History of U production in the Czech Republic

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Prehistory of U mining

In the 1st half of the 19th century Uranium became a coveted material for a pigment production.

The metallurgic chemists Adolf Patera and Arnošt Vysoký from Jáchymov prepared the pigment production technology. The colors were used for coloring of glass and porcelain.

The old silver works was adapted to uranium processing plant. It was the first site of the industrial usage of uranium in Jáchymov.
Foundation of the state enterprise

• The original national enterprise Jáchymov Mines with the seat in Jáchymov was established on the 1st January 1946.

• It was subsidiary to the Czechoslovak mines, but the activities were managed by Permanent mixed Czechoslovak-soviet commission in Prague that solved all tasks from the Czechoslovak-soviet agreement from November 1945.

• The national enterprise assumed 3 active U mines in Jáchymov – Rovnost, Svornost, Bratrství.
Areas of former U mining

Quick development of uranium survey, opening of new deposits and uranium production increase after 1 January 1946.
186 deposits found, 86 exploited.
Main mining areas (main mining periods):

<table>
<thead>
<tr>
<th>Time period</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946–1955</td>
<td>Jáchymov, Horní Slavkov, Zadní Chodov, Příbram</td>
</tr>
<tr>
<td>1956–1966</td>
<td>Příbram, Rožná, Olší, Licoměřice, Hamr</td>
</tr>
<tr>
<td>1967–1988</td>
<td>Rožná, Příbram, Hamr, Stráž</td>
</tr>
<tr>
<td>1989–2001</td>
<td>Rožná (other mining areas dumping and disposal)</td>
</tr>
<tr>
<td>2002–2016</td>
<td>Rožná</td>
</tr>
</tbody>
</table>
86 exploited deposits
Western Bohemia

Uranium survey: 1945 – 1990, 26 sites
Uranium mining: 1946 – 1991, 21 sites
Total U production: 20 695.4 t

Biggest sites:
- Jáchymov (7 950 tU)
- Zadní Chodov (4 150.7 tU)
- Vítkov II (3 972.6 tU)
- Horní Slavkov (2 668.3 tU)
- Dyleň (1 100.5 tU)
Příbram region and Southern Bohemia

- Uranium survey: 1947 – 1989, 27 sites
- Total U production: 52 221 t
- Biggest sites: Příbram (50 342,2 tU), Okrouhlá Radouň (1 339.5 tU)
Bohemian-Moravian Highlands


Uranium mining: 1956 – 2016, 17 sites

Total U production: 27 072.8 t

Biggest sites: Rožná (22 865.3 tU)
               Olší (2 922.2 tU)
               Licoměřice (400.7 tU)
               Jasenice – Pucov (311.2 tU)
Northern Bohemia

Uranium survey: 1962 – 1993, 3 sites

Uranium mining: 1967 – 1996, 3 sites

Total U production: 30 775.5 t

Sites: Sráž (ISL; 17 511.7 tU)
       Hamr (13 263.8 tU)
       Břevniště (1 107.8 tU)
Northeastern Bohemia

Uranium survey: 1947 – 1978, 10 sites
Uranium mining: 1953 – 1973, 9 sites
Total U production: 654 t
Biggest sites: Radvanice (387.2 tU), Rybníček (170.8 tU)
Jeseník mountains

Uranium survey: 1957 – 1964, 3 sites
Uranium mining: 1959 – 1968, 2 sites
Total U production: 417.4 t
U mines: Javorník (405.3 tU) Jelení vrch (11.9 tU)
Metal production (after treatment process): 132,944 tons
Situation of the mining areas
Employment 1946-2015
Branch SUL Příbram
## Ore mining history

<table>
<thead>
<tr>
<th></th>
<th>Ore district</th>
<th>Uranium district</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining period</td>
<td>1311 - 1979</td>
<td>1949 - 1991</td>
</tr>
<tr>
<td>Main shafts</td>
<td>11,32 km</td>
<td>24,9</td>
</tr>
<tr>
<td>Corridors</td>
<td>405 km</td>
<td>2 188 km</td>
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<tr>
<td>Ag production</td>
<td>3 836 t</td>
<td>28,9 t</td>
</tr>
<tr>
<td>Pb production</td>
<td>517 961 t</td>
<td>2 417 t</td>
</tr>
<tr>
<td>U Production</td>
<td>-</td>
<td>48 432 t</td>
</tr>
</tbody>
</table>
Mine water treatment

- Příbram I – Bytíz and Příbram II – annually 2.2 – 3.3 mil. m³ of treated water
- Horní Slavkov (Ra, Fe, Mn, SO₄)
- Okrouhlá Radouň (Ra, U)
- Zadní Chodov (Ra, U; wetland)
Waste rock dumps

- 28 mil. tons of waste rock are stored in many heaps near Příbram.

<table>
<thead>
<tr>
<th>Waste rock dump number (name)</th>
<th>Area (m²)</th>
<th>Volume by 31.12.2015 (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56 151</td>
<td>439 310</td>
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<tr>
<td>2</td>
<td>40 697</td>
<td>645 119</td>
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<tr>
<td>3, 3A</td>
<td>35 811</td>
<td>756 130</td>
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<tr>
<td>3C</td>
<td>18 298</td>
<td>130 000</td>
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<tr>
<td>4</td>
<td>87 276</td>
<td>2 463 200</td>
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<tr>
<td>4A</td>
<td>90 677</td>
<td>519 360</td>
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<tr>
<td>5</td>
<td>44 928</td>
<td>466 908</td>
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<tr>
<td>6</td>
<td>61 857</td>
<td>1 394 301</td>
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<tr>
<td>Svatá Hora (6A)</td>
<td>13 154</td>
<td>61 936</td>
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<tr>
<td>9</td>
<td>90 782</td>
<td>2 252 655</td>
</tr>
<tr>
<td>10</td>
<td>29 226</td>
<td>333 995</td>
</tr>
<tr>
<td>11</td>
<td>196 072</td>
<td>4 456 810</td>
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<tr>
<td>11A</td>
<td>45 064</td>
<td>636 480</td>
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<tr>
<td>15</td>
<td>199 450</td>
<td>7 530 600</td>
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<tr>
<td>16</td>
<td>179 271</td>
<td>708 170</td>
</tr>
<tr>
<td>17</td>
<td>5 237</td>
<td>13 340</td>
</tr>
<tr>
<td>18</td>
<td>25 844</td>
<td>74 161</td>
</tr>
<tr>
<td>19</td>
<td>159 151</td>
<td>3 794 230</td>
</tr>
<tr>
<td>20</td>
<td>39 500</td>
<td>555 954</td>
</tr>
<tr>
<td>21</td>
<td>43 270</td>
<td>120 860</td>
</tr>
<tr>
<td>22</td>
<td>10 226</td>
<td>18 429</td>
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<tr>
<td>24</td>
<td>4 138</td>
<td>6 142</td>
</tr>
<tr>
<td>25</td>
<td>6 371</td>
<td>18 106</td>
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<tr>
<td>Surf 55</td>
<td>8 565</td>
<td>19 100</td>
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<td>Surf František</td>
<td>1 714</td>
<td>3 551</td>
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<td>Surf 47</td>
<td>4 444</td>
<td>18 297</td>
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<td>Svatá Hora (6A)</td>
<td>13 154</td>
<td>61 936</td>
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<tr>
<td>Total</td>
<td>1 497 174</td>
<td>27 437 144</td>
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</table>
Remediation and recultivation of old tailings ponds in Mydlovary
Branch GEAM Dolní Rožínka
## Uranium deposits

<table>
<thead>
<tr>
<th>Locality</th>
<th>Start of survey</th>
<th>End of survey</th>
<th>Start of mining</th>
<th>End of mining</th>
<th>t of U</th>
<th>Max depth</th>
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<tbody>
<tr>
<td>Rožná</td>
<td>1954</td>
<td>1991</td>
<td>1957</td>
<td>2016</td>
<td>22 865,3</td>
<td>1 200</td>
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<td>Olší</td>
<td>1954</td>
<td>1987</td>
<td>1959</td>
<td>1989</td>
<td>2 922,2</td>
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<td>Licoměřice</td>
<td>1961</td>
<td>1984</td>
<td>1968</td>
<td>1982</td>
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<td>Chotěboř</td>
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<td>1964</td>
<td>1956</td>
<td>1977</td>
<td>148,8</td>
<td>100</td>
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<td>Slavkovice</td>
<td>1957</td>
<td>1969</td>
<td>1964</td>
<td>1970</td>
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<td>Bernardov</td>
<td>1960</td>
<td>1963</td>
<td>1964</td>
<td>1965</td>
<td>55,5</td>
<td>80</td>
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<tr>
<td>Písečné</td>
<td>1955</td>
<td>1963</td>
<td>1975</td>
<td>1975</td>
<td>2,8</td>
<td>41</td>
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</table>

<table>
<thead>
<tr>
<th>Locality</th>
<th>Start of survey</th>
<th>End of survey</th>
<th>Start of mining</th>
<th>End of mining</th>
<th>t of U</th>
<th>Max depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>N.Ves u N.Města</td>
<td>1957</td>
<td>1963</td>
<td>1971</td>
<td>1972</td>
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<td>1957</td>
<td>1957</td>
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<td>1960</td>
<td>1964</td>
<td>1973</td>
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<td>1967</td>
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<td>Lačnov</td>
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<td>Ždánice</td>
<td>1955</td>
<td>1963</td>
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<td>Rudov</td>
<td>1965</td>
<td>1969</td>
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<td>Rašov</td>
<td>1959</td>
<td>1960</td>
<td>1981</td>
<td>1981</td>
<td>0,2</td>
<td>10</td>
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<td>Tasov</td>
<td>1964</td>
<td>1990</td>
<td>1985</td>
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<td>634</td>
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<td>Líšná</td>
<td>1956</td>
<td>1971</td>
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<td></td>
<td>0,2</td>
<td>72</td>
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<td>Vysoké</td>
<td>1968</td>
<td>1971</td>
<td></td>
<td></td>
<td>0,1</td>
<td>178</td>
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</tbody>
</table>
Uranium mine Rožná

- Last underground U mine in EU, 1957-2016.
- 11 shafts, 509 km corridors, depth 1,200 m.
- Extracted 17 mil. t of ore, 20,220 t U.
- Since 1968 chemical treatment plant and mill and 2 tailings ponds.
- Since January 2017 liquidation of underground.
- Pumping and treatment of mine water.
- Treatment of tailings pond water.
Other uranium mines

- Licoměřice (Chrudim, A) –1968-1982, 383,3 t U.
- Olší (Brno-venkov) -1959-1989, 2 922,2 t U.
Chemical mill

U ore treatment from mines Rožná I, Rožná II a Olší since 1968
Process: transport, milling, separation, thickening – density 1 100 to 1 500 g.l⁻¹;
alkalic leaching – leaching agent Na₂CO₃;
U sorption on IER (anex), elution of U from IER using Na₂SO₄ and Na₂CO₃,
precipitation of U-concentrate by NH₃;
sedimentation and filtration, drying and expedition in steel casks.
Branch TÚU Stráž pod Ralskem
Localization

Stráž tectonic block
Cretaceous basin

IAEA Interregional Workshop on Case Study of Conventional Uranium Production from Exploration to Closure
14–18 October 2019 Prague, Czech Republic
Discovery of uranium deposits

• 1962
  1st exploration well HJ-1

• 1963 - 1967
  finding of sites:
  Hamr, Osečná, Stráž, Křižany
  (Břevniště)

• 1971
  end of exploration
History of underground mining

- DH I (shaft no. 1, 2, 3, 13) 1972-1993
- DK I (shaft no. 4, 5) 1983-1989
- DH II (shaft no. 6, 7, 9P) -

- Length of shafts: 2 246 m
- Length of crosscuts: 50.5 km
- Length of corridors: 37 km
- Length of chimneys: 8 km
- Volume of the fill: 4 961 000 m$^3$
- Amount of extracted ore: 10,7 mil. t
- Production of U: 11 740 t
History of underground mining
Chemical treatment plant and mill

1973 start of building of the chemical mill. Parallel building of the I. stage (1978-1980) and II. stage (1988-1991) of tailings pond with the total area of ca. 200 ha and capacity ca. 33 mil. m³.

1979 building of the main technological facilities finished, start of the delivery track operation, start of the verification operation.

1980-1988 permanent operation of the chemical mill, the final maximal capacity was 800 000 t of processed ore per year.
Chemical mill
Rehabilitation of the underground mines

1988-2003  decommissioning of underground and backfilling of all shafts
2001-2003  flooding of the DH I using the water from tailings pond – 4.7 mil. m³ of alkaline water (pH 9 - pH 11) was injected into the underground of DH I
1991-2013  sequential decommissioning of the surface areas
2014-2015  areal decommissioning of the surface area DH I – shaft no. 3, area of CDS and decommissioning of the technological objects of the chemical treatment plant
Rehabilitation of the deep mines

IAEA Interregional Workshop on Case Study of Conventional Uranium Production from Exploration to Closure
14–18 October 2019   Prague, Czech Republic
History of chemical mining

1965–1967 1st leaching experiments
1974 beginning of chemical mining
1996 start of the remediation

- 15 000 wells (8 000 technological) were drilled during chemical mining period
- Area of leaching fields 745 ha
- Injected chemicals:
  - H$_2$SO$_4$ 4 120 000 t
  - HNO$_3$ 320 000 t
  - NH$_4^+$ 111 000 t
  - HF 26 000 t
- Production of U 15 800 t
Extent of contamination

- **Cenomanian aquifer:**
  - area larger than 27 km²
  - influenced volume of groundwater is more than 380 million m³
  - the total amount of dissolved \( \text{SO}_4^{2-} \)
    is about 3.6 million tons

- **Turonian aquifer:**
  - locally isolated plums
  - influenced volume of groundwater
    is 26.7 million m³
  - the total amount of dissolved \( \text{SO}_4^{2-} \)
    is about 7,500 tons

- \( \text{SO}_4^{2-} \), \( \text{NH}_4^+ \) and Al are the main contaminants in both aquifers
Remediation till now

- **1996** start of the remediation, start of the evaporation technology SLKR I
- **1998** start of the drilling of remedial abstraction wells
- **2004** start of the tailings pond adjustment
- **2006** the first NDS 6 reconstruction
- **2009** start of the technology NDS ML
- **2011** determination and approval of TVRP
- **2012** start of the technology NDS 10
- **2016** first million tons of contaminants was extracted
- **2017** the second NDS 6 reconstruction
Experience and transfer of knowledge

• Uranium production in the Czech Republic has been going on for more than 72 years. DIAMO, s. e. in that time has passed through the whole U production cycle – prospecting, design, operation and in the present time liquidation and remediation.

• DIAMO, s. e. established in 2006 World Nuclear University School of Uranium Production under the auspices of the World Nuclear University in London in partnership with international nuclear organizations OECD/NEA and IAEA.

• During its more than 12 years experience over 150 participants within the framework of IAEA TC projects and 300 commercial participants from more than 35 countries successfully passed almost 60 different training programs.
Thank you for your attention