using rod deep-well pumps operated by rods and a derrick on the surface or using deep-well screw pumps (PCP) with an electric drive on the surface. The oil is stored in tanks and transported by tank trucks for further processing and shipment to the collection center in Lužice. The natural gas deposit in Vacenovice was located about 4 km to the south from Vracov. In locations such as Sedmirohé, Pastviska, and Čertobrd, significant tectonic faults occur, and natural gas escaped through cracks along these faults. Drilling exploration began in 1925, and by the end of World War II, gas from 24 wells was extracted, totaling almost 5 million cubic meters (Muzeum naftového dobývání a geologie 2023).

References

see Streitová and Kubernátová (2023): Oil and natural gas deposits of Southern Moravia

Personal notes