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Secondary minerals of the Jáchymov (Joachimsthal) ore district

Sekundární minerály jáchymovského rudního revíru (Czech summary)

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Two hundred and seven secondary mineral species are described and/or referenced. Approximately seventy secondary minerals were known from the district before the present study. All known reliable data on the individual secondary minerals from Jáchymov are presented. New and more complete X-ray powder diffraction data for compreignacite, irhtemite, lavendulan, lindackerite, masuyite, mcnearite, metaschoepite, mottramite, rabbittite, rabejacite, richetite, sodium-zippeite, voglite, zellerite, zippeite, and zýkaite are presented. A list of secondary minerals arranged according to chemical composition and list of "non-secondary" minerals are included at the end of this paper.

Key words: secondary minerals, new data, Jáchymov, encyclopaedia

MOTTO

OBSCURE LEGENDS UNSETTLING THE IMAGINATION OF MANY COLLECTORS.....
TALES OF A MYSTERIOUS GREEN URANIUM-BEARING MINERAL FROM ELIÁŠ MINE.....,
NOT LEAVING IN PEACE THEIR LIVES.
STORIES WHICH FOR AGES STIMULATED THE MINDS OF RENOWNED MINERALOGISTS,
CHEMISTS AND STRUCTURAL CRYSTALLOGRAPHERS REQUIRE US TO LOOK WITH HUMILITY
AT THE ONLY CHEMICAL QUANTITATIVE ANALYSIS
OF THE MINERAL VOGLITE CARRIED OUT
BY THE CHEMIST JOSEF LINDACKER
ALREADY IN 1853...

THE AUTHORS WITH DEEP RESPECT
DEDICATE THIS WORK TO THE MEMORY
OF AN OUTSTANDING MINERALOGIST,
WHOSE WORK SECURED WORLD FAME
OF THE JÁCHYMOV DEPOSIT,

JOSEF FLORIAN VOGL

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CORRESPONDING MEMBER OF THE IMPERIAL GEOLOGICAL INSTITUTE IN VIENNA
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FULL MEMBER AND CURATOR OF THE MONTANISTIC GROUP
IN THE KRUŠNÉ HORY (ERZGEBIRGE)

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Introduction

> *.... Progressive steps that attracted and led us to the middle of known and unknown horizons, deeper and deeper into the depths of natural knowledge, and indicating that it is natural for a man to learn not only about himself, but also his mirror. These steps demanded that we tried to look two centuries back and recognise, as has happened many times in this period, one small, for someone maybe insignificant, but still so famous and big episode of secondary minerals in the Jáchymov Ore District.*
>
> *Having in mind only a negligible possibility of approaching these invisible touches of the endless existence of the universe, we present this work, in hope that it shifts our knowledge, albeit infinitesimally, and, perhaps, our longing and emotions....*

The project of study of the secondary minerals in the Jáchymov ore district was undertaken in the years 1993 to 1996, thanks to the support by the Grant Agency of the Czech Republic [299].

The secondary minerals, usually of little interest for mining economy, attracted in the past attention of mineralogists, often equipped only with modest instruments. The present project aimed at obtaining new information on topographic, systematic, and genetic mineralogy. Special attention was paid to genetic aspects, which could provide valuable information on conditions and processes of formation of the secondary minerals.

During work on the project it appeared that the amount of our own new work and data exceeded the originally expected extend, owing to ever increasing number of newly identified mineral species, which were new for this district. For this reason, only reliable information is included from the literature to gain space for new data. In the limited time span, it was not possible to study in detail all the minerals identified; also, it was not possible to characterise completely several newly discovered phases.

It was possible to confirm occurrence of a great majority of minerals previously reported from the Jáchymov district. New results and all available data are presented in a condensed form, as a data table. X-ray powder diffraction data are omitted in case of correspondence with values already published for a species from this district. Instead, newly measured and calculated unit-cell dimensions are often included.

During this study of secondary minerals, the number of primary and rock-forming minerals was also expanded (lists are included at the end of this paper). Moreover, several new unknown natural phases were identified and thirty of them are described in more detail in a separate paper - see *New naturally occurring phases of secondary origin from Jáchymov* in this issue.

Reference system by numbers in “[ ]” was used to reduce the length of the paper. Since all papers in this issue refer to similar set of references, the literature references are presented as a single list at the end of this paper. In the section *Encyclopaedia of secondary minerals from Jáchymov ore district*, all used references corresponding to individual mineral species are listed in reference row of data table.

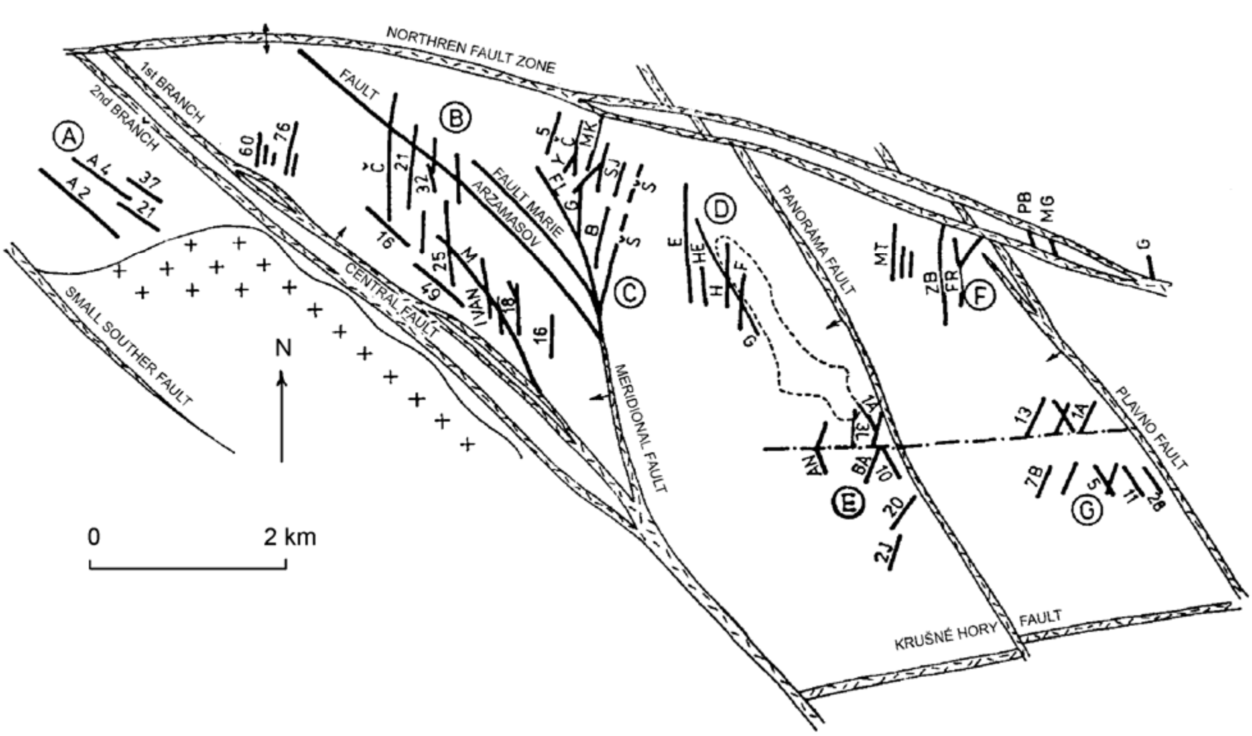
The study of old literature often resulted in putting together fragmentary information on type specimens and the history of new minerals described from Jáchymov in the past century. In view of the significant contribution of the district to systematic mineralogy, the old data, which are of permanent interest, are grouped in the paper *History of secondary minerals discovered in Jáchymov*.

Geology

Jáchymov is located on the southern slope of the Krušné hory Mountains, approximately 20 km north of Karlovy Vary. The Jáchymov ore district coincides with the immediate area of the town and its close surrounding. Elevation of the ore district ranges from 450 to 850 m a.s.l.

The region is underlain by a complex of metamorphosed sedimentary rocks of Cambrian and Ordivician age, representing the mantle of granite pluton. The Variscan granitic rocks belong to the Karlovy Vary granite pluton [100]. Metasedimentary rocks comprise biotite or biotite-muscovite mica schists, often affected by albitization and pyritization; graphite and garnet are sometimes present. Minor interlayers are represented by calc-silicate gneiss, quartzites, amphibolites and orthogneisses. According to Macourek and Čumrda [184], the complex can be classified into two divisions, including the Jáchymov division with four horizons and the Barbora division with two horizons. Granitoids which intruded this metasedimentary complex range in age from 330 to 310 Ma [188]. The intrusive contacts are dominantly subhorizontal with small undulations. The older types of granitoids include mainly porphyritic biotite granodiorite with an elevated content of Th and U and Th > U relation.

Fig. 1. Sketch map of the Jáchymov ore district [187] with countours of the town (ruling pattern).



Vein clusters: A - Abertamy, B - Barbora-Eva, C - Rovnost, D - Svornost, E - Panoráma, F - Bratrství, G - Plavno.
Veins (from west to east): Č - Čertova, M - Mariánská, Fl - Fluther, Z - Ypsilon, Č - Nová Červená, MK - Malá Krásná, G - Geister, B - Bergkittler, SJ - Severní Jeroným, Š - Švýcar, E - Evangelista, HE - Heuerzecher, H - Hildebrand, F - Fundgrubner, G - Geschieber, AN - Anna, MT - Matěj, ZB - - Zdař Bůh, FR - Františka.

The younger granitoids are leucocratic, show a strong predominance of U above Th and contain increased Nb, Sn, and Be [76]. The apical parts of this granite are often greisenized, featuring Sn mineralization and minor contents of topaz, fluorite and Li-bearing micas.

The immediate intrusive contact is marked by a biotite-rich zone about 10 cm thick.

The whole region contains abundant aplite, pegmatite, granite porphyry, lamprophyre dykes as well as dykes of the Tertiary basalts and basaltic tufs.

In the framework of regional classification the Jáchymov ore district belongs to the Saxothuringian Zone [183] and to the Krušné hory metallogenetic unit. The ore district coincides with the Gera-Jáchymov fault zone trending NW-SE [293] which exhibits recurrent activity during the Variscan and post-Variscan evolution of this region. Deposition of majority of ore minerals took place during the Variscan mineralization from mesothermal fluids.

The ore district is bound by several faults, including the major northern fault zone. The fault pattern and location of mineral veins is shown in Fig. 1. The width of the most important faults and fault zones is variable, up to 300 m in case of the Krušné hory fault. For centuries, mineralised veins were classified according their trend in N-S trending veins ("midnight veins") and E-W trending veins ("morning veins").The mineralization is irregular, barren parts of veins alternate with rich ore lenses and ore pillars developed at places. The N-S trending veins tend to be richer and wider, the E-W trending veins show more variation in trend and dip as well as thicknes. The richest parts coincide with splitting of a vein in several branches. Towards contact with granite, the veins become barren and disappear [116].

The mineralization of the deposit was classified by Mrňa and Pavlů [126], [123] and Arapov et al. [76]. The two classifications show many common features

1) **Sn-W stage** connected with autometamorphism of younger granites, which according to Mrňa and Pavlů [126] underlay the metamorphic complex in the whole ore district.

2) **quartz-sulphide stage** is of minor importance and it is developed mainly at deeper levels of the eastern part of the district; it includes galena, sphalerite, chalcopyrite, pyrite, arsenopyrite, pyrrhotite and dolomitic carbonates.

3) **carbonate-pitchblende mineralization** with fluorite.

4) **carbonate-arsenide stage** with native Ag and Bi, skutterudite, nickeline, rammelsbergite, safflorite and minor pitchblende.

5) **sulpharsenide stage**

The most widespread stages in the district are the pitchblende, arsenide and sulpharsenide stages.

During the pitchblende stage, veins composed mainly of dolomitic carbonate pigmented red by disseminated hematite were deposited. Uraninite is accompanied by a dark violet to black fluorite.

The sulpharsenide stage is characterized by dendritic native silver, usually overgrown by zones of Ni-skutterudite, rammelsbergite and other Ni-minerals such as nickeline or maucherite. Native silver was often leached out, leaving hollow perimorphoses; the free space was sometimes filled by argentite or quartz.

Skeletal crystals of native Bi are overgrown by arsenides carrying increased cobalt content, i.e., skutterudite and safflorite, less common are rammelsbergite and löllingite. Gersdorffite a glaucodot may be also present; millerite and bismuthinite are rare. Quartz and dolomite constitute gangue material.

The sulpharsenide stage is characterized by the presence of native arsenic in botryoidal aggregates, which can be up to 1 m long. Rare orange red realgar is deposited on native arsenic and proustite in small crystals occurs in a similar position or in hollow places in arsenic. Finely disseminated pyrite and löllingite accompany the above minerals.

Other silver-bearing minerals belonging to this stage include equant acanthite and short prismatic stephanite crystals. Less common are tabular crystals of polybasite and pearceite. Sternbergite and argentopyrite are very rare.

The younger sulphidic stage with pyrite, marcasite, galena, sphalerite and chalcopyrite in calcite gangue is closing the list of mineralization stages published by Mrňa and Pavlů [33], [126]. Arapov et al. [76] consider this stage as representing the final episode of the preceeding sulpharsenide stage and they proposed a still younger quartz-hematite stage.

The intrusion of the autometamorphosed granites took place in the Saale phase [304] , the pitchblende mineralization is dated to the Permian [303], the arsenide and sulpharsenide stage mineralization took place during the range Upper Carboniferous-Jurassic-Tertiary (?) [303].

The age of the uranium mineralization in Krušné hory Mts. (Erzgebirge) is comparable to similar mineralization in other parts of the Variscan orogen in Europe. The highest age obtained for the hydrothermal assemblage quartz-uraninite-calcite is 271 ± 6 Ma (2σ) [294]. Younger remobilization stages were dated to 190 ± 4 Ma (2 σ) and 120 ± 6 Ma (2 σ). The U-Pb isotope system in uraninite was again disturbed and loss of radiogenic Pb occurred in some samples by 80 ± 8 Ma (2 σ) and 0-40 Ma [294]. These ages correlate with reactivation of the Earth's crust rather than with magmatic activity. The age of 270 Ma corresponds to collapse of the Variscan orogen, the age of 190 Ma correlates with subsidence during Jurassic and the age of 120 Ma may coincide with opening of the North Atlantic ocean. Younger events during the Upper Cretaceous and Tertiary correspond to effects of the Alpine orogen in the foreland [294]. The quoted ages were measured on samples from the deposit Aue-Niederschlemma (in Germany), in the zone Gera-Jáchymov.

Legierski measured the following ages on uraninite from Jáchymov: 76, 140, 165, 202, 247, and 285 Ma [301]. The isotopic composition values of galena from Jáchymov by Legierski are presented in the following Table. The samples 224A and 22 belong to the young polymetallic stage which followed the main stage of Bi-Co-Ni mineralization [301] [307].

The isotopic composition values of galena from Jáchymov [301], [307]

Mine, locality, sample	**Pb^{206}**	**Pb^{207}**	**Pb^{208}**
	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}
Bratrství, 1. máj mine	**25.06**	**21.30**	**52.30**
	18.60	15.81	38.83
Bratrství, gallery, 224A	**25.06**	**21.34**	**52.25**
	18.58	15.82	38.73
Bratrství, sample 22	**25.06**	**21.34**	**52.25**
	18.60	15.84	38.79
Eliáš	**25.07**	**21.32**	**52.26**
	18.54	15.77	38.65
Rovnost, Bergkitler vein	**25.55**	**21.25**	**51.89**
	18.88	15.70	38.35
Svornost	**24.95**	**21.40**	**52.29**
	18.41	15.79	38.59

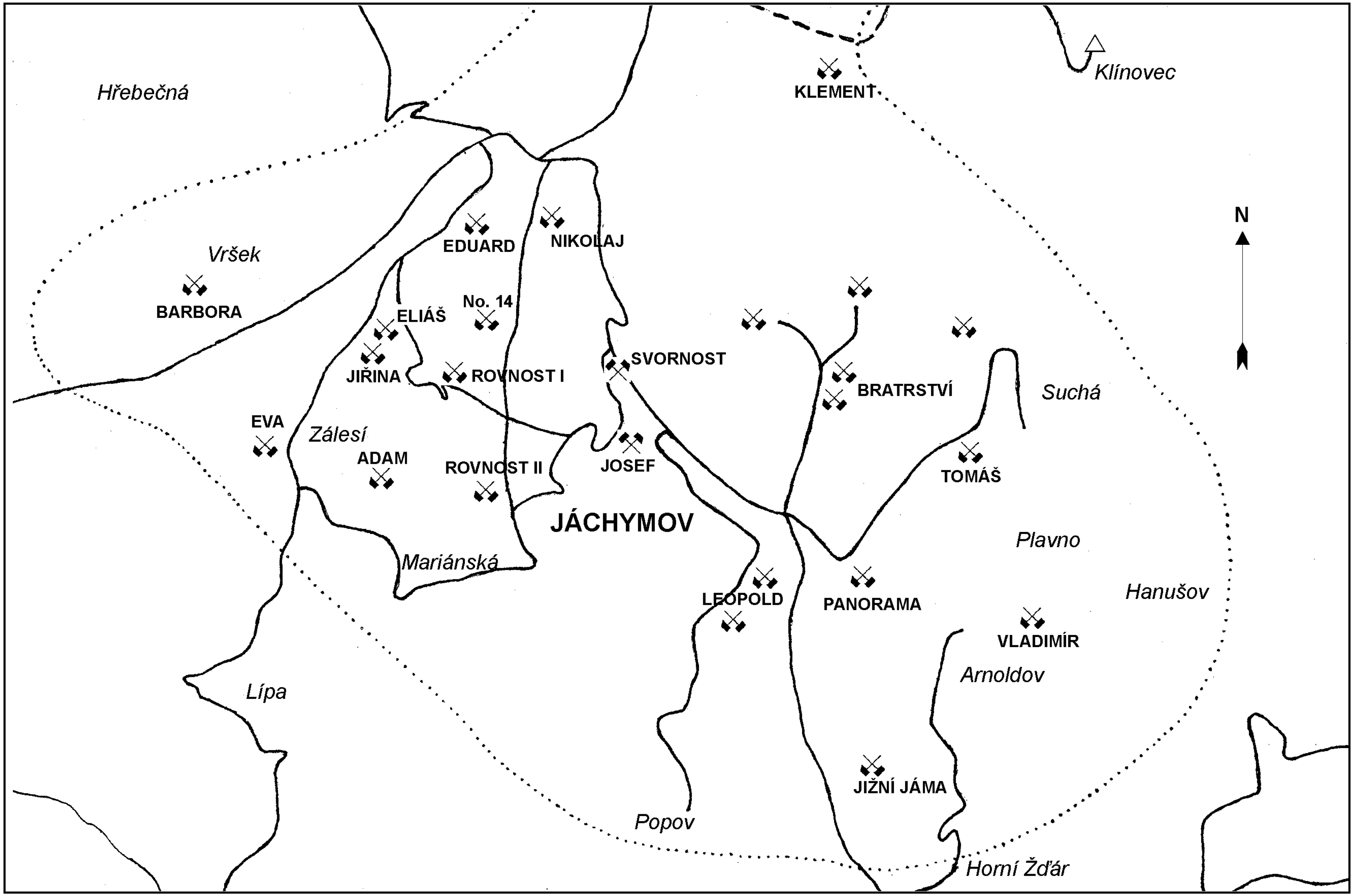
A thermometric measurement conducted on medium-grained violet to violet blue and greenish fluorite yielded homogenization temperatures of 190-198 °C for primary inclusions having the shape of negative crystals. Primary to secondary and secondary inclusions gave 158 °C and 105 to 145 °C [302].

The Jáchymov ore district can be described as consisting of six vein clusters: Rovnost, Barbora-Eva, Bratrství, Svornost, Plavno, and Panoráma. The vein clusters bear names of the respective most important mines. Position of these clusters is shown in Fig. 1.

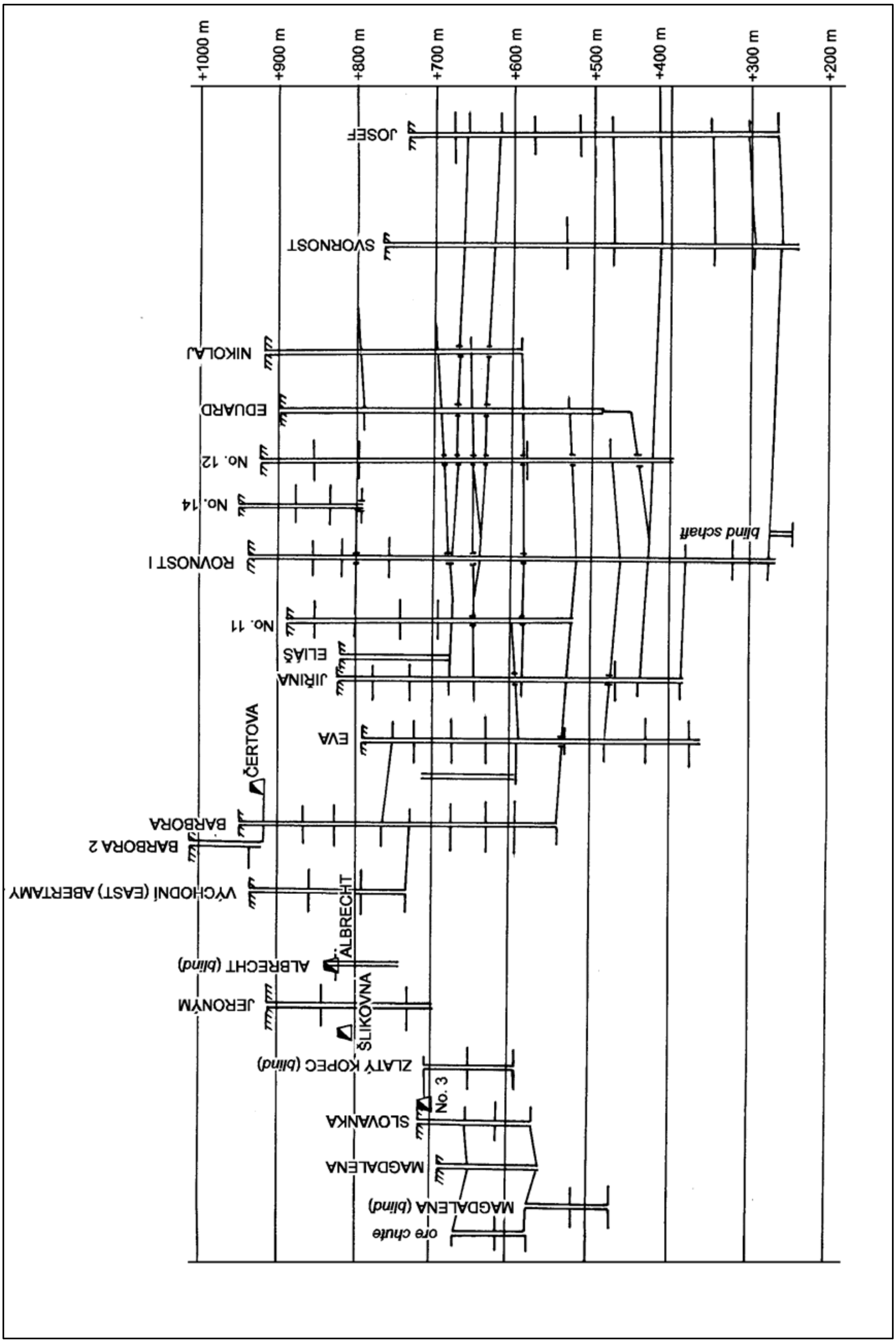
Hydrogeology of the Jáchymov ore district is characterized by the presence of the following two systems of waters: (1) descending water and (2) ascendant water. The descending water is bound to fractures and has a lime-sulphate composition. Its composition evolved during transport along veins and fractures, including often portions with pyrite. Its median molar ratios are $[HCO_3^-]/[SO_4^{2-}]=0.18$ and $[Ca^{2+}]/[Na^+]=6.0$ [120]. In difference to this composition, ascendant water has a composition influenced by the underlying granitoids, median molar ratios: $[HCO_3^-]/[SO_4^{2-}] = 34$ and $[Ca^{2+}]/[Na^+] = 0.18$.

It has a temperature near 30 °C and pressure between 1.9 and 4.0 MPa. The waters derived from granitoids have an increased radioactivity which led to their curative utilization. The first springs used in such application early in this century were the Štěpa's springs at the Daniel level of the Rovnost mine. In 1924, the spring Curie at the 12th level of re-opened mine Svornost was brought to use. The spring Becquerel was encountered in 1928 at the same level of this mine and in 1952 the springs Evangelist and Prokop were taped.

Hydrogeological prospecting commenced in 1960, which resulted in taping by underground boreholes of springs *C1*, *HG1*, and *Academician F. Běhounek* and in their use in local spa. During the first part of the sixtees, thick walls were built across all adits connecting with the Rovnost and Bratrství mines and the neighbouring mining fields were flooded. These activities did not influence the discharge capacity of springs with radioactive water or their chemical composition [185].



Localization of major mines of the Jáchymov ore district. Scale 1 : 50 000



Projection revealing mutual relationship of individual levels in major shafts (horizontal labels) and adits (vertical labels) of the Jáchymov ore district

It is interesting that the two systems of water circulation behave as separate systems free of mutual influence or mixing. There is lack of communication between respective conduits, though the underground springs (i.e., disruptions of the conduits by mine works) occur at various altitudes (personal communication by T. Pačes)

Methods of study

In many cases, the quantity of pure mineral phase available for study was rather small. Separation of subsamples was done with the aim to preserve at least a portion of the mineral on the specimen, which is important for any future study.

All separated samples, including also pure minerals (often only 0.1 to 1 mg in weight) were measured by X-ray powder diffraction and their qualitative chemical composition was studied with the electron microprobe.

The qualitative X-ray diffraction work was done with powder Phillips X'pert System (Cu radiation, 40 kV/40 mA, step 0.01 - 0.05 °2θ, time 1-10 s, graphite secondary monochromator). To minimize complicated shape of background due to classic glass sample holders, the sample studied was placed on the surface of flat silicon wafer from alcoholic suspension.

Data obtained were processed with the use of the X-ray diffraction software, ZDS-system, version 6.01 [291]. The unit cell parameters were calculated from the powder diffraction data using the ZDS-system (module *Gener*). The samples were calibrated with an internal standard, most frequently quartz, or using a calibration procedure which corrects for eccentricity of the sample (correction term $(\cos\theta.\cot\theta)/\lambda^2$). Data from published original studies were used for indexing.

The qualitative, and in some cases quantitative, chemical composition of minerals was measured with the scanning electron microprobe CamScan 4 with energy-dispersive analyser EDX system LINK eXL and wave-dispersive analyser WDX system Microspec - 3PC.

For quantitative chemical analysis of mineral phases in the system Ca-Cu-UO_2-CO_3-H_2O the following standards were used: azurite (Cu, C, O), calcite (Ca, C, O), uranium (U). Operating voltage and sample current 20 kV and 40 nA respectively. Specimen beam size was 15×10 µm. The samples for quantitative chemical analysis were usually coated with carbon; for measurement of carbon content, aluminium coating was used.

Correction procedures ZAF, Phi(rho×Z), and Quadrilateral were used for calculation of all quantitative analyses.

Mineral morphology was studied with the use of the scanning electron microscope TESLA BS 340, with magnification in the range 75 to 3000. The samples were coated with Au-Pd alloy, C, or Al.

TG, DTG curves were recorded simultaneously on the thermobalance TG 750 Stanton Redcroft. The operating conditions: sample weight about 1-3 mg, heating rate 10 $°C.min^{-1}$, dynamic air atmosphere 10 $ml.min^{-1}$ and temperature range 20-1000 °C.

Infrared absorption spectra in the 480-4000 cm^{-1} range were recorded with an FTIR spectrometer Nicolet 740 using KBr pellets and/or diffusion reflection mode.

In the case of rösslerite, program FullProf (version 3.2 for PC-compatibles - [284]) was used for the Rietveld refinement of crystal structure of this mineral from experimentally measured powder X-ray diffraction data. Background was approximated via polynomial of the fifth order, corrections for sample displacement (cosine term) and preferred orientation (in March-Dollase form) were applied. Pseudo-Voigt profile shape function was utilized. Peak base was set to 5.5 FWHM.

List of secondary minerals from the Jáchymov ore district

○ Acanthite
Adamite
Agardite-(Y)
● Albrechtschraufite
● Allophane
Alunogen
Andersonite
Anglesite
○ Annabergite
Antlerite
○ Apatite
Apjohnite
○ Aragonite
○ Arsenolite
Arsenuranospathite
● Asbolan
Atelestite
○ Autunite
Bayldonite
Beaverite
Becquerelite
Beudantite
Beyerite
○ Bieberite
○ Bismite
○ Bismutite
Bismutoferrite
Brassite
Brochantite
○ Calcite
Carbonate-fluorapatite
Cerussite
● Cervantite
○ Chalcanthite
Chalcophyllite
Chenevixite
○ Chlorargyrite
○ Chrysocolla
Churchite-(Y)
Chvaleticeite
Claudetite
Cobaltkoritnigite
Coffinite
Compreignacite
Copiapite
○ Copper
Coquimbite
Corkite
Cornwallite
Coronadite
Cryptomelane
Cuprite
○ Cuprosklodowskite
Curienite
Devilline
Dewindtite
● Diadochite
Duftite
Epsomite
○ Erythrite
○ Eulytite
Ferrohexahydrite
Fluckite
Geminite
Goethite
● Goslarite
Goyazite
Guerinite
Gunningite-Szomolnokite
○ Gypsum
○ Haidingerite
Halotrichite
○ Hematite
○ Hemimorphite
Hexahydrite
Hidalgoite
○ Hörnesite
Hydronium jarosite
Hydrozincite
†● Isoclasite
Irhtemite
Jáchymovite
○ Jarosite
○ Johannite
Kaatialaite
Kahlerite
Kamotoite-(Y)
Kańkite
Kasolite
○ Kermesite
Kettnerite
Koritnigite
Köttigite
Krautite
Langite
○ Lavendulan
Libethenite
○ Liebigite
○ Lindackerite
Magnesium-zippeite
Malachite
Masuyite
Mcnearite
○ Melanterite
Meta-autunite
Metalodevite
Metanováčekite
Metaschoepite
Metatorbernite
Metatyuyamunite
†● Meta-uranopilite
Meta-uranospinite
Metavoltine
Metazellerite
Metazeunerite
Mimetite
○ Mixite
Monohydrocalcite
Moorhouseite
○ Morenosite
Mottramite
Mrázekite
Namibite
Natrojarosite
○ Neshquehonite
Nickelhexahydrite
Nickel-zippeite
Nováčekite
Olivenite
Opal
Orpiment
Pararealgar
Parascorodite
Parasymplesite
Parnauite
Parsonsite
Petitjeanite
○ Pharmacolite
Pharmacosiderite
Phosphuranylite
Picropharmacolite
○ Pitticite
Plumbojarosite
Posnjakite
Preisingerite
Proustite
Pseudomalachite
Psilomelane
Pucherite
Pyrolusite
○ Pyromorphite
Rabbittite
Rabejacite
Rauenthalite
○ Retgersite
Rhomboclase
Richetite
Römerite
○ Rösslerite
Rozenite
Sainfeldite
Scorodite
Schoepite
○ Schröckingerite
Schultenite
○ Silver
Sklodowskite
● Smrkovecite
● Soddyite
Sodium-zippeite
Strashimirite
○ Sulphur
Symplesite
Synchisite
● Talc
Talmessite
● Tenorite
Thenardite
○ Torbernite
● Trögerite
Tyuyamunite
Urancalcarite
● Uranocircite
○ Uranophane
○ Uranophane-beta
○ Uranopilite
Uranospathite
● Uranosphaerite
Uranospinite
● Valentinite
Vandendriesscheite
Villyaellenite
● Vivianite
○ Voglite
Vochtenite
○ Walpurgite
Weeksite
Weilite
○ Widenmannite
Wölsendorfite
Wulfenite
Yingjiangite
Zellerite
○ Zeunerit
○ Zippeite
Znucalite
Zýkaite

Explanation of the symbols used in the table above

●	*species known before this study - not confirmed*
○	*species known before this study - confirmed*
†	*doubtful mineral species*
no symbol	*species newly found in this study*

Encyclopaedia of secondary minerals from Jáchymov ore district

Acanthite Ag_2S

Acanthite was described by Kenngott [221] using two specimens collected in Jáchymov in the 18th century and kept in the Emeperror's collection in Vienna.

Kenngott [221] characterised acanthite as small, seemingly orthorhombic crystals terminated by a steep pyramid, overgrowing argentite. The mineral is black, has a metallic lustre, it is malleable. Acanthite occurs in scattered radiating aggregates up to 2 mm long, rarely as larger coatings. Individual crystals are platy, elongated in one direction, with a rounded termination. It occurs in proximity of silver-bearing minerals, which provided Ag for acanthite. The formation of acanthite is probably taking place in the presence of sulphuric acid formed by decomposition of pyrite and marcasite, in some cases arsenic acid derived from arsenides was also involved. Rarely, it overgrowth directly sulphidic minerals with Ag. Native silver is often coated by scattered, minute acicular acanthite crystals. It was observed in many veins. Acanthite also forms on specimens after deposition in collection. Annabergite, gypsum, picropharmacolite, and pharmacolite are common associated minerals.

Hardness	1	< 2.5
Density [g.cm^{-3}]	1	D_m = 7.31-7.36
References		221

1 - Acanthite, Jáchymov. Kenngott [221]

Adamite $Zn_2(AsO_4)(OH)$

Adamite occurs sparsely in small spherical aggregates up to 2 mm in diameter. The spheres are largely isolated, rarely coalesce to larger aggregates. Small-scale facets on the spheres, seen at magnification near to 1000, correspond to termination of individual crystals. The aggregates are pale pinkish in colour.

Adamite was determined in specimens from the Geschieber vein, deposited on wallrock together with köttigite showing a striking colour banding (pale grey brown and buff white). Adamite accompanies whitish köttigite only and crystallised mainly in small fractures while köttigite coated surfaces of larger free cavities.

Lattice par. [Å]		a = 8.329(3)	b = 8.530(5)	c = 6.061(3)
EDX, WDX		major elements: Zn, As		minor elements:
References		248		

Agardite-(Y) $(Y,Ca)Cu_6(AsO_4)_3(OH)_6 . 3H_2O$

This mineral was identified in a single specimen only as glassy crust with a smooth and lustrous surface and with an intense emerald green colour. The crust is 1 mm thick coating with area of several cm^2.

Lattice par. [Å]		a = 13.52(1)		c= 5.86(1)
EDX, WDX		major elements: Cu, As, Y		minor elements: TR
References		88, 99, 110, 143		

Albrechtschraufite $MgCa_4F_2[(UO_2)(CO_3)_3]_2 . 17H_2O$

This phase was proposed as a new mineral to the Commission on New Minerals and Mineral Names (IMA) by Mereiter in 1983. Data for albrechtschraufite based on a single sample from Jáchymov were not published, except an abstract indicating that the crystal structure was studied [62].

The abstract gives the following information: the new mineral occurs on a specimen of schröckingerite. The crystal structure and chemical composition were derived using single-crystal X-ray study. Albrechtschraufite has a triclinic cell, space group $P\bar{1}$, Z=2. It contains two independent complex anions $[(UO_2)(CO_3)_3]^{4-}$. Colour is yellow green, hardness 2 to 3.

It is possible that Mereiter had an insufficient amount of the new phase, which could explain why he refrained from publication of the data. During our work, no phase corresponding to albrechtschraufite was encountered.

Lattice par. [Å, °]	1	a=13,562(3)	b=13,406(3)	c=11,636(3)
		α=115,75(2)	β=107,66(2)	γ = 92,86(2)
Density [g.cm^{-3}]	1	D_m = 2.6, D_x=2.67		
References		12, 62		

1 – Albrechtschraufite, Jáchymov. Mereiter [62]

Allophane (amorphous alunimium silicates)

Allophane was described [118] as strong blue spheroidal aggregates. The present study did not confirm presence of allophane.

Alunogen $Al_2(SO_4)_3 . 17 H_2O$

Alunogen occurs in a mixture with halotrichite in widely dispersed clusters of thin acicular crystals. The crystals are white, greenish or bluish. Alunogen occurs in porous quartz gangue, being deposited on pyrite and on minute crystals of proustite together with other secondary minerals, which show the following succession: gypsum - halotrichite + alunogen - melanterite + Mo-phase - metavoltine + copiapite.

The specimens originate from the Geschieber vein.

Andersonite $Na_2Ca[(UO_2)(CO_3)_3] . 6H_2O$

Andersonite belongs to the most rare uranyl-carbonates in Jáchymov. It occurs in coherent, yellow, irregular aggregates (up to 3 mm) on pieces of wallrock in old workings. Andersonite occurs with schröckingerite and liebigite. In the ultraviolet light, it fluoresces an intense light green.

Lattice par. [Å]		a = 7.912(6)		c = 23.36(4)
		Z = 18		
EDX, WDX		major elements: U, Ca, C	minor elements: Na	
IR [cm^{-1}]	1	215,254,272,286,300,320,347,425,475, 545,701,728,795,849,854,(880),903,915, 1081,1091,1378,1417,1522,1560,1578, (1662),2620,(3220),(3430),3563		
Therm. analysis [°C]	1	50-185 (release of 4 H_2O), 185-315 (release of 1.6 H_2O), 315-450 (release of 1.5 CO_2), 450-725 a 725-860 (release of a rest of CO_2) endothermic reaction: 145, 365		
References		12, 17, 56		

1 - andersonite, Jáchymov. Čejka et al. [17]

Anglesite $PbSO_4$

It occurs in isometric or slightly elongated rounded crystals with adamantine lustre, up to 3 mm long. Its transparent, pale yellow or partly rusty crystals were found in minor open fractures in weathered pitchblende, among remains of a dump from the Schweizer vein. Anglesite was also identified, free of accompanying minerals, in open fractures in wallrock near the Geister vein. Black material coating fractures in two specimens designated pateraite (sample Nos. NM 45173 and NM 16899) in the National Museum, Prague, was also identified as anglesite.

Annabergite $Ni_3(AsO_4)_2 . 8 H_2O$

Annabergite forms mainly powdery coating or fragile crusts on weathered Ni-Co ores. It is typically pale blue green in colour, grading to grey green and greyish white. The aggregates consist of microcrystals 1 to 10 m long.

Although annabergite is often earthy in appearance, green glassy and botryoidal coatings or spheroidal aggregates with radiating texture were also observed. Chemical analyses show variable proportions of Ni, Co, Zn, Fe, and Mg; pure Ni member was not encountered.

Lattice par. [Å,°]		a = 10.20(3)	b = 13.27(3)	c = 4.68(2)
			β=104.61(2)	
EDX, WDX		major elements: As, Ni	minor elements: Zn, Ca, Mn, Mg	
IR [cm^{-1}]		440,470,515,595,795,865,(920),1120, 1625,3050,3200,3450		
References		27, 91		

Antlerite $Cu_3(SO_4)(OH)_4$

Antlerite forms glassy, very thin coatings of a strong green colour, deposited on tabular aggregates of zeunerite. Coatings up to several cm^2 in size were observed. Antlerite was analysed in a single sample, representing a mixture with langite and in paragenesis with zeunerite, richetite, and an unknown phase of the type "UO_3-$H_2O(1)$".

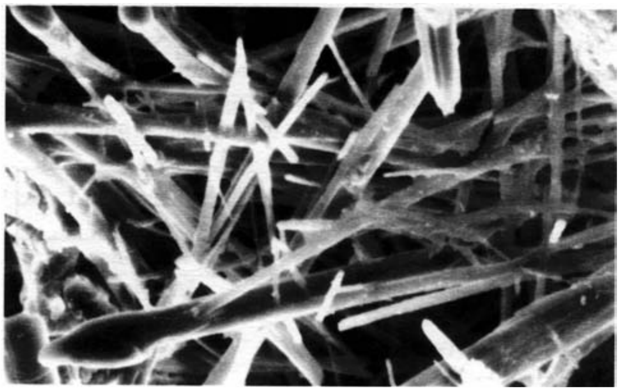
Lattice par. [Å]		a = 8.261(2)	b=12.030(8)	c = 6.039(3)
References		275		

Apatite $Ca_5(PO_4)_3(F,Cl,OH)$

Apatite was found as microscopic, short prismatic crystals embedded in goethite coating cavities in vein quartz. This mineral was listed by Kratochvíl [118] from wallrock gneisses, but he mentioned also apatite occurrence in an ore vein.

Apjohnite $MnAl_2(SO_4)_4 . 22 H_2O$

Apjohnite occurs as whitish to light pink aggregates composed of very fine acicular crystals in radiating clusters. The aggregates are deposited on compact crusts of sulphur-yellow copiapite. Central parts of some of the radiating aggregates are filled by compact, light pink chvaleticeite. Apjohnite occurs in paragenesis with copiapite, chvaleticeite, whitish epsomite and gypsum on specimens from the Geschieber vein.



Acicular crystals of apjohnite. Magnification 250

Aragonite $CaCO_3$

Aragonite occurs in thin coatings 1 to 2 cm^2 in size and spheres up to 2 mm in diameter. The coatings are light bluish grey, non-lustrous, while the spheres are always grey green with a variable intensity of green shade. There are also paragenetic differences - the coatings occur with Ca and Mg arsenates and in the Kryštof vein on carbonate gangue with disseminated skutterudite, while the spheres associate with lavendulan and pink köttigite overgrowing quartz and chalcopyrite crystals in cavities of the Geister vein.

Arsenolite As_2O_3

It occurs mainly with native arsenic or in its proximity in the form of colourless crystalline or powdery coating. Individual octahedral crystals 2 to 3 mm long are less common. In rare cases of arsenic covered by powdery dickite, arsenolite octahedrons are up to 6 mm long, however, large arsenolite crystals do not accompany massive, hard dickite aggregates. The arsenolite crystals have cleavage along {111}, conchoidal fracture, and remarkably strong glassy lustre.

Arsenolite often accompanies arsenates, in particular pharmacolite and sometimes annabergite. In one sample, arsenolite formed together with gypsum, pharmacolite, and lavendulan after altered Co-Ni arsenide, probably skutterudite.

Lattice par. [Å]		a =11.051(3)		
EDX, WDX		major elements: As	minor elements:	
Density [g.cm^{-3}]		D_m = 3.798 (determined by pycnometer)		
References		27		

Arsenuranospathite $HAl(UO_2)_4(AsO_4)_4 \cdot 40\ H_2O$

Arsenuranospathite forms inconspicuous planar to spheroidal aggregates of light green to light yellow green colour, composed of fine rose-shaped groups of tabular tetragonal crystals. The crystals show a strong pearly lustre. Arsenuranospathite aggregates are deposited directly on partly weathered uraninite or on unidentified, very thin coating of a strong yellow colour.

It was observed in paragenesis with uranospathite, whitish to transparent anglesite, nováčekite a white green metatorbernite.

The semiquantitative chemical analyses suggest that in the specimens studied there are members of a continuous series uranospathite-arsenuranospathite. The specimens were collected on dumps of the Eliáš mine.

EDX, WDX		major elements: U, As, Al	minor elements: P
References		289	

Asbolan $(Co,Ni)_{1-y}(Mn^{4+}O_2)_{2-x}(OH)_{2-2y-2x} \cdot n\ H_2O$

Asbolan was described in the past as *psilomelane*, *cobalt black*, or as *cobalt-manganese ore*. It forms largely minor botryoidal or powdery coatings. Massive material is black, with waxy lustre. Asbolane occurs in cavities of the Geister and Eliáš veins, in part mixed with *silver black ore* [118].

Atelestite $Bi_8(AsO_4)_3O_5(OH)_5$

Atelestite was observed only as mixture with preisingerite. The mixture forms compact aggregates or irregular veinlets with total surface of several cm^2, intergrown in quartz gangue. The aggregates are rather hard, they have a pitch-like lustre (similar to that of mimetite) and grey yellow to dark grey colour. Some poorly formed crystals up to 3 mm long, with a waxy yellow colour, crystallised in a cavity in quartz.

Atelestite, always mixed with preisingerite, is associated with bismuth, beyerite and walpurgite. The material analysed was collected in the Rovnost I shaft.

Lattice par. [Å,°]		a=10.896(7)	b = 7.431(6)	c = 6.978(5)
			β=107.45(1)	
EDX, WDX		major elements: Bi, As	minor elements: P	
References		274		

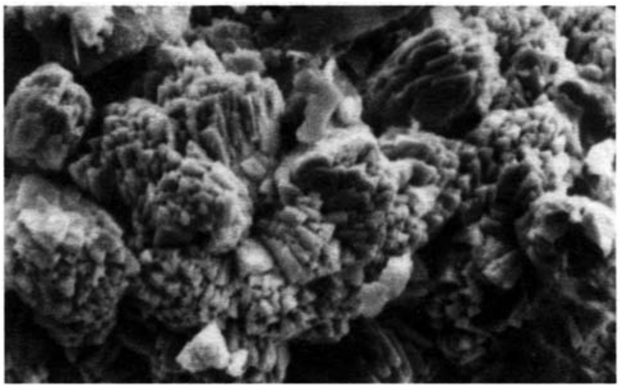
Autunite $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12\ H_2O$

Autunite was described by Kratochvíl [118] as yellow, tetragonal tabular crystals, which are rare in the Eliáš mine and occur in small crystals in the Hohe Tane mine. The present study did not confirm autunite in Jáchymov. All specimens designated previously as autunite were redefined as meta-autunite.

Bayldonite $PbCu_3(AsO_4)_2(OH)_2 \cdot H_2O$

Bayldonite minute crystals form thin coatings strong green or pale yellow in colour. They are deposited on limonite in vugs of vein quartz. On its turn, bayldonite is overgrown by zeunerite, metazeunerite, hidalgoite, and mimetite

Lattice par. [Å, °]		a = 14.06(2)	b = 5.893(8)	c = 10.15(1)
			β=105.75(1)	
EDX, WDX		major elements: Pb, Cu, As	minor elements:	
References		231		



Crust of bayldonite crystals in vug of vein quartz. Magnification 1000

Beaverite $Pb_2(Cu,Fe,Al)_6(SO_4)_4(OH)_{12}$

It has been found in a mixture with anglesite and metatorbernite as a fine-grained crust up to 3 mm thick. Its colour ranges from light green to brown yellow. The crust developed on a matrix of quartz vein with pyrite. Jarosite, anglesite, limonite and gypsum occur as a coating on the specimen or as fill of minor fractures.

The specimen originated in the Eliáš mine.

Becquerelite $Ca(UO_2)_6O_4(OH)_6 \cdot 8\ H_2O$

Becquerelite occurs as spheroidal aggregates up to 0.5 mm in diameter, consisting of very fine acicular crystals with a silky lustre. The light yellow aggregates have a matte surface. They occur as coating on fractures in the vein or in country rock close to the vein. Becquerelite tends to be covered by spheres of compreignacite.

The specimens originate in the Geschieber vein.

Lattice par. [Å]		a=13.835(7)	b=12.378(5)	c= 14.924(9)
EDX, WDX		major elements: U		minor elements: Ca
References		200, 262, 270		

Beudantite $PbFe_3(AsO_4)(SO_4)(OH)_6$

Beudantite is rarely coating quartz crystals in vugs of some veins. It has honey yellow brown colour, glassy to waxy lustre. Beudantite is overgrown by a mixture of nováčekite and metanováčekite. The mineral was found in vuggy vein quartz enclosing sphalerite and bismuthinite on the dump of the Eliáš mine.

Lattice par. [Å]		a = 7.351(1)		c=17.057(3)
EDX, WDX		major elements: Fe, Pb, As		minor elements: Ca, P,(Si)
References		270		

Beyerite $Ca(BiO)_2(CO_3)_2$

Beyerite occurs in coatings on quartz and eulytite crystals, powdery material filling small vugs and aggregates of very minute crystals with an adamantine lustre. It is usually lemon yellow, grass green, and pale yellow or grey green. It is accompanied by eulytite, namibite, pucherite, kettnerite, native bismuth, and yellow or white powdery bismutite, which usually replace bismuthinite.

Beyerite occurs in Bi vein fill in the Eliáš and Rovnost mines.

Lattice par. [Å]	1	a=3.7780(8)		c= 21.756(6)
EDX, WDX		major elements: Bi, Ca, Pb, C as $(CO_3)^{2-}$		minor elements: As, Cu, Fe, Mn, Si
IR [cm^{-1}]	1	572,678,701,862,1065,1138,1194,1428, 1481,2392,2452,2520,2850,2940,2980, 3400		
References		27, 49, 81,111, 193		

1 - beyerite, Jáchymov, Sejkora [193]

Bieberite $CoSO_4 . 7 H_2O$

Bieberite forms minute skeletal crystals, mainly orthorhombic tablets with uneven edges. It has a buff pink colour and a weak glassy lustre. Bieberite overgrowths koritnigite and it is accompanied by pink köttigite and picropharmacolite. The secondary minerals crystallised on fractured quartz-carbonate gangue. It occurs in Geschieber and Evangelista veins.

Spontaneous dehydration of bieberite results in alteration to moorhouseite.

Bieberite was also described [118] as crystalline efflorescence grey buff to reddish or brownish, coating skutterudite, pateraite, native bismuth, and on cobalt ore minerals. It was found on the Geister vein.

Bismite Bi_2O_3

Bismite in white grey grains with a high waxy lustre in vein quartz forms pseudomorphs after isolated grains of native bismuth, which is often preserved in part in the core of the pseudomorph. The increase in volume, accompanying this replacement, resulted in radial fractures in quartz around altered native bismuth.

Bismite is accompanied by yellow powdery bismutite coating, remnants of native bismuth, and dispersed acicular crystals of bismuthinite, which is altered in part into yellow material. These products were too scarce for identification. Bismite was identified in samples from dumps of the Eliáš mine.

Sejkora [193] reported on bismite associated with white powdery bismutite, walpurgite, younger bismutoferrite and bismutite.

Lattice par. [Å, °]	1	a = 5.835(8)	b = 8.138(6)	c = 7.482(8)
			β= 67.04(8)	
References		38, 89, 193		

1 - bismite, Jáchymov, Sejkora [193]

Bismutite $(BiO)_2CO_3$

Bismutite occurs as powdery coating and earthy crusts, white, grey, or pale yellow in colour. It formed by replacement of bismuthinite. Bismutite, accompanied by kettnerite and beyerite, occurs in brown pseudomorphs after eulytite. Bismutite with preisingerite compose pseudomorphs after native bismuth in a quartz veinlet. It also replaces skeletal crystals of native bismuth. Bismutite is often accompanied by bismutoferrite and represents the most abundant oxidic mineral of bismuth.

Lattice par. [Å]		a = 3.877(2)		c = 13.75(1)
	1	a = 3.871(2)		c = 13.87(1)
EDX, WDX		major elements: Bi, C as $(CO_3)^{2-}$		minor elements: Fe, Ca, As, Si
Density [g.cm^{-3}]	1	D_x = 8.15		
References		27, 38, 81, 190		

1 - bismutite, Jáchymov. Sejkora et al. [190]

Bismutoferrite $BiFe_2(OH)(SiO_4)_2$

It is a yellow, yellow green or olive green mineral in soft coatings and crusts. Bismutoferrite is a common component of the so-called bismuth ochres and in western part of the district, it accompanies almost invariably native bismuth. It is often accompanied by yellow white powdery bismutite, while association with beyerite and walpurgite is rare.

Sejkora [193] described bismutoferrite as bright yellow, small tabular crystals filling minor vugs in vein quartz and accompanied by mixite. He documented bismutoferrite also from the 6th level of the Geister vein (Rovnost mine). Sejkora [193] gave the following chemical analysis: Bi_2O_3 42.34, SiO_2 23.73, Fe_2O_3 29.64, H_2O 1.68, Total 97.39 wt. %. Recalculation on the basis of 9(O,OH) results in the formula:

$Bi_{0.95}(Fe_{1.95}Si_{0.08})_{2.03}Si_2O_8(OH)$

Lattice par. [Å,°]		a = 5.220(3)	b = 9.007(3)	c = 7.731(4)
			β=101.63(5)	
EDX, WDX		major elements: Bi, Fe, Si		minor elements: Mg, Ca
IR [cm^{-1}]	1	461, 489, 568, 673, 759, 797, 999, 1022, 1069, 3545		
References		45, 49, 52, 97, 118, 193		

1 - bismutoferrite, Jáchymov. Sejkora [193]

Brassite $MgHAsO_4 . 4 H_2O$

The first description of the mineral, known at present as brassite, was presented by Haidinger [225] and Turner [226] as early as 1825. Turner reported contents of As_2O_5 50.1 and H_2O 31.6 wt. %. In 1867, Tschermak [224] published a very good description of brassite, without suggesting a name for this species. It is a paradox that only about a century later (1973) brassite was described by Fontan et al. [210] using museum specimens from Jáchymov.

Brassite forms monoclinic, pseudo-orthorhombic crystals with a glassy lustre. The white crystals are very fragile, with a good {100} cleavage. Tschermak [224] gave the following chemical analysis: As_2O_5 49.1, MgO 17.0, H_2O 34.7, Total 100.8 wt. %. Only a trace of Ca was found by a recent spectral analysis.

Brassite forms in a dry environment by dehydration of rösslerite. Rösslerite deposited in collections readily whitens and alters to brassite in a few weeks. The alteration starts at certain sites distributed at random throughout the crystal. Surprisingly, some rösslerite crystals, kept in collections, resist alteration for over 20 years. Possibly, small amounts of sulphuric or arsenic acid present in the latter specimens may account for a sufficient content of water. X-ray analysis of some whitened rösslerite crystals shows that the original structure is preserved.

Fontan et al. [210] gave the following analysis: As_2O_5 48.1, MgO 15.6, CaO 0.9, H_2O (calculated to 100%) 35.4 wt. %. This mineral is identical with a synthetic phase crystallised from solutions at pH 2 to 4 [210].

In view of the above relations, the paragenesis of brassite and rösslerite is analogous. The old museum specimens with brassite show more visible haidingerite and other minerals, which remained transparent, but were unnoticed by the old time mineralogists.

Lattice par. [Å]		a = 7.472(1)	b=10.891(1)	c=16.585(5)
		Z = 8		
Density [$g.cm^{-3}$]	1	D_m = 2.28, D_x = 2.326		
References		107, 210, 224, 225, 226		

1- Brassite, Jáchymov. - [210]

Brochantite $Cu_4(OH)_6SO_4$

Brochantite occurs in green to emerald green crusts of minute crystals with a high glassy lustre. Powder of the mineral is pale green. The mineral is biaxial, negative, weakly pleochroic in green to blue green colours. It is accompanied by gypsum, devilline, langite, and posnjakite, often in proximity of primary chalcopyrite and tennantite.

Lattice par. [Å, °]		a =13.445(4)	b=9.856(6)	c =6.024(3)
			β=103.42(1)	
EDX, WDX		major elements: Cu, S		minor elements: Ca
References		27		

Calcite $CaCO_3$

Calcite forms up to 2 cm thick coatings on mine walls. They are snow white, grey to brown or rusty, depending on colouring admixture. Calcite stalagmites have the same colour as accumulations on floor; up to 20 cm long tubes, 3 mm in diameter occur, often showing twisted and irregular shape. Some of these odd shapes result from coating of algae fibres by calcite.

Carbonate-fluorapatite $Ca_5(PO_4, CO_3)_3F$

It occurs as crystalline crusts deposited on fractures and small cavities in mineralised vein. The crusts are up to 1 mm thick, with short prismatic crystals on its surface. The mineral is white or rusty, if containing limonite admixture. Crystal faces show glassy or pearly lustre. Carbonate-fluorapatite occurred in the Geschieber vein.

EDX, WDX		major elements: Ca, P, C as $(CO_3)^{2-}$	minor elements:

Cerussite $PbCO_3$

Vogl [20] described white cerussite coatings on galena in the Geister vein. The present study confirmed cerussite on a specimen from the same vein as minute equant or long dipyramidal crystals of white grey colour and greasy adamantine lustre, grown on bismutoferrite.

Cervantite $Sb^{3+}Sb^{5+}O_4$

Cervantite was also described under the name of antimony ochre. According to Vogl, it accompanies stibnite and pyrargyrite as a coating on sphalerite [118] on samples from the Geister vein.

Cervantite was not confirmed during the present study.

Chalcanthite $CuSO_4 . 5 H_2O$

Chalcanthite occurs as dark blue crystalline aggregates in gangue impregnated by melanterite from the Kaiser Josef mine [118].

Recently it was found in light blue aggregates composed of fine crystals, together with lindackerite and erythrite on samples collected in the Geister vein.

Lattice par. [Å, °]		a = 7.149(1)	b=10.701(7)	c =5.956(1)
		α=97.677(4)	β=125.26(4)	γ =94.331(3)
EDX, WDX		major elements: Cu, S		minor elements:
References		118, 275		

Chalcophyllite $Cu_9Al(AsO4)_2(SO4)_{1.5}(OH)_{12} . 18H_2O$

Chalcophyllite associated with parnauite was identified as a coating of light green spherical aggregates up to 2 mm in diameter. The X-ray diffraction pattern with diffuse lines indicates an imperfect crystallinity and probably a rapid deposition from weakly acid to neutral solutions.

The associated minerals include parnauite, brochantite, and malachite. The specimen is from the Geschieber vein.

EDX, WDX		major elements: Cu, As, S	minor elements:

Chenevixite $Cu_2Fe_2(AsO_4)_2(OH)_4 . H_2O$

Chenevixite forms earthy aggregates of a green-olive colour. It was analysed in a single specimens only.

X-ray powder diffraction pattern with diffuse lines indicates an imperfect crystallinity.

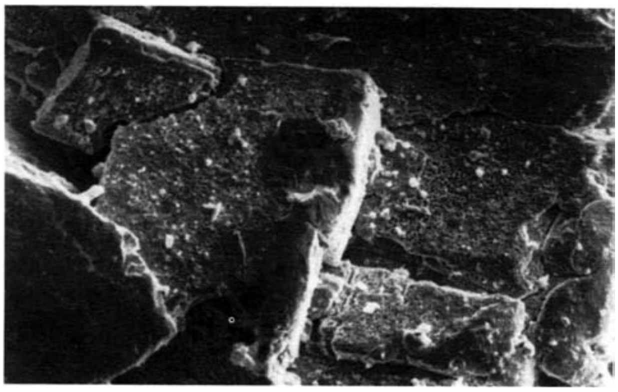
The mineral was identified on specimen from the Werner main.

EDX, WDX		major elements: Cu, Fe, As	minor elements: S, Si, Ca

Chlorargyrite AgCl

Chlorargyrite was found during the early stages of mining, probably in shallow mines as white hexahedral crystals. Later on, it was recorded in an altered porphyry in the Barbora adit [118], [51].

Lattice par. [Å]		5.5514(2)		
EDX, WDX		major elements: Ag, Cl		minor elements: Br



Hexahedral crystals of chlorargyrite. Magnification 200

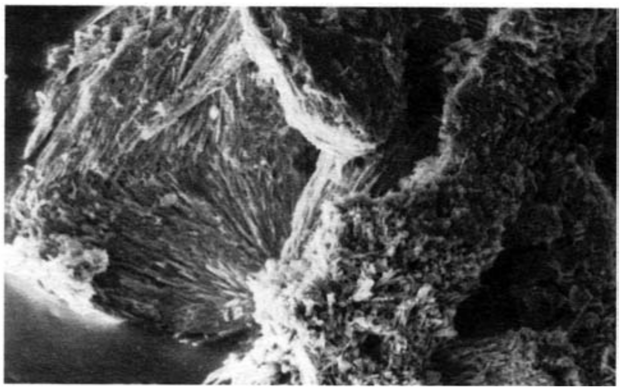
Chlorargyrite was considered as a very rare mineral in reports from the 19th century [46], [63]. A specimen kept in the mineral collection of the Faculty of Science, Masaryk University in Brno (sample No.: 4947a), contains 1 cm wide argentite veinlet in quartz, carrying chlorargyrite in small crevices. The cubes are up to 1 mm long and violet-brown in colour.

Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4 . n H_2O$

It was mentioned by an anonymous author [213] as accompanying waltherite in the Geister vein. Its identity was confirmed by Fischer [108] in the course of revision of the waltherite specimens.

Churchite-(Y) $YPO_4 . 2 H_2O$

Churchite occurs as minute, exceptionally 1 mm large spheres with a rough surface and composed of radiating acicular crystals. The mineral is white with a glassy lustre, but the surface of aggregates is usually slightly rusty coloured. It is deposited on small quartz crystals in vugs of vein quartz, being accompanied by yellow or yellow green spheroidal aggregates of parsonsite, ferruginous pseudomorphs after autunite, and by anglesite. Minute crystals of zeunerite were observed on some churchite spheres. The mineral was identified on specimens from the Geister vein.

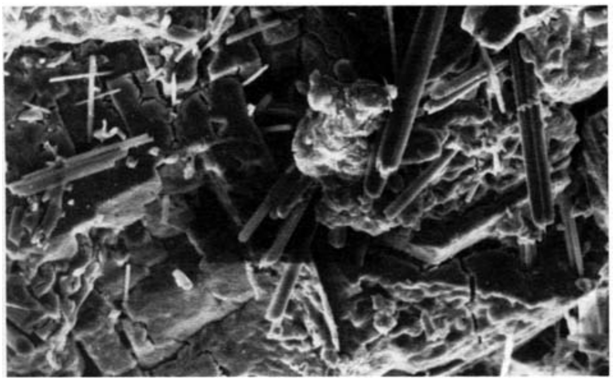


Churchite-(Y) in radiating aggregates of minute crystals. Magnification 250

Lattice par. [Å, °]		a = 5.61(2)	b = 15.18(7)	c = 6.22(1)
			β=115.17(5)	
EDX, WDX		major elements: P,Dy,Ca, Y		minor elements: Nd,Sm,Gd,Tm
References		77		

Chvaleticeite $(Mn, Mg)SO_4 . 6 H_2O$

Chvaleticeite forms earthy fill of light pink colour among radiating crystals of apjohnite. The latter mineral crystallised on compact crust of sulphur-yellow copiapite. Chvaleticeite occurs with fine acicular apjohnite, copiapite, whitish epsomite and gypsum on specimens from the Geschieber vein.

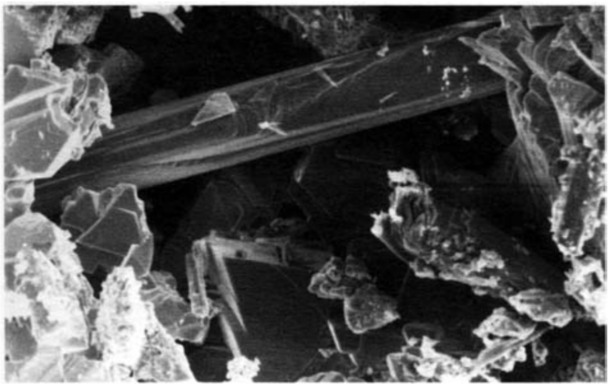


Equant crystals of chvaleticeite constitute matrix covered by acicular crystals of apjohnite. Magnification 250

Claudetite As_2O_3

It was observed as individual acicular crystals up to 2 mm long, sometimes in radiating groups. It is transparent, highly lustrous; the latter property makes it distinct from gypsum. Elasticity of the crystal is characteristic. It overgrows native arsenic together with the other polymorph of As_2O_3 - arsenolite. Claudetite also occurs together with kaatialaite and scorodite on specimens from the Geschieber vein.

Lattice par. [Å, °]		a =5.336(2)	b =12.981(1)	c =4.5393(6)
			β =94.242(2)	



Needle-like claudetite crystal in vug with crystals of arsenolite. Magnification 500

Cobaltkoritnigite $(Co, Zn)(AsO_3)OH . H_2O$

The type of occurrence is similar as for koritnigite, except for the dark violet red colour, characteristic for the cobalt-dominated species. The cobalt/zinc ratio varies from specimen to specimen and the composition correlates with intensity of violet colour. Other physical and mineralogical properties of cobaltkoritnigite and koritnigite are nearly identical

Cobaltkoritnigite forms rare isolated radiating aggregates of minute crystals with glassy lustre on open fractures of the Geschieber vein.

Lattice par. [Å, °]		a = 7.834(8)	b =15.70(2)	c = 6.70(1)
		α = 90.30(2)	β =96.12(2)	β = 89.77(1)
EDX, WDX		major elements: As, Co, Ni	minor elements: Mg	
References		43, 277		

Coffinite $U(SiO_4)_{1-x} . (OH)_x$

Coffinite occurs as minute grape-shaped brittle aggregates of a cinnamon brown colour. The surface material is of a lighter colour compared to the interior parts. The aggregates are matte on surface and on fractures. It occurs in crevices up to 3 mm long in a uraninite specimen with pyrite. Coffinite is overgrown by acicular crystals of milky white calcite. The specimen was collected in the mine Eliáš.

EDX, WDX		major elements: U, Si	minor elements: Mg
References		150	

Compreignacite $K_2(UO_2)_6O_4(OH)_6 . 8 H_2O$

Compreignacite carries striking and massive red brown to orange glassy crystalline crusts, which are very friable, soft and have a yellow colour of powder. X-ray analysis shows that the crusts correspond to mixture of several phases, with vandendriesscheite predominating over compreignacite.

X-ray powder diffraction pattern of compreignacite from Jáchymov

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	1)	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	1)	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
5	7.898						4	2.766					*	2	1.8587	1.8582	0	0	8
76	7.397	7.433	0	0	2		6	2.582	2.579	2	0	4		5	1.7988				
100	7.214					*	7	2.557	2.560	1	3	4		3	1.7799				
3	4.791					*	18	2.528					*	6	1.7705				
5	4.434					*	3	2.4782	2.4776	0	0	6		4	1.7499				
6	3.943						5	2.4090					*	4	1.7221				
25	3.711	3.716	0	0	4		2	2.3080					*	2	1.7030				
60	3.607	3.581	2	0	0	*	2	2.2659						2	1.6757				
29	3.546	3.531	1	3	0	*	4	2.1984						2	1.6500				
22	3.508						6	2.0494	2.0578	3	3	0		3	1.6361				
20	3.235	3.226	2	0	2		14	2.0323	2.0289	0	6	0	*	4	1.6069				
79	3.183	3.189	1	3	2	*	16	1.9898	1.9832	3	3	2	*	3	1.5929				
24	3.149						8	1.9762						1	1.5788				
4	2.985						8	1.9550	1.9589	1	5	4		2	1.5207				
3	2.914						2	1.8786											

*1) - diffractions of vandendriesscheite (signed " * ")*

Kasolite and uranophane are associated with these minerals in the form of buff powdery coating. All these secondary minerals are deposited on weathered uraninite.

Compreignacite forms also glassy spheres up to 0.5 mm in diameter. They have an uneven surface, glassy lustre and light yellow or brown yellow colour. It occurs on fractures penetrating the vein or the country rock close to the vein. Compreignacite forms coating on cuprosklodowskite or becquerelite.

The specimens originate in the Geschieber vein.

Compreignacite was also identified as glassy spheres up to 0.5 mm in diameter with uneven surface and glassy lustre. The colour is light yellow or brown yellow. The spheres are coating fractures in vein material or in proximity of the vein, deposited on cuprosklodowskite or becquerelite. The specimen with compreignacite was collected in the Geschieber vein.

Lattice par. [Å]		a = 7.16(1)	b = 12.17(2)	c = 14.87(2)
EDX, WDX		major elements: U	minor elements: K	
References		205		

Copiapite $Fe^{2+}Fe_4^{3+}(SO_4)_6(OH)_2 \cdot 20\ H_2O$

Copiapite forms compact flow films and crusts up to 5 mm thick composed mainly of very fine crystals of sulphur-yellow colour. Some parts show light yellow to grey brown yellow colour. The crusts rim strongly weathered parts of the Geschieber vein composed of quartz, proustite and pyrite. Copiapite occurs in paragenesis with whitish epsomite, gypsum, light pink and acicular apjohnite, and pink compact chvaleticeite.

Copiapite was also identified in mixture with metavoltine. The mixture forms small, fine-grained, earthy aggregates up to 0.5 mm long which are olive yellow in colour. It is typically deposited on radiating halotrichite aggregates, in other cases on pyrite, in cavities of porous quartz gangue with pyrite and proustite in paragenesis with halotrichite, alunogen and melanterite. The specimens were collected in the Geschieber vein.

Copiapite, in analogy to jarosite, is a common product of decomposition of Fe sulphides (± arsenides). However, the two minerals never occur together in Jáchymov. This situation is caused by different conditions of their crystallisation. Copiapite is more soluble and mobile than jarosite, especially in an acidic environment. For this reason, it tends to accumulate at a longer distance from primary sulphides.

EDX, WDX		major elements: S, Fe	minor elements: Mn, Mg

Copper Cu

Native copper forms arborescent groups associated with parasymplesite and gypsum on wallrock fractures next to the Geister vein [40] and also up to 4 mm long aggregates in vugs of vein quartz in the Geschieber vein. Local precipitation of copper was also observed on old iron pieces, e.g., rails. The absence of carbonates is characteristic for copper formation as a cementation mineral.

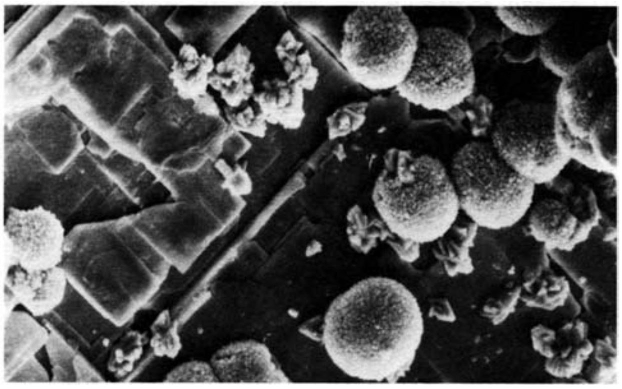
Coquimbite $Fe_2(SO_4)_3 \cdot 9\ H_2O$

Coquimbite (mixed with other sulphates) occurs in earthy to powdery yellow brown aggregates. They are cemented with fragments of quartz and gypsum as a deposit on fractures of wall rock near weathered pyrite-arsenopyrite veins. Only a single sample with coquimbite was analysed in a mixture with natrojarosite and gypsum.

Corkite $PbFe_3(PO_4)(SO_4)(OH)_6$

Corkite has been found as minute spheres only several tens of microns in diameter, sitting on brown tabular pseudomorphs composed of amorphous iron hydroxides, probably after autunite. The pseudomorphs used to be designated by an incorrect name *bassetite*. The corkite spheres have a glassy lustre and yellow brown colour.

EDX, WDX		major elements: Pb, Fe, P	minor elements: S



Corkite spheres deposited on amorphous pseudomorphs of Fe-oxi-hydroxides after meta-autunite. Magnification 600

Cornwallite $Cu_5(AsO_4)(OH)_4 \cdot H_2O$

It was identified in a single specimen from the Geister vein. Cornwallite forms minor isolated spheres and botryoidal crusts coating the wallrock as a single secondary mineral. Its colour is strong green, the lustre is glassy.

Coronadite $Pb(Mn^{4+}, Mn^{2+})_8O_{16}$

In several samples examined, coronadite was identified in a mixture with pyrolusite or cryptomelane, i.e., either in crystalline pyrolusite aggregates or in compact crusts with cryptomelane. It occurs on porous quartz gangue at the Mariánská locality.

Cryptomelane $K(Mn^{4+}, Mn^{2+})_8O_{16}$

Cryptomelane forms grape-shaped to botryoidal crusts of grey black colour, with a brown shade. The crusts are matte and show relatively high to moderate hardness. They are compact to fine-grained on fracture surface. Cryptomelane is intergrown with coronadite and it is younger than pyrolusite. It occurs on porous quartz gangue at the Mariánská locality.

Cuprite Cu_2O

Cuprite was found in the rim of a cake 5 cm in diameter of cementation copper, deposited on wall rock, probably under a (man-made) iron object. The rim, brown black in colour, is powdery, composed of a mixture of cuprite and native copper. It formed by oxidation of cementation copper.

Cuprosklodowskite $(H_3O)_2Cu(UO_2)_2(SiO_4)_2 . 2 H_2O$

Although this mineral was defined and named in 1933 by Vaes [198] on specimens from the Shaba Province, Zaire, mineral corresponding to cuprosklodowskite was mentioned and partly analysed by John [199] in 1845, using specimens from Jáchymov. John designated this mineral *Kieselkupfer-Uranoxyd.*

Nováček [35] described cuprosklodowskite as very minute acicular crystals in radiating groups with a silky lustre, forming light green crusts and thin coatings on limonitized and brittle vein material. The green colour in the centres of aggregates changes to green yellow towards terminations. Slightly flattened crystals are 5 to 10 µm wide and up to 50 µm long. Nováček gave two chemical analyses, the first one designated as uranochalcite, the second as *voglianite*: CuO 8.99 (9.07), PbO trace (0.18), UO_3 64.96 (64.65), SiO_2 13.40 (13.90)? H_2O 11.72 (11.88), Total 99.07 (99.68) wt. %.

Lattice par. [Å, °]	1	a = 9.21	b = 6.63	c = 7.06
		α = 90.0	β = 110.0	γ = 108.5
EDX, WDX		major elements: U, Si, Cu	minor elements:	
Therm. analysis [°C, wt. %]	2	20-145 8.09 (4.05 H_2O), 145-228 2.31 (1.13 H_2O), 228-844 5.20 (1.80 H_2O), 844-1000 (0.5 O_2)		
Density [g.cm^{-3}]	1	D_m = 3.50, D_x=3.83 for Z=1		
References		35, 158, 159, 198, 199		

1 - Cuprosklodowskite, Jáchymov. Bariand [158]
2 - Cuprosklodowskite, Jáchymov. Čejka et al. [7] (NM 26534)

Nováček gave the following values of the indices of refraction: n_α = 1.654, n_β = 1.664, n_γ = 1.664, 2V = 15°. Cuprosklodowskite is pleochroic, X = a (nearly colourless), Y = c and Z = b (yellow green) [36].

According to Kašpar [106], secondary uranium silicates form only in the stage of sulphates, i.e., after decomposition of sulphides. Sufficient time, necessary for decomposition of sulphides, was represented in Jáchymov by the pause between silver mining (since the 16th century) and uranium mining (since about 1850). This is the reason why this mineral was encountered only in the past and in shallow workings.

Curienite $Pb(UO_2)_2V_2O_8. 5H_2O$

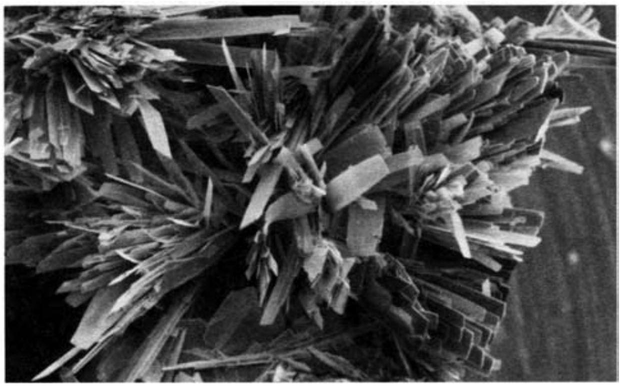
The typical mode of occurrence is in abundant coatings and as fill of strongly silicified and hematitized gangue. It is yellow to yellow brown. Compact soft aggregates of yellow brown colour, showing a waxy lustre and yellow streak, are rare.

Curienite was identified in paragenesis with mottramite, metatorbernite and zeunerite in vanadium-enriched parts of the Geister vein.

Lattice par. [Å]		a = 10.41(1)	b = 8.464(8)	c = 16.25(2)
EDX, WDX		major elements: U, Pb, V	minor elements: Si	
References		256		

Devilline $CaCu_4(SO_4)_2(OH)_6 . 3 H_2O$

Devilline forms aggregates of randomly oriented, flat acicular crystals with a characteristic silky lustre on cleavage planes. The colour is light blue. Devilline is accompanied by brochantite, langite, and posnjakite coating tennantite with pyrite in vein quartz.



Radiating aggregates of lath-shaped crystals of devilline. Magnification 80

Lattice par. [Å, °]		a = 20.82(1)	b= 6.113(6)	c = 22.18(2)
			β=102.55(1)	
EDX, WDX		major elements: Cu, Ca, S	minor elements:	
References		233		

Dewindtite $Pb_3(UO_2)_6H_2(PO_4)_4O_4 . 12H_2O$

Dewindtite occurs as compact coatings of yellow to yellow orange colour. It is usually mixed with other minerals of the paragenesis, i.e., uranophane, tyuyamunite, meta-autunite, torbernite, and sklodowskite ?, on weathered material of uraninite vein in the Eliáš mine.

In a rare occurrence in the Geister vein, dewindtite forms minute, indistinct tabular yellow crystals deposited on fine-grained yellow core in paragenesis with an orange mixture of zippeite and "pseudo-zippeite (Mg)".

Lattice par. [Å]	1	a= 15.817(8)	b=17.286(6)	c= 13.667(5)
	2	a= 15.79(3)	b= 17.32(1)	c= 13.62(1)
EDX, WDX		major elements: U, Pb, P	minor elements:	
References		276		

1 - sample: 25Jb, Albrecht vein, Rovnost I. mine
2 - sample: BM-5865a, Eliáš mine

Diadochite $Fe_2(PO_4)(SO_4)(OH) . 5 H_2O$

Diadochite was described from old adits on the Geister vein as brown red translucent coating on skutterudite, gypsum, pateraite, and pyrite [118]. This mineral was not confirmed by the present study.

Duftite PbCu(AsO$_4$)(OH)

Duftite forms minor spheres on limonite-coated open fractures in vein quartz. The spheres tend to cluster into continuous crust up to 0.5 mm thick, eventually passing in minute three-dimensional curtains. The colour is variable from light yellow green to black green. In cross section, the crusts are homogeneous, with a uniform composition. No compositional difference was found for variously coloured portions.

Duftite from Jáchymov is a solid solution transitional between mottramite and duftite. In view of difference in the crystal structure of duftite and mottramite, indexing of the powder diffraction pattern is not equivocal, see mottramite [156, 157]. It is also noted that some published diffraction data and newly measured patterns for the Jáchymov duftite show inconsistencies for some diffraction.

EDX, WDX		major elements: Pb, Cu, As	minor elements: V, P, Ca
References		156, 157	

Epsomite MgSO$_4$. 7 H$_2$O

No pure end-member epsomite has been found and the samples studied correspond to solid solutions of Mg, Fe, Ni heptahydrate sulphate, showing prevalence of Mg relative the other cations. The composition of such solid solutions changes from place to place.

The variation in composition can be also estimated visually from colour variation. Highly magnesian members are light coloured to transparent, relatively intermediate members are pale yellow to dark grey greenish-blue. In case of increased Fe the colour depends on the content of other complex hydro-sulphates and grades to red brown. Epsomite with other sulphates forms massive crystalline crusts and hollow stalactites, which are internally coated by minute imperfectly shaped crystals.

In addition to the assemblage with other Mg. Fe, and Ni sulphates, i.e., hexahydrite, melanterite, rozenite, szomolnokite, rhomboclase, morenosite, and nickel-hexahydrite, epsomite was found with arsenolite, gypsum, and further unidentified phases with the following qualitative composition: Mg-AsO$_4$-SO$_4$, Mn-SO$_4$-AsO$_4$, and Mg-Ni-SO$_4$.

Epsomite forms in places where mining encountered pyrite-marcasite or arsenopyrite veins. Owing to action of acid water in the mine, catalytic reactions take place resulting in decomposition of the sulphide vein in relatively short time; sulphuric acid is the catalyzer. Besides Mg sulphates, iron sulphates, dominantly melanterite, are also formed. However, introduction of Mg derived from carbonates of weathered veins is an important condition. The role of mineral waters (encountered in the mines) in introduction of Mg is at present uncertain.

Epsomite stability exceeds that of melanterite; it is dependent not only on concentration and composition of supplied solutions and pH (lower values are stabilising), but mainly on other local conditions in the mine, i.e., temperature, humidity, and air circulation. In case that the latter conditions are unfavourable (relatively high temperatures, intense air circulation, dry air), these phases undergo dehydration and recrystallisation.

Erythrite Co$_3$(AsO$_4$)$_2$. 8 H$_2$O

It occurs in radiating aggregates up to 3 mm long. They are dark violet red. In one of few erythrite specimens verified it formed as crust coating radiating spherical Fe-erythrite, which is reddish orange in colour. Erythrite is mainly coating weathered skutterudite.

In numerous papers, erythrite is erroneously mentioned as a common mineral in Jáchymov. Köttigite coloured pink by Co substitution was often taken for erythrite. Cobalt-bearing phases of the erythrite group are younger, as indicated by the increasing intensity of pink colour in outer parts of radiating aggregates, and by other aggregates which are dark green in the centre, grading to pink towards periphery. The pink arsenates are increasing in abundance in specimens containing native bismuth. The material studied comes from the Geschieber vein.

EDX, WDX		major elements: Co, As	minor elements: Ni, Fe
References		59	

Eulytite Bi$_4$(SiO$_4$)$_3$

Eulytite forms dominantly half-spheroidal to spheroidal radiating aggregates up to 1 cm large, translucent to opaque, or small spheres and individual dodecahedral crystals up to 2 mm long. It is usually yellow grading to brown yellow or grey yellow. Brown and nearly black colour was also recorded. It has a conchoidal fracture and adamantine lustre.

The quantitative chemical analyses done by P. Černý, GPUP, (using Microscan M-5, Cambridge, 1975): Bi$_2$O$_3$ 83.16, SiO$_2$ 16.48, PbO 1.39, ZnO 0.13, FeO 0:08, CuO 0.06, Total 101.30 wt. % results in the following formula based on 12 oxygen atoms:

$$(Bi_{4.00}Pb_{0.07}Zn_{0.02}Cu_{0.01}Fe_{0.01})Si_{3.01}O_{12}$$

Another analysis (average of four analyses) done by V. Šrein using JEOL JXA-50 analyser was published by Sejkora [193]. It results in the following formula:

$$Bi_{4.00}[(SiO_4)_{2.96}(AsO_4)_{0.03}]_{2.99}$$

Eulytite was also studied as a 2 cm thick vein, partly altered to a massive grey to grey brown mixture of bismutite and kettnerite. These massive aggregates, as well as eulytite, are coated by powdery, strong yellow bismutite. The associated minerals include native bismuth, beyerite, bismutite, kettnerite, namibite, and pucherite.

Lattice par. [Å, °]		a = 10.298(4)		
	1	a = 10.3146(6)		
EDX, WDX		major elements: Bi, Si, Pb		minor elements: Zn, Cu, Fe
IR [cm^{-1}]		495,545,920 and 1050		
Density [$g.cm^{-3}$]		D_m = 6.523 (determined by pycnometer), D_x = 6.757		
References		27, 68, 50, 101, 102, 193		

1 - eulytite, Jáchymov. Sejkora [193]

Ferrohexahydrite $FeSO_4 . 6 H_2O$

It was identified in isostructural mixtures of Fe-Mg sulphates of the hexahydrite group. Ferrohexahydrite forms coatings and crusts with very fine crystalline texture and glassy, transparent to translucent crusts of light green colour. The mineral paragenesis includes hexahydrite, epsomite, gypsum and unidentified Fe (Mg) sulphates, sampled in the Geschieber vein.

EDX, WDX		major elements: Fe, S	minor elements: Mg, Ni

Fluckite $CaMn(HAsO_4)_2 . 2 H_2O$

The mineral forms isolated spheres up to 3 mm in diameter with a characteristic rugged surface, corresponding to high pyramidal terminations of radiating crystals. Fluckite is always pale pink with a violet shade. It occurs on vein carbonates strongly corroded by products released during weathering of native arsenic. Arsenic is rimmed by an amorphous yellow green fractured material, passing towards arsenic to weakly coherent porous aggregates of pink carbonate with fluckite spheres. It is accompanied by additional arsenates of Ca, Mg, and Mn, i.e., picropharmacolite, rösslerite, sainfeldite and sometimes villyaellenite.

Lattice par. [Å, °]		a = 8.48(3)	b = 7.61(1)	c = 6.940(9)
		α = 82.05(2)	β = 98.70(3)	γ = 96.21(2)
EDX, WDX		major elements: As, Ca, Mn		minor elements:

A detail of terminated crystal of fluckite. Magnification 150

Carbonate gangue of buff pink colour in a place carrying fluckite has the following composition: CaO 29.29, MgO 19.48, FeO 2.94, MnO 1.42, CO_2 45.35, insoluble residue 0.99 wt. %. This shows that the reaction of the weathering products of native arsenic with the dolomitic carbonate results in separation of manganese, which enters the calcium and manganese arsenate - fluckite.

Geminite $Cu_2(HAsO_4)_2 . 2 H_2O$

Geminite ranks among very rare secondary copper minerals in Jáchymov. Groups of tabular crystals are coating arsenolite, which covers native arsenic. Geminite is grey green with a glassy lustre. It occurs as a single mineral in the respective paragenetic stage.

Geminite was synthesised via the reaction of As_2O_3 with malachite [137]. In Jáchymov, geminite probably formed through reactions of weathered arsenic or arsenolite with Cu-bearing solutions.

Aggregate of tabular crystals of geminite. Magnification 300

Lattice par. [Å, °]		a = 6.402(7)	b = 8.113(9)	c = 15.78(2)
		α = 92.23(2)	β = 94.13(2)	γ = 95.13(1)
EDX, WDX		major elements: Cu, As		minor elements:
References		137		

Goethite $FeO(OH)$

Goethite forms up to 2 mm thick coating in open fractures and vugs. It formed by crystallisation from amorphous oxides-hydroxides of iron resulting from weathering of pyrite and marcasite. Goethite is not as abundant as could be expected, mainly owing to very low pH of solutions, which favours iron leaching and removal.

Goslarite $ZnSO_4 . 7 H_2O$

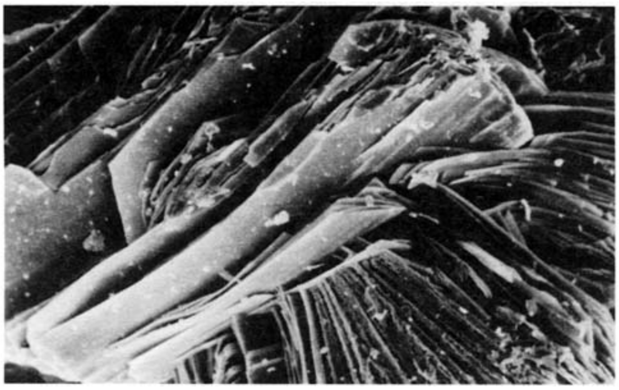
Goslarite was listed by Kratochvíl [118] without any specific information. It was not confirmed by the present study.

Goyazite $SrAl_3(PO_4)_2(OH)_5 . H_2O$

Goyazite was identified as an intermediate member of the goyazite-florencite-(Nd) series. It forms minute equant crystals 0.1 mm in diameter. The crystals are nontransparent, brown red in colour, with a weak glassy lustre. Goyazite was found on fracture of altered wall rock with arsenopyrite. It occurs as overgrowth on black equant anatase crystals. Specimens of goyazite originate from the vein No. 3.

Guerinite $Ca_5(AsO_4)_2(AsO_3OH)_2 . 9 H_2O$

Guerinite is a rare secondary mineral in Jáchymov. It occurs in isolated radiating groups of tabular crystals with a glassy lustre and grey white colour. They formed in proximity of or directly on a glassy coating of bluish white aragonite. Carbonate specimens with minor skutterudite carrying guerinite originate from the Kryštof vein.



Aggregate of very thin tabular crystals of guerinite. Magnification 150

Lattice par. [Å, °]		a = 17.71(4)	b = 6.72(1)	c = 23.53(4)
			β = 90.38(3)	
EDX, WDX		major elements: Ca, As	minor elements:	
References		107, 129, 130		

Gunningite-Szomolnokite $(Zn,Mn)SO_4 . H_2O$, $FeSO_4 . H_2O$

A member of this solid solution series was identified in a single specimen (No. NM 17259) from the collection of the National Museum in Prague. The original designation is morenosite.

It forms grey white powdery efflorescence and coatings on weathered pyrite-marcasite vein material. The analyses of separated material indicate a mixture of rhomboclase and an intermediate member of the gunningite-szomolnikite group.

Szomolnokite forms as a final member of a series of gradual dehydration products derived from melanterite and rozenite. The reaction of rozenite to szomolnokite is reversible, though at a slower rate compared to the alteration of melanterite to rozenite. The presence of szomolnokite indicates that the original melanterite was free of copper, since siderotile would form from a Cu-bearing melanterite [292].

Gypsum $CaSO_4 . 2 H_2O$

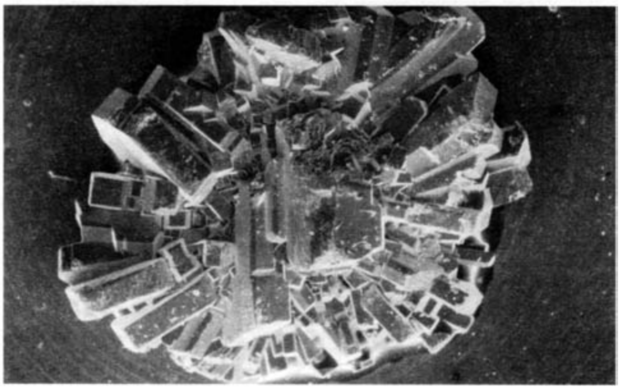
Gypsum is the most common secondary mineral in Jáchymov. The typical mode of occurrence is in small crystals to 5 mm and fine-grained crystalline crusts. Gypsum is pure white, yellowish, yellow brown and rarely pink.

Haidingerite $Ca_2(HAsO_4)_2 . 2H_2O$

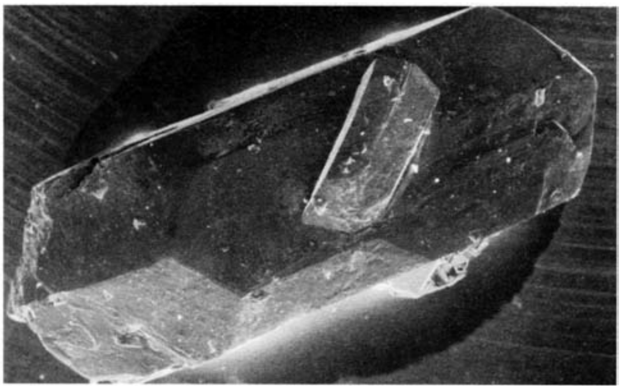
The mineral was first studied by Haidinger [225], who described its crystal morphology in 1825, as one of a new mineral from Jáchymov. In the same year, Turner [226] provided a chemical analysis and in 1827 suggested the name haidingerite for this mineral, to honour the outstanding Austrian mineralogist Wilhelm Haidinger.

Lattice par. [Å]		a = 6.946(3)	b = 16.16(2)	c = 7.955(4)
Density [g.cm^{-3}]	1	2.848		
Hardness	1	2 - 2.5		
EDX, WDX		major elements: Ca, As	minor elements:	
References		27, 70, 107, 130		

1 - haidingerite, Jáchymov. Haidinger [225]



A fan-shaped aggregate of haidingerite crystals. Magnification 25



A single orthorhombic crystal of haidingerite. Magnification 70

Turner [226] obtained the following composition: CaO 28.4, As_2O_5 58.1, H_2O 14.3, Total 100.8 wt. %. The crystal morphology of haidingerite was later studied by Tschermak [224].

Haidingerite forms radiating spherical aggregates up to 5 mm long composed of shortly prismatic crystals. The surface of the spheres shows a distinct faceting. It also forms flat radiating aggregates with a small central sphere of the same species. Isolated single crystals to 1 mm long are relatively rare. It is colourless, transparent with a rather high glassy lustre, which makes it distinct from some similar arsenates. Haidingerite occurs with other Ca-Mg arsenates such as rösslerite, pharmacolite, and picropharmacolite.

The mineral is optically positive, n_α= 1.590, n_β = 1.602, n_γ = 1.638, $2V_{meas.}$= 58° [162].

Halotrichite $FeAl_2(SO_4)_4 . 22 H_2O$

Halotrichite forms clusters of thin acicular crystals of a glassy lustre. The crystals are white, greenish (coloured by melanterite) or bluish (coloured by a Mo-phase). The intensity of blue colour tends to vary depending on variation in temperature and humidity of the environment. This behaviour is typical of some Mo-phases. Halotrichite occurs in mixture with alunogen in porous quartz gangue as deposited on pyrite and minute proustite crystals. It is associated with other secondary minerals showing the following succession: gypsum, halotrichite + alunogen - melanterite + Mo-phase - metavoltine + copiapite. The specimens were collected in the Geschieber vein.

Hematite Fe_2O_3

Finely disseminated hematite is common as intergranular material imparting a characteristic colour mainly to dolomite veins. Because these veins are often carrying primary uraninite, it is possible that iron for hematite was released from the primary minerals by radiolysis. However, a correlation between uranium abundance and hematite coloration is not supporting this mode of hematite formation. Uraninite may occasionally contact hematite-free carbonates.

At least some part of hematite probably formed by oxidation of Fe^{2+} ions during reduction of the uranyl ion $(UO_2)^{2+}$ to insoluble UO_2 as uraninite was deposited in the veins [106].

Hemimorphite $Zn_4Si_2O_7(OH)_2 . H_2O$

Hemimorphite was described as crystals groups, small transparent hemi-spherical or fan-shaped aggregates, and as fibrous/prismatic textured pieces. It occurred on the Geister vein, the Eliáš mine, in a vug coated with sphalerite crystals [118].

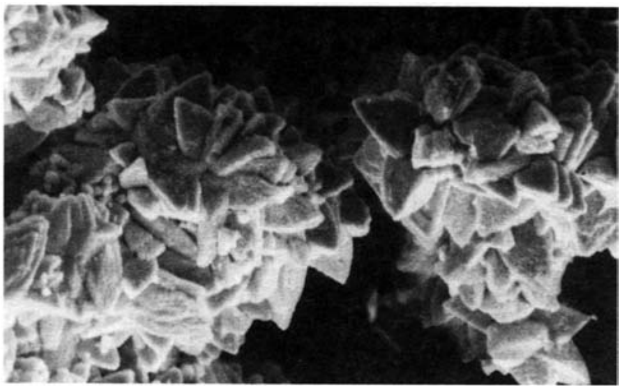
EDX, WDX		major elements: Zn, Si	minor elements: S
References		118	

Hexahydrite $MgSO_4 . 6 H_2O$

It was identified in isostructural mixtures of hexa- and hepta-sulphates of Mg, Ni, (and Fe). These minerals constitute coatings and crusts with a very fine-grained texture, which are transparent or translucent, glassy crusts, and aggregates of acicular crystals. Hexahydrite was identified in association with nickelhexahydrite, annabergite, gypsum, and closer unidentified Fe-arsenates on the Geschieber vein. See also information on nickelhexahydrite and epsomite.

Hidalgoite $PbAl_3(AsO_4)(SO_4)(OH)_6$

Hidalgoite was found on a single specimen as minor irregular aggregates greenish yellow brown in colour, with a waxy matte surface. They are deposited on coarse, thick tabular crystals of zeunerite-metazeunerite. Mimetite, pyromorphite, and parsonsite accompany hidalgoite. The specimen consisting mainly of vuggy vein quartz was collected on the Geister vein.



Aggregate of hidalgoite crystals. Magnification 600

Lattice par. [Å]		a = 7.099(9)		c = 17.00(2)
EDX, WDX		major elements: Pb,Al,As		minor elements: Fe, (Cu,S,P)

Hörnesite $Mg_3(AsO_4)_2 . 8 H_2O$

Hörnesite occurs in radiating spherical aggregates or crystalline crusts composed of acicular crystals up to 1 mm long. Individual crystals are colourless, transparent or white, with a glassy lustre. It also forms white efflorescence or powdery coating. Chemical composition frequently corresponds to solid solutions of Mg, Zn, Ni, Co, and Fe arsenates of the erythrite group, rather than to pure Mg end member.

Larsen [162] measured the following optical properties on hörnesite from Jáchymov: n_α = 1.563, n_β = 1.571, n_γ = 1.596, 2V = 60°, extinction angle between Z and the direction of elongation = 31°, the mineral is optically positive.

It occurs with other arsenates of Ca and Mg on carbonate vein containing arsenides, which on weathering gave rise to the secondary minerals.

EDX, WDX		major elements: Mg, Ni, As	minor elements: Co
References		98, 117	

Hydronium jarosite $(H_3O)Fe_3(SO_4)_2(OH)_6$

Hydronium jarosite occurs as relatively common powdery to earthy fill of a strong yellow colour in porous parts of the Geschieber vein composed of quartz, proustite and pyrite. It was observed in paragenesis with parasymplesite, annabergite and gypsum.

Hydronium jarosite is a common decomposition product of Fe sulphides (± arsenides). In Jáchymov, it often occurs in proximity of decomposed primary sulphides. This probably reflects instability of rather acidic solutions of Fe sulpho-complexes (in absence or near-absence of alkalis); the complexes were buffered over a short distance by surrounding solutions and precipitated (or recrystallized) as hydronium jarosite.

Lattice par. [Å]		a = 7.323(5)		c = 16.94(3)
EDX, WDX		major elements: S, Fe		minor elements: Ca, Na
References		259		

Hydrozincite $Zn_5(CO_3)_2(OH)_6$

It is coating walls in old mine workings as a white crust with a smooth and lustrous surface. The crusts up to 3 mm thick consist of numerous thin layers, which may show a texture of perpendicular fibres. Hydrozincite may form minor stalactites, up to 2 cm long, which are largely composed of an amorphous material. Owing to local presence of znucalite, some parts of hydrozincite coatings show an intense yellow colour. The mineral formed by decomposition of sphalerite which, although inconspicuous, is relatively abundant in Jáchymov veins.

Hydrozincite-znucalite accumulations formed only in those parts, where marcasite-pyrite or arsenic-arsenide, as well as low pH solutions were absent. Some connections also exist to abundance and composition of carbonates in veins or in wall rocks. Ca-rich carbonates buffer solutions with relatively mobile Zn^{2+} and UO_2^{2+} cations and result in formation of carbonate and hydrogen-carbonate hydro-complexes of Zn and Zn-U, which are unstable at low pH values. The mobility of the complexes is thus diminished and owing to release of CO_2, hydrozincite and znucalite precipitated.

Irhtemite $Ca_4Mg[(AsO_4)_2(AsO_3OH)_2] . 4 H_2O$

Irhtemite occurs in very fine acicular white crystals, typically in radiating aggregates. It is coating carbonate gangue in aggregates extremely similar to those of picropharmacolite. This probably contributed to its late recognition and, in some cases, to possible misidentification for picropharmacolite.

Stability of picropharmacolite is not known and therefore it is difficult to exclude the possibility of irhtemite formation by dehydration of some picropharmacolite specimens in a special condition.

The X-ray powder diffraction pattern of irhtemite (15J) indicates a mixture of irhtemite and an unidentified Ca-Mg arsenate. The table below lists all diffractions observed. We record indexing of some irhtemite diffractions which were not reported in the original description [265].

Lattice par. [Å, °]		a = 16.56(1)	b = 9.539(4)	c= 10.873(5)
			β=97.239(7)	
EDX, WDX		major elements: Ca, As, Mg	minor elements:	
References		265		

Isoclasite $Ca_2(PO_4)(OH) . 2 H_2O$

This mineral was described by Sandberger [212] in 1875 on a specimen from Jáchymov kept in the Würzburg collection. It was described as transparent prismatic crystals up to 4 cm long, with a pearly lustre on cleavage planes. Its hardness is 1, density 2.92 gcm^{-3}. The analysis given by Sandberger [212] is: CaO 49.51, P_2O_5 29.90, H_2O (to 100 °C) 2.06, H_2O (above 100 °C) 18.53, Total 100.00 wt. %. Larsen [162] characterised isoclasite as biaxial, optically positive, with indices of refraction n_α = 1.565, n_β = 1.568, n_γ = 1.580; crystal morphology indicates the monoclinic symmetry.

The direction X//b, the angle Z/c is not large, 2V is moderate. Isoclasite crystals were described by Sanberger [212] as orthorhombic, the angle between prismatic faces measured by contact goniometer was 136°50' and the angle between prism and basal faces 110°.

X-ray powder diffraction pattern of mixture of irhtemite and unnamed Ca-Mg-arsenate.

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
6	12.953				
32	9.485				
9	8.788				
10	7.973				
16	6.873				
100	6.715	6.762	1	1	-1
32	6.466				
12	6.122				
1	5.361	5.393	0	0	2
16	5.137				
6	5.043				
<1	4.822	4.794	2	0	-2
23	4.693				
2	4.392	4.389	1	1	2
13	4.326	4.362	0	2	1
<1	4.115	4.125	2	2	0
30	4.115	4.108	4	0	0
9	3.993				
7	3.804	3.775	3	1	-2
40	3.689				
15	3.594	3.573	0	2	2
6	3.447	3.486	4	0	-2
18	3.362	3.375	1	1	-3
49	3.246				
45	3.220	3.222	1	1	3
7	3.098	3.107	5	1	0
5	3.060	3.069	4	2	-1
5	3.018	3.018	1	3	-1
17	2.983	2.980	1	3	1
3	2.893	2.895	5	1	1
22	2.857	2.871	0	2	3
18	2.812	2.815	4	2	-2
10	2.770				
5	2.711	2.706	3	3	-1
3	2.659	2.663	2	0	-4
1	2.617	2.612	1	1	-4
10	2.589	2.591	4	2	2
4	2.4777	2.4729	4	2	-3
3	2.4038	2.3971	4	0	-4
5	2.3465	2.3474	0	2	4
8	2.2402	2.2421	3	1	4
5	2.2187	2.2244	2	4	1
3	2.1835	2.1810	0	4	2
4	2.1176	2.1202	1	1	-5
4	2.0850	2.0893	6	2	-3
5	2.0409	2.0412	7	1	-3
4	2.0110	2.0099	5	3	-3
7	1.8981	1.8930	8	2	-1
<1	1.8981				
5	1.8056	1.8053	9	1	-1
3	1.7554	1.7561	8	2	-3
6	1.7307	1.7305	3	5	-2
8	1.7129	1.7117	2	0	6
12	1.6113	1.6111	2	2	6
2	1.5908	1.5916	9	3	-1
4	1.5581	1.5577	6	4	3
3	1.5371	1.5369	5	5	-3
2	1.5247	1.5250	0	6	2
2	1.4710	1.4713	9	1	-5

Admitting that the measurement was rather inaccurate, the crystals could be hexagonal, probably of apatite, which is possible with the analysis given above.

However, the indices of refraction are by 0.1 lower than for apatite. Doubts concerning validity of data on isoclasite are supported by absence of any additional description or find of isoclasite anywhere.

Sandberger [212] noted that some isoclasite crystals are partly altered to a white matte phase with the composition CaO 1.00, MgO 17.30, Na_2O 9.80, P_2O_5 34.00, Fe_2O_3 (+ Al_2O_3) 0.36, insoluble residue 0.18, H_2O (to 100 °C) 24.26, H_2O (above 100 °C) 9.22, Total 96.12 wt. %.

Larsen described isoclasite as white, cotton-like fibres composed of minute prisms. This description is different from that given by Sandberger.

Isoclasite was described [212] in paragenesis with a reddish dolomite vein in hornfels.

Jáchymovite $(UO_2)(SO_4)(OH)_{14} . 13\ H_2O$

The mineral name jáchymovite was used in 1935 by Nováček [35] for cuprosklodowskite. In the publication [35] Nováček pointed this synonymity and the name jáchymovite was abandoned.

A new mineral identified in 1979 [175] on a single specimen from Jáchymov and later described by Čejka et al. [18] was named jáchymovite. The type specimen is in the collection of the National Museum in Prague, No. NM 68905.

All the data on jáchymovite are given following Čejka et al. [18]. Jáchymovite forms rich, up to 5 mm thick microcrystalline aggregates and earthy crusts 3 by 5 cm in size, accompanied by small prismatic gypsum crystals, on weathered vein material. The individual jáchymovite crystal are up to 0.1 mm long, translucent; they have a yellowish colour, glassy lustre, and light yellow colour of powder. Cleavage on (010) is very good. Luminescence is moderate, with yellow colour. Jáchymovite occurs with gypsum, uranopilite, and uraninite.

Similar to other sulphates of uranium, jáchymovite forms in small amounts in oxidation zone in presence of sulphides of heavy metals and uraninite. Sulphuric acid forms in the course of the hydration-oxidation process, which results in complex ions with uranyl cations. Although these ions are not as stable as the uranyl-carbonate ions [173], they significantly increase solubility of uranium and support its migration. Jáchymovite and other uranyl-sulphates form by a quick evaporation of such solutions, which carried only small amounts of other cations.

Lattice par. [Å, °]		a= 18.553(8)	b= 9.276(2)	c= 13.532(2)
			β=125.56(2)	
Density [$g.cm^{-3}$]		D_x = 4.79 for Z = 2		
IR [cm^{-1}]		582,622,860,880,902,932,1071,1120, 1145,1175,1590,1620,1670,3200,3445		
Therm. analysis [°C, wt. %]		20-97 3.26 (5 H_2O), 97-145 3.53 (5 H_2O), 145-576 6.53 (10 H_2O), 576-884 4.05 (1 SO_3 + 1.32 O_2)		
References		all data after [18] 18, 35, 58, 173, 175		

X-ray powder data of jáchymovite result in a monoclinic cell with the space group $P2_1/a$; unit cell dimensions are given in the table above. The mineral is biaxial, optically negative, with the following indices of refraction: $n_\alpha = 1.715(2)$, $n_\beta = 1.718(2)$, $n_\gamma = 1.720(2)$, $2V_{calc.} = 78°$. The quantitative chemical analysis gave: UO_3 84.20, SO_3 2.79, H_2O 13.32, Total 100.31 wt. %, corresponding to the formula:

$$(UO_2)(SO_4)(OH)_{14} . 13\ H_2O$$

Jarosite $KFe_3(SO_4)_2(OH)_6$

Jarosite was described by Ulrich [194] as coating on mine walls with pyrite affected by weathering. Jarosite was considered without additional data for natrojarosite and hydronium - jarosite.

Johannite $Cu[(UO_2)_2(SO_4)_2(OH)_2] . 8\ H_2O$

Johannite was found in Jáchymov for the first time in 1819 on the vein Geister and in 1850 on the veins Fluther and Fiedler. In both cases, the occurrence was in old re-opened adits. Johannite occurred on pieces of weathered uraninite ore with gypsum, uranopilite, and zippeite. Johannite was first described as a new mineral from Jáchymov in 1828 by John [165] under the name *Uranvitriol*. In the year 1830 Haidinger named this mineral johannite [26] to honour the Austrian archduke and founder of the museum in Styria in Graz - Johann Baptist Josef Fabian Sebastian (1782-1859) [161].

Lattice par. [Å, °]	1	a=16.509(4)	b=17.871(4)	c = 6.812(2)
		α = 91.14(1)	β = 90.48(1)	γ= 110.66(1)
	4	a = 8.908(2)	b= 9.502(2)	c = 6.814(2)
		α=109.89(1)	β=112.01(1)	γ= 100.39(1)
IR [cm^{-1}]	2	250,384,426,619,790,821,912,935,1035, 1093,1137,1628,1657,3220,3525,3598		
Therm. analysis [°C, wt. %]	2	60-100 7.34 (H_2O), 100-145 7.02 (H_2O), 145-235 2.76 (H_2O), 235-390 2.69 (H_2O), 390-550 0.05 (H_2O), 550-750 13.79 (SO_3), 750-810 0.86 (SO_3), further partial disintegration of the uranates formed and oxygen release. endothermic reaction: 135,165,215,760, exothermic reaction: 370, 495		
Density [$g.cm^{-3}$]	3	D_m = 3.32 (average of 5 measurements, Berman's method)		
	5	D_x = 3.27		
References		11, 26, 28, 41, 59, 161, 164, 165, 166, 167, 168, 169, 189, 201		

1 - johannite, Jáchymov - Mereiter, [166]
2 - johannite, Jáchymov - Čejka et al., [11]
3 - johannite, Jáchymov - Hurlbut, [168]
4 - johannite, Jáchymov - Čejka et al., [201]
5 - johannite, Jáchymov - [164]

Following Haidinger [26], johannite has hardness 2 to 2.5 and a weak sour, rather than astringent, taste on tongue. It is weakly soluble in cold water. Ježek [189] described its crystal morphology as monoclinic but the optics is of a triclinic mineral.

Johannite occurs most frequently on vein fractures in exploited parts of the Eliáš mine. It forms as a recent to sub-recent mineral, in less than 15 years. Johannite crystallised from acid sulphate solutions enriched in Cu and U in oxidation zone of uranium-bearing vein material with pyrite, chalcopyrite and rarely bornite, in absence of arsenides and carbonates.

Johannite crystals with acicular habit are up to 2 mm long and are grouped in radiating aggregates. Its colour is bright apple green to emerald green. It has a strong glassy lustre, it is translucent to transparent, brittle, with a pale green colour of powder. Johannite does not fluoresce in ultraviolet light. New optical data for johannite [169]: $n_\alpha = 1.572$, $n_\beta = 1.595$, $n_\gamma = 1.614$, 2V = 90°, with strong pleochroism and dispersion. The extinction angle between Y and the direction of elongation is 5-8° [41].

Nováček considered the original analysis by Lindacker [59] as erroneous and he performed a new analysis: CuO 8.07, UO_3 61.34, SO_3 16.59, H_2O 13.84, Total 99.84 wt. %, corresponding to formula:

$$Cu[(UO_2)_2(SO_4)_2(OH)_2] \cdot 6\,H_2O$$

On the basis of single crystal X-ray measurement of johannite from Jáchymov [166], thermogravimetric study [167], and calculation of compatibility using the Gladstone-Dale relationship [166], the following formula was proposed [166]:

$$Cu[(UO_2)_2(SO_4)_2(OH)_2] \cdot 8\,H_2O$$

Hurlbut [168] suggested from single crystal X-ray study a multiple face-centered unit cells. Mereiter [166] proposed a primitive cell (see table above). The paper [11] gives thermogravimetric analysis and infra-red spectra (concise information in table above), and accurate X-ray powder diffraction data.

Johannite was recorded in assemblage with gypsum, uranopilite, zippeite, and exceptionally with schröckingerite. Several cases of intergrowth with a new phase "pseudo-johannite" were observed.

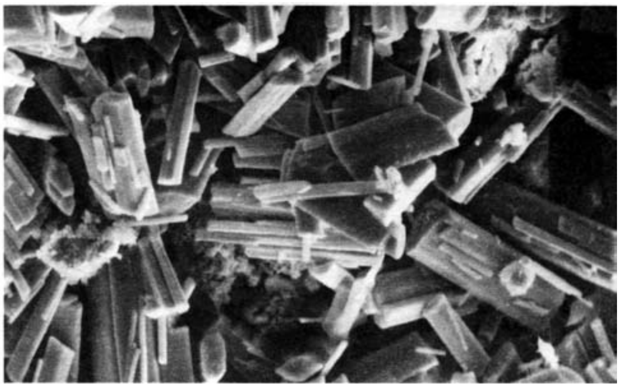
Kaatialaite $Fe[AsO_2(OH)_2]_3 \cdot 5.25\,H_2O$

It was found as abundant white or greenish weakly coherent or powdery fill of vugs in native arsenic and as relatively compact aggregates of greenish colour.

Lattice par. [Å, °]		a=15.3377(8)	b=19.8051(8)	c =4.7520(3)
			β=91.898(3)	
EDX, WDX		major elements: Fe, As	minor elements: Ca, K	
IR [cm^{-1}]		236,318,419,475,600,665,748,781,855, 1150,11981342,1632,2318,2420,2970, 3390, 3500		
Therm. analysis [°C, wt. %]		20-145 17.89 %, 145-370 8.13 %, 370-610 3.25% endothermic reaction: 159, 201, 252, 783, 884, exothermic reaction: 612, 675, 816		
Density [g.cm^{-3}]		D_m = 3.32 (average of 5 measurements, Berman's method), D_x = 3.27 [164]		
References		44, 64, 177, 214, 261		

Kaatialaite aggregates are composed of acicular crystals from several µm up to 100 µm long. Fine-grained aggregates have a silky lustre, coarser aggregates a glassy lustre. It is often accompanied by scorodite, arsenolite, and claudetite. Kaatialaite aggregates contain some sulphuric acid, which was instrumental in its formation and stabilisation. The specimens are from the Geschieber vein.

Kaatialaite from Jáchymov has $n_\alpha = 1.579(2)$, $n_\beta \approx n_\alpha$, $n_\gamma = 1.638$. The chemical analysis gave H_2O 24.8 wt. %.



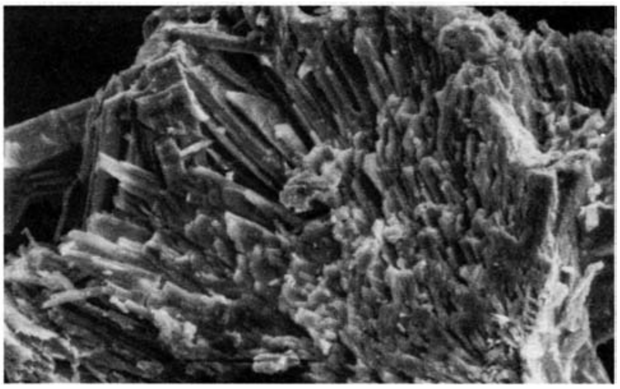
Aggregate of a little elongated crystals of kaatialaite. Magnification 400

Kahlerite $Fe(UO_2)_2(AsO_4)_2 \cdot 10\text{-}12\,H_2O$

Kahlerite occurs as soft coating composed of light yellow platy crystals, locally with a green shade. It shows a greasy lustre and does not fluoresce in UV light. Kahlerite is a component of symmetrically zoned polymineral coatings with the following full sequence (from centre outwards): kahlerite - zeunerite - tyuyamunite - phase "Ca-(VO)-AsO_4", with pink köttigite, agardite, lavendulan and strashimirite further on sides. The coatings are deposited on quartz vein with pyrite, uraninite and tennantite. The source of vanadium is unknown. The specimen studied was collected in the Geister vein.

Kamotoite-(Y) $Y_2(UO_2)_4(CO_3)_3O_4 \cdot 14.5\,H_2O$

Kamotoite-(Y) is identified as minute, flat radiating aggregates composed of flattened needles. The strong yellow aggregates are 0.5 mm in maximum diameter.



Radiating aggregate of kamotoite-(Y) crystals. Magnification 500

Kamotoite-(Y) has a glassy lustre and it does not fluoresce in UV light. It occurs in a minor fracture cutting thin quartz veinlet in muscovite pegmatite. No other radioactive mineral occurs in the veinlet.

Kaňkite $FeAsO_4 . 3.5\ H_2O$

Two types of kaňkite were identified. It forms minute spheres with a matte surface, occurring in cavities of porous quartz. It also accompanies or covers small crystals of pyrite or proustite. The material was collected in the Geschieber vein.

The second type is identical in appearance with the type locality at Kaňk near Kutná Hora. It occurs as grape-like aggregates of a bright light green colour on specimens with altered arsenopyrite, in association with green grey scorodite. The original arsenopyrite is replaced in part by grey powdery sulphur.

Lattice par. [Å, °]		a=18.795(7)	b=17.487(4)	c = 7.635(2)
			β=92.749(3)	
EDX, WDX		major elements: Fe, As		minor elements:
References		261		

Kasolite $Pb(UO_2)SiO_4 . H_2O$

Kasolite occurs in earthy microcrystalline aggregates up to 5 mm long, which may represent pseudomorphs or fill of vugs in vein quartz. Colour of the aggregates is yellow, grading to brown towards margins. It does not fluoresce in ultraviolet light. The specimen identified is from the Geister vein.

Lattice par. [Å, °]		a=13.307(9)	b=7.022(7)	c =6.730(6)
			β=104.90(1)	
EDX, WDX		major elements: U,Pb,Si		minor elements: Ca
References		7, 83		

Kasolite was also identified in the course of revision of old specimens in the collection of the National Museum in Prague. Specimen No. NM 17365 (donated by V. Wraný in 1902) was designated as *bismutosferit*. It consists of weathered uraninite with orange crusts, representing mixture of vandendriesscheite with compreignacite, with powdery coatings of beige kasolite-uranophane mixture.

Kermesite Sb_2S_2O

Kermesite was described as fan-shaped aggregates of acicular crystals, cherry-red or brown red in colour. It occurred in a vug with sphalerite, quartz, and antimony ochre on the Geister vein, at contact of porphyry with schist of blue colour [59]. Kermesite was mentioned without further data already by Glückselig [247].

Lattice par. [Å, °]		a= 8.158(2)	b=10.718(2)	c= 5.7889(9)
		α=102.800(3)	β=110.547(3)	γ=101.022(3)
References		59, 247		

Kettnerite $CaBi(CO_3)OF$

Kettnerite was identified in a mixture with eulytite, bismutite, and beyerite, constituting a massive 2 cm thick fill in quartz veinlet. The mixture has brown to brown-grey colour. It is probable that the three carbonates of bismuth form a pseudomorph after original veinlet composed of black eulytite with minute grains of native bismuth.

Lattice par. [Å]		a = 3.806(3)		c = 13.54(2)
References		236		

Koritnigite $Zn[(H_2O)AsO_3(OH)]$

Koritnigite forms spheroidal radiating aggregates of minute crystals, which are up to 1 mm long. In the aggregates, the crystals are only 1 to 10 μm long. Due to a low Co content, the colour is mainly red violet to strawberry pink and violet red in the coarser aggregates.

Schmetzer [43] published a partial analysis: As_2O_5 53.66 (54.67), CoO 3.88, (4.54), NiO 0.52 (2.44), CuO 0.08 (0.08), ZnO 29.06 (25.83), FeO 0.03 (0.05) wt. %. Koritnigite forms by reaction of weathering arsenides with sphalerite and it is not confined exclusively on veins with carbonates. The specimens are from the Geschieber vein.

Lattice par. [Å, °]		a = 7.948	b = 15.829	c = 6.668
		α = 90.86	β = 96.56	γ = 90.05
References		43		

Köttigite $Zn_3(AsO_4)_2 . 8\ H_2O$

At least three genetic types of köttigite occur in Jáchymov. The youngest, recent to sub-recent type, forms powdery coatings and crusts on vein material, whitish, pink to red in colour. The older, second type occurs as light pink radiating groups of crystals. The oldest köttigite is in the form of crystals, dark red wine in colour, composing spheroidal aggregates or crystalline crusts.

Lattice par. [Å, °]	1	a=10.109(2)	b=13.421(1)	c= 4.7653(8)
			β=101.77(1)	
	2	a=10.124(5)	b=13.434(6)	c = 4.765(3)
			β=101.86(1)	
IR [cm^{-1}]		430, 480, 530, 795, 860, 1045, 1110, 1450, 1635, 3100, 3175 a 3455		
EDX, WDX		major elements: As, Zn		minor elements: Ca, Mg, (Ni, Co, Mn)
References		27, 91, 127		

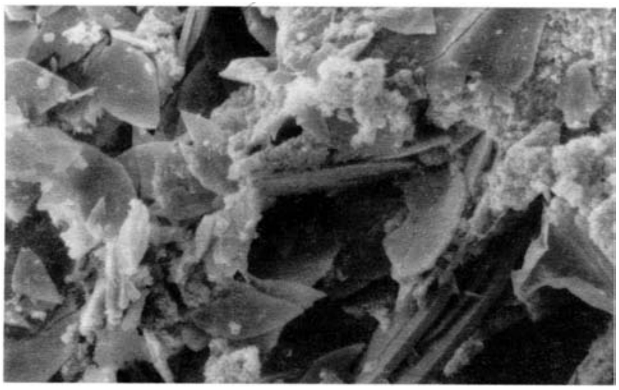
1 - this study, köttigite, crystals (second type)
2 - this study, köttigite, red powder (youngest type)

Krautite $Mn[(H_2O)AsO_3(OH)]$

It occurs in irregular aggregates of microscopic, randomly oriented crystals. Its colour ranges from pink buff to dark pink. Wet aggregates on freshly collected specimens are soft and harden after drying.

As in koritnigite, the intensity of pink colour depends on the content of cobalt, which substitutes Mn. Krautite occurs on crusts consisting of gypsum crystals of variable size or as powdery coating on mine walls together with annabergite or nickelhexahydrite. It was identified in specimens from the Geschieber vein.

Lattice par. [Å, °]		a=7.963(3)	b=15.813(7)	c =6.709(4)
			β=96.498(7)	
EDX, WDX		major elements: Mn, As	minor elements: Zn, Co, Ni	
References		237		



Krautite in minute crystals with acute termination. Magnification 700

Langite $Cu_4(SO_4)(OH)_6 . 2\ H_2O$

Langite was observed always in mixture with posnjakite as small blue crystalline coating.

Lattice par. [Å, °]		a=11.253(2)	b = 6.059(8)	c = 7.089(3)
			β = 89.86(1)	
EDX, WDX		major elements: Cu, S	minor elements:	
References		242		

The minute crystals are imperfect, grown on open fractures of vein quartz, in a proximity of tennantite and chalcopyrite. It occurs with brochantite, devilline, and gypsum.

Lavendulan $NaCaCu_5(AsO_4)_4Cl . 5\ H_2O$

Lavendulan is a typical species for the assemblage of secondary minerals in Jáchymov and at the same time it is rare in this ore district. It was described in 1853 by Vogl from the Eliáš mine [60] on the Geister and Červená veins as an alteration product in old adits [125]. However, the type locality for this mineral is Annaberg, where lavendulan was described in 1837 by Breithaupt [200]. The most typical form of lavendulan are sky blue, glassy botryoidal crusts and coatings on vein material carrying tennantite and chalcopyrite. The coatings are composed of microscopic spheroidal radiating aggregates of platy crystals. Crystalline aggregates are rare. Lavendulan formation is dependent on acidity, influenced by the primary Cu-sulphides. It is accompanied by several younger minerals such as lindackerite, köttigite, picropharmacolite, strashimirite, and olivenite.

Scanning electron photographs show that lavendulan crystals are several tens of μm long and only fractions of 1μm thick. This corresponds to interpretation of X-ray powder diffraction patterns (the Bragg-Brentano method), indicating a prominent preferred orientation of microcrystals. As the X-ray patterns of various samples of this mineral from Jáchymov show differences and also differ from lavendulan data given by Guillemin [25], full listing of diffractions is presented in table below.

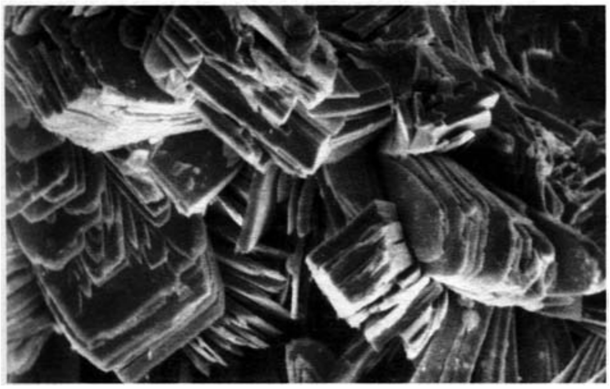
Lattice par. [Å]	1	a=9.817(4)	b=40.39(1)	c=9.997(6)
	2	a=9.821(9)	b=40.43(5)	c=9.97(1)
EDX, WDX	1	major elements: Cu,As,Ca	minor elements: Si, Na, Cl	
	2	major elements: Cu,As,Si	minor elements: Ca	
References		25, 60, 200		

1 - lavendulan, Jáchymov. This study (J-263)
2 - lavendulan, Jáchymov. This study (NM4892)

X-ray powder diffraction patterns of two lavendulan samples

NM4892						J-263					
I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
26	10.370										
100	9.898	9.821	1	0	0	100	9.859	9.817	1	0	0
4	7.879	7.936	1	3	0	0.3	7.668	7.933	1	3	0
3	7.374										
6	7.165	7.098	0	4	1	0.6	7.123	7.105	0	4	1
3	5.962										
4	5.763	5.773	0	7	0						
6	4.950	4.949	0	1	2	1.6	4.928				
						3.2	4.896	4.909	2	0	0
3	4.512	4.506	0	8	1	0.5	4.481	4.480	0	4	2
						0.2	4.170	4.188	2	3	1
2	3.798	3.780	1	9	1						
2	3.508	3.502	2	7	1	0.1	3.529	3.526	1	7	2
3	3.374	3.368	0	12	0	0.4	3.354	3.366	0	12	0
14	3.355										
3	3.347	3.338	1	8	2						
3	3.024	3.031	3	3	1						
3	2.978	2.978	2	10	1	0.9	2.980	2.978	2	10	1
2	2.918	2.903	3	5	1						
7	2.872	2.876	2	8	2						
2	2.778	2.777	0	8	3	1.1	2.749	2.751	2	1	3
						0.8	2.721	2.713	3	2	2
2	2.680	2.682	3	3	2						
2	2.656	2.656	2	4	3						
2	2.622	2.627	2	13	0						
3	2.536	2.535	3	6	2	0.4	2.560	2.556	3	9	1
						0.3	2.509	2.5137	1	15	1
1	2.4702	2.4700	3	7	2	0.7	2.4428	2.4432	3	11	0
3	2.2428	2.2414	3	5	3						
						0.1	1.9609	1.9612	5	1	0
						0.3	1.9172	1.9180	5	2	1
						0.3	1.8213	1.8215	2	4	5

						2.9	3.259	3.262	3	1	0
5	3.180	3.181	3	3	0	0.5	3.185	3.184	1	12	0
2	3.065	3.066	1	3	3	2.2	3.102	3.101	3	1	1
						0.3	1.7669	1.7660	1	21	2
						0.5	1.6265	1.6262	2	22	2
						0.3	1.5511				



Lavendulan aggregate of thin tabular orthorhombic crystals. Magnification 300

Libethenite $Cu_2(PO_4)(OH)$

It forms rare thin coatings of small needle crystals of green colour. Libethenite occurs on fractures of the Geister vein.

EDX, WDX		major elements: Cu, P	minor elements:

Liebigite $Ca_2[(UO_2)(CO_3)_3] . 11 H_2O$

It was first found in Jáchymov in 1853 and described by Vogl [60]. The specimens originated from the Fluther vein, the Eliáš mine at a depth of 150 to 170 m under surface. Liebigite was accompanied by voglite, uranium ores, fluorite, dolomite, clay, and a decomposed schist. However, the first mention of this mineral is in 1848 by J. L. Smith [218], who also introduced the name liebigite.

The mineral forms thin crystalline crusts or equant to short prismatic crystals, usually tenths of a mm long, rarely up to 5 mm long. The colour is green yellow, yellow green to apple green, always bright to fluorescent (in day-light). The crusts are clouded but crystals are translucent, with a glassy lustre. In ultraviolet light, it shines an intense grey green.

Liebigite is typically coating uraninite set in carbonate gangue with minor pyrite and chalcopyrite, together with schröckingerite and zellerite. Occasionally, liebigite impregnates schröckingerite aggregates, which are then devoid of the characteristic silky lustre and the aggregates are similar to andersonite. The continuos coating of liebigite on uraninite is absent over sulphides (mainly pyrite), where limonite occurs instead of liebigite. The sulphuric acid released by decomposition of sulphides prevents formation of uranyl-carbonates.

Copper can substitute for a part of Ca owing to similarity of the ion radii. Members of the continuous substitution series between Ca and Cu end-members were synthesised [106]. According to Kašpar [106] liebigite in Jáchymov is unstable and transforms to schröckingerite. No support for this statement was found in the present study.

Frondel et al. [23] gave X-ray powder pattern of Jáchymov liebigite. Following Evans et al. [160], the mineral is biaxial, positive, with indices of refraction $n_\alpha = 1.497$, $n_\beta = 1.502$, $n_\gamma = 1.539$, $2V = 40°$.

Thermogravimetric analysis of liebigite is discussed by Čejka et al. [4] (see table below). Mereiter [29] presented structure analysis using liebigite single crystal from Jáchymov.

Several published liebigite chemical analyses are included in table below:

	1	2	3	4
CaO	15.56	16.42	16.28	15.40
FeO			2.48	
UO_3	37.11	36.29	35.45	39.27
CO_2	23.87	22.95	23.13	18.13
H_2O	23.35	23.72	22.44	27.21
Sum	99.89	99.38	99.78	100.00

1 - liebigite, Jáchymov. Vogl [59]
2 - liebigite, Jáchymov. Schrauf [208]
3 - liebigite, Jáchymov. von Foullon in Brezina [55]
4 - liebigite, theoretical values

Liebigite was also recorded in old uranium workings, including the Hieronymus vein [60] and in Dürrnberger and Johann Bock adits [55].

Lattice par. [Å]	1	a = 16.71	b = 17.55	c = 13.79
	3	a=16.699(3)	b=17.557(3)	c=13.697(3)
EDX, WDX		major elements: U, Ca, C as $(CO_3)^{2-}$	minor elements: Cu, Sr, Fe	
IR [cm^{-1}]	5	520, 685, 738, 841, 888, 902, 932, 1020, 1069, 1110, 1378, 1538, 1590, 1630, 3450, 3570		
Therm. analysis [°C, wt. %]	2	50-150 22.75 (9.2 H_2O), 150-300 2.22 (0.9 H_2O), 300-510 14.28 (2.3 CO_2), 510-650 3.07 (0.5 CO_2), 650-720 2.43 (0.5 CO_2), 720-900 0.27 endothermic reaction: 105, 480		
Hardness	4	2.5 - 3		
Density [$g.cm^{-3}$]	1	$D_m = 2.41$, $D_x = 2.43$		
	3	$D_x = 2.41$		
References		4, 14, 27, 29, 55, 56, 59, 60, 106, 160, 208, 218		

1 - liebigite, Jáchymov. Evans et al. [160]
2 - liebigite, Jáchymov. Čejka et al. [4]
3 - liebigite, Jáchymov. Mereiter [29]
4 - liebigite, Jáchymov. Vogel [60], Schrauf [208]
5 - liebigite, Jáchymov. Čejka et al. [14]

Lindackerite $(Cu, Co)_5(AsO_4)_2(AsO_3OH)_2 . 10 H_2O$

This rare mineral was described in 1853 for the first time by Vogl [60] in specimens from old workings on the Geister and Eliáš veins, mine Eliáš. Lindackerite with erythrite, annabergite, pitticite, and *ganomatit* coated Ni, Co, Bi, Pb, and Cu complex ores. It was named by Haidinger [118] to honour the pharmacist Josef Lindacker, who did the first analysis of this species [161].

The chemical analyses given in [60] and results of the present study suggest that the older descriptions of lindackerite ([60], [25]) are based on mixture of two mineral phases: lindackerite proper and another phase, which we provisionally denote "pseudo-lindackerite"

Lindackerite occurs as inconspicuous crystalline crusts or aggregates composed of fine, lustrous crystals. The crystals are up to 2 mm long, lath-shaped, showing an orthorhombic habit and a single set of perfect cleavage. Radiating aggregates of the crystals are common. A typical feature of the crusts is their similarity in appearance to those of gypsum. Unlike other associated Cu arsenates, lindackerite is always transparent.

Formation of lindackerite is strongly dependent on acidity, influenced by the primary minerals (tennantite, chalcopyrite, bornite, and others) and their chemical stability. At very low pH values, lindackerite without lavendulan forms on grains of primary minerals. More often, it forms an aggregate deposited centrally on older lavendulan. Lindackerite occurs in crystalline or glassy crusts and no powdery aggregates were observed.

Lindackerite occurs in assemblage with light apple green "pseudo-lindackerite", geminite, lavendulan, strashimirite, olivenite, and pink köttigite. It appears among the early decomposition products of tennantite or chalcopyrite in the environment of strongly acid, mobile ions $[AsO_3OH]^{2-}$. This mineral was found on the Geister and Geschieber veins.

Until present, definition of lindackerite was subjected to major modifications because of both rarity of this mineral (including Jáchymov) and its intergrowths with “pseudo-lindackerite”. Vogl [60] published the following analysis: CuO 36.34, NiO 16.15, As_2O_5 25.58, FeO 2.90, SO_3 6.44, H_2O 9.32, Total 99.73 wt. %, resulting in the formula:

$$Cu_6Ni_3(AsO_4)_4(SO_4)(OH)_4 \,.\, 5\ H_2O$$

Guillemin [25] presented analyses of lindackerite from 8 specimens from Jáchymov. Lindackerite is given as monoclinic (table below), Z = 1, non-pleochroic, biaxial, optically positive, 2V = 68°, indices of refraction $n_\alpha = 1.627$, $n_\beta = 1.659$, $n_\gamma = 1.729$.

According to Larsen [162], the optical character of the mineral is the same, $n_\alpha = 1.629$, $n_\beta = 1.662$, $n_\gamma = 1.727$, Y=b, extinction angle between X and the direction of elongation = 26°.

Guillemin [25] also stated that the mineral contains also Ni, minor Co, while SO_3 is always absent. Two full quantitative analyses were given by Guillemin [25]. For the first one (original specimen number: n°5): CuO 34.5, CoO 2.3, NiO 1.5, As_2O_3 44.4, Fe_2O_3 0.2, H_2O 16.9, Total 99.8 wt. %, was calculated to: $2(As_2O_3)$, 5.04(CuO, CoO, NiO), 9.74 H_2O, simplified to:

$$(Cu,Co,Ni)_5H_2(AsO_4)_4 \,.\, 9\ H_2O$$

On the basis of the present study, the following recalculation of the analysis is proposed:

$$(Cu,Co,Ni)_{5.04}(AsO_4)_{2.08}(AsO_3OH)_{1.92} \ .\ 9\ H_2O.$$

The second complete analysis by Guillemin [25] (specimen n°7): CuO 39.0, CaO 0.5, Fe_2O_3 0.3, As_2O_5 43.7, H_2O 16.2, Total 99.7 wt. %, corresponds to material free of Co and Ni. The following simplified formula was proposed:

$$Cu_5H_2(AsO_4)_4 \ .\ 8\ H_2O$$

However, the second analysis can be alternatively calculated (based on 16 O):

$$Cu_{5.17}(AsO_4)_{2.34}(AsO_3OH)_{1.60} \ .\ 8.67\ H_2O$$

In conclusion of his study, Guillemin gives the following formula for lindackerite:

$$Cu_5H_2(AsO_4)_4 \ .\ 8 - 9\ H_2O$$

As a result of the present study, the following formula is preferred:

$$Cu_5(AsO_4)_2(AsO_3OH)_2 \,.\, 9\ H_2O$$

The monoclinic cell suggested by Guillemin [25] appears as unrealistic, because it is not compatible with the strongest reflections measured in the powder patterns. Compatibility coefficients [153], [154] were calculated from the analyses given by Guillemin. For the specimen n°5 *Compat.* = 0.050 (good), for the specimen n°7 *Compat.* = 0.080 (fair poor), which shows that some measurements are not sufficiently accurate. It is suggested that for the specimen n°7, density value is inaccurate.

The X-ray powder diffraction patterns obtained in this study show some differences from data of Guillemin [25], including absence of some reflections or differences in reflection intensity. It is noted that in 1956 only the Debye-Scherrer camera was available. In view of the excellent cleavage of the mineral, resulting in preferred orientation of sample used in powder diffractometer measurement, it is concluded that the measurements were done on the same species.

X-ray powder diffraction pattern of lindackerite from Jáchymov (sample J-268).

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
100	10.139	10.174	0	1	0
7	7.954	8.019	1	0	0
1	6.727	6.456	1	1	0
2	6.097	6.152	-1	1	0
4	5.131	5.158	1	0	1
2	5.071	5.087	0	2	0
2	4.951	4.967	1	1	1
1	4.476	4.522	-1	1	1
1	4.413	4.395	1	2	0
2	4.268	4.305	1	-1	1
3	4.171	4.172	1	1	-1
7	3.984	3.990	1	2	1
3	3.794	3.795	2	1	0
10	3.237	3.236	0	3	1
2	3.156	3.162	0	0	2
2	3.088	3.095	1	3	1
7	3.052	3.056	1	1	2
4	2.910	2.915	-1	3	1
1	2.860	2.869	-1	0	2
1	2.790	2.790	0	-3	1
11	2.666	2.664	1	1	-2
1	2.640	2.642	1	3	-1
4	2.609	2.612	2	1	2
1	2.569	2.579	2	0	2
4	2.535	2.532	3	0	1
1	2.507	2.500	1	3	2
1	2.2998	2.2986	2	3	-1
2	2.2642	2 .2608	-2	2	2
2	2.2100	2 .2132	2	4	1
1	2.1658	2.1669	3	-2	1
<1	2.1396	2.1369	1	-4	1
1	2.1256	2.1216	3	0	2
1	2.0556	2 .0540	-1	4	2
2	2.0323	2.0348	0	5	0
1	2.0015	2 .0020	-1	0	3
1	1.9800	1 .9792	-3	3	1
2	1.9464	1 .9474	-1	5	1
1	1.9213	1 .9230	3	-3	1
1	1.8982	1.8982	2	-3	2

11	3.637	3.661	0	-2	1	2	2.4836	2 .4833	2	2	2	1	1.8434	1 .8428	-2	4	2
1	3.492	3.508	2	0	1	1	2.4710	2.4599	1	4	0	1	1.7799	1.7800	-2	2	3
7	3.387	3.391	0	3	0	1	2.4188	2.4188	-2	3	1	1	1.7644	1.7648	-3	4	1
3	3.341	3.340	1	-2	1	2	2.3794	2.3809	3	2	1	1	1.5497	1.5483	3	-2	3

Sharp at al. [279] re-defined lindackerite as an analogue of geigerite (Mn-member) and chudobaite (Mg, Zn), with the following composition: CoO 1.24, CuO 36.47, NiO 0.50, As_2O_5 43.71, H_2O (18.08), Total 100.00 wt. %, corresponding to:

$$(Cu_{4.90}Co_{0.18}Ni_{0.07})(AsO_4)_{2.02}\,[(AsO_3)_{2.03}(OH)_{2.21}]\ .\ 9.6\ H_2O$$

ideally:

$$(Cu,Co)_5(AsO_4)_2(AsO_3OH)_2\ .\ 10\ H_2O$$

Lattice par. [Å, °]	1	a = 3.95	b = 8.02	c = 6.277
			β = 100.30	
	2	a = 8.14(3)	b = 10.40(3)	c = 6.45(2)
		α = 80.35(4)	β = 84.25(5)	γ = 88.36(4)
	3	a = 8.103(7)	b=10.394(8)	c = 6.474(8)
		α = 79.60(1)	β = 85.35(2)	γ = 86.07(1)
	4	a = 8.056(8)	b=10.357(9)	c = 6.454(5)
		α=79.568(7)	β=85.042(7)	γ =86.327(7)
	5	a = 8.035(2)	b=10.368(4)	c = 6.453(5)
		α = 79.60(3)	β = 84.83(3)	γ = 86.17(3)
EDX, WDX		major elements: Cu, As		minor elements: (Mg)
Density [g.cm^{-3}]	1	D_m = 3.27(2), 3.20(3) D_m = 3.39 for Z = 1		
	5	D_m = 3.35(2), D_x = 3.37(1) for Z = 1		
References		25, 60, 118, 154, 155, 161, 163		

1 - lindackerite, Jáchymov. Guillemin [25]
2 - newly calculated values from original Guillemin's data (sample n°7) [25]
3 - newly calculated values from original Guillemin's data (sample n°5) [25]
4 - lindackerite, Jáchymov. This study (J-268)
5 - lindackerite, Jáchymov. Sarp et al. [279]

Tabular crystals of lindackerite. Magnification 250

The single crystal X-ray study [279] indicated triclinic symmetry (unit cell parameters are given in table below), Z = 1, *P*1 or *P*1, transparent, glassy, biaxial (+), $2V_{meas}$ = 74°, $2V_{calc}$ = 72°, indices of refraction n_α = 1.632(2), n_β = 1.662(2), n_γ = 1.725(5), r < v strong, weak pleochroism from green (γ) to colorless (α = β), β Λ a = 21.3° on {010}, and 34.4° on {001}.

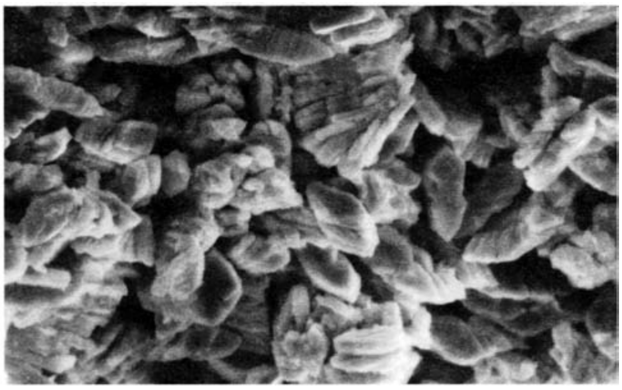
Magnesium-zippeite $[Mg(UO_2)_2(SO_4)(OH)_4]_2\ .\ 3\ H_2O$

Magnesium-zippeite often occurs in powdery coatings or as earthy aggregates, in mixture with other uranium sulphates, which include several types of zippeite (Na, K, Fe, Ni, Mn) with various cations, "pseudo-zippeite (Mg)", uranopilite, jáchymovite, and other phases. Magnesium-zippeite aggregates show variety of habits, including earthy, granular/crystalline, and soft or hardened intense yellow to orange to red brownish yellow.

The specimens were collected in the Evangelista vein.

		a = 8.649(1)	b= 14.241(2)	c =17.696(2)
			β=104.111(5)	
EDX, WDX		major elements: U, S, Mg, Fe		minor elements: (K)
References		132, 152, 161, 165, 170, 252, 260		

Detail of sandwich-like aggregate of minute magnesium-zippeite crystals. Magnification 600



Mixture of short, acute and doubly-terminated crystals of the "pseudo-zippeite (Mg)" and of magnesium-zippeite in sandwich-like aggregates. Magnification 900

Occasionally, it forms isolated crystals and their radiating aggregates, probably favoured by lower-concentration solutions and a moderate pH gradient.

Magnesium-zippeite was described as associated with gypsum, uranopilite, zippeite, sodium-zippeite, nickel-zippeite, "ferro-zippeite", "pseudo-zippeite (Mg)", johannite, exceptionally jáchymovite, sklodowskite, metaschoepite.

In present study, mixtures of "pseudo-zippeite (Mg)" always with zippeites (all types) were regularly observed.

On a basis of a structure of a synthetic zinc-zippeite [152] and a chemical analogy of isostructural zippeites (Ni, Mg, Co, Zn, Mn, Cd) [132], it is possible to proposed a chemical formula for magnesium-zippeite as follows:

$$[Mg(UO_2)_2(SO_4)(OH)_4]_2 \,.\, 3\,H_2O$$

See also other minerals of the zippeite group (sodium-zippeite, zippeite, nickel-zippeite, "ferro-zippeite", "pseudo-zippeite (Mg)").

Malachite $Cu_2(CO_3)(OH)_2$

It was found only once as small spheres composed of malachite and brochantite mixture, deposited on fractures of vein quartz with thin veinlets of a white carbonate. The spheres are accompanied by small brochantite crystals and by picropharmacolite.

The rarity of malachite can be explained by composition and migration of solutions responsible for mineralization. Copper-bearing veins always contain sulphides and sulpho-arsenides, which give rise to rather acid solutions. Vein or country rock carbonates do not contain sufficiently abundant carbonate (mainly dolomite) to neutralise the solutions. Calcite veins are relatively rare. This situation results in common occurrence of arsenates, hydrogen-arsenates, or sulphates in place of carbonates.

Masuyite $Pb_3U_8O_{27} \,.\, 10\,H_2O$

Masuyite was identified as crystalline aggregates up to 1 cm^2 in size, composed of yellow-orange to orange brown minute acicular crystals. It also occurs as a substantial component of orange-red crystalline aggregates with poorly defined radiating pattern.

Masuyite occurs usually with other minerals of the PbO-UO$_3$-H$_2$O group in a paragenesis with uranophane and gypsum, next to partly weathered uraninite.

X-ray powder diffraction data of masuyite given in the table below include indexing of some diffraction missing in the original description [266]. The diffraction data for Jáchymov masuyite are based on the sample BM 6106.

Lattice par.[Å]		a= 13.847(6)	b= 12.211(6)	c= 14.128(8)
EDX, WDX		major elements: U, Pb		minor elements: Si
References		266		

X-ray powder diffraction pattern of magnesium-zippeite from Jáchymov.

I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***	I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***	I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***
17	8.567	8.581	0	0	2	19	2.859	2.860	0	0	6	1	2.0027	2.0021	4	1	-5
5	7.590					4	2.809	2.811	1	3	-5	1	1.9919	1.9950	3	5	-3
8	7.481					3	2.738	2.740	0	4	4	5	1.9759	1.9771	1	7	-1
100	7.112	7.121	0	2	0	6	2.714	2.714	2	4	-2	5	1.9575	1.9556	2	6	2
5	6.212	6.211	1	1	1	6	2.714	2.713	1	2	-6	7	1.9546	1.9552	2	6	-4
17	5.477	5.480	0	2	2	6	2.691	2.689	2	0	4	22	1.9518	1.9522	0	6	5
13	4.288	4.290	0	0	4	22	2.653	2.654	0	2	6	22		1.9514	1	7	1
13	4.191	4.194	2	0	0	13	2.632	2.633	1	5	1	5	1.9310	1.9304	4	0	-6
13	4.191	4.193	2	0	-2	6	2.515	2.516	2	2	4	4	1.9022	1.9028	1	7	-3
4	4.130	4.131	1	3	-1	21	2.4774	2.4779	2	4	2	5	1.8477	1.8481	4	4	-2
1	4.078	4.085	1	1	-4			2.4771	2	4	-4	8	1.8268	1.8266	0	6	6
15	3.911	3.911	1	3	1	3	2.4075	2.4087	3	3	-3	4	1.7885	1.7896	3	5	3
3	3.747					16	2.3731	2.3736	0	6	0	12	1.7798	1.7802	0	8	0
6	3.674					10	2.2873	2.2877	0	6	2	4	1.7572	1.7575	1	7	-5
10	3.613	3.614	2	2	0	12	2.2293	2.2298	0	4	6	10	1.7439	1.7444	2	0	-10
10	3.613	3.613	2	2	-2	3	2.2039	2.2013	3	3	-5	9	1.7243	1.7253	4	0	4
58	3.559	3.558	1	3	-3	9	2.1614	2.1622	4	0	-2	2	1.7163	1.7162	0	0	10
38	3.449	3.451	2	0	2	4	2.1444	2.1452	0	0	8	2	1.7144				
38	3.449	3.449	2	0	-4	7	2.1317	2.1322	2	0	-8	13	1.6945	1.6950	2	2	8
11	3.288	3.289	0	4	2	5	2.0968	2.0964	4	0	-4			1.6943	2	2	-10
2	3.244					12	2.0686	2.0690	4	2	-2	9	1.6760	1.6768	4	2	4
1	3.225					3	2.0520	2.0540	0	2	8			1.6759	4	2	-8
4	3.181	3.183	0	3	4	8	2.0432	2.0436	2	2	6	<1	1.6669	1.6684	0	2	10
40	3.104	3.105	2	2	2			2.0426	2	2	-8	<1	1.6592	1.6579	0	7	6
40	3.104	3.104	2	2	-4	1	2.0278					4	1.6441	1.6449	3	7	-3
3	3.041					5	2.0116	2.0116	4	2	0	2	1.6375	1.6374	2	3	-10
5	2.950							2.0111	4	2	-4						

X-ray powder diffraction pattern of masuyite from Jáchymov (sample BM 6106).

I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***	I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***	I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***
3	7.603	7.685	1	1	1	14	3.109	3.109	4	0	2	6	2.2592	2.2602	5	3	1
100	7.067	7.064	0	0	2	11	2.989	2.984	0	4	1	4	1.9838	1.9838	3	2	6
5	6.023	6.023	2	1	0	10	2.919	2.917	1	4	1	10	1.9479	1.9470	4	0	6
4	4.564	4.579	2	2	0	12	2.734	2.734	3	1	4	8	1.9099	1.9083	6	1	4
6	4.382	4.382	1	2	2	3	2.699	2.700	1	1	5	6	1.8813	1.8816	5	2	5
5	3.598	3.601	1	2	3	8	2.632	2.637	4	3	0	7	1.7684	1.7686	6	1	5

75	3.530	3.532	0	0	4	<1	2.3578	2.3643	3	1	5	5	1.7180	1.7180	1	7	1
50	3.440	3.462	4	0	0	5	2.3578	2.3547	0	0	6	4	1.5803	1.5802	6	5	3
8	3.256	3.265	3	2	2	<1	2.3488	2.3429	5	1	3	7	1.5702	1.5700	8	2	3
<1	3.140	3.146	2	0	4	10	2.2912	2.2916	4	2	4						

X-ray powder diffraction pattern of mcnearite from Jáchymov.

I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***	I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***	I_{rel}	d_{obs}	d_{calc}	***h***	***k***	***l***
42	14.089					5	4.495					7	2.4579	2.4586	-5	4	1
87	12.412	12.477	0	1	0	76	4.438					9	2.4371	2.4366	1	-4	2
100	12.203					18	4.376	4.391	-3	1	0	7	2.4134	2.4158	1	3	2
26	11.690	11.742	1	0	0	8	4.273					11	2.4016				
4	7.776					11	4.161	4.159	0	3	0	16	2.3761	2.3737	-3	6	0
4	7.585					28	4.141					7	2.2990	2.3000	-1	1	3
9	7.160					11	4.028					17	2.2706	2.2685	-3	6	1
6	7.144	7.121	-1	2	0	38	3.912	3.914	3	0	0	9	2.2521	2.2506	1	-1	3
33	7.061	7.020	1	1	0	59	3.895	3.886	2	1	-1	5	2.2407	2.2403	-2	6	1
39	6.953	6.953	0	0	1	51	3.812	3.818	1	2	1	5	2.1922	2.1918	3	3	1
4	6.713	6.710	-2	1	0	23	3.762	3.766	2	-3	1	8	2.1739	2.1726	-6	3	1
15	6.652					12	3.693					10	2.1489	2.1508	-4	5	2
35	6.559					9	3.614	3.621	3	-2	1	14	2.1298	2.1301	-5	4	2
12	6.276					4	3.569	3.577	0	3	-1	8	2.0470	2.0485	5	-2	2
11	6.242	6.239	0	2	0	14	3.536	3.534	-3	3	1	13	2.0378	2.0364	-3	7	0
43	6.193	6.160	-1	1	1	23	2.930	2.929	2	-2	2	9	2.0229	2.0235	2	1	3
6	6.087	6.086	0	-1	1	29	2.895					13	1.9967	1.9953	-2	7	0
34	5.710					31	2.867					8	1.9658	1.9651	-2	6	2
10	5.685					11	2.850	2.851	0	4	-1	14	1.9618	1.9593	2	4	-2
19	5.662					18	2.819	2.820	-3	1	2	15	1.9503	1.9495	3	4	-1
12	5.437					4	2.815	2.812	2	3	0	5	1.9304	1.9305	2	-6	2
5	5.266					36	2.807	2.810	-3	5	0	5	1.9124	1.9128	5	-5	2
31	5.214					27	2.747	2.748	1	2	2	14	1.9071	1.9066	3	3	2
14	5.176					14	2.724	2.724	-1	5	0	6	1.8913	1.8915	1	5	-2
10	5.042	5.041	1	1	-1	5	2.704	2.707	1	4	0	9	1.8832	1.8829	4	-6	2
8	4.897	4.898	1	-2	1	27	2.635	2.637	2	3	-1	9	1.8230	1.8229	-3	5	3
32	4.831	4.845	1	1	1	8	2.590	2.591	4	1	0	2	1.8135	1.8142	7	-4	1
6	4.746					6	2.576	2.577	2	3	1	12	1.8095	1.8099	7	-3	1
17	4.690	4.702	-1	3	0	13	2.551	2.553	-5	3	1	11	1.7866	1.7885	0	-6	2
42	4.587	4.606	-2	3	0	4	2.537	2.538	1	4	-1	10	1.7625	1.7602	2	3	3

Mcnearite $NaCa_5H_4(AsO_4)_5 . 4 H_2O$

It occurs as thin and soft powdery crust covering about 1 cm thick zoned crust of gypsum and arsenate, deposited on wall rock. The full sequence of the crust is as follows: at the base a thin, milky amorphous zone deposited on wall rock, followed by radiating aggregates of white picropharmacolite, zone of crystalline gypsum, followed by milky rösslerite zone, and the topmost zone of mcnearite - thenardite mixture. The specimens were collected in the Geschieber vein.

The matrix to the crust studied is a partly greisenized granite (with kassiterite grains) collected at a site near to the subsurface discharge of radioactive water used in the Jáchymov spa. Sodium bound in mcnearite was possibly supplied by the spring, while the ultimate source of Na is probably plagioclase in the granite (Na released due to activity of sulphuric acid).

Lattice par. [Å, °]		a= 13.450(6)	b=14.258(6)	c = 6.963(7)
		α = 88.38(1)	β=93.828(8)	γ=119.01(1)
EDX, WDX		major elements: As, Ca, Mg	minor elements: Na	
		D_m = 3.35(2), D_x = 3.37(1) for Z = 1		
References		273		

Melanterite $FeSO_4 . 7 H_2O$

Melanterite accompanied by other sulphates forms massive crystalline crusts and hollow stalactites with imperfect skeletal crystals coating the internal free surfaces. The colour varies from light yellow to dark greenish blue with variation in the Fe/Mg ratio and the content of complex hydroxyl-sulphates of ferric iron. The latter may result in a red-brown colour.

It occurs often in solid solutions with other heptahydrates of Fe, Mg, and Ni in places with pyrite-marcasite veins. Owing to action of acid mine waters, containing sulphuric acid as a catalyzer, the vein fill can be decomposed in a rather short time. Stability of melanterite (with a general formula $Me^{2+}SO_4.7 H_2O$) is affected not only by composition of solutions and by their pH value, because other conditions in the mine including temperature and circulation of dry air are important. Elevated temperatures and circulation of dry air result in gradual dehydration of melanterite and its alteration to powdery material.

In the sulphate heptahydrate solid solutions melanterite was identified as a marginal member associated with nickelhexahydrite, morenosite, gypsum, rozenite, epsomite, and as yet unidentified Fe-arsenates. Kratochvíl [118] described melanterite as coatings of imperfect crystals accompanied by chalcanthite. The mineral also occurs on mine dumps.

EDX, WDX		major elements: Fe, S	minor elements: Mg, Ni
References		118	

Meta-autunite $Ca(UO_2)_2(PO_4)_2 .\ 2\text{-}6\ H_2O$

This mineral occurs in Jáchymov in two different associations. In the first one, it forms light yellow-green tabular crystals with a light yellowish colour or dark green tabular crystals dominated by the (001) faces. It is associated with walpurgite. Light green meta-autunite fluoresces in ultraviolet light intense yellow green, the dark type shows only a weak fluorescence.

In the associations of the second type, meta-autunite is often replaced by amorphous iron oxides and hydroxides. It occurs on small quartz crystals as tabular crystals up to 1 cm long in vugs of the Geister vein.

X-ray study confirmed the mineral as U-mica related to meta-autunite. Spectral analyses done in the past confirmed elevated iron content and absence of Ca which led to the suggestion that the mineral is bassetite. Recent microscopic and microprobe study of polished sections resulted in identification of the supposed bassetite as a mixture of meta-autunite and amorphous Fe-hydroxides, which replaced the original U-mica. The pseudomorphs fluoresce mottled yellow in ultraviolet light. Glassy yellow-brown spherules tens of microns in diameter, coating the pseudomorphs, correspond to corkite in composition. The second association includes churchite-(Y), fresh meta-autunite, and parsonsite.

Lattice par. [Å]		a = 6.991(3)	c = 8.438(2)
EDX, WDX		major elements: U, P, Ca	minor elements: Fe, Sr, Ba
Water content [wt. %]		14.37 (dark green), 11.86 (yellow)	
Density [g.cm^{-3}]		D_m = 3.68 (dark green), 3.45 (yellow). (determined by pycnometer)	
References		27	

Metalodevite $Zn(UO_2)_2(AsO_4)_2 .\ 10\ H_2O$

Metalodevite forms isolated think tabular crystals up to 7 mm in size. It has bright yellow colour and vitreous lustre. Metalodevite was found in a small vugs in quartz vein containing bismuthinite and native bismuth. It is very rare. It originates in the Eliáš mine.

EDX, WDX		major elements: Zn, U, As	minor elements: Mg

Metanováčekite $Mg(UO_2)_2(AsO_4)_2 .\ 4\text{-}8\ H_2O$

It was always identified in a mixture with nováčekite. It occurs in two paragenesis. In the first one it forms small light yellow coating on carbonate gangue carrying disseminated chalcopyrite and tennantite. Metanováčekite formed here probably by neutralisation of acid solutions containing uranyl-arsenate ions, while Mg was released from carbonate. The specimens were collected in the Evangelista vein.

The second type forms 3 mm long crystals accompanied by bismutite in vugs of quartz vein. On fresh exposure it has a strong yellow green colour and is nearly transparent. During one day, the mineral becomes turbid and non-transparent. The specimens were collected on dump of the Eliáš mine.

Lattice par. [Å]		a= 7.166(5)	c= 8.598(8)
EDX, WDX		major elements: Mg, U, As	minor elements:

Metaschoepite $UO_3 .\ n\ H_2O,\ n < 2$

Metaschoepite occurs as yellow soft earthy aggregates.

Similar to other hydrated uranyl-oxide-hydroxides, it is rather unstable [6], which results in limited data on its properties. The new X-ray powder diffraction data for metaschoepite from Jáchymov (see table bellow) correspond to the phase $Na_2(UO_2)_6(OH)_{14}$. 4 H_2O described by Brindley et al. [205].

X-ray powder diffraction patterns of metaschoepite from Jáchymov.

Jáchymov		1)		Jáchymov		1)		Jáchymov		1)		Jáchymov		1)	
I_{rel}	d_{obs}	I_{rel}	d_{obs}	I_{rel}	d_{obs}	I_{rel}	d_{obs}	I_{rel}	d_{obs}	I_{rel}	d_{obs}	I_{rel}	d_{obs}	I_{rel}	d_{obs}
18	9.561					10	3.480	10	2.1610	<1	2.1771	16	1.7456	2	1.7474
4	8.827	2	8.644	2	3.440			4	2.1379	3	2.1528			3	1.7412
4	8.388	1	8.325	11	3.350	2	3.330	3	2.1237	1	2.1184			1	1.7263
100	7.367	100	7.327	5	3.317	1	3.310	17	2.0923	2	2.0863			1	1.7208
4	7.142			68	3.231	50	3.220	5	2.0576	3	2.0661	8	1.7088	2	1.6998
8	6.495	1	6.440	42	3.172	25	3.160	26	2.0442	7	2.0342	5	1.6750	1	1.6819
		2	6.060	3	3.050			15	2.0223	5	2.0195			1	1.6681
		1	5.510	7	2.974	1	2.960	18	2.0115	2	2.0072			1	1.6559
3	5.388	<1	5.360	3	2.889	4	2.890	9	2.0074	4	2.0038	10	1.6333	2	1.6326
6	5.058	2	5.040	6	2.833	3	2.830	4	1.9945			3	1.6270	2	1.6250
4	4.982			7	2.756	2	2.730	6	1.9865	1	1.9888	11	1.6139	2	1.6137
5	4.879	1	4.870			<1	2.670	25	1.9692					3	1.6098
3	4.790					1	2.630	3	1.9534	9	1.9599	8	1.5863	1	1.5869
4	4.750					1	2.590					4	1.5682	2	1.5774
10	4.460	5	4.450	30	2.569	15	2.560			1	1.9194	1	1.5625	2	1.5644
3	4.341	<1	4.330	6	2.553			4	1.9030	1	1.9030			1	1.5414
		<1	4.290	16	2.539	8	2.530			1	1.8951	4	1.5227	1	1.5307
3	4.199	1	4.174			1	2.4600			1	1.8775	2	1.5128	1	1.5185
		1	4.010	12	2.4467	2	2.4500			<1	1.8496			1	1.5109
		1	3.830	3	2.4232	1	2.4200			2	1.8348			<1	1.4951
				8	2.3204	1	2.3832	9	1.8168	2	1.8140			<1	1.4837

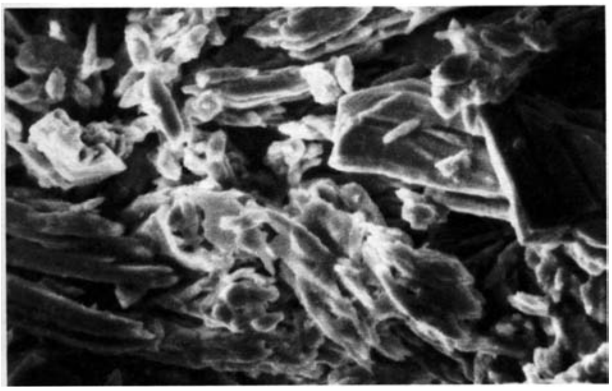
45	3.674	25	3.670	3	2.2710	2	2.3068			1	1.8089			<1	1.4788
62	3.598	40	3.580	5	2.2629	2	2.2674	12	1.7974	2	1.7925			<1	1.4728
7	3.560	5	3.560	5	2.2331	2	2.2259	16	1.7854	7	1.7789			<1	1.4569
38	3.518	20	3.490	6	2.2132	1	2.2010	7	1.7566	1	1.7566	4	1.4486	1	1.4466

1 - metaschoepite. Debets et al. [87]

The mineral does not fluoresce in ultraviolet light.

Metaschoepite was observed with gypsum, uranopilite, zippeite, sodium-zippeite, magnesium-zippeite, "ferro-zippeite", sklodowskite and, "pseudo-zippeite (Mg)" on specimens from the Evangelista vein.

EDX, WDX		major elements: U, S	minor elements:
References		6, 87, 205	



Detailed image of metaschoepite earthy aggregate. Magnification 700

Metatorbernite $Cu(UO_2)_2(PO_4)_2 . 8 H_2O$

Metatorbernite crystals up to 5 mm long or fine-grained scaly aggregates occur as coatings. The light green crystals are tabular on (001) and often compose radiating aggregates. The mineral with glassy lustre is translucent to transparent and very brittle.

It is a common secondary mineral in Jáchymov. Powdered torbernite kept in a dry place dehydrates to metatorbernite. A single crystal of uranium mica, 5 mm long, was identified as a mixture of torbernite and minor metatorbernite 20 years after collecting. Only metatorbernite was present in a subsample studied three weeks after it was powdered. However, some metatorbernite formed as a primary phase.

It is relatively common on all veins carrying uranium minerals. Metatorbernite is accompanied by torbernite, zeunerite, metazeunerite, tyuyamunite, churchite-(Y), and parsonsite on specimens from the Geister vein.

Lattice par. [Å]	1	a = 6.978(3)		c = 17.37(1)
	2	a = 6.982(1)		c= 17.356(5)
EDX, WDX		major elements: U, P, Cu	minor elements:	
IR [cm^{-1}]	3	258,295,405,465,550,615,680,800,845, 910,930,990,1100,1645,2930,3350		
References		15, 27, 75, 84		

1, 2 - metatorbernite, Jáchymov. This study
3 - metatorbernite, Jáchymov. Čejka et al. [15] (NM 26719)

Metatyuyamunite $Ca(UO_2)_2(VO_4)_2 . 3 H_2O$

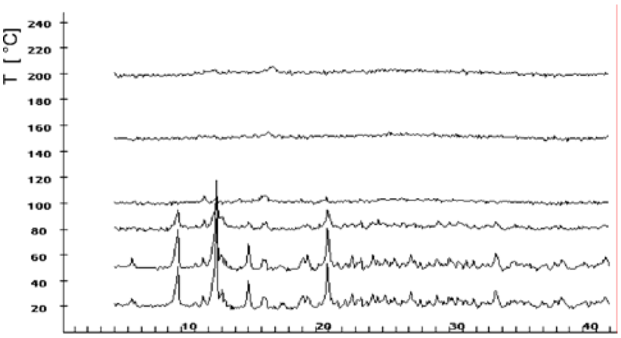
Metatyuyamunite occurs as a strong yellow powdery coating on fractures in the vein or in wall rock close to the vein. It does not fluoresce in UV light. It is associated with green zeunerite, gypsum and pink köttigite. The primary minerals in this vein are tennantite, pyrite and uraninite. Specimens studied were collected in the Geister vein.

Meta-uranopilite $(UO_2)_6(SO_4)(OH)_{10} . 5 H_2O$

Meta-uranopilite was first described on specimens from Jáchymov in 1935 by Nováček [35] under the name uranopilite; the name meta-uranopilite was introduced by Nováček in 1941 [35].

Kašpar [106] described meta-uranopilite as a grey green to brownish mineral, which contrasts with bright yellow uranopilite. Meta-uranopilite was described on a single specimen No. NM 17365 from the National Museum in Prague [35]. Though a specimen with this number was located during the present revision study, it is designated *bismutosferit* and notably differs from the description given by Nováček. Vandendriesscheite, compreignacite, uranophane, and kasolite were identified by X-ray and chemical analysis of this specimen i.e., no phase containing sulphur was observed. A re-numbering of specimens is considered as a probable reason of this disagreement. Another specimen No. NM 24272, designated as β-uranopilite, carries yellow acicular crystals containing U, Si, and Ca and corresponding to a mixture of uranophane and minor schoepite, determined by X-ray analysis. Negative results from search for type material in the collection were also reported by Čejka et al. [6]. The type specimen of meta-uranopilite was never studied by X-ray methods and Nováček [196] stated that there was insufficient material for additional work.

Based on a thermogravimetric analysis of uranopilite, Nováček [196] assumed that meta-uranopilite forms by dehydration of uranopilite at 60 to 70 °C. In the course of the present study, uranopilite was heated to 60, 80, 100, 150, and 200 °C, and kept in each step for 30 minutes under respective temperature. The dehydrated samples were studied by X-ray (figure below) with the result that uranopilite transforms to an amorphous phase during quick dehydration.



Results of this experiment correspond to a spontaneous re-hydration under room temperature of uranopilite dried at 150 °C, described by Frondel [174]. The single chemical analysis reported by Nováček [35] yielded: UO_3 82.40, Fe_2O_3 2.03, (CaO not determined), SO_3 4.17, H_2O 9.40, Total 98.00 wt. %, which he interpreted to the formula:

$$6UO_3\ .\ SO_3\ .\ 10\ H_2O$$

The indices of refraction $n_\alpha = 1.72$, $n_\beta = 1.76$, $n_\gamma = 1.76$ given by Nováček [35] are significantly higher than indices for uranopilite. The mineral is weakly pleochroic, optically negative, it has extinction parallel with elongation (// Y) and the obtuse bisectrice (Y) coincides with the large faces of lath-shaped crystals - (010).

The colour is grey-yellow with a brownish shade; it shows a very weak fluorescence in ultraviolet light.

References		6, 35, 106, 196

Meta-uranospinite $Ca(UO_2)_2(AsO_4)_2\ .\ 8H_2O$

Meta-uranospinite (17Å) forms a thin, firm and finely crystalline crust with distinct crystal faces on its surface. It also tends to occur as indistinct botryoidal aggregates. It is whitish grey to light yellow and shows a glassy lustre. Meta-uranospinite is associated with yellow coatings of zellerite and minor liebigite and schröckingerite. It was identified in specimen collected in 1869 or 1870 and deposited in the Landesmuseum Joaneum in Graz, Austria.

Meta-uranospinite (18Å) occurs as distinctly crystalline crust composed of flat crystals constituting an isolated convex rib. It is light yellow in colour. The associated schröckingerite crystallised in exceptionally coarse flakes. The minerals are deposited on uraninite-carbonate vein.

Meta-uranospinite (17Å) fluoresces a low-intensity yellowish white in UV light, while meta-uranospinite (18Å) fluoresces a greenish yellow white of a moderate intensity.

The calculated unit cell parameters and the X-ray powder diffraction pattern of meta-uranospinite (18Å) from Jáchymov (specimen VS-12698a) show a very good agreement with abernathyite (ICDD PDF2-[275]) (unlike meta-uranospinite [275]), but the chemical composition excludes this possibility. The mineral studied probably represents a member of the meta-uranospinite - trögerite series.

Lattice par. [Å]	1	a = 7.180(2)		c= 18.116(5)
	2	a = 7.155(4)		c = 17.27(7)
EDX, WDX		major elements: U, As, Ca	minor elements: Mg, Si	
References		263, 264, 275		

1 - sample VS-12698a (white-yellowish crust like schröckingerite, with nováčekite)

2 - sample JG-13142 (white-grey-yellowish crust on uraninite, with uranospinite)

Metavoltine $K_2Na_6Fe^{2+}Fe_6^{3+}(SO_4)_{12}O_2\ .\ 18\ H_2O$

Metavoltine always occurs in a mixture with copiapite as olive yellow, small, fine-grained earthy aggregates up to 0.5 mm long. They are deposited on radiating aggregates of halotrichite or sometimes directly on pyrite. The aggregates occur in porous vein quartz with pyrite and proustite, in paragenesis with halotrichite, alunogen and melanterite. The specimens were collected in the Geschieber vein.

Metazellerite $Ca[(UO_2)(CO_3)_2(H_2O)_2] . H_2O$

Metazellerite ranks among rare minerals in Jáchymov. Hloušek [27] gave the first description of its occurrence. The mineral forms buff yellow botryoidal aggregates and earthy coatings, which fluoresce intense yellow in ultraviolet light. Its appearance is similar to that of uranium sulphates, in particular zippeite. Metazellerite is associated with zellerite, schröckingerite, liebigite and rabbittite.

Lattice par. [Å]	1	a = 9.65(5)	b=18.40(10)	c = 5.03(3)
	2	a = 9.73(2)	b= 18.25(3)	c = 4.90(3)
EDX, WDX		major elements: U, Ca, C	minor elements: Mg, Fe	
References		27, 96		

1 - Metazellerite. This study, sample J-384 (Bratrství mine)

2 - Metazellerite. This study, sample 26J (Svornost mine, Daniel level, Evangelista vein)

Metazeunerite $Cu(UO_2)_2(AsO_4)_2 . 8\ H_2O$

It occurs as coatings of thick tabular to equant crystals on fractures of the vein fill. The crystals up to 3 mm long are transparent, of a strong green or grey-green colour, and a strong lustre.

Metazeunerite forms by a slow dehydration of zeunerite at the room temperature and normal humidity. The alteration can take place in mine if appropriate conditions prevailed.

It was always observed as intergrown with zellerite. Zeunerite, torbernite, metatorbernite, tyuyamunite, and hidalgoite are associated with metazeunerite. It is a relatively abundant mineral observed in all mines with veins of uranium minerals. The majority of specimens in collections come from the Rovnost mine where it was less common than zeunerite.

Lattice par. [Å]		a = 7.113(1)		c= 17.433(3)
EDX, WDX		major elements: U, As, Cu	minor elements:	
References		238		

Mimetite $Pb_5(AsO_4)_3Cl$

The single occurrence of mimetite was in the form of yellow-white powdery aggregates filling vugs in porous quartz gangue in the Geister vein. It was associated with zeunerite, metazeunerite, and bayldonite.

Lattice par. [Å]		a =10.233(4)		c = 7.432(5)
EDX, WDX		major elements: As, Pb, P	minor elements:	
IR [cm^{-1}]		430,475,550,575,790,825,980,1025		
References		27, 90		

Mixite $BiCu_6(AsO_4)_3(OH)_6 . 3 H_2O$

Jáchymov is the type locality for this mineral. It was first found on the sixth level of the Geister vein by Anton Mixa in 1880 and described by Schrauf [136], who named the mineral after its discoverer.

Schrauf [136] described mixite as bluish or emerald green coating and aggregates composed of fine acicular crystals, which are showing six faces in the prismatic zone and extinction under an angle of up to 6-9°. Sejkora [193] described several morphological types of mixite. The first type is dark green coating up to 1 mm thick and with botryoidal surface, similar to cornubite, on quartz-native bismuth veins. The second type represents isolated light green acicular crystals associated with bismutoferrite, bismutite, walpurgite, and eulytite. The third type includes aggregates up to 1 cm across, composed of very fine acicular crystals, accompanied by bismutoferrite on vein quartz. Mixite of the fourth type is in pearly lustrous aggregates of microscopic acicular crystals. All the types described in [193] are from the sixth level of the Geister vein in the Rovnost mine.

Sejkora [193] gave two quantitative mixite analyses: Bi_2O_3 20.76 (20.78), SiO_2 0.55 (0.55), As_2O_3 23.54 (25.03), P_2O_5 4.36 (3.60), CuO 42.11 (43.05), CaO 0.79 (0.75), H_2O 8.56 (8.71), Total 100.67 (102.47) wt. %. Recalculation of the first analysis on the basis of 18 oxygen atoms gives the following formula:

$$Bi_{0.99}(Cu_{5.88}Ca_{0.16})_{6.04}[(AsO_4)_{2.28}(PO_4)_{0.68}(SiO_4)_{0.10}]_{3.05}(OH)_{5.76} . 2.4 H_2O$$

The deficiency in molecular H_2O is possibly due to inaccuracy of the analysis.

In the present restudy, mixite was observed in association with bayldonite, zeunerite, metazeunerite, torbernite, metatorbernite, and parsonsite.

Lattice par. [Å]	1	a =13.608(5)		c = 5.904(6)
EDX, WDX		major elements: Bi, Cu, As		minor elements: P
Hardness	2	3 - 4		
Density [g.cm^{-3}]	2	D_m = 2.66		
IR [cm^{-1}]		284,384,428,473,535,802,842,1001, 1082,1624,3340,3490		
References		118, 121, 136, 143, 193		

1 - mixite, Jáchymov, Sejkora [193]
2 - mixite, Jáchymov, Schrauf [137]

Monohydrocalcite $CaCO_3 . H_2O$

It forms minute spheres with smooth surface, grey-white in colour. The mineral occurred exclusively with talmessite, also accompanied by picropharmacolite, köttigite, annabergite, and gypsum. It was identified only on several specimens of coarse-grained carbonate vein with isolated skutterudite grains from the Josef vein.

Moorhouseite $(Co,Ni, Mn)SO_4 . 6 H_2O$

Moorhouseite forms pseudomorphs after minute skeletal and orthorhombic tabular crystals of bieberite. It has a buff pink colour and a weak glassy lustre. It overgrows koritnigite and is accompanied by pink köttigite and picropharmacolite. The secondary minerals crystallised on fractured quartz-carbonate gangue.

Moorhouseite formed by spontaneous dehydration of bieberite.

It was identified on samples from the Geschieber and Evangelista veins.

Lattice par. [Å, °]		a =10.034(1)	b = 7.226(1)	c=24.277(4)
			β=98.356(2)	
EDX, WDX		major elements: Co, S		minor elements: Ni
References		275		

Morenosite $NiSO_4 . 7 H_2O$

Morenosite was described by Ulrich [195] as efflorescence composed of light blue-green fibrous aggregates and acicular crystals coating ore minerals. Indices of refraction are according to Ulrich [195] nearly identical to those given for natural morenosite by Topsoe and Christiansen [in 195]: n_α = 1.4669, n_β= 1.4888, n_γ = 1.4921. The mineral has a stringent taste [195].

EDX, WDX		major elements: Ni, S	minor elements: Fe
References		195	

Mottramite $PbCu(VO_4)(OH)$

Mottramite forms small spheres deposited on limonite-coated fractures in vein quartz. The spheres tend to coalesce to continuous crusts up to 0.5 mm thick or curtain-like aggregates. Its colour varies from light yellow-green to black-green.

Lattice par. [Å]	1	a = 7.65(1)	b = 9.25(1)	c = 6.03(1)
	2	a = 7.545(4)	b = 9.550(8)	c = 5.927(6)
	3	a = 7.50(1)	b = 9.66(4)	c = 5.91(2)
EDX, WDX	1	major elements: Pb, Cu, V		minor elements: Ca, As
	2	Pb, Cu, As		V, Ca, P
	3	Pb, Cu, V		Ca, As
References		156, 157		

1 - mottramite, Jáchymov. This study, (black-green)
2 - mottramite, Jáchymov. This study, (light yellow-green sample)
3 - mottramite, Jáchymov. This study, (dark-green)

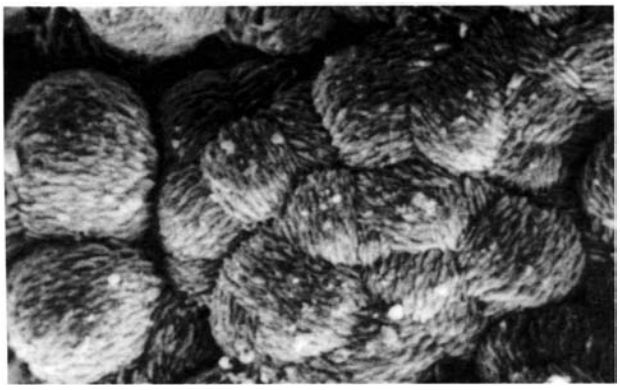
Mottramite from Jáchymov represents a member of a hypothetical mottramite-duftite compositional series. Differences in crystal structure between mottramite and duftite indicate that additional study is needed.

The lattice parameters for the specimen 1 (table above) are similar to those of mottramite [157]. The specimens 2 and 3 correspond to Ca-mottramite [156]. The X-ray powder diffraction data for mottramite from Jáchymov show some significant differences for some diffractions, compared to published data for mottramite.

X-ray powder diffraction patterns of mottramite from Jáchymov.

			1			2			3		
h	***k***	***l***	**I_{rel}**	**d_{obs}**	**d_{calc}**	**I_{rel}**	**d_{obs}**	**d_{calc}**	**I_{rel}**	**d_{obs}**	**d_{calc}**
			31	8.773		21	8.716		100	8.782	
						8	6.730				
0	1	1	40	5.044	5.042	51	5.009	5.044	31	5.046	5.038
			6	4.785					9	4.807	
0	2	0				6	4.650	4.620			
1	1	1	38	4.206	4.193	44	4.191	4.214	25	4.209	4.181
1	2	0				10	3.971	3.957			
2	0	0	5	3.792	3.776	5	3.834	3.834	8	3.707	3.747
			6	3.567							
2	1	0	15	3.518	3.511	16	3.541	3.541	10	3.526	3.489
1	2	1	14	3.341	3.336	22	3.343		44	3.360	3.334
			23	3.253					25	3.232	
			42	3.202							
2	0	1	66	3.188	3.186	100	3.224	3.234	51	3.189	3.167
						21	3.182				
2	2	0	37	2.964	2.969	54	2.969	2.950	21	2.973	2.962
			53	2.934	2.931				29	2.940	2.936
1	3	0	15	2.871		48	2.870	2.858	10	2.878	
2	2	1	100	2.651	2.650	88	2.651	2.649	52	2.654	2.641
1	1	2	34	2.627	2.654				10	2.628	2.647
			15	2.588		35	2.586		8	2.594	
0	2	2	19	2.515	2.521	20	2.505	2.522	8	2.518	2.519
3	1	0				5	2.4638	2.4633			
2	3	0	6	2.4389	2.4325						
3	0	1							5	2.2859	2.3018
3	1	1				29	2.2792	2.2798			
2	1	2	34	2.2654	2.2672				16	2.2648	2.2582
3	2	0				11	2.2525	2.2363			
1	4	0	5	2.2260		7	2.2158	2.2116			
1	4	1	7	2.1221	2.1240						
3	2	1	21	2.0824	2.0847	9	2.0929		9	2.0840	2.0744
1	3	2				16	2.0676	2.0726			
3	1	2	5	1.8882	1.8824						
3	3	1	27	1.8725	1.8731	16	1.8715	1.8695	12	1.8759	1.8668
2	0	3				5	1.7878	1.7781			
3	2	2							7	1.7701	1.7737
4	1	1	14	1.7652	1.7681	23	1.7654		5	1.7525	1.7560
1	3	3	32	1.6404		28	1.6412	1.6424	12	1.6424	
4	0	2	11	1.5901		7	1.6108	1.6169			
0	6	0				8	1.5426	1.5398			

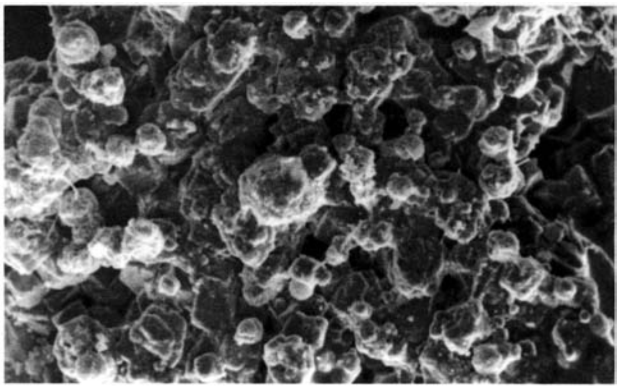
1 - mottramite, Jáchymov. This study, (black-green)
2 - mottramite, Jáchymov. This study, (light yellow-green sample)
3 - mottramite, Jáchymov. This study, (dark green)



Botryoidal crust of the light-coloured type of mottramite. Magnification 700

Mrázekite $Bi_2Cu_3(PO_4)_2O_2(OH)_2 . 2 H_2O$

Mrázekite forms thin coating on fractures or small isolated spheres up to 0.1 mm in diameter, deposited in cavities. The coatings are light blue, spheres are strong blue. It occurs with native Bi and secondary Bi minerals in porous vein quartz. Mrázekite is younger than pyromorphite as it is implanted on pyromorphite needles and older than pseudomalachite, which covers mrázekite. Small spheres of eulytite tend to be associated with mrázekite and they show a similar size.



Crystalline aggregates of mrázekite. Magnification 250

Mrázekite is also associated with torbernite which is deposited on pseudomalachite, and preisingerite, bismutite and petitjeanite, constituting pseudomorphs after native Bi. The specimen studied was collected in the Geister vein.

EDX, WDX		major elements: Bi, Cu, P	minor elements: Fe, Si, Ca
References		176	

Namibite $Cu(BiO)_2(VO_4)(OH)$

It is a light to dark green mineral forming coatings and minute acicular crystals enclosed in beyerite or overgrowing beyerite. Spheroidal aggregates of acicular crystals, 0.3 mm long in maximum, are deposited on quartz. Rarely, namibite accompanies spheroidal aggregates or individual crystals of eulytite. It occurs in vuggy, fractured, fine-grained quartz with disseminated native bismuth. Also associated with namibite are beyerite, eulytite, bismutite, and rare tabular crystals of pucherite.

Namibite was found on dumps of the Eliáš mine, in veinlets along gneiss-quartz porphyry contacts. All analytical data in table below are from Mrázek et al. [32]. Namibite is biaxial, with extremely high indices of refraction (n > 2.2); the median refraction index calculated following [153, 154] is 2.7. Chemical analysis: CuO 12.03, Bi_2O_3 72.24, V_2O_5 13.77, H_2O 1.51 Total 99.55 wt. %, can be recalculated on the basis of 7 (O,OH) to the following formula:

$$Cu_{0.98}(BiO)_{2.01}(VO_4)_{0.98}(OH)_{1.03} \, . \, 0.03 \, H_2O$$

Lattice par. [Å, °]		a= 11.877(2)	b = 3.702(1)	c = 7.497(1)
			β=109.76(1)	
EDX, WDX		major elements: U, Ca		minor elements: Cu, Sr, Fe
IR [cm^{-1}]		230,330,360,430,480,510,552,630,736, 850,1030,1630,3400		
Therm. analysis [°C], [wt. %]		430 - 490, 1.5 (dehydoxylation), 810 - 880, 0.6 (release of oxygen) endothermic reaction: 463, 796		
Density [g.cm^{-3}]		D_x = 6.91 for Z=2		
References		all data after Mrázek et al. [32], 153, 154		

Natrojarosite $NaFe_3(SO_4)_2(OH)_6$

Natrojarosite occurs as yellow dusty fill and coatings in weathered ore veins. It was formed by decomposition of pyrite and marcasite in a relatively dry environment. Natrojarosite is always accompanied by gypsum and often by limonite. It is common on all sulphide-bearing veins in Jáchymov. Older reports on jarosite occurrence in this ore district probably relate to natrojarosite.

The mineral was also described by Ulrich [194] as coating of walls with weathered pyrite in old workings.

Lattice par. [Å]		a= 7.331(3)		c =16.76(2)
References		194		

Neshquehonite $Mg[(CO_2OH)(OH)] \, . \, 2 \, H_2O$

It occurs as transparent to white, compact or fine-grained crusts up to 2 mm thick in patches 15 by 5 mm in maximum size. The crusts are deposited on altered rock together with dusty aggregates of bright-yellow sodium-zippeite. It fluoresces in intense yellow green to green in short-wave ultraviolet light. Neshquehonite, identified by Sejkora [203], was very rare on several specimens from the Geschieber vein at the fifth level of the Svornost mine.

Lattice par. [Å, °]	1	a = 12.12(1)	b = 5.365(4)	c = 7.701(4)
			β = 90.58(1)	
EDX, WDX	1	major elements: Mg		minor elements: Ca, Si, Pb a S
Density [g.cm^{-3}]	1	D_m = 2.686 (determined by pycnometer)		
References		203		

1 - Neshquehonite, Jáchymov. Sejkora [203]

Nickel-zippeite $Ni_2(UO_2)_6(SO_4)_3(OH)_{10} \, . \, 16 \, H_2O$

The mineral was first described in 1976 by Frondel [24] on type specimens from Happy Jack mine, Utah and from Jáchymov. For the specimen from Jáchymov, Frondel [24] gives Ni/Co ratio near to 10/3 and minor Fe and Zn. According to Frondel the Ni/Co ratio corresponds to relative contents in primary ores in the uraninite vein (smaltite-chloanthite and nickeline).

Nickel-zippeite aggregates are earthy or granular, soft or somewhat hardened, brown-yellow to orange yellow in colour. Nickel-zippeite, in analogy to zippeite, forms by relatively quick precipitation of free uranyl-sulphate ions, which are mobile and stable in highly acid solutions.

Nickel-zippeite was observed with gypsum, zippeite, sodium-zippeite, and johannite, exceptionally with jáchymovite, sklodowskite, and "pseudo-zippeite (Mg)".

See also other minerals of the zippeite group (sodium-zippeite, zippeite, magnesium-zippeite, "ferro-zippeite", "pseudo-zippeite (Mg)").

EDX, WDX	1	major elements: U, S, Ni	minor elements: Co
References		6, 24	

1 - nickel-zippeite, Jáchymov. Frondel [24]

Nickelhexahydrite $NiSO_4 \, . \, 6 \, H_2O$

It forms coatings and crusts with very fine crystalline texture, acicular crystals and glassy crusts. The crystals and glassy crusts are transparent to translucent, with a glassy lustre. Although the crystals are very brittle, one crystal 1 cm long and 1 mm wide at its base was observed.

Nickelhexahydrite occurs in Jáchymov at a depth of approximately 500 m, where it forms by oxidation of marcasite and nickel arsenides. Its coatings cover altered granite portions rich in clay minerals and vuggy quartz next to granite. The mineral is accompanied by annabergite, gypsum, a mineral similar to jarosite, and a probable lavendulan.

It is interesting that nickelhexahydrite was found only in the deepest level of the mine, near contact of granite with metamorphic rocks. Probably, granite buffers pH of solutions at values necessary for crystallisation of this mineral. The same vein some 50 m higher, positioned in metamorphic rocks, is free of nickelhexahydrite.

The quantitative chemical analysis by M. Waldman (1974) is NiO 22.69, MgO 4.07, CoO 0.21, SO_3 30.67, H_2O 41.96, Total 99.60 wt. %. Recalculation based on 10 oxygen atoms gives the formula:

$$(Ni_{0.78}Mg_{0.26}Co_{0.01})(SO_4)_{0.99} \,.\, 5.99\ H_2O$$

Lattice par. [Å, °]		a = 9.93(2)	b = 7.21(2)	c = 24.01(4)
			β = 98.03(2)	
EDX, WDX		major elements: Ni, S	minor elements: Mg, Co, Ca	
IR [cm^{-1}]	485,635,670,790,1120,1645,2370,3300 and 3470			
Density [$g.cm^{-3}$]	D_x = 2.01			
References	27, 114, 139			

Nováčekite $Mg(UO_2)_2(AsO_4)_2 .\ 12\ H_2O$

Nováčekite was always identified in a mixture with metanováčekite. It occurs in two paragenesis. In the first type it forms small and thin light yellow coating on vein carbonates with disseminated chalcopyrite and tennantite. Nováčekite probably formed by neutralisation of acid solutions containing uranyl-arsenate ions and Mg released from carbonates. The specimens were collected in the Evangelista vein.

The second type is represented by crystals up to 3 mm long with bismuthinite in vugs of vein quartz. Freshly exposed crystals are transparent to translucent and intense yellow. During 24 hours the crystals turn milky and gradually change to opaque. Specimens of this type come from vein fragments on the dump of the Eliáš mine.

EDX, WDX		major elements: U, Mg, As	minor elements: Ca

Olivenite $Cu_2(AsO_4)(OH)$

It occurs as minor spheres to 0.2 mm in diameter, composed of dark olive radiating crystals. The aggregates are deposited on botryoidal aggregates of strashimirite. Olivenite is associated with lavendulan and lindackerite on fractures of vein quartz carrying minor tennantite and pyrite.

Lattice par. [Å, °]		a = 8.230(5)	b = 8.627(4)	c = 5.934(3)
			β=90.119(6)	
EDX, WDX		major elements: Cu, As	minor elements:	
References		240		

Opal $SiO_2 .\ n\ H_2O$

Opal forms transparent coating on fractures and vugs of vein quartz. It also fills free spaces as massive material coloured yellow-brown by disseminated limonite. Opal is associated with secondary Pb minerals in the Geister vein.

Orpiment As_2S_3

It occurs as thin cleavable grains of bright yellow colour along cleavages of a carbonate in specimens with arsenic and proustite. Proustite forms minute crystals and powdery pseudomorphs after skeletal crystals of silver originally intergrown in arsenic.

The specimens are from the Geschieber vein.

Pararealgar *AsS*

Pararealgar occurs as thin powdery or fine-grained coating of brown-orange colour on specimens of arsenic intergrown with carbonate and on realgar crystals grown on native arsenic. Pharmacolite and rösslerite occur on pararealgar.

The specimens originate in the Geschieber vein.

Parascorodite $FeAsO_4 .\ 2\ H_2O$

Jáchymov is the second locality for parascorodite, after the type locality Kutná Hora, Czech Republic [290].

The mineral occurs in very rare earthy aggregates with a conchoidal fracture. The aggregates are deposited in small cavities of quartz gangue with pyrite and proustite, accompanied by small spheres of kaňkite. The specimens analysed appear to be always a mixture of scorodite and parascorodite. The specimens were collected in the Geschieber vein.

References		67, 290

Parasymplesite $Fe_3(AsO_4)_2 .\ 8\ H_2O$

In Jáchymov, this mineral occurs always in a mixture with symplesite. Both the minerals form flat radiating aggregates up to 5 mm in diameter, composed of minor acicular crystals. It is green, light green to black-green, often with a blue shade.

Lattice par. [Å, °]		a = 10.41(4)	b = 13.44(5)	c = 4.83(2)
			β=105.46(6)	
EDX, WDX	1	major elements: Fe,As	minor elements: Mn<Co	
	2	Fe,As	Mn~Co	
	3	Fe,As	Mn>Co	
References		27, 91, 112		

1 - parasymplesite, Jáchymov. This work (needle end)
2 - parasymplesite, Jáchymov. This work (needle centre)
3 - parasymplesite, Jáchymov. This work (aggregate centre)

Parasymplesite often accompanies glassy green-brown amorphous Fe, Ni - arsenates, which form in the first stage of decomposition of Fe, Co, Ni - sulpho-arsenides (arsenopyrite, löllingite, skutterudite, marcasite, a. o.). It also occurs with köttigite and arsenates of Mg and Ca, as well as on specimens with native arsenic.

Parnauite $Cu_9(AsO_4)_2(SO_4)(OH)_{10} . 7 H_2O$

Parnauite was identified in association with chalcophyllite in coating of light green spheroidal aggregates, with individual spheres to 2 mm. The diffuse and weak diffractions suggest that parnauite formed by rather rapid precipitation from weakly acid to neutral solutions. The specimens from the Svornost mine, carrying parnauite with chalcophyllite represent the single confirmed occurrence.

EDX, WDX		major elements: Cu, As	minor elements: Al

Parsonsite $Pb_2(UO_2)(PO_4)_2 . 2 H_2O$

Parsonsite forms yellow to brown-yellow acicular crystals, exceptionally to 4 mm long, with a waxy-glassy lustre. The crystals occur sometimes in radiating groups. It is deposited on pyromorphite which covers limonite (or Mn-oxide) coated quartz. Alternatively, parsonsite crystallised on transparent torbernite-metatorbernite. It is associated also with mottramite. Another type of parsonsite forms minute radiating spheres of acicular crystals, accompanied by churchite-(Y), meta-autunite, ferruginous pseudomorphs after meta-autunite, and by corkite.

Lattice par. [Å, °]		a = 6.873(6)	b=10.416(5)	c = 6.684(3)
		α=101.41(6)	β=98.358(7)	γ = 86.39(1)
EDX, WDX		major elements: Pb, P, U	minor elements:	
References		241, 268		

Petitjeanite $Bi_3O(OH)(PO_4)_2$

It was identified most often in a mixture with bismutite as powdery to earthy fill in cavities after leached native Bi in vein quartz. Powdery petitjeanite is light grey buff, the earthy type is somewhat darker and more brownish. Exceptionally, it was identified in compact pseudomorphs after native Bi, which are composed dominantly of bismutite and preisingerite. Petitjeanite belongs to the youngest secondary Bi minerals. Though it occurs in the same vein as mrázekite, the succession relation could not be determined, since the two minerals have not been found together.

Pharmacolite $Ca[(H_2O)_2AsO_3(OH)]$

Acicular crystals elongated parallel the c axis are most common. They are typically 3 to 5 mm long, but crystals up to 15 mm long have been found. Radiating aggregates and crystalline crusts are very common. It is colourless, grey or yellowish, transparent to translucent with a glassy lustre and a perfect (010) cleavage.

Chemical analysis was done by M. Waldmann in 1975: As_2O_5 52.74, CaO 26.12, MgO 0.21, H_2O 21.16, insoluble residue 0.31, Total 100.54 wt. %, corresponds to the following formula (recalculation based on 6 oxygen atoms):

$$Ca_{1.00}Mg_{0.02}(HAsO_4)_{0.91}(AsO_4)_{0.07} . 2.06 H_2O$$

It occurs with picropharmacolite on primary ores containing As or native As in carbonate gangue. The other associated minerals include rösslerite, minerals of the erythrite group, haidingerite, and sometimes gypsum.

Lattice par. [Å, °]		a = 5.948(1)	b = 15.41(1)	c = 6.267(1)
			β=114.42(2)	
EDX, WDX		major elements: As, Ca	minor elements: Si, Bi, Fe, Mg	
IR [cm^{-1}]	1	425, 435, 460, 540, 620, 670, 708, 875, 915, 1120, 1190, 1390, 1640, 1700, 2380, 2870, 2930, 3230, 3465, 3555		
	2	420, 435, 460, 545, 625,675, 715, 880, 915, 1130, 1195, 1405, 1655, 1705, 2380, 2945, 3225, 3470, 3540		
	3	435, 460, 540, 620, 665, 707, 875, 910, 1025, 1125, 1185, 1395, 1455, 1640, 1700, 2380, 2860, 2945, 3220, 3465, 3535		
Therm. analysis [wt. %, °C]		0.5 (20-110), 6.75 (110-200), 10.75 (200-285), 3.0 (285-495), 1.0 (495-1000) at 250 °C endothermic dehydratation and dehydoxylation, at 460 °C endothermic recrystalization of anhydrous arsenate		
Density [g.cm^{-3}]		D_m = 2.686, D_x = 2.732		
References		27, 68, 105, 107, 115, 130, 135		

1, 2, 3 - different type of pharmacolite, Jáchymov. This work

Pharmacosiderite $KFe_4(AsO_4)_3(OH)_4 . 6\text{-}7 H_2O$

It was identified only in a single specimen as yellow-brown to brown-black indistinct crystalline aggregates. It shows no cleavage and it has a glassy lustre on fracture surface. Pharmacosiderite was observed in paragenesis with erythrite in sample PF20851 collected in 1853 and originally listed as *ganomatit*.

Lattice par. [Å]		a= 15.993(3)		
EDX, WDX		major elements: Fe, As, Si, K, Al	minor elements: Co, Ni, Zn, Ca, S	
References		269		

Phosphuranylite $KCa(H_3O)_3(UO_2)_7(PO_4)_4O_4 . 8\ H_2O$

This mineral occurs, together with unidentified phases, only in several specimens as crystalline coating and crusts composed of fine, yellow accicular crystals.

The mineral probably corresponds to intermediate members of the series phosphuranylite - yingjiangite, with predominance of Ca above K.

The X-ray powder pattern does not show good correspondence with the pattern in the original description [227].

Lattice par. [Å]		a = 15.48(2)	b =17.41(4)	c = 13.82(2)
EDX, WDX		major elements: U, P, Ca	minor elements: K	
References		277		

Picropharmacolite $Ca_4Mg(AsO_4)_2(AsO_3OH)_2 . 11\ H_2O$

Picropharmacolite is a common secondary mineral in Jáchymov. It occurs in white acicular to hair-thin crystals grouped in radiating aggregates and spheres.

Lattice par. [Å, °]		a= 13.546(5)	b=13.528(5)	c = 6.728(3)
		α=99.823(5)	β=96.511(5)	γ= 91.576(4)
EDX, WDX		major elements: Ca, As, Mg	minor elements: (Sr)	
IR [cm^{-1}]		420, 435, 460, 625, 730, 810, 870, 900, 1030, 1120, 1260, 1400, 1535, 2300, 2380, 2540, and 5425		
Therm. analysis [wt. %] [°C]		13.6 (20-245), 9.2 (245-575) endothermic reaction: 180, 385 exothermic reaction: 690		
Density [g.cm^{-3}]		D_m = 2.605, D_x = 2.630 (determined by pycnometer)		
References		27, 68, 107, 130, 131		

The aggregates are either compact or carry a compact core from which radiate thin, up to 1 cm long crystals. It also forms botryoidal or compact crusts. Picropharmacolite tends to accompany nearly all secondary arsenates. A pale pink variety is probably coloured by a minor cobalt admixture.

The quantitative chemical analysis As_2O_5 49.11, MgO 4.46, CaO 23.66, H_2O 22.69, insoluble residue 0.40, Total 100.32 wt. %, analyst P. Povondra 1976 (Geological Institute, Czechoslovak Academy of Science).

Recalculation of the analysis on 16 oxygen atoms gives the following formula:

$$Ca_{3.95}Mg_{1.04}(AsO_4)_{1.97}(AsO_3OH)_{2.03} . 10.77\ H_2O$$

Pitticite (amorphous hydrated Fe-arsenates-sulphates)

Pitticite was described as a secondary red-brown mineral, which forms compact masses with a botryoidal surface; it is yellow when powdered. Pitticite can be overgrown by gypsum and pharmacolite. It also forms dropstone and fills vugs. Occurrences in the Anna, Himmel Krone, Geister, and Geschieber veins were recorded by [118].

Plumbojarosite $PbFe_6(SO_4)_4(OH)_{12}$

Plumbojarosite occurs as very fine-grained, soft earthy aggregates up to 2 mm long. The colour is light brown. It is deposited on the surface of samples carrying gypsum, uranopilite and minerals of the zippeite and jarosite group. The specimens originate from the Evangelista vein.

Lattice par. [Å]		a = 7.318(1)		c = 33.73(1)
EDX, WDX		major elements: Pb, S, Fe	minor elements:	
References		98		

Posnjakite $Cu_4(SO_4)(OH)_6 . H_2O$

It is always mixed with langite in small, strong blue crystalline patches. The aggregates consist of imperfectly shaped crystals, deposited on fractures of vein quartz close to tennantite or chalcopyrite, which served as a source of Cu and S. Posnjakite is associated with brochantite, devilline, and gypsum.

EDX, WDX		major elements: Cu, S	minor elements:
References		242	

Preisingerite $Bi_3O(AsO_4)_2(OH)$

Preisingerite associated with atelestite occurs as compact aggregates or irregular veinlets with surface of up to several cm^2 in vein quartz. The yellow to dark grey aggregates show a pitch-like lustre (similar to that of mimetite) and a moderate hardness.

Preisingerite associated with bismutite constitute pseudomorphs after native Bi. The pseudomorphs are rather similar to quartz but show a stronger lustre. Relics of native bismuth were observed in cores of some pseudomorphs.

Preisingerite occurs in two paragenesis:

1. *paragenesis with atelestite*: atelestite, native bismuth, beyerite and walpurgite; it was identified in specimens from the Rovnost I shaft.
2. *paragenesis with bismutite*: bismutite, bismutoferrite, walpurgite, torbernite, and metatorbernite; it was identified on the Geister vein.

Lattice par. [Å, °]	1	a = 9.986(7)	b = 7.401(8)	c = 6.943(7)
		α= 87.77(1)	β=115.14(1)	γ= 111.03(1)
EDX, WDX	1	major elements: Bi, As	minor elements: P	
References		92		

1 - Preisingerite from paragenesis with atelestite

Proustite Ag_3AsS_3

Secondary proustite forms powdery fill of minor cavities after leached skeletal crystals of silver, originally intergrown in arsenic in a carbonate veinlet. The secondary proustite is red-brown.

The specimen was collected in the Geschieber vein.

Pseudomalachite $Cu_5(PO_4)_2(OH)_4$

It was found on a single specimen as a botryoidal crust on altered wallrock, free of additional minerals. The individual small aggregates are up to 2 mm across, blue-green in colour, with a matte glassy lustre. The specimen is from the Geister vein.

Psilomelane (amorphous Mn-oxides)

It occurs as black powdery or earthy coating on fractures and as thin depositions between layers of secondary minerals. Psilomelane also occurs on radiating aggregates of talmessite.

Pucherite $BiVO_4$

Pucherite forms rare brown tabular crystals with an adamantine lustre, exceptionally up to 1.5 mm long. The crystals occur in widely disseminated small clusters deposited on powdery bismutite, which fills places among eulytite spheres. It is accompanied by beyerite and namibite. Pucherite was found on dump of the Eliáš mine.

Sejkora [193] gave two quantitative analyses of pucherite: Bi_2O_3 72.82 (72.62), V_2O_5 24.74 (24.97), As_2O_5 0.50 (1.55), P_2O_5 1.68 (0.69), Total 99.74 (99.83) wt. %, which were calculated on the basis of four oxygen atoms to the formula:

$$Bi_{1.03}(V_{0.90}As_{0.03}P_{0.05})O_4$$

Lattice par. [Å]	1	a = 5.08(1)	b = 12.04(3)	c = 5.27(1)
References		121		

1 - pucherite, Jáchymov. Sejkora [193]

Pyrolusite MnO_2

It occurs as black lenticular crystals, as steel grey, short prismatic crystals with longitudinal striation, or as granular aggregates showing locally radiating structure, deposited on fractures of a porous vein quartz. Pyrolusite is the oldest mineral in the succession pyrolusite - coronadite - cryptomelane. It occurs in the Mariánská locality.

Pyromorphite $Pb_5(PO_4)_3Cl$

Pyromorphite forms compact light yellow mass with a high waxy lustre, filling small vugs in quartz veins.

Lattice par. [Å]	1	a = 9.926(3)		c = 7.292(5)
	2	a = 9.875(3)		c = 7.218(6)
EDX, WDX	1	major elements: Pb, P		minor elements: Ca
	2	Pb, P, Ca		As
IR [cm^{-1}]		400,440,480,550,580,795,810,1030		
References		27, 90		

1 - pyromorphite, Jáchymov. This study
2 - pyromorphite, Jáchymov. This study

It represents one of the youngest secondary Pb minerals. Pyromorphite was also found in minute white acicular crystals. It is associated with wulfenite, parsonsite, mottramite, and other minerals in the Geister vein.

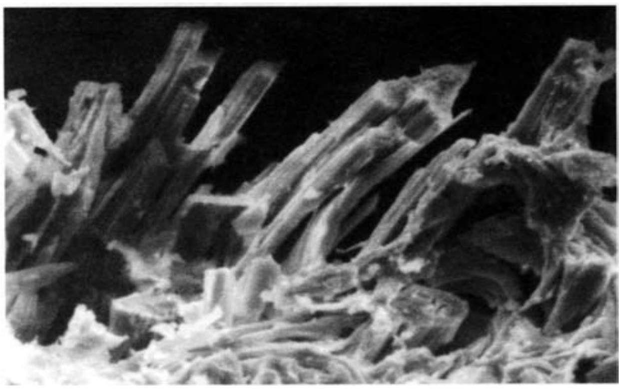
X-ray powder diffraction patterns of rabbittite from Jáchymov.

Minute crystals of the youngest generation of pyromorphite grown on needles of Ca-pyromorphite. Magnification 400

Rabbittite $Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 . 18 H_2O$

Rabbittite occurs in radiating aggregates of freely grown acicular crystals, which are often malformed, including bent and conical crystals. It does not fluoresce in ultraviolet light.

Lattice par. [Å, °]		a= 32.492(2)	b=23.654(8)	c = 9.410(3)
			β=89.838(5)	
		V = 7232.3(5)		
EDX, WDX		major elements: U, Ca, F (C not analysed)		minor elements: S, Mg
References		12, 54		



Aggregates of imperfect acicular crystals of rabbittite. Magnification 700

It is often associated with zellerite, schröckingerite, liebigite, and gypsum, which constitute coating of weathered uraninite-bearing vein.

The qualitative chemical analysis of rabbittite from Jáchymov confirmed an elevated content of fluorine, which probably substitutes for the (OH) group in the above formula. X-ray powder diffraction pattern corresponds to the original rabbittite data [54].

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
29	19.096	19.123	1	1	0	9	6.754	6.812	3	1	1	15	4.018	4.030	6	3	-1
21	13.390	13.392	2	1	0	18	6.442	6.498	5	0	0	15	4.018	4.008	4	1	-2
43	11.099	11.114	1	2	0	11	5.902	5.913	0	4	0	21	3.871	3.854	4	2	2
23	9.834	9.847	3	1	0	30	5.807	5.818	1	4	0	13	3.818	3.816	5	0	2
12	9.543	9.562	2	2	0	32	5.660	5.658	4	3	0	23	3.548	3.547	4	6	0
15	9.165	9.046	1	0	1	18	4.473	4.464	6	3	0	25	3.340	3.340	9	1	1
23	8.997	9.032	1	0	-1	30	4.375	4.374	5	4	0	17	3.308	3.308	2	7	0
100	8.135	8.133	2	0	-1	34	4.331	4.334	1	2	2	5	2.854	2.852	3	8	0
39	7.733	7.691	2	1	-1	9	4.268	4.259	4	4	-1	13	2.800	2.801	11	1	1
22	7.362	7.364	0	2	1	5	4.180	4.191	1	5	-1	8	2.691	2.690	12	1	0
82	7.090	7.093	2	3	0	23	4.065	4.062	8	0	0						

X-ray powder diffraction pattern of rabejacite from Jáchymov.

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
13	8.585	8.592	1	0	0	23	2.857	2.860	2	3	3	6	2.0750	2.0733	4	0	2
28	8.347	8.347	0	2	0	14	2.824	2.823	0	5	3	2	2.0568	2.0574	4	1	2
100	7.924	7.926	0	0	2	12	2.778	2.779	3	1	1	5	2.0478	2.0435	0	7	4
2	7.606	7.640	1	1	0	4	2.691	2.694	3	0	2	5	2.0130	2.0141	1	5	6
3	7.169	7.160	0	1	2	3	2.680	2.682	1	5	3	2	1.9967	1.9957	3	6	0
3	5.226	5.251	0	3	1	8	2.640	2.642	0	0	6	5	1.9806	1.9809	2	4	6
1	4.347	4.346	1	1	3	7	2.604	2.605	2	4	3	3	1.9360	1.9357	4	2	3
30	4.154	4.161	2	1	0	3	2.550	2.551	2	0	5	3	1.8999	1.8962	4	4	1
46	3.960	3.962	1	2	3	2	2.507	2.511	1	6	2	4	1.8837	1.8849	2	3	7
4	3.622	3.599	1	0	4	<1	2.4754	2.4620	0	6	3	2	1.8475	1.8465	0	8	4
43	3.479	3.500	1	3	3	5	2.4344	2.4396	2	2	5	3	1.7954	1.7962	4	4	3
16	3.409	3.401	2	3	0	1	2.3909	2.3887	2	4	4	5	1.7551	1.7564	0	6	7
7	3.381	3.393	1	4	2	1	2.2848	2.2838	0	7	2	11	1.7414	1.7422	2	7	5
17	3.346	3.339	0	5	0	5	2.2158	2.2209	1	5	5	6	1.7283	1.7254	1	0	9
8	3.245	3.228	0	3	4	10	2.1589	2.1606	1	4	6	5	1.7194	1.7205	4	4	4
9	3.174	3.170	0	0	5	12	2.1354	2.1361	2	6	3	5	1.7017	1.7030	2	9	0
9	3.132	3.125	2	3	2	8	2.1245	2.1253	3	0	5	4	1.6769	1.6771	3	8	1
6	2.956	2.964	0	2	5	4	2.1062	2.1074	1	7	3						

The unit cell parameters given in the table above represent an improvement in precision by two or three orders, compared to values presented in [54]. Newly measured X-ray powder diffractions and their indices are included above

Rabejacite $Ca(UO_2)_4(SO_4)_2(OH)_6 . 6 H_2O$

Rabejacite was identified in a single specimen collected in 1887. It forms soft earthy aggregates up to 1 mm long, across an area of several cm^2. The aggregates are fine-grained, strong yellow with a green grey shade. The mineral fluoresces yellow-white of a moderate intensity in UV light.

Aggregate of small rabejacite crystals showing acute double termination. Magnification 900

Rabejacite occurs in paragenesis with johannite deposited on strongly weathered uraninite breccia.

Lattice par. [Å]		a = 8.592(4)	b=16.695(7)	c= 15.852(8)
References		19		

Rauenthalite $Ca_3(AsO_4)_2 . 10 H_2O$

It was found by Fontan [237] on a brassite specimen in a mixture with weilite, haidingerite and pharmacolite. No detailed description is available. The specimen is deposited in the collections of École nationale supérieure des mines in Paris.

Retgersite $NiSO_4 . 6 H_2O$

Retgersite from Jáchymov was described by Sejkora and Řídkošil [47] as crusts deposited on gersdorffite and veinlets penetrating this mineral. It forms apple green granular mass or blue-green fibrous aggregates. Retgersite is accompanied by gypsum, aragonite, and fine-grained annabergite. It is easily soluble in water. A quantitative wet chemical analysis: NiO 28.31, SO_3 29.77, MgO 0.63, CaO 0.33, FeO 0.09, CoO 0.12, H_2O 40.35, Total 99.60 wt. %, gives on recalculation to four oxygen atoms the formula:

$$(Ni_{1.01}Mg_{0.04}Ca_{0.02})(S_{0.99}O_4) . 5.96 H_2O$$

The indices of refraction are n_o = 1.511(3) and n_e=1.483(3). The authors [47] suggested that retgersite formed directly in its primary occurrence, not by dehydration of heptahydrate (i.e., morenosite). This is indicated by the fact that no morenosite was found in the specimen rich in retgersite. It was also noted that temperatures of crystallisation of morenosite, retgersite, and nickelhexahydrite are 31.5, 31.5 to 53.5, and 53.5°C respectively. The crystallisation temperature can be lowered by surplus acid by as much as 15°C. Surplus acid can be expected in the environment of Jáchymov veins.

Lattice par. [Å]	1	a = 6.772(1)		c=18.249(5)
IR [cm^{-1}]	1	467,631,797,1100,1306,1635,1689, 1755,2364, 3418		
Therm. analysis [°C]	1	Endothermic reaction: 130 (2 H_2O), 170 (3 H_2O), 405 (H_2O), 910 (disintegration $NiSO_4$ to NiO a SO_3)		
References		47, 103, 179, 180		

1 - retgersite, Jáchymov. Sejkora et al. [47]

Sejkora and Řídkošil [47] indicated location of retgersite-bearing specimens as the fifth level of the Svornost mine, the Geschieber vein, because this locality was given in the description of krutovite as a new mineral [180]. The circumstances of collecting of these specimens are somewhat complicated. Kašpar and Paděra [179], in their first description of krutovite as gersdorffite with unusually large unit cell, indicated Potůčky as the locality, where the material was collected in 1963 at a secondary storage place. This results in some uncertainty concerning the original locality of krutovite and retgersite specimens.

Rhomboclase $HFe(SO_4)_2 . 4\ H_2O$

Rhomboclase was identified in a single specimen (No. NM 17259) in the collection of the National Museum in Prague. This specimen was originally designated as morenosite.

It forms grey-white powdery efflorescence and coating on weathered gangue material with pyrite and marcasite. The analyses correspond to a mixture of rhomboclase with a member of the series gunningite-szomolnokite.

EDX, WDX		major elements: Fe, S	minor elements: Zn

Richetite $PbU_4O_{13} . 4H_2O$

The mineral was identified in a single specimen as brown yellow powdery aggregates about 2 cm^2 in size. Richetite formed as an immediate weathering product of uraninite or gummite. It is accompanied by an unidentified orange-brown oxide, listed in this study as "UO_3-H_2O(1)", green aggregates of antlerite, zeunerite and langite mixture, and light yellow aggregates of tabular crystals representing a mixture mainly of metazeunerite and nováčekite.

The unit cell dimensions of Jáchymov richetite show clearly shifts in comparison with the original data [258], but the unit cell volume is comparable. The indices of diffractions presented in [258] correspond very well to the measured pattern.

Lattice par. [Å, °]		a=20.352(7)	b=12.232(7)	c=16.252(5)
		α=103.86(1)	β=114.92(1)	γ=89.47(1)
EDX, WDX		major elements: U, Pb	minor elements: Si,Cu,V	
References		21, 258		

X-ray powder diffraction pattern of richetite from Jáchymov (sample J-361).

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
15	16.285					3	3.849	3.833	-5	1	1	8	2.2862	2.2857	2	5	-4
4	15.656					22	3.787	3.795	-5	1	2	13	2.2549	2.2546	2	2	-7
10	15.201					17	3.710	3.716	1	-3	2	5	2.2057	2.2069	8	1	-6
27	10.437	10.440	-1	1	0	32	3.576	3.575	-2	3	1	5	2.1784	2.1784	6	0	3
3	9.696					44	3.551	3.558	0	0	4	10	2.1597	2.1603	7	-2	2
11	8.382	8.355	1	-1	1	21	3.485	3.480	-3	3	0	5	2.1074	2.1079	2	-5	4
48	7.779					15	3.375	3.374	-5	2	1	4	2.0896	2.0894	-9	1	5
64	7.693					7	3.305	3.303	0	2	3	4	2.0666	2.0674	8	2	0
48	7.141	7.117	0	0	2	100	3.216	3.220	-6	1	1	19	2.0353	2.0350	0	3	-7
9	6.769	6.784	-3	0	1	21	3.174	3.178	1	3	-4	6	2.0204				
5	6.414					10	3.103	3.107	3	-3	2	34	1.9776				
10	6.047	6.038	0	2	-1	13	3.052	3.053	0	-4	1	6	1.9669				
18	5.945	5.924	-1	1	2	19	2.922	2.920	2	0	4	9	1.9311				
18	5.945	5.905	0	2	0	15	2.904	2.900	-7	0	2	21	1.8952				
23	5.676	5.680	-3	1	0	3	2.824	2.818	6	2	-1	12	1.8563				
8	5.211	5.216	3	1	0	13	2.765	2.766	-7	1	1	2	1.8147				
16	5.049	5.051	-4	0	1	6	2.637	2.633	0	-4	4	6	1.7967				
10	4.980					9	2.625	2.627	-3	0	6	6	1.7739				
5	4.546	4.565	1	2	1	8	2.572	2.574	4	3	1	1	1.7543				
4	4.458	4.459	-4	1	2	11	2.518	2.516	-2	2	5	14	1.7296				
9	4.314	4.294	1	-1	3	1	2.505	2.506	0	4	2	8	1.7200				
5	4.177	4.178	3	2	-3	10	2.4479	2.4483	-6	3	3	3	1.6701				
1	4.062	4.056	0	2	2	11	2.3715	2.3722	0	0	6	11	1.6425				
10	3.976	3.966	1	-3	1	7	2.3073	2.3069	-8	2	1	5	1.5963				
21	3.925	3.934	-1	3	0												

Römerite $Fe^{2+}Fe_2^{3+}(SO_4)_4 . 14\ H_2O$

It was analysed in a mixture with an unidentified sulphate. The mixture forms a light pink efflorescence composed of very fine rhombohedral crystals adhering to pyrite. Römerite formed by a slow decomposition of pyrite, probably in a low-humidity environment.

EDX, WDX		major elements: Fe, S	minor elements: Si

Rösslerite $MgHAsO_4 . 7\ H_2O$

Rösslerite usually forms colourless or milky white single crystals 1 to 40 mm in size. The crystals are typically tabular on (010) and contact matrix by this face. Crystals of prismatic habit parallel the vertical zone show parallel growth on (010). On rare occasions, rösslerite occurs as acicular crystals in radiant groups. This type of rösslerite is similar to picropharmacolite, except for a rather weak vitreous lustre of the former species. Rösslerite also forms coatings and crystalline crusts. Skeletal or bent crystals, reminiscent of some quickly growing soluble sulphates, were also observed. Some rösslerite crystals are matte. A weak blue green shade in some specimens is caused by Ni and Cu admixture.

Rösslerite is often intergrown with pharmacolite or encloses acicular crystals of picropharmacolite. Rarely it is overgrown by sainfeldite. Köttigite, parasymplesite, and symplesite accompany rösslerite in few cases. All these minerals are deposited on vein carbonates intergrown with partly altered primary ore minerals including skutterudite, native arsenic, bismuth, and sphalerite. Rösslerite and associated secondary minerals form by alteration of arsenic-bearing ores.

It occurs in long time abandoned mine workings, typically at a depth near 160 m. The tabular crystals are recorded mainly from levels between -120 and -240 m. At deeper levels, it attains a different habit and becomes scarce. At the levels -350 to -400 m it forms small acicular aggregates similar to picropharmacolite.

The quantitative chemical analysis: As_2O_5 39.45, MgO 14.08, H_2O 46.26, insoluble residue 0.36, Total 100.15 wt. %; analyst P. Povondra, ČSAV, 1976. Recalculation on the basis of 11 oxygen atoms results in the formula:

$$Mg_{1.02}H_{0.96}AsO_4.\ 7.00\ H_2O$$

Larsen presented optical data for rösslerite under the heading of wapplerite. Optical character of the mineral is positive, $n_\alpha = 1.525$, $n_\beta = 1.53$, $n_\gamma = 1.550$, 2V is small or moderate.

In a dry environment rösslerite turns white during several weeks and alters to brassite. The alteration starts from randomly positioned sites, including positions inside crystals. In other instances, rösslerite remains unaltered in collections for time longer than 20 years. Possibly, presence of free sulphuric or arsenic acid supports water retention in rösslerite. X-ray diffraction examination of some whitened rösslerite crystals shows no newly formed crystalline phase.

The paragenesis of rösslerite is similar to that of brassite. However, haidingerite and other minerals, which remain transparent, are more striking than brassite in old specimens.

IR [cm^{-1}]		475,740,860,885,1055,1120,(1465), 1655,2440,2945 a 3430
Density [$g.cm^{-3}$]		$D_m = 1.911$, $D_x = 1.945$
Water content [wt. %]		46.25
References		27, 68, 107, 135, 145

Rozenite $FeSO_4 . 4\ H_2O$

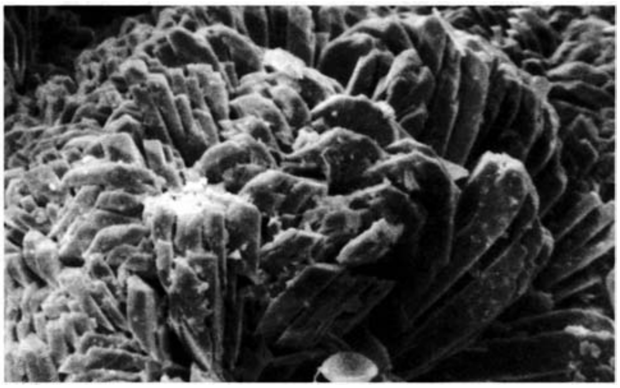
Rozenite forms brittle clusters of irregular skeletal crystals, in part fibrous or striated parallel to elongation, which are in part bent. It is grey-green, with milky clouding, translucent. Rozenite occurs in the same paragenesis as melanterite, because it forms by dehydration of melanterite. Dehydration depends on environment of a particular specimen. Separated, powdered pure melanterite dehydrates in less than one hour. Melanterite next to partly weathered pyrite matrix, i.e., with hygroscopic sulphuric acid, may persist unaltered.

The alteration of melanterite to rozenite is reversible. Additional hydration of rozenite results in its alteration to szomolnokite [292].

Sainfeldite $Ca_5(AsO_4)_2(AsO_3OH)_2 . 4\ H_2O$

Sainfeldite occurs in Jáchymov in small spheres, less than 1 mm in diameter, in part clustered in grape-like aggregates. Some spheres are hollow, others are composed of radiating acicular crystals. The spheres are milky white to vitreous transparent; occasional pink violet sainfeldite contains up to 1 wt. % MnO.

Lattice par. [Å, °]		a=18.656 (4)	b= 9.489(2)	c= 10.015(3)
			β=96.932(3)	
IR [cm^{-1}]		440, 480, 640, 755,(860), 885, (900), 1055, 1110 1290, 1640, 1460, 1640, 2315, 2485, 2890, 2950, 3240 a 3475 (data identical with villyallenite from Jáchymov)		
EDX, WDX		major elements: Ca, As	minor elements: Mn,Mg,Cu,Zn,Co	
References		27, 68, 69, 71, 107, 130, 151		



Surface of spheroidal aggregates of sainfeldite. Magnification 300

X-ray diffraction pattern of Jáchymov sainfeldite does not compare closely enough to published data on this mineral [130]. It corresponds better to Ca-villyaellenite [69]. Because these minerals are isostructural, variation in diffraction pattern may depend largely on the Mn/Ca ratio.

Sainfeldite occurs with Ca-Mg arsenates and with minerals of the erythrite group.

Scorodite $FeAsO_4 . 2 H_2O$

Scorodite is a relatively common mineral forming radiating aggregates of acicular crystals, or compact spheres. The mineral has a vitreous lustre and white, greenish grey or brown-yellow colour. It occurs on vein quartz or intergrown with dickite next to weathered native arsenic, löllingite or arsenopyrite. Scorodite with a metallic lustre and white streak forms sometimes compact pseudomorphs after decomposed löllingite or arsenopyrite.

Lattice par. [Å, °]		a= 8.9530(7)	b=0.3264(6)	c=10.0456(8)
References		66, 257		

Schoepite $[(UO_2)_8O_2(OH)_{12}] . 12 H_2O$

It was identified as a minority component in long yellow acicular crystals is specimen No. NM 24272, designated as *β-uranopilite*, in collection of the National Museum, Prague. Uranophane is the main species besides schoepite.

References		280

Schröckingerite $NaCa_3[(UO_2)(CO_3)_3](SO_4)F . 10 H_2O$

This mineral was found in 1873 by Schröckinger, who named it *Uranoxyd-Karbonat* [159]. In the same year, Schrauf [183] published description of this mineral and named it schröckingerite. The type specimen was collected in the Evangelista vein.

The original description by Schrauf [183] gives only a qualitative determination of U, CO_2, H_2O, minor CaO and traces of SO_3. Loss on ignition was 36.7 wt. %. Nováček [211] reported the following analysis: CaO 19.1, UO_3 32.4, SO_3 9.1, H_2O 20.2, insoluble residue 0.4, loss on ignition 36.04, Total 100.12 wt. %. Na_2O and CaO were not determined for lack of material.

Schrauf [183] gave the angle of 58.5° between edges of the hexagonal plates; following Nováček [211] the angle is 60° and the mineral with perfect basal cleavage is hexagonal. It is pleochroic: X- colourless to light yellow, Y and Z - light green-yellow, optically negative, with 2V 0 to 25°, exceptionally 40°. The indices of refraction are $n_\alpha = 1.496$, $n_\beta = n_\gamma = 1.539$ to 1.545.

Minute scales and hexagonal platy crystals, somewhat similar to uranium micas, make soft, earthy aggregates. The aggregates are transparent, with a high vitreous to pearly lustre, yellow to greenish yellow. It fluoresces bright yellow-green in ultra-violet light.

Schröckingerite is fairly soluble, especially at pH<4 (Kašpar [106]). Its occurrence thus indicates a lower acidity, in agreement with association with uraninite-carbonate. It is deposited on uraninite or in its proximity. Schröckingerite is accompanied and penetrated by liebigite. The aggregates of these two minerals are unlike schröckingerite and they are rather similar to andersonite. Coating of uranyl-carbonates avoids pyrite or marcasite grains, which are covered by limonite.

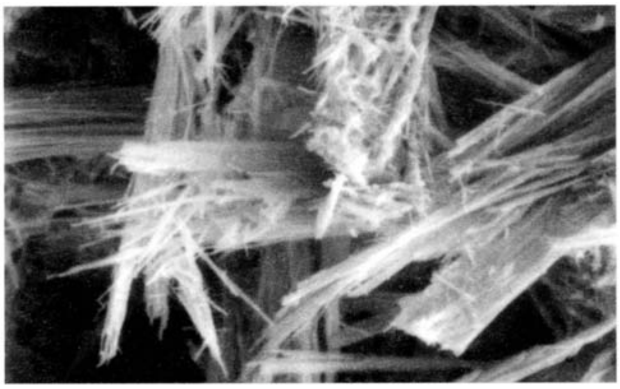
Mereiter [202] studied structure and crystallography of schröckingerite. The following optical properties are given: n_α=1.4892(3), n_β= 1.5388(3), n_γ = 1.5412(3), and $2V_{calc}$ = 24.6(3) °.

Lattice par. [Å, °]	1	a = 9.634(1)	b = 9.635(1)	c= 14.391(2)
		α = 91.41(1)	β = 92.33(1)	γ= 120.26(1)
IR [cm^{-1}]	2	525, 608, 665, 705, 739, 750, 790, 816, 842, 903, 932, 1015, 1078, 1093, 1182, 1367, 1572, 1638, 2640, 3260, 3455, 3620		
Density [$g.cm^{-3}$]	1	D_x = 2.563		
	3	D_m = 2.515		
EDX, WDX		major elements: U, Ca, C as $(CO_3)^{2-}$	minor elements: Mg, Na	
References		10, 12, 27, 56, 106, 159, 202, 211		

1 - schröckingerite, Jáchymov. Mereiter [202]
2 - schröckingerite, Jáchymov. Čejka et al. [10]
3 - schröckingerite, Jáchymov. Nováček. [211]

Schultenite $PbHAsO_4$

Very fine schultenite needles constitute cotton-like aggregates with a silky lustre. It occurs with yellow uranium ochres, light yellow uranium mica and glassy anglesite crystals on fracture in uraninite veinlet with pyrite and sphalerite. Schultenite is identified on specimens collected in the Eliáš mine.



Aggregates of small randomly oriented crystals of schultenite. Magnification 100

Silver Ag

It was described, besides other forms, as wire silver; some types of silver formed by cementation process. Small leaves of silver are marginally altered to argentite. In other specimens, argentite crystals are sometimes corroded and covered by minor scales of silver [118].

Secondary silver was also found along fractures of vein quartz as sheet-like aggregates intergrown in tennantite and pyrite. These specimens come from the Geschieber vein.

Sklodowskite $(H_3O)_2Mg(UO_2)_2(SiO_4)_2 \cdot 2\,H_2O$

Sklodowskite occurs as soft, earthy and buff coloured nodules up to 2 mm long. It was rare on some specimens with gypsum, sodium-zippeite, uranopilite, and "pseudo-zippeite (Mg)". It does not fluoresce in ultra-violet light. Specimens were collected in the Evangelista vein.

Lattice par. [Å, °]		a = 17.39(1)	b = 7.07(1)	c = 6.624(6)
			β=105.60(1)	
EDX, WDX		major elements: U, Mg, Si		minor elements: S
References		53, 249		

Smrkovecite $Bi_2O(PO_4)(OH)$

Smrkovecite [48] was identified by Sejkora [193] by quantitative analysis as very minor aggregates among mixite acicular crystals. In view of the small size of the aggregates, the mineral could not be examined by X-ray diffraction.

Soddyite $(UO_2)_2SiO_4 \cdot 2\,H_2O$

Soddyite from Jáchymov was listed by Kašpar [106] as a rare, compact light brown to brown mineral. It was considered to be younger than cuprosklodowskite; no additional data on soddyite was presented.

Sodium-zippeite $Na_4(UO_2)_6(SO_4)_3(OH)_{10} \cdot 4\,H_2O$

Sodium-zippeite belongs to some of the least studied uranium minerals with a layered structure. It appears to belong to relatively unstable or meta-stable minerals which alter readily under natural conditions [6]. An additional problem is analytical-instrumental and results from difficulties of analysis of relatively low concentrations of alkalis, in particular potassium, in presence of uranium (see: new chemical re-definition of the zippeite group [24]).

Sodium-zippeite forms by relatively quick precipitation of free sulphate and uranyl ions, which are mobile and stable only in an acid environment. It typically occurs as efflorescence, powdery coating, or in earthy mixtures with other uranium sulphates. Aggregates of the mineral tend to be soft or hardened, strong yellow, orange to red, brownish yellow.

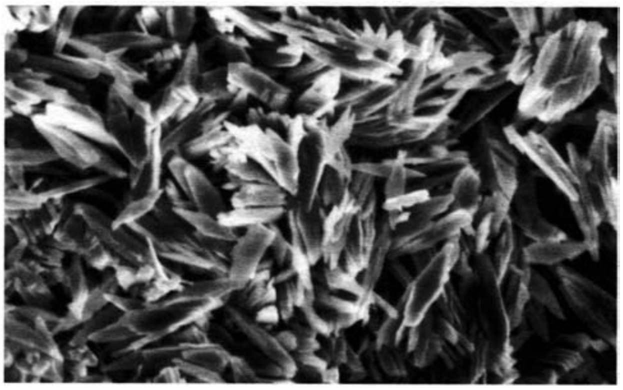
Somewhat larger isolated crystals or radiating aggregates probably formed from relatively diluted solutions or in places with a moderate pH gradient. Due to variety of appearance and habit of various types of zippeite, it is impossible to identify sodium-zippeite from several unknown phases (see "pseudo-zippeite (Mg)"). The mineral fluoresces a weak yellow-brown in ultra-violet light.

Powder X-ray diffraction pattern was indexed using orthorhombic model proposed by Frondel [24]. Sodium-zippeite was observed in association with gypsum, uranopilite, zippeite, nickel-zippeite, johannite, and exceptionally with jáchymovite, metaschoepite and "pseudo-zippeite (Mg)".

See also other minerals of the zippeite group (magnesium-zippeite, zippeite, nickel-zippeite, "ferro-zippeite", "pseudo-zippeite (Mg)").

Lattice par. [Å]	1	a = 8.816(9)	b = 17.16(2)	c = 7.323(8)
	2	a = 8.82	b = 17.12	c = 7.32
EDX, WDX		major elements: U, S		minor elements: Na
References		6, 24, 132, 152, 191, 252		

1 - sodium-zippeite, Jáchymov. This study, sample J-331
2 - orthorhombic model proposed by Frondel[24]



Aggregate of minute doubly terminated crystals of sodium-zippeite. Magnification 600

X-ray powder diffraction pattern of sodium-zippeite from Jáchymov (sample J-331).

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
2	8.618	8.582	0	2	0
100	7.353	7.323	0	0	1
1	5.859				
4	5.587	5.571	0	2	1
3	4.707	4.709	1	2	1
2	4.364	4.408	2	0	0
4	4.291	4.291	0	4	0
5	4.251	4.269	2	1	0
16	4.120				
7	4.010	4.014	1	3	1
45	3.667	3.661	0	0	2
<1	3.580	3.581	0	1	2
40	3.501	3.492	2	3	0
1	3.409	3.413	1	4	1
1	3.369	3.368	0	2	2
8	3.224	3.199	1	5	0
52	3.159	3.152	2	3	1
1	3.067	3.075	2	4	0
2	2.891	2.896	3	1	0
21	2.863	2.861	0	6	0
1	2.752	2.779	2	1	2
1	2.740	2.727	3	0	1
3	2.700	2.708	2	5	0
<1	2.663	2.665	0	6	1
1	2.592	2.599	3	2	1
6	2.576				
2	2.562	2.551	1	6	1
1	2.510	2.504	0	5	2
1	2.4699	2.4618	3	3	1
1	2.4117	2.4166	0	1	3
1	2.3980	2.3997	2	6	0
1	2.3488	2.3478	0	2	3
1	2.2909	2.2918	3	0	2
<1	2.2747	2.2803	2	6	1

Strashimirite $Cu_8(AsO_4)_4(OH)_4 . 4 H_2O$

It forms minor bright green spheres or botryoidal coatings, fractions of mm thick, and developed as small patches several mm^2 in size. The aggregates show a radiating structure and silky lustre. It is accompanied by lindackerite, lavendulan, and olivenite on fractures of quartz vein with tennantite.

Lattice par. [Å, °]		a = 9.71(3)	b = 18.93(7)	c = 8.91(8)
			β = 97.7(1)	
EDX, WDX		major elements: Cu, As	minor elements: S, Si	
References		243		

Sulphur S

Kratochvíl [118] described small sulphur crystals on native arsenic accompanied by calcite.

Sulphur occurs as small light yellow equant crystals with a high adamantine lustre. It crystallised on corroded specimens with sulpho-arsenides and arsenides, from which it was released. Sulphur is associated with köttigite and picropharmacolite. This type is documented from the Geschieber and Evangelista veins.

Sulphur also forms pseudomorphs after barrel-shaped grey crystal up to 2 mm long, striated parallel to elongation, grown scattered in porous vein quartz. Probably, marcasite or argentopyrite was the original mineral of the pseudomorphs. The specimens come from the Geschieber vein.

Greyish white powdery sulphur constitutes pseudomorphs after altered arsenopyrite or chalcopyrite. This type occurs in the Schweizer vein as a product of partial oxidation of sulphides and sulpho-arsenides, a process slower (and characterised by less acidic conditions) than decomposition of pyrite or marcasite. The latter sulphides feature a spontaneous decomposition characterised by the catalytic role of H_2SO_4. During slow decomposition of arsenopyrite, the surplus arsenate acid is gradually removed or neutralised and the process may locally result in neutral pH conditions.

For this reason, "less acidic" or neutral iron arsenates - scorodite and kaňkite formed by decomposition of arsenopyrite

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Symplesite $Fe_3(AsO_4)_2 . 8 H_2O$

Symplesite forms radiating aggregates of accicular crystals. It is light green-grey, sometimes with a yellow shade. Mixture with parasymplesite is common and pure symplesite is rather rare. Symplesite is accompanied by annebergite and köttigite in porous vein quartz in the Geschieber vein.

Symplesite often accompanies green-brown amorphous arsenates of Fe and Ni, which form in the first stage of alteration of sulphides and sulpho-arsenides of Fe, Co, and Ni (arsenopyrite, löllingite, skutterudite, marcasite a.o.). It also associates with köttigite and arsenates of Mg and Ca. It was observed on specimens with native arsenic.

Lattice par. [Å, °]		a = 7.88(1)	b = 9.476(4)	c = 4.713(5)
		α=100.61(1)	β= 96.68(1)	γ= 105.41(1)
EDX, WDX	1	major elements: Fe,As	minor elements: Mn<Co	
	2	Fe,As	Mn~Co	
	3	Fe,As	Mn>Co	
References		27, 65, 91		

1 - symplesite, Jáchymov. This study (needle end)
2 - symplesite, Jáchymov. This study (needle centre)
3 - symplesite, Jáchymov. This study (aggregate centre)

Synchisite $Ca(Ce,La)(CO_3)_2F$

Synchisite was identified on a single specimen from the dump of the Eliáš mine. It forms mixture with beyerite pseudomorphs after acicular crystals of bismuthinite in a vug of vein quartz. The pseudomorphs consist of whitish yellow spheres; dusty coating of the mixture also developed on walls of the vug. It was identified only by X-ray diffraction.

Talc $Mg_3Si_4O_{10}(OH)_2$

It forms coating on wall rock fractures and occurs in some veins. Talc has a variable colour including white to green, yellow, and red. Coloration is caused by incorporated admixtures [118].

It is probable that the talc mentioned in older reports corresponds to compact aggregates of dickite, which are relatively common in the veins [3].

Talmessite $Ca_2Mg(AsO_4)_2 . 2 H_2O$

Talmessite occurs in fan-shaped and spheroidal radiating aggregates of buff yellow colour. Central parts of the aggregates are compact. Its higher hardness makes it distinct from otherwise similar picropharmacolite. It has a matte lustre.

One particular specimen carries talmessite overgrown by radiating acicular crystals of gypsum, mimetically arranged in the same growth pattern as the radiating talmessite. On other specimens, talmessite is the oldest secondary mineral, on which Mn-oxide, annabergite-köttigite, and picropharmacolite deposited. Monohydrocalcite is also associated with talmessite. It is rare secondary mineral in Jáchymov, which was identified on several specimens of coarse-grained carbonate vein with skutterudite from the Josef vein. The carbonate vein is only 2 cm wide.

The powder X-ray pattern was indexed following Rios [178].

Lattice par. [Å, °]		a = 5.912(5)	b = 6.97(1)	c = 5.567(7)
		α = 97.11(2)	β=109.06(2)	γ= 108.03(2)
EDX, WDX		major elements: Mg, Ca, As	minor elements:	
References		107, 130, 178		

Tenorite CuO

Tenorite was described by Kratochvíl as coating and vinlets. It forms from chalcocite and occasionally it is accompanied by native copper. It was found in the Eliáš mine and the Červená vein.

Thenardite Na_2SO_4

Thenardite was identified as accompanying the assemblage of Mg-arsenates. The specimens represent several cm thick fragile crust, consisting of perpendicular vitreous prismatic/skeletal crystal aggregates, with powdery thenardite on surface. Milky white, radiating acicular crystals of picropharmacolite deposited directly on matrix rock, constitute the base on which thenardite crystallised. Middle part of the crust consists of glassy acicular crystals of an unknown arsenate, mixed with gypsum and thenardite. These arsenate-sulphate crusts originate from the Geschieber vein.

Formation of the thick crusts was associated with transport of significant amounts of material. As primary arsenides-sulphides are the source of As and S, it could be expected that Fe is also a significant element. In fact, no Fe was detected. It is probable that several cations in these crusts derive from mineral waters percolating through fractured granite. The arsenate-sulphate crusts were observed at three sites, always associated with granite. Springs of mineral water occur only several tens of metres of these occurrences. It is assumed that the carbonate mineral water was first neutralised by acid sulphates and arsenates of Fe and Fe was removed as neutral and insoluble carbonates. The arsenates/sulphates of Na, Ca, and Mg probably recrystallized through action of additional batches of mineral water.

Thenardite was observed in association with a new Mg-arsenate, picropharmacolite, and gypsum.

Lattice par. [Å]		a= 9.826(2)	b= 12.317(3)	c = 5.867(2)
EDX, WDX		major elements: Na, S	minor elements:	
References		244		

Torbernite $Cu(UO_2)_2(PO_4)_2 . 8\text{-}12\ H_2O$

Torbernite was first described from Jáchymov by Werner [192] as early as 1793. Compared to metatorbernite, torbernite is less common in Jáchymov. Its fractured or powdered aggregates are unstable and easily dehydrate to metatorbernite. Under natural conditions of humidity, low temperature, suitable pH and composition of solutions, torbernite is relatively stable. A transparent torbernite crystal, collected more than 20 years ago and associated only with minor metatorbernite, changed to metatorbernite during three days after powdering.

According to Kašpar [106], water in uranium micas is comparable to zeolite water and escapes rather continuously. According to Frondel [164], the loss of water in torbernite is irreversible.

Torbernite occurs mainly on fractures of veins, which are covered by tabular crystals with perfect (001) cleavage and minor scales. The crystals are 1 mm long on average, rarely up to 5 mm long. Crystals of equant, dipyramidal habit was also observed. Parallel growth of crystals is relatively common and it may involve other uranium mica minerals. Torbernite shows various shades of green, from apple green to yellow-green, and dark emerald green. It is transparent to translucent, with a vitreous lustre. Opaque torbernite with a matte surface also occurs.

Torbernite was observed with metatorbernite, zeunerite, metazeunerite, tyuyamunite, churchite-(Y), parsonsite, etc. It was relatively common mineral in all mines with uranium veins. The Werner mine supplied majority of specimens.

EDX, WDX		major elements: U, P, Cu	minor elements:
References		27, 75, 84, 93, 133, 192	

Trögerite $(UO_2)_3(AsO_4)_2 . 12\ H_2O$

The occurrence of trögerite was mentioned by Ježek [189] as questionable. New studies did not confirm its occurrence.

The indices of refraction measured by Mrose [8]: $n_\alpha = 1.584$, $n_\beta = 1.620$, $n_\gamma = 1.623$, correspond to values given by Larsen [162] but they are lower than those for specimens from Schneeberg, which are described as trögerite. A comparison of X-ray data also shows differences between samples from these two localities. The mineral from Jáchymov corresponds to values for nováčekite but contains no Ca and Mg. It contains As > P [8].

Quantitative chemical analysis could not be obtained due to the small quantity of material. Trögerite is pleochroic: X - nearly colourless, Y and Z - light lemon yellow, sign-, $2V \approx 20°$, X = c [8].

Tyuyamunite $Ca(UO_2)_2V_2O_8 . 5\text{-}8\ H_2O$

Tyuyamunite was identified in several specimens as powdery coating light yellow in colour, passing to light green-yellow. It was always closely associated with thin veinlets of primary bornite and chalcocite. Transport of vanadium, contained in these sulphides, took place over a minimal distance. Vanadate ions, formed during oxidation, were quickly bound in tyuyamunite. This is indicated by widened and lower-intensity diffractions, which indicate poor crystallinity of the material.

The specimens originated in the Geister vein, the Werner mine.

EDX, WDX		major elements: U, V, Ca	minor elements: Fe, Cu

Urancalcarite $Ca(UO_2)_3(CO_3)(OH)_6 . 3\ H2O$

It was identified or indicated by X-ray powder diffraction of mixture with zellerite and metazellerite, which constitute soft powdery coating or fine-grained crusts, light yellow or light buff in colour. The coatings formed on surface of partly weathered uraninite. The material does not fluoresce in UV light. The paragenesis includes zellerite, metazellerite, liebigite and schröckingerite.

In view of poor crystallinity of urancalcarite, the identification is not quite safe.

Uranocircite $Ba(UO_2)_2(PO_4)_2 . 12\ H_2O$

Uranocircite from Jáchymov is mentioned by Ježek, who considered its presence as questionable [189]. It was not confirmed by new studies.

Uranophane $Ca(UO_2)_2[SiO_3(OH)]_2 . 5\ H_2O$

It is a common uranium mineral in Jáchymov. Uranophane forms powdery fill of vugs in uraninite or in weathered uraninite-bearing veins and coating on these materials. Its colour is variable, powdery aggregates are beige yellow to brown. Minute acicular crystals are less common. It is associated with a variety of secondary uranium minerals, regular associated phase is uranophane-beta.

Nováček [35] gave indices of refraction for two specimens from Jáchymov:

a) minute yellow acicular crystals: n_α=1.648, n_β=1.666, n_γ=1.675
b) thin acicular crystals from a vug in uraninite: n_α=1.647, n_β=1.661, n_γ=1.668.

Pjatnitzky [39] gave the extinction angle of 2°, according to Frondel [164] the extinction is parallel.

Lattice par. [Å, °]		a= 15.909(6)	b = 7.007(4)	c = 6.669(2)
			β=97.447(5)	
EDX, WDX		major elements: U, Si, Ca	minor elements:	
References		7,53, 78,80,85		

Uranophane-beta $Ca(UO_2)_2[SiO_3(OH)]_2 . 5\ H_2O$

It was first described from Jáchymov in 1935 by Nováček [35, 36] under the name *β-uranotile*. The latter name was abandoned in recognition of priority of the name uranophane [206, 207] before uranotile [124], though the description by Websky was incomplete, inaccurate, based on a qualitative chemical analysis, density and hardness, obtained on a mixture. Uranophane-beta usually forms coatings on uraninite and in vugs.

Nováček in his description [35] gave the following chemical analysis: UO_3 66.29, SiO_2 13.11, CaO 7.32, H_2O 12.87, Total 99.59 wt. %, and the formula:

$$CaO . 2SiO_2 . 2UO_3 . 6H_2O$$

The following data are also given: an oblique extinction on the face (010), c/Z = 41°, c/Y = 49°, in the plane (100) the extinction is parallel. The acicular crystals are yellow-green; the crystals are much thicker compared to uranophane and nearly always twinned, and show a strong pleochroism X - colourless, Y and Z - dark yellow. The indices of refraction are distinctly higher compared to uranophane, n_α=1.665, n_β=1.686, n_γ=1.696. Very strong dispersion is characteristic.

This mineral usually forms coating on uraninite but occurs also as small crystals grown freely into cavities.

The mineral has positive elongation, $2V_m$ = 71.5° perfect cleavage on (010). In distinction to other localities, uranophane-beta from Jáchymov has a notable zoning, most prominent on fragments lying on (010) and at termination of crystals. The early (most internal) zone shows lower indices of refraction and a larger extinction angle, compared to the outer zone. The cause of the zoning is unknown. Zoning-free uranophane-beta from other localities has indices of refraction corresponding to those of the outer zone in Jáchymov specimens [319].

	n_α	**n_β**	**n_γ**	**γ:c [°]**	**biref.**	**$2V_{calc}$ [°]**
Min.	1.661	1.682	1.689	52-57	0.028	66
Max.	1.671	1.694	1.702	44-48	0.031	60

According to the authors [319], uranophane-beta is less stable than uranophane under normal pressure and room temperature. It can transform to uranophane during powdering of a sample.

X-ray diffraction data of uranophane-beta from Jáchymov are given by Frondel et al. [23].

It is relatively rare mineral in Jáchymov, which was identified in several specimens only, including those in collections of the Mineralogical Institute, Charles University and National Museum, both in Prague. The maximum crystal size observed was 3 mm. The specimen No. NM 26537 contains relatively thick acicular crystals on matrix of brown silicified vein material. It provided the single subsample of pure uranophane-beta.

Lattice par. [Å, °]		a = 6.636(8)	b = 15.46(2)	c = 14.07(2)
			β=91.355(9)	
IR [cm^{-1}]	1	450,550,(615),710,779,(792),850,882, 939,990,1418,1635,(1668),(3200)3445		
Density [$g.cm^{-3}$]	2	D_m = 3.953		
References		7, 23, 35, 36, 53, 124, 206, 207		

1 - uranophane-beta, Jáchymov (NM 27465) [7]
2 - uranophane-beta, Jáchymov. Nováček [35]

Uranopilite $(UO_2)_6(SO_4)(OH)_{10} . 12\ H_2O$

Uranopilite was first described from Jáchymov in 1854 by Dauber [171] under the name *basisches Uransulfat*. The name uranopilite was introduced by Weisbach [172].

As other uranium sulphates, uranopilite forms in oxidation zone enriched in heavy metals and uraninite. Sulphuric acid, resulting from the hydration-oxidation process, results in formation of complex uranyl-sulphate ions. According to Čejka et al. [173], these ions are more stable in acid conditions than uranyl carbonates, and the uranyl sulphate ions have better migration capability. A quick evaporation of such solutions with low concentration of other cations results in precipitation of uranopilite in the form of coating and crusts, or as an efflorescence on walls of mine workings.

Uranopilite occurs as crystalline aggregates of randomly oriented minute, short acicular crystals. The aggregates are strong yellow to greenish yellow, with a vitreous to silky lustre. Unlike zippeite, uranopilite fluoresces strong yellow-green in ultra-violet light. The crystals are pleochroic, exhibit good cleavage parallel to flattening, and oblique extinction Y/c = 18° (Nováček [35]).

Larsen [162] presented indices of refraction by 0.002 lower, positive optical character and extreme dispersion of optical axes (increasing from red to violet). The extinction angle Y/elongation = 15°.

Uranopilite is associated with gypsum, zippeite, sodium-zippeite, metaschoepite, johannite, uraninite, and as yet closer unidentified phases "pseudo-johannite" and "pseudo-zippeite (Mg)". Uranopilite is relatively abundant in the Eliáš mine.

The first reliable compositional data on uranopilite were provided by Nováček [35]. He presented three quantitative analyses of which the following he considered as representative: UO_3 81.20, CaO 0.93, SO_3 4.04, H_2O 14.03, Total 100.20 wt. % and suggested the formula:

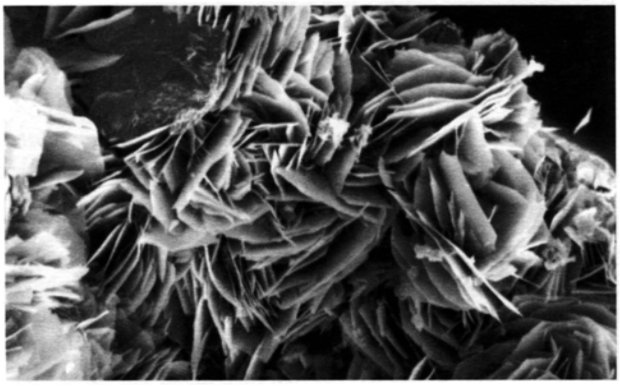
$$6UO_3 . SO_3 . x\ H_2O$$

where x = 16 or 17. The following indices of refraction were measured: $n_\alpha = 1.6228$, $n_\beta = 1.6248$, $n_\gamma = 1.6336$. The X-ray powder diffraction data and unit-cell parameters (table below) are given in [18].

Lattice par. [Å, °]	1	a = 14.03(1)	b = 14.60(1)	c = 9.184(6)
			β = 96.87(6)	
IR [cm^{-1}]	2	248,257,280,423,465,545,585,624,843, 895,955,1082,1106,1145,1169,1622, 3200,3430, 3610		
	1	530,581,620,845,900,936,1073,1108, 1140,1165,1625,1650,3180,3440,3590		
Therm. analysis [°C, wt. %]	1	20-104 6.59 (8 H_2O),104-128 2.11 (2 H_2O), 128-575 6.72 (8 H_2O), 575-884 5.01 (1 SO_3 + 1 O_2)		
References		18, 35, 171, 172, 173		

1- uranopilite, Jáchymov - Čejka et al. [18], sample A
2 - uranopilite, Jáchymov - Čejka et al. [18], sample B

Uranospathite $HAl(UO_2)_4(PO_4)_4 . 40\ H_2O$



Aggregates of thin tabular crystals of uranospathite. Magnification 300

Uranospathite occurs as inconspicuous planar to spheroidal aggregates of light green to light yellow-green colour, composed of rose-shaped clusters of tabular tetragonal crystals.

The crystals show a strong pearly lustre. Uranospathite aggregates are deposited directly on partly weathered uraninite or on unidentified, very thin strong yellow coating. It was observed in paragenesis with arsenuranospathite, whitish to transparent anglesite, nováčekite and white-green metatorbernite.

EDX, WDX		major elements: U, Al, P	minor elements:
References		289	

The semiquantitative chemical analyses suggest that in the specimens studied there are members of a continuous series uranospathite-arsenuranospathite. The specimens were collected on dumps of the Eliáš mine.

Uranosphaerite $Bi_2U_2O_9 . 3\ H_2O$

The specimen No. NM 17365 in the collection of the National Museum in Prague, donated by V. Wraný in 1902, is designated "uranosphaerite". The following minerals were identified in the specimen during the present re-study: vandendriesscheite, compreignacite, kasolite, and uranophane.

According to Ježek [189] the mineral from Jáchymov, marked as uranosphaerite, is identical with uranopilite (as well as the mineral designated *uraconite*). This strengthens the view that uranosphaerite was listed as occurring in Jáchymov by error. The present re-study of many specimens did not confirm presence of uranosphaerite. Ježek [189] suggested that the names uranosphaerite (and *uraconite*) can be considered as synonymous to Vogl's term *Uranoker* (uranium ochres), as far as specimens from Jáchymov are concerned.

Uranospinite $Ca(UO_2)_2(AsO_4)_2 . 10\ H_2O$

Ježek [189] considered its occurrence in Jáchymov as questionable. But it was identified in a mixture with meta-uranospinite (see description) on a sample (No. 13142) from Joaneum, Graz.

Valentinite Sb_2O_3

Kratochvíl [118] listed valentinite from Jáchymov as *okt. Arseniksäure*, which suggests that valentinite was mentioned by error. The presence of this mineral was not recently confirmed.

Vandendriesscheite $PbU_7O_{22} . 12\ H_2O$

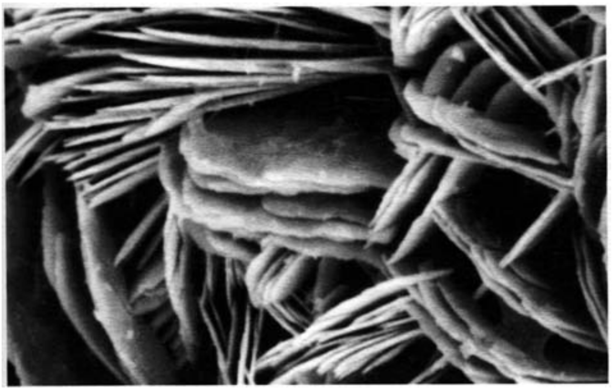
The mineral was identified in a single specimen, in the course of revision of old specimens in the collection of the National Museum in Prague. The specimen No. 17365 (donated by V. Wraný in 1902) was designated uranosphaerite. The specimen contains massive glassy red-brown to orange crusts with a yellow streak, which are soft and very friable. The present study shows that the crusts are composed of several phases, with vandendriesscheite predominating over compreignacite. Also associated are kasolite and uranophane in beige powdery coatings. The matrix of the specimen is a weathered piece of uraninite, covered by crusts and penetrated by veinlets of the above secondary minerals.

Lattice par. [Å]		a = 14.18(1)	b=39.43(13)	c = 43.25(3)
EDX, WDX		major elements: U,Pb,Si		minor elements: K
References		21		

Villyaellenite $(Mn,Ca,Zn)_5(AsO_4)_2[AsO_3(OH)]_2 . 4 H_2O$

Villyaellenite occurs in small tabular crystals with vitreous lustre, which are either isolated or grouped in grape-like or radiating aggregates. The colour is light pink buff. No example of the extreme Mn-rich member was recorded and the samples examined represent Ca-villyaellenite.

EDX, WDX		major elements: As, Mn, Ca	minor elements:
IR [cm^{-1}]		440, 480, 645, 755, (855), 875, 900, 1055, 1100, 1290, 1450, 1640, 2515, 2475, 2885, 2935, 3190, a 3475. (data identical with sainfeldite from Jáchymov)	
Density [g.cm^{-3}]		D_m = 2.686 (determined by pycnometer)	
References		69, 71, 151, 130	



Aggregate of villyaellenite crystals. Magnification 500

It is noted that some specimens show chemical composition similar to sainfeldite [130], but lattice parameters and the diffraction patterns, including intensities, compares much better with villyaellenite. The two species are isostructural and the diffraction patterns can be expected to reflect merely variation in the Mn/Ca ratio.

Villyaellenite is associated with rösslerite, pharmacolite, picropharmacolite, and fluckite.

Vivianite $Fe_3(PO_4)_2 . 8 H_2O$

Vogl [59] mentioned vivianite as earthy aggregates in peatbog near Jáchymov and as indigo blue dusty coating in vugs of corroded limonite.

Vochtenite $Fe^{2+}Fe^{3+}[(UO_2)(PO_4)]_4(OH) . 12\text{-}13 H_2O$

Vochtenite occurs as minute foliated aggregates similar to mica. The colour is light beige to brown. It does not fluoresce in UV light. Vochtenite occurs with limonite, occasionally with autunite and torbernite as coating of fractures in the vein material or in the country rock next to the vein. The specimen identified was collected in the Geister vein.

EDX, WDX		major elements: Fe, P	minor elements:

Voglite $Ca_2Cu(UO_2)_2(CO_3)_2O_3$

The mineral was first found in Jáchymov and described in 1853 by Vogl [60] under the name *Uran-Kalk-Kupfer-Carbonat*. The name voglite was introduced by the Austrian mineralogist and geologist Haidinger, to honour the discoverer Josef Florian Vogl, who published studies of minerals from the Jáchymov mines [16]

A quantitative chemical analysis of voglite was done in 1853 by J. Lindacker [60], a pharmacist and chemist in Abertamy. No additional analysis appears to be done in later times.

Voglite is described as rhomboidal scales similar in shape to gypsum, constituting thin coatings and also scaly twins of emerald green to grass green colour, with a green streak and pearly lustre [60]. It is compared by its appearance to zeunerite or metatorbernite.

It was found by Vogl in the Fluther vein (which yielded also eliasite), Eliáš mine, at a depth of 150-170 m. It was associated with liebigite, uranium ores, fluorite, dolomite, clay, and disintegrated schist [60]

Čejka et al. [16] presented three infrared spectra of voglite and noted absence of fluorescence in ultra-violet light.

Piret et al. [42] published powder X-ray pattern of voglite from Jáchymov and proposed a monoclinic unit-cell (table below) for Z = 16.

Voglite is pleochroic: X - dark blue-green, Y - dark blue-green, Z - light yellowish. Directions Y and Z lie in the plane of cleavage [162].

In the present study we attempted to index (table below). The X-ray powder data by Piret et al. [42] with a unit-cell (table below) approximately three times small compared to that of Piret et al. Čejka et al. [16] gave powder X-ray data, obtained with Debye-Scherrer camera, for four specimens. However, diffraction values and intensities vary substantially and it is uncertain if the results are reflecting extremely small amounts of sample, properties of the mineral, or a polyphase nature of the sample.

Optical properties of voglite were published by several authors as follows:

	n_α	n_β	n_γ	2V [°]	note
Larsen [162]	1.541	1.547	1.564	60	---
Berman 1954	1.513	1.525	1.542		in [164]
Piret, Deliens [42]	1.544		1.558		white light

Optical character is positive [162]. Schrauf [138] measured under the microscope angle of edges 78 to 80° seen on the platy crystals.

X-ray powder diffraction pattern of two types of voglite from Jáchymov compared to data from [42]

voglite (the first type), this study						**voglite (the second type), this study**						**Piret et al. [42]** (Debye-Scherrer)					
I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
100	13.284																
16	12.854	12.851	2	0	0	92	12.908	12.742	2	0	0	100	12.6	12.599	2	0	0
						53	12.304					10	11.2	11.204	2	1	0
						16	10.176										
13	9.831					17	9.608	9.648	1	1	-1	80	9.65	9.67	1	1	-1
4	9.452	9.507	0	1	1												
19	8.839					48	8.586	8.599	2	1	-1	100	8.7	8.782	2	1	-1
18	8.711	8.709	2	2	0												
5	8.323	8.349	1	1	1												
1	7.553	7.547	1	3	0												
20	7.220	7.181	3	1	-1	43	7.150	7.183	3	1	-1	60	7.1	7.136	3	1	-1
52	6.735	6.727	2	3	0	15	6.858	6.847	2	3	0						
42	6.629					45	6.587										
17	6.383	6.358	3	2	-1	100	6.405	6.397	3	2	-1						
						27	6.184	6.163	4	1	0						
						31	6.107	6.089	0	4	0	40	6.13	6.124	0	4	0
						15	6.000	5.986	1	3	1						
2	5.666	5.648	4	2	0												
11	5.182	5.190	0	0	2	12	5.170	5.169	0	0	2	10	5.19	5.19	0	0	2
						26	5.093	5.097	5	0	0						
10	4.968	4.965	4	0	1												
5	4.897	4.883	3	1	-2	24	4.869	4.871	0	5	0	20	4.83	4.835	2	2	-2
						8	4.758	4.758	0	2	2						
17	4.674	4.658	1	5	0							30	4.65	4.653	2	4	1
24	4.607	4.602	4	0	-2	20	4.551	4.550	2	5	0						
						11	4.499	4.500	1	2	2						
1	4.421	4.421	1	3	-2	15	4.404	4.407	0	5	1						
						12	4.300	4.300	4	2	-2	50	4.32	4.32	4	2	-2
9	4.275	4.284	6	0	0												
						11	4.206	4.206	4	3	1						
						10	4.105	4.109	5	1	-2	10	4.1	4.095	5	1	-2
2	4.009	4.010	3	5	-1	15	4.077	4.088	3	5	-1						
12	3.965	3.964	1	4	-2	16	3.939	3.941	0	4	2	30	3.94	3.939	0	4	2
13	3.836	3.821	3	2	2												
41	3.551	3.558	2	0	-3	18	3.502	3.502	3	0	-3	10	3.55	3.553	1	0	-3
7	3.454	3.460	0	0	3												
2	3.421	3.424	0	1	3	6	3.431	3.434	1	5	2	20	3.42	3.420	2	2	-3
4	3.349	3.355	1	7	0	3	3.370	3.366	3	2	-3						
8	3.311	3.306	4	3	2	6	3.277	3.278	2	5	2						
						10	3.242	3.242	5	0	-3						
3	3.154	3.154	5	5	1	5	3.176	3.175	5	5	1						
7	3.149	3.147	3	7	0	10	3.135	3.134	2	7	1						
8	3.042	3.042	8	3	-1	6	3.028	3.026	4	7	-1						
2	2.970	2.970	6	2	-3												
2	2.719	2.719	7	6	-1	6	2.717										
						6	2.643										
						12	2.604										
4	2.4307	2.4309	10	3	-2	8	2.4054										
5	2.0951	2.0952	2	7	-4	3	2.1111										
4	2.0615	2.0613	6	1	-5	7	2.0787										
						11	2.0427										
3	1.9538	1.9538	5	8	3	5	1.9519										
6	1.9301	1.9303	10	5	2												
12	1.9081	1.9079	6	8	-4												
4	1.8607	1.8606	4	9	-4												
						6	1.7405										
20	1.6443	1.6443	2	8	5												
18	1.5929	1.5931	10	11	1												

The analysis by Lindacker (in 1853) gave the following results: CaO 14.09, CuO 8.40, UO_2 37.0, CO_2 26.41, H_2O 13.9, Total 99.8 wt. % and the proposed formula:

$$Ca_2CuU^{4+}(CO_3)_5 \,.\, 6\ H_2O,$$

which, recalculated by Berman [cited in 164] gave:

$$Ca_2Cu(UO_2)(CO_3)_4 \,.\, 6\ H_2O$$

This formula does not correspond well with the analysis, which would show a surplus of carbonate anions. Presence of anions $(CO_2OH)^{1-}$ appears improbable.

Authors of the present work assume, that the original analysis may be in error. For this reason, the compatibility factor, calculated density, and Z number were not computed.

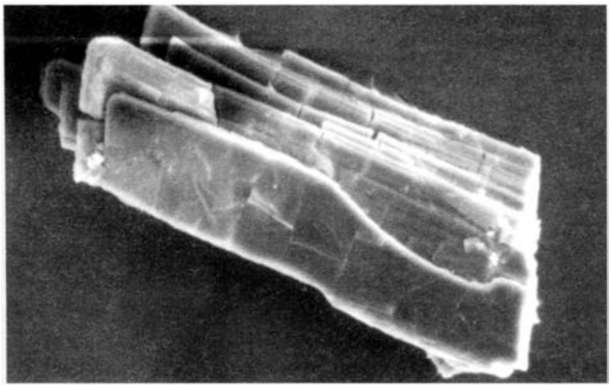
Lattice par. [Å, °]	1	a = 25.97	b = 24.50	c = 10.70
			β = 104	
	2	a=26.416 (8)	b=23.702(8)	c=10.680(5)
			β=103.63(1)	
	3	a=26.27 (2)	b=24.36(1)	c=10.655(5)
			β=104.02(1)	
EDX, WDX		major elements: U, Ca, Cu,CO_3^{2-}	minor elements:	
IR [cm^{-1}]	4a	610,741,796,841,875,903,1030,1053, 1073,1105,1151,1410,1465,1540,1618, 3340, 3385		
	4b	615,675,742,795,836,903,1015,1110, 1410,1535,1560,1620,3400		
	4c	612,633,741,833,902,1020,1115,1170, 1420,1512,1560,1620,3400		
Density [g.cm^{-3}]	1	D_m = 2.8 D_x = 2.81 for $Ca_2Cu(UO_2)(CO_3)_3(OH)_2 . 4 H_2O$ D_x = 2.77 for $Ca_2Cu(UO_2)(CO_3)_4 . 2 H_2O$ D_x = 3.06 for $Ca_2Cu(UO_2)(CO_3)_4 . 6 H_2O$		
References		16, 30, 42, 56, 60, 161, 163, 164		

1 - voglite, Jáchymov [42]

2 - voglite (the first type), Jáchymov. This study (Joaneum, Graz, No.1656A)

3 - voglite (the second type), Jáchymov. This study

4 - voglite, Jáchymov [16] (a - M17, b - M19, c - M20)



Group of voglite crystals showing parallel growth. Magnification 500

Piret et al. [42] recommend the chemical formula:

$$Ca_2Cu(UO_2)(CO_3)_3(OH)_2 . 4 H_2O$$

because of similarity between measured and calculated densities.

Two different types of voglite were studied in this paper.

Description of the *first type*, from Joaneum (Graz, number: 1656A) corresponds with voglite described above.

Average result of 5 quantitative chemical analyses of this sample is: Ca 10.64, Cu 6.54, U 53.93, O 25.32, C 3.19, total 99.62 wt. %, and the proposed empirical formula (based on 13 O):

$$Ca_{2.18}Cu_{0.84}(UO_2)_{1.86}(CO_3)_{2.18}O_{2.68}(OH)_{0.05}$$

leads to simplified formula:

$$Ca_2Cu(UO_2)_2(CO_3)_2O_3$$

The *second type* forms very thin flat crystals with furrows in one direction. Their max. size is 0.5 mm. It is of bright bluish green colour. Its lustre is vitreous. Crystals are perfectly transparent and extremely brittle. Voglite is associated with small balls of cuprosklodowskite, liebigite, rösslerite, brassite, zellerite, unnamed phase Ca-Cu-(UO_2)-(CO_3)-H_2O, and amorphous vitreous dark yellow-green U-Cu-carbonate.

The sample of voglite of the *second type* originates from the vein No. 3.

Voltaite $K_2Fe_5^{2+}Fe_4^{3+}(SO_4)_{12} . 18 H_2O$

Voltaite was listed by Kratochvíl [118] clearly by error, as Tschermak [224] described voltaite from Kremnica.

Walpurgite $(BiO)_4(UO_2)(AsO_4)_2 . 2 H_2O$

Walpurgite occurs in thin tabular to lath-shaped crystals up to 3 mm long. Its colour - waxy yellow - is notably different from other uranium minerals in Jáchymov. The lustre is vitreous to adamantine. Walpurgite has perfect (001) cleavage. The present study dealt with specimen No. NM 4877 from the collection of the National Museum in Prague; the specimen designated as waltherite was identified as walpurgite. Massive crystalline crusts tens of cm^2 are covered by flat, imperfect crystals of grey-brown mineral up to 1 cm long, which is accompanied by torbernite.

The mineral is optically negative, n_α = 1.90, n_β = 2.00, n_γ = 1.205, the angle 2V is moderate; the direction X is nearly normal to the large face of tabular crystals [162].

Lattice par. [Å, °]		a = 7.111(4)	b = 10.38(1)	c = 5.495(2)
		α=101.48(1)	β=110.72(1)	γ =88.044(9)
	1	a = 7.098(7)	b = 10.37(1)	c = 5.479(6)
		α=101.52(9)	β=110.81(8)	γ = 88.04(7)
EDX, WDX		major elements: Bi, U, As	minor elements: P	
References		2, 23, 27, 75, 104, 108, 122, 144, 193		

1 - walpurgite, Jáchymov. Sejkora [193]

Walpurgite is associated with torbernite, metatorbernite, bismutite or bismutoferrite in vein material including minor native bismuth.

It is interesting that the arsenate mineral walpurgite is accompanied by phosphorus-bearing torbernite, which may reflect preference of P for the particular mineral structure.

Some specimens of walpurgite originate from the Geister vein.

Weeksite $K_2(UO_2)_2Si_6O_{15} . 4 H_2O$

It was identified only in the specimen No. 4913 in collection of the National Museum in Prague. The specimen designated as gummite contains part of weathered uraninite vein. Colour of this secondary material, which appears as metamict and amorphous, varies from brownish to yellow or orange. Weeksite was identified in the part of specimen containing sulphur-yellow vitreous lustrous layers, seemingly of amorphous nature.

Lattice par. [Å]		a = 14.32(2)	b = 35.92(3)	c = 14.24(3)
EDX, WDX		major elements: U, K, Si		minor elements: (Ca)
References		246		

Weilite $CaHAsO_4$

Weilite probably forms by dehydration of pharmacolite. Early stages of this alteration are indicated by change of transparent prismatic crystals of pharmacolite to milky white. The alteration tends to affect only certain parts of a crystal. Weilite was never observed in freshly collected material but in specimens collected at least several years ago. However, some specimens collected more than a century ago still contain fresh pharmacolite. The mechanism controlling alteration of pharmacolite to weilite is unknown.

Lattice par. [Å, °]		a = 7.20(4)	b = 7.01(2)	c = 7.18(2)
		α = 94.99(3)	β= 101.77(3)	γ = 85.72(5)
References		250		

Widenmannite $Pb_2(UO_2)(CO_3)_3$

Widenmannite was identified in a single specimen, in which it forms relatively abundant yellow to yellow orange powdery fill of vugs up to 1 cm long in orange to red Pb-U oxides.

Widenmannite from Jáchymov does not fluoresce in ultra-violet light, in agreement with data for the material from Schwarzwald. All the data in tables below, and the description are from [203].

Lattice par. [Å]	1	a = 8.975(7)	b = 9.367(1)	c = 4.951(7)
EDX, WDX	1	major elements: Pb, U		minor elements: Al (up to 0.5 wt%)
References		61, 203		

1 - widenmannite, Jáchymov. Sejkora [203]

Wölsendorfite $(Pb,Ca)U_2O_7 . 2 H_2O$

Wölsendorfite was identified as a substantial component of red crystalline aggregates with poorly defined radiating structure or yellow-brown coatings on weathered uraninite.

Lattice par. [Å]		a = 14.00(1)	b=11.908(6)	c = 6.884(7)
EDX, WDX		major elements: U, Ca, Pb		minor elements: Si
References		270		

As a rule, it forms mixtures with other minerals of the $PbO-UO_3-H_2O$ group in paragenesis with uranophane and gypsum next to weathered uraninite.

Wulfenite $PbMoO_4$

Wulfenite was identified in two specimens only. In the first specimen, it crystallised on quartz crystals. Up to 2 mm long, pseudo-hexahedral crystals are deposited on quartz crystals in a quartz vein. Wulfenite as well as the quartz matrix are coated by limonite, on which some isolated whitish acicular crystals of pyromorphite occur. On fresh fracture, wulfenite is grey-white, with adamantine lustre.

In the second specimen, wulfenite forms rare long dipyramidal crystals and up to 2 mm long crystals of grey-brown colour on a matrix of small quartz crystals and compact grey pyromorphite. All these minerals are coated by limonite. The second type of wulfenite was collected in the Geister vein.

Lattice par. [Å]		a= 5.4310(6)		c= 12.115(1)
EDX, WDX		major elements: Pb, Mo		minor elements: Si
References		251		

Yingjiangite $K_2Ca(UO_2)_7(PO_4)_4(OH)_6 . 6 H_2O$

The mineral has been found only in several specimens as crystalline coating and crusts composed of minute acicular crystals of yellow colour. Uranophane accompanies yingjiangite in this paragenesis.

The material probably corresponds to intermediate members of the series phosphuranylite - yingjiangite, with prevalence of K over Ca.

The X-ray powder diffraction pattern of Jáchymov yingjiangite does not compare well with data in the original description [278].

EDX, WDX		major elements: U, P, Ca, K	minor elements: Fe
References		278	

X-ray powder diffraction pattern of widenmannite from Jáchymov [203]

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
21	6.505	6.480	1	1	0	6	3.146	3.134	2	1	1	6	2.1542	2.1601	3	3	0
3	4.723	4.683	0	2	0	17	2.983	2.992	3	0	0	8	2.1187	2.1264	1	2	2
9	4.389	4.378	0	1	1	7	2.950	2.949	1	3	0	8	1.9682	1.9672	2	2	2
14	4.340	4.335	1	0	1	9	2.844	2.850	3	1	0	7	1.9271	1.9399	0	3	2
100	4.154	4.152	1	2	0	15	2.558	2.561	3	0	1	8	1.9096	1.9073	3	0	2
11	4.037	4.047	2	1	0	16	2.517	2.521	3	2	0	15	1.8723	1.8690	3	1	2
11	3.950	3.934	1	1	1	17	2.4827	2.4700	3	1	1	7	1.8446	1.8440	3	4	0
45	3.325	3.325	2	0	1	52	2.3445	2.3417	0	4	0	6	1.7357	1.7280	3	4	1
64	3.244	3.240	2	2	0	4	2.2408	2.2467	3	2	1	9	1.6816	1.6761	5	2	0
23	3.188	3.182	1	2	1	12	2.1785	2.1820	4	1	0	5	1.6575	1.6608	5	1	1

X-ray powder diffraction pattern of zellerite from Jáchymov.

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
100	9.537	9.528	0	2	0	10	3.713	3.696	2	0	1	10	2.678	2.677	3	5	0
7	7.393	7.280	1	2	0	8	3.659	3.666	1	3	1	9	2.4078	2.4089	2	6	1
12	5.558	5.535	1	3	0	15	3.495	3.499	3	2	0	7	2.1748	2.1746	4	4	1
28	4.851	4.855	2	2	0	10	3.461	3.446	2	2	1	5	2.0132	2.0105	3	7	1
36	4.776	4.764	0	4	0	9	3.190	3.176	0	6	0	12	1.9567	1.9590	4	7	0
26	4.334	4.352	0	2	1	10	3.085	3.057	1	6	0	8	1.9326	1.9339	2	5	2
9	4.241	4.219	2	3	0	20	2.924	2.920	2	4	1	8	1.9021	1.9056	0	10	0
23	3.810	3.811	0	5	0	10	2.788	2.791	4	1	0						

Zellerite $Ca[(UO_2)(CO_3)_2(H_2O)_2] . 3 H_2O$

Zellerite belongs to very rare minerals in Jáchymov. Zellerite was found as buff yellow botryoidal aggregates to earthy coating. It has a similar appearance as uranium sulphates, which are often designated as zippeite. It does not fluoresce in ultra-violet light.

It is associated with metazellerite, schröckingerite, liebigite, and rabbittite

Table above gives powder X-ray diffraction data for zellerite from Jáchymov. The data are indexed following [96], however, some of the diffractions measured are absent in the original description [96].

Lattice par. [Å]		a = 11.29(2)	b = 19.06(2)	c = 4.892(8)
EDX, WDX		major elements: U, Ca, C	minor elements: (K)	
References		27, 96		

Zeunerit $Cu(UO_2)_2(AsO_4)_2 . 10\text{-}16 H_2O$

Zeunerite often occurs along fractures in vein material. The fracture surface is coated by thick tabular to equant crystals which are transparent, strong green or milky grey-green. The transparent crystals are notably lustrous. The crystals are up to 2 mm long but on average the size is much smaller.

Zeunerite from Jáchymov is unstable under room temperature and humidity and through loss of water it slowly changes to more stable metazeunerite. The alteration is much slower than with torbernite.

Zeunerite was observed in association with metazeunerite, torbernite, metatorbernite, tyuyamunite, churchite (Y), and hidalgoite. It is relatively common mineral found in all the mines with uraninite veins but most specimens originate from the Werner mine.

Lattice par. [Å, °]		a= 1.3564(2)	b=1.3564(2)	c= 1.3564(2)
		α=122.35(2)	β=122.35(2)	γ= 122.35(2)
EDX, WDX		major elements: U, As, Cu	minor elements: Fe, Si	
References		93		

Zippeite $K(UO_2)_2(SO_4)(OH)_3 . H_2O$

Zippeite was first described from Jáchymov by Zippe [161] and in 1845 Haidinger [170] introduced the name zippeite. Concurrently, John in 1821 [165] described the same mineral under the name *basisches schwefelsäures Uranoxyd*. In 1857 Vogl [59] published the first quantitative chemical analyses by Lindacker. Zippeite was redefined by Frondel [24] on a specimen analysed by Nováček [24], in absence of the original type specimen.

Zippeite often occurs in powdery coating or as earthy aggregates, in mixture with other uranium sulphates, which include several types of zippeite with various cations (Na, Mg, Fe, Ni, Mn), "pseudo-zippeite (Mg)", uranopilite, jáchymovite, and other phases. Zippeite aggregates show variety of habits, including earthy, granular/crystalline, and soft or hardened intense yellow to orange to red brownish yellow. Occasionally, it forms isolated crystals and their radiating aggregates, probably favoured by lover-concentration solutions and a moderate pH gradient. It is this variability in appearance, which decisively contributed to ignorance of additional associated phases, which can not be recognised and identified without a detailed study. Jáchymovite and "pseudo-zippeite (Mg)" can serve as example of the latter minerals.

During this study, zippeite containing K only was detected in one sample only. It forms relatively large crystals (up to 0.5 mm), which are flat and a little elongated. The crystals are mostly grouped in small aggregates in fractures of rock. Their colour is yellow, brownish yellow or brownish orange.

Zippeite was described as associated with gypsum, uranopilite, sodium-zippeite, nickel-zippeite, magnesium-zippeite, "ferro-zippeite", johannite, exceptionally jáchymovite, sklodowskite, metaschoepite. In present study were regularly observed mixtures of "pseudo-zippeite (Mg)" always with zippeite (all types).

Nováček [35] considered the analyses by Lindacker [59] as erroneous and analysed three specimens (unfortunately, K and Na were not determined), with the following results for the first analysis: UO_3 71.98, Fe_2O_3 1.17, CaO 1.88, SO_3 10.02, H_2O 13.95, Total 99.00 wt.%. He proposed the following formula:

$$2UO_3 . SO_3 . 5\text{-}6 H_2O$$

Indices of refraction for the three specimens show significant variation and brought Nováček [35] to conclusion that water bonding in zippeite is rather unstable. It is probable that Nováček studied a mixture of uranium sulphates, possibly with presence of uranium sulphates with various additional cations.

Though natural uranyl-sulphates with sheet structure, including zippeite, are known for long time, they belong to uranium minerals, which were not sufficiently studied and characterised. Difficulties of their study are aggravated by their instability and tendency to alteration under natural conditions [6].

Frondel [24] gave X-ray powder diffraction pattern of zippeite from Jáchymov. On the basis of single crystal Weissenberg and precession measurements he concluded that all types of zippeite have identical or very similar structure with a very large orthorhombic unit-cell (table below); the space group was not determined. Traill [191] derived a monoclinic cell for Z = 1, with parameters shown in table below. Frondel discussed older analyses and did new ones, including determination of cation elements. The following formula was proposed:

$$K_4(UO_2)_6(SO_4)_3(OH)_{10} \ . \ 4\ H_2O$$

One partial analysis of zippeite gave: K_2O 8.06, Na_2O 0.62, loss on ignition at 500 °C 10.7 wt. %. The corresponding optical data include: optically negative, biaxial mineral, 2V = 60(15)°, indices of refraction n_α = 1.655, n_β = 1.716, n_γ = 1.768.

Vochten et al. [260] gave complete crystal structure of synthetic zippeite. On the basic of crystal structure interpretation he proposed following formula:

$$K(UO_2)_2(SO_4)(OH)_3 \ . \ H_2O$$

Larsen [162] presented optical data of Jáchymov zippeite for orange-yellow powder and minute crystals. The powder has n_α = 1.630, n_β = 1.70, n_γ = 1.720; crystals gave n_α = 1.620, n_β = 1.680, n_γ = 1.720.

In both cases, zippeite is optically negative with a large 2V.

Zippeite forms by relatively quick precipitation of free sulphate and uranyl ions with extensive mobility and stability only at a low pH. Frondel [24] supposed that potassium in zippeite is derived from the country rock. According to Kašpar [106], conditions of uranyl-sulphate formation can be derived by analogy with laboratory experiments, which indicate their formation in relatively narrow range near pH = 3, in the stage of intense decomposition of sulphides, prior to neutralisation of solutions. It is probable that the variable quantity of water in the range 3 to 5 water molecules per formula unit, indicated by various analyses, is caused, similar to other sulphates, by gradual dehydration and "aging" of the mineral, often after the specimen was collected.

Old publications about zippeite contain no information of determination or detection of potassium and other cations. This situation reflects analytical problems of K determination in the presence of uranium, particularly if K content is near 5 wt. % or lower.

Lattice par.	1	a = 8.80	b = 68.43	c = 14.55
[Å, °]	2	a = 8.88	b = 14.10	c = 8.83
			β = 103.50	
	3	a = 8.656(2)	b= 14.240(4)	c =17.706(5)
			β=104.112(4)	
	4	a = 8.755(3)	b= 13.987(7)	c =17.730(7)
			β=104.13(3)	
Density [g.cm^{-3}]	4	D_c = 4.696		
References		6, 24, 35, 59, 106, 132, 152, 161, 165, 170, 191, 252, 260		

1 - zippeite, Jáchymov - Frondel et al., [24]
2 - zippeite, Jáchymov - Traill [191]
3 - zippeite, Jáchymov. This study
4 - synthetic zippeite - $K(UO_2)_2(SO_4)(OH)_3 \ . \ H_2O$ - Vochten et al., [260]

Our work shows that many specimens have K content below the detection level, but have significant content of Mg and Fe. It means, pure zippeite (K-member) is relatively rare in Jáchymov. In opposite, the magnesium-zippeite or "ferro-zippeite" are rather common.

The present work suggests that some Jáchymov specimens analyzed in the past represented a mixture of zippeites with the "pseudo-zippeite (Mg)", which effectively diluted zippeite in the polymineral sample.

See also other minerals of the zippeite group (sodium-zippeite, magnesium-zippeite, nickel-zippeite, "ferro-zippeite", "pseudo-zippeite (Mg)").

X-ray powder diffraction pattern of zippeite from Jáchymov.

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
2	9.955					2	3.332					1	1.9737	1.9770	1	7	-1
2	9.475					5	3.289	3.288	0	4	2	8	1.9537	1.9524	0	6	5
4	9.155					1	3.225					1	1.9346	1.9319	4	0	-6
9	8.571	8.586	0	0	2	2	3.145	3.184	0	3	4	1	1.9009	1.9027	1	7	-3
6	7.607					12	3.109	3.107	2	2	2	1	1.8657				
100	7.124	7.120	0	2	0	2	3.063	3.106	2	2	-4	1	1.8472	1.8492	4	4	-2
1	6.223					10	2.858	2.862	0	0	6	2	1.8282	1.8268	0	6	6
8	5.487	6.214	1	1	1	2	2.716	2.715	2	4	-2	6	1.7799	1.7799	0	8	0
1	4.982	5.481	0	2	2	2	2.692	2.691	2	0	4	1	1.7696				
0	5.074					5	2.655	2.655	0	2	6	3	1.7440	1.7454	2	0	-10
1	4.754					6	2.635	2.633	1	5	1	2	1.7270	1.7267	4	0	4
3	4.583					2	2.509	2.517	2	2	4	3	1.6957	1.6960	2	2	8
5	4.286	4.293	0	0	4	6	2.4799	2.4787	2	4	2	1	1.6775	1.6780	4	2	4
3	4.204	4.198	2	0	0	10	2.3713	2.3733	0	6	0	0	1.6463	1.6452	3	7	-3
1	4.139	4.132	1	3	-1	4	2.2882	2.2875	0	6	2	1	1.6385	1.6382	2	3	-10
4	3.916	3.912	1	3	1	2	2.2292	2.2300	1	3	-7	2	1.5826	1.5819	2	8	-4
1	3.769					1	2.1640	2.1641	4	0	-2	1	1.5138				
2	3.799					2	2.1342	2.1335	2	0	-8	1	1.5245				
2	3.677	3.616	2	2	0	4	2.0706	2.0706	4	2	-2	4	1.5427				
38	3.558	3.559	1	3	-3	1	2.0465	2.0448	2	2	6	2	1.5536				
8	3.456	3.453	2	0	2	0	2.0106	2.0126	4	2	-4	1	1.5668				

Znucalite $Zn_{12}Ca(UO_2)(CO_3)_3(OH)_{22} . 4 H_2O$

Znucalite forms white to light yellow-green compact coating and stalactitic accumulations in mine workings near carbonate, uranium-bearing veins. Its formation is favourably affected by weakly acid to neutral solutions of pH > 4. Znucalite therefore does not form on weathered pyrite or arsenide-bearing veins.

The aggregates of radiating scaly crystals of a microscopic size form crusts up to 1 mm thick. Minute crystals are closely intergrown with amorphous hydrozincite, powdery calcite, and transparent gypsum. Znucalite fluoresces yellow-green in ultra-violet light. It can be relatively common in mine adits but its coloration contributes to the characteristics of an inconspicuous mineral. It was identified on specimens from the Evangelista and Ondřej veins.

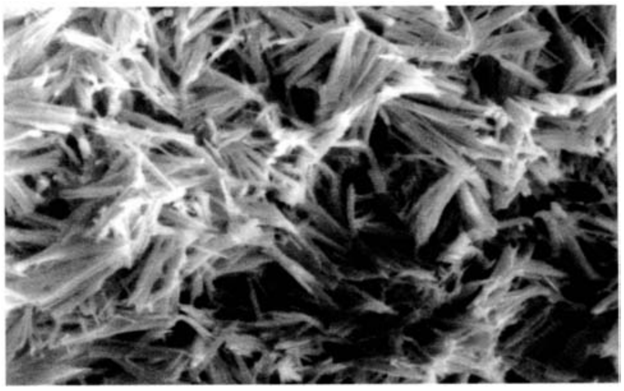
Lattice par. [Å, °]		a =12.689(8)	b = 25.11(2)	c= 11.689(7)
		α=88.974(4)	β=91.694(4)	γ= 90.342(5)
EDX, WDX		major elements: Zn, U, Ca, C	minor elements:	
References		37		

Zýkaite $Fe_4(AsO_4)_3(SO_4)(OH) . 15 H_2O$

Zýkaite occurs as soft, wet earthy pieces of weakly coherent material up to 5 cm across. The mineral has grey-white colour with a weak green shade and a weak silky lustre. The surface is locally covered by irregular aggregates of kaňkite. The mineral formed from arsenopyrite in wet places.

The mineral was identified in samples from the vein No. 3.

Zýkaite is described to be orthorhombic on the basis of optical data in the original paper [177]. Indexing of the powder pattern collected (mainly of low-angle reflections) on material from Jáchymov using original orthorhombic unit-cell does not provide satisfactory results and observed and calculated d-spacings are not in good agreement. This agreement becomes better when angle β is simultaneously refined with parameters a,b, and c corresponding to the monoclinic symmetry. Parameter β is very close to 90°, so authors of the original description having only the data from the film Guinier de Wolf camera probably cannot find this subtle discrepancy which becomes apparent only using most recent diffraction technique.



Aggregate of minute randomly oriented crystals of zýkaite. Magnification 800

Lattice par. [Å, °]		a =20.911(5)	b = 7.062(2)	c= 36.794(7)
			β=90.99(1)	
EDX, WDX		major elements: Fe, As, S	minor elements:	
Reference		177		

X-ray powder diffraction pattern of zýkaite from Jáchymov.

I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*	I_{rel}	d_{obs}	d_{calc}	*h*	*k*	*l*
5	13.616	13.694	1	0	2	8	4.285	4.296	4	0	-5	4	2.903	2.904	3	2	-5
100	10.709	10.658	1	0	-3	3	4.087	4.088	0	0	9	6	2.831	2.829	2	2	-7
13	8.460	8.473	1	0	-4	8	4.028	4.025	1	0	-9	1	2.810	2.811	1	0	-13
3	7.346	7.358	0	0	5	5	3.787	3.785	2	0	9	5	2.779	2.780	1	2	-8
24	6.850	6.847	2	0	4	11	3.735	3.738	4	0	-7	5	2.743	2.744	2	0	-13
4	6.547	6.555	3	0	-2	5	3.569	3.576	5	1	1	4	2.657	2.654	1	2	-9
3	6.304	6.299	1	1	-2	5	3.510	3.515	0	2	1	4	2.638	2.638	3	0	-13
8	6.118	6.120	0	1	3	5	3.309	3.311	1	0	-11	4	2.4461	2.4452	3	1	13
5	5.911	5.911	1	0	-6	8	3.277	3.277	6	0	-4	5	2.4111	2.4110	8	1	-3
23	5.590	5.592	2	1	-2	3	3.244	3.245	5	0	7	4	2.3931	2.3924	6	0	11
5	5.427	5.425	1	1	-4	2	3.146	3.144	1	2	5	8	2.3651	2.3642	4	0	-14
4	5.190	5.187	4	0	-1	19	3.049	3.045	3	2	3	8	2.3142	2.3150	0	2	12
10	5.076	5.076	1	0	7	5	2.997	2.998	1	1	-11	4	2.2903	2.2897	9	0	-3
19	5.012	5.017	3	0	5	4	2.949	2.949	5	0	-9	4	2.2829	2.2841	3	2	11
4	4.573	4.579	3	1	3												

List of secondary minerals from the Jáchymov ore district arranged according to chemical composition

Arsenates

Adamite $Zn_2(AsO_4)(OH)$
Agardite-(Y) $(Y,Ca)Cu_6(AsO_4)_3(OH)_6 . 3H_2O$
Annabergite $Ni_3(AsO_4)_2 . 8 H_2O$
Arsenuranospathite $HAl(UO_2)_4(AsO_4)_4 . 40 H_2O$
Atelestite $Bi_8(AsO_4)_3O_5(OH)_5$
Bayldonite $PbCu_3(AsO_4)_2(OH)_2 . H_2O$
Beudantite $PbFe_3(AsO_4)(SO_4)(OH)_6$
Brassite $MgHAsO_4 . 4 H_2O$
Chalcophyllite $Cu_9Al(AsO_4)_2(SO4)_{1.5}(OH)_{12} . 18H_2O$
Chenevixite $Cu_2Fe_2(AsO_4)_2(OH)_4 . H_2O$
Cobaltkoritnigite $(Co, Zn)(AsO_3)OH . H_2O$
Cornwallite $Cu_5(AsO_4)(OH)_4 . H_2O$
Duftite $PbCu(AsO_4)(OH)$
Erythrite $Co_3(AsO_4)_2 . 8 H_2O$
Fluckite $CaMn(HAsO_4)_2 . 2 H_2O$
Geminite $Cu_2(HAsO_4)_2 . 2 H_2O$
Guerinite $Ca_5(AsO_4)_2(AsO_3OH)_2 . 9 H_2O$
Haidingerite $Ca_2(HAsO_4)_2 . 2H_2O$
Hidalgoite $PbAl_3(AsO_4)(SO_4)(OH)_6$
Hörnesite $Mg_3(AsO_4)_2 . 8 H_2O$
Irhtemite $Ca_4Mg[(AsO_4)_2(AsO_3OH)_2] . 4 H_2O$
Kaatialaite $Fe[AsO_2(OH)_2]_3 . 5.25 H_2O$
Kahlerite $Fe(UO_2)_2(AsO_4)_2 . 10\text{-}12 H_2O$
Kańkite $FeAsO_4 . 3.5 H_2O$
Koritnigite $Zn[(H_2O)AsO_3(OH)]$
Köttigite $Zn_3(AsO_4)_2 . 8 H_2O$
Krautite $Mn[(H_2O)AsO_3(OH)]$
Lavendulan $NaCaCu_5(AsO_4)_4Cl . 5 H_2O$
Lindackerite $(Cu, Co)_5(AsO_4)_2(AsO_3OH)_2 . 10 H_2O$
Mcnearite $NaCa_5H_4(AsO_4)_5 . 4 H_2O$
Metalodevite $Zn(UO_2)_2(AsO_4)_2 . 10 H_2O$
Metanováčekite $Mg(UO_2)_2(AsO_4)_2 . 4\text{-}8 H_2O$
Meta-uranospinite $Ca(UO_2)_2(AsO_4)_2 . 8H_2O$
Metazeunerite $Cu(UO_2)_2(AsO_4)_2 . 8 H_2O$
Mimetite $Pb_5(AsO_4)_3Cl$
Mixite $BiCu_6(AsO_4)_3(OH)_6 . 3 H_2O$
Nováčekite $Mg(UO_2)_2(AsO_4)_2 . 12 H_2O$
Olivenite $Cu_2(AsO_4)(OH)$
Parascorodite $FeAsO_4 . 2 H_2O$
Parasymplesite $Fe_3(AsO_4)_2 . 8 H_2O$
Parnauite $Cu_9(AsO_4)_2(SO_4)(OH)_{10} . 7 H_2O$
Pharmacolite $Ca[(H_2O)_2AsO_3(OH)]$
Pharmacosiderite $KFe_4(AsO_4)_3(OH)_4 . 6\text{-}7 H_2O$
Picropharmacolite $Ca_4Mg(AsO_4)_2(AsO_3OH)_2 . 11 H_2O$
Pitticite amorphous hydrated Fe-arsenates-sulphates
Preisingerite $Bi_3O(AsO_4)_2(OH)$
Rauenthalite $Ca_3(AsO_4)_2 . 10 H_2O$
Rösslerite $MgHAsO_4 . 7 H_2O$
Sainfeldite $Ca_5(AsO_4)_2(AsO_3OH)_2 . 4 H_2O$
Scorodite $FeAsO_4 . 2 H_2O$
Schultenite $PbHAsO_4$
Strashimirite $Cu_8(AsO_4)_4(OH)_4 . 4 H_2O$
Symplesite $Fe_3(AsO_4)_2 . 8 H_2O$
Talmessite $Ca_2Mg(AsO_4)_2 . 2 H_2O$
Trögerite $(UO_2)_3(AsO_4)_2 . 12 H_2O$
Uranospinite $Ca(UO_2)_2(AsO_4)_2 . 10 H_2O$
Villyaellenite $(Mn,Ca,Zn)_5(AsO_4)_2[AsO_3(OH)]_2 . 4 H_2O$
Walpurgite $(BiO)_4(UO_2)(AsO_4)_2 . 2 H_2O$
Weilite $CaHAsO_4$
Zeunerite $Cu(UO_2)_2(AsO_4)_2 . 10\text{-}16 H_2O$
Zýkaite $Fe_4(AsO_4)_3(SO_4)(OH) . 15 H_2O$

Carbonates

Albrechtschraufite $MgCa_4F_2[(UO_2)(CO_3)_3]_2 . 17H_2O$
Andersonite $Na_2Ca[(UO_2)(CO_3)_3] . 6H_2O$
Aragonite $CaCO_3$
Beyerite $Ca(BiO)_2(CO_3)_2$
Bismutite $(BiO)_2CO_3$
Calcite $CaCO_3$
Cerussite $PbCO_3$
Hydrozincite $Zn_5(CO_3)_2(OH)_6$
Kamotoite-(Y) $Y_2(UO_2)_4(CO_3)_3O_4 . 14.5 H_2O$
Kettnerite $CaBi(CO_3)OF$
Liebigite $Ca_2[(UO_2)(CO_3)_3] . 11 H_2O$
Malachite $Cu_2(CO_3)(OH)_2$
Metazellerite $Ca[(UO_2)(CO_3)_2(H_2O)_2] . H_2O$
Monohydrocalcite $CaCO_3 . H_2O$
Neshquehonite $Mg[(CO_2OH)(OH)] . 2 H_2O$
Rabbittite $Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 . 18 H_2O$
Schröckingerite $NaCa_3[(UO_2)(CO_3)_3](SO_4)F . 10 H_2O$
Synchisite $Ca(Ce,La)(CO_3)_2F$
Urancalcarite $Ca(UO_2)_3(CO_3)(OH)_6 . 3 H2O$
Voglite $Ca_2Cu(UO_2)_2(CO_3)_2O_3$
Widenmannite $Pb_2(UO_2)(CO_3)_3$
Zellerite $Ca[(UO_2)(CO_3)_2(H_2O)_2] . 3 H_2O$
Znucalite $Zn_{12}Ca(UO_2)(CO_3)_3(OH)_{22} . 4 H_2O$

Elements

Copper Cu
Silver Ag
Sulphur S

Halogenides

Chlorargyrite $AgCl$

Molybdates

Wulfenite $PbMoO_4$

Oxides, Hydroxides

Allophane (amorphous aluminium silicates)
Arsenolite As_2O_3
Asbolan $(Co,Ni)_{1-y}(Mn^{4+}O_2)_{2-x}(OH)_{2-2y-2x} . n H_2O$
Becquerelite $Ca(UO_2)_6O_4(OH)_6 . 8 H_2O$
Bismite Bi_2O_3
Cervantite $Sb^{3+}Sb^{5+}O_4$
Claudetite As_2O_3
Compreignacite $K_2(UO_2)_6O_4(OH)_6 . 8 H_2O$
Coronadite $Pb(Mn^{4+}, Mn^{2+})_8O_{16}$
Cryptomelane $K(Mn^{4+}, Mn^{2+})_8O_{16}$
Cuprite Cu_2O
Goethite $FeO(OH)$
Hematite Fe_2O_3
Kermesite Sb_2S_2O
Masuyite $Pb_3U_8O_{27} . 10 H_2O$
Metaschoepite $UO_3 . n H_2O, n < 2$
Opal $SiO_2 . n H_2O$
Psilomelane (amorphous Mn-oxides)
Pyrolusite MnO_2
Richetite $PbU_4O_{13} . 4H_2O$
Schoepite $[(UO_2)_8O_2(OH)_{12}] . 12 H_2O$
Tenorite CuO
Uranosphaerite $Bi_2U_2O_9 . 3 H_2O$

Valentinite Sb_2O_3
Vandendriesscheite $PbU_7O_{22} . 12 H_2O$
Wölsendorfite $(Pb,Ca)U_2O_7 . 2 H_2O$

Phosphates

Apatite $Ca_5(PO_4)_3(F,Cl,OH)$
Autunite $Ca(UO_2)_2(PO_4)_2 . 10\text{-}12 H_2O$
Carbonate-fluorapatite $Ca_5(PO_4, CO_3)_3F$
Churchite-(Y) $YPO_4.2 H_2O$
Corkite $PbFe_3(PO_4)(SO_4)(OH)_6$
Dewindtite $Pb_3(UO_2)_6H_2(PO_4)_4O_4 . 12H_2O$
Diadochite $Fe_2(PO_4)(SO_4)(OH) . 5 H_2O$
Goyazite $SrAl_3(PO_4)_2(OH)_5 . H_2O$
Isoclasite $Ca_2(PO_4)(OH) . 2 H_2O$
Libethenite $Cu_2(PO_4)(OH)$
Meta-autunite $Ca(UO_2)_2(PO_4)_2 . 2\text{-}6 H_2O$
Metatorbernite $Cu(UO_2)_2(PO_4)_2 . 8 H_2O$
Mrázekite $Bi_2Cu_3(PO_4)_2O_2(OH)_2 . 2 H_2O$
Parsonsite $Pb_2(UO_2)(PO_4)_2 . 2 H_2O$
Petitjeanite $Bi_3O(OH)(PO_4)_2$
Phosphuranylite $KCa(H_3O)_3(UO_2)_7(PO_4)_4O_4 . 8 H_2O$
Pseudomalachite $Cu_5(PO_4)_2(OH)_4$
Pyromorphite $Pb_5(PO_4)_3Cl$
Smrkovecite $Bi_2O(PO_4)(OH)$
Torbernite $Cu(UO_2)_2(PO_4)_2 . 8\text{-}12 H_2O$
Uranocircite $Ba(UO_2)_2(PO_4)_2 . 12 H_2O$
Uranospathite $HAl(UO_2)_4(PO_4)_4 . 40 H_2O$
Vivianite $Fe_3(PO_4)_2 . 8 H_2O$
Vochtenite $Fe^{2+}Fe^{3+}[(UO_2)(PO_4)]_4(OH) . 12\text{-}13 H_2O$
Yingjiangite $K_2Ca(UO_2)_7(PO_4)_4(OH)_6 . 6 H_2O$

Silicate:

Bismutoferrite $BiFe_2(OH)(SiO_4)_2$
Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4 . n H_2O$
Coffinite $U(SiO_4)_{1-x} . (OH)_x$
Cuprosklodowskite $(H_3O)_2Cu(UO_2)_2(SiO_4)_2 . 2 H_2O$
Eulytite $Bi_4(SiO_4)_3$
Hemimorphite $Zn_4Si_2O_7(OH)_2 . H_2O$
Kasolite $Pb(UO_2)SiO_4 . H_2O$
Sklodowskite $(H_3O)_2Mg(UO_2)_2(SiO_4)_2 . 2 H_2O$
Soddyite $(UO_2)_2SiO_4 . 2 H_2O$
Talc $Mg_3Si_4O_{10}(OH)_2$
Uranophane $Ca(UO_2)_2[SiO_3(OH)]_2 . 5 H_2O$
Uranophane-beta $Ca(UO_2)_2[SiO_3(OH)]_2 . 5 H_2O$
Weeksite $K_2(UO_2)_2Si_6O_{15} . 4 H_2O$

Sulphates

Alunogen $Al_2(SO_4)_3 . 17 H_2O$
Anglesite $PbSO_4$
Antlerite $Cu_3(SO_4)(OH)_4$
Apjohnite $MnAl_2(SO_4)_4 . 22 H_2O$
Beaverite $Pb_2(Cu,Fe,Al)_6(SO_4)_4(OH)_{12}$
Bieberite $CoSO_4 . 7 H_2O$
Brochantite $Cu_4(OH)_6SO_4$
Chalcanthite $CuSO_4 . 5 H_2O$
Chvaleticeite $(Mn, Mg)SO_4 . 6 H_2O$
Copiapite $Fe^{2+}Fe^{3+}_4(SO_4)_6(OH)_2 . 20 H_2O$
Coquimbite $Fe_2(SO_4)_3 . 9 H_2O$
Devilline $CaCu_4(SO_4)_2(OH)_6 . 3 H_2O$
Epsomite $MgSO_4 . 7 H_2O$
Ferrohexahydrite $FeSO_4 . 6 H_2O$
Goslarite $ZnSO_4 . 7 H_2O$
Gunningite-Szomolnikite $(Zn,Mn)SO_4 . H_2O, FeSO_4 . H_2O$
Gypsum $CaSO_4 . 2 H_2O$
Halotrichite $FeAl_2(SO_4)_4 . 22 H_2O$
Hexahydrite $MgSO_4 . 6 H_2O$
Hydronium jarosite $(H_3O)Fe_3(SO_4)_2(OH)_6$
Jáchymovite $(UO_2)(SO_4)(OH)_{14} . 13 H_2O$
Jarosite $KFe_3(SO_4)_2(OH)_6$
Johannite $Cu[(UO_2)_2(SO_4)_2(OH)_2] . 8 H_2O$
Langite $Cu_4(SO_4)(OH)_6 . 2 H_2O$
Magnesium-zippeite $[Mg(UO_2)_2(SO_4)(OH)_4]_2 . 3 H_2O$
Melanterite $FeSO_4 . 7 H_2O$
Meta-uranopilite $(UO_2)_6(SO_4)(OH)_{10} . 5 H_2O$
Metavoltine $K_2Na_6Fe^{2+}Fe_6^{3+}(SO_4)_{12}O_2 . 18 H_2O$
Moorhouseite $CoSO_4 . 6 H_2O$
Morenosite $NiSO_4 . 7 H_2O$
Natrojarosite $NaFe_3(SO_4)_2(OH)_6$
Nickel-zippeite $Ni_2(UO_2)_6(SO_4)_3(OH)_{10} . 16 H_2O$
Nickelhexahydrite $NiSO_4 . 6 H_2O$
Plumbojarosite $PbFe_6(SO_4)_4(OH)_{12}$
Posnjakite $Cu_4(SO_4)(OH)_6 . H_2O$
Rabejacite $Ca(UO_2)_4(SO_4)_2(OH)_6 . 6 H_2O$
Retgersite $NiSO_4 . 6 H_2O$
Rhomboclase $HFe(SO_4)_2 . 4 H_2O$
Römerite $Fe^{2+}Fe^{3+}_2(SO_4)_4 . 14 H_2O$
Rozenite $FeSO_4 . 4 H_2O$
Sodium-zippeite $Na_4(UO_2)_6(SO_4)_3(OH)_{10} . 4 H_2O$
Thenardite Na_2SO_4
Uranopilite $(UO_2)_6(SO_4)(OH)_{10} . 12 H_2O$
Zippeite $K_4(UO_2)_6(SO_4)_3(OH)_{10} . 4 H_2O$

Sulphides

Acanthite Ag_2S
Orpiment As_2S_3
Pararealgar AsS
Proustite Ag_3AsS_3

Vanadates

Curienite $Pb(UO_2)_2V_2O_8. 5H_2O$
Metatyuyamunite $Ca(UO_2)_2(VO_4)_2 . 3 H_2O$
Mottramite $PbCuVO_4(OH)$
Namibite $Cu(BiO)_2(VO_4)(OH)$
Pucherite $BiVO_4$
Tyuyamunite $Ca(UO_2)_2V_2O_8 . 5\text{-}8 H_2O$

List of all “non-secondary” minerals from the Jáchymov ore district

Primary vein minerals

Acanthite	[221]	Ag_2S
Alloclasite	*	$(Co,Fe)AsS$
Ankerite	[118]	$Ca(Fe,Mg,Mn)(CO_3)_2$
Antimony	[118]	Sb
Argentite	[239]	Ag_2S
Argentopyrite	[118]	$AgFe_2S_3$
Arsenic	[239]	As
Arsenopyrite	[59]	$FeAsS$
Barite	[118]	$BaSO_4$
Bismuth	[239]	Bi
Bismuthinite	[239]	Bi_2S_3
Bornite	[228]	Cu_5FeS_4
Breithauptite	[118]	$NiSb$
Calcite	[239]	$CaCO_3$
Cinnabar	[118]	HgS
Chalcocite	[59]	Cu_2S
Chalcopyrite	[239]	$CuFeS_2$
Clinosafflorite	*	$(Co, Fe, Ni)As_2$
Cobaltite	[118]	$CoAsS$
Coffinite	[150]	$U(SiO_4)_{1-x}(OH)_{4x}$
Dickite	[141]	$Al_2Si_2O_5(OH)_4$
Dolomite	[239]	$CaMg(CO_3)_2$
Fluorite	[239]	CaF_2
Galena	[239]	PbS
Gersdorffite	[118]	$NiAsS$
Glaucodot	[141]	$(Co,Fe)AsS$
Gold	[118]	Au
Hematite	[59]	Fe_2O_3
Kaolinite	[118]	$Al_2Si_2O_5(OH)_4$
Krutovite	[180]	$NiAs_2$
Linnaeite	*	Co_3S_4
Löllingite	[118]	$FeAs_2$
Luzonite	*	Cu_3AsS_4
Manganite	[118]	$MnO(OH)$
Marcasite	[239]	FeS_2
Matildite	[215]	$AgBiS_2$
Maucherite	[141]	$Ni_{11}As_8$
Millerite	[239]	NiS
Molybdenite	[118]	MoS_2
Nickeline	[239]	$NiAs$
Nickel-skutterudite	[118]	$(Ni,Co)As_{2-3}$
Orpiment	[118]	As_2S_3
Pararammelsbergite	*	$NiAs_2$
Pearceite	[118]	$Ag_{16}As_2S_{11}$
Polybasite	[239]	$(Ag,Cu)_{16}Sb_2S_{11}$
Proustite	[239]	Ag_3AsS_3
Pyrargyrite	[239]	Ag_3SbS_3
Pyrite	[239]	FeS_2
Pyrolusite	[118]	MnO_2
Pyrostilpnite	[118]	Ag_3SbS_3
Pyrrhotite	[59]	$Fe_{1-x}S$
Quartz	[239]	SiO_2
Rammelsbergite	*	$NiAs_2$
Realgar	[239]	AsS
Rhodochrosite	[59]	$MnCO_3$
Safflorite	[118]	$CoAs_2$
Siderite	[239]	$FeCO_3$
Siegenite	*	$NiCo_2S_4$
Silver	[239]	Ag
Skutterudite	[239]	$CoAs_{2-3}$
Smithsonite	[118]	$ZnCO_3$
Smythite	*	$Fe_{13}S_{16}$
Sphalerite	[239]	$(Zn,Fe)S$
Stephanite	[239]	Ag_5SbS_4
Sternbergite	[239]	$AgFe_2S_3$
Stibnite	[59]	Sb_2S_3
Stromayerite	*	$AgCuS$
Tennantite	[59]	$(Cu,Fe)_{12}As_4S_{13}$
Tetradymite	[118]	Bi_2Te_2S
Tetrahedrite	[59]	$(Cu,Fe)_{12}Sb_4S_{13}$
Uraninite	[239]	UO_2
Violarite	*	$Fe^{+2}Ni_2{}^{+3}S_4$
Xanthoconite	[59]	Ag_3AsS_3

Rock-forming minerals

Actinolite	[118]	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
Amphibole	[59]	$NaCa(Mg,Fe)_5Si_7AlO_{22}(OH)_2$
Analcime	[118]	$NaAlSi_2O_6 . H_2O$
Anatase	*	TiO_2
Annite	*	$KFe_3AlSi_3O_{10}(OH,F)_2$
Apatite	[118]	$Ca_5(PO_4)_3(F,OH,Cl)$
Augite	[118]	$(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$
Biotite	[59]	$K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$
Calcite	[239]	$CaCO_3$
Cassiterite	[59]	SnO_2
Chlorite	[141]	$(Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$
Diopside	[118]	$CaMgSi_2O_6$
Epidote	[59]	$Ca_2(Al,Fe^{+3})_3(SiO_4)_3(OH)$
Garnet	[59]	$(Mg,Ca,Fe)_3(Al,Fe)_2(SiO_4)_3$
Graphite	[118]	C
Grossular	[118]	$Ca_3Al_2(SiO_4)_3$
Magnetite	[59]	Fe_3O_4
Muscovite	[59]	$Kal_2(Si_3Al)O_{10}(OH,F)_2$
Natrolite	[118]	$Na_2Al_2Si_3O_{10} . 2H_2O$
Oligoclase	[118]	$(Na,Ca)Al(Al,Si)Si_2O_8$
Olivine	[118]	$(Mg,Fe)_2SiO_4$
Opal	[118]	$SiO_2 . nH_2O$
Orthoclase	[59]	$KalSi_3O_8$
Palygorskite	[118]	$(Mg,Al)_2Si_4O_{10}(OH) . 4H_2O$
Phillipsite	[118]	$(K,Na,Ca)_{1-2}(Si,Al)_8O_{16} . 6H_2O$
Prehnite	[59]	$Ca_2Al_2Si_3O_{10}(OH)_2$
Pyrolusite	[141]	MnO_2
Quartz	[239]	SiO_2
Rutile	[59]	TiO_2
Sanidine	[118]	$(K,Na)AlSi_3O_8$
Scapolite	[118]	$(Na,Ca)_4(Si,Al)_{12}O_{24}(Cl,CO_3,SO_4)$
Serpentine	[118]	$(Mg,Al,Fe)_{2-3}(Si,Al,Fe)_2O_5(OH)_4$
Smectite	*	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2.nH_2O$
Titanite	[118]	$CaTiSiO_5$
Topaz	[118]	$Al_2SiO_4(F,OH)_2$
Tourmaline	*	$NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Vesuvianite	[141]	$Ca_{10}Mg_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$
Wolframite	[215]	$(Fe, Mn)WO_4$
Wollastonite	[141]	$CaSiO_3$
Xenotime-(Y)	*	YPO_4

*(* - this study)*

Origin and deposition of studied samples

The specimens studied originate from numerous private collections, from several institutional collections:

- in the Czech Republic: the National Museum in Prague, the Moravian Museum in Brno, the Faculty of Science, Masaryk University, Brno, the Institute of Chemistry of Solid Phases of the Chemical-Technical University in Prague, and the Institute of Geochemistry and Mineralogy of the Faculty of Science, Charles University in Prague.
- in Austria: Naturhistorisches Museum, Vienna, Landesmuseum Joaneum, Graz,
- in Germany: Staatliches Museum für Mineralogie und Geologie, Dresden, Technische Universität Bergakademie Freiberg, Freiberg.

The private collections and donators of specimens are too numerous to be listed individually; 80 to 90% of specimens used and studied originated from private collections. Altogether, several thousand specimens were inspected and studied, but mineral subsamples were separated from a smaller part of the specimens.

In the most favourable cases, several samples from a specific site were available, including at least the name of the ore vein. Such sample suites, unfortunately not numerous and contained mostly in private collections, provided valuable paragenetic information. Specimens collected in mid-nineteenth century are often accompanied by relatively accurate locality information, including name of the mine and vein, sometimes even level in the mine.

Lists of studied samples from Jáchymov

Moravian Museum, Brno, Czech Republic (BM)

sample	original name (locality, year)	determination	references
***	bismuthochre	scorodite, quartz, phlogopite?, bismite	*
A271	pharmacolite	pharmacolite, picropharmacolite, sainfeldite	*
A440	pharmacolite	pharmacolite, brassite, picropharmacolite	*
A852	liebigite	metatorbernite, uranophane	*
A973	pharmacolite	picropharmacolite, köttigite	*
A1742	pharmacolite	picropharmacolite	*
A1769	morenosite Svornost shaft 12th lev.	retgersite, arsenolite, annabergite	*
A1840	pharmacolite	“Mg-villyaellenite”, haidingerite, picropharmacolite	*
B114	liebigite	cuprosklodowskite	*
B1631	uranochre	rabbittite, gypsum	*
B1725	annabergite	annabergite, millerite	*
B2186***	bismite	** bindheimite, dussertite?, vanadinite?,carminite, beudantite, ogdensburgite?, cerussite, As-tsumebite on tetraedrite	*
B5252	rösslerite	pharmacolite	*
B6430	johannite	cuprosklodowskite	*
B6868	pharmacolite	picropharmacolite	*
B6932	cuprosklodowskite	metatorbernite, torbernite, uranophane	*
367	zippeite	uranophane, zippeite	*
399	liebigite	pharmacolite, picropharmacolite	*
1889	pharmacolite	picropharmacolite	*
2367	uranophane	uranophane-beta, quartz, calcite, illite, goethite, smectite	*
2400	wapplerite	brassite, picropharmacolite	[237]
3725	*Eliášit*	kasolite	*
5264	liebigite	liebigite	*
5268	liebigite	liebigite, schröckingerite, zellerite	*
5270	liebigite	liebigite, zellerite	*
5701	johannite	** hedyphane, bayldonite, ogdensburgite ?, arsenogoyazite, stolzite	*
5749	uranosphaerite, Geister vein	amorphous, arsenolite	*
5860	gummite with *Uranothallit*	uranophane, uranophane-beta	*
5861	*Eliášit*	amorphous	*
5862	gummite with uranochre	dewindtite	*
5864	uranochre, Eliáš mine	uranophane, tyuyamunite, meta-autunite	*
5865	uranochre, Eliáš mine	dewindtite, (uranophane, torbernite, sklodowskite)	*
5920	pharmacolite	picropharmacolite	*
5923	pharmacolite	picropharmacolite	*
5925	lavendulan	devilline	*
5929	lavendulan, *Kobaltblüthe*	cobaltkoritnigite	*
6106	uranopilite, uranochre	uranopilite, masuyite, wölsendorfite, uranophane	*
6183	mixite	** variscite	*
6184	mixite	mixite	*
9366	uranophane, Werner shaft	uranophane-beta	*
9367	uranophane	uranophane-beta	*

* - *this study*
** - *most probably not from Jáchymov*
*** - *Lichtenstein collection*

National museum, Prague, Czech Republic (NM)

sample	original name (locality, year)	determination	references
2006	johannite	johannite	[11]
2009	zippeite	zippeite	[35]
4877	*Waltherit*	walpurgite	*
4879	*Uranothallit*	liebigite, rabbittite	*
4880	voglite	voglite	[16]
4881	schröckingerite	schröckingerite	[10]
4882	schröckingerite	schröckingerite	[10]
4888	johannite	johannite	[36], [11]
4889	johannite	johannite	[36], [11]
4890	zippeite	uranopilite	[35]
4891	zippeite	zippeite	[35]
4892	lindackerite	lavendulan	*
4902	pharmacolite	Ca-Mg-AsO4(1), picropharmacolite	*
4905	*Ganomatit*	amorphous	*
4910	hemimorphite	hemimorphite	*
4913	gummite	weeksite, + ?	*
12913	*Voltzin*	sphalerite	*
12914	*Voltzin* 1902	sphalerite	*
15693	cuprosklodowskite	cuprosklodowskite	[7]
15695		liebigite	[57]
15697	*Uranothallit*	cuprosklodowskite, brochantite	*, [7]
15698	liebigite	cuprosklodowskite	[7]
15699	voglite	voglite	[16]
15700	voglite	voglite	[16]
15701	schröckingerite, 1902	schröckingerite, uranophane,	*, [10]
15702	schröckingerite, 1872	schröckingerite, metanováčekite, villyaellenite, weilite, pharmacolite	*, [10]
15703	schröckingerite	schröckingerite	[10]
16892	*Paterait*	anglesite	*
17259	morenosite	gunningite - szomolnokite, rhomboclase	*
17270	bieberite 1902	annabergite, aragonite, (illite)	*
17351	uranopilite	uranopilite	[9]
17353	zippeite	johannite	[11]
17354	uranopilite	uranopilite	[9]
17357	uranopilite	uranopilite	[9]
17358	uranopilite	uranopilite	[9]
17359	zippeite	uranopilite	[9]
17365	uranosphaerit 1902	vandendriesscheite, compreignacite, uranophane, kasolite	*
19216	lindackerite 1872	lavendulan, gypsum	*
19223	*Ganomatit* 1902	amorphous	*
24272	β-uranopilite	uranophane, schoepite	*, [7]
25017	liebigite 1927	liebigite	*, [57]
25907	haidingerite 1932	haidingerite, pharmacolite, weilite	*
25913	*Uranotil*	uranophane, uranophane-beta, sklodowskite	*, [7]
26325	zippeite	uranopilite	[9]
26534	cuprosklodowskite	cuprosklodowskite	[7]
26535	cuprosklodowskite	cuprosklodowskite	[7]
26536	*Uranotil*	uranophane	[7]
26537	*β-uranotil*	uranophane-beta	*
26538	uranophane-beta	uranophane-beta	[7]
26719	torbernite	metatorbernite	[15]
27147	johannite	johannite	[11]
27465	*β-uranotil*	uranophane-beta	[7]
27961	schröckingerite	schröckingerite	[10]
28212	schröckingerite	schröckingerite	[10]
29581	schröckingerite	schröckingerite	[10]
29641	haidingerite 1939	villyallenite, picropharmacolite	*
29922	uranopilite	uranopilite	[9]
30357		liebigite	[57]
30481	uranopilite	uranopilite	[9]
32295	zippeite	uranopilite	[9]
33949	*Uranotil*	uranophane	[7]
36542		liebigite	[57]
37167		zippeite	[57]
37633		uranopilite	[9]
37634		zippeite	[57]
38310		zippeite	[57]
38370	zippeite	uranopilite	[9]
38403		uranopilite	[57]
38405	schröckingerite	liebigite	[10]
39060		liebigite	[57]

To be continued

Cont.

sample	original name (locality, year)	determination	references
41443	schröckingerite	schröckingerite	[10]
43410	*Uranotil*	uranophane-beta	[7]
43865		zippeite	[57]
43866	uranopilite	uranopilite	[18]
43867		zippeite	[57]
43872		uranopilite	[57]
43873		uranopilite	[57]
44797	uranopilite	uranopilite	[9]
45149	liebigite	metatorbernite	[16], [57]
45157	schröckingerite	schröckingerite	[10]
45158	schröckingerite	liebigite	[10]
45159	schröckingerite	liebigite	[10]
45160	cuprosklodowskite	cuprosklodowskite	[7]
45161	schröckingerite	liebigite	[10]
45162	cuprosklodowskite	cuprosklodowskite	[7]
45163	cuprosklodowskite	cuprosklodowskite	[7]
45164	schröckingerite	liebigite	[10]
45165	schröckingerite	liebigite	[10]
45168	cuprosklodowskite	cuprosklodowskite	[7]
45170	schröckingerite	voglite ?	[10]
45171	johannite	johannite	[11]
45172	voglite	voglite	[16], [57]
45173	*Paterait*	arsenolite, skutterudite, chalcopyrite, moorhouseite	*
45180	cuprosklodowskite	cuprosklodowskite	[7]
45181	voglite	voglite	[16], [57]
45182	schröckingerite	schröckingerite	[10], [57]
45183	sklodowskite	uranophane	[7]
45208	*Uranotil*	uranophane-beta	[7]
45225	voglite	metatorbernite	*
45562	cuprosklodowskite	cuprosklodowskite	[7]
48847		liebigite	[57]
48975	schröckingerite	schröckingerite	[10]
49191	cuprosklodowskite	cuprosklodowskite	[7]
49298	cuprosklodowskite	cuprosklodowskite	[7]
51527	cuprosklodowskite	cuprosklodowskite	[7]
59707	kermesite	kermesite	*
68905	jáchymovite	jáchymovite	[18]
70241	*Uranotil*	uranophane	[7]
71021	*Uranotil*	uranophane	[7]
71624		liebigite	[57]
71668		zippeite	[57]
73554	zippeite	uranopilite	[9]

** - This study*

Faculty of Science, Masaryk University, Brno, Czech Republic (BU)

sample	original name (locality, year)	determination
1724	pharmacolite 1923	picropharmacolite
4947	kerargyrite	chlorargyrite, acanthite, illite

Institute of Chemical Techonology, Prague, Czech Republic (VS)

sample	original name (locality, year)	determination
738		schoepite
829	uranopilite (939)	weeksite, zippeite
1819	*Nasturan* with *Uranothallit*	liebigite, schröckingerite
9294 (3849)	schröckingerite and *Uranothallit*	zellerite, liebigite, uranophane
9293	*Uranothallit*	zellerite, liebigite
10072	lindackerite	amorphous
11683	zippeite	zippeite+UO_3-SO_3-H_2O(1)
11684	uranopilite	uranopilite, vandendriesscheite
12694	cuprosklodowskite	cuprosklodowskite, zeunerite
12695	cuprosklodowskite	cuprosklodowskite
12698	schröckingerite	meta-uranospinite, novacekite-20A, schröckingerite
12808	zippeite	jáchymovite, zippeite
14291	uranopilite	uranopilite
14545	pharmacolite	weilite, pharmacolite
15628	zippeite	zippeite
15828	*Uranothallit*	rabbittite, liebigite, urancalcarite, zellerite, metazellerite
15987	zippeite	zippeite
19256	cuprosklodowskite	cuprosklodowskite, compreignacite, UO_3. nH_2O(2), zeunerite
19352	liebigite	liebigite
20072	zippeite 1871	zippeite+UO_3-SO_3-H_2O(1)
20247	cuprosklodowskite	compreignacite, cuprosklodowskite
20780	zippeite with uranopilite	zippeite, compreignacite, sklodowskite

Faculty of Science, Charles University, Prague, Czech Republic (PF)

sample	original name (locality, year)	determination
2859	mixite	mixite, “phosphate-walpurgite”
2882	uranopilite 1882	yingjiangite or (phospuranylite ?), uranophane
3884	uranopilite 1887 (sample 1. and 2.)	1. rabejacite, 2. uranopilite
3912	*Uranothallit* 1887	liebigite, zellerite
6058	zeunerite 1915	autunite, meta-autunite, metatorbernite, metanováčekite?
6470	*Uranothallit* 1915	"kalium-schröckingerite", liebigite
6968	zippeite 1918	zippeite
10068	uranopilite 1934	uranopilite
10137	cuprosklodowskite (*Uranochalcit*)	cuprosklodowskite, torbernite
10415	schröckingerite 1938	nováčekite, metanováčekite
10774	*Uranothallit*	liebigite, zellerite
11541	zippeite, Saxony-noble-men adit 1946	zippeite
11542	zippeite, Saxony-noble-men adit 1946	zippeite
11729	zippeite, Werner shaft 1957	zippeite
15622	gummite, Rother vein, Werner shaft 1899	gummite
15623	gummite, Rother vein, Werner shaft 1899	gummite
15869	voglite, Eliáš mine 1854	lindackerite
16237	mixite, Geister vein, Geister shaft 6th lev. 1883	mixite, walpurgite, metazeunerite
16249	zeunerite, uranophane	uranophane, zeunerite, metatorbernite
19825	Zippeite	nováčekite ?, metanováčekite ?
20851	*Ganomatit* (*Kobaltblüthe*) 1853	pharmacosiderite

Naturhistorisches Museum, Vienna, Austria (WM)

sample	original name (locality, year)	determination
D3533	voglite, 1886	cuprosklodowskite, compreignacite
4538	voglite	voglite

Landesmuseum Joaneum, Graz, Austria (JG)

sample	original name (locality, year)	determination
452	*Frieseit*	pyrite, marcasite
453	*Frieseit*	hematite
1656	voglite	voglite
1713	*Paterait* 1939	arsenolite, skutterudite, erythrite
3403	uranochre, *Urangrün*, johannite	cuprosklodowskite, jáchymovite
9076	pitchblende with uranochre 1923	schröckingerite
9805	uranochre, uranopilite	torbernite, nováčekite, metanováčekite
13140	johannite	schröckingerite, liebigite, uranophane
13141	johannite	zellerite, schröckingerite
13142	johannite, 1869/70	uranospinite, meta-uranospinite, liebigite, schröckingerite
13143	johannite	cuprosklodowskite, uranopilite
13144	zippeite	uranopilite
13145	zippeite	uranopilite
13146	zippeite	uranopilite
14714	johannite	cuprosklodowskite
14716	voglite Eliáš mine, Glüchsgang 1859/60	voglite.
35519	bismuthinite 1859 - 60	"phosphor-walpurgite", torbernite
38117	erythrite	erythrite
38717	erythrite	arsenolite, erythrite
38829		rozenite
39257	uranopilite	zippeite, uranopilite
75479	lindackerite	lindackerite, parasymplesite, lavendulan, erythrite

Das mineralogische Museum der Wiener Universität, Viena, Austria

sample	original name (locality, year)	determination	references
8874		gummit, torbernit, uranofan	[39]
8875		uranin, torbernit, uranofan	[39]

TU Bergakademie Freiberg, Freiberg, Germany

sample	original name (locality, year)	determination	references
10957	picropharmacolite	brassite, pharmacolite	[237]
16347	voglite, Fluther vein	voglite	*
16348	voglite, Eliáš mine, 1852	voglite	*
20865	*wapplerite*, pharmacolite	brassite	[237]

** - This study*

Staatliches Museum für Mineralogie und Geologie, Dresden, Germany (DD)

sample	original name (locality, year)	determination
2497 Ba	zippeite with annabergite	uranopilite, cuprosklodowskite
2498 Ba	zippeite	sodium-zippeite?,uranophan?, liebigite?
2499 Ba/A	zippeite	"Mn-zippeite"
2556 Ba	uranochre with e*liasit*	massuite, smectite, ?
2557 Ba	uranochre	uranophane, massuite?
6306	voglite	voglite
7025	zippeite, uranopilite	uranopilite
7026	zippeite (m*edjidit*)	metaschoepite
7027	zippeite	zippeite
7028	zippeite	zippeite, uranopilite
7035	uranochre (zippeite with gypsum)	uranopilite
7676	uranopilite on e*liasit*	uranophane, cuprosklodowskite, vandendriesscheite
13495	uranochre	cuprosklodowskite, antlerite
14865	uranochre with uranothallite	liebigite
15020	zippeite (*Uranblüthe*)	uranopilite, zippeite, johannite

Harvard University, Cambridge, MA, USA

sample	original name (locality, year)	determination	references
977	trögerite	trögerite ?	[8]
94861	*uranothallite*	liebigite	[5]

Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington DC, USA

sample	original name (locality, year)	determination	references
	isoklasite		[162]×
R 2763	voglite	liebigite	[34]
52057	uranothalite	liebigite	[162]
83971	walpurgite	walpurgite	[162]
84651	uranopilite	uranopilite	[162]

R - Roebling collection

× - missing from the collection (P. Dunn, privat com.)

Musée Royal de l´Afrique Centrale, Tervuren, Belgium

sample	original name (locality, year)	determination	references
RGM 13 390	voglite	voglite	[42]

Muséum National d´Histoire Naturelle, Paris, France

sample	original name (locality, year)	determination	references
61-10	lavendulan	lavendulan	[152]
54 391	lindackerite	lindackerite	[152]
99 498	lavendulan	lavendulan	[152]
99 706	lindackerite	lindackerite	[152]
99 978	lindackerite	lindackerite	[152]
104 116	lindackerite	lindackerite	[152]
106 611	lindackerite	lindackerite	[152]
108 660	lavendulan	lavendulan	[152]
108 980	lavendulan	lavendulan	[152]

Laboratoire de Minéralogie de la Sorbonne, Paris, France

sample	original name (locality, year)	determination	references
La, 2	lavendulan	lavendulan	[152]
Li. 53 331	lindackerite	lindackerite	[152]
LIND. 5	lindackerite	lindackerite	[152]
305 L	lavendulan	lavendulan	[152]
310, P	lavendulan	lavendulan	[152]
371	lavendulan	lavendulan	[152]
383	lindackerite	lindackerite	[152]
53 363	lavendulan	lavendulan	[152]

École Nationale Supérieure des Mines, Paris, France

sample	original name (locality, year)	determination	references
14	haidingerite	brassite, haidingerite	[237]
20	pharmacolite, haidingerite	brassite, weilite, haidingerite, pharmacolite, rauenthalite	[237]
1963	pharmacolite	brassite (type)	[237]

Conclusions

The present publication contains results of four year project of detailed study of secondary minerals and their genetic relations in the Jáchymov ore district.

The papers deals with results of new study. The total number of valid secondary mineral species described from Jáchymov in the literature (70 minerals), was increased by the present study to 207 (plus 30 new secondary phases). For this reason, characteristics of minerals is given in alphabetic order. Besides new own data, the systematic part presents also reliable data taken from the literature. This made it possible to give a complete review of contemporaneous knowledge of secondary minerals in this district.

The extent of data does not permit to mention individually minerals newly identified in this district. In the course of the project, approximately 300 specimens were analysed using instrumental qualitative chemical analysis and studied by X-ray powder diffraction. Unit-cell parameters were calculated for 90 minerals. This resulted in proposals of alternative unit-cells for some minerals and in alternative indexing of diffractions. New quantitative chemical analyses were calculated to emiprical formulae and published analyses were recalculated.

The main emphasy of the project was not primarily on increasing the number of identified secondary mineral to 207 species. Registration of mineral distribution, their succession, and coexistence of secondary minerals in Jáchymov were considered as important topics. The present publication brings significant new information in this respect. The information is used for interpretation of weathering conditions and processes resulting in crystallisation of secondary minerals. In the context of chemical and mineralogical composition of ore veins, pH conditions, humidity, and temperature, it is possible to predict to some extent formation of some paragenetic groups of minerals. It is typical for the Jáchymov district that the secondary minerals form under conditions of high acidity, resulting from the presence of free sulphuric and arsenic acid, which derive from quick decomposition of sulphides, arsenide-sulphides, arsenides, and native arsenic. The low content of carbonates in veins is a contributing factor. These conditions are responsible for prevalence of acidic secondary minerals. The variability in composition of ore veins also contributed to the multitude of secondary minerals.

The data presented in this study and the fact that 308 ore and non-ore minerals were found in Jáchymov show that this locality ranks with mineralogically most profilic localities (as far as number of mineral species is concerned), such as Franklin, Langban, or Saint Marie aux Mines.