Exotic pyrope–almandine garnets in the Lukáčovce Mb. (Quaternary)

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Abstract: The Lukáčovce Mb. presents sediments of the alluvial fan formed by braided river(s) in areas of the Nitrianska pahorkatina Upland and of the Trnavská pahorkatina Upland. Detritic garnets were separated in fraction from 0.25 down to 0.10 mm and analysed by microprobe. Acquired results were compared with other analyses of garnets from various Slovak rock types. In the Lukáčovce Mb. occur four types of garnets: 1) Almandine and almandine-spessartite garnets derived mainly from paragneisses, in tributary sources maybe from pegmatites; 2) Almandine-spessartite-grossular garnets came from rocks with low-grade metamorphosis (mica schists; eventually phyllites); 3) Almandine-grossular-pyrope garnets which are following trend of mica schists, volcanites, amphibolites and amphibolized eclogites. 4) The last type are pyrope-almandine garnets with content of pyrope molecules from 27 % to 45 %. Composition of the first three garnet types suggests the source area formed by the crystalline complex of the Považský Inovec Mts. and neovolcanites. This source responses to results of petrographic analyses of gravels and also to analyses of heavy minerals. The primary source of pyrope-almandine garnets was not described in Slovakia until now. Similar garnets were analysed so far only as detrital grains in Jurassic carbonates of the Klippen Belt and of Central Carpathians (Aubrecht and Méres; 2000).

Key words: garnet, Lukáčovce Mb., alluvial fan

Introduction

Analysed garnets are component of heavy fraction in the Lukáčovce Mb. The Lukáčovce Mb. was formed in the area of the Nitrianska pahorkatina Upland and of the Trnavská pahorkatina Upland from of Upper Pliocene till Mindel (Fig. 1), during hot and dry climate with some periods of intensive rainfalls (Šarinová, 2004). They were deposited in form of alluvial fan caused by braided river(s). Within their grain size composition it is possible to detach weaker sorted, lesser mineral matured sands (sulitharenites) with content of gravel above 17 %; and better sorted, mineral more matured sands (subarkose) with content of gravel up to 5 % (sorting = 0.65 to 3.7 φ; Mz = -0.6 to 3.7 φ). Gravels fillings of river channels are sporadic. Within heavy fraction there are present limonite, ilmenite, hematite, magnetite, tourmaline, garnet, staurolite, zircon, rutile, epidote and in accessory amounts also sillimanite, kyanite, monazite and cromite. In fillings of riverbeds is present gold too. Clay fraction includes clastic quartz, kaolinite, illite and smectite ± goethite. Clasts of gravel size are composed by lower Triassic sandstones, glauconitic sandstones, quartz, organogenic and volcanogenic silicites and in smaller amount by granitoids and freshwater sandy limestones. There are present Fe–Mn concretions with peas size and secondary Ca–concretions too. Petrographic composition of gravels and heavy fraction is suggested having source in crystalline complex of the Považský Inovec Mts. Secondary sources consist of Neogene filling of basins. A part of material is derived from neovolcanites (rutiles with inclusions of trachydacite, basanite to the basalts composition melt, silicified volcanic glass with magmatic corroded quartz or with post lamellar crystals pseudomorphs), namely straight from neovolcanites alternatively they are redeposits from Neogene fillings of the basins.

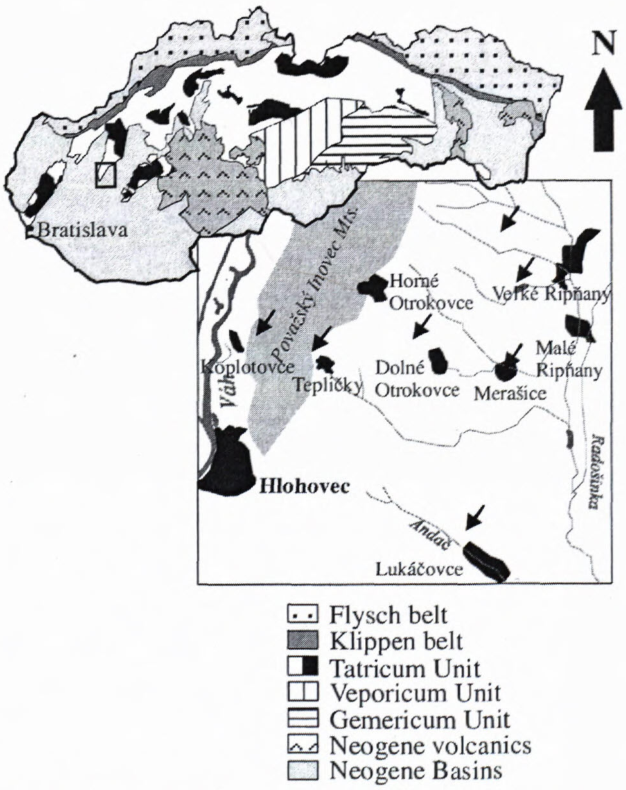

Fig. 1. Map of studied area (arrows – localities of the Lukáčovce Mb.).

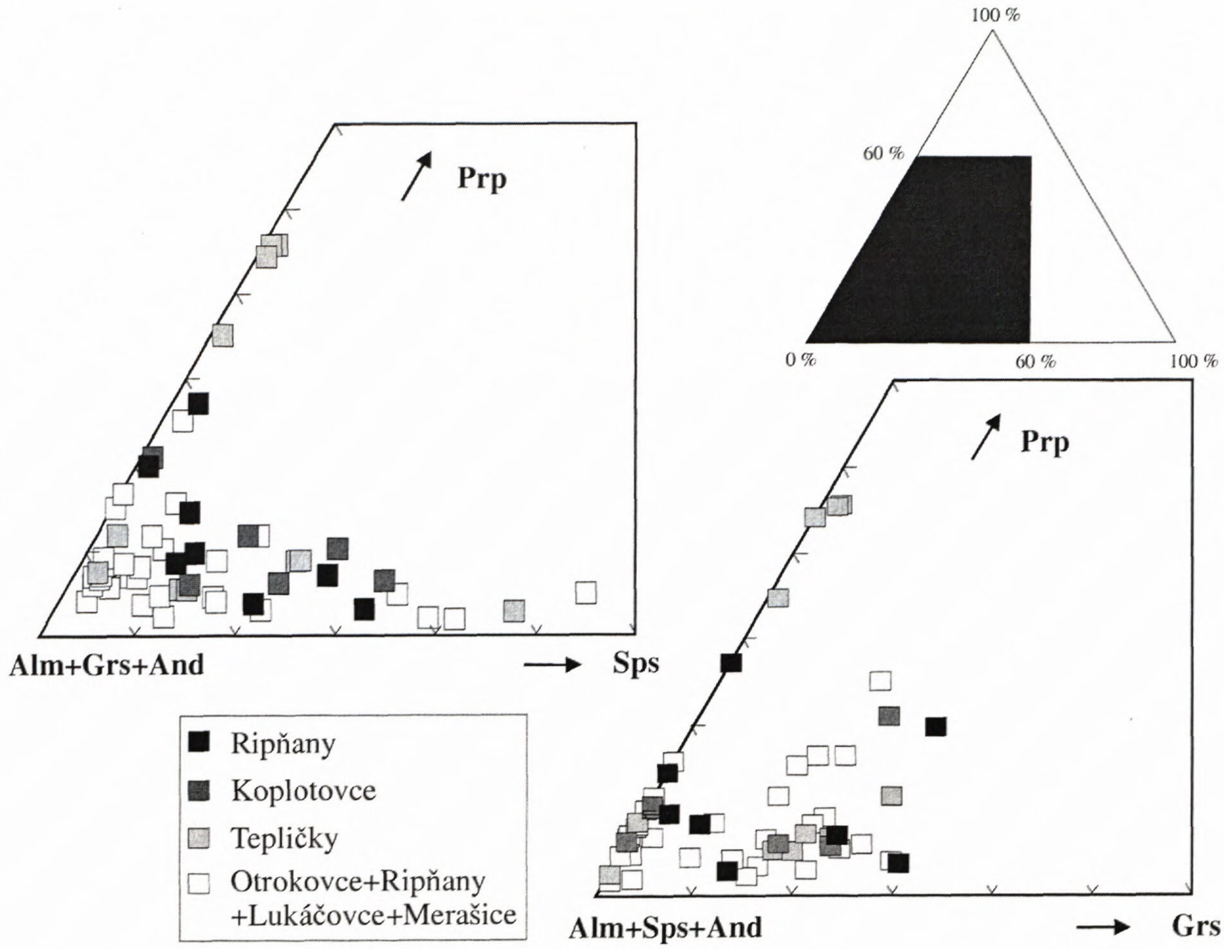

Fig. 2. Distribution of garnets in studied localities (Alm – almandine, Sps – spessartite, Grs – grossular, Prp - pyrope, And – andradite).

This work aims to determine the source rocks by crystallochemical composition of garnets, and mainly to determine the source of exotic pyrope–almandine garnets with content of pyrope molecule over 30 %.

Share of garnet in the heavy fraction is moved from 2 up to 4 %; mainly in coarse-grained samples the garnet fraction is increased (from 8 up to 13 %). Grains are often angular, without optical zonality. Pink coloured garnets were dominant.

Method

There were analysed 43 detritic garnets corresponding to fraction 0.25–0.10 mm. Chemical composition of garnets was determined by the instruments CAMECA SX 100 and HITACHI S – 4700. A portion of garnets was point-wise analysed (core - rim). Separate analysis was performed on garnets from localities Tepličky, Ripňany nad priehradou and Koplotovce. Garnets from localities Lukáčovce, Merašice, Otrokovce and Ripňany nová piesočnica were analysed together (Fig. 2). Total number of analyses was 57. Obtained analyses were re-counted to the base of 8 cations. For identification of the source rocks of garnets there were used 420 published and unpublished analyses of garnets from various Slovak rocks, elaborated by different authors, which were calculated in the identical way.

Results

All garnets were splitted into four types on the basis of predominating molecules (Tab. 1; Fig. 3a; Prp – pyrope, Alm – almandine, Sps – spessartite, Grs – grossular, And – andradite). Point-wise analyses (core - rim) within the scope of a grain suggested to very small chemical changes in the garnet grain center – rim composition (Fig. 3b, Tab. 2).

First garnet type: Formed by almandine and almandine-spessartite garnets (Alm 68–85 %; Sps 2–52 %), with content of pyrope molecules 2–14 %. Content of grossular molecule varies from 0 to 2 %. This garnets type had the biggest share (38.8 % of analyses); and it was found in all localities.

Second garnet type: Created by grossular – spessartite – almandine garnets (Alm 51–73 %, Sps 8–31 %, Grs 7–32 %), with content of pyrope and andradite molecules from 3 up to 7 %. This garnets type had represented 24.56 % of all analyses, and it was found in all localities.

Third garnet type: Consisting of garnets of pyrope – grossular – almandine composition (Alm 52–65 %, Grs 14–27 %, Prp 5–25 %), with content of spessartite and andradite molecules up to 5 %. These garnets formed 28.07 % of all analyses. It is possible to divide third garnet type into two separate groups. *First group* of garnets has affinity toward the garnets of second type. Into

Tab. 1. Selected representative analyses garnets of the Lukáčovce Mb. (calculated by 8 cations; CAMECA SX-100.)

garnet	type 1		type 2		type 3		type 4	
sample	LV-2	LV-5	R-8	K-4	K-5	T-3a	T-4a	T-6
SiO_2	36.93	36.21	37.55	37.31	38.86	36.00	39.23	37.64
TiO_2	0.06	0.06	0.16	0.08	0.11	0.09	0.03	0.00
Al_2O_3	20.86	20.48	20.97	20.98	21.74	19.82	21.99	21.42
Cr_2O_3	0.00	0.00	0.00	0.00	0.02	0.02	0.04	0.04
FeO	38.51	19.45	20.75	25.43	27.26	30.87	24.07	28.31
MnO	1.94	22.84	11.39	9.49	0.46	1.00	0.47	0.49
MgO	2.05	1.16	1.80	1.51	5.48	1.78	12.05	8.93
CaO	0.48	0.19	8.26	6.43	7.61	8.73	1.54	1.35
Na_2O	-	-	-	-	-	0.00	0.02	0.03
Total	*100.83*	*100.39*	*100.88*	*101.230*	*101.54*	*98.30*	*99.43*	*98.22*
Si	2.985	2.958	2.977	2.969	2.987	2.935	2.979	2.958
Al T	0.015	0.042	0.023	0.031	0.013	0.065	0.021	0.042
ΣT	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*
AL Y	1.972	1.929	1.936	1.936	1.956	1.840	1.947	1.942
Ti	0.004	0.004	0.010	0.005	0.006	0.005	0.002	0.000
Cr	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003
Fe Y	0.024	0.067	0.055	0.059	0.037	0.153	0.049	0.056
ΣY	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*
Fe X	2.579	1.262	1.321	1.633	1.716	1.952	1.479	1.805
Mg	0.247	0.141	0.213	0.179	0.628	0.217	1.364	1.046
Mn	0.133	1.580	0.765	0.640	0.030	0.069	0.030	0.033
Ca+Na	0.042	0.017	0.702	0.548	0.627	0.763	0.127	0.116
ΣX	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*
prp	8.234	4.709	7.091	5.970	20.929	7.229	45.465	34.873
sps	4.427	52.675	25.492	21.319	0.998	2.298	1.012	1.092
alm	85.954	42.062	44.032	54.438	57.184	65.051	49.305	60.155
grs	0.163	0.000	20.652	15.319	18.997	17.679	1.657	0.965
and	1.222	0.554	2.734	2.954	1.831	7.669	2.453	2.788
uvr	0.000	0.000	0.000	0.000	0.061	0.074	0.108	0.127

this group belong garnets with lower content of pyrope molecules (below 10 %). *Second group* formed garnets with pyrope over 10 %.

Fourth garnet type: The last, fourth garnet type is created by mentioned exotic pyrope–almandine garnets (Alm 49–66 %, Prp 27–45 %; other molecules up to 2 %). This type of garnets covered only 8.77 % from analyses; and so far such garnets were analysed only from localities Tepličky and Ripňany nad priehradou.

Discussion

Composition of garnets of *first type* (almandine and almandine-spessartite garnets) corresponds mainly to analyses of paragneisses garnets (Fig. 4), especially to the garnets from paragneisses originated at temperatures from 450 up to 600 °C (biotitic, biotite-sillimanite and staurolite paragneisses from the Považský Inovec Mts., Tríbeč Mts., Suchý Mts., Malá Magura Mts., Malé Karpaty Mts., Spišsko-gemerské rudohorie Mts.; Dyda, 1981, 1990, 2002; Hovorka et al., 1987; Méres and Hovorka, 1989; Faryad, 1996; Zaťko and Broska, 1996; Vozárová – unpublished). These garnets do not overlap with analyses from higher temperature paragneisses (650 –700 °C; Branisko Mts., Malá Fatra Mts.; Hovorka et al., 1987; Méres and Hovorka, 1989; Faryad, 1995; Vozárová and Faryad, 1997). They are corresponding fairly with the composition of garnets from paragneisses of the Považský Inovec Mts. and Tríbeč Mts. (Fig. 5; Zaťko and Broska, 1956; Vozárová - unpublished). One part of garnets is overlapping with analyses of garnets from pegmatites, too (Fig. 6; Malé Karpaty Mts. – Dávidová, 1968) and neovolcanites - andesites (Fig. 6; Zorkovský, 1956 in Kaličiak et al., 1988; Harangi et al., 2001).

Composition of garnets of *second type* (grossular – spessartite – almandine garnets) is similar mainly as garnets from mica schist and phyllites (Veporicum – Vozárová, unpublished), what suggests their origin in the metamorphic rocks of lower grade – mica schist of the Považský Inovec Mts. (Fig. 7). Amphibolites also reach the field of second garnet type occurrence, but only marginally (Fig. 8), particularly garnets from leptynite–amphibolite complex of the Tríbeč Mts. (Fig. 5; Hovorka and Méres, 1990).

Third garnet type (pyrope – grossular – almandine): *First group* with lower content of pyrope molecules (below 10 %), has originated from lower metamorphosed rocks (mica schist and phyllites – Fig. 7) following comparison. *Second group,* garnets (with pyrope over 10 %) resemble mainly garnets from amphibolites, amphibolized eclogites and neovolcanites (Figs. 6 and 8). Garnets with content of pyrope molecules from 10 up to 15 % respond to garnets from neovolcanites – andesites in composition (Fig. 6; Veľký Šariš – Zorkovský, 1956 in Kaličiak et al., 1988; Visegrád Mts., Börzsöny, Central Slovakian Volcanic Field - Harangi et al., 2002) and also to garnets from amphibolites of Branisko Mts., Spišsko-Gemerské rudohorie Mts., Malá Fatra Mts., which were metamorphosed at lower temperatures (490–650 °C at 5 kBar – Spišiak and Hovorka, 1985; Hovorka et al., 1992; Faryad, 1995; Vozárová, Faryad, 1997; Fig. 8). Garnets with content of pyrope molecules from 17 up to 22 % correspond to garnets from metabasites of Branisko Mts. (Faryad, 1996; Méres et al., 2000), which were metamorphosed in eclogite facies (600–770 °C, 8–10 kBar) with subsequently retrograde metamorphosis under conditions of amphibolites facies (Fig. 8). Therefore, we can consider mica schists of Považský Inovec Mts., neovolcanites and eventually amphibolites of the Považský Inovec Mts. and Tribeč Mts. to be the source of the third type garnets. None analyses of garnets with content of pyrope molecules above 17 %, which would correspond to amphibolized eclogites, I was able to obtain/found from the Považský Inovec Mts. or Tríbeč Mts.

Exotic pyrope–almandine garnets of *fourth type* from the Lukáčovce Mb. are by their lower bound touched to paragneisses composition from Branisko Mts. and Malá Fatra Mts., what were originated from rocks metamorphosed at temperatures from 700 up to 730°C and under pressure of 7–8 kBar (Faryad, 1996). However, content of pyrope molecules from 30 to 45 % (locality Tepličky)

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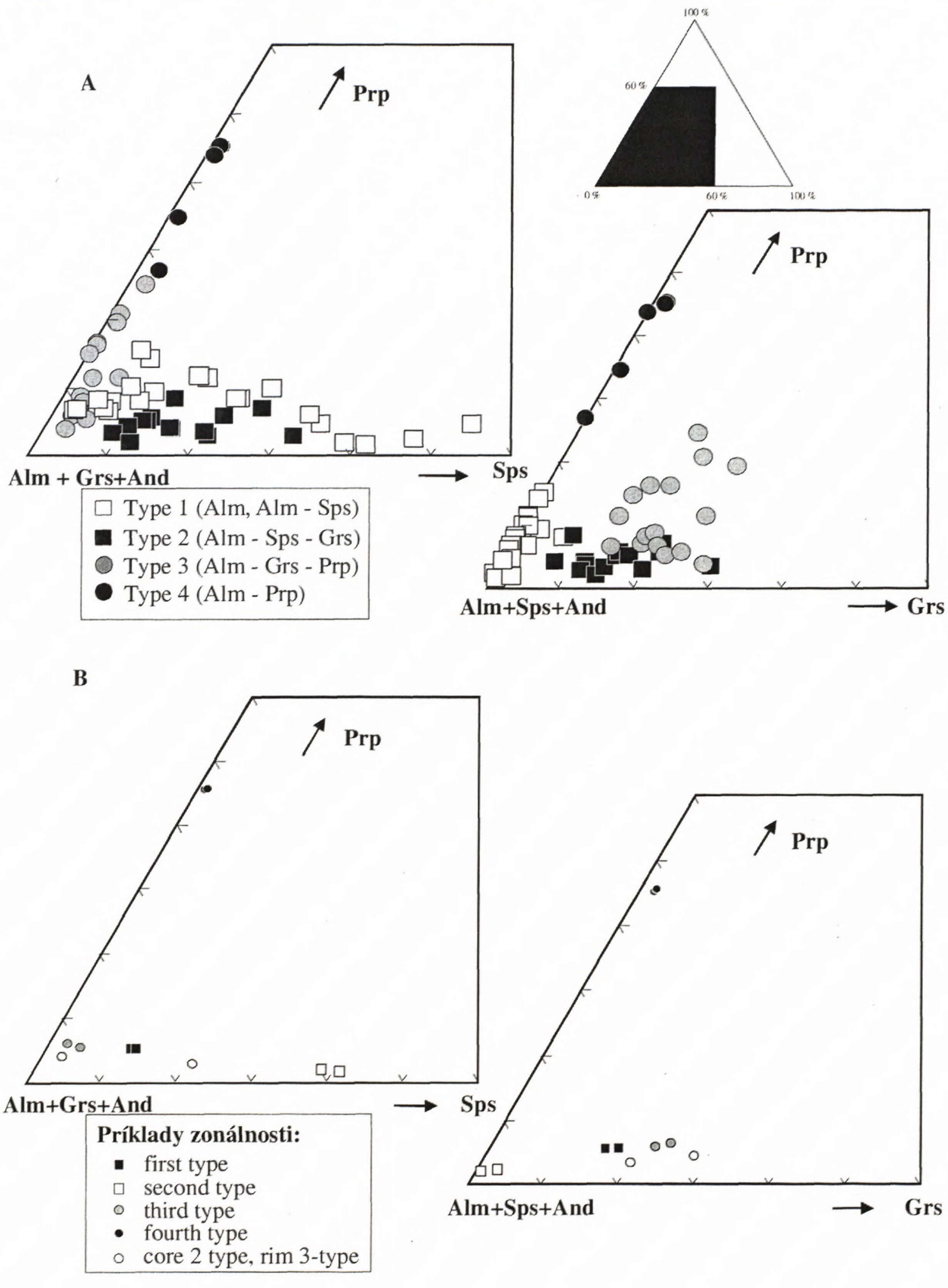

Fig. 3A. Distribution of garnets of the Lukáčovce Mb. on base of their chemical composition. B – Samples of chemical zonality which occurred in particular types of garnets (Alm – almandine, Sps – spessartite, Grs – grossular, Prp – pyrope, And – andradite).

*Tab. 2. Samples of chemical zoning of the garnets of the Lukáčovce Mb. (Fig. 3 b; A - center, B - rim; calculated by 8 cations; CAMECA SX-100, *HITASCHI S-4700.)*

Garnet	Type 1		Type 2		Type 3		Type 4		Max. zonal garnet	
Sample	pl 4a*	pl 4b*	T-1a	T-1b	pl 10a*	pl 10b*	T-4a	T-4b	pl 5a*	pl 5b*
SiO_2	35.30	34.50	36.46	37.21	35.96	36.05	39.23	39.39	35.90	36.96
TiO_2	0.15	0.23	0.12	0.11	0.13	0.00	0.03	0.00	0.08	0.08
Al_2O_3	18.09	18.51	19.91	20.13	19.45	19.86	21.99	21.90	19.62	19.62
Cr_2O_3	0.00	0.14	0.02	0.03	0.10	0.00	0.04	0.07	0.00	0.00
FeO	22.80	22.36	28.74	28.70	28.62	28.86	24.07	23.91	23.66	27.47
MnO	16.04	17.18	5.30	5.08	1.94	1.07	0.47	0.55	8.88	1.21
MgO	0.49	0.44	1.31	1.34	1.33	1.45	12.05	12.07	0.74	0.95
CaO	4.58	4.14	7.35	7.42	9.29	9.48	1.54	1.51	8.49	10.91
Na2O	-	-	0.02	0.02	-	-	0.02	0.02	-	-
Total	*97.45*	*97.50*	*99.24*	*100.03*	*96.82*	*96.77*	*99.43*	*99.41*	*97.37*	*97.20*
Si	2.972	2.907	2.964	2.997	2.979	2.979	2.979	2.991	2.973	3.040
Al T	0.028	0.093	0.036	0.003	0.021	0.021	0.021	0.009	0.027	0.000
ΣT	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.040*
AL Y	1.767	1.745	1.872	1.908	1.878	1.913	1.947	1.951	1.888	1.902
Ti	0.010	0.015	0.007	0.006	0.008	0.000	0.002	0.000	0.005	0.005
Cr	0.000	0.009	0.001	0.002	0.007	0.000	0.002	0.004	0.000	0.000
Fe Y	0.224	0.231	0.120	0.083	0.108	0.087	0.049	0.045	0.107	0.093
ΣY	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*
Fe X	1.382	1.345	1.834	1.851	1.875	1.907	1.479	1.474	1.532	1.797
Mg	0.061	0.055	0.158	0.161	0.164	0.179	1.364	1.366	0.091	0.117
Mn	1.144	1.226	0.365	0.347	0.136	0.075	0.030	0.035	0.623	0.084
Ca+Na	0.413	0.374	0.642	0.642	0.825	0.839	0.127	0.125	0.753	0.962
ΣX	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*3.000*	*2.960*
prp	2.050	1.842	5.280	5.353	5.475	5.954	45.465	45.549	3.046	3.937
sps	38.126	40.871	12.164	11.564	4.537	2.496	1.012	1.171	20.765	2.849
alm	46.053	44.827	61.148	61.688	62.503	63.573	49.305	49.127	51.076	60.722
grs	2.585	0.449	15.348	17.134	21.776	23.619	1.657	1.718	19.787	27.789
and	11.186	11.543	5.986	4.158	5.382	4.357	2.453	2.228	5.327	4.704
uvr	0.000	0.466	0.074	0.102	0.327	0.000	0.108	0.207	0.000	0.000

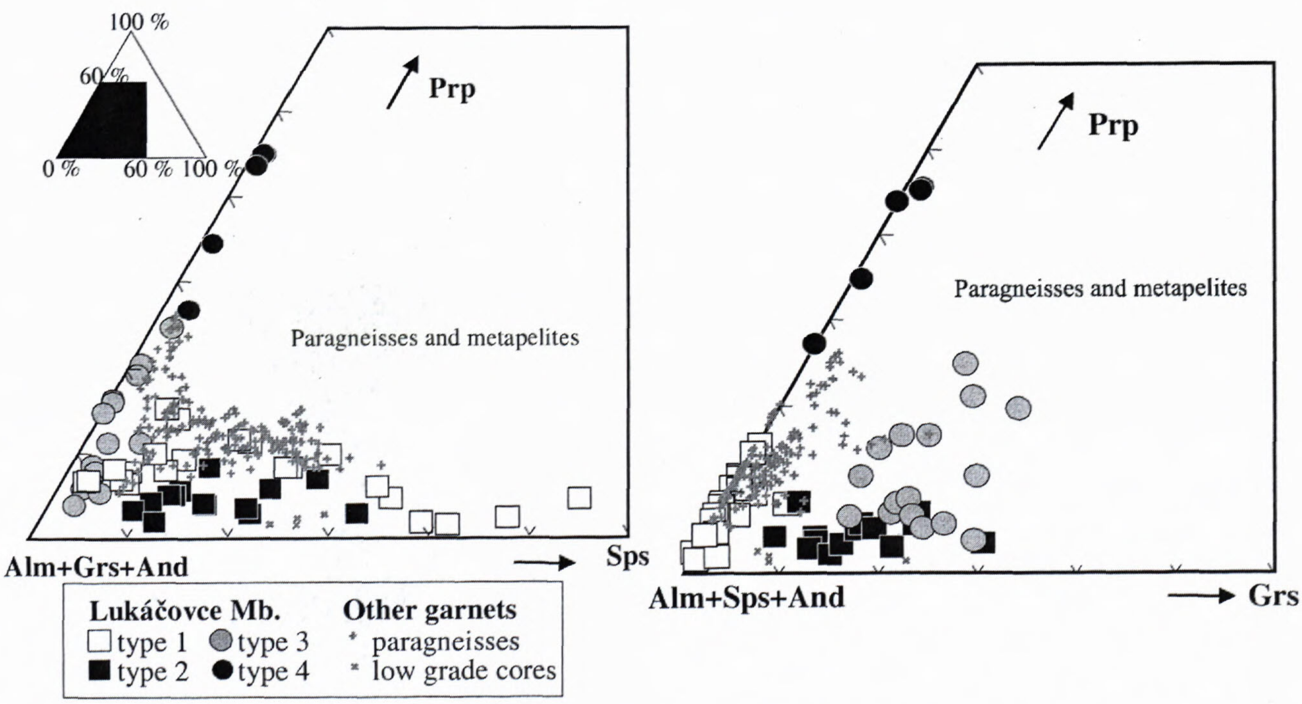

Fig. 4. Comparison of garnets of the Lukáčovce Mb. and garnets from metapsammites and paragneisses (comparative analyses – Dyda, 1981, 1990, 2002; Hovorka et al., 1987; Méres and Hovorka, 1989; Faryad, 1990, 1995, 1996; Vozárová and Faryad, 1997; Vozárová – unpublished).

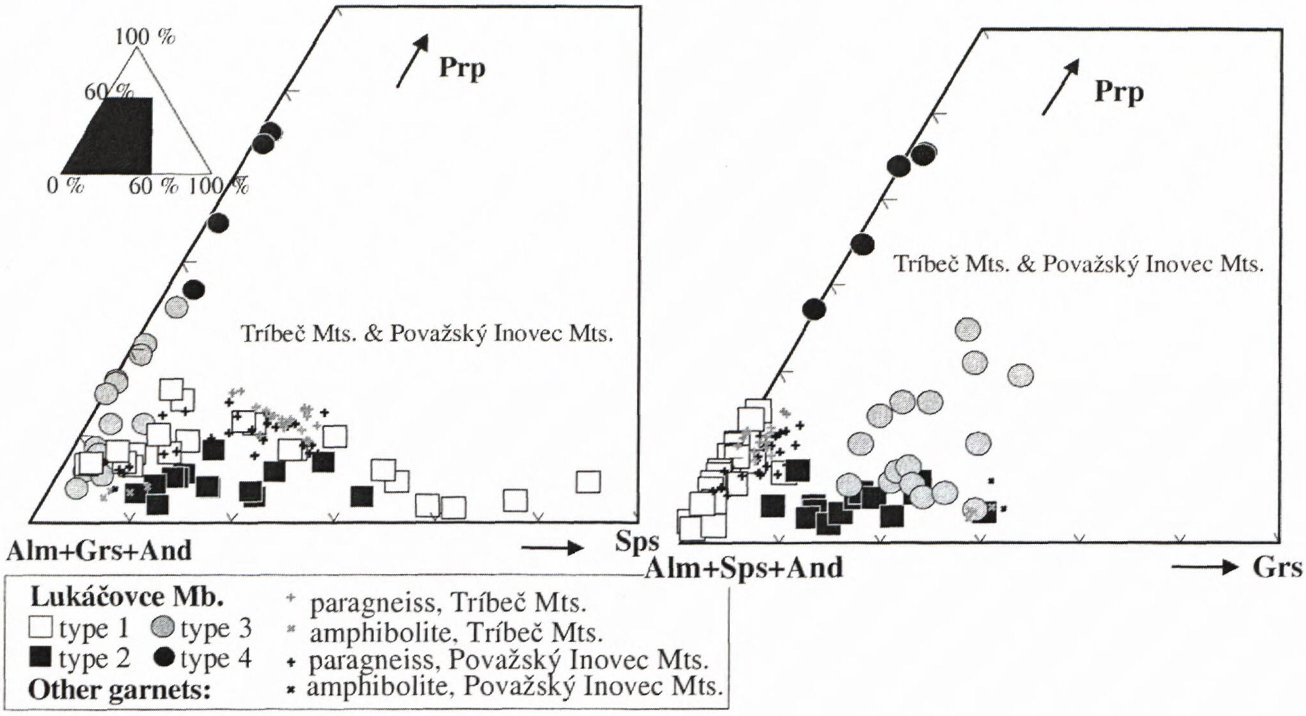

Fig. 5. Comparison of garnets of the Lukáčovce Mb. and garnets from crystalline complex of the Považský Inovec Mts. and Tribeč Mts. (analyses of garnets from mountains – Hovorka and Méres, 1990; Zaťko and Broska, 1996; Olšavský and Demko, 2005; Vozárová – unpublished).

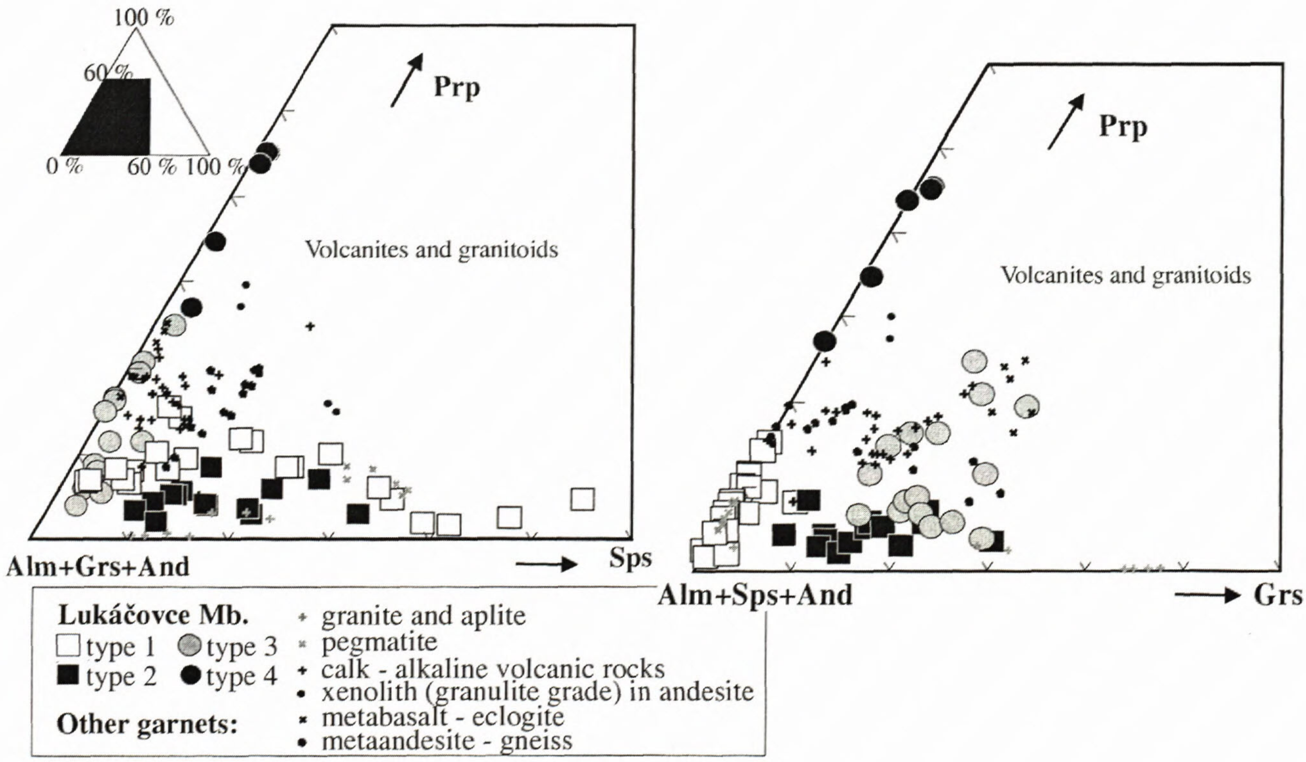

Fig. 6. Comparison of garnets of the Lukáčovce Mb. and garnets from neovolcanites and granitoids (analyses of garnets from granitoids – Dávidová, 1968; Petrík et al., 1995; analyses of garnets from neovolcanites – Zorkovský, 1956 in Kaličiak et al., 1988; Harangi et al., 2001; from metavolcanites: Faryad, 1990; Méres et al., 2000).

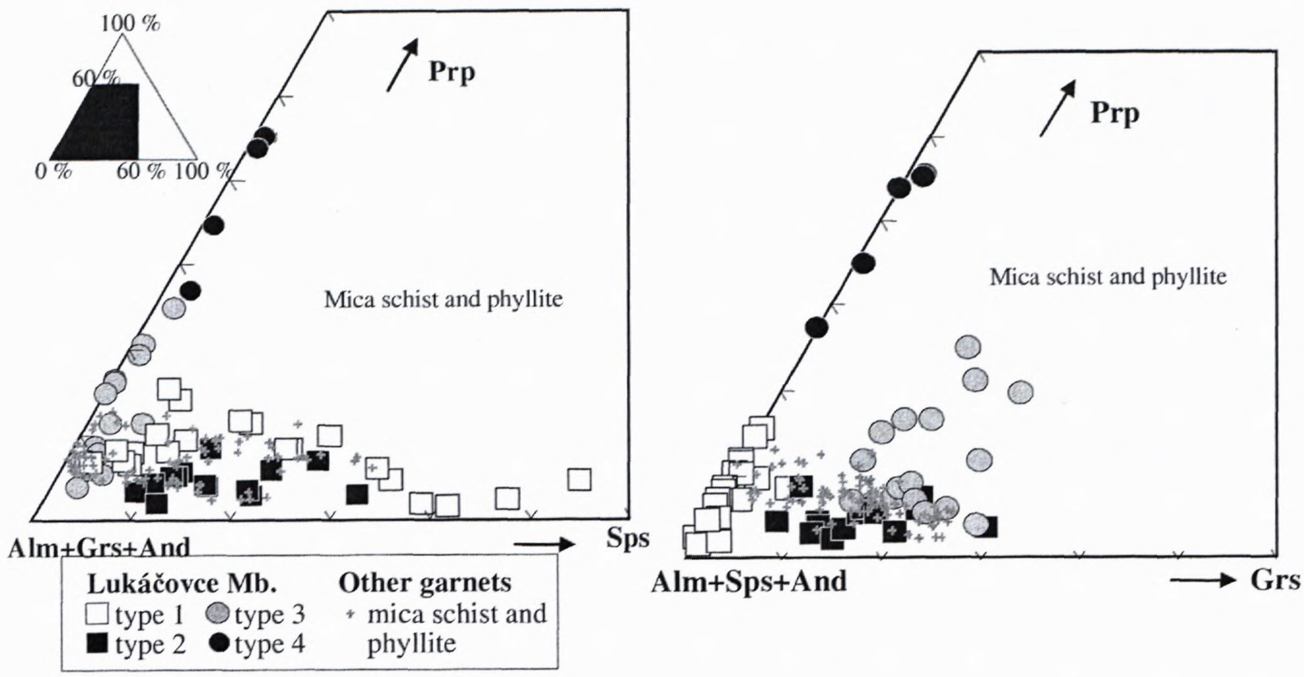

Fig. 7. Comparison of garnets of the Lukáčovce Mb. and garnets from mica schist and phyllites (comparative analyses: Vozárová – unpublished).

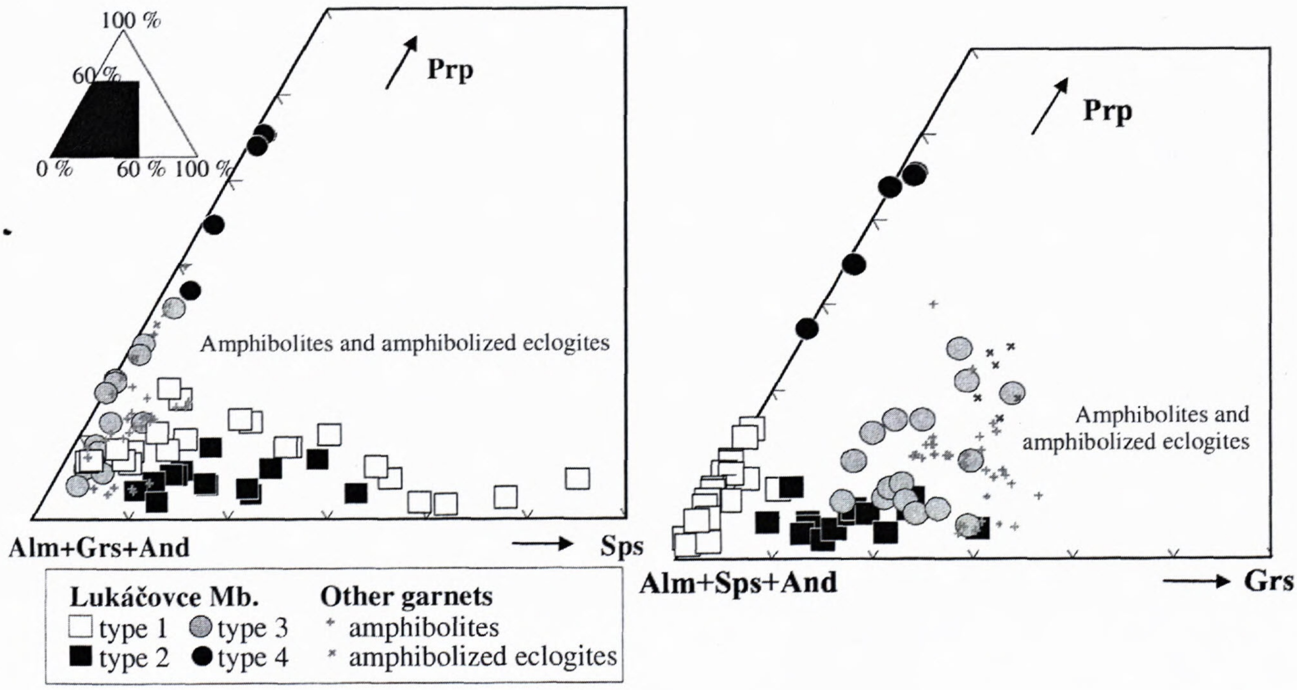

Fig. 8. Comparison of garnets of the Lukáčovce Mb. and garnets from amphibolites and amphibolized eclogites (comparative analyses – Spišiak and Hovorka, 1985; Hovorka and Méres, 1990; Faryad, 1995, 1996; Vozárová and Faryad, 1997; Méres et. al., 2000; Olšavský and Demko; 2005).

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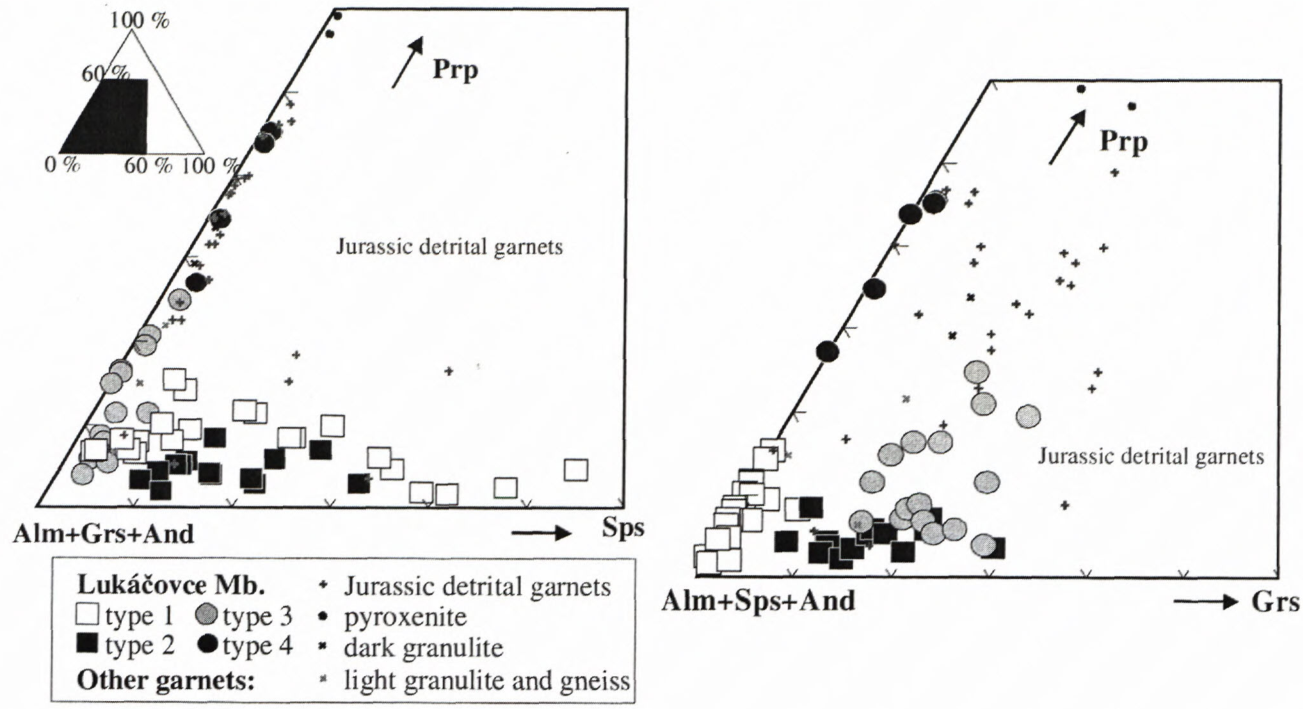

Fig. 9. Comparison of garnets of the Lukáčovce Mb., Jurassic detrital garnets and garnets from pyroxenites, light and dark granulites (comparative analyses: Jurassic garnets – Aubrecht and Méres, 2000; others – Dobretsov et al., 1984).

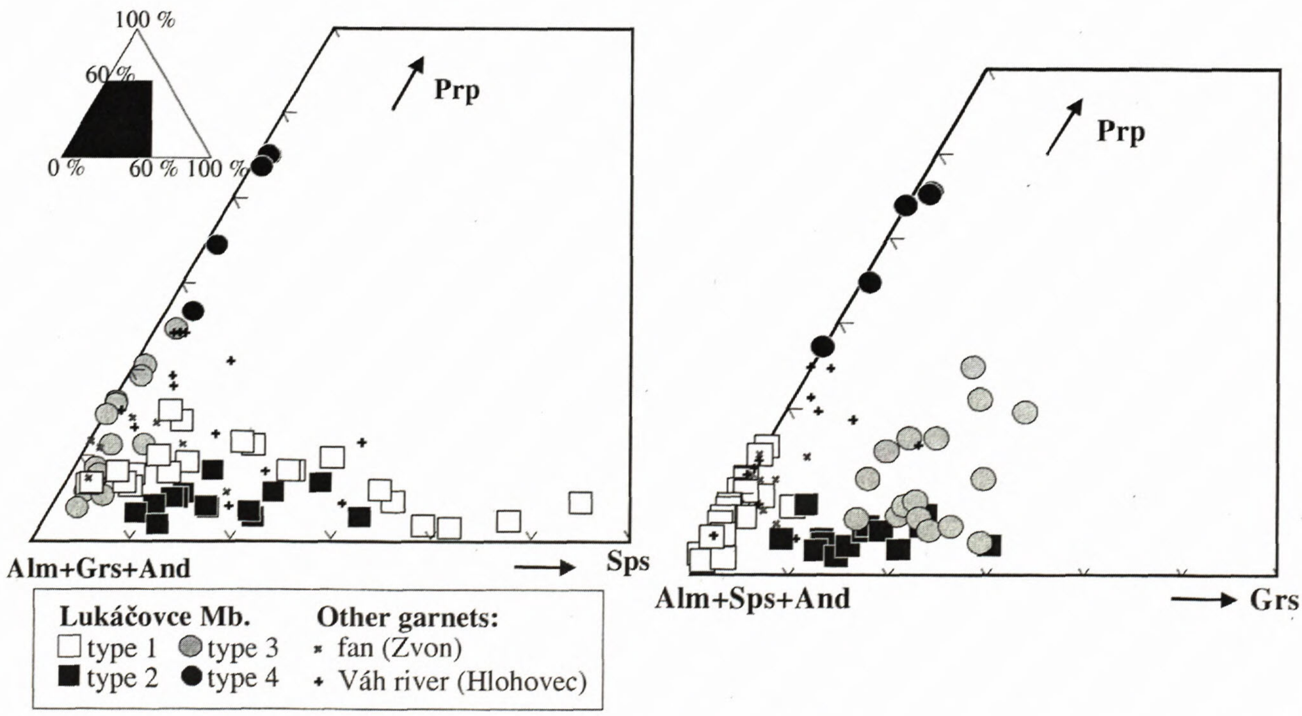

Fig. 10. Comparison of garnets of the Lukáčovce Mb. and garnets from Váh river (Würm) and alluvial fan from Považský Inovec Mts. (comparative analyses – Šarinová, 2004).

highly exceeded content of pyrope molecules in garnets from these paragneisses. Granulites are the only possible source, but such rocks until were not described in Slovakia. Only Aubrecht and Méres (2000) indicated similar values from Jurassic detrital garnets of the Klippen Belt and of the Central Carpathians (Fig. 9). They have set apart three big groups. First two groups represented garnets from the low grade and medium grade metamorphosed rocks, as phyllites, mica schists, gneisses and amphibolites. Third group included pyrope–almandine and pyrope–almandine–grossular garnets, whose source is still question under debate. Pyrope–almandine garnets should be originated from granulites, and pyrope–almandine–grossular garnets from eclogites. These authors stated as potential sources: 1) Moldanubian Zone of the Bohemian Massif; 2) exotic crustal segment (Sliezka cordillera); 3) high grade leptynite-amphibolite complex (LACWECA), to which authors (Hovorka and Méres, 1993) classified amphibolized eclogites of Branisko Mts. and Malá Fatra Mts., as well as complexes from Nízke Tatry Mts., Tríbeč Mts., Veporicum and Gemericum. The present garnets from LACWECA do not reach demanded percent of pyrope molecules, and so LACWECA cannot be a primary source of pyrope–almandine garnets from the Lukáčovce Mb. Furthermore, minimal content of grossular molecules within the Lukáčovce Mb. garnets suggest their formation from granulites and not from eclogites.

With respect to presence of similar pyrope–almandine garnets at the Jurassic sedimentary rocks of the Klippen Belt and Central Carpathians (Aubrecht and Méres, 2000), there is possible to search their source in the Jurassic rocks from the cover, eventually nappe units of the Považský Inovec Mts. Fact, that during the time of the Lukáčovce Mb. sedimentation, there came into carbonates the weathering products is confirmed by the presence of silicified crinoidal carbonates debrises and cryptocrystalline silicites with organogenic texture, often with pseudomorphoses after calcite and deformations (Šarinová, 2004). However, these mentioned garnets would have to be found straight in the Jurassic rocks of the Považský Inovec Mts. to confirm this theory.

Another potential source is represented with garnets with similar composition as the granulite facies xenoliths in neovolcanites (Fig. 6; Harangi et al., 2001). But this alternative is extreme unlike. In that case garnets would have to be redeposited from xenoliths; and with supreme probability they would not reach needed percentage occurrence.

A possibility of transportation of such type garnets from the Klippen Belt area by rivers is practically excluded (low expectation to find such garnets; absence of such type garnets in the present deposits of the Váh river (Fig. 10); uplifted Považský Inovec Mts.). Naturally, it does not eliminate redeposition from older fillings of the basin. In this point maybe warns, that similar garnets were found at the flysh belt too (Otava et al., 1997, 1998 in Aubrecht and Méres, 2000). But these garnets still were not described in the Rišňovce depression. There is rather low probability, that the primary source of these garnets (granulites; metamorphosed rocks within granulite facies) might have been found in the crystalline complex of the Považský Inovec Mts. or Tribeč Mts. Even if these granulite rocks were totally eroded, their presence ought to be manifested at least in the rounded pebbles material of the older Neogene or Paleogene basin fillings, what there does not happen until now.

Conclusion

Garnets of the Lukáčovce Mb. are derived dominantly from rocks of crystalline complex of the Považský Inovec Mts., namely from paragneisses and mica schists (types 1, 2 and 3). A portion of garnets could be alternatively originated from pegmatites (type 1) and nevolcanites (type 3). The source in pegmatites and neovolcanites is supported by the presence of the granitoid fragments within the gravel fraction. This source can be the primary one, or garnets can be redeposited from Neogene filling of the basin with other materials. The secondary source is likely for garnets from neovolcanites.

The source in amphibolites is not excluded (type 3). However, published analyses of garnets from leptynite–amphibolite complex from the Tríbeč Mts. (Hovorka, Méres, 1990) are similar to garnets from the Lukáčovce Mb. only very marginally. Besides, composition of these garnets does not explanain presence of pyrope–grossular –almandine garnets with contents of pyrope molecules 17-22 %. There were not described some amphibolized eclogites in the Považský Inovec Mts. up to the present time.

The primary source of pyrope–almandine garnets on the Slovak territory was not found until now. The presence of pyrope–almandine garnets in Jurassic carbonates of the Klippen Belt and Central Carpathians (Aubrecht and Méres, 2000) suggests potential source of these garnets type in Jurassic carbonates of the cover and nappes of the Považský Inovec Mts.

Although the primary source of pyrope–almandine garnets still remains undetected, presence of pyrope–almandine garnets is undeniable proved in the Quaternary sediments, and that contributes to extension of occurrence of such garnets in the Slovak territory.

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