SBORNÍK NÁRODNÍHO MUZEA V PRAZE
ACTA MUSEI NATIONALIS PRAGAE
Volumen XXXIV B (1978), No. 2 - 4
REDAKTOR: JIŘÍ ČEJKA

ALEXANDRA KODYMOVÁ
Ústřední ústav geologický Praha

ACCESSORY HEAVY MINERALS OF THE MORAVICUM OF THE DYJE DOME AND THE DYJE MASSIF

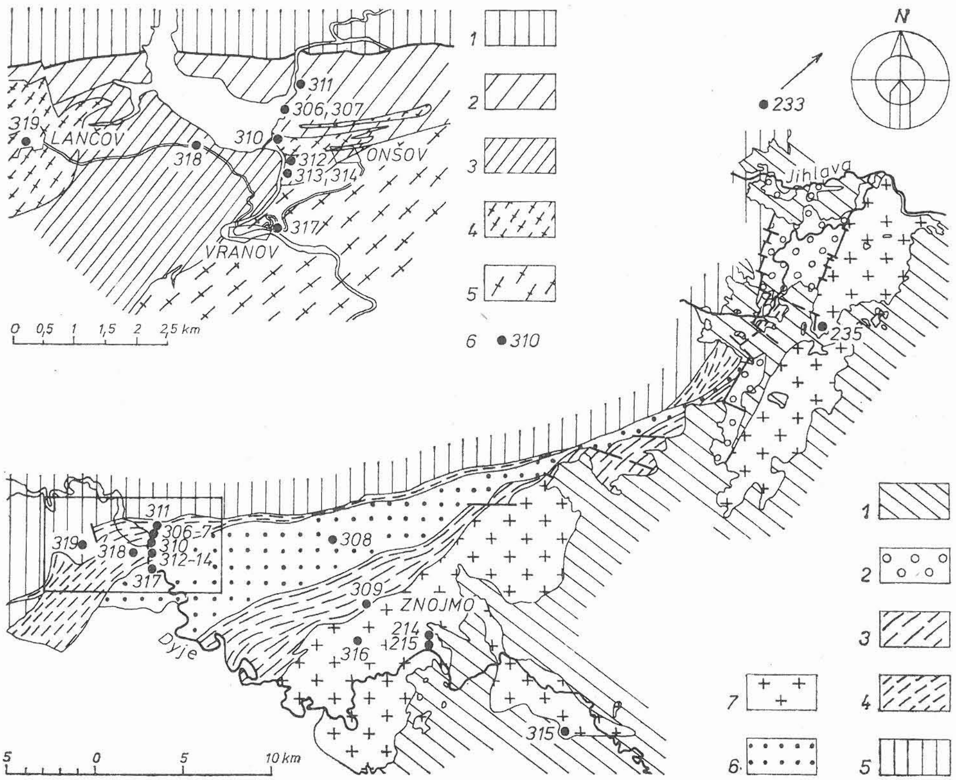
INTRODUCTION

The Moravicum forms the eastern, less metamorphosed marginal unit of the Bohemian Massif. It consists of several single units with monoclinal dipping towards the NW. Mica schist belt (the Nedvědice Group) bordering the Moldanubicum passes downwards into the Vranov-Olešnice Group underlain by the Bíteš gneiss body and the Bílý potok Group (Inner phyllites). The easternmost part of the Moravicum is formed by granitoids of the Dyje and Brno massifs. Geologic situation is demonstrated on fig. 1B.

It has not so far been decided (JENČEK—DUDEK 1971, JAROŠ—MÍSAŘ 1976, FUCHS 1976, FUCHS—MATURA 1976, FRASL 1968, 1970), whether the Moravicum was metamorphosed by the Moldanubian overthrust (origin of the mica schist belt by retrograde metamorphism), or whether its metamoarphic development was independent (the origin of mica schist belt by progressive metamorphism and its primary transition into the Vranov-Olešnice Group).

Groups of the Moravicum are formed by metamorphic clastis sediments that are often flyschoid, with abundant layers of other rocks. According to mineral associations the metamorphism corresponds to the amphibolite facies, namely to the kyanite-muscovite subfacies (DUDEK 1962), which somewhat lowers to the staurolite-quarz subfacies towards the E. Metamorphic zoning is thus oblique towards rock series (HÖCK 1975). The series are thought to be of either Palezoic or rather Upper Proterozoic age; the later seems more probable as the age of the Bíteš orthogneiss has been determined to be 800 mil. years (SCHARBERT 1977).

The Dyje massif is formed mainly of granodiorites and granites smaller part also of diorites and quartz diorites that are sometimes schistose.



1. Position of samples studied

Fig. 1A is a cut of fig. 1B.

1A 1 — Moldanubicum, 2 — mica schist belt, 3 — Vranov-Olešnice Group, 4 — Lančov and the mica schist belt orthogneisses, 5 — Bíteš orthogneiss, 6 — sampling site.

1B 1 — Neogene, 2 — Culm and Permo-Carboniferous, 3 — Bílý potok Group, 4 — mica schist belt and the Vranov-Olešnice Group, 5 — Moldanubicum, 6 — Bíteš orthogneiss, 7 — Dyje and Brno massifs. Map of A. Dudek 1962 has been modified by A. Kodymová.

Based on analogy with the Brno massif, this massif is probably also of Cadomian age (DUDEK, MELKOVÁ 1975). It intrudes into the Bílý potok Group.

Heavy minerals have so far been analyzed from orthogneisses in Austria (FRASL 1963, NIEDERMAYR 1967, THIELE 1977) and in the Brno massif (KRYSTEK 1961, SVOBODA, VYNŠOVÁ 1973). The aim of this paper is to extend the study of heavy minerals in some other rocks of the Moravian part of the Dyje Dome. Heavy minerals of the Dyje massif are compared with some samples of heavy minerals of the Brno massif.

In cooperation with A. Dudek the samples were taken from best exposed sections; P. Batík took two samples from the Dyje massif, and J. Weiss the samples from the Brno massif. Samples of fresh rocks weighing approximately 7 kg were crushed to the grain-size of 0,3 mm. The desintegration was done partly in laboratories of the Geological Survey, partly in laboratories of the Institute of Mineral Raw Materials in Kutná Hora. Heavy minerals were determined using the quantitative analyses of on an average 6 fractions, the determination of minerals was checked using the Debye—Scherrer X-ray method by Z. Štveráková, Z. Falc, H. Moravcová and M. Pošíková. Additionally mass values were calculated by S. Kořalka. Crosses (tables 1, 2) were used for minerals that did not appear in quantitative analyses (number of crosses acording to estimated amount). Their highest values corresond approximately to g/t units. The content of single opaque minerals was also estimated additionally within the range of the sum determined by quantitative analysis. Chemical determinations of rocks were done by M. Janáčková, J. Štícha, and M. Veselý, of apatite by A. Klímová and Z. Valný, refraction indexes of apatite were measured by M. Fassová. The data obtained are stated in tables No 1 and 2.

One part to the express my thanks to all colleagues and namely to A. Dudek for his help in obtaining the samples, for his critical remarks to the manuscript, and for writing the geological introduction to the paper.

ACCESSORY HEAVY MINERALS OF THE MORAVICUM OF THE DYJE DOME

Viewed petrographicaly the rocks of the Moravicum were characterized by A. DUDEK 1962; other authors cited describe them briefly, too. The mineral association mentioned agrees well with that found in heavy fractions of analyzed samples; the quantitative contents correspond to the described frequency of corresponding minerals (table 1), too. Besides, only several rarer minerals occurred here.

The variability in the composition of paragneisses from the mica schist belt and those from the Vranov-Olešnice Group is not great and is manifested mainly by the variability in the content of single minerals in dependence on the original composition of the sediment. Poorest in heavy minerals is quartitze, the greywacke layers are usually also poorer than the schistose ones. Majority of minerals originates by the recrystallization of the interstitial mass of the sediment. It is only ilmenite, rutile and tourmaline that occur in metapsammites in greater amount than in metapelites.

Samples of paraschists somewhat differ also in their chemical composition. While the mica schists are richer in K_2O, i. e. in micas, the paragneisses (including the schistose ones) contain more Na_2O and CaO, i. e. plagioclase. This difference (Dudek 1962) may be ascribed to the difference of their original sediments. Both series are connected most probably by continuous transition. Thus a sample of mica schist intercalated into the Vranov-Olešnice Group is similar to samples from the mica schist belt and vice versa, a sample of the intercalating massive paragneiss from the mica schist belt approximates the paragneisses from the Vranov-Olešnice Group (with Na_2O content being somewhat lower). The differences in the content of oxides are not so great and are reflected in the representation of heavy minerals: samples from the mica schist belt poorer in calcium contain more monazite and Al-rich minerals (kyanite, sillimanite, staurolite, garnet), samples from the Vranov-

TABLE 1 Accessory heavy minerals in rock samples of the Moravicum (g/t)

	para — schists								orthogneisses			
	Bílý potok Group	mica schist belt			Vranov—Olešnice Group				Lančov	mica schist belt	Bíteš	
minerals	309	306	307	311	312	313	314	318	319	310	308	317
anatase	—	122	9	+	—	—	—	+ + +	+	+ + +	—	+
apatite	153	1.662	751	2.460	1.280	710	752	2	82	1.399	54	356
epidote group	+ +	—	+	—	—	+	+	—	—	—	+ +	+ + + +
garnet	70	57.414	22.819	8.323	42.009	15.613	4.248	8	19	85	10	20
hornblende	—	—	+ +	—	—	7.625	17	+ + + +	1	+ + + +	+ + + +	—
kyanite	2	1.601	19	—	163	32	+ +	+ + +	—	+ +	+ +	+
limonite	13	189	16	13	7	378	92	17	20	7	29	201
monazite	+ + + +*	123	46	+ +	10	33	+	6	3	5	6	+ + +
rutile	10	10	41	198	15	6	38	198	+ + + +	+ + + +	3	+ + + +
sillimanite	—	1.655	1.261	—	—	3	1	1	—	—	—	—
staurolite	+ + + +	7.056	991	8	108	+	+ +	+ +	2	+ + + +	+ + + +	+ +
titanite	278	—	—	7	—	—	+ + +	+ +	+ + +	—	+	+ +
tourmaline	81	+ + + +	184	2	65	—	+ + +	+ + + +	+ + + +	+	+ + + +	+
xenotime	+ +*	—	—	—	—	—	—	—	—	1	3	—
zircon	16	14	60	291	18	124	109	39	1	21	14	6
sum of opaque minerals	1.445	1.210	1.875	3.788	1.491	2.546	618	143	338	84	201	186
estimation of the amount of: galenite	—	—	—	—	+	—	+	+	—	—	—	—
ilmenite	1.030	1.210	1.875	3.788	1.490	2.000	300	5	300	+ + + +	50	+
leucoxene	—	—	—	—	—	—	—	1	+	+	—	—
maghemite	—	—	—	—	—	540	—	—	+ + + +	—	—	—
magnetite	15	—	—	+ +	—	+	—	—	+	—	—	—
?	+ + +	+ +	+ +	+ + +	—	+ + +	+	+ +	38	+	1	+ + + +
pyrite	+ + +	+	+ +	+ +	1	+ + + +	+ +	73	+	+ +	150	+ + +
limoniti — sed pyrite	400	—	—	—	—	6	318	—	—	84	—	150
P_2O_5 %	0.15	0.27	0.10	0.50	0.15	0.20	0.15	0.011	0.047	0.23	0.061	0.093
Na_2O %	2.23	1.14	1.92	1.46	1.62	3.65	3.24	1.26	6.00	2.82	4.49	5.02
K_2O %	3.76	3.85	3.13	1.95	3.45	3.08	2.65	0.13	1.42	5.30	2.98	1.98
CaO %	0,91	0.57	0.95	2.01	0.64	2.50	2.11	0.16	1.44	1.00	1,27	2.59
Zr ppm	284	166	214	1026	141	147	165	120	112	112	84	70
Sr ppm	131	120	244	237	133	466	238	<5	625	94	404	530
Rb ppm	140	171	171	120	152	122	108	26	76	112	84	79
Y ppm	39	42	25	53	26	7	38	31	<5	60	5	<5
ω of apatite	1,645	1,632	1,637	1,641	1,637	1,647	1,649	1,641	1,647	1,645	1,641	1,643

Following minerals: 314 — sphalerite 1 g/t, fluorite; 318 — columbite 70 g/t, sphalerite 1 g/t, chrome spinel, diopside, orthite?; 308 — green hornblende with variable orientation, arsenopyrite, brown mineral from epidote group, carbonate; 317 — mineral Fe 36 g/t, brown mineral from epidote group, hematite.

* clastic

Olešnice Group richer in calcium contain smaller amount of minerals mentioned; besides they contain hornblende, epidote, titanite, and pyrite. Apatite contains more H_2O. Contents of heavy accessory minerals in mica schist increase in dependence on the increase of K_2O (apatite, kyanite, garnet), or Na_2O and CaO (ilmenite, zircon, tourmaline). Paragneisses are not so uniform.

Position of the sample of phyllite from less metamorphosed Bílý potok Group is usually different in diagrams due to somewhat different relations between oxides. Mineral association and the apatite richer in H_2O are similar rather to paragneisses of the Vranov-Olešnice Group than to mica schists in spite of relatively lower content of CaO (epidote, magnetite, carbonate, pyrite, and especially relatively much titanite). The content of heavy accessory minerals is very low for they were probably subjected to low-grade metamorphism; nearly al heavy minerals contain many small inclusions.

Interesting in phyllite is the admixture of approximately 1 mm large, wel rounded grains of ilmenite, monazite, xenotime, and very rarely also of somewhat smaller, lilac zircon that has not so far been found in the Crystalline of Bohemia; this zircon also differs from pink zircon in the Proterozoic of the Barrandian region. TOMITA 1954 ascribes lilac zircon to Archean rocks (Early Algoman). Rare are also rounded rods formed by pyrite reminding of products of the activity of organisms.

Orthogneisses of the Moravicum are composed of granites to granodiorites closed in places by xenoliths of surrouding rocks. Intercalations of amphibolites are especially abundant at the contact of the Bíteš orthogneiss above.

Analyzed samples from various orthogneiss bodies are very similar and may be thus included into one group. Na_2O in samples is in positive correlation with CaO (plagioclase) and both are in negative correlation with K_2O (micas + K-feldspar). It is only the sample from the margin of the Bíteš orthogneiss that disturbs the dependence by its anomalous content of CaO.

Samples contain great number of minerals in small amounts approximating often the low boundary of the sensitivity of the method; it is

---

Table 1 (list of samples)

Para-schists: 306 — schistose garnet mica schist. Vranov dam, mouth of the Švýcarský potok brook valley, left bank; 307 — garnet mica schist richer in greywacke layers, dto; 309 — chlorite-muscovite phyllite, Citonice, 1 km to the E of the village near the railway leading to Znojmo; 311 — plagioclase gneiss poor in mica, Vranov dam, to the W of the elevation point 455, mouth of the Švýcarský potok brook valley, left bank; 312 — garnet mica schist, left bank of the Dyje river 400 m below the dam; 313 — schistose biotite paragneiss with garnet, dto; 314 — massive two-mica paragneiss, dto; 318 — quartzite, Vranov, bend of the road to the N of the elevation point 407.5.

Orthogneisses: 308 — two-mica Bíteš orthogneiss with relics of phenocrysts, quarry Žerůtky; 310 — two-mica orthogneiss of the mica schist belt, Vranov dam, left bank; 317 — biotite Bíteš orthogneiss, Vranov, left bank of the Dyje river, on the way leading to Hamry; 319 — two-mica Lančov orthogneiss, Lančov, excavation on the village green.

only apatite, garnet, pyrite, and in places ilmenite that are more abundant. Many heavy minerals are close to minerals of mantle rocks including part of zircon, part of garnet, and the black-spotted rutile.

Characteristing of single minerals

Nearly all heavy acessory minerals found in orthogneisses of the Moravicum of the Dyje Dome originated in the course of rock metamorphism. Rounding caused by transport has been preserved in the sample of phyllite and quartize in some minerals only. The type and the shape of minerals assimilated by orthogneisses are in fact the same as in paragneisses, only the grain surface is more simple and smoother.

A n a t a s e is blue-grey, yelow-rown, and spotted; its colour does not depend on the composition of the rock due to its secondary origin. Very tiny blue-grey crystalls rim fissures in colourless mica, yellow anatase originates from ilmenite. It forms both dipyramids and grains.

A p a t i t e forms colourles grains reaching in orthogneiss the size of as much as 0.5 mm. Surface of apatite grains displays sometimes biotite. Apatite in phyllite closes abundant tiny bodies, in more metamorphosed rocks it closes only hollow globular forms (bubbles). Apatite from the margin of the Bíteš orthogneiss (sample No 317) contains acicular zircon. Dark "cores" are everywhere scarce, rocks of the mica schist belt miss them entirely.

Acording to refraction index, the apatite from mica schists corresponds to fluorapatite (TABORSZKY 1972). The apatite from phyllite, quartzite, and all gneisses contains admixture of hydroxylapatite (0.20 % of H_2O, in phyllite 0.59 %, the Cl content being 0.04—0.06 %). This composition is in relation with the composition of apatite in similar metamorphic rocks (Krasnobajev et al. 1975). The decrease of the fluorapatite component in apatite corresponds to the decrease of K_2O in the rock as well.

The amount of apatite is highest in samples from the mica schist belt (including orthogneisses) but it is very low in the Lančov and Bíteš orthogneisses. The apatite in phyllite is probably very fine-grained and escapes during separation.

C o l u m b i t e is formed by black plates to flat columns with rounded surface. It has been proved by both the X-ray and special methods.

By its pink colour, refraction index approximately 1.8, and the density nearly 4.0, g a r n e t corresponds to almandine. It forms in mica schists nearly 7 mm large phenocrysts that are sometimes corroded, sometimes bounded by striated faces. Edges between faces are usualy lacking. Garnet surface often displays biotite or chlorite. Garnet closes abundant small plates of ilmenite and rarely rutile.

According to the increase of CaO in the rock, the refraction index of garnet decreases to 1.78. In orthogneisses the composition of almandine within the range of one sample varies as demonstrated by the refraction index varying from 1,78 in fragments of grains to approximately 1.8 in nearly idiomorphic phenocrysts. Part of garnet lacks inclusions.

H o r n b l e n d e is most often green, its brown colour (sample No 313) is less frequent. The amount of hornblende is in positive correlation with the CaO content.

Ilmenite is formed partly by grains bound in light bands of rocks, partly it is tabular, bound in micas, weakly leucoxenized. Its surface displays impressions as if left by micas. It is often grown together with light minerals (light mica, sillimanite) and closed by staurolite, garnet etc. It cannot be usually visible in fresh biotite.

Cores of some grains of ilmenite contain rutile with black spots increasing towards the surface of grains. K. Tuček 1960 describes similar type of ilmenorutile as fairly common in rocks of the amphibolite facies and does not consider it to be a product of the transformation of rutile into ilmenite. Using the X-ray method no other mineral than rutile was demonstrated in such grains, by spectral analysis only greater amount of Ti was found. Therefore the unmixing of Nb and Ta (ČERNÝ et al. 1964) cannot be used for the explanation of the origin of rutile, either.

Monazite is formed by small, originally globular crystals. Sample of phyllite contains grains of monazite nearly 0.5 mm large, mechanically rounded, with typical pitted surface.

Pyrite was originally present in all samples, now it is partly decomposed.

Rutile is formed mainly by oval or irregular, somewhat flattened grains of brown to red-brown colour, pervaded by black spots. Dark parts in grains are scarce in orthogneisses. Orange, thinly columnar rutile often forms inclusions in minerals (kyanite, tourmaline, garnet).

Silimanite is fibrous and occurs in para-schists only, in some places in samples poorer in calcium.

Staurolite closes often plates of ilmenite and bubbles. Its surface and grain cracks containing biotite and chlorite give evidence of its frequent alteration.

Larger amount of titanite was found in fact in phyllite only. It is light to colourless.

Tourmaline is sometimes idiomorphic, brown, rarely green. It often closes rutile in mica schists and tiny opaque bodies in phyllite.

Xenotime is formed by small grains. It is clastic and rounded in phyllite.

The undetermined mineral is opaque, dark grey, sheeny, its structure being that of chalkozite. The presence of Cu failed to be proved.

Finally, small amount of following minerals was found in places: minerals belonging to the epidote group, diopside, fluorite, galenite, chrome spinel, hercynite, hematite, carbonates, magnetite, sphalerite, maghemite, orthite?, arsenopyrite, leucoxene; some of them might have appeared during laboratory analyses.

Zircon and its characteristics

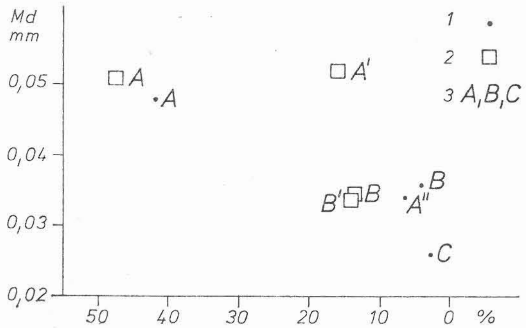
Paraschists of the Moravicum contain colourless to rosy, rarely pink to lilac zircon, sample No313 contains admixture of brown, metamict zircon.

According to its shape, several types of zircon may be distinguished:
1. Zircon of probably clastic origin occurs mainly in quartzite and in phyllite; it is at least partly prismatic being rarely mechanically rounded, more often broken, corroded, and partly regenarated. Shape of

crystals often fairly varies, displays numerous pits, elevations, and apexes. Original crystallographic shapes are incomplete. It corresponds to combinations of faces (111) with (110), or (111) with (100) and (311) with (100) that are approximately equal. Last two types of crystals have cores.

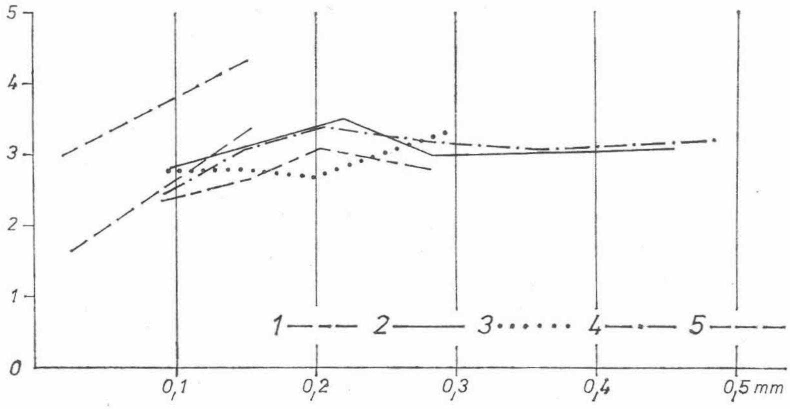
2. Zircon with cores (rounded or fragmentary) entirely covered by regenerated shell or having crystals without a core is probably newly formed. It is usually fine-grained, its shell is sometimes zoned. Crystal shape is globular to shortly prismatic terminated by (311) or (111) with frequent intergrowths. It is sometimes difficult to distinguish it from untouched clastic crystals of the same type. Rare are small, clear, and perfectly idiomorphic crystals (111) with (100).

Zirconium is not only clastic in sediments (as supposed until lately) but the newly formed zircon appears already in the course of the diagenesis during the recrystallization of the clay component and ferrous gels (SAXENA 1966 a, b). Thus the amount of zircon depends not only on the amount of clastic zircon but also on the amount of interstitial mass and on the intensity of metamorphic processes concentrating dispersed Zr into larger crystals of zircon (fig. 2). Separation of coarser zircon is conected with smaller loss and the amount of Zr obtained approximates rather the amount of zircon calculated from chemical analysis of Zr.



2. Dependence of the medium grain size of zircon (Md of the grain-size curve by mass) on the mass proportion of zircon in heavy fraction expressed in % of the zircon content in the rock calculated on the basis of the X-ray fluorescence analyses. 1 — metalites, 2 — metapsammites, 3 — A — Vranov-Olešnice Group (A' — quartzite, A" — mica schist), B — mica schist belt (B' — plagioclase gneiss), C — Bílý potok Group.

Zircon from orthogneisses of the Austrian part of the Moravicum, studied by FRASL 1963, NIEDERMAYR 1967, and THIELE 1977, and that from orthogneisses of the Bohemian part are very similar. In addition to the admixture of fine-grained, similar zircon in para-schists, also rosy, mainly clear, prismatic zircon with well developed faces and edges may be found. Crystal shapes (the combination (111) with (100), rarely with (311) and the combination (311) with (100), sometimes also with (110) agree with crystal shapes of the newly formed zircon of para--schists and might represent the final stage of its recrystalization as demonstrated also by numerous cores closed in more than one third of crystals (POLDERVAART 1955). Proportionate representation of both varieties in the rock varies. Zircon with (111) is predominating in smaller bodies and partly also at the margin of the Bíteš orthogneiss while that with (311) predominates in the centre of the body. Difference of this sample is demonstrated also in fig. 3. While in majority of samples the relatively high coefficient of elongation incerases in dependence on on the increasing length of crystals becoming somewhat lower in longest crystals (with limited number of measurements), it does not change according to the length in this sample.



3. Dependence of the coefficient of elongation (length : width) on the length of zircon crystals in samples from orthogneisses. Lines 1—4 were designed as connecting lines of 4—6 points. Each point is an arithmetic mean of 4—30 measurements. 1 — 319; 2 — 310; 3 — 308; 4 — 317; 5 — orthogneisses from Austria (Niedermayr 1967.)

ACCESSORY HEAVY MINERALS OF THE DYJE MASSIF AND THEIR COMPARISON WITH ACCESSORY HEAVY MINERALS OF THE BRNO MASSIF

Analyzed samples from the Dyje massif contain predominantly biotite-granites to granodiorites affected by alterations (chloritization, epidotization) to weakly metamorphosed ones (sample No 316). It is only the sample from the later Tasovice granodiorite that is not mylonitized and only weakly altered (chloritization, secondary muscovite).

As proved by partial chemical determinations (tab. 2), the Na_2O content is constant and is slightly lower than the K_2O content. K_2O is in negative correlation with CaO and in positive corelation with Rb. The amount of Sr closely depends on the amount of apatite that increases in dependence on the CaO increase. The Y level is constant.

Mineral association of samples from the Dyje massif (tab. 2) rather varies due to the admixture of mantle minerals.

TABLE 2

Accessory heavy minerals in samples from the Dyje and Brno Massif (g/t)

	Dyje Massif				Brno Massif	
	central part			eastern part		
minerals g/t	214	215	316	315	235	233
apatite	5	71	351	33	181	2.065
carbonate	—	+	—	—	2	+++
epidote group	52	1.856	++	—	1.882	1.610
garnet	582	445	277	237	23	++++
hornblende	9	—	++	+++	—	1.709
kyanite	+++	+	1	+++	—	—
monazite	1	++	+++	+++	++++	++++
rutile	++	—	+++	3	—	—
sillimanite	—	—	1	11	+	—
staurolite	—	—	+++	22	—	—
titanite	25	312	1.008	12	—	5.918
tourmaline	++++	++++	+++	+++	++	—
xenotime	++	—	+	+	—	—
zircon	4	48	58	62	32	56
limonite	283	13	49	474	114	445
sum of opaque minerals	302	193	119	802	587	14.971
estimation of the amount of: hematite	—	—	—	790	—	4.900
ilmenite	2	2	90	—	—	50
magnetite	—	—	3	12	—	10.000
?	—	—	3	+++	—	—
pyrite	130	1	1	++++	587	11
P_2O_5 %	0.014	0.072	0,084	0.031	0.093	0.29
Na_2O %	4.11	3.99	3.48	3.67	3.85	5.39
K_2O %	4.44	4.01	4.02	5.02	3.81	2.27
CaO %	0.98	1.96	2.04	0.23	1.89	2.83
Zr ppm	16	118	88	132	148	236
Sr ppm	88	298	304	188	346	765
Rb ppm	151	136	88	148	130	82
Y ppm	20	35	24	24	5	6
ω of apatite	1.632	1.637	1.649	1.649	1.633	1.634

Following minerals:

214—pyrrhotine 170 g/t; chalcopyrite; 215—maghemite 190 g/t, fluorite, lölingite, sphalerite; 233—barite 12g/t, decomposed mineral Fe 10 g/t, cassiterite, moissanite, pseudomorphs (after augite?, orthite?), pyroxenes (diopside), siderite, topaz; 235—fluorite 2 g/t, diopside, pseudomorphs (after augite?); 315—anatase, diopside, fluorite; 316—anatase, decomposed mineral Fe 22 g/t.

Table 2 (list of samples)

The Dyje massif: 214 — granodiorite poorer in biotite, Znojmo, quarry in the NW part of the town; 215 — medium-grained granodiorite, Znojmo, right bank of the Dyje river on the dam; 315 — Tasovice granodiorite, abandoned quarry at the SE margin of Derflice; **316** — transitional form between oriented biotite granodiorite and gneiss, Mašovice.

The Brno massif: 233 — hornblende-biotite granodiorite, darker facies, Blansko; 235 — biotite granodiorite, light facies, Olbramovice.

Epidote and titanite originate together with carbonate and anatase during rock alteration. Epidote is usually developed along joints, titanite follows the foliation planes and biotite bands. Idiomorphic crystals of titanite reach 1 mm. Titanite is usually without inclusions.

Apatite is oval or more frequently columnar, terminated by a dipyramid and (0001). Thickness of columns is nearly 1/4 mm. Apatite closes numerous bubbles, opaque grains, acicles of zircon, and flakes of biotite. Typical are "dark" cores whose shape is that of apatite crystal or its fragment; their reddish pleochroism reminds of reddish biotite that has not been found in samples and whose inclusions may account for the dark colour of "cores". Dark apatite has not been found in any other mineral and has probably been preserved under the protection cover of clear apatite only.

Variable refraction index of apatite accounts for its variable composition from nearly pure fluorapatite to mixed one (Cl 0,7 %, H_2O 1.26 %). Its composition corresponds to biotite-granite of K-Na series (KRASNOBAJEV et al. 1975). Apatite is also a probable host-mineral of Sr in the rock.

Garnet is mostly pink with refraction index about 1.8, either without inclusions or with iclusions of ilmenite or rutile. It is similar to the garnet of para-schists. Strongly recrystallized parts of the rock contain idiomorphic garnet of similar composition. Perfectly idiomorphic colourless light garnet with n 1. 78 originates in places along joints.

Ilmenite is formed by grains or plates released from micas slightly leucoxenized on the surface.

Zircon is partly (4 g/t in the sample No 214) assimilated from surrounding rocks, rounded, of variable shape, partly it is prismatic, idiomorphic, sometimes zoned. Small amount of its crystals contains cores. Prismatic zircon formes several varieties:

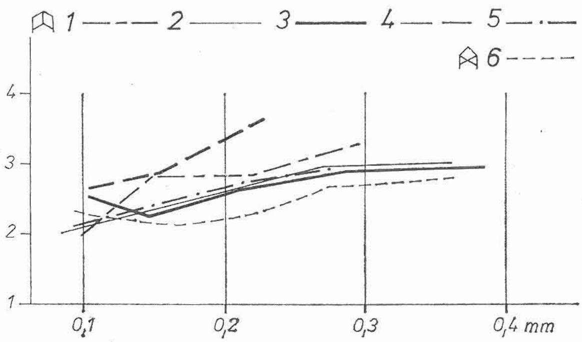
1. Zircon with the combination (111) with prisms (100) and often rudimentary (110) is brown and strongly cloudy. Larger crystals are entirely decomposed into rusty or grey mass containing fresh globular cores. This variety predominates (> 30 % of the concentrate).

2. Both prisms are equal in some crystals and prism (110) only rarely predominates over prism (100) — (< 10 % of the concentrate). Their elongation and decomposition approximate the preceding variety.

3. Rose, idiomorphic, clear zircon, somewhat cracked and sometimes cloudy, bounded by (111) with (110) and sometimes also with rudimentary (100), with distinct incomplete faces (311). It closes columns of apatite. Its amount is variable in samples, below 32 %, maximum in sample No 316.

4. Rose, clear to weakly cloudy and cracked zircon with combination of pyramids (311) and (111) with prism (100), sometimes also even (110), which forms as much as 10 % of zircon concentrate.

Coefficient of elongation of the 1st predominating variety of zircon increases evenly in dependence on the increasing length of crystals from value 2 to 3 nearly identicaly in both samples (fig. 4). The Tasovice granodiorite has the coefficient of elongation of the 1st variety of zircon distinctly higher, the curve is somewhat sheerer. Variety 3 that is somewhat more frequent in the sample No 316 has the curve similar to the variety 1 in the sample, but the value of the elongation is somewhat lower.

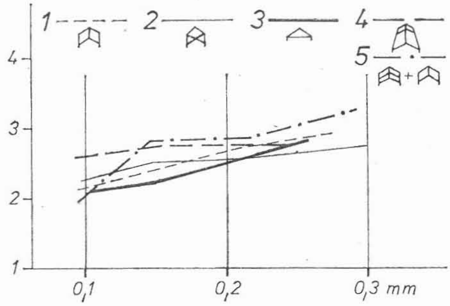


4. Dependence of the coefficient of elongation (length : width) of predominating varieties of zircon in samples from the Dyje and Brno massifs on the length of zircon crystals. Lines connect 4—5 points, each point is an arithmetic mean of 8—22 measurements. 1 — 233; 2 — 215; 3 — 316; 4 — 315; 5 — 235; 6 — 316, crystallographic type of zircon is demonstrated in the diagram.

One sample from the southern and another from the northern part of the Brno massif (from localities described by ŠTELCL et al. 1974) were analyzed for better comparison. With the exception of the Y content, the chemical composition of the samples mentioned is in accordance with the samples from the Dyje massif (tab. 2); both samples are also strongly altered, namely the somewhat darker sample from the vicinty of Blansko. They contain abundant pseudomorphs (leucoxenized ilmenite, idiomorph pseudomorphoses with outer shape reminding of augite, composed of Fe, Mg, and with X-ray lines of pyroxene, pseudomorphs formed by a mixture of chlorite, epidote, titanite, carbonate, and magnetite, and brown pseudomorphs reminding of orthite) and minerals originating during alterations (siderite, barite, fluorite, topaz, tourmaline).

Character of heavy fractions of both samples from the Brno massif corresponds to the results obtained by M. KRYSTEK 1961, the appearance of minerals (including zircon) is similar as in the Dyje massif. SVOBODA, VYNŠOVÁ 1973 demonstrated stability in the elongation of zircon, low content of zircon assimilated, and small amount of cores in crystals.

Zircon in the sample No 235 from the vicinty of Olbramovice contains the same varieties of zircon as samples from the Dyje massif. Both the coefficient of elongation of the predominating variety 1 of zircon and its relation to the length of crystals measured correspond to variety 1 in the Dyje massif (fig. 4). Coefficient of elongation of probably younger variety with dipyramid faces (311) slightly depend on the length of crystals similar as the same varieties in the orthogneiss (fig. 5); different is only the zircon from more distant sample No 233. Predominating variety 1 is somewhat more complicated — faces of pyramid (111) are rimmed by parallel faces (311). This type of crystals is unique in other samples. The difference may also be seen in the relation of the coefficient of elongation of this variety to the length of the crystal (the shape of the curve is different), even though the value of the coefficient is similar to that in other samples.



5. Dependence of the coefficient of elongation (length : width) of various varieties of zircon in samples from the Brno massif on the length of zircon crystals. Lines connect 4 points, each point is an arithmetic mean of 4—17 measurements. 1—4 — 235; 5 — 233; crystallographic type of zircon is demonstrated in the diagram.

Sample No 235 contains idiomorphic hematite similarly as the Tasovice granodiorite.

CONCLUSION

1. Heavy accessory minerals were determined in rock samples from the Moravicum and the Dyje massif together with the comparative samples from the Brno massif with great precision using the sensitive quantitative method. Results that are in relation with check data in the content of P_2O_5 (in acid HNO_3 extract 1 : 4) and Zr were correlated with chemical composition of samples using the Na_2O, K_2O and CaO contents. Single minerals were characterized and the elongation of zircon in both massifs and in individual crystallographic varieties were studied.

2. The association of heavy minerals and their amount in paraschists of the Moravicum are strongly influenced by the CaO content. Its slight increase causes the decrease of minerals rich in Al and monazite, while epidote, hornblende, and titanite apear. This is the main cause for the difference in the composition of heavy fractions of mica schists and paragneisses. It seems that each group displays typical relations between the chemical and mineral composition (best correlations are in mica schists) and has sometimes also typical amount of several components. E. g. the content of apatite does not always increase in relation to the CaO content but it is increased in all samples from the mica schist belt including orthogneiss; contrary to paragneiss rich in CaO, phyllite poor in CaO displays increased amount of titanite etc.

Contents of majority of heavy minerals (rich in Al, apatite) increase in dependence on the increasing content of K_2O, i. e. on the amount of pelitic ground mass of original sediment; only contents of ilmenite and rutile increase in dependence on Na_2O, i. e. the psammitic component in the schists-greywacke pair. Majority of minerals are newly formed and their content is highed in mica schists and paragneisses rather than in phyllites. Similarly the medium size of zircon crystals increases in dependence on the increasing metamorphic grade and the (111) and (311) becomes a dominating shape. Relict clastic minerals (ilmenite, monazite, xenotime, zircon) have been preserved in phyllite only. Rocks subjected to more intensive metamorphism contain relics of original shapes on coaser grains of imperfectly recrystalized zircon (mainly in quartzite poor in interstitial mass). Partly rounded columbite occurs in quartzite only.

Samples from the mica schist belt lack xenotime and mineral relics of rocks subjected to high-grade metamorphism and, on the contrary, contain relict lilac zircon whose colour disappears under high-grade metamorphism. This fact together with the type of the recrystallization of zircon and its medium size support the presumption of the primary origin of this unit.

3. Orthogneiss of the Moravicum are anomalously poor in heavy minerals displaying well the contamination with the surrounding material. While the prismatic type of zircon is in agreement with the nature of intrusive rocks, its crystallographic forms with abundant cores and high portion of prismatic zircon terminated by dipyramid (311) in some parts of rocks remind rather of migmatites. Compared with plutons products of later alerations of rocks are missing.

4. Heavy fractions of rocks from the Dyje massif are similar to orthogneisses by their contamination, low contents of heavy minerals, and by relatively high values of the coefficient of elongation of zircon. They differ in higher amount of garnet belonging probably to three generations, of epidote, and mainly of titanite. The pre dominating variety of zircon is similar to the zircon in orthogneisses; it closes sometimes cores, too, but the prismatic zircon terminated by (311) is accessory and has been replaced by variable admixture of the variety formed by the combination of faces (111), (110), and (100) with incomplete (311). This variety is typical for igneous rocks. Zircon from the Tasovice granodiorite has higher coefficient of elongation than the zircon in other samples. Based on analogy with KOSTOV'S 1966 interpretation it could be assumed that the zircon in the Tasovice granodiorite crystallized under higher oversaturation, i. e. most probably during quicker cooling than the zircon in remaining parts of the massif.

Camparative samples from the Brno massif demonstrate the decrease in the contamination of rocks towards the N, newly formed garnet developed joints disappears, varieties of zircon become less numerous, and the pseudomorphs are more frequent. Shape of zircon becomes more complicated and its elongations change unevenly in dependence on the length of crystals. Acording to diagrams published by KOSTOV 1966 for minerals of the rutile group, the shape of a mineral becomes more complicated during slow crystallization under low undersaturation.

Translated by M. Pličková

LITERATURA

ČERNÝ, P., ČECH, F., POVONDRA, P. (1964): Review of ilmenorutile — strüverite minerals. — Neues Jahrbuch für Mineralogie, Abhandlungen, **101** č. 2, str. 142—172, Stuttgart.

DUDEK, A. (1960): Problém moldanubického nasunutí v severní části dyjské klenby. — MS Geofond, Praha.

DUDEK, A. (1962): Zum Problem der moldanubischen Überschiebung im Nordteil der Thayakuppel. — Geologie **11** (7), 757—791, Berlin.

DUDEK, A., MELKOVÁ, J. (1975): Radiometric age determination in the crystalline basement of the Carpathian Foredeep and of the Moravian Flysch. — Věstník Ústřed. úst. geol. **50**, 257—264, Praha.

FUCHS, G. (1976): Zur Entwicklung der Böhmischen Masse. — Jb. Geol. B.—A. **119**, 45—61, Wien.

FUCHS, G., MATURA, A. (1976): Zur Geologie des Kristallins der südlichen Böhmischen Masse. — Jb. Geol. B.—A. **119**, 1—43, Wien.

FRASL, G. (1963): Die mikroskopische Untersuchung der akzessorischen Zirkone als eine Routienearbeit des Kristallingeologen. — Jb. Geol. Bundesanstalt **106** (2), 405—428, Wien.

FRASL, G. (1970): Zur Metamorphose und Abgränzung der Moravischen Zone im niederösterreichischen Waldviertel. — Nachr. Deutsch. Geol. Ges. 2, 55—61, Tübingen.

FRASL, G. (1968): The Bohemian Massif in Austria — The Moravian Zone. — Int. Geol. Congr., 23. Sess. Prague, Guide to Exc. 32 C, 13—24, Wien.

HÖCK, V. (1975): Mineralzonen in Metapeliten und Metapsammiten der Moravischen Zone in Niederösterreich. — Mitt. Geol. Ges. Wien **66/67**, 49—60, Wien.

JAROŠ, J., MÍSAŘ, Z. (1976): Nomenclature of the tectonic and lithostratigraphic units in the Moravian Svratka Dome (Czechoslovakia). — Věstník Ústř. úst. geol. **51**, 113—122, Praha.

JENČEK, V., DUDEK, A. (1971): Beziehungen zwischen dem Moravikum und Moldanubikum am Westrand der Thaya-Kuppel. — Věstník Ústř. úst. geol. **46**, (3), 31—338, Praha.

KODYMOVÁ, A. (197): Occurence of pink (Archean?) zircon in the pre-Cambrian of central and western Bohemia. Věstník Ústř. úst. geol. **52**, 121—123, Praha.

KOSTOV, I. (1966): Veränderungen des Kristallhabitus von Mineralen mit Rutil-Struktur. Berichte Dtsch. Ges. Geol. Wiss., **B 11** (3), 295—304, Berlin.

KRASNOBAJEV, A. A., CHOLODNOV, V. V., FOMINYCH, V. G. (1975): Letučije v apatitach — indikatory proischožděnija i facialnoj prinadležnosti granitoidov i drugich porod Urala. Trudy Inst. geol. geochim **120**, 95—104, Moskva.

KRYSTEK, I. (1961): Petrografie sedimentů opěrné vrtby Nesvačilka 1. — Práce VŮ Čs. naft. dolů XVII, 37—62, Brno.

NIEDERMAYR, G. (1967): Die akzessorischen Gemengteile von Gföler Gneiss, Granitgneiss und Granulit im niederösterreichischen Waldviertel. Ann. Naturhist. Mus. **70**, 19—27, Wien.

POLDERVAART, A., ECKELMANN, F. D. (1955): Growth phenomena in zircon of Autochtonous granites. Bull. Geol. soc. Am. **66**, 947, New York.

SAXENA, S. K. (1966, a): Evolution of zircons in sedimentary and metamorphic rocks. Sedimentology **6**, 493—502, Amsterdam — New York.

SAXENA, S. K. (1966, b): A note on the origin of zircons in sedimentary and metamorphic rocks. Geol. Föreningens Stock. Förhandlingar **88** (2), 276—279, Stockholm.

SCHARBERT, S. (1977): Neue Ergebnisse radiometrischer Altersbestimmungen an Gesteinen des Waldviertels. Arbeitstagung der Geol. B.—A., Wien, Waldviertel, 11—15, Wien.

SVOBODA, L., VYNŠOVÁ, D. (1973): On the morphology and distribution of zircons in some rocks the northern part of the Brno massif. Scr. Fas. sci. natur. Univ. Purkynianae Brunensis, geol. **3** (2—3), 61—79, Brno.

ŠTELCL, J., SVOBODA, L., HÁJEK, J., HROUDA, F., MUSILOVÁ, L., STANĚK, J., WEISS, J. (1974): Exkursní profil granodiority brněnského masivu. Universita J. E. Purkyně v Brně, Brno.

TABORSZKY, F. K. (1972): Chemismus und Optik der Apatite. Neues Jahrb. Min., Monatshefte, 2, 79—91, Stuttgart.

THIELE, O. von (1977): Stuiden an Akzessorien und Zirkontrachten von Gföhlergneiss und ähnlichen Gesteinen und ihr Bezug auf die Tektonik des Drosendorfer Fensters (Waldviertel, Niederösterreich). Verh. Geol. B.—A., (2), 53—67, Wien.

TOMITA, T. (1954): Geologic significance of the color of granite zircon and the discovery of the pre-Cambrian in Japan. Mem. Fac. Sci. Kyushu Univ., Ser. D. Geol. 4 (2), 135—161, Fukuoka.

TUČEK, K. (1960): Příspěvky k poznání některých nových nálezů rutilu a ilmenitu. Sbor. Národ. musea v Praze **B 16** (4), 165—197, Praha.

ALEXANDRA KODYMOVÁ

AKCESORICKÉ TĚŽKÉ MINERÁLY MORAVIKA DYJSKÉ KLENBY A DYJSKÉHO MASIVU

Těžké minerály moravika byly analyzovány citlivou kvantitativní metodou. Výsledky jsou v relaci s kontrolními stanoveními Zr a P_2O_5 ve výluhu a byly prostřednictvím částečných chemických analýz navázány na chemismus horniny. Byly charakterizovány jednotlivé minerály a byla studována elongace sloupečkovitého zirkonu, v plutonech jednotlivě pro hlavní variety.

V parabřidlicích moravika se složení těžkého podílu mění i s nepatrnými změnami v obsahu CaO. Tato skutečnost je hlavní příčinou rozdílů ve složení svorů a pararul. Dalším rozdílem je vyšší hladina apatitu ve vzorcích svorové zony včetně ortoruly.

Pozitivní korelace obsahu většiny minerálů s obsahem K_2O dokazuje jejich závislost na množství pelitické složky sedimentu, kdežto ilmenitu a rutilu je více v drobové poloze než v břidličné. Reliktní klastické minerály byly zjištěny hojněji jen ve fylitu. Ve výše metamorfovaných horninách jsou původní klastické tvary zachovány neúplné jen na zirkonu ev. kolumbitu v kvarcitu. Většina zirkonu je rekrystalizována s tvarem (311) a (111) s (100). Se stoupající metamorfosou se zvětšuje velikost krystalů zirkonu a tím ubývá ztrát při separaci.

Ve vzorcích ze svorové zony nebyly nalezeny xenotim ani relikty minerálů vyšších metamorfních facií, ale naopak, stupeň rekrystalizace zirkonu spolu s velmi vzácně se vyskytujícím sytě růžovým zirkonem, který nesnáší vysokou metamorfosu, potvrzují domněnku o primárním původu této série proti názoru o původu diaftoritickém.

Ortoruly jsou anomálně chudé na těžké minerály a proto vyniká silně jejich kontaminovanost materiálem okolních hornin. Jejich sloupečkovitý zirkon připomíná svým habitem vyvřeliny, krystalografickým omezením a častým výskytem jader se podobá migmatitům. Chybí zde minerály a produkty pozdněmagmatických procesů.

Dyjský masiv se podobá ortorulám nízkými obsahy těžkých minerálů, kontaminací materiálem pláště a charakterem převládající variety zirkonu. Liší se nedostatkem sloupečkovité variety zirkonu zakončené (311), která je nahrazena varietou typickou pro vyvřeliny. Vyznačuje se poměrně vysokým množstvím granátu, jehož část vznikla pravděpodobně při metamorfose vyvřelin masivu.

Těžké podíly severnějšího brněnského plutonu, látkově podobného dyjskému, se se vzrůstající vzdáleností směrem k severu liší stále více úbytkem kontaminace, metamorfního granátu a podílu vedlejších variet zirkonu. Místo toho se uplatňují produkty četných proměn minerálů a komplikuje se tvar převládajícího zirkonu.