Chapter 3

Shear Zone-Hosted Uranium Deposits of the Bohemian Massif (Central European Variscan Belt)

Miloš René

Additional information is available at the end of the chapter

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Abstract

The Bohemian Massif hosts a significant quantity of uranium deposits bound by brittle shear zones developed in high-grade metamorphic rocks (Rožná, Okrouhlá Radouň, Zadní Chodov and Dyleň) and/or granites (Vítkov II and Lhota). According to the international atomic energy agency (IAEA) uranium deposits classification, these deposits are classified as metamorphic deposits. For shear zone-hosted uranium mineralisation, the no direct relationship between ore mineralisation and granite bodies is significant. Ore lenses and/or disseminated ore mineralisation form the shear zone-hosted uranium deposits. The host rocks of these deposits are transformed in aceites. Aceites are defined as low-temperature alkaline metasomatic rocks, which are closely associated with uranium mineralisation. Complex coffinite-uraninite or coffinite-uraninite-brannerite assemblages form the shear zone mineralisation with predominance coffinite about uraninite.

Keywords: uranium, shear zone, aceite, coffinite, uraninite, brannerite, Bohemian Massif

1. Introduction

The Bohemian Massif as part of the Central European Variscan belt hosts a high quantity of uranium mineralisation [1, 2]. The shear zone-hosted uranium mineralisation is recently classified as metamorphic uranium deposits (e.g., Ace Fay, Canada) [3]. In the Bohemian Massif, the Rožná, Olší, Okrouhlá Radouň and Zadní Chodov ore deposits in the high-grade metamorphic rocks of the Moldanubian Zone and the Vítkov II and Lhota ore deposits in granitoids of the Bor pluton represent this group of uranium deposits. Apart from the predominant vein-type uranium deposits in the Ore Mts. (Niederschlema-Alberoda, Jáchymov) and the Příbram ore deposit, these deposits show no direct genetic relationship between mineralisation and granitic plutons (**Figure 1**).

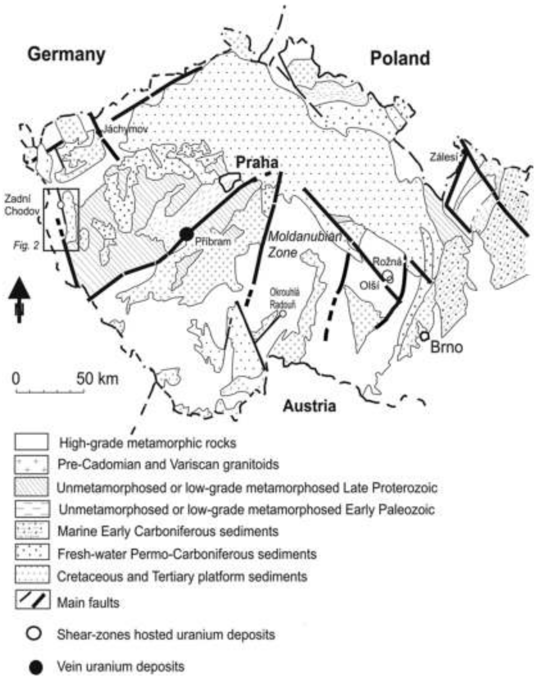

Figure 1. Simplified geological map of the Bohemian Massif with the most significant hydrothermal uranium deposits.

The shear zone-bounded uranium deposits consist of peneconcordant lenses or highly disseminated uranium mineralisation evolved in brecciaed shear zones and/or in fractures. The host rocks of these deposits are strongly altered in aceites, exhibiting extensive albitisation, chloritisation and hematitisation of the host rock series. In the recent classification of metamorphic and metasomatic rocks, these metasomatic rocks are named as aceites [4].

According to their mineral composition, the aceites are very similar to episyenites developed in uranium deposits of the Massif Central and the Armorican Massif in France, linked to leucogranitic plutons. Episyenites are defined as igneous-like rocks of syenite composition; displaying cavities produced by hydrothermal dissolution of quartz grains than can ultimately host uranium ore deposits [5]. Both rock types are products of low-temperature alkaline metasomatism associated with a significant input of Na_2O and the loss of SiO_2. Distinctly different mineral compositions have metasomatic deposits, which originated by high-temperature alkali metasomatism (e.g., Central Ukraine). Metasomatic facies in these uranium deposits include albitites, aegirinites and alkali-amphibole-rich rocks. In the recent international union of geological sciences (IUGS) classification of metamorphic rocks, these metasomatites are classified as fault-related metasomatites, which are common in the Precambrian shields [4]. The aim of this chapter is to present the detailed petrology, mineralogy and geochemistry of aceites and associated uranium mineralisation evolved in shear zone-hosted uranium ore deposits of the Bohemian Massif.

2. Geological setting

In high-grade metamorphic rocks of the Moldanubian Zone are evolved the Rožná, Olší, Okrouhlá Radouň, Zadní Chodov and Dyleň uranium deposits. The high-grade metamorphic rocks are represented by biotite paragneisses with intercalations of amphibolites, calc-silicate rocks, marbles and lenses of partly serpentinised ultrabasic rocks (dunites).

The Vítkov II and Lhota uranium deposits occur in granitoids of the Bor pluton. An N-S trending, 35-km long magmatic body forms the Bor pluton, which is emplaced in the fault zone, which is a part of regional West Bohemian shear zone. The most voluminous rocks in the Bor pluton are coarse-grained biotite, usually porphyritic biotite granites. In the northern block, older amphibole-biotite granodiorites, tonalites and quartz diorites were also observed. Dykes of two-mica monzogranites, aplites, which predominates in the southern part of the Bor pluton, fill N-S faults. (**Figure 2**) [6].

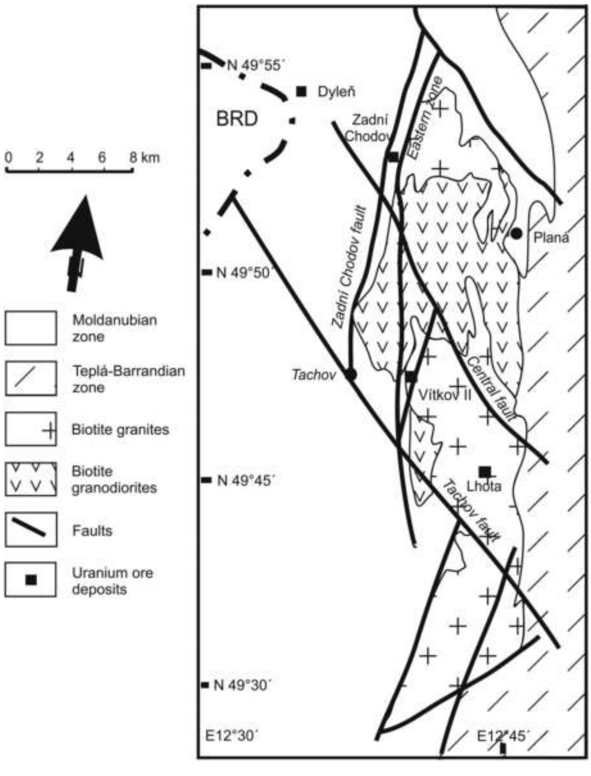

Figure 2. Geological map of the Bor pluton, modified from [6].

2.1. Rožná uranium deposit

The Rožná uranium deposit occurs in the uppermost Gföhl unit of the Moldanubian Zone. The host rocks of this ore deposit are formed predominantly by biotite paragneisses, amphibolites and small bodies of calc-silicate rocks, marbles, serpentinites and pyroxenites. The uranium mineralisation is bounded on the longitudinal shear zones (R1–R4). The main part of disseminated uranium mineralisation hosts the Rožná 1 (R1) and Rožná 4 (R4) shear zones. In the less strongly mineralised Rožná 2 (R2) and Rožná 3 (R3) shear zones, numerous pinnate carbonate veins occur. Longitudinal shear zones are segmented by NW-SE and SW-NE faults, which host post-uranium carbonate-quartz-sulphide mineralisation (**Figure 3**) [1].

Uranium mineralisation could be divided into (1) disseminated coffinite > uraninite > U-Zr-mineralisation evolved in altered rocks (aceites) of the mineralised shear zones (R1–R4), (2) uraninite > coffinite mineralisation in carbonate veins, (3) disseminated coffinite > uraninite in aceites adjacent to main shear zones (R1, R4) and (4) mostly coffinite mineralisation bound to the intersection of shear zones with an younger NW-SE and SW-NE faults. Ore lenses of disseminated uranium mineralisation in fault zones R1 and R4 are 3.5-m thick on average, ore grade is around 0.5% U, up to 10% U locally. Ore bodies in ore zones R2 and R3 host a large number of carbonate veins up to 2-m thick with U-mineralisation of the average grade 0.6% U. Ore bodies in aceites with predominance of coffinite on uraninite and U-Zr silicate have U-mineralisation of

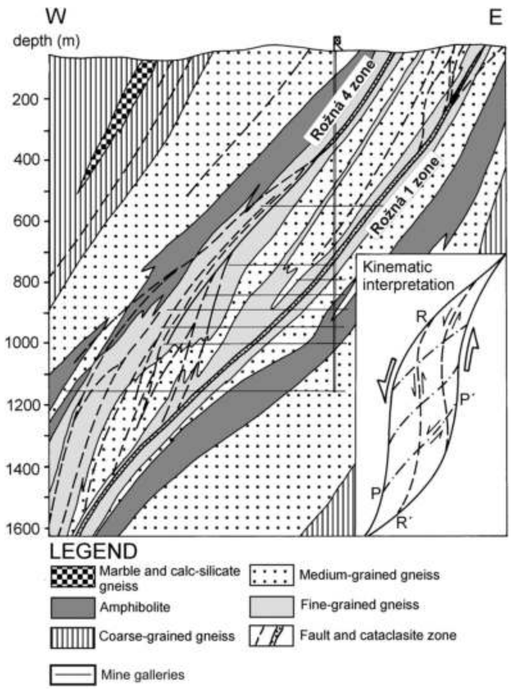

Figure 3. Schematic cross section of the Rožná uranium deposit, modified from [1].

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a grade 0.1–0.15% U, exceptionally 0.3% U. Disseminated U-mineralisation bound to oblique fault zones is usually hosted by quartz-carbonate-sulphide breccias at intersections with diagonal and longitudinal structures. Compared to other types of mineralisation, the ore bodies are small but contain relatively high-grade ore of average grade 0.8 and up to 20% U in some ore shoots. Total mine production of the Rožná ore deposit was 22,220 tons U with average grade of 0.24% U, mined from 1957 to April 2017 [7]. The Rožná uranium deposit was the last mined uranium deposit in the Central Europe.

2.2. Olší uranium deposit

The Olší uranium deposit is also evolved in the NE part of the Moldanubian Zone. The host rocks of this uranium deposit consist mainly of plagioclase-biotite and amphibole-bearing paragneisses with small lenses of K-rich granitoids and serpentinites. Longitudinal N-S and NNW-SSE striking ductile shear zones (O1, O2 and O3) dip to W at an angle of 45–70°. Longitudinal shear zones are crosscut by ductile to brittle NW-SE and SW-NE striking fault zones that host lenses of contrasted uranium mineralisation. The main uranium ore bodies are evolved on the N-S longitudinal shear zones. The Variscan calcite-chlorite-uraninite association and the Mesozoic albite-chlorite-coffinite association represent the uranium mineralisation. Total mine production of the Olší ore deposit was 2922.2 tons U with average grade of 0.10% U, mined from 1959 to 1989 [7].

2.3. Okrouhlá Radouň uranium deposit

The Okrouhlá Radouň uranium deposit is situated in a NNW-SSE striking shear zone on the NE margin of the Klenov pluton, which is a part of the Moldanubian plutonic complex. The host rock series comprises partly migmatised biotite paragneisses and sillimanite-biotite paragneisses of the Moldanubian Zone and two-mica leucogranites of the Klenov pluton. Granites that formed a series of the NE-SW to NNE-SSW elongated sheets or larger irregular bodies with sheeted margins intruded into the high-grade metasediments. The sheets are mostly parallel to the foliation in the metasediments.

The most significant mineralised structure in this area, the Radouň shear zone, was explored along a strike length of approximately 3 km and to a depth of 650 m. The highest grade uranium mineralisation was developed at depths of 250–400 m beneath the present surface. The thickness of the mineralised shear zone is highly variable, ranking from 30 cm to approximately 7 m. The thickest portion of this zone was observed in the southern part of the uranium deposit, where a shear zone was developed in altered two-mica leucogranites and in highly hydrothermally altered, partly migmatised biotite paragneisses. The shear zone is infilled with cataclasites formed by host rock breccias, which were altered to clay-mineral-rich and chlorite-rich assemblages containing a disseminated uranium mineralisation comprising mainly coffinite and lesser amounts of uraninite. Total mine production of the Okrouhlá Radouň uranium deposit was 1339.5 tons U with average grade of 0.084% U, mined from 1972 to 1990 [7].

2.4. Zadní Chodov uranium deposit

The Zadní Chodov uranium deposit, which is located in the northern tectonic block of the Bor pluton, was developed by mine workings down to a level of 1250 m with a length of over 2.5 km. The host rock series are formed by migmatised biotite paragneisses of the Moldanubian Varied

Group with intercalations of quartzites, amphibolites, calc-silicate rocks and crystalline limestones. Uranium mineralisation is associated with N-S trending zones of the Zadní Chodov fault in areas of their intersection with NW-SE trending fault structures. The shear zones are infilled by highly chloritised and arigilitised host rocks.

The thickness of main mineralised shear zones (CH-1, CH-4 and CH-11) ranges from 30 cm to approximately 1–2.5 m. Their total thickness is about 50–150 m (**Figure 4**). The high-grade uranium mineralisation was developed at the depths of 440–960 m beneath the present surface. The most common uranium minerals are coffinite (65 vol.%), uraninite (25 vol.%) and brannerite (10 vol.%). Total mine production of the Zadní Chodov uranium deposit was 4150.7 tons U with average grade of 0.195% U, mined from 1952 to 1992 [8].

2.5. Dyleň uranium deposit

The Dyleň uranium deposit was located in high-grade metasediments of the Moldanubian Zone (migmatised biotite, biotite-sillimanite and quartzitic paragneisses with intercalations of quartzites). The main tectonic zone in the area of the Dyleň ore deposit is N-S trending zone of the Dyleň fault, dip to W at an angle of 60–70°. However, the uranium mineralisation is associated with NW-SE trending shear zones, dip to SW at an angle of 70–90°. The W-E striking faults crosscut both shear zone structures. All these shear zones and faults are infilled by chlorite-enriched aceites. Highly disseminated apatite-brannerite-coffinite association with up to 90 vol.% of coffinite represents the Variscan uranium mineralisation. Main part of uranium mineralisation is bounded on highly altered biotite paragneisses. Total mine production of the Dyleň uranium deposit was 1100.5 tons U with average grade of 0.14% U, mined from 1965 to 1991 [7].

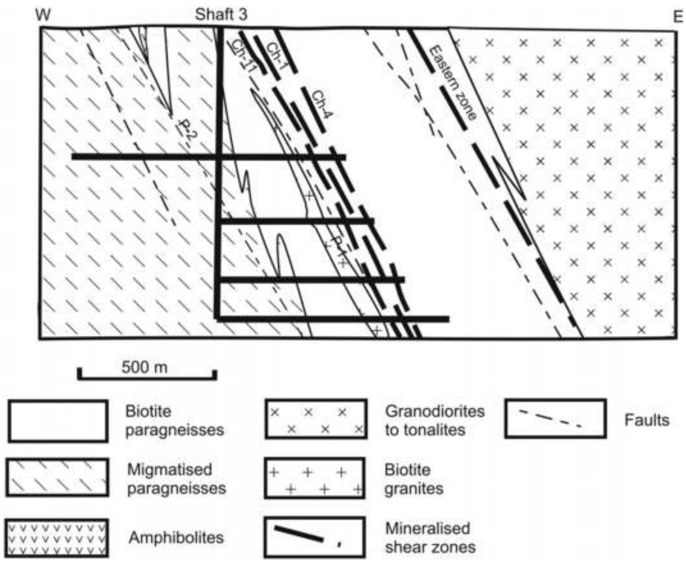

Figure 4. Schematic cross section of the Zadní Chodov uranium deposit, modified from [8].

2.6. Vítkov II uranium deposit

The Vítkov II uranium deposit occurs in the central part of the Bor pluton. Its main mineralised shear zones are zone 0–30 in the east and the Vítkov zone in the west. The thickness of the shear zones varies from 5 to 7 m to several tens of metres. Both the shear zones are infilled by crushed altered rocks, quartz and carbonates. Rich accumulations of U-minerals often occur in their vicinity. The pennate NW-SE faults evolved between both shear zones are infilled by dykes of biotite and two-mica granites and aplites. Granites of the Bor pluton in the area of the Vítkov II uranium deposit are usually intensely altered to aceites. The ore bodies comprise coffinite, uraninite and brannerite finely disseminated in the surrounding altered granites. The ore bodies are grouped into four ore pipes, which are accumulated in environs of the shear zone 0–30. Total mine production of the Vítkov II uranium deposit was 3972.6 tons U with average grade of 0.124% U, mined from 1961 to 1990 [7].

2.7. Lhota uranium deposit

The Lhota uranium deposit is situated in the central block of the Bor pluton. Uranium mineralisation is evolved in altered coarse-grained biotite granites, accompanied by smaller bodies of amphibole-biotite granodiorites and tonalites. All these granitoids are overlain by remnants of the Moldanubian high-grade metasediments. The NW-SE, partly also N-S trending aplite dykes, pierces this rock complex. The two ore bearing shear zones (Os-2 and Os-17) strike NW-SE and dip steeply NE. The thickness of these mineralised shear zones are 5–18 m. The mineralised shear zones comprise coffinite and brannerite.

This uranium deposit has been verified between 1953–1967 and 1975–1989 by five exploration shafts down a depth of 250 m and by numerous boreholes down to levels of 300–600 m. During these two exploration stages, uranium mineralisation with the total amount of 158 t U and average grade of 0.120% U was identified [7].

3. Analytical methods

The rock-forming (chlorite, plagioclase) and uranium minerals were analysed in polished thin sections using CAMECA SX-100 electron probe micro-analyser (EPMA) operated in WDX mode. The contents of selected elements were determined using an accelerating voltage and beam current of 15 keV and 20 or 40 nA, respectively, with a beam diameter of 2–5 μm. The raw data were converted into concentrations using appropriate PAP-matrix corrections [9]. The detection limits were approximately 400–500 ppm for Y, 600 ppm for Zr, 500–800 ppm for REE and 600–700 ppm for U and Th. Back-scattered electron (BSE) images were acquired to study the internal structure of mineral aggregates.

The whole-rock composition of the selected, unaltered and altered high-grade metasediments and granitic rocks from investigated uranium deposits is based on analyses of 50 samples. The selected trace elements (U, Th, REE, Y and Zr) were determined by ICP-MS (a Perkin Elmer Sciex ELAN 6100 ICP mass spectrometer) at Activation Laboratories, Ltd., Ancaster, Canada.

The decomposition of the rock samples for ICP-MS analysis involved lithium metaborate/tetraborate fusion.

4. Results

4.1. Petrography of altered rocks

In altered high-grade metasediments and granitic rocks of above-mentioned uranium deposits (Rožná, Okrouhlá Radouň, Zadní Chodov, Lhota and Vítkov II), four major stages of hydrothermal alteration can be distinguished, namely pre-ore, ore and two post ore-ore stages. During pre-ore alteration, when main part aceites originated, original biotite from biotite paragneisses (Rožná, Okrouhlá Radouň and Zadní Chodov) and two-mica leucogranites (Okrouhlá Radouň) and/or biotite granites (Vítkov II and Lhota) were altered to chlorite I enriched in Fe. Transformation of biotite was sometimes accompanied by origin of rutile. Original plagioclases were altered into albite I ($An_{0–9}$). Albitisation is sometimes accompanied by K-feldspatisation, which was found at the Vítkov II uranium deposit in highly altered parts of original biotite granites. The albitisation and K-feldspatisation precede the quartz removal. The transitional zones between unaltered and altered high-grade metasediments and granitic rocks are usually gradational, spanning a few tens of centimetres to 1 m. Commonly, the transitional zone displays a weak red colouring due to the presence of fine-grained hematite laths distributed irregularly in originally albitised plagioclase (albite I). Hydrothermally altered rocks have medium porosities due to the hydrothermal leaching of original quartz (typically 10–15 vol.%). In highly altered high-grade metasediments and granitic rocks, the authigenic generations of albite II occur as epitactic overgrowths on pseudomorphs of albite II. The voids resulted through leaching of quartz were later filled by younger generations of albite (albite III) and chlorite (chlorite III). The newly originated albites II and III have near-end-member composition ($An_{0–0.8}$). The authigenic chlorites II and III are Mg-enriched (chlorite II Fe/Fe + Mg = 0.12–0.54, chlorite III Fe/Fe + Mg = 0.47–0.50). However, the original metamorphic and/or magmatic textures in the altered high-grade metasediments and/or granitic rocks are usually preserved.

During the ore stage, chlorite II, albite II, III, apatite and uranium minerals (uraninite, coffinite, brannerite) were originated. Uranium mineralisation usually comprises three different morphologic-mineralogical types. The highly altered granitoids of the Okrouhlá Radouň and Vítkov II ore deposits are marked by metasomatic coffinite and/or coffinite-uranium mineralisation. The metasomatic mineralisation is usually coupled with highly intensive albitisation and carbonatisation of granitic rocks. The lenticular-shaped uraninite and uraninite-coffinite mineralisation (Vítkov II and Lhota in the Bor pluton) occurs usually on boundary of granitic rocks with metamorphites. The disseminated uranium mineralisation occurs in the xenoliths of metamorphic rocks (Lhota) and in mineralised shear zones (Rožná, Zadní Chodov and Dyleň). In these uranium deposits, coffinite and brannerite occur predominantly in highly chloritised metamorphites. The suitable sources of Ti in brannerites were probably altered high-grade metasediments and/or amphibolites.

Albite and carbonates are the main constituents of the aceites formed through hydrothermal alteration of granites and high-grade metasediments and occupy 65–85 vol.% of the bulk rocks. The quartz post-ore stage is characterised by filling of voids, created by removal of magmatic and/or metamorphic quartz, by quartz II, origin of quartz veinlets (quartz III), veinlets of chlorite III and origin of younger hematite laths (hematite II).

The carbonate bearing post-ore stage is connected with the origin of calcite and relatively rarely sulphides, selenides and zeolites. Carbonates fill cavities in the altered rocks and/or form fine veinlets in highly altered granitic rocks. Occasionally, dolomite and siderite were found.

4.2. Geochemistry of altered rocks

In previous papers about shear zone-hosted uranium deposits in the Bohemian Massif [1, 10, 11], chemical composition of unaltered and altered host rocks was described in detail. Also, in those papers, detailed investigations of losses and gains during hydrothermal alteration of host rock series were performed using isocon method [12]. This chapter discusses about geochemistry of unaltered and altered rocks series concentrated on behaviour of selected trace elements, especially REE, Y and Zr.

The chloritised high-grade metasediments from the Rožná and Okrouhlá Radouň uranium deposits without uranium mineralisation are depleted in REE. This depletion is also displayed by lower ΣREE (Rožná 69–98 ppm, Okrouhlá Radouň 106–196 ppm) and high LREE/HREE ratios (4.0–17.6) relative to the unaltered metasediments. In contrast to chloritised high-grade metasediments without uranium mineralisation, mineralised metasediments from the Rožná and Zadní Chodov uranium deposits are enriched in REE (ΣREE = 108–390 ppm), especially in HREE (LREE/HREE 1.2–4.7) (**Figures 5** and **6**).

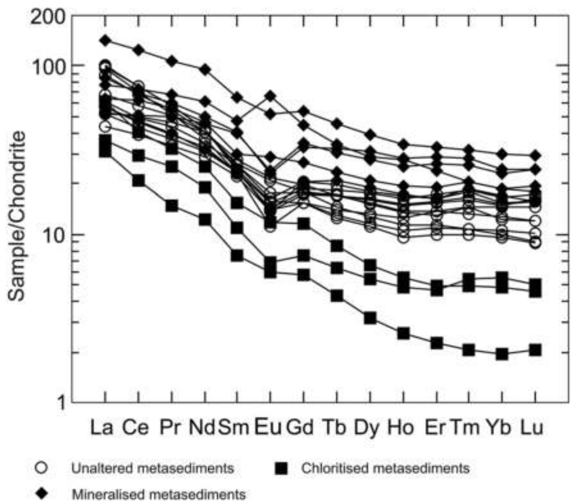

Figure 5. REE patterns of the high-grade metasediments and their hydrothermally altered equivalents from the Rožná uranium deposit. Original data normalised to chondrite according to [13].

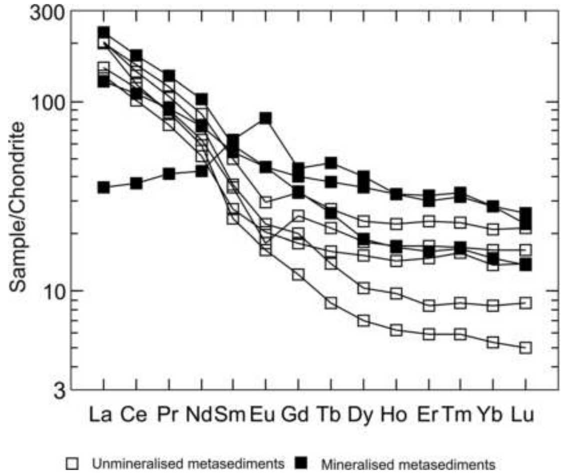

Figure 6. REE patterns of the high-grade metasediments and their hydrothermally altered equivalents from the Zadní Chodov uranium deposit. Original data normalised to chondrite according to [13].

The behaviour of Y and Zr in mineralised aceites from shear zone-hosted uranium deposits in the Bohemian Massif is variable. Yttrium is enriched in mineralised aceites from the Rožná and Okrouhlá Radouň ore deposits and its behaviour is close to behaviour of HREE in these rocks. Yttrium in these rocks occurs usually in coffinite (up to 3.4 wt.% Y_2O_3). In altered biotite granites from the Bor pluton, the concentrations of Y are similar to their concentrations in unaltered granitic rocks (**Figure 7**).

The concentrations of Zr in unaltered and altered rocks from all above-mentioned uranium deposits are similar. In unaltered host rocks from these ore deposits, Zr is concentrated in zircons. However, during hydrothermal alterations of these rocks, zircon is often highly altered and Zr is concentrated in uranium minerals, especially in coffinite.

4.3. Mineralogy

Coffinite in shear zone-hosted uranium deposits occurred in the Bohemian Massif usually prevails uranium mineral. In the Rožná and Zadní Chodov ore deposits, coffinite is concentrated in the deepest part of these deposits. The coffinite occurring in these shear zone-hosted ore deposits is commonly intimately associated with flakes of newly originated chlorite II. A majority of analysed coffinites from the Rožná, Okrouhlá Radouň and Lhota uranium deposits are enriched in Y_2O_3 (up to 3.4 wt.%) and ZrO_2 (up to 13.8 wt.%).

Uraninite in shear zone-hosted uranium deposits from the Bohemian Massif usually occurs as colloform aggregates in highly heterogeneous aggregates together with coffinite. In mineralised aceites, both minerals often form rims around chlorite flakes (**Figure 8**). In the Rožná ore deposit, the SiO_2 and UO_2 contents vary from UO_{2+x} to $USiO_4$, indicating the variable coffinitisation of uraninite (**Figure 9**). Almost all uraninite grains and aggregates were replaced by coffinite to a variable degree.

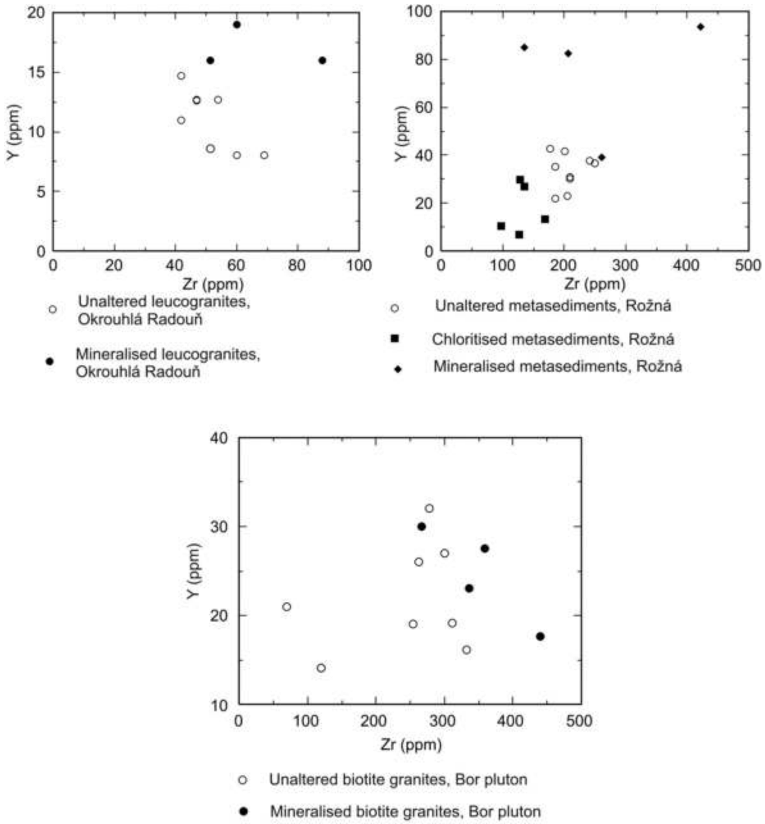

Figure 7. Plot Y versus Zr for unaltered and mineralised rocks from the Okrouhlá Radouň, Rožná and Zadní Chodov uranium deposits.

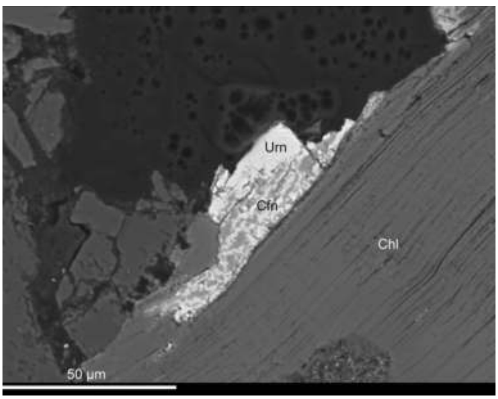

Figure 8. BSE image of uraninite (urn) and coffinite (Cfn) around chlorite flakes, Rožná uranium deposit.

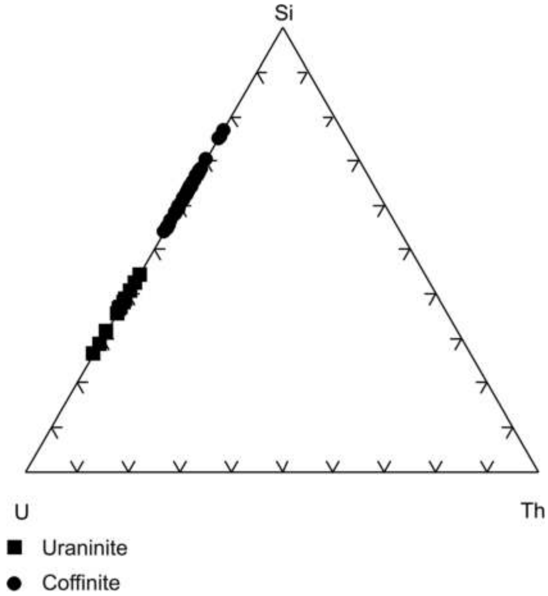

Figure 9. Chemical composition of coffinite and uraninite from the Rožná uranium deposit (wt.%).

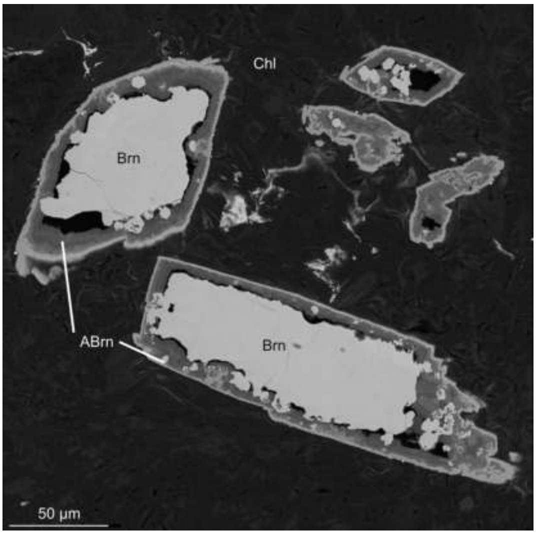

Figure 10. BSE image of brannerite (Brn) and altered brannerite (Abrn) enclosed in finely grained chlorite (Chl) from the Zadní Chodov uranium deposit.

Brannerite was found in the Rožná uranium deposit and in uranium deposits from the Bor pluton (Zadní Chodov, Dyleň and Lhota). In mineralized aceites brannerite occurs in form of acicular aggregates and/or irregular grains. Larger brannerite grains are usually heterogeneous and on their rims altered to Ti-enriched brannerite and rutile (**Figure 10**). Brannerite from the Rožná uranium deposit is enriched in ZrO_2 (up to 4.82 wt. %). Brannerites from the Rožná uranium deposit were sometimes decomposed in complex non-stoichiometric U-Ti-Si-Zr phases.

5. Discussion

5.1. Origin of aceites

The differences in mineralogical composition of aceites in the studied shear zone-hosted uranium deposits from the Bohemian Massif are expressed by different composition of original host rock series (high-grade metasediments vs. granitic rocks) and different tectonic movements on shear zones of individual ore deposits. For altered metasediments (Rožná and Zadní Chodov), high concentrations of chlorite I and clay minerals (illite, kaolinite and smectite) as fillings of shear zones are significant. The clay minerals filling in these uranium deposits differ in composition of the assemblage of these minerals. The Fe-illite predominates at the Rožná ore deposit and in the shear zones at Zadní Chodov chlorite predominates over illite. For aceites evolved in altered granitic rocks (Okrouhlá Radouň, Vítkov II and Lhota), the rock matrix composed of chlorite I, albite I and hematite framework is characteristic.

Uranium in the host high-grade metasediments and granitic rocks of all investigated uranium deposits is essentially hosted in monazite and zircon, in leucocratic granites from the Okrouhlá Radouň ore deposit, and also in xenotime. In barren aceites, monazite and xenotime are usually missing and zircon is often highly altered. Therefore, the source of uranium may be found in the decomposition of uranium-bearing accessories, as is also proposed for the inconformity-type uranium deposits in Canada [14]. The titanium necessary for the origin of brannerite was probably released during chloritisation of Ti-enriched biotite and hydrothermal alteration of the Ti-rich accessory minerals (titanite and allanite).

A prominent hematitisation occurred in aceites from the Okrouhlá Radouň, Vítkov II and Lhota uranium deposits, and deeper parts of the Rožná uranium deposit indicates deep infiltration of oxidised, surface-derived fluids to the crystalline basement during the pre-ore stage. The deep circulation of fluids gave rise to desilification, hematitisation and albitisation of host rock complexes along shear zones. The fluids responsible for origin of aceites differ from earlier low-salinity metamorphic fluids in their generally higher but highly variable salinities (0–25 wt.% $NaCl_{eq.}$). Differences in the salinity of these fluids probably reflect the mixing of chemically heterogeneous basinal brines with meteoric water [1, 15].

5.2. Behaviour of REE, Zr and Y in aceites

Rare earth elements, Zr and Y, are usually considered as the immobile elements by hydrothermal alteration of host rock series [16]. However, hydrothermal experiments and some mineralogical research of nature rock series have demonstrated that these elements could be mobile during hydrothermal alterations, especially if the fluids contained strong complexation agents (e.g., fluoride or phosphate anions) [17–19]. The mobility of REE, especially HREE in aceites in the all studied uranium deposits, is suggested by enrichment of HREE in aceites from Rožná, Okrouhlá Radouň and Lhota uranium deposits. The mobility of Zr and Y in the studied aceites is suggested by the occurrence of Zr- and Y-enriched coffinite from the Rožná, Okrouhlá Radouň and Lhota uranium deposits.

Enrichment in HREE during origin of uranium deposits in shear zone-hosted uranium mineralisation was found in unconformity uranium deposits from Australia and Canada [20–24]. Coffinites enriched in Zr and Y were found only in the uranium sedimentary deposits in New Mexico, United States [25] and in the natural fission reactor environment of the Oklo uranium deposit, Gabon [26].

6. Conclusion

The Bohemian Massif hosts a significant quantity of uranium deposits bound by brittle shear zones developed in high-grade metamorphic rocks (Rožná, Okrouhlá Radouň, Zadní Chodov and Dyleň) and/or granites of the Klenov and Bor plutons (Okrouhlá Radouň, Vítkov II and Lhota). The shear zone-hosted uranium deposits consist of peneconcordant lenses or highly disseminated uranium mineralisation evolved in brecciaed shear zones. The host rocks of these deposits are strongly altered, exhibiting extensive albitisation, chloritisation, hematitisation, and desilification in pre-ore stages. By hydrothermal alteration, aceites are products of low-temperature alkaline metasomatism associated with a significant input of Na_2O and the loss of SiO_2. Complex coffinite-uraninite or coffinite-uraninite-brannerite assemblages form the shear zone mineralisation with predominance coffinite about uraninite. Mineralisation evolved in shear zone-hosted uranium deposits of the Bohemian Massif displays enrichment of HREE, Y and Zr in examined uranium minerals, especially in coffinite. For analysed coffinites and brannerites, enrichment of Y (up to 3.4 wt.% Y_2O_3) and Zr (up to 13.8 wt.% ZrO_2) is significant.

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Author details

Miloš René

Address all correspondence to: rene@irsm.cas.cz

Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, Prague, Czech Republic

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