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Provenance of detrital tourmaline in the Lower Jurassic of the Malé Karpaty Mts.

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Abstract

Clastic tourmaline grains from the Lower Jurassic clastic admixture of the Borinka, Kuchyňa, Kadlubek and Orešany Units (Tatricum) in Malé Karpaty Mts. were analysed. The purpose was to clarify their source rock since the tourmaline is very scarce in recently outcropped crystalline basement of Malé Karpaty Mts. The analyses proved the metamorphogenous origin of the majority of tourmaline; tourmaline grains of granitoid origin were found only in the Lower Jurassic of the Kadlubek Unit deposited on the elevation (the erosion reached the granitoid basement), and in the Lower Triassic quartzites (Lúžna Formation). The most probable source of the rest of tourmaline are the low-grade metamorphosed rocks (sericitic phyllites) preserved only as clasts in some formations of Borinka Unit.

Key words: tourmaline, heavy minerals, Lower Jurassic, Malé Karpaty Mts., Western Carpathians

Introduction

Analysing the heavy mineral assemblages in the Lower Jurassic of Borinka Unit (which can be probably correlated with Penninicum) and Tatric units (they can be correlated with Lower Austroalpine) of Malé Karpaty Mts. (Aubrecht, in press) a high percentage of tourmaline was found which is in contradiction with the contents in recently outcropped crystalline basement where it is very scarce (Mišík, 1955; Veselský, 1972; Veselský and Kovalská, 1981). The contradiction was explained by the presence of tourmaline bearing low-grade metamorphites, mainly sericitic phyllites, in the top of the crystalline complexes being continually removed by the erosion during Mesozoic (Aubrecht, l. c.). To testify this theory more than 80 microprobe analyses of the detrital tourmaline were carried out. The results have been plotted into ternary diagrams introduced by Henry and Guidotti (1985) based on the Al, Fe, Mg and Ca substitutions in tourmaline depending on the chemical composition of the wall-rock.

Examined samples

Five samples from the Borinka Unit were examined. Their list together with the samples from Kuchyňa and Kadlubek Units is comprised in Aubrecht (l. c.). As the possible primary or secondary sources the tourmalines of following samples have been analysed:

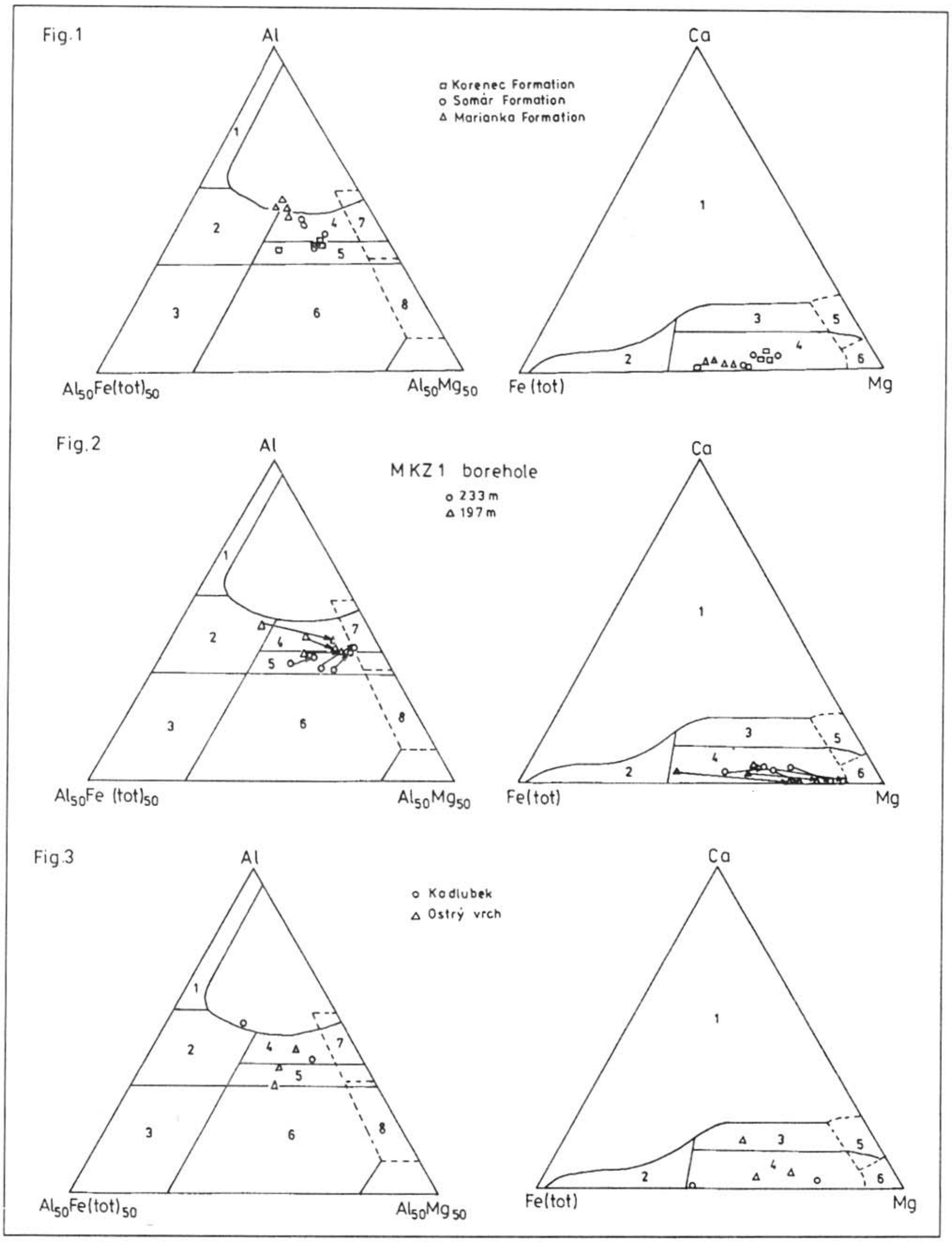
1. Devín - southernmost part of castle hill - chloritic phyllite (the sample rendered by Doc. RNDr. J. Veselský, CSc. - see Veselský and Kovalská, 1981).
2. Marianka - large quarry E of the village near one of the last preserved outcrops of the Marianka Formation - sericitic quartzites and metagreywackes.
3. Braunsberg - Hundsheimerberge, Austria - Lower Triassic quartzite (Lúžna Formation, Semmering quartzite).
4. Trattenbach - near Weinweg, Austria, Lower Austroalpine - pebble of tourmalinic rock in Semmering Quartzite identical with those mentioned by Mišík and Jablonský (1978) from the Lower Triassic quartzites (Lúžna Formation) in the Malé Karpaty Mts.

The tourmaline from the granitoids of the Malé Karpaty Mts. has not been analysed for its very scarce occurrence (absent or locally under 1% - see Mišík, 1955; Veselský, 1972).

Analytical techniques

The chemical composition of tourmaline samples was carried out by an electron microanalyser JXA 840 A, with wavelength dispersive spectrometers of JEOL - KEVEX system. For quantitative analyses the computer program SESAM and ZAF corrections were used. In each analysed sample corresponding proceedings of point analyses and the dimension of electron beam 2 μm were used. The analysed points were in the center and on the rims of the sample. In some samples two main phases were identified. The bright phase in the core and in the rims was analysed as well as the dark phase. The surface of the separate samples was documented by backscattered electrons with magnification 50 and 1000x. The results of analyses ascertain some more homogeneity in the bright, vitreous parts than in the dark ones. The quantitative analyses were carried out under conditions of 15 kV and 18 nA of the electron beam. The following standards were used: Si, Al (kyanite), Ca (wollastonite), Fe, Mg (olivine), Ti (rutile), K (adularite), Na (albite). The accuracy of the measurements was + 1,5 relative %.

Boron amounts were calculated assumed 3 boron atoms



Obr. 1 - 6. Ternárne diagramy zobrazujúce molekulárne pomery prvkov Al, Fe, Mg a Ca v skúmaných vzorkách (podľa Henry a Guidotti, 1985). Diagram Al-Fe(tot)-Mg: 1 - granitoidné pegmatity a aplity bohaté na Li, 2 - granitoidy a s nimi spojené pegmatity a aplity chudobné na Li, 3 - kremenno-turmalinické horniny (hydrotermálne alterované granity) bohaté na Fe^{3+}, 4 - metapsamity a metapelity koexistujúce s fázou nasýtenia Al, 5 - metapsamity a metapelity nekoexistujúce s fázou nasýtenia Al, 6 - kremenno-turmalinické horniny bohaté na Fe^{3+}, vápenato-silikátové horniny a metapelity, 7 - nízkovápenaté metaultramafity a sedimenty bohaté na Cr a V, 8 - metakarbonáty a metapyroxenity. Diagram Ca-Fe(tot)-Mg: 1 - granitoidné pegmatity a aplity bohaté na Li, 2 - granitoidy a s nimi spojené pegmatity a aplity chudobné na Li, 3 - metapelity a metapsamity bohaté na Ca a vápenato-silikátové horniny, 4 - metapelity, metapsamity a kremenno-turmalinické horniny chudobné na Ca, 5 - metakarbonáty, 6 - metaultramafity.

in structural formula. Since the H_2O contents were not estimated by the microprobe, the structural formula was calculated on the basis of 29 oxygens.

Results

Borinka Unit

Korenec Formation - 4 unzoned grains were analysed. All of them lay in the field No.5 in the Al-Fe(tot)-Mg diagram and in the field No.4 of the Ca-Fe(tot)-Mg diagram indicating the origin from Al- and Ca- poor metapelites and metapsammites (Fig. 1, Tab. 1).

Somár Formation - 4 unzoned grains were analysed. Three of them are in the field No. 4, one in the field No. 5 in the Al-Fe(tot)-Mg diagram and all of them are in the field No.4 in Ca-Fe(tot)-Mg diagram. That indicates their origin from the Ca-poor and Al-indifferent metapelites and metapsammites (Fig. 1, Tab. 1).

Marianka Formation - 4 unzoned grains were analysed. Their Al values in the Al-Fe(tot)-Mg diagram are very high. Two of them can be considered as belonging to the field No. 4 but the rest occurs in the undefined field (reflecting the gap of miscibility between dravite and elbaite) above the border of the fields 2 and 4 (some analyses of Henry and Guidotti, 1985 occur also in this field but the maximum Al- contents are not given). In spite of this the Ca-Fe(tot)-Mg diagram shows clearly the origin from the Ca-poor metapelites and metapsammites (Fig. 1, Tab. 1).

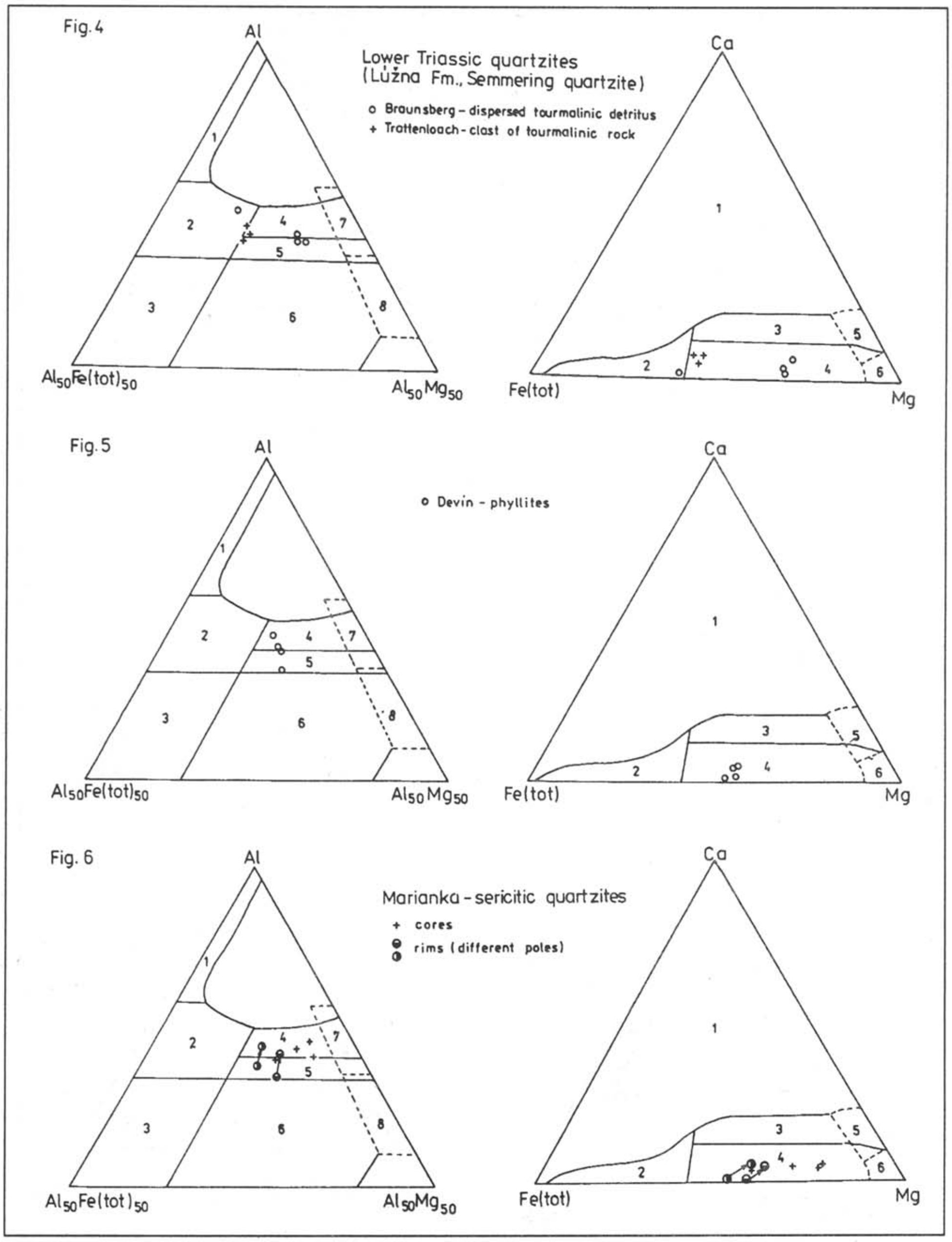


Fig. 1 - 6. Ternary diagrams exhibiting Al, Fe, Mg an Ca molecular proportions of the examined samples. Al-Fe(tot)-Mg diagram: 1 - Li-rich granitoid pegmatites and aplites, 2 - Li-poor granitoids and their associated pegmatites and aplites, 3 - Fe^{3+}-rich quartz-tourmaline rocks (hydrothermally altered granites), 4 - metapelites and metapsammites coexisting with an Al-saturating phase, 5 - metapelites and metapsammites not coexisting with an Al-saturating phase, 6 - Fe^{3+}-rich quartz-tourmaline rocks, calc-silicate rocks and metapelites, 7 - Low-Ca metaultramafics and Cr, V-rich metasediments, 8 - metacarbonates and metapyroxenites. Ca-Fe(tot)-Mg diagram: 1 - Li-rich granitoid pegmatites and aplites, 2 - Li-poor granitoids and associated pegmatites and aplites, 3 - Ca-rich metapelites, metapsammites and calc-silicate rocks, 4 - Ca-poor metapelites, metapsammites and quartz-tourmaline rock, 5 - metacarbonates, 6 - metaultramafics.

MKZ1 borehole - 197 m - the examined formation seems to be transitional one between Marianka and Korenec Formations (black shales with numerous sandy intercalations) - 3 rimed grains were analysed. The cores represent the detrital tourmaline grains on which the metamorphic rims developed later, during the metamorphosis. The majority of cores are of metamorphogenous origin but one came probably from granitoids as indicated by the Al-Fe(tot)-Mg diagram. The rims are concentrated in the field No.4 representing the metamorphites coexisting with Al-saturating phase. In the Ca-Fe(tot)-Mg diagram all the analyses fell into the field of Ca-poor metapelites and metapsammites (Fig. 2, Tab. 2).

MKZ1 borehole - 233 m - 3 discontinuously zoned grains were examined. All the cores come from Al- and Ca-poor metasediments (see diagrams). Two of the rims are concentrated in the field close to the rims in the previous sample which indicates the same source. The third one differs mainly by its Fe-contents (Fig. 2, Tab. 2).

Other Tatric units

Kuchyňa Unit - Ostrý vrch locality - 3 unzoned grains were analysed. They occur in the fields No. 4, 5 and 6 of the Al-Fe(tot)-Mg diagram and in the fields No. 3 and 4 of the Ca-Fe(tot)-Mg diagram. That indicates the origin of the whole scale of the metasediments together with quartz-tourmalinic rocks (Fig. 3, Tab. 2).

Kadlubek Unit - Kadlubek Hill locality - 2 unzoned grains were analysed. One coming probably from the Li-

Tab. 1 - 3

Representative analytical results of the detrital tourmalinic grains in the examined samples

Reprezentatívne analytické výsledky zo zŕn klastického turmalínu v skúmaných vzorkách

	Somár Fm.		Korenec Fm.				Marianka Fm.		
Grain No	1	2	3	4	5	6	7	8	9
Part									
B_2O_3	10,4651	10,41379	10,61396	10,317	10,763511	10,6369	10,506	10,8573271	10,94025
SiO_2	36,54	35,97	36,54	35,98	36,99	37,15	35,46	36,69	36,59
Al_2O_3	32,21	30,99	31,89	30,77	32,48	31,47	33,82	35,94	37,9
TiO_2	0,68	0,52	0,72	0,19	0,93	0,82	0,63	0,82	0,14
FeO	6,42	6,9	6,32	9,93	6	5,93	7,26	7,22	5,99
MgO	6,11	7,18	7,41	5,43	7,5	7,55	5,35	4,69	4,98
CaO	0,03	0,73	0,56	0,18	0,89	0,44	0,21	0,28	0,12
Na_2O	2,03	2,1	2,22	2,27	1,83	2,16	2,24	1,61	1,29
Sum	94,4851	94,80379	96,27396	95,067	97,383511	96,1569	95,476	98,1073271	97,95025

Structural formulas

B	3	3	3	3	3	3	3	3	3
Si	6,078147	6,012814	5,992905	6,07091	5,9824149	6,0798	5,87556	5,88262216	5,82212
Al-T	0	0	0,007095	0	0,0175851	0	0,12444	0,11737784	0,17788
Al-Z	6	6	6	6	6	6	6	6	6
Al-Y	0,310674	0,101565	0,153259	0,115084	0,169564	0,0661	0,47589	0,66971318	0,925095
Ti	0,084984	0,065308	0,088721	0,024086	0,1130056	0,10083	0,07843	0,09877836	0,016737
Fe	0,891851	0,963254	0,865646	1,399253	0,8103973	0,81047	1,00462	0,96675177	0,795976
Mg	1,513668	1,78751	1,80998	1,364518	1,8065095	1,8402	1,32023	1,11990933	1,180144
Y-total	2,801177	2,917637	2,917606	2,902942	2,8994763	2,81759	2,87917	2,85515264	2,917951
Ca	0,005342	0,130638	0,098326	0,032514	0,1540966	0,07709	0,03725	0,04806092	0,020441
Na	0,658469	0,684531	0,71	0,746887	0,5771384	0,68932	0,72376	0,50336826	0,400263
X-total	0,663811	0,81517	0,808326	0,779402	0,731235	0,76641	0,76101	0,55142919	0,420704

Tab.2

	MKZ1-197 m			MKZ1 - 233 m				Ostrý vrch
Grain No	10	11		12		13		14
Part		core	rim	core	rim	core	rim	
B_2O_3	10,47778	10,30151	10,98804	10,70383	10,574888	10,3139	10,3509	10,424687
SiO_2	35,25	33,55	36,83	36,25	35,97	34,96	34,78	35
Al_2O_3	33,11	34,21	35,72	31,81	32,98	30,95	31,67	32,97
TiO_2	0,8	0,97	0,58	0,76	0,08	0,57	0,7	0,95
FeO	6,13	9,59	5,58	5,17	2,79	8,71	6,29	5,17
MgO	6,65	4,14	6,99	9,15	9,45	6,52	7,58	7,04
CaO	0,78	0,5	0,28	0,89	0,06	0,56	0,74	0,67
Na_2O	1,63	1,48	1,88	2,16	2,3	2,37	2,02	1,75
Sum	94,82778	94,74151	98,84804	96,89383	94,204888	94,9539	94,1309	93,974687

Structural formulas

B	3	3	3	3	3	3	3	3
Si	5,856473	5,669408	5,834823	5,895421	5,9212148	5,90057	5,84919	5,84455146
Al-T	0,143527	0,330592	0,165177	0,093304	0,0787852	0,09943	0,15081	0,15544854
Al-Z	6	6	6	6	6	6	6	6
Al-Y	0,335631	0,478366	0,500123	0	0,3156677	0,05327	0,1225	0,32917021
Ti	0,09986	0,123152	0,069036	0,092864	0,0098943	0,07228	0,08845	0,1191877
Fe	0,850535	1,353376	0,738269	0,702186	0,3835563	1,22771	0,88343	0,72098831
Mg	1,645453	1,041915	1,649263	2,216229	2,3168023	1,63892	1,89855	1,75082435
Y-total	2,931479	2,996809	2,956692	3,011279	3,0259206	2,99218	2,99293	2,92017057
Ca	0,138734	0,090454	0,047489	0,154956	0,0105738	0,10119	0,13323	0,11977572
Na	0,528082	0,48769	0,580792	0,685011	0,7383035	0,78002	0,66245	0,56984652
X-total	0,666816	0,578143	0,628281	0,839966	0,7488773	0,88121	0,79568	0,68962224

Tab.3

	Kadlubek		Braunsberg		Trattenbach	Marianka-seric. quartzite			Devín		
Grain No.	15	16	17	18	19	20			21	22	23
Part						core	rim1-	rim1+			
B_2O_3	10,53066	10,7498	10,39308	10,44519	10,313640771	10,6322	10,3425	10,67968458	10,41249	10,45521	10,48326
SiO_2	36,11	35,73	35,99	36,59	35,25	36,45	35,13	37,44	36,32	36,15	35,47
Al_2O_3	34,79	33,81	32,87	31,17	31,98	32,47	29,77	31,68	31,14	31,48	30,61
TiO_2	0,25	0,63	0,69	0,82	0,39	0,49	0,98	0,33	0,45	0,65	1,16
FeO	8,71	4,49	9,67	5,65	9,75	8,02	8,95	9,51	8,32	8,29	9,2
MgO	3,68	8,56	3,66	7,06	4,6	6,53	7,3	5,92	6,01	5,75	6,76
CaO	0,04	0,38	0,22	0,51	0,72	0,7	1,09	0,05	0,18	0,62	0,86
Na_2O	1,57	2,52	1,64	1,99	2,04	1,69	1,95	2,41	2,38	2,36	2,36
Sum	95,68066	96,8698	95,13308	94,23519	95,043640771	96,9822	95,5125	98,01968458	95,21249	95,75521	96,90326
Structural formulas											
B	3	3	3	3	3	3	3	3	3	3	3
Si	5,969226	5,786005	6,028146	6,098068	5,9496755847	5,96786	5,91288	6,102721892	6,072077	6,018965	5,889941
Al-T	0,030774	0,213995	0	0	0,0503244153	0,03214	0	0	0	0	0
Al-Z	6	6	6	6	6	6	5,90176	6	6	6	5,986809
Al-Y	0,742946	0,234722	0,484611	0,118557	0,3073016709	0,22948	0	0,082124	0,131862	0,173487	0
Ti	0,03105	0,07665	0,086831	0,102676	0,0494565108	0,06028	0,12393	0,040413492	0,056523	0,081311	0,144721
Fe	1,202439	0,607221	1,352642	0,786381	1,3743372481	1,09661	1,25805	1,294561816	1,161634	1,152717	1,275828
Mg	0,905994	2,064459	0,912998	1,752352	1,1563219572	1,59229	1,82991	1,437130552	1,496417	1,425831	1,671796
Y-total	2,882429	2,983052	2,837082	2,759966	2,8874173869	2,97864	3,21189	2,85422986	2,846437	2,833347	3,092345
Ca	0,007079	0,065878	0,039449	0,090994	0,1301000594	0,1227	0,19641	0,008725063	0,032216	0,110514	0,152883
Na	0,506089	0,795762	0,535652	0,646725	0,6714304685	0,53957	0,64002	0,766022445	0,775899	0,766235	0,764185
X-total	0,513168	0,86164	0,575101	0,737719	0,8015305279	0,66226	0,83643	0,774747508	0,808115	0,876749	0,917068

The general formula of tourmaline is: $XY_3Z_6(BO_3)_3SiO_6O_{18}(OH)_4$, where Z is usually Al, which can occur also in Y site or in T site (substitution for Si). The most common substituents in Y site are Ti, Fe, Mn, Mg and Al; X site is occupied mostly by Ca, K and Na. B and OH- are indeterminable by a microprobe, can be estimated indirectly (after Henry and Guidotti, 1985).

Všeobecný vzorec turmalínu je: $XY_3Z_6(BO_3)_3SiO_6O_{18}(OH)_4$, kde Z býva zvyčajne Al, ktoré sa môže vyskytovať aj v pozícii Y alebo T (nahrádzanie Si). Obvyklé prvky v pozícii Y sú: Ti, Fe, Mn, Mg a Al; pozícia X býva obsadená najmä prvkami: Ca, K a Na. B a OH-, ktoré sú na mikrosonde neurčiteľné sa dajú nepriamo vypočítať (podľa Henry a Guidotti, 1985).

poor granitoids (similar to the recently outcropping Hercynian granitoids of the Malé Karpaty Mts.), the second one came from the Al-rich - Ca-poor metasediments (Fig. 3, Tab. 3).

Lower Triassic quartzites (Lúžna Formation, Semmering quartzite) - secondary possible source

Braunsberg Hill (Austria) - geological continuation of the Malé Karpaty Mts. - 4 unzoned grains were examined. Three of them are concentrated in the fields reserved for the metasediments; one grain came from the Li-poor granitoids (Fig. 4, Tab. 3).

Weinweg near Trattenbach (Austria) - 3 unzoned grains were analysed from the clast of tourmalinic rock from the Semmering Quartzite (Lower Triassic, part of Lower Austroalpine, Eastern Alps). The element ratios are concentrated in the fields of the metasediments but they occur nearby the field of the Li-poor granitoids (Fig. 4, Tab. 3). The granitoid source cannot be fully excluded since the location of the boundaries is only approximate.

Primary possible sources

Devín - castle hill - 4 unzoned tourmaline grains were examined from the chloritic phyllites. The ternary diagrams display almost stable proportions of the Fe, Mg and Ca, but the strong variations in Al contents are evident. Therefore in Al-Fe(tot)-Mg diagram the element ratios occur in the fields No. 4, 5 and 6 (Fig. 5, Tab. 3).

Marianka - large quarry - 2 bizonal and 2 simply zoned grains were analysed from the sericitic quartzites (metagreywackes to metaarcoses). Mutual relations of the zones fit well in all the grains though the zones are not always completely developed. The first rims reflect an increasing content of Fe, the second phase caused the increasing Al and Ca contents (notice the reversal core-rim relations if compared with the samples from MKZ1 borehole). The differences in the chemical composition of the opposite poles of tourmaline grains described by Henry and Dutrow (1992) are evident also in this sample (two parallel, mutually shifted arrows in Fig. 6). The clastic cores were originally also of metamorphogenous origin (Fig. 6, Tab. 3).

The tourmaline occurrences in the pre-Jurassic complexes of the Western Carpathians

Hercynian granitoids are relatively poor in the tourmaline content. Mišík (1955), Veselský (1972), Veselský and Gbelský (1978) found less than 1% in all samples from the granitoids of Malé Karpaty Mts. The

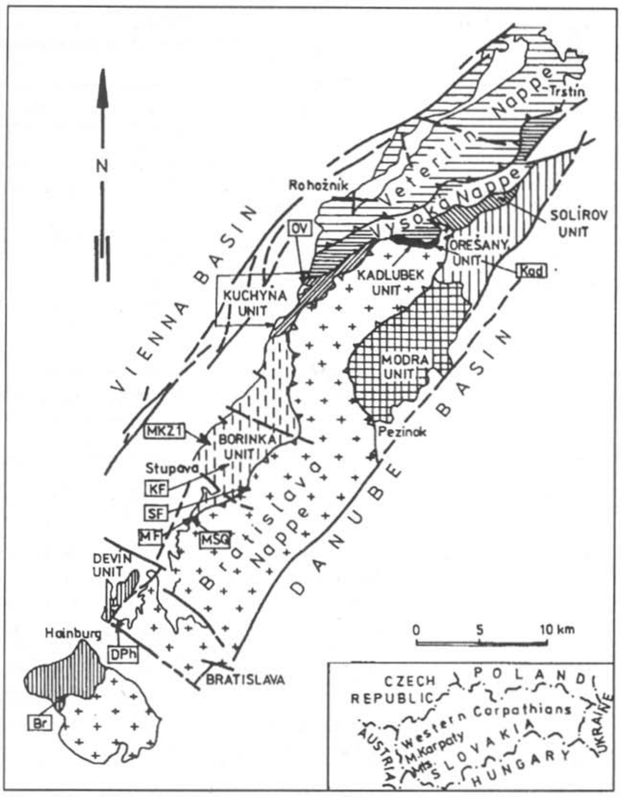


Fig. 7. Schematic map showing the sampling sites, KF - Korenec Formation, SF - Somár Formation, MF - Marianka Formation, MKZ1 - MKZ1 borehole, Br - Braunsberg Hill, DPh - Devín - castle hill - phyllites, MSQ - Marianka - sericitic quartzites (large quarry).

Obr. 7. Schematická mapka znázorňujúca miesta odberu vzoriek. KF - súvrstvie Korenca, SF - súvrstvie Somára, MF - mariatálske súvrstvie (bridlice), MKZ1 - vrt MKZ1, Br - Braunsberg, DPh - Devín - hradný vrch - fylity, MSQ - Marianka - sericitické kvarcity (veľký lom).

same introduced Hovorka and Hvožďara (1965) from 8 samples of the Veporic granitoids. They mentioned the tourmaline occurrences mainly in the mylonite zones. Hvožďara and Határ (1978) found no tourmaline in the examined samples from the Veporic granites. Hovorka (1968) mentioned only two occurrences of tourmaline (both under 1%) from 6 samples of Malá Magura, Malá Fatra and Tribeč Mts. Only one tourmaline occurrence was found by Miko and Határ (1976) in 6 examined samples from the Žiar Mts.

More frequent, but still in small amounts, are the tourmalines in the pegmatites of these granitoids. They were referred from Nízke Tatry Mts. by Turan (1961) and Valach (1954), from Žiar Mts. (Valach, 1954), from Malé Karpaty Mts. (Valach, 1954a) and from Malá Fatra Mts. (Ivanov and Kamenický, 1957). Pawlica (1914 - in Hovorka, 1972) brought two results of the chemical analyses of tourmaline grains from pegmatites from Vysoké Tatry Mts.

Late Hercynian to post-Hercynian granitoids (in Gemericum) are rich in tourmaline. Ončáková (1954) examined the granitoids from the localities Betliar, Hnilec, Súľová, Zlatá Idka, Poproč, Medzev, Železník and Turčok. She referred about tourmaline forming the considerable part of the heavy fraction in all the granites except the last two localities. Tourmaline reaches up to 97 % of heavy fraction (Gubač, 1977) and is not accessoric but rock-forming mineral. Gubač (l. c.) also introduced a chemical analysis of the tourmaline. The Al, Fe, Mg, Ca proportions place it to the field of Li-poor granitoid rocks. Gubač (l. c.) stated that the Li - content in the Gemerid granites is slightly increased if compared with average values in the granitoids, but it is not expressed in forming Li - minerals e.g. lepidolite or zinnwaldite. The tourmalinization in the granitoids was so strong, that also tourmalinites have been formed. J. Kamenický and L. Kamenický, 1955 mentioned the tourmaline occurring mainly in pneumatolitic most acid parts and within the contact with the surrounding rocks.

However, these granitoids play no role as the possible source of the clastic material in the Central Western Carpathians since the Gemeric area is supposed to belong to the different paleogeographical province in the Lower Jurassic. Tourmalines coming from these sources can be expected in the clastic admixture of the Silica and Meliata Units.

Metamorphosed rocks in the Western Carpathians have varying tourmaline contents sometimes depending on the grade of metamorphosis. The results of Broska and Janák (1985) can be taken as an example. They examined the profile in the Malé Karpaty Mts. crossing the main metamorphic zones. The tourmaline content decreases from 2,1 - 5,5 g/t in the chlorite and biotite-garnet zones to 0 - 0,5 g/t in the staurolite zone. On the other hand Veselský and Kovalská (1981) showed no relations between the grade of metamorphosis and the tourmaline content. However, the maximum content has been ascertained in the low-grade metamorphosed phyllites at Devín-castle (analyses also in this paper - chapter 4,4). Hovorka (in Bernard et al., 1981) mentioned a tourmaline occurrence connected with the quartz lenses in the mica-schists of Považský Inovec Mts. Hvožďara (1980), based on the heavy mineral contents in the recent stream sediments, considered the tourmaline as one of the very frequent heavy minerals in the Tatric and Veporic crystalline complexes.

In Veporicum already Zoubek (1928) mentioned some tourmaline occurrences in the retrogradely metamorphosed mica-schists while the absence of the tourmaline in the granites and gneisses was evident. He regarded the tourmaline as a product of diaphtoresis. Bouška et al. (1973) described in detail, together with chemical analyses, an occurrence of uvite from the talc deposit near Hnúšťa. Later Miko and Hovorka (1978) described the occurrences of tourmalinites and quartz-tourmalinic rocks in the relatively low-grade metamorphosed volcanoclastics from Jánov grúň crystalline complex.

In regards to the Gemericum, Gubač (1977) considered the tourmaline and apatite as the most frequent accessoric minerals in the phyllites of Gelnica and Rakovec groups which form the main part of Gemericum. The strong tourmaline influx, which can also have a regional significance in this area, came from the hydrothermal mineralization. These tourmalines differ from the metamorphogenous ones mainly by its bigger size.

Permian sediments and volcanites were not examined in detail with regard to their tourmaline contents. From the work of Vozárová and Vozár (1988) results, that the tourmaline is one of the most frequent heavy minerals in these formations throughout the Western Carpathians. It occurs in form of clastic admixture or it was originated directly in the Permian complex. Vozárová (1966) mentioned the clasts of tourmalinites in the Permian of the Ľubietová zone in Veporicum. They came probably from the later discovered rocks in Jánov grúň complex mentioned above (Miko and Hovorka, 1978). Pták (1956) described strong tourmalinization that took place in the Permian metaarcoses in the zone between Gemericum and Veporicum. Its lack in the surrounding orthogneisses is noteworthy; the occurrences found in these rocks were always related to the hydrothermal activity.

Triassic complexes in the Western Carpathians are relatively poor in the silicate minerals. Tourmaline can be found in the siliciclastic formations i.e. Lúžna Formation (Mišík and Jablonský, 1978), Carpathian Keuper facies (Al-Juboury, 1992) and in the Lunz Beds (Michalík et al., 1992) as their detrital component, or as an authigenous admixture in the Triassic gypsum and anhydrite deposits (Mišík, 1962). Tourmalines of the first mentioned formation were examined in chapter 4.3. However, the Lower Triassic quartzites contain predominantly zircon which is not reflected in the zircon/tourmaline ratios in the Lower Jurassic. Also the zircon grains of the specific oval shape rounded by aeolian processes, frequent in the Lower Triassic, are missing in the Lower Jurassic (Aubrecht, in press). Carpathian Keuper absents in the many places in the Tatricum due to the erosion during the Lower Jurassic. However the recently known heavy mineral proportions from this formation (Al-Juboury, l. c.) show mainly the predominance of zircon and lack of apatite. In the Lunz Beds the tourmaline is only the fourth one in the heavy mineral contents after apatite, zircon and garnet (Michalík et al., 1992; Behrens, 1972). Thus the complete resedimentation of the tourmaline in the Lower Jurassic sediments from the mentioned formations is improbable.

Conclusions

1. The majority of the tourmaline in the Lower Jurassic sediments of the Malé Karpaty Tatric Units was evidently derived from the low-grade metamorphosed rocks. An absence of the garnet in the heavy mineral assemblages of the Lower Jurassic excludes the higher grades of metamorphism in the source rocks. The explanation of the lack of garnet by the intrastratal dissolution is improbable since its absence is evident in all the Tatric units of the Western Carpathians. In the Lower Jurassic of the Pienidic units (Klippen Belt), for instance, the garnet occurs in huge amounts. The absence or presence of the garnet indicates the different heavy mineral provinces.

2. The source of tourmaline was most probably formed by the sericitic phyllites occurring frequently in the detrital admixture of the Somár Formation as indicated already by Aubrecht (in press). These were continually eroded untill the higher-grade metamorphites were denuded. Garnet appears in the vicinity of Malé Karpaty Mts. much later, in the Paleogene sediments (Salaj and Priechodská, 1987).

3. Primary source of tourmaline was not discovered yet. The samples taken as a possible source-rocks are not suitable though they also contain metamorphogenous tourmaline. Phyllites from Devín contain predominantly garnet, which absents in the Lower Jurassic. The sericitic quartzites near Marianka belong to the group of the most probable sources, but they contain polyphase metamorphic zonation almost reverse to that one found in the MKZ1 borehole samples. The granites were primarily excluded to be the main source for the expressive lack of tourmaline. However the presence of the tourmaline coming from the granitoids in the Kadlubek Unit such as in the Lower Triassic quartzites suggests some possible from this source (if not resedimented from the older formations).

The comparison with some analyses of tourmaline from the Köszeg-Rechnitz Penninic tectonic window (Demény, 1988) indicates a similar chemical composition also with the reverse zonation to those found in the MKZ1 borehole. Borinka Unit is also considered to be a part of the South Penninic zone (Plašienka et al., 1991).

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Pôvod klastického turmalínu v liasových sedimentoch Malých Karpát

Analýzou spoločenstiev ťažkých minerálov v jure rôznych jednotiek tatrika Malých Karpát, ale aj iných jadrových pohorí sa zistilo bohaté zastúpenie turmalínu. Podľa doterajších údajov je turmalín v podložnom kryštaliniku pomerne vzácny a v kryštaliniku centrálnych Západných Karpát vzácny vôbec, a preto sa vynorila otázka pôvodu klastického turmalínu v skúmaných asociáciách. Na jej vyriešenie sa použili mikrosondové analýzy a ich výsledky sa interpretovali pomocou diferenčných diagramov práce Henryho a Guidottiho (1985). Analyzoval sa turmalín z piatich vzoriek z borinskej jednotky a po jednej vzorke z kuchynskej jednotky a jednotky Kadlubka. Ako porovnávací materiál možného klastického zdroja sa analyzoval turmalín z fylitov z devínskeho hradného vrchu, zo sericitického kremenca a metaarkóz v Mariánke (mariánske súvrstvie), zo spodnotriasového kremenca na Braunsbergu (Rakúsko, pokračovanie Malých Karpát) a z exotického klastu turmalínickej horniny z analogického kremenca od Trattenbachu (Rakúsko, Unterostalpin). Vo vzorkách z jurských sedimentov takmer všetky analyzované zrná spadajú do poľa metamorfovaných hornín. Jediné zrno spadajúce do poľa granitoidov bolo identifikované v jednotke Kadlubka (zrno z vrtu MKZ1, 197 m, má neskorší metamorfný lem). Uvedené fakty poukazujú na to, že väčšia časť turmalínu bola pravdepodobne derivovaná z kryštalinika budovaného metamorfitmi. Pre veľmi malé zastúpenie granátu vo vzorkách predpokladáme nižší stupeň metamorfózy. Chýbanie granátu sa potvrdilo vo všetkých doteraz skúmaných jurských sedimentoch tatrika Západných Karpát, čo dokazuje, že ho pravdepodobne neodstránilo len intrastratálne rozpúšťanie a že ide o samostatnú provinciu ťažkých minerálov, odlišnú napríklad od pienidných jednotiek Západných Karpát.

Zo skúmaného porovnávacieho materiálu ako možný zdroj turmalínu plne nevyhovuje ani jedna vzorka.

1. Turmalín z fylitov z devínskej hradnej skaly je homogénny a chemicky spadá do poľa metamorfitov. Ale dominantný obsah granátu vo fylitoch (Veselský a Kovalská, 1981) je v protiklade s obsahom granátu v jurských sedimentoch.

2. V sericitických kremencoch a metaarkózach od Marianky sa vyskytuje turmalín s viacnásobnou zonálnosťou, aká sa nezaznamenala pri detritickom turmalíne. Navyše metamorfný lem zistený na turmalíne vo vrte MKZ1 sa vyznačujú úplne opačným trendom chemizmu.

3. Turmalín zo spodnotriasového kremenca (lúžňanské súvrstvie) bol derivovaný z metamorfitov aj z granitu. Skúmaný exotický klast turmalínickej horniny spadá na hranicu polí metamorfitu a granitu (v rámci prekryvu chemizmov). Pravdepodobne bol derivovaný z kontaktnometasomaticky premenenej aureoly granitu.

Pôvod väčšiny detritického turmalínu v jurských vzorkách treba pravdepodobne hľadať v nízkometamorfovaných horninách charakteru sericiticko-chloritických fylitov, ktoré už vo väčšine malokarpatského kryštalinika odstránila erózia, ale zachovali sa napríklad ako klasty v spodnejších častiach brekcií Somára (lom pri Medených Hámroch).