GEOLOGICA CARPATHICA, 42, 6, BRATISLAVA, DECEMBER 1991
331–339

Be-Nb-Ta GRANITIC PEGMATITES – A NEW TYPE OF RARE-ELEMENT MINERALIZATION IN THE WESTERN CARPATHIANS

PAVEL UHER

Geological Institute, Slovak Academy of Sciences, Dúbravská 9, 842 26 Bratislava, Czecho-Slovakia

(Manuscript received September 7, 1990; accepted in revised form June 20, 1991)

Abstract: A new type of rare-element Be-Nb-Ta mineralization can be defined in the Western Carpathian crystalline complexes; it is bound to granitic pegmatites genetically connected with Hercynian granite intrusions. The mineralization has been characterized on the site Moravany nad Váhom (rare-element, accessory, rock-forming minerals, rocks), however, the described mineralization type is assumed to occur also in other Western Carpathian regions, which allows a new view on the character of pegmatites and rare-element mineralization in this region.

Key words: Western Carpathians, granitic pegmatites, Be-Nb-Ta mineralization, accessory minerals, geochemistry of pegmatites.

Introduction

In the course of a study of accessory minerals in granitic rocks of the Považský Inovec Mts. (Broska and Uher 1988), the authors determined in the pegmatite body of Moravany nad Váhom among other minerals also columbite-tantalite – an indicator of rare-element mineralization. Since granite pegmatites of the Western Carpathians were generally considered to be sterile as far as rare-element mineralization is concerned, the finding caused considerable attention to be aimed at the locality and it became the object of further studies (Uher and Broska 1989; Uher et al. 1989; Klinčuchová 1989). New analytical data from this locality, as well as indications of rare-element pegmatite mineralization otherwhere in the Western Carpathians (Žiar Mts., Malé Karpaty Mts., Nízke Tatry Mts. – Fiala 1931; Valach 1954; Határ 1979; Pitoňák & Janák 1983; Uher et al. 1989; Gargulák & Vanek 1989) led us to the conclusion on the existence of a so far in the Western Carpathians unknown rare-element Be-Nb-Ta mineralization bound to granitic pegmatites.

Methods of study

Quantitative spot microanalysis of separated minerals in polished sections was obtained using the electron microprobe JEOL Superprobe JCXA 733, at the following conditions: accelerating potential – 20–25 *kV*, sample current 20–40 *nA*, electron beam diameter 3–5 *μm*, standards – $LiNbO_3$ (for Nb), $LiNbO_3$ (Ta), TiO_2 (Ti), SnO_2 (Sn), $CaWO_4$ (W), chromite (Fe, Cr, V), Mn-willemite (Mn, Zn), MgO (Mg), wollastonite (Ca), albite (Si, Al, Na), orthoclase (K), zircon (Si, Zr, Hf), ThO_2 (Th), YAG (Y), LaB_6 (La), CeO_2 (Ce). ZAF correction was used. Analysts: F. Caño, P. Siman and P. Konečný, D. Štúr Institute of Geology, Bratislava (GÚDŠ).

The method of backscattered electron images (BEI) was carried out with the help of electron microscope JEOL JSM 840, at accelerating potential of 25, or 30 *kV*, by Dr. J. Stankovič, GÚDŠ Bratislava.

The method of secondary electron images (SEI) was carried out on scanning electrone microscope Tesla BS 300, at accelerating potential of 26 *kV*, by I. Holický (Geol. Inst. Slov. Acad. Sci. Bratislava).

Moravany nad Váhom pegmatite

Geological setting and zoning of the pegmatite

The occurrence at Moravany nad Váhom is situated in a forest on the crest of the hill Striebornica, approx. 3 *km* E of the village Moravany nad Váhom and approx. 5 *km* E of the town Piešťany (75 *km* NE of Bratislava) – Fig. 1. From geological point of view this is the crystalline core of the Považský Inovec Mts., belonging to the Tatricum zone of the Central Western Carpathians. The geology of the surrounding crystalline complex has been studied recently above all by Putiš (1981, 1983) and Korikovsky and Putiš (1986). The pegmatite itself is probably of an elongated lense shape with maximum size of 150 × 20 *m*. It occurs in the form of material from abandoned shafts and small ditches, which were originally assumed to be the remnants of prospecting for gold (Polák 1971), however, they proved to have originated as a result of local-scale exploitation of muscovite as an admixture to plaster (Uher and Broska 1989). The pegmatite

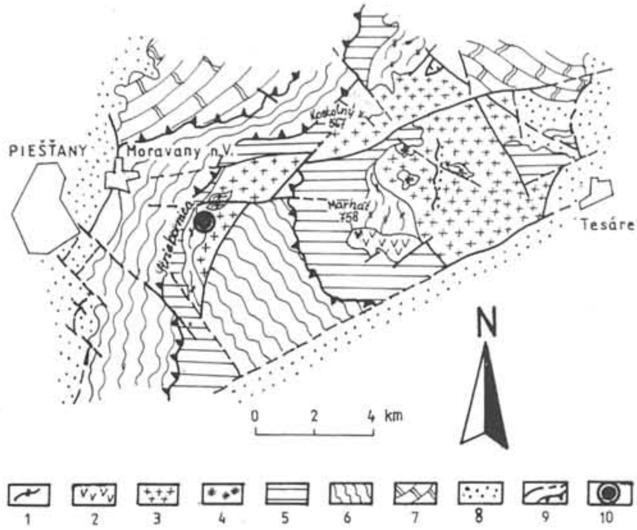

Fig. 1. Geological map of the surroundings of the Moravany nad Váhom pegmatite (Mahel' 1986 – adapted).
1 – paragneisses; 2 – amphibolites; 3 – two-mica granites, granodiorites and leucotonalites; 4 – leucocratic granites; 5 – mantle Mesozoic (1–5 – the Tatricum); 6 – Mesozoic of the Krížna Nappe; 7 – Mesozoic of the Choč Nappe; 8 – Cainozoic; 9 – faults, thrust lines; 10 – location od the pegmatite.

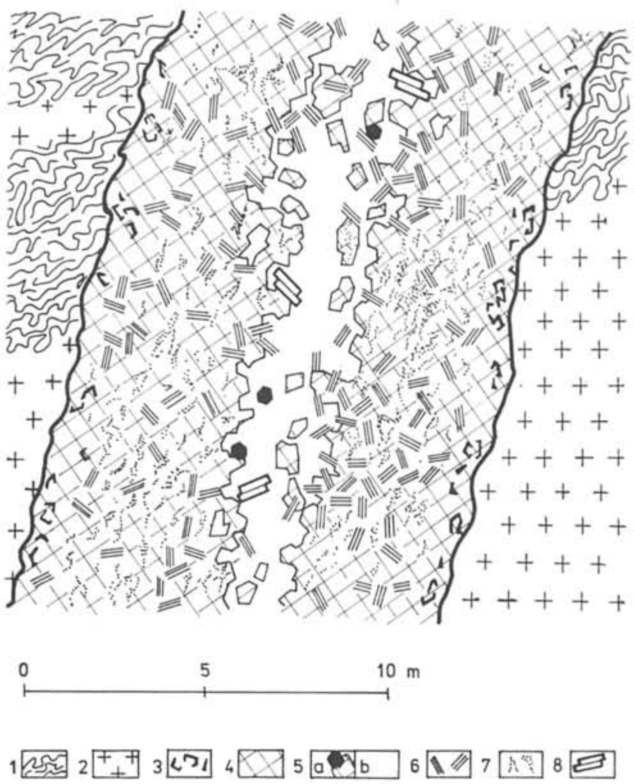

Fig. 2. Idealised cross-section of the Moravany nad Váhom pegmatite.
1 – paragneiss; 2 – granodiorite; 3–8 – paragenetic units of the pegmatite; 3 – graphic pegmatite zone; 4 – block microcline zone; 5 – block quartz zone, a – beryl on the boundary of block quartz and microcline, b – quartz core s. s.; – 6 – coarse-grained quartz-muscovite complex with relics of microcline; 7 – saccharoidal albite complex; 8 – cleavelandite complex.

body occurs at the contact of granitoids and paragneisses. The granitoid intrusion of Hercynian age caused in its mantle contact periplutonic metamorphism at maximal PT-conditions of 540–580 °*C* and 3.5–4 *kbar*, with the formation of biotite-garnet paragneisses with sillimanite, locally also andalusite and kyanite (Korikovsky and Putiš 1986). To the Hercynian granitoids in the Považský Inovec Mts. crystalline complex are bound numerous vein derivates, especially pegmatites. As indicated by the results of Klinčuchová (1989) as well as so far unpublished results of the author, they are unzoned to slightly zoned bodies having simple mineral composition (feldspars, quartz, muscovite, biotite, garnet, apatite, zircon), without signs of rare-element mineralization. The pegmatite at Moravany and Váhom seems to be from this viewpoint exceptional.

The body has marked zoned structure (Fig. 2). The locally developed zone of graphic pegmatite gradually passes into light-gray block microcline-perthite. The quartz core is composed of as much as 1/2 *m* large blocks of pure opaque white quartz, only exceptionally with tiny cavities with 1 *mm* long crystals of clear colourless quartz. Occurrences of coarse-crystalline beryl and muscovite are bound to the boundary of block microcline and quartz. Secondary complexes of metasomatic character are with varying intensity distributed in different parts of the pegmatite. The most widespread paragenetical unit of the whole body is a coarse-grained quartz-muscovite complex, conspicious especially because of abundant coarse-platy muscovite I (3–10 *cm*), formed above all from K-feldspar. The result are coarse-grained microcline-quartz-muscovite rocks. Another typical and in places abundant paragenetical unit is the complex of saccharoidal albite which forms irregular up to 30 *cm* large, almost monomineralic nests, substituting block microcline as well as the quartz-muscovite complex. The saccharoidal albite complex is composed above all of a fine-grained albite aggregate (An_{02-07}) with an average grain-size of 0.1–0.3 *mm*, less frequent is quartz and fine-grained muscovite II, locally there are abundant relics of older microcline, quartz and muscovite I. At last, at the boundary of block microcline and quartz, less in the quartz-muscovite complex, there are sporadical occurrences of a cleavelandite complex in the form of white, lath-like and fan-shaped aggregates of albite-cleavelandite, the size of aggregates usually not exceeding 10 *cm*. To the albite metasomatic complexes is related the principal part of rare-element and other accessory minerals (columbite-tantalite, microlite, gahnite, garnet and zircon).

Rare-element and other accessory minerals

Beryl occurs on the contact of block microcline and quartz, or in the quartz core of the pegmatite itself, in the form of light-green, hexagonally limited columnar crystals, or their parallel aggregates with a length of up to 10 *cm* and thickness of maximally 3 *cm*. The mineral has been positively identified by X-ray diffraction analysis. It is a common low-alkali beryl ($Na_2O + K_2O$ = 0.43–0.49% – Tab. 1.), chemically homogeneous, almost unzoned. Generally this is a classical example of an early-stage, coarse-grained, primary beryl, crystallizing at the beginning of the formation of quartz core

Table 1. Microprobe analysis of beryl from the Moravany nad Váhom pegmatite.

	C1	C2	R
SiO_2	66.74	66.11	65.80
TiO_2	0.00	0.00	0.00
Al_2O_3	18.37	18.06	18.15
Cr_2O_3	0.00	0.00	0.07
FeO	0.23	0.22	0.36
MnO	0.06	0.06	0.00
MgO	0.19	0.19	0.17
CaO	0.07	0.00	0.02
Na_2O	0.38	0.39	0.36
K_2O	0.05	0.10	0.07
TOTAL	86.09	85.13	85.00

C – core, R – rim of crystal.

and before the Na-metasomatism stage (Beus 1960; Ginzburg et al. 1977), perhaps simultaneously with the formation of the quartz-muscovite complex. It cannot be excluded that in the saccharoidal albite there is also younger, alkaline beryl, which is frequently fine-grained and irregularly developed, making thus its identification more difficult (Beus l.c.; Ginzburg et al. l.c.). This assumption is supported by increased Be content in the saccharoidal albite (35–69 *ppm*).

Columbite-tantalite (Tab. 2, Figs. 3a, 4a–c, 5) belongs to relatively frequently occurring accessory minerals of the pegmatite. It occurs in the form of tiny, 0.2–5 *mm* black tabular crystals in saccharoidal albite, albitized quartz-muscovite complex and at the contact of cleavelandite with block quartz. The columbite-tantalite crystals often show complicated zoned internal structure and large variations between Nb_2O_5 and Ta_2O_5, or FeO and MnO (Figs. 4a–c, Tab. 2), which is a typical feature of this mineral (Barsanov et al. 1971; von Knorring & Condliffe 1984; Lahti 1987; Voloshin and Pakhomovsky 1988), caused by multistage growth at varying PTX parameters of the crystallization environment.

Microlite occurred in the form of hypidiomorphic to xenomorphic inclusions in columbite-tantalite (crystal No. 3 – Tab. 2), its size being 20–80 *μm* (Fig. 4c). Optical and microprobe study (Tab. 2) indicates its inhomogeneous composition. Generally it is Ca-microlite with Na-deficit and low totals of the analyses, which is caused mainly by incompleteness of the analyses (increased content above all of UO_2, H_2O has to be considered) and metamictization of the mineral, connected also with a depletion of alkalies, especially Na (Voloshin and Pakhomovsky 1988). Microlite is younger than columbite-tantalite, it formed especially at its edges, or it follows various fissures in columbite-tantalite.

Garnet is the most frequent accessory mineral on the studied locality, its concentration can in some parts of the quartz-muscovite and saccharoidal albite complex attain as much as approx. 1 vol. %. Garnet occurs in the form of 0.1–1.5 *mm* large pink transparent crystals {211}, or a combination of {211} and {100}, characteristic is the parquet-like surface of the crystals. In places there were interesting garnets with cuboidal morphology (Fig. 3b). Their unusual form and sculptured surface with numerous cavities indicates that they are garnets affected by dissolution due to alkaline solutions in the process of pegmatite albitization. The formation of cuboidal shapes of garnet has been explained in a similar way by Sobolev (1975). The composition of garnet indicates almandine-spessartite with a low content of pyrope as well as grossularite and andradite molecule (Tab. 3). Such garnets are typical for rare-element pegmatites, in contrast to simple feldspar and mica-bearing pegmatites without rare-element mineralization, which always have increased MgO content (Sokolov et al. 1962; Černý and Hawthorne 1982). This holds also for pegmatites of the Považský Inovec Mts.; the simple ones without rare-element mineralization usually plot into the field of mica-bearing pegmatites on the diagram of Sokolov et al. l.c. (Broska and Uher 1988; Klinčuchová 1989, unpublished data of the author), the Moravany nad Váhom pegmatite, however, contains garnets which plot into the field of rare-element pegmatites on the above mentioned diagram (Fig. 6). All measured garnet crystals are zoned, showing

Table 2. Representative microprobe analysis of columbite-tantalite in the saccharoidal albite complex (crystals No. 1, 2) and columbite-tantalite in the cleavelandite comples (crystal No. 3) with microlite inclusions (4,5) from the Moravany nad Váhom pegmatite.

	Columbite – Tantalite										Microlite	
	1A	1B	1C	2A	2B	2C	3A	3B	3C	3D	4	5
Nb_2O_5	47.88	55.77	49.95	38.88	26.07	34.05	23.38	34.06	38.63	42.49	3.63	3.23
Ta_2O_5	33.58	25.78	30.28	43.95	57.20	52.01	60.72	46.44	42.53	36.63	63.62	71.01
TiO_2	0.40	0.62	0.74	0.36	0.72	0.59	0.34	0.08	0.13	0.15	2.72	2.46
SnO_2	0.08	0.10	0.08	0.05	0.10	0.12	0.23	0.05	0.00	0.00	0.21	0.23
WO_3	0.00	0.00	0.04	0.00	0.09	0.00	0.00	0.25	0.28	0.00	0.00	0.00
FeO	13.55	13.13	13.05	12.62	12.24	12.32	10.49	8.16	7.73	7.93	0.09	0.27
MnO	4.06	4.68	4.10	3.19	2.64	2.67	5.80	9.31	9.84	10.02	0.20	0.53
MgO	0.03	0.02	0.04	0.02	0.01	0.00	0.00	0.02	0.00	0.02	0.00	0.00
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.46	12.37
Na_2O	0.00	0.04	0.05	0.02	0.00	0.00	0.04	0.04	0.00	0.02	0.91	0.84
TOTAL	99.58	100.14	98.33	99.09	99.07	101.76	101.00	98.41	99.14	97.26	81.84	90.94
Ta/(Ta + Nb)	0.30	0.22	0.27	0.40	0.57	0.48	0.61	0.45	0.40	0.34	0.91	0.93
Mn/(Mn + Fe)	0.23	0.27	0.24	0.20	0.18	0.18	0.36	0.54	0.56	0.56	0.70	0.66

A–D – various points within the measured crystal.

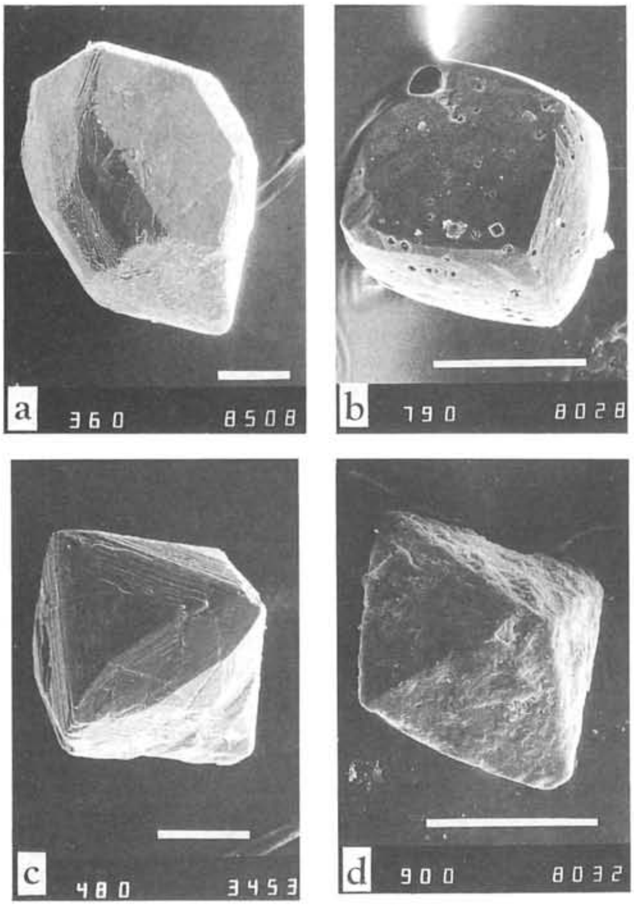

Fig. 3. Morphology of columbite-tantalite (a), cuboidal garnet (b), gahnite (c) and zircon (d) from the Moravany nad Váhom pegmatite. Scale = 100 μm. SEM, SEI method (photo I. Holický).

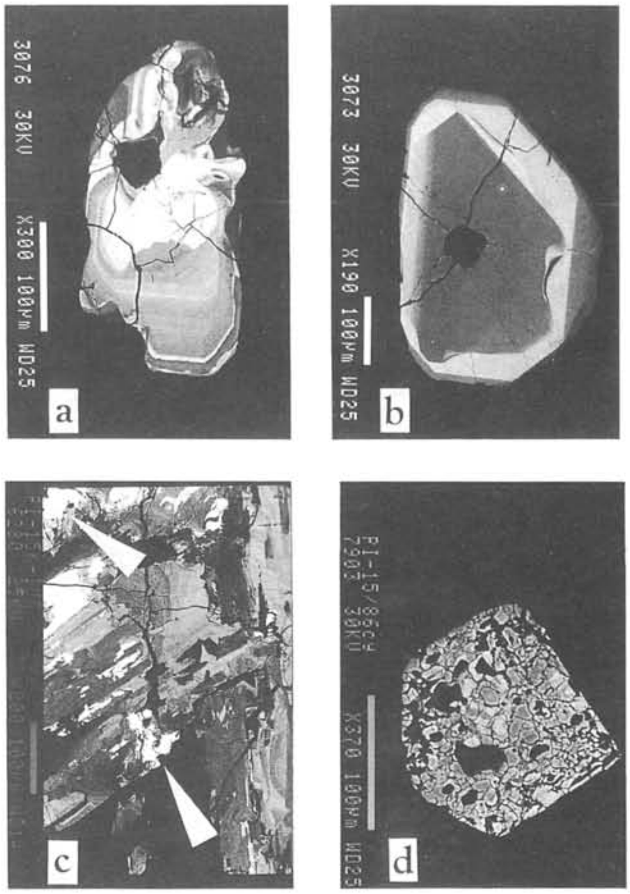

Fig. 4. Internal structure (zoning) of columbite-tantalite (a, b) columbite-tantalite with microlite inclusions – marked by arrows (c) and zircon (d) from the Moravany nad Váhom pegmatite. The lightness of the zones is directly proportional to Ta/ (Ta + Nb), Hf/ (Hf + Zr) respectively. Scale = 100 μm. SEM, BEI method (photo J. Stankovič).

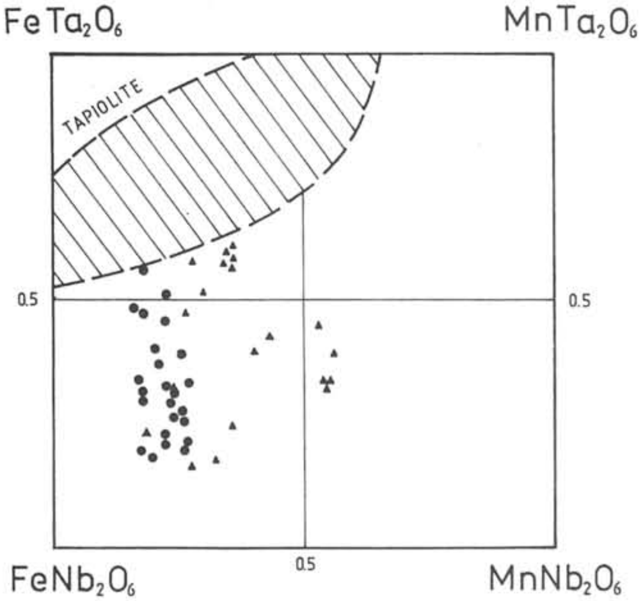

Fig. 5. Quadrilateral diagram of columbite-tantalite (Lahti 1987; Černý and Ercit 1989) with projections of analysed columbites-tantalites in saccharoidal albite (full circles) and with cleavelandite (triangles) from the Moravany nad Váhom pegmatite. Hatched field – the region of isomorphic miscibility gap.

a decrease of MnO and increase of FeO and MgO contents in the direction from cores to the rims of crystals (Tab. 3). Similar trend is common in granitic pegmatites, even though it is not the only possible one (Gbelský 1980; Baldwin and von Knorring 1983) and it is related to the changes of PTX parameters during the crystallization of garnet.

Gahnite is a typical and locally relatively abundant mineral of the pegmatite, it attains its maximal concentration in the saccharoidal albite and albitized quartz-muscovite complex. It occurs in the form of rich green, perfectly transparent crystals, often with steps-like faces (Fig. 3c). In some cases gahnite is replaced by fine-grained muscovite II, or sericite, along fissures, or the mineral is covered by muscovite, in other cases it is oxidized ($Fe^{2+} \rightarrow Fe^{3+}$), the mineral thus looses its original transparency and lustre, and green colour is changed into brownish green. The chemical composition of gahnite (Tab. 4, Fig. 7) is characterized by high content of the gahnite molecule s.s. – $ZnAl_2O_4$ and at the same time by very low contents of the spinel molecule – $MgAl_2O_4$, which is typical for gahnites from pegmatites (Němec 1973; Batchelor and Kinnaird 1984). Gahnite is considered to be a typical mineral of granite pegmatites, connected with subsolidus conditions of albite metasomatism (Černý and Hawthorne 1982).

Table 3. Representative microprobe analyses of garnet from the Moravany nad Váhom pegmatite.

	1C	1R	2C	2R	3A	3B	3C	3D	3E	3F	3G	3H
SiO_2	35.38	35.63	36.53	36.29	36.69	35.99	35.49	36.73	36.38	36.04	35.70	35.83
TiO_2	0.10	0.00	0.00	0.01	0.01	0.03	0.02	0.01	0.05	0.09	0.04	0.00
Al_2O_3	20.94	21.06	21.36	21.16	20.95	20.67	19.98	20.07	20.43	20.86	20.46	20.54
FeO	25.41	29.68	24.01	27.93	27.26	26.55	25.91	25.32	25.75	26.13	27.61	28.43
MnO	18.13	12.61	19.06	13.06	14.70	15.97	16.38	17.05	16.58	17.16	15.02	13.96
MgO	0.09	0.19	0.11	0.34	0.24	0.15	0.11	0.11	0.10	0.14	0.17	0.27
CaO	0.18	0.25	0.21	0.25	0.19	0.25	0.28	0.20	0.25	0.26	0.20	0.21
Total	100.23	99.42	101.23	99.03	100.03	99.62	98.17	99.48	99.54	100.68	99.19	99.24
Alm	57.30	68.86	54.86	66.37	63.67	61.29	59.91	58.25	59.73	59.13	63.54	65.60
Spes	41.83	29.62	44.11	31.43	34.77	37.35	38.81	40.69	39.11	39.56	35.18	32.69
Pyr	0.35	0.77	0.44	1.45	0.98	0.63	0.44	0.45	0.43	0.57	0.69	1.11
Gros	0.52	0.74	0.59	0.76	0.57	0.73	0.84	0.60	0.73	0.74	0.59	0.61
Mn/(Mn + Fe)	0.42	0.30	0.45	0.32	0.35	0.38	0.39	0.41	0.39	0.40	0.36	0.33

C – core, R – rim of the measured crystal, 3A – 3H – profile across a crystal.

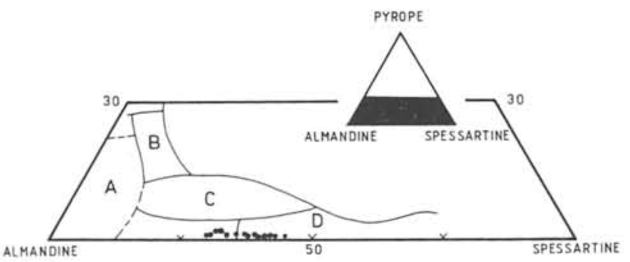

Fig. 6. Triangular diagram (molecular ratios) of garnets after Sokolov et al. (1962).
A – field of garnets from crystalline schists of the amphibolite facies, B – field of garnets from feldspar pegmatites, C – field of garnets from mica-bearing pegmatites, D – field of garnets from rare-element pegmatites. Full circles – projections of analysed garnets from the Moravany nad Váhom pegmatite.

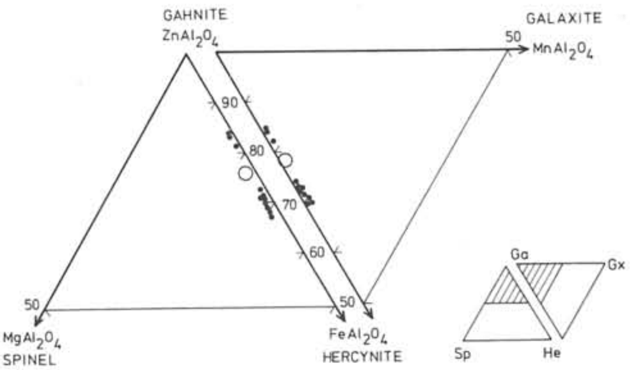

Fig. 7. Triangular diagrams of gahnite (molecular ratios).
Full circles – gahnites from the Moravany nad Váhom pegmatite in comparison with analyses of gahnites from the pegmatite Bratislava--Železná studienka, Malé Karpaty Mts. – large empty circle (Gbelský and Krištín 1985).

Table 4. Representative microprobe analyses of gahnite from the Moravany nad Váhom pegmatite.

	1C	1R	2C	2R	3C	3R
Al_2O_3	58.48	58.56	56.77	57.03	57.61	58.94
V_2O_3	0.06	0.03	0.07	0.00	0.05	0.08
Cr_2O_3	0.00	0.04	0.02	0.00	0.00	0.08
FeO	6.08	6.82	11.02	10.59	11.71	11.46
MnO	0.18	0.26	0.26	0.22	0.34	0.47
MgO	0.03	0.11	0.25	0.15	0.34	0.32
CaO	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	37.03	35.45	31.09	31.18	26.69	29.80
Total	101.59	100.83	98.88	98.80	99.01	100.20
Gahnite	83.7	81.2	70.1	71.3	67.4	67.8
Hercynite	15.6	17.6	28.1	27.4	30.1	29.6
Spinel	0.1	0.5	1.1	0.8	1.6	1.5
Galaxite	0.5	0.7	0.6	0.5	0.9	1.2
Zn/(Zn + Fe)	0.84	0.82	0.71	0.72	0.69	0.70
Mn/(Mn + Mg)	0.80	0.56	0.36	0.40	0.37	0.45

C – core, R – rim of the measured crystal.

Zircon occurs as well especially in the saccharoidal albite complex, to a lesser extent it is present also in the quartz-muscovite complex, sometimes with cleavelandite. The mineral is due to strong metamictization almost isotropic in trasmitted light, almost opaque, ochre, grey or brown in colour. It forms 0.1–1 *mm* crystals, or their intergrowths with a prevalence of pyramidal faces, or purely bipyramidal crystals {111} – Fig. 3d. Zircon crystals are irregularly zoned with domains enriched sometimes by Zr sometimes by Hf (Fig. 4d). Rarely, up to 5 *μm* large inclusions of uraninite have been observed in zircons. Chemical composition of zircon (Tab. 5) is characterized by high HfO_2 contents; it is known that the ratio of Hf:Zr progressively increases in relation to geochemical differentiation and fractionation of granitic pegmatites from primitive to complex rare-element pegmatites (Černý et al. 1985). On the basis of a comparison of HfO_2 values in zircons of the Moravany nad Váhom pegmatite with published data it follows that zircons from the studied localities are the product of a medium-developed pegmatite process, since the values of Hf:Zr are lower than in strongly differentiated pegmatite bodies (Correia Neves et al. 1974; Černý and Siivola 1980; Törnroos 1982, 1985; Cassedanne et al. 1985), but generally

Table 5. Representative microprobe analyses of zircon from the Moravany nad Váhom pegmatite.

	1A	1B	2A	2B	2C
SiO_2	32.22	30.92	31.50	30.51	31.80
ZrO_2	53.77	52.10	57.70	55.23	57.04
HfO_2	3.91	3.93	6.79	7.34	7.85
ThO_2	0.00	0.00	0.00	0.02	0.05
Y_2O_3	0.06	0.00	0.00	0.00	0.01
La_2O_3	0.00	0.00	0.00	0.00	0.00
Ce_2O_3	0.03	0.04	0.03	0.02	0.00
CaO	0.02	0.16	0.04	0.04	0.00
Total	90.01	87.15	95.86	93.16	96.75
ZrO_2/HfO_2	13.8	13.3	8.5	7.5	7.3
(Zr/Hf)wt	12.0	11.5	7.4	6.6	6.3
(Zr/Hf)at	23.4	22.6	14.5	12.9	12.5
100 Hf/ (Hf + Zr)at	4.1	4.2	6.5	7.2	7.4

A–C – various points within the measured crystal.

higher than it is usually the case in weakly differentiated pegmatites of the Western Carpathians (Malé Karpaty Mts. – Gbelský 1979, Považský Inovec Mts. – unpublished data of the author).

From other accessory minerals of the pegmatite at Moravany nad Váhom, we can mention sporadic apatite, monazite, pyrite (Uher and Broska 1989) and newly identified arsenopyrite.

Geochemical characteristics of the studied pegmatite

The specific character of the Moravany nad Váhom pegmatite within the Western Carpathians is confirmed also by the distribution of indicative trace elements in the pegmatite itself and its rock-forming minerals. Already in the surrounding granitoids (PI-15A/87, PI-24/87) the Rb and Be contents are slightly increased in comparison with average values from granitoids of the Považský Inovec Mts. (Tab. 6), which, together with the presence of accessory Nb-rutile in two-mica granodiorite PI-15A/87 (Uher et al. 1989) supports the idea of the genetical relationship of the Moravany nad Váhom pegmatite with the surrounding granitoid rocks. In an average pegmatite sample, represented by less albitized coarse-grained quartz-muscovite complex with microcline relics (PI-15/86) the contents of Li, Rb, Cs, Be, Ta and Sn are several times higher than in other, weakly differentiated pegmatites of the Považský Inovec Mts. The ratios of alkalies, Ba and Sr differ even by an order (Tab. 6).

Similarly, if we compare the contents of Rb, Ba, Sr and the ratio Ba/Rb in K-feldspars from the Moravany nad Váhom pegmatite with average values from weakly differentiated feldspar-mica pegmatites of the Tatricum of the Western Carpathians (Dávidová 1978), there are order-size differences (Tab. 7).

The pegmatite at Moravany nad Váhom is thus geochemically far more differentiated as common types of feldspar-mica pegmatites in the Western Carpathians without rare-element mineralization. The contents of its indicative trace elements and their ratios in the rock as well as in feldspars and muscovite approach the values of rare-element, or rare-element – muscovite granite pegmatites (Tab. 6).

Occurrences in other Western Carpathian regions

Similar rare-element pegmatites can be assumed to occur at other localities in the Western Carpathians too. Available, so far incomplete data, especially mineralogical, indicate occurrences of Be-Nb-Ta pegmatite mineralization besides in the Považský Inovec Mts. also in the Bratislava Massif of the Malé

Table 6. Average contents of indicative trace elements *(ppm)* and their ratios in various crystalline rocks of the Považský Inovec Mts., their contents in an average samples of the Moravany nad Váhom pegmatite (PI/15/86) and in the surrounding granitoid rocks (PI-15A/87, PI-24/87) compared with trace element contents in various types of rare-element granitic pegmatites (Kuzmenko et al. 1976, ex Černý 1982 – adapted).

	Li	Rb	Cs	Be	Ta	Sn	K/Rb	Rb/Cs	Ba/Rb	Rb/Sr
P. Inovec Mts.:										
paragneisses	56 (7)	72 (10)	2.2 (4)	2.6 (8)	1 (2)	4.6 (8)	271	33	8.8	0.40
granitoids	38 (19)	95 (20)	3.5 (7)	3.1 (21)	1 (4)	2.9 (15)	240	27	6.0	0.38
pegmatites	16 (5)	155 (6)	1.9 (1)	3.4 (7)	1 (1)	6.9 (5)	209	82	1.3	4.10
PI-15A/87	90	155	n.a.	4.0	n.a.	1.5	197	n.a.	3.5	0.87
PI-24/87	12	134	n.a.	4.0	n.a.	3.5	241	n.a.	2.7	2.10
PI-15/86	70	403	33	41	16.5	41	43	12	0.37	18.00
Rare-element pegmatites:										
U-REE	1–23	4–280	2–47	11–18	4–41	n.a.				
Nb-Y	19–210	max. 190	max. 12	6–100	8–630	n.a.				
Ta-Be	6–470	170–1900	28–160	16–1700	8–90	20–620				
Be-Ta-Li	19–6200	100–1100	4–140	3–500	2–190	13–530				
Complex RE	37–8500	190–10000	9–9400	3–610	10–4100	11–32000				
F-Ta-Li	90–3100	280–1900	28–240	65–440	8–310	60–560				

Analytical data from the Považský Inovec Mts.: INAA, AAS (Li, Rb, Cs, Ta), SPA (Be, Sn, Ba, Sr) and classical, or X-ray fluorescence analysis, n.a – not determined. Numbers in brackets – number of analyses.

Table 7. Contents of Li, Rb, Ba and Sr (*ppm*) in feldspars and muscovite I from the Moravany nad Váhom pegmatite (Li – AAS, analyst Ing. E. Martiny, Geol. Inst. Slov. Acad. Sci., Ba, Sr – SPA, analyst Dr. J. Medveď, Geol. Inst. Slov. Acad. Sci.) compared with average values of K-feldspars from simple feldspar-mica pegmatites of Tatricum of the Western Carpathians (Dávidová 1978) and K-feldspars and muscovites from rare-element-muscovite pegmatites from various regions of the world (Makagon and Shmakin 1988).

	Li	Rb	Ba	Sr	Ba/Rb
Moravany n. V. pegmatite:					
Microcline-perthite	10.9 (2)	1339 (2)	123	9	0.092
Saccharoidal albite	11.0	n.a.	135	12	–
Cleavelandite	6.3	65.6	n.a.	n.a.	–
Muscovite	279 (2)	1768	186	7	0.11
Tatric pegmatites: K-feldspars	n.a.	217	1382	217	6.37
Rare-elements – muscovite pegmatites: K-feldspars	5.3–10	460–1800	70–1050	17–113	0.046–1.68
Rare-elements – muscovite pegmatites: muscovites	40–723	658–2620	14–675	6–28	0.006–1.03

Numbers in brackets – number of analyses, n.a. – not determined.

Karpaty Mts., in the Tatricum part of the Nízke Tatry Mts. and probably also in the Žiar Mts. (Fig. 8).

In the Bratislava Massif of the Malé Karpaty Mts., on the territory of the city Bratislava (Mlynská dolina Valley, Železná studienka) there are concentrated numerous occurrences of mostly very small pegmatite dykes in leucocratic two-mica granites-granodiorites. The pegmatites are often zoned, with developed aplitoid, graphitic, block, pegmatoid as well as metasomatic zones (Dávidová 1970), from accessories there were studied garnet, gahnite and zircon with as much as 8% Hf (Gbelský 1979, 1980; Dávidová 1968; Gbelský and Krištín 1985). Be-Nb-Ta mineralization from this region is characterized by coarse-crystalline beryl in quartz core (Gargulák and Vanek 1989), an unidentified mineral from the pyrochlor-microlite group (Valach 1954) and especially 0.5–2 *cm* large tabular crystals of columbite-tantalite in fissures of coarse-crystalline microcline (Uher et al. 1989).

In the region of Prašivá and the adjoining Sopotnica Valley (the Tatricum part of the Nízke Tatry Mts.), in biotite granites-granodiorites with pink porphyric K-feldspars (so-called Prašivá type) there were found irregular pegmatites with beryl in association with K-feldspar, accessory columbite-tantalite as well as another Nb-Ta mineral (betafite?, formanite?) (Pitoňák and Janák 1983; Határ 1979). The assemblage contains according to our investigations also spessartite-almandine garnet and zircon with increased Hf content.

Rare-element mineralization can be assumed also in pegmatites of the Žiar Mts., near the village Sklené. An old finding of beryl (Fiala 1931) is known from a feldspar-quartz-muscovite pegmatite close to the contact of leucocratic granites with crystalline schists. From accessories we have found again gahnite, besides garnet and zircon.

Even though it is evident that Be-Nb-Ta mineralization in the above mentioned regions has not been studied sufficiently, the available data indicate its presence in the wider Western Carpathian region.

Fig. 8. Localities of granitic pegmatites with Be-Nb-Ta mineralization in Western Carpathian region.
1 – Moravany nad Váhom; 2 – Bratislava; 3 – Prašivá; Sopotnica Valley; 4 – Sklené.

Conclusions

On the basis of the previously mentioned mineralogical and geochemical data it is possible to state the presence of a new type of rare-element mineralization in the Western Carpathians, connected with granitic pegmatites of Be-Nb-Ta type. The mineralization, described in detail on the locality Moravany nad Váhom in the Považský Inovec Mts., can be assumed to occur in various regions of the Western Carpathian crystalline complexes (Malé Karpaty Mts., Nízke Tatry Mts., Žiar Mts.). It is present especially in regions with occurrences of leucocratic, two-mica or biotite Hercynian granitoids, sometimes at their contact with crystalline schists. The rare-element Be-Nb-Ta mineralization is characterized by the assemblage beryl-columbite-tantalite-other Nb-Ta minerals, accompanied by garnet, Hf-rich zircon and usually gahnite.

Even thought according to available data they are sporadic, small and economically insignificant occurrences, their presence by itself enriches our knowledge of the character of pegmatites and rare-element mineralization in the Western Carpathians.

Acknowledgements: The author would like to thank all analysts, especially Dr. F. Caňo, Dr. P. Siman and Dr. P. Konečný (Dionýz Štúr Institute of Geology, Bratislava) for numerous microprobe analyses, Dr. I. Petrík (Geological Institute, Slovak Academy of Sciences, Bratislava) for unpublished analytical data and last but not least Prof. D. Hovorka (Comenius University, Bratislava) and Doc. J. Staněk (Masaryk University, Brno) for their careful and critical reading of the manuscript.

Translated by K. Janáková

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