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MINERALOGICAL-GEOCHEMICAL CHARAKTERIZATION OF U-Mo-Cu MINERALIZATION IN THE PERMIAN OF THE SPIŠSKO-GEMERSKÉ RUDOHORIE MTS.

(Figs. 1—16)

Abstract: In the lower part of the Permian effusive-sedimentary complex in the surroundings of Novoveská Huta U-Mo-Cu mineralization occurs. The mineralization is bound to a tuffite horizon with the highest concentration in lenticles and to a smaller degree occurs in quartz porphyries. Mineralogical observation and evaluation of analytic data with employing of statistical mothods show mineralization character and confirm its syngenetic origin and relation with quartz porphyry volcanism.

The uranium mineralization in the surroundings of Novoveská Huta was first mentioned in literature by J. Ilavský (1957), who described it as Ni-Co-U mineralization of effusive-sedimentary origin. An important factor for genesis ascertainment of the deposit was the absolute age determination of the mineralization by J. Kantor (1959). According to the author the ore mineralization is of Permian age and shows very close genetic relation with quartz porphyry extrusions. The mineralized quartz porphyry pebbles were according to J. Kantor already mineralized before transportation. E. Drndzík (1965) supposes mineralization in quartz porphyries already in the time of magmatic differentation in volcanic hearth. The source of U-Mo-Cu mineralization in tuffites were volcanic exhalations. The author supposes partial migration and local concentration in the time of metamorphosis. F. I. Žukov (1963) explains the origin of mineralization as a consequence of Permian postvolcanic activity (hydrotherms, fumaroles). This is confirmed according to him by the occurrence of ore lenticles in the effusive-sedimentary complex, their position congruent with the complex and the discordance of dislocation tectonics with ore bodies elements.

MINERALOGICAL CHARACTERIZATION OF THE ORE MINERALIZATION

U-Mo-Cu mineralization occurs in tuffite horizons and to a smaller degree in quartz porphyries in the surroundings of Novoveská Huta. Heightened uranium concentrations are also observed in the underlying arcose shales and outside the deposit area in porphyroids and tuffs. For clearer presentation of mineralization I present the description of ore minerals occurrence and their characterizations ranged in three groups:

1. U-Mo-Cu mineralization in tuffites;
2. U-Mo-Cu mineralization in quartz porphyries;
3. heightened uranium concentrations in arcose shales, porphyroids and tuffs.

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1. *Mineralization in Tuffaceous Rocks*

The mineralization in tuffaceous rocks is the most important mineralization type in the area under consideration. The tuffite horizon in the rock overlying the lower quartz porphyries of the first volcanic phase (I. R o j k o v i č 1965) contains the highest concentrations of U-Mo-Cu mineralization. The ore-bearing rock are mainly tuffaceous conglomerates, to a smaller extent finer grained tuffites.

The mineralization occurs in the form of lenticles, frequently overlapping. The general position of ore lenticles mostly coincides with the strike and dip of surrounding rocks of the effusive-sedimentary complex. The mineralization is present in the form of the cement of tuffaceous rocks (fig. 1, 2).

Ore content percentage is roughly arranged concentrically as it was ascertained by radiometry and also by chemical, spectral and luminiscence analyses. The highest contents are in the centre of lenticles and gradually decrease towards the surrounding rock. Inside the tuffite horizon certain regularities in the distribution of ore lenticles can be observed. In the Hnilčík syncline (southern part of the deposit) ore lenticles appear closely overlying quartz porphyries and prevailingly concentrate in the lower part of the tuffite horizon. In the Huta anticline (northern part of the deposit) ore lenticles are found in the upper part of the tuffite horizon. This regularity in the occurrence of ore lenticles can be a consequence of later migration in the time of metamorphosis, however the general reduction of beds underlying the ore lenticles in the Hnilčík syncline is to take into consideration, where shales and sandstones are absent in the rock overlying the quartz porphyries in contrast to the Huta anticline, where they

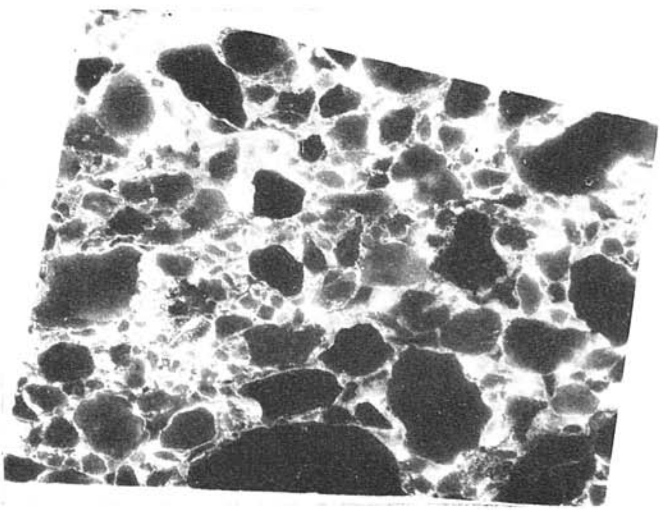


Fig. 1. Radiogram of tuffaceous comglomerate showing concentration of uranium minerals in the cement. Novoveská Huta, scale 2 : 1, polished section. Photo T. M a s t i h u b a.

Fig. 2. Ore minerals in the cement of tuffaceous conglomerate. Novoveská Huta, thin section, 1 nicol, magn. 15×. Photo F. Vrbovský.

are present. A distinct dependence on tectonics is shown in a lenticle in the Hnilčík syncline: the surface of the ore lenticle is conformable to average cleavage orientation (P. Adámek 1965). In this case migration of ore elements with metamorphosis is provable. The relatively highest ore elements contents in this lenticle also point tu subsequent concentration.

In the deposit area no tectonic dislocations were ascertained which could have served as channelway of ore-forming solutions. The metasomatic origin of the mineralization from deeper source does not agree with low contents of ore elements in surrounding rocks (except quartz porphyries in underlying rock) as well as the occurrence of several layers of shales underlying the mineralized horizon, which would act as a barrier in the case of penetration of metasomatism inducing solutions. The mineralization character appears as independent on mechanical permeability of rocks, since the ore lenticles appear as mentioned in tuffites of various grain size, even in shales, what agrees with stratigraphic control of the mineralization. U-Mo-Cu mineralization also does not induce alteration characteristic of hydrothermal deposits in its surroundings (I. Rojkovič 1964, 1965).

Younger veins of the siderite formation intersect U-Mo-Cu mineralization at some places. Apart from difference in strike and age the mineralogical and chemical composition also are unequivocally different. In the area of Novoveská Huta pitchblende and molybdenite neither have been ascertained microscopically nor by analyses in veins of siderite formation.

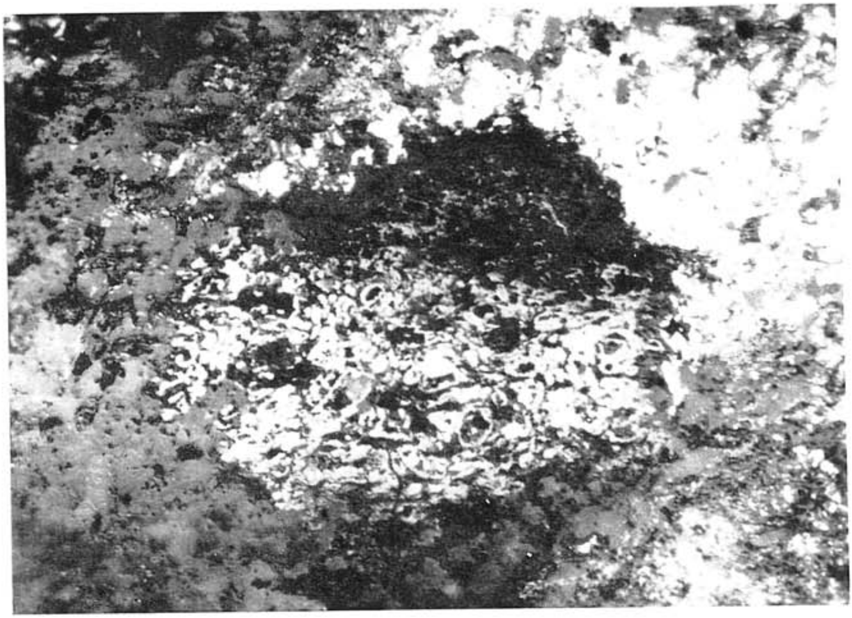


Fig. 3. Colloform pitchblende in tuffaceous sandy shale (light chalcopyrite). Novoveská Huta, polished section, magn. 150×. Photo F. Vrbovský.

Ore Minerals

Pitchblende was ascertained by microscopy, radiography, roentgenography and spectrally. It forms allotriomorphic grains, veinlets and frequently is also colloform (fig. 3). Its reflectibility greatly depends on the degree of oxidation, what sometimes can be observed within one aggregate of grains. It is found in close paragenesis with molybdenite, in quite distinct paragenesis also with pyrite and less with chalcopyrite. In tuffaceous sandstone it occurs on both sides of pyrite beds. In tuffaceous conglomerates pitchblende veinlets around larger pyrite crystals can be observed. It contains also galenite inclusions. The separation of pitchblende was rendered more difficult by its finer grain size and intergrowth with ore and rock-forming minerals. The roentgenogram showed very good coincidence with data from literautre (tab. 1) but spectral analysis showed as a consequence of intergrowth with other minerals except Pb, Y and Yb contents also trace quantities of Mo, Cu, Ni, Co, Al, Si, Ti, Cr and Ba.

Uranium black forms mostly earthy aggregates, very bad to polish. Under microscope it is observed as blackishgrey allotriomorphic aggregates and as a consequence of oxidation uranium black is frequently also observed at the margins of pitchblende aggregates and on joints of pitchblende veinlets.

Molybdenite occurs in all the deposit area, relatively more abundant in the southern (synclinal) part. It forms small scales, more rarely their aggre-

T a b l e 1. Results of pitchblende roentgenogram

Radius of chamber: 57,4 mm
Anticathode: Cu
Filter: Ni

1		2		3		4		5	
d	I	d	I	d	I	d	I	d	I
3,112	10	3,102	10	3,112	6	3,14	10	3,11	7
2,699	6	2,707	6	2,698	5	2,73	5	2,70	6
1,920	8	1,916	8	1,917	8	1,926	8	1,92	10
1,633	7	1,630	8	1,634	8	1,645	9	1,63	10
1,563	2	1,561	2	1,564	2	1,574	4	1,56	2
		1,495	2	1,494	1			1,49	1
1,359	2	1,361	1	1,358	2	1,365	3	1,36	2
1,248	4	1,244	3	1,246	4	1,251	6	1,25	5
1,212	4	1,212	3	1,213	4	1,220	6	1,21	5
				1,149	2			1,15	2
1,113	3	1,110	4	1,105	4	1,115	6	1,11	5
				1,043	3	1,051	7	1,04	4
						0,966	4		
						0,924	7		
						0,911	5		
						0,864	6		
						0,833	5		
						0,824	5		
						0,789	3		

Ascertainment: 1, 2 — Novoveská Huta. Literature: 3 — V. I. M i c h e j e v and V. N. D u b i n i n a (1939) — J. D. D a n a et al. (1951) (in V. I. M i c h e j e v 1957), 4 — C. F r o n d e l (1958), 5 — ASTM card-index in M. B u t s c h k o w s k y j (1958).

Preparation of roentgenogram: R. G a v e n d a. Evaluation of roentgenogram: R. G a v e n d a, I. R o j k o v i č.

gates, sometimes striking conformably to the position of rocks. In tuffaceous sandstones and shales the scales are concentrated together with pitchblende in thin strips. They are situated around chalcopyrite and locally their penetration into chalcopyrite can be observed. Considerable directing and bending of scales, some of which show undulatory extinction indicated, attest for the most part its pre-metamorphic crystallization. The identification of molybdenite was unequivocally confirmed roentgenographically (table 2).

C h a l c o p y r i t e is in tuffaceous rocks abundantly concentrated but with regard to pitchblende and molybdenite vertical shift of its maximum concentrations is observed. It forms allotriomorphic aggregates of grains and small veins. Chalcopyrite encloses colloform concentric, mainly idiomorphic pyrite crystals and also intersects it in the form of veinlets. It intergrows with tetrahedrite-tennantite, which in most cases replaces and grows around it. It encloses, on the contrary, pitchblende and ilmenite. Qualitative spectral analyses found except Cu and Fe (more than 1 %) also Mg, Mo, Na, As, Ca (0,01—0,001 %), Mn and Ag (less than 0,001 %, analysed by G. K u p č o).

T e n n a n t i t e - t e t r a h e d r i t e. The brown, more rarely green tint under the microscope attests the presence of both minerals. The mineral from the richest sample, analysed spectrally and roentgenographically, showed values nearer to tennantite (tab. 3). The calculated lattice constant is also nearer to tennantite

Table 2. Results of molybdenite roentgenogram

Fe anticathode
GON-3
Filter Mn
2° min

1		2		3		4			
d	I	d	I	d	I	dα/n	dβ/n	I'	I
6,20	10	6,16	1	6,61	0,8	6,61		3,0	
				5,63	0,9	5,63		5,0	
						3,37	3,06		1
3,005	3	3,00	0.5			3,07	2,78		3
2,719	8	2,71	0,7	2,74	0,7	2,744	2.487	2	2
2,64	2	2,63	0,5	2,66	0,3	2,676	2,426	0,5	1
2,518	2	2,52	0,7	2,49	0,5	2,502	2,268	1	4
2,264	7	2,26	1,0	2,27	1,0	2,267	2,055	8	9
2,042	1	2,04	0,5	2,040	0,7	2,045	1,854	2	10
						2,012	1,823		3
1,817	9	1,827	0,7	1,820	1,0	1,826	1,656	7	10
		1,749	0,2						
		1,699	0,2			1,693	1,535		5
		1,635	0,2	1,635	0,3	1,637	1,484	0,5	5
1,569	2	1,575	0,5	1,578	0,7	1,578	1,431	2	4
1,538	6	1,529	0,7	1,530	0,9	1,534	1,390	6	10
		1,476	0,2	1,475	0,2	1,475	1,337	0,3	6
		1,431	0,2						
		1,362	0,2	1,365	0,2	1,365		0,3	
		1,333	0,5	1,335	0,7	1,337	1,212	2	8
1,282	3	1,289	0,7	1,295	0,7	1,295	1,173	2	5
1,248	2	1,247	0,5	1,251	0,7	1,248	1,131	2	6
						1,228	1,112	0,3	7
		1,221	0,5	1,222	0,2	1,220	1,106		6
						1,211	1,098		4
		1,191	0,5	1,195	0,5	1,193	1,081	1	6
		1,146	0,2			1,139	1,033		6
		1,121	0,2	1,100	0,7	1,120	1,015		5
		1,197	0,7			1,098	0,996	2	10
						1,079	0,978		1
		1,035	1,0	1,034	0,8	1,035	0,936	3	10
		1,021	0,2	1,021	0,5	1,021	0,925	1	5
		1,000	0,5	1,092	0,7	1,092		2	
				0,968	0,3	0,968		0,5	
				0,953	0,7	0,953		2	
				0,912	0,3	0,912		0,5	
				0,901	0,2	0,901		0,3	
				0,894	0,7	0,894		2,0	
				0,865	0,5	0,865		1,0	
				0,858	0,3	0,858		0,5	
				0,834	0,1	0,834		0,2	

Ascertainment: 1 — Novoveská Huta. Literature: 2, 3 — ASTM card-index. 4 — V. I. Michejev. V. N. Dubinina (1948) — G. A. Harcourt (1942) (in V. I. Michejev 1957). I' — Intensity ascertained according to G. A. Harcourt.

Preparation of roentgenogram: R. Gavenda. Evaluation: R. Gavenda, I. Rojkovič.

Table 3. Results of tennantite roentgenogram

GOX-3
Anticathode Fe
Filter Mn
2°/min

1		2		3		4	
d	I	d	I	d	I	d	I
4,26	4	4,16	6				
3,63	3,5	3,70	3				
2,966	10	2,95	10	2,94	10	3,00	10
2,744	3	2,74	3				
2,57	6	2,56	7	2,55	6	2,60	6
2,42	3,5	2,41	5	2,40	4	2,45	4
2,103	1	2,09	3				
2,014	3,5	2,01	4	2,00	4	2,04	4
1,875	6	1,87	6	1,862	4	1,900	4
1,820	8	1,81	9	1,803	10	1,839	10
1,763	2	1,77	2	1,749	2	1,784	2
1,712	2	1,71	2	1,700	2	1,734	2
1,669	3	1,655	4	1,654	2	1,687	2
1,548	7	1,541	9	1,537	8	1,568	8
						1,502	2
1,482	1	1,475	2	1,472	2	1,471	2
1,453	1,5	1,445	3	1,443	2	1,301	2
1,285	2	1,277	4	1,274	2	1,243	2
1,228	2	1,222	2	1,219	2	1,209	2
1,194	1,5	1,190	3	1,185	2	1,193	4
1,179	3	1,172	5	1,170	4	1,122	2
1,145	1	1,142	3				
1,106	1,5	1,102	3	1,100	2	1,096	2
				1,075	2		
1,049	5	1,042	6	1,041	4	1,061	4
		0,982	3				
		0,974	3				
		0,910	3				
		0,902	2				
		0,868	2				
		0,863	2				

Ascertainment: 1 — Novoveská Huta. Literature: tennantite: 2 — G. A. Harcourt (1942) (in V. I. Michejev 1957), 3 — A. W. Waldo (1935) — F. Machatschki (1928) (in V. I. Michejev 1957), 4 — A. W. Waldo (1935) — G. A. Harcourt (1942) — F. Machatschki (1928) (in V. I. Michejev 1957).

Preparation of roentgenogram: R. Gavenda. Evaluation: R. Gavenda, I. Rojkoviè.

(tab. 4). These ascertainments however do not exclude the presence of tetrahedrite, besides microscopic observation also attested by frequent Sb contents in mineralized tuffites.

Pyrite is one of the most abundant minerals of tuffaceous rocks. It appears with pitchblende and molybdenite in ore lenticles and less scarttered in all the tuffite horizon. It forms cubic and pentagonal dodecahedral crystals and small veins. Most frequent however is colloform pyrite appearing in all the tuffite

Table 4. Lattice Constant

a	mineral	author
10,223 ± 0,003 Å	tennantite	G. A. Harcourt (1942) in V. I. Michejev (1957)
10,196 ± 0,001 Å	tennantite	A. W. Waldo (1935) in V. I. Michejev (1957)
10,400 ± 0,001 Å	tetrahedrite	V. I. Michejev (1957)
10,244 ± 0,015 Å	tennantite	Novoveská Huta — calculated from above mentioned roentgenogram

horizon, also in tuffite conglomerates as well as in finer grained varieties. It is of colloformy concentric and reniform shape. Pyrite spheroids are grown round with chlorite, sericite and quartz, which chystallized during metamorphosis and are distinctly directed perpendicularly to pressure, thus clearly attesting premetamorphic origin of these pyrites. The source of sulphur were most likely hydrogen sulphide exhalations, which caused reduction of cations of ore elements and their precipitation. Pyrite spheroids are in stratified position and in case the schistosity does not agree with stratification the direction of chlorite, sericite and quartz does not: agree with the position of pyrite beds (fig. 4, 5). Pyrite, mainly idiomorphic, is frequently enclosed by chalcopyrite, tetrahedrite-tennantite, pitchblende and intersected by quartz veinlets. Pyrite appears in close paragenesis mainly with pitchblende, what manifests in radiograms by concentration of higher radioactivity at the circumference of pyrite grains and beds.

Molybdenum, considered by B. Cambel and J. Jarkovský (1967) as element accompanying syngenetic pyrites, was ascertained in both analyses (tab. 5), what accords with other data about genesis of the mineralization under study. For reliable characterization of pyrite chemism however a higher number of analyses would be necessary and this could not be reached because of difficulties in their separation.

Galenite was only ascertained in tuffite conglomerates. It is relatively more abundant in the southern part of the deposit, most frequently as small veins and aggregates. In galenite veins pyrite, sphalerite and chalcopyrite are enclosed. Small galenite grains frequently are enclosed by pitchblende.

Sphalerite appears in very close paragenesis with chalcopyrite. Grain aggregates intergrow with chalcopyrite and mostly replace it. The reflectibility of sphalerite is lower as compared with brown sphalerites of other localities, rich in iron. In traversing light it is transparent with brownish-yellow tint. The inner reflexes are of equal colour, attesting to sphalerite poor in iron.

Arsenopyrite has been found only sporadically in tuffite conglomerates

Fig. 4. Pyrite concretions in bedded position and their directed growing round with chlorite (in direction of scale lengthening). Novoveská Huta, polished sample, scale in cm. Photo F. Vrbovský.

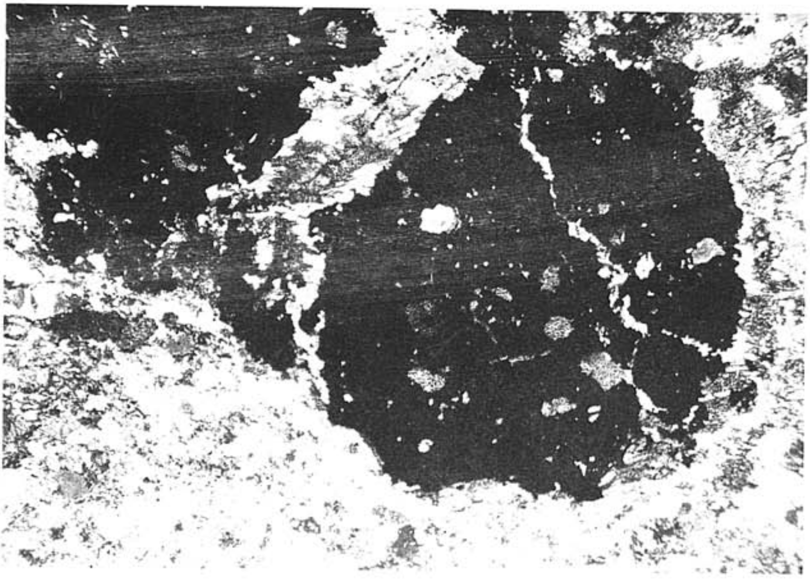


Fig. 5. Pyrite concretion, its directed growing round with pyrite and quartz. Novoveská Huta, thin section, magn. 28×. Photo F. Vrbovský.

in the southern part of the deposit. It forms prismatic crystals and isolated rhombic cross-sections are observed.

Ilmenite was abundantly found in the mineralized tuffite horizon in the northern part of the deposit, whereas in the southern part it is only sporadic. It is present as rounded grains, rods and very frequent are its skeletons with more rare relics of magnetite and isolated hematite in the interstices. In some skeletons indications of undulatory extinction and cataclasis are observed. Ilmenite grains and their skeletons frequently suffer from leucoxenization, also

Table 5. Quantitative spectral analysis of pyrite
(analysed by J. Jarkovský)

	a %	b %		a %	b %
Au	0	0	V	0	0
Tl	0	0	Sn	traces	0
Mn	0.041	0.014	Cu	0.1	0.1
Pb	0.022	0.091	Zn	0.007	0.012
As	1.0	0.174	Ti	0.015	0
Sb	0	0	Ag	0.001	0.001
Bi	0.001	traces	Ni	0.068	0.030
Mo	0.001	0.002	Co	0.091	0.030

Fig. 6. Skeletal ilmenite, partly enclosed by chalcopyrite. Novoveská Huta, polished section, magn. 360×. Photo F. Vrbovský.

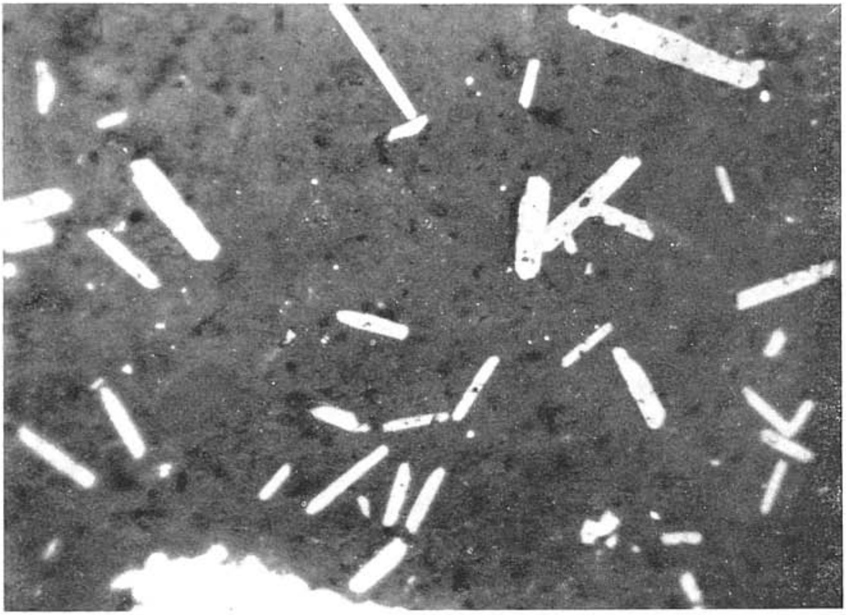


Fig. 7. Rods of mineral X. Novoveská Huta, polished section, magn. 360 ×. Photo F. V r b o v s k ý.

observable in skeleton interstices. Leucoxenes show rich inner reflexes of yellowish-white to brownish-yellow colour. Ilmenite skeletons (fig. 6) probably are relics after disintegration of solid solution of titanomagnetite into magnetite and titanite constituens. Magnetite constituent underwent separate leaching and ilmenite skeleton remained only, which has preserved original rounded delimitation of titanomagnetite, thus attesting its allogene origin. In the northern part of the deposit in tuffite conglomerates diabase pebbles from the underlying Rakovec Group are more abundant with ilmenite appearing more frequently (L. K a m e n i c k ý, M. M a r k o v á 1957). Basic rocks probably were the main source of ilmenite supplied into the area of sedimentation. Similar cases are described in detail by P. R a m d o h r (1956, 1960), considered by him as a consequence of separate leaching with oxidation and more frequently with hydrothermal processes. In many cases original magnetite constituent was replaced by pyrite, either completely or as distinct concentration of pyrite crystals within the skeleton with reference to the environment. Chalcopyrite frequently encloses ilmenite skeletons and also preserves original delimitation of titanomagnetite.

M a g n e t i t e appears only rarely in the mineralized horizon and mostly in close paragenesis with ilmenite in the form of rounded grains and relics in ilmenite skeletons.

H e m a t i t e is found only sporadically in mineralized tuffites in the northern

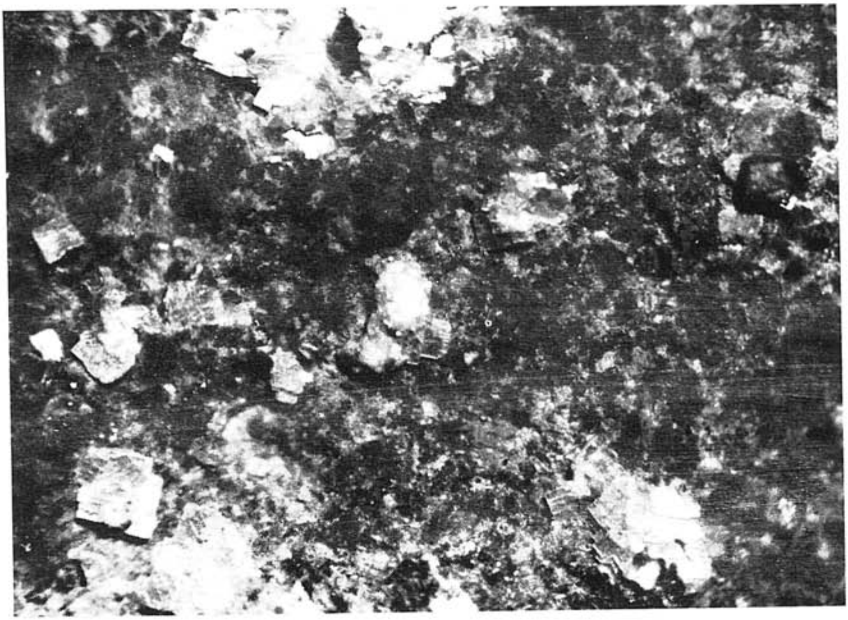


Fig. 8. Autunite crystals of idiomorphic delimitation on the surface of tuffite conglomerate. Novoveská Huta, sample, magn. 15×. Photo F. Vrbovský.

part of the deposit, mostly in interstices of ilmenite skeletons or in close proximity to them.

Covellite was found only sporadically on margins of chalcopyrite aggregates.

Mineral X. In some tuffite samples with highest vanadium contents ascertained spectrally were found longish prismatic crystals, to 0.02 mm long, of unknown mineral. The mineral is opaque and appears as isolated rods (fig. 7), their more rare accumulation can be observed on sericite aggregates. The mineral is of lower reflectibility than sphalerite, weakly anisotropic in immersion liquid and inner reflexes are not observed. As the mineral did not show radioactivity in radiograms and appears in samples with highest vanadium contents it is probably a vanadium mineral. According to optical characters the unknown mineral is with regard to vanadium minerals mostly related to montroseite (A. D. Weeks, M. E. Thompson 1954). For small dimensions and prevailingly scattered character of distribution we were not able to carry out separation of pure fraction of this mineral in sufficient quantity and the roentgenogram did not show sufficient accordance with data from literature. That's why the mineral cannot be considered as identified sufficiently and is described as mineral X in the next.

Oxidation minerals of uranium are rare at the deposit. They are better to observe in refuse piles only, where autunite, torbernite and tyuyamunite were found. Oxidation minerals of copper also are rare but they can be observed in mine workings too. They are represented by malachite and azurite which fill up joints and form coatings. The most frequent oxidation mineral is limonite,

Table 6. Results of autunite roentgenogram

Radius of chamber: 57,4 mm
Anticathode: Cu
Filter: Ni

1		2		3		4		5	
d	I	d	I	d	I	d	I	d	I
8,73	10	8,52	f	9,032	10	8,10	5		
5,330	6	5,41	f	5,556	5	5,25	1		
4,874	6	4,95	f	4,971	4				
				4,542	1/2				
4,353	7	4,26	m	4,360	3	4,19	3		
3,633	10	3,64	m	3,779	9	3,59	8		
3,427	9	3,51	f	3,511	7	3,47	1	3,46	8
3,236	10	3,23	f	3,270	8	3,21	2	3,23	3
2,922	5	2,94	m	2,964	6			2,88	2
2,732	3	2,705	dd	2,765	7				
2,593	3	2,52	d	2,576	3	2,60	6		
2,481	3	2,48	d	2,488	3				
2,378	3	2,38	d	2,397	4			2,41	2
		2,25	d	2,267	2				
2,201	4	2,215	m	2,216	3	2,21	1		
2,141	4	2,14	d	2,163	5	2,106	6	2,16	6
2,018	4	2,10	dd	2,075	4	2,031	3	2,03	1
1,941	3	2,05	d	1,902	2	1,940	5		
1,888	2	1,89	dd	1,844	3	1,876	1		
1,780	3	1,77	dd	1,789	3				
		1,75	dd	1,755	2	1,762	3		
		1,71	dd	1,722	2			1,726	2
		1,66	dd	1,697	3				
1,652	3	1,65	dd	1,633	3			1,632	2
1,600	4			1,61	3	1,600	8		
1,555	3			1,546	1	1,569	1	1,542	2
1,523	4			1,477	1	1,527	5		
1,451	3			1,439	1				
				1,401	2				
1,382	2			1,383	1	1,384	2		
1,345	3			1,359	1	1,348	2	1,359	1
				1,338	1/2				
				1,288	1/2				
				1,270	1				
2,255	2			1,249	2				
				1,221	1/2				
1,192	2			1,194	3	1,194	1	1,201	1
						1,159	1		
						1,130	1		

Ascertainment: 1 — Novoveská Huta. Literature: 2 — H. Brichard and H. Brasseur (1958) (in M. Butschkowskyj 1958), 3 — V. Ross (1955) (in C. Frondel 1958), 4 — G. A. Sidorenko (1960), 5 — E. Przybora (1957).

Preparation of roentgenogram: R. Gavenda. Evaluation of roentgenogram: R. Gavenda, I. Rojkovič.

mainly abundant at places with heightened pyrite concentration, forming coatings and filling up joints there.

A u t u n i t e was as well as torbernite found in the whole area of the deposit, more abundantly however in the southern part. Autunite forms brittle micaceous scaly aggregates of light-yellow colour and frequently also well-developed tabular crystals are observed (fig. 8) with fissility along the basal plane. The identification of autunite was also confirmed by roentgenography (tab. 6). Except Ca, U and P (more than 1 %) also Ba (1—0.1 %), Al, Ti, Sr, Mn (0.01—0.1 %), Y, Cu, Zr (0.01—0.001 %), Ag, Cr (less than 0.001 %) were found by spectral analysis.

T o r b e r n i t e is found much more rarely than autunite. It appears as pulverulent coatings of deep-green colour. The identification is confirmed by roentgenogram (tab. 7). Spectral analysis was carried out on relatively contaminated sample as a consequence of insufficient quantity and its pulverulent character, manifesting in the presence of a considerable amount of trace elements. Besides U, Cu and P are represented there: Si, Al, Mo, Ti, Ca, Pb, Ba, Sr, Fe, B, Mg, Cr, Ni and Co.

T y u y a m u n i t e was ascertained in the northern part of the deposit only, at places where autunite and torbernite did not appear. It forms canary-yellow tinge on tuffite sandstones. Except characteristic colour it manifests by radioactivity on radiograms and also was identified by roentgenography.

2. *Ore Minerals in Quartz Porphyries*

Ore minerals in quartz porphyries mostly are not in important concentration. Accessory amount of magnetite, hematite and more rarely of ilmenite is found mainly in violet, less in green quartz porphyries and porphyroids.

The lower quartz porphyries near Novoveská Huta and mainly some of their pebbles in tuffite conglomerates are rich in ore minerals. Chalcopyrite is mostly found in them, less pyrite, tennantite-tetrahedrite, pitchblende and uranium black. Pebbles of mineralized quartz porpyries were found in the tuffite horizon only. They are not related to the ore lenticles only but also appear in tuffite conglomerates with lower contents of ore elements. The mineralization in lower quartz porphyries as well as in quartz porphyries pebbles in tuffite conglomerates is of scattered character. In upper quartz porphyries except Fe minerals mentioned sometimes also pyrite and chalcopyrite are observable, present in quartz-sulphidic and siderite-ankerite veins related with later hydrothermal mineralization of the siderite formation. The lower quartz porphyries differ from the upper ones also in higher acidity and association of elements similar to mineralized tuffite rocks.

P i t c h b l e n d e and u r a n i u m b l a c k are scattered in quartz porphyry pebbles and the lower quartz porphyries, as also the radiograms confirm (fig. 9). Pitchblende mostly forms irregularly confined and colloform aggregates with enclosed fine grained galenite. As a consequence of oxidation pitchblende passes into uranium black mainly on the margin of aggregates and on joints.

Table 7. Results of torbernite roentgenogram

Radius of chamber: 57,4 mm
Anticathode: Cu
Filter: Ni

1		2		3		4		5	
d	I	d	I	d	I	d	I	d	I
9,408	8	9,41	1	10,2	d	10,03	m	10,3	10
8,673	10	9,85	5	8,84	f				
						6,62	d	6,61	4
5,246	5	5,47	2	5,49	m			5,18	3
4,848	6	4,96	2	4,93	m	4,91	m	4,94	9
4,230	5	4,37	3	4,32	d	4,48	dd	4,48	4
3,633	10	3,69	10	3,70	f			3,67	4
3,427	5	3,52	4	3,59	d	3,52	mf	3,58	9
3,302	2					3,30	d	3,51	8
3,187	5	3,26	5	3,24	m	3,10	dd	3,10	1
2,885	4	2,95	3	2,99	dd	2,87	dd	2,90	3
								2,85	2
						2,72	dd	2,73	1
2,637	3	2,68	5	2,67	m			2,67	1
2,501	5	2,56	3	2,54	d	2,50	dd		
2,443	3	2,49	2					2,48	1
						2,41	dd	2,41	2
2,356	4	2,39	2					2,37	1
								2,32	1
		2,26	1	2,25	d			2,24	1
		2,22	2			2,22	d	2,21	3
2,181	5	2,18	5	2,17	m	2,16	d	2,158	2
2,141	3	2,14	3	2,12	d				
2,040	5	2,07	4	2,05	m	2,04	d	2,040	3
1,973	5	1,989	6	1,98	m			1,917	1
1,870	2	1,892	1	1,84	d			1,873	1
		1,852	2						
1,814	2	1,821	1						
1,797	2	1,781	2	1,77	d				
1,753	5	1,746	1						
1,698	2	1,713	1						
1,627	3	1,642	7	1,64	f				
1,596	2	1,613	2						
1,566	2	1,583	2	1,58	dd				
1,537	4	1,556	8	1,55	f				
		1,461	1						
		1,449	1	1,45	d				
1,411	3	1,419	5	1,42	m				
		1,389	2	1,39	d				
1,354	5	1,366	5	1,369	m				
1,319	3	1,336	3	1,336	d				
1,306	3	1,313	4	1,313	d				
		1,264	1						
		1,247	1						
		1,243	2						
		1,222	2						
		1,211	2						
		1,197	1						
		1,159	5						

Ascertainment: 1 — Novoveská Huta. Literature: 2 — J. D. Dana et al. (1951) (in M. Butschkowskyj 1958), 3 — W. D. Keller (1952) (in M. Butschkowskyj 1958), 4 — C. Guillemin (1956) (in M. Butschkowskyj 1958), 5 — R. Berman (1956) (in C. Frondel 1958).

Preparation of roentgenogram: R. Gavenda. Evaluation of roentgenogram: R. Gavenda, I. Rojkovič.

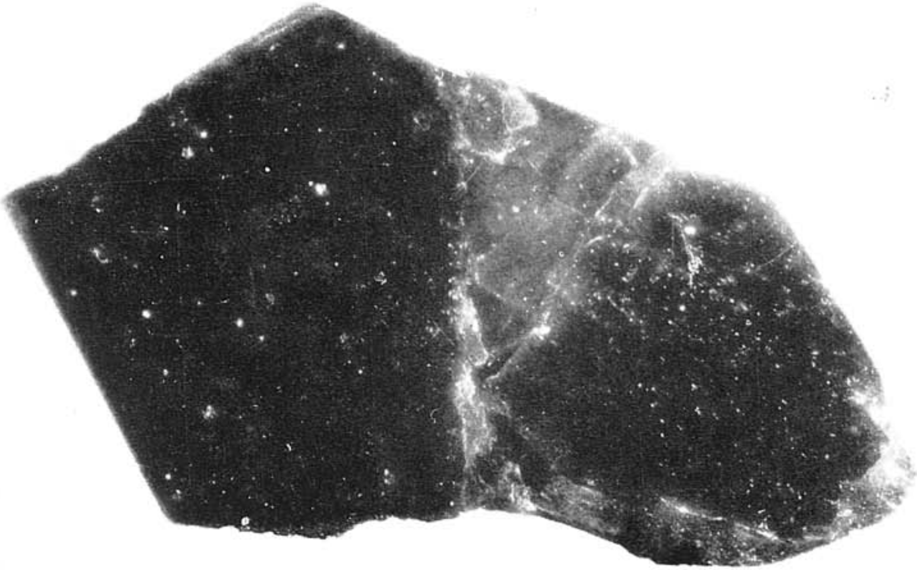


Fig. 9. Radiogram of quartz porphyry pebbles (dark) in tuffite conglomerate. Novoveská Huta, scale 2 : 1. Photo T. M a s t i h u b a

Fig. 10. Quartz porphyry pebble with chalcopyrite (light). Novoveská Huta, polished sample, scale in cm. Photo F. V r b o v s k ý.

Chalcopyrite is the most abundant mineral in quartz porphyries affected by mineralization. Aggregates of chalcopyrite, frequently to 2 mm large, graitly impregnate the rock (fig. 10).

Tennantite-tetrahedrite mostly appears in closed paragenesis with chalcopyrite, intergrowing and replacing it. More rarely it forms independent grain aggregates.

Pyrite is mostly very fine grained and colloform. It is more abundant in cases of relatively lower chalcopyrite content. Pyrite enclosed in chalcopyrite is mostly idiomorphic. In several cases complete replacement of magnetite constituent of titanomagnetites by pyrite was observed, contradicting the opinion of E. Drndzík (1965), according to which U-Mo-Cu mineralization in quartz porphyries took place as early as magmatic differentiation in the volcanic hearth. Primary ore minerals in violet as well as in green quartz porphyries were originally magnetite and ilmenite. U-Mo-Cu mineralization in quartz porphyries is later than these accessories and is related to hydrothermal solutions, which were a consequence of volcanic activity.

Sphalerite is sporadic only, in closed intergrowth with chalcopyrite.

Molybdenite has not been found in quartz porphyries but heightened Mo contents, ascertained spectrally, relate with ore minerals mentioned, confirm U-Mo-Cu association of elements in quartz porphyries affected by mineralization and enable to asume the presence of molybdenite, although to a smaller degree than in ore minerals mentioned.

3. *Higher Uranium Concentration in Shales, Porphyroides and Tuffs*

In arcosic and partly also in quartz-sericite shales underlying the mineralized tuffite horizon near Novoveská Huta, porphyroids north of Kolínovce and in tuffs of quartz porphyries near Stratená higher uranium concentration was ascertained. The occurrence of uranium could be observed mineralogically with relatively highest concentration only, where uranium is related to uranium black appearing at planes of schistosity and joints. As compared with contents of elements in mineralized tuffites and quartz porphyries marked enrichment in one element only uranium is evident here.

In the rock underlying the mineralized tuffite horizon higher uranium concentration was ascertained in strongly cleaved arcosic and less in quartz-sericite shales. Differential enrichment of shales in uranium is most probably of infiltration origin. Solutions with easily migrating uranium percolated into strongly destructed shales and precipitation took place there.

In strongly cleaved porphyroids nort of Kolínovce and in tuffs near Stratená, where manifestations of hydrothermal activity of the siderite formation were not observed, higher uranium contents, although relatively lower than in shales underlying the mineralized horizon, also were ascertained. Equally as in the foregoing case also in these rocks differential enrichment in uranium only without accompanying elements of U-Mo-Cu mineralization and again in strongly cleaved rocks was ascertained. Mineralogical occurrence of uranium and manifestations of radioactivity in radiograms have not been ascertained. Local infiltration migration of uranium most probably took place only in these rocks, relatively richer in uranium.

GEOCHEMICAL CHARACTERIZATION OF THE ORE MINERALIZATION

The scattered and fine grained character of ore minerals made mineralogical characterization of ore mineralization possible more or less in ore lenticles only. For better knowledge of the character of distribution of ore elements chemical, spectral and luminiscence analyses of trace elements were carried out.

Tuffaceous sandy shales, sandstones and conglomerates show clear heightening of ore elements contents, which not only is characteristic of ore lenticles with highest concentration but also of the whole tuffite horizon. Enrichment in ore elements in the tuffite horizon presents the graph mentioned next (fig. 11), where trace elements contents in clastic sedimentary rocks and tuffites with

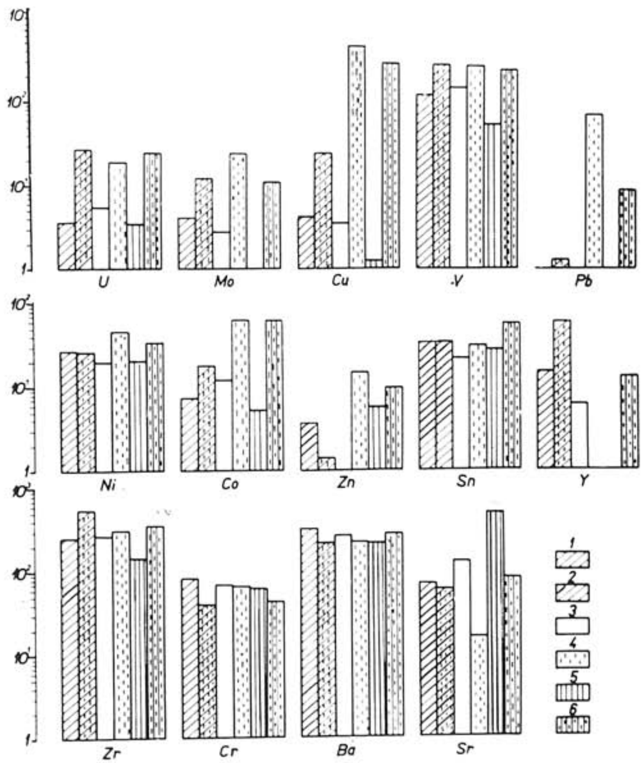


Fig. 11. Average contents of trace elements in clastic sedimentary rocks and tuffites near Novoveská Huta (1 — shales, 2 — tuffaceous shales, 3 — sandstones, 4 — tuffaceous sandstones, 5 — conglomerates, 6 — tuffaceous conglomerates; 66 spectral analyses).

Table 8. Tests of normal and lognormal distribution of elements

	normal		lognormal	
	a	b	a	b
U	12,11	16,80	1,75	1,07
Mo	11,42	16,14	3,56	0,61
Pb	19,49	59,98	21,09	80,18
Ni	15,85	41,88	0,32	3,56
Co	10,10	15,75	0,32	1,38
Cu	10,44	16,88	0,09	1,66
Y	13,44	28,80	2,42	1,21
Zn	16,37	48,32	2,04	1,36
V	6,43	6,10	0,61	0,17
Zr	6,89	6,97	0,09	0,16
Cr	3,47	0,75	3,33	1,60
Ba	6,38	4,27	0,28	0,01
Sr	9,15	11,19	2,28	2,28
Sn	7,17	9,61	2,15	1,85
Ga	0,45	0,65	0,56	0,91
C_{org}	0,99	0,96	1,26	1,21

a $-\left|\frac{\gamma_1}{\delta\gamma_1}\right|$, b $-\left|\frac{\gamma_2}{\delta\gamma_2}\right|$, γ_1 — asymmetry, γ_2 — excess, $\delta\gamma_1$ — standard deviation of asymmetry, $\delta\gamma_2$ — standard deviation of excess. The distribution is normal or lognormal at elements with relations mentioned (a, b) less than or equal to 3 (Z. A. Janočkina 1966). The calculations were carried out by J. Klučárová (Institute of Technical Kybernetics at the Slovak Academy of Science with computer ZRA-1).

exclusion of contents in ore lenticles are compared. The graph shows enrichment in U, Mo, Cu, V, Pb, and Co and less distinct in Y, Ni, Zr and Zn in the whole tuffite horizon. In Sn and Ba contents larger deviations are not observed. Cr shows, on the centrary, lower contents and Sr even relative impoverishment in contrast to clastic sedimentary rocks.

In sedimentary rocks certain dependence of ore elements on grain size may be observed, manifesting in the increase in Mo, Cu and less also in U, V, Ni and Co contents in finer grained varieties. In tuffaceous rocks however similar dependence has not been observed, as concentration in them was dependent neither on adsorption nor on rock permeability. Highest contents of ore elements in the whole tuffite horizon as well as in ore lenticles apper equeally in tuffaceous conglometrates and in tuffaceous sandstones an shales.

Ore lenticles are in contrast to surrounding tuffites most distinctly enriched in uranium, molybdenum, lead and cobalt. Increase in Cu, Ni, Y and Zn contents also is provable not evident in Sn, Zr, Cr, Ba and Sr. It may be said generally that in ore lenticles highest concentration of the same elements is reached, which are enriched in the whole tuffite horizon as compared with clastic sedimentary rocks.

Average contents of trace elements in tuffites show the following order according to descreasing contents: U, Zr, V, Cu, Mo, Ba, Pb, Co, Sr, Y, Ni, Sn, Cr, Ga and Zn. The distribution character of trace elements contents in tuffites was verified by statistical tests (tab. 8), which confirmed lognormal distribution of all elements ascertained quantitatively. An exception are Pb contents only, considerable amount of which is less than the sensitivity limit of spectral analysis, what then results in untrue picture of distribution character of Pb contents. Tests of normal distribution of trace elements contents showed a proximity with this distribution at elements not connected with U-Mo-Cu mineralization, i. e. Ga, C org., Cr, Ba, V, Zr, Sn and Sr, whereas ore elements contents U, Mo, Cu, Pb, Ni, Co (Zn) and (Y) are very distant from this distribution.

The values of standard deviation of trace elements contents (fig. 12) more clearly show the ability of individual elements to reach highest concentration within the mineralized horizon as well as with regard to clastic sedimentary rocks (shales, sandstones, conglomerates) and to form ore lenticles. Notable is the high standard deviation at uranium, molybdenum and copper in tuffites. Elements mostly related to rock-forming minerals show lower variation coefficient, the lowest is at Ga, Zr, Ba and Sn (table 9).

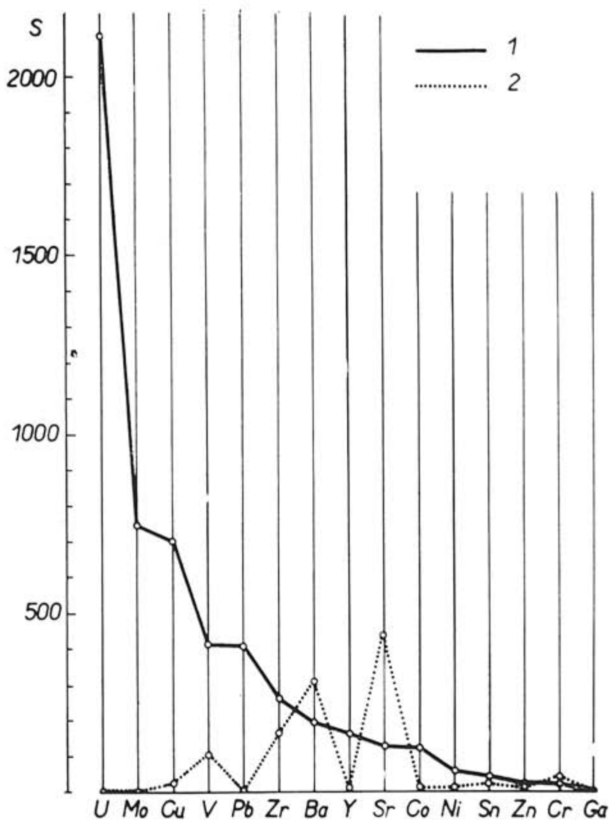


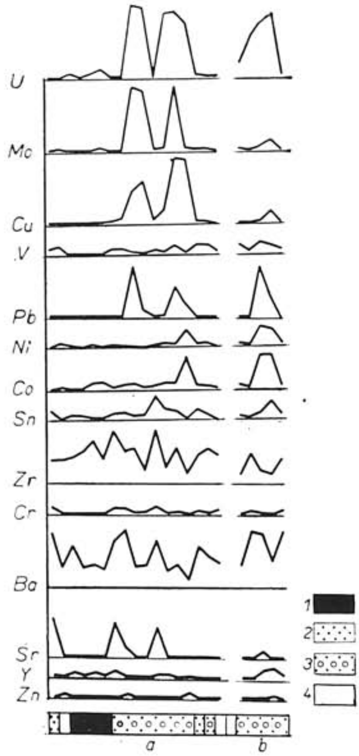
Fig. 12. Standard deviation (s) of trace elements contents in tuffites (1) and sediments (2); (130 quantitative analyses).

Table 9. Statistical evaluation of trace elements in tuffites

	$\overline{x}$ (ppm)	s^2	s	V (%)	r		r	
U		4 491 999	2119	269				
Mo	269	570 730	755	280	U/Mo	0,705	Mo/Cu	0,298
Pb	124	173 861	417	336	U/Pb	0,690	Ni/Co	0,774
Ni	46	3 447	59	128	U/Ni	0,372	Ni/V	− 0,093
Co	79	14 781	122	153	U/Co	0,524	Co/V	0,172
Cu	349	501 655	708	203	U/Cu	0,198	Cu/V	0,144
Y	52	28 067	168	324	U/Y	0,388	Y/Zr	0,465
Zn	8	808	28	368	U/Zn	− 0,046		
V	363	175 764	419	116	U/V	0,151	V/Mo	0,311
Zr	393	70 171	265	67	U/Zr	0,076		
Cr	42	780	28	66	U/Cr	− 0,202	Cr/V	0,082
Ba	268	39 640	199	74	U/Ba	0,101		
Sr	66	16 874	130	198	U/Sr	0,204		
Sn	43	2 043	45	105	U/Sn	− 0,004		
Ga	15	21	5	30	U/Ga	− 0,051		
C_{org}	1297	1 230 492	1109	85	U/C_{org}	− 0,271	U/CO_2	− 0,192

$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ — arithmetrical average (number of analyses: U — 86, Ga — 21, C_{org} — 22, other 80) $s^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i-\overline{x})^2$ — dispersion, s = standard deviation, $V\,(\%) = \frac{s}{x} \,.\, 100$ — variation coefficient, $r_{xy} = \frac{1}{n}\sum\left(\frac{x-\overline{x}}{s_x}\right)\left(\frac{y-\overline{y}}{s_x}\right)$ — correlation coefficient. The calculations were carried out by J. Klučárová (Institute of Technical Kybernetics at the Slovak Academy of Science with computer ZRA-1).

In spatial distribution of trace elements near Novoveská Huta we also observe distinct enrichment in ore elements of the tuffite horizon and less of the lower quartz porphyries (fig. 13, 14). Within the mineralized horizon however several differences are evident. As already mentioned in mineralogical characterization certain deviations are observed in the distribution of minerals in the northern part of the deposit (Huty anticline) and in the southern part (Hnilčík syncline), also reflected in spatial distribution of trace elements. Whereas in the Hnilčík syncline we observe highest concentration of ore elements in rock directly overlying the lower quartz porphyries (fig. 13), in the Huty anticline appear highest contents of ore elements in upper part of the tuffite horizon (fig. 14). Although vanadium contents show considerable variation, also confirmed by relatively high standard deviation, however their distinct increase is not observed at places with highest concentration of ore elements. Generally it may be said that vanadium distribution is of more scattered character also with higher contents. Its contents are distinctly heightened in the whole tuffite horizon in the northern part of the deposit, in the southern part they are to 10 times lower, what is in accordance with spatial distribution of magnetite and ilmenite, considerable part of vanadium is related to. The highest contents of copper agree with the localization of ore lenticles, however vertical shift of the highest contents



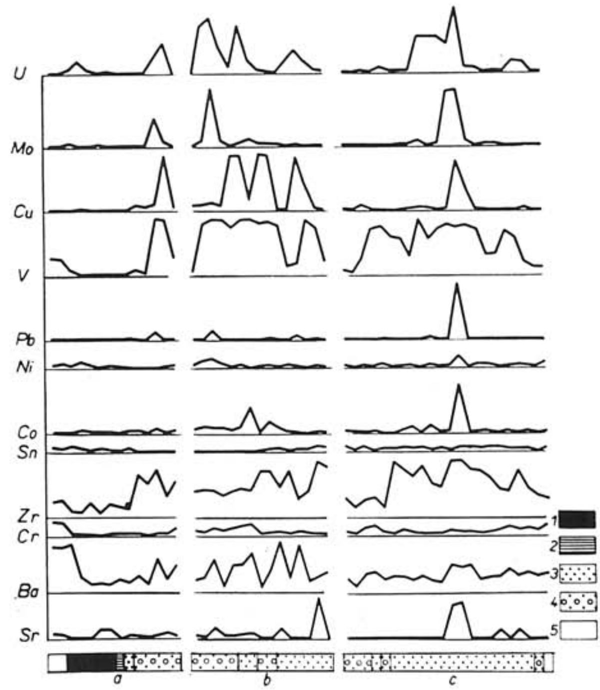


Fig. 13. Geochemical profiles of the lower part of effusive-sedimentary complex in the Hnilčík syncline. 1 — quartz porphyry, 2 — tuffaceous sandstone, 3 — tuffaceous conglomerate, 4 — shales and sandstones. (The highest contents of elements are reduced.)

Fig. 14. Geochemical profiles of the lower part of effusive-sedimentary complex in the Huta anticline. 1 — quartz porphyry, 2 — tuff, 3 — tuffaceous sandstone and sandy shale, 4 — tuffaceous conglomerate, 5 — shales and sandstones. (The highest contents of elements are reduced.)

toward the overlying stratum is observed, as it was also the case at copper minerals.

The geochemical profiles make evident that not all elements enriched in the tuffaceous horizon show highest contents together with uranium. According to decreasing values of the coefficient of correlation of uranium to other elements (fig. 15, table 9) individual trace elements show the following degree of interrelation proximity to uranium:

a) high ($r > 0{,}7$): Mo
b) considerable ($0{,}7 > r > 0{,}5$): : Pb, Co
c) moderate ($0{,}5 > r > 0{,}3$) : Y, Ni
d) low ($r < 0{,}3$) : Sr, Cu, V, Ba, Zr, Sn, Zn, Ga, Cr and C org.

The correlation of other elements showed following degree of interrelation

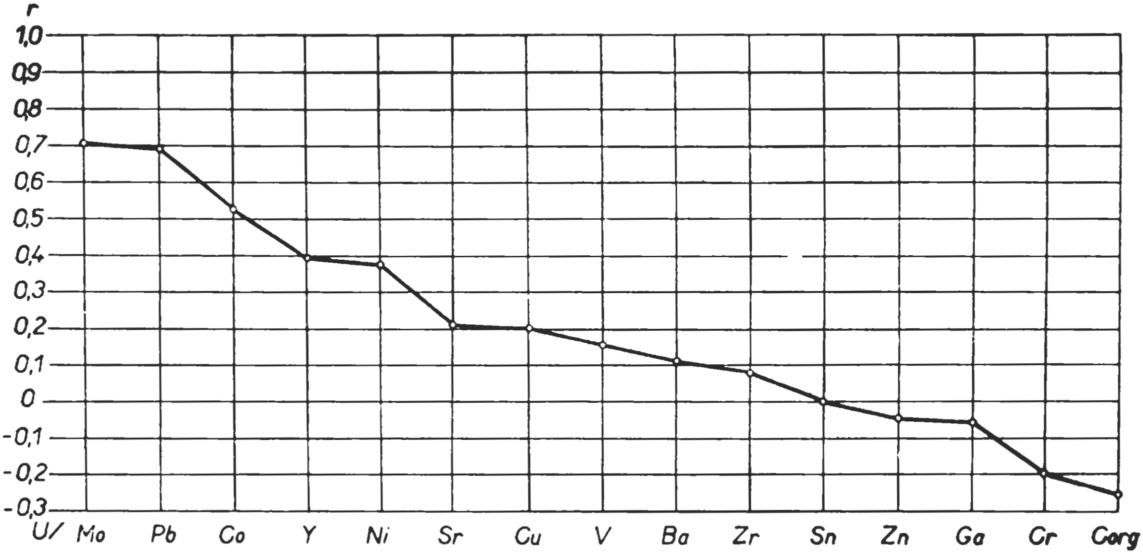


Fig. 15. Diagram of coefficients of correlation (r) of uranium to other trace elements.

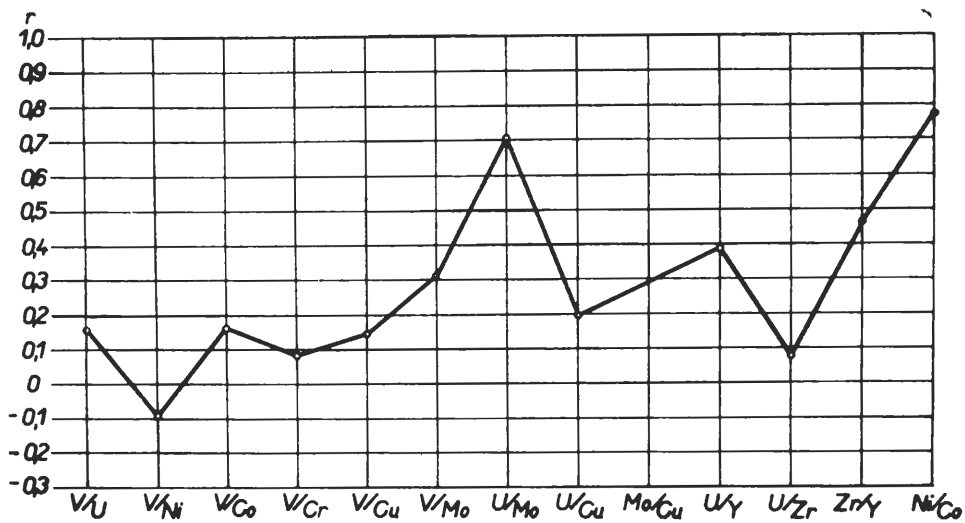


Fig. 16. Diagram of coefficient of correlation (r) of trace elements.

(fig. 16, table 9):

a) high: Ni/Co

b) moderate: Zr/Y, V/Mo

c) low: Mo/Cu, V/Co, V/Cu, V/Cr, V/Ni.

The correlation coefficients mentioned make evident that together with uranium reach highest concentration in ore lenticles Mo, Pb, Y, Co and Ni, conditioned as a consequence of their occurrence in uranium minerals (Pb, Y) or in minerals found in close paragenesis with uranium minerals, i. e. in molybdenite (Mo) and pyrite (Ni, Co). Moderate correlation of Y/U and Y/Zr is caused by the presence of yttrium in zircon and uranium minerals. The common occurrence of Ni and Co in pyrite also caused their high intercorrelation. Vanadium and copper, enriched distinctly in the tuffite horizon, reach low degree of correlation with uranium only and moreover also their intercorrelation is low. Vanadium shows low correlation with Ni and Co in contrast to clastic sedimentary rocks, where it was related to iron oxides together with these both elements. Lower correlation of U/Cu is caused by vertical shift of highest Cu values already mentioned. The more scattered distribution character of vanadium related to allogene minerals (magnetite, ilmenite) results in low U/V correlation.

Sb, Bi, As and Ag also are bound to U-Mo-Cu mineralization, were ascertained qualitatively only in ore lenticles and are related to minerals of mineralization, i. e. pyrite (As, Bi), chalcopyrite (Ag), tetrahedrite-tennantite (Sb, Bi, Ag), arsenopyrite (As) and galena (Bi?).

Elements which are a part of rock-forming minerals show low correlation with uranium only. Cr mostly appears in sericite, Zr in zircon, Ba in orthoclase and sericite, Sr in plagioklase and carbonates and Ga substitutes Al in feldspars and micas. Zn is bound to sphalerite, mostly it is found however together with tin in magnetite, ilmenite and rutile.

The mode of occurrence of organic carbon has not been identified, most probably it is present in carbonized plant remnants. The contents of organic carbon are very low (0.129 %) and no distinct enrichment in contrast to not mineralized sediments is observed (0.124 %). According to H. A. Tourelot's division (1964) the rocks under study would belong to „rocks without carbon". Possible influence of organic substance on ore concentration formation is except by low contents of C org. also denied by low negative correlation of U/C org.

With regard to possible relation of later hydrothermal processes of the siderite formation with mobilization or concentration of U-Mo-Cu mineralization correlation coefficients of U/CO_2, were calculated, also showing low negative correlation. On the basis of these results it may be supposed that U-Mo-Cu mineralization does not show relation with organic carbon and hydrothermal processes of the siderite formation.

CONCLUSIONS

U-Mo-Cu mineralization appears in the lower part of the Permian effusive-sedimentary complex in tuffaceous rocks. Ore minerals are found in the cement of these rocks, their highest contents are concentrated in lenticles, in position coinciding in strike and dip with effusive-sedimentary complex. The main ore minerals are: pitchblende, uranium black, molybdenite, chalcopyrite, tetrahedrite, tennantite, pyrite, galenite and sphalerite. From oxidation minerals are represented: autunite, torbernite, tyuyamunite, limonite, malachite and azurite. Geochemical observation with statistical method employed confirmed the following association of elements of the mineralization under study: U, Mo, Cu, Pb, Ni, Co, (Y), (Zn), Sb, Bi, Ag and As.

Quartz porphyries in the rock underlying the mineralized horizon as well as quartz porphyry pebbles in this horizon showed different composition as compared with quartz porphyries in the upper part of the effusive-sedimentary complex, which generally manifests in higher acidity and similar association of trace elements, to a smaller degree also of ore minerals as in the mineralized horizon.

Higher uranium concentrations in shales underlying the mineralized horizon and also in porphyroids and tuffs outside the deposit area are of different character. There is a case of local and selective infiltration enrichment in uranium of these rocks.

Characteristic features of U-Mo-Cu mineralization are as follows:

1. Relation with the horizon of tuffaceous rocks with observable effects of volcanic activity of the lower quartz porphyries, manifested in the supply of ash matter and in exhalations of ore elements.

2. Permian absolute age of ore mineralization (J. Kantor 1958).

3. The ore mineralization appears in the rock overlying the lower quartz porpyhries, which are characterized by similar association of ore elements. In the tuffite horizon moreover pebbles of mineralized quartz porphyries are found.

4. The ore mineralization is not accompanied with wall rock alteration, typical for hydrothermal mineralization.

5. On the basis of the position of ore lenticles as well as of spatial distribution of ore elements certain influence of regional metamorphosis on local migration of ore elements can be observed.

6. Low contents of organic carbon are not in relation with U-Mo-Cu mineralization.

7. Tectonic dislocations suitable for supply of mineralizing solutions have not been found.

8. Younger veins of the siderite formation neither in matter nor in space show relation to the mineralization under study.

The text mentioned shows that quartz porphyry volcanism was accompanied with hydrothermal activity with effects manifested in exhalatory activity in a basin, sedimentation of tuffaceous rocks was proceeding in. Hydrogen sulphide exhalations had induced reduction environment in the area of sedimentation, which also caused precipitation of ore elements supplied from dectructed quartz porphyries. Another local migration and concentration of ore elements took place in the time of regional metamorphosis.

Translated by J. Pevný.

REFERENCES

Adámek P., 1965: Výskum efusívně-sedimentárního souvrství permských sedimentů severogemeridní synklinály, jeho stratigrafické rozčlenění a mineralogicko-geochemická charakteristika rudonosných horizontů. Manuscript. Geofond, Bratislava. — Butschkowskyj M., 1958: Minerales radioactives, Revista del Museo Argentino de ciencias naturales, Ciencias Geolócas 4, 3, Buenos Aires. — Cambel B., Jarkovský J., 1967: On the character of the distribution of manganeze, vanadium, molybdenum and titanium in pyrites. Geol. sborn. Slov. akad. vied 18, 1, Bratislava. — Drndzík E., 1965: K vzájomným vzťahom osobitných typov zrudnení v perme severnej časti gemeríd. Geol. práce, Zprávy 35, Bratislava. — Frondel C., 1958: Systematic mineralogy of uranium and thorium. Geol. Survey Bull. 1064, Washington. — Ilavský J., 1957: Geológia rudných ložísk Spišsko-gemerského rudohoria. Geol. práce 46, Bratislava. — Janočkina Z. A., 1966: Statističeskije metody izučenija pestroevetov. „Nedra", Moskva. — Kamenický L., Marková M., 1957: Petrografické štúdiá fylit-diabázovej série gemeríd. Geol. práce 45, Bratislava. — Kantor J., 1959: Niekoľko poznámok k uránovému zrudneniu v perme severogemeridnej geosynklinály. Acta Geol. et Geogr. Com., Geologica 2, Bratislava. — Michejev V. I., 1957: Rentgenometričeskij opredeliteľ mineralov. Gostechizdat, Moskva. — Przybora E., 1957: Rentgenostrukturalne metody identyfikacji mineralow i skal. Warszawa. — Ramdohr P., 1956: Die Beziehungen von Fe-Ti-Erzen aus magmatischen Gesteinen. Bull. de la Commision Geol. de Finlande 173, Helsinki. — Ramdohr P., 1960: Die Erzmineralien und ihre Verwachsungen. Berlin. — Rojkovič I., 1964: Zpráva o petrografickom výskume permu v okolí Novoveskej Huty. Zprávy o geol. výskumoch 1, Bratislava. — Rojkovič I., 1965: Über den vererzten Perm-Horizont im Gebirge Spišsko-gemerské rudohorie. Carpatho-Balkan Geological Association, VII, Congress, Reports III, Sofia. — Sidorenko G. A., 1960: Rentgenografičeskij opredeliteľ uranovych i uransoderžaščich mineralov. Gosgeoltechizdat, Moskva. — Tourtelot H. A., 1964: Minor-element composition and organic carbon content of marine and non-marine shales of late cretaceous age in the western interior of the United States. Geochim. et Cosmochim. Acta 28. — Weeks A. D., Thompson M. E., 1954: Identification and occurrence of uranium and vanadium minerals from the Colorado Plateau. Geol. Surv. Bull. 1009-B, Washington. — Žukov F. I., 1963: Perspektívy vyhľadávania vzácnych kovov v efuzívne-sedimentárnych komplexoch permu v Slovenskom rudohorí. Geol. práce, Zprávy 27, Bratislava.

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