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GARNETS FROM GRANITOIDS OF THE SPIŠSKO-GEMERSKÉ RUDOHORIE MTS.

(9 Figs., 2 Tabs.)

Abstract: Five garnet types have been distinguished in the Spišsko-gemerské rudohorie Mts. granitoids. Garnet (type A) with a content of the pyrope molecule attaining 18 % originated probably during the crystallization of basic members of granitoid magma, but its restite origin cannot be excluded. On the basis of phase relations between the coexisting early magmatic garnets (type B) and biotite, temperatures of 750—780 °C have been calculated, corresponding most probably to temperatures attained during the anatexis of metasediments. The depth of magma generation has been estimated to lie in minimally 21 km (850 MPa). Spessartite-rich garnet (type C), in accordance with the results of the study of contact metamorphism, indicates a level of magma solidification of 7—5 km (200—150 MPa). Spessartite garnet (type D) with a relatively higher content of the grossular component than the type C is most probably of post-magmatic origin. The youngest garnet (type E, with a ratio of grossular-spessartite-almandine components of approx. 1/3 : 1/3 : 1/3) is similar to the newly formed Alpine garnet described in granitoids of the Alps and Western Carpathians.

Резюме: В гранитоидах Спишско-гемерского рудогория было определено 5 типов гранатов. Гранат (тип А) содержащий макс. 18,9 % пироповой молекулы правдеподобно возникал в течении кристаллизации более основных членов гранитоидной магмы, но его реститовое происхождение нельзя исключить. На основе фазовых отношений между сосуществующими раннемагматическим гранатом (тип В) и биотитом были определены температуры 750—850 °С соответствующие наиболее правдеподобно температурам достигнутым в течении анатексиса метаосадок. Глубина образования магмы приблизительно определяется на минимально 21 км (850 MPa). Спессартитовой составляющей богатый гранат (тип С) в соответствии с результатами изучения контактового метаморфизма указывает на застывание магмы на глубине 7—5 км (200—150 MPa). Спессартитовый гранат (тип D) с релативно повышенным содержанием гроссулярового компонента в сравнении с типом С наиболее правдеподобно является послемагматическим. Самый молодой гранат (тип Е, имеющий отношение компонентов гроссуляр-спессартит-альмандин прибл. 1/3 : 1/3 : 1/3) похожий на новообразованный альпийский гранат описанный в гранитоидах Альп и Западных Карпат.

Garnets of granitoid rocks can be of restite, magmatic, post-magmatic — metasomatic and metamorphic — neogenic origin (Green, 1977; Clarke, 1981; Pattison et al., 1982; Kontak—Corey, 1988; Steck—Burni, 1971 and others). Only a detailed study of texture relations and chemical composition can explain the formation of various garnets (Clarke, 1981),

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which are an important and a relatively reliable indication of magmatic and metamorphic conditions. The chemical composition of garnets is a result of phase relationships between the garnets and coexisting minerals during their crystallization in certain P-T-X conditions. This composition of garnets is often preserved until metamorphic conditions corresponding to the amphibolite facies.

On the basis of textures and chemical composition, we have distinguished for the first time five garnet types of the Spišsko-gemerské rudohorie Mts. granitoids (leucogranites with biotite, granite porphyries and aplites). In accordance with the results of petrological study of the granitoids and the surrounding rocks, the studied garnets allow to clarify the problems of granitoid magmatism in this region.

Geological setting

The occurrence of granitoids on the recent surface of the Spišsko-gemerské rudohorie Mts. is in comparison with other Western Carpathian units conspiciously less frequent. Several small granitoid bodies are known to occur in the southeastern part of the Spišsko-gemerské rudohorie Mts. (the largest one - in Poproč - having a surface of approx. 10 km^2), or north of Rožňava (Betliar) - Fig. 1. However, greater extent of granitoids is assumed in depth; it is indicated by gravimetric measurements (Grzywacz—Margul, 1980; Plančár et al., 1977; Šefara, 1971) and by deep structural boreholes made in the last years (PsS-1, RS-1, SG-1, MPV-8 etc.). It can be assumed that none of the abovementioned bodies is eroded to a depth exceeding 300—500 m.

The granitoid bodies are subsequent to the main tectonometamorphic processes taking place in the Palaeozoic of Gemericum, and they acquired their position after the principal structure - forming deformation of the Palaeozoic. Their emplacement constituted the final part of a uniform tectonometamorphic cycle affecting the Palaeozoic mantle. It is indicated by the existing radiometric data (especially Rb-Sr isochrone data) of Kovách et al. (1986) which show that SGR granites, or their substantial mass, is of Late Variscan age (Upper Carboniferous - boundary of Permian—Triassic), i.e. that they are postorogenic intrusions. Radiometric data indicating for the granitoids an age interval of Jurassic—Lower Cretaceous (Kovách et al., 1979; Kantor—Rybár, 1979 and others) have been obtained by K-Ar age determination of whole-rock and mineral (biotite, K-feldspars) samples, and thus their petrogenetic importance is questionable. Such age of the granitoids has been hitherto confirmed only by few Rb-Sr datings of whole-rock and mineral samples (Kovách et al., 1986).

Granitoids of the Spišsko-gemerské rudohorie Mts. intruded into folded Early Palaeozoic crystalline rocks, dynamometamorphosed in the greenschist facies (phyllites, metarhyolite tuffs and tuffites etc.). Contact-metamorphic effects of the granitoids on mantle rocks can be followed from the contact to a distance of several hundreds of meters. Their products are mainly spotted varieties of metaclastic and metapyroclastic rocks, with the mineral assemblage

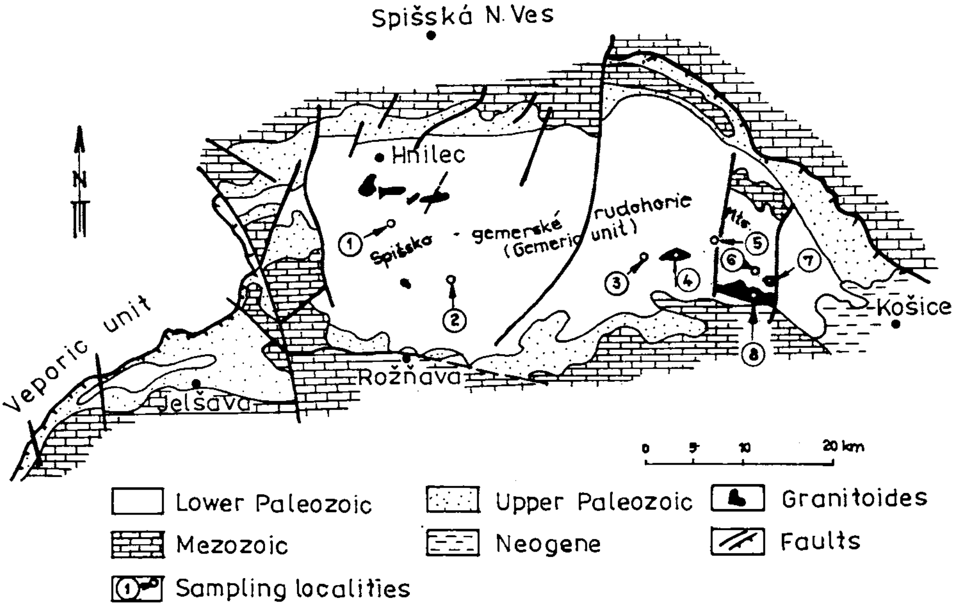

Fig. 1. Simplified geological map of the Spišsko-gemerské rudohorie Mts. with sampling localities.

Explanations: 1 — borehole PsS-1. Coarse-grained leucogranite with biotite. Occurrence of B-type garnet; 2 — borehole RS-1. Granite porphyry with biotite. Occurrence of E-type garnet; 3 — borehole SG-1. Medium-coarse-grained leucogranite with biotite. Occurrence of E-type garnet; 4 — surface. Medium-grained leucogranite with biotite. Occurrence of D and E-type garnet; 5 — borehole ID-1. Medium-grained leucogranite with biotite. Occurrence of C and E-type garnet; 6 — gallery Hennel. Markedly porhyric biotite granite (even granite porhyry). Occurrence of A and E-type garnet; 7 — borehole ID-2. Vein granite aplite with biotite. Occurrence of C-type garnet; 8 — borehole ID-25. Fine-medium-grained leucogranite with biotite. Occurrence of E-type garnet.

chlorite + muscovite + quartz ± biotite ± albite ± garnet, in places, in the inner zone of the aureole, with developed andalusite (Dianiška, 1983; Faryad — Dianiška, in prep.).

Contact-metasomatic processes - silicification, microclinization, albitization, greisenization, skarnization, etc. - affected intensively the mantle as well Dianiška, in Grecula et al., 1983; Faryad — Peterec, 1987) reaching several tens to a few hundreds of meters from the contact.

The studied garnet-containing granites are represented by medium- to coarse-grained leucogranites, granite porphyries and fine-grained granite aplites, while structural variations have been observed in the leucogranites and granite porphyries not only as far a different bodies are concerned, but also within the intrusions themselves. The frequent and marked preferred orientation of the rock varieties is most probably a result of subsequent tectonic processes.

Principal features

The existing data indicate that SGR granitoids originated from a metasedimentary source, i.e. they are classified with S-type granites in the sense of Chapell — White (1974). The granitoids also have a typical "sedimentary" course of the normalized REE-values curve. Light rare earths are relatively enriched in comparison with heavy REE and there is a marked negative Eu anomaly (Matula et al. in Malachovský, 1983; Cambel — Petrík, 1982). This origin of granites is indicated as well by a high $^{87}Sr/^{86}Sr$ ratio (Kovách et al., 1986). This ratio is in all studied granitoid types greater than 0.731. The value of normative corundum in these rocks varies between 1 and 3 %.

Petrography

Granitoid varieties in which accessory garnet has been studied are generally characterized by a high SiO_2 content varying in the range of 73 to 77 %, i.e. they are acid to ultraacid. Only in biotite-bearing, uneven-grained to markedly porphyric granites (even granite porphyries) with A-type garnet the value of SiO_2 content vary between 70—72 wt. %. A characteristic feature of these rocks is the predominance of K-feldspar (40 vol. %) over plagioclase (20 vol. %). From mafic minerals, except accessory garnet (O.X vol. %), biotite and late-postmagmatic tourmaline are always present.

A more complete information on the petrography of the studied granitoids can be found in the works of Snopko et al. (1977), Dianiška (1977), Snopko et al. (1980) and others.

Mineralogy

Garnets have been analyzed in 14 representative granitoid samples from eight locations in the Spišsko-gemerské rudohorie Mts. (Fig. 1). A total of 49 analyses of garnet, as well as a few analyses of biotite and chlorite have been carried out on the electron analyser JEOL 733 Superprobe (Dionýz Štúr Geological Institute, Bratislava). A majority of these analyses is listed in Tabs. 1 and 2.

Garnets

The studied garnets occur in the granitoids in accessory amounts - up to 1 vol. %. Only the B-type garnet is locally accumulated to 3 vol. %. The garnets have predominantly the character of little-altered xeno-idiomorphic grains with a size of 0.0X—4 mm. 5 garnet types have been distinguished according to their chemical composition, form and interrelationships of garnets with principal mineral phases.

Type A

This garnet type has been observed only in markedly porphyric biotite granite (even granite porphyry) from the gallery tunnel near Zlatá Idka (location 6, Fig. 1). Its occurrence is rare. It forms 2.5—4.0 mm large grains of isometric shape, irregularly confined, occurring always in sericitized plagioclase. Its size clearly exceeds the grain size of the matrix (O.X mm) in which it occurs, (Fig. 2). The reaction rim characteristic of this garnet is formed by an even-grained aggregate of flaked muscovite which prevails over biotite and epidote (grain size 0.1 mm). This rim does not extend beyond the boundaries of plagioclase grains. E-type garnet grows sometimes on this one in the form of a thin margin (Figs. 3 and 4).

Fig. 2. A-type garnet located in plagioclase enclosed in fine-grained matrix of a markedly porphyric biotite granite. Locality 6.

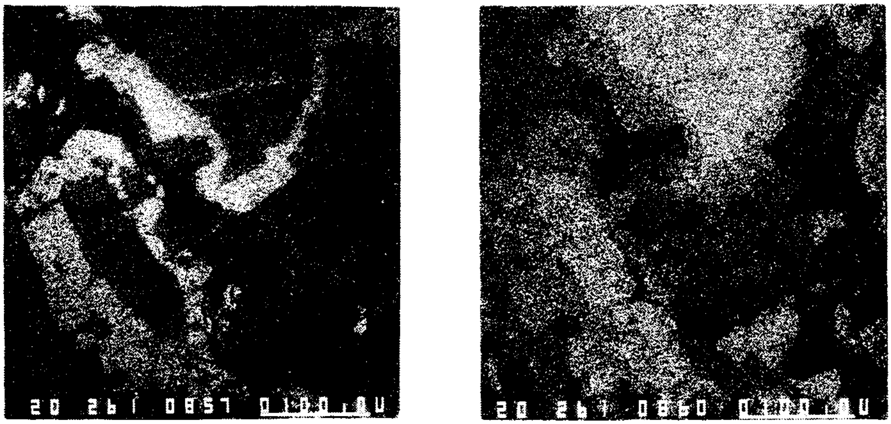

Fig. 3. Distribution of Ca (a) and Mg (b) in A-type garnet (core) and E-type garnet (margin). Markedly porhyric biotite granite, locality 6.

Along the abundant fissures in the garnet, bluish-green, not individualized chlorite (?) or greenish-brown flaked biotite were formed.

The chemical composition corresponds to pyrope-almandine garnet, with contents of MgO of 4.03—4.80 wt. % and of FeO 32.33—33.94 wt. % (Tab. 1, analyses 1—3). In the Ca-Mg-Mn diagram (Fig. 5) it forms a separate field near the Mg-apex. Zoned development of A-type garnet has not been observed.

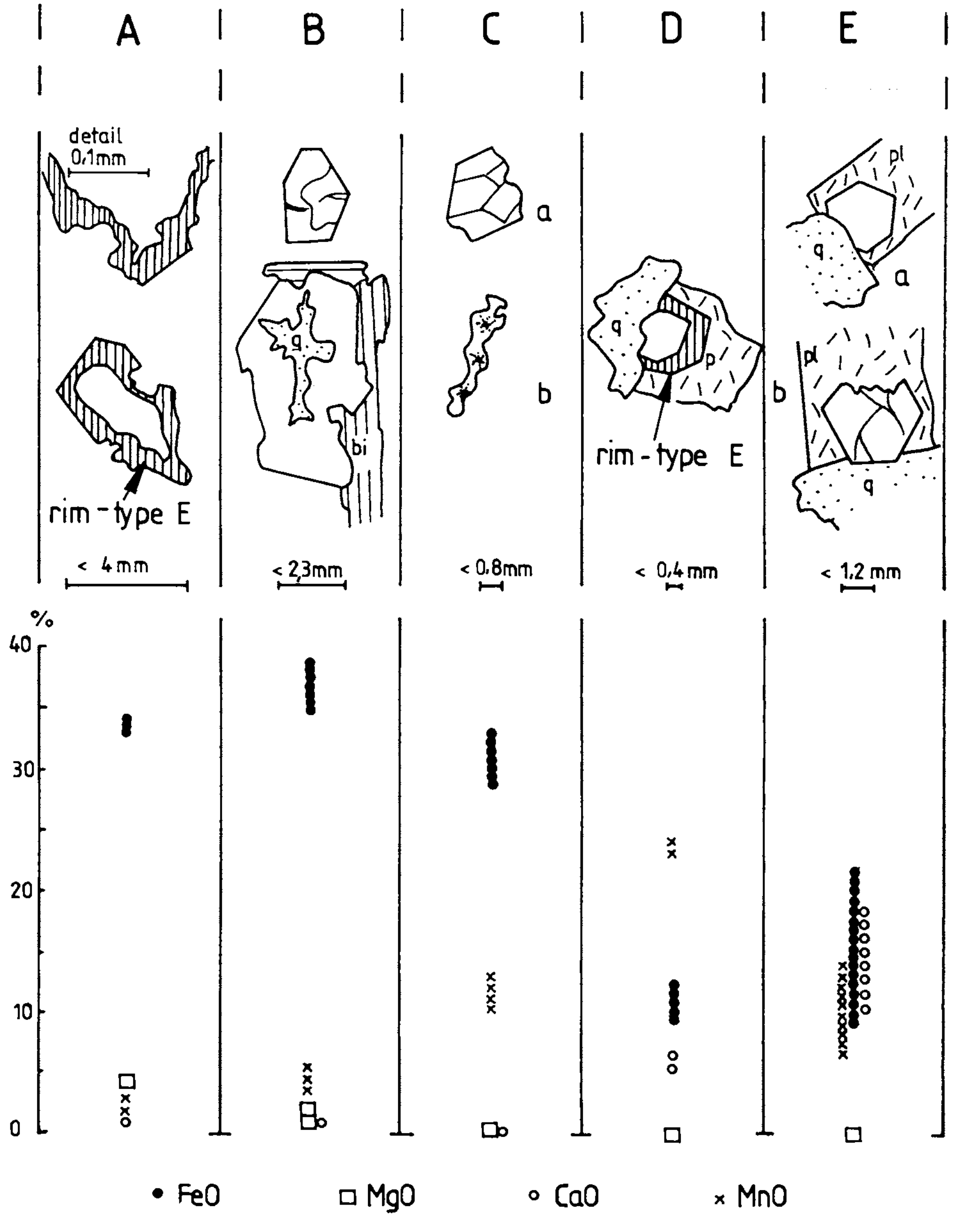

Fig. 4. Chemical composition and most characteristic forms of various garnet types.

It is possible to observe only minimal changes in MgO and MnO values from the center to the rim of grains (anal. 2 and 3) - i.e. retrogressive character of alterations which could have been the result of chemical changes caused by E-type garnet (anal. 3 on the contact with the margin of this garnet.).

Table 1

Chemical composition of garnets

	Type A			Type B								
	He-72 g			PsS-1-1263.2					PsS-1-1481.5		PsS-1-1481.5A	
	1c	2c	3r	4r	5c →	6 →	7 →	8r	9r	10c	11r	c
SiO_2	37.46	36.80	37.83	36.87	37.38	37.66	37.42	37.38	35.51	36.57	36.35	36.25
Al_2O_3	21.34	21.39	21.59	20.11	20.21	20.00	19.59	19.79	19.73	20.38	20.22	20.15
MgO	4.80	4.75	4.03	0.90	1.17	1.04	1.01	0.64	0.74	1.18	1.45	2.30
FeO	32.75	33.94	33.32	33.61	35.79	35.29	35.54	35.03	37.09	36.55	38.72	35.13
MnO	2.44	2.24	3.08	4.48	3.47	4.90	4.70	6.74	5.69	4.52	4.28	3.89
CaO	1.17	1.25	1.38	0.51	0.55	0.52	0.35	0.47	0.54	0.46	0.54	0.79
Total	99.96	100.37	101.23	98.48	98.57	99.41	98.61	99.95	99.30	99.66	101.56	99.51
Si	2.987	2.942	2.991	3.056	3.078	3.065	3.095	3.082	2.971	3.00	2.962	2.998
Al^{IV}	0.013	0.058	0.009	0.000	0.000	0.000	0.000	0.000	0.029	0.00	0.038	0.002
Al^{VI}	1.991	1.956	2.002	1.964	1.961	1.946	1.910	1.922	1.916	1.97	1.904	1.962
Mg	0.570	0.565	0.474	0.111	0.143	0.128	0.1242	0.078	0.092	0.14	0.175	0.283
Fe	2.184	2.269	2.202	2.468	2.465	2.434	2.458	2.415	2.595	2.51	2.639	2.430
Mn	0.164	0.151	0.206	0.314	0.242	0.342	0.329	0.414	0.403	0.31	0.295	0.272
Ca	0.099	0.106	0.116	0.044	0.048	0.045	0.030	0.041	0.048	0.04	0.049	0.069
Py	18.9	18.4	15.8	3.8	4.9	4.3	4.2	2.6	2.9	4.8	5.6	9.3
Alm	72.4	73.4	73.5	83.9	85.1	82.6	83.5	81.9	82.7	83.4	83.6	79.6
Spess	5.4	4.8	6.8	10.8	8.4	11.6	10.5	14.2	12.9	10.5	9.3	8.9
Gross	3.3	3.4	3.9	1.5	1.6	1.5	1.0	1.3	1.5	1.3	1.5	2.2

1-st continuation of Tab. 1

	Type C								Type D		
	ID-2/21				ID-2/21A			ID-1/65	FG-151A		
	13r	14 →	15	16c	17r →	18	19c	20	21r	22c	23r
SiO_2	35.64	36.42	35.70	34.79	35.70	36.41	37.11	37.11	38.15	37.93	37.92
Al_2O_3	21.68	21.18	19.69	20.39	20.35	20.27	20.69	20.69	21.22	21.17	21.10
MgO	0.43	0.40	0.47	0.39	0.34	0.28	0.31	0.38	0.08	0.06	0.03
FeO	33.21	32.93	31.60	31.02	29.99	28.80	28.59	32.19	12.49	9.50	10.97
MnO	10.73	11.03	10.55	11.95	12.21	11.96	13.14	10.03	23.77	24.50	24.71
CaO	0.26	0.25	0.22	0.27	0.19	0.22	0.20	0.19	6.37	6.81	5.30
Total	101.95	101.91	98.23	99.81	98.78	97.94	100.04	100.59	102.08	99.97	100.03
Si	2.901	2.952	3.006	2.928	2.985	3.044	3.043	3.029	3.000	3.007	3.021
Al^{IV}	0.098	0.047	0.000	0.071	0.015	0.000	0.000	0.000	0.000	0.000	0.000
Al^{VI}	1.982	1.976	1.954	1.951	1.990	1.997	1.989	1.990	1.983	2.004	1.980
Mg	0.051	0.048	0.058	0.048	0.041	0.034	0.037	0.046	0.009	0.005	0.003
Fe	2.261	2.231	2.225	2.183	2.097	2.013	1.960	2.197	0.828	0.644	0.730
Mn	0.739	0.757	0.752	0.851	0.864	0.847	0.912	0.593	1.596	1.667	1.667
Ca	0.022	0.021	0.019	0.024	0.016	0.019	0.017	0.016	0.541	0.586	0.452
Py	1.6	1.5	1.9	1.5	1.4	1.1	1.3	1.5	0.3	0.2	0.1
Alm	73.6	73.0	72.8	70.3	69.5	69.2	67.0	74.5	27.8	22.2	25.6
Spess	24.1	24.8	24.7	27.5	28.6	29.1	31.2	23.5	53.7	57.4	58.5
Gross	0.7	0.7	0.6	0.7	0.5	0.6	0.5	0.5	18.2	20.2	15.8

2-nd continuation of Tab. 1

	Type E										Type E			
	FG-151A	He-72g	ID-1/323.5		ID-25/100		ID-25/100A		RS-1/992		SG-1/376.5		SG-1/385	
	24	25	26c	27r	28r	29c	30r	31c	32r	33c	34r	35c	36r	37c
SiO_2	38.82	37.85	37.76	38.12	37.66	38.40	37.50	37.83	36.83	37.41	35.38	37.01	38.20	37.53
Al_2O_3	21.30	21.31	21.02	21.10	20.34	20.38	20.03	20.39	19.37	20.66	20.71	21.26	20.83	21.58
MgO	0.10	0.19	0.16	0.21	0.13	0.06	0.04	0.08	0.01	0.11	0.08	0.08	0.11	0.07
FeO	19.24	16.09	14.88	16.91	17.64	17.18	14.50	13.98	19.74	19.34	15.09	12.28	12.90	9.22
MnO	8.24	8.32	8.95	7.00	7.76	8.89	11.99	13.15	11.81	13.25	8.00	9.63	9.66	14.60
CaO	12.22	17.35	15.75	14.09	15.25	14.97	15.57	14.93	12.12	11.46	17.90	18.87	17.52	17.35
Total	102.89	101.11	98.52	97.43	98.78	99.88	99.63	100.36	99.88	102.23	97.16	99.13	99.22	100.35
Si	3.024	2.973	3.024	3.069	3.030	3.055	3.004	3.019	3.001	2.969	2.906	2.953	3.033	2.963
Al^{IV}	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.093	0.046	0.000	0.037
Al^{VI}	1.984	1.949	1.984	2.002	1.928	1.910	1.910	1.903	1.859	1.901	1.912	1.953	1.948	1.970
Mg	0.012	0.022	0.018	0.024	0.015	0.007	0.004	0.008	0.000	0.028	0.009	0.009	0.012	0.008
Fe	1.272	1.056	0.996	1.138	1.187	1.143	0.970	0.932	1.345	1.283	1.036	0.819	0.856	0.608
Mn	0.552	0.553	0.606	0.477	0.528	0.598	0.812	0.888	0.803	0.890	0.556	0.650	0.649	0.976
Ca	1.035	1.460	1.351	1.215	1.314	1.275	1.336	1.276	1.058	0.974	1.575	1.613	1.490	1.467
Py	0.4	0.7	0.6	0.8	0.5	0.2	0.1	0.2	0.0	0.4	0.3	0.3	0.4	0.2
Alm	44.3	34.2	33.5	39.9	38.9	37.3	31.1	30.1	41.9	40.7	32.6	26.4	28.4	19.8
Spess	19.2	17.8	20.4	16.7	17.4	19.8	26.1	28.6	25.1	28.1	17.5	21.1	21.6	32.0
Gross	36.1	47.3	45.5	42.6	43.2	42.2	42.7	41.1	33.0	30.8	49.6	52.2	49.6	48.0

Type B

Garnets of the type B have been found in coarse-grained leucogranite from the borehole PsS-1 - locality 1. It is hypidiomorphic-idiomorphic, with no accompanying inclusions. Its grain-size varies from 0.X to 2 mm. It contacts all principal minerals of the rock as well as biotite, or it is enclosed by them. Garnets of this type are sometimes intensively replaced by green matter with chemical composition approaching thuringite (FeO - 31.7—33.9 %). Quartz and greenish-brown biotite have been found in the fissures of the garnet.

In contrast to the A-type garnet, this one has a lower content of CaO (up to 0.78. %) and MgO (up to 2.3 %) and relatively higher contents of MnO (up to 5.94 %) and FeO (up to 38.85 %) - see analyses 4—12, Tab. 1. This garnet type is slightly retrogressively zoned (Fig. 6). There is a quite marked change of MnO (3.47—5.94 %) and MgO (1.17—0.64 %) contents from the centres to the rims of the grains.

In some grains we could observe also changes of the content of FeO (anal. 11—12, Tab. 1), namely an increase of its values towards the rims of the grains.

Type C

Garnet of this type is characteristic of granite aplite from the borehole ID-2 (locality 7), which cuts - in the form of several tens of cm thick veins - the biotite porphyric granite with A-type garnet. Sporadically it has been determined also in medium-grained leucogranite from the borehole ID-1, where it occurs in association with the abundant E-type garnet. The size of the xeno-idiomorphic garnet grains does not exceed 1—2 mm. Usually it is in the range of 0.2—0.5 mm. The grains are without inclusions, sometimes they are partly chloritized.

In comparison with garnets of the type B it has twice to three times higher MnO content (10.73—13.14 %) and lower content of FeO (28.59—33.21 %)

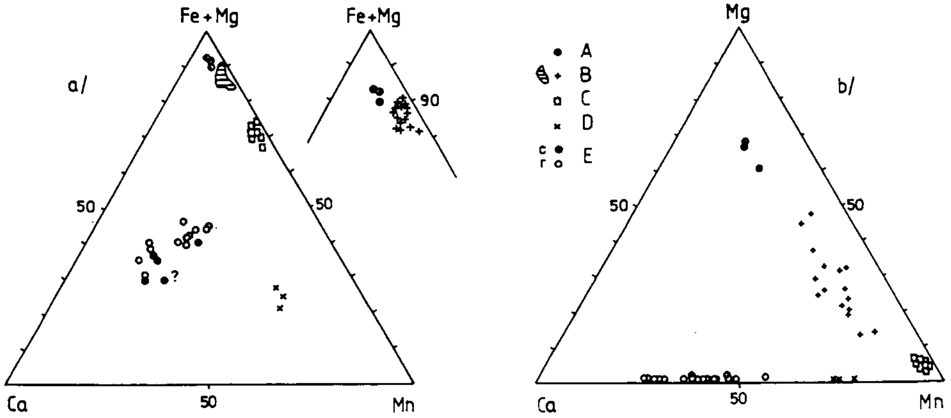

Fig. 5. Composition of garnets from Gemeric granites.
A-E — garnet types.

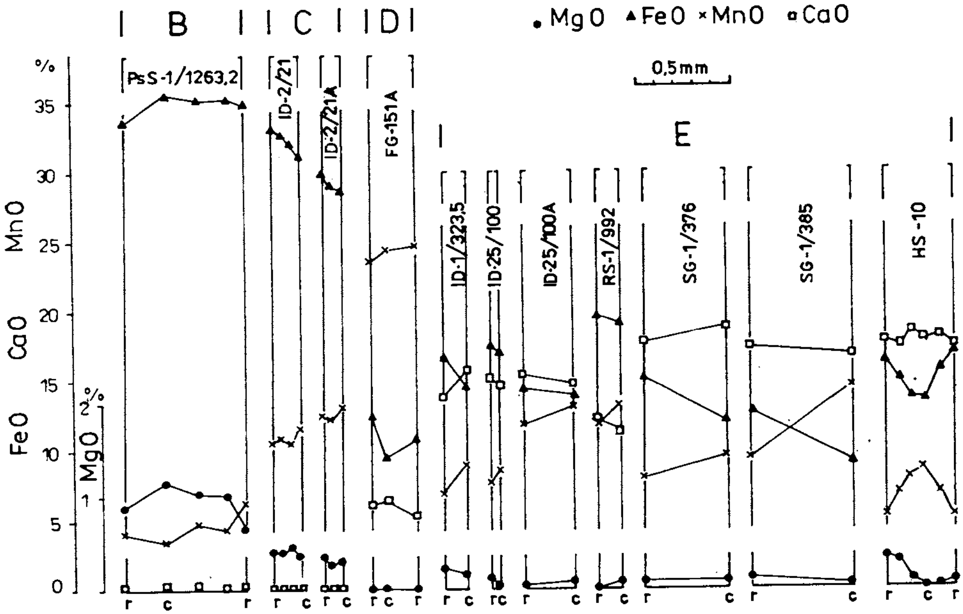

Fig. 6. Oxide variations (wt. %) in the studied garnets. The sample HS-10 is taken from the work of Korikovsky et al. (in press).

- Tab. 1. We could observe zoning of its structure (Fig. 6). Its position in the Ca : Mg + Fe : Mn and Ca : Mg : Mn diagrams is shown on Fig. 5.

In connection with C-type garnet we have observed in aplites garnet having a markedly different form (b-variation of the C-type garnet - Fig. 4). It is developed along the contact of quartz and feldspars; replacement of these minerals is evident. Its chemical composition has not yet been determined. The irregular form (elongated) and the position of this garnet indicate a possible chemical difference in comparison to the above described C-type garnet, as well as its having been formed later (D-type garnet ?).

Type D

The studied D-type garnet has been observed sporadically in medium-grained leucogranite exposed north of the village Medzev - locality 4. It forms hypidiomorphic grains with a size not exceeding 0.4 mm, situated in the intergranular matter of quartz and feldspars. In places it is surrounded by garnet of the type E.

According to its chemical composition it is high-spessartite garnet with a content of MnO 23.77—24.71 wt. %; it is not markedly zoned.

Type E

This is the most frequent type among the studied garnets. It has been found in all studied garnet-containing granite types, with the exception of

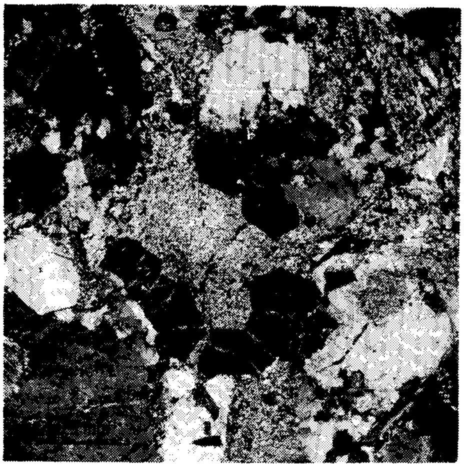

Fig. 7. E-type garnet in medium-grained leucogranite from the borehole ID-1 (depth 323.5 m), locality 5.

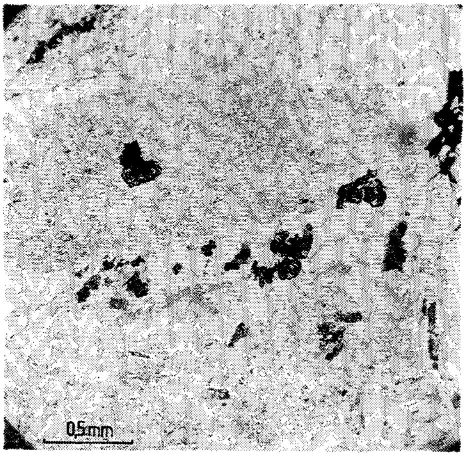

Fig. 8. Distribution of garnet similar to the type E on a tectonically affected and altered zone of coarse-grained leucogranite with biotite from the borehole SG-1 (depth 376.5 m), locality 3.

coarse-grained leucogranite from the borehole PsS-1 (locality 1). It appears in the form of lypidic-idiomorphic grains, heir size ranging usually from 0.2 to 0.7 mm, The grains are almost always inside plagioclase - to be more precise, in its peripheral part, almost always on contact with quartz (Fig. 7). The part lying in plagioclase has usually perfect crystal forms, whereas the part contacting quartz is usually irregular (Fig. 4). Garnet of the same chemical composition has been determind also in the form of a thin margin growing on garnets of the types A and D.

Characteristic features of this garnet type are contents of CaO (11.46—18.87 %), MnO (7.0—14.6 %) and FeO (9.22—19.34 %) varying in a relatively wide range (Tab. 1). In comparison with other garnet types this one is evidently richer in CaO. It is indistinctly progressively zoned. Towards the rims the value of FeO increases and that of MnO decreases (Fig. 6). The projection points of this garnet in the Ca : Mg + Fe : Mn diagram are placed near its centre and they form a relatively wide field, which indicates a considerable variability of its chemical composition in comparison with other garnet types. Looking at Fig. 4b, a deficit in the MgO content of this garnet type is evident.

In some leucogranite samples from the borehole SG-1, fine (up to 0.4 mm) grains of chemically unidentified garnet associated with the type E have been observed. It occurs in intensively altered and tectonically affected plagioclase zones (Fig. 8). They frequently form cumuloblasts and the total number of grains in these zones is 20—40. The alteration of plagioclase is characterized by the formation of a white mica aggregate oriented frequently perpendicularly to these zones, or by an aggregate of albite and quartz (± biotite). The chemical composition of this garnet has not been determined yet, but according to its distribution in the rocks it belong most probably to the type E.

Biotite

Biotite usually forms hypidiomorphic plates with a size of 0.3 to 0.5 mm, clustered frequently in aggregates. It is enclosing zircon, monazite, apatite, and it has brown to dark brown pleochroism. The analysed biotite is in most cases (with the exception of the locality 6) rich in iron, the ratio of FeO/FeO + MgO being about 0.89, and the contents of TiO_2 = 2.28—1.43 % and MnO = 0.53—0.61 %. Representative analyses of this biotite type are listed in Tab. 2. Biotite associated with A-type garnet (locality 6) is in comparison with other biotites higher magnesian (FeO/FeO + MgO = 0.80) and it contains relatively less TiO_2 and MnO (Tab. 2).

Table 2

Chemical composition of biotite

	PSS-1/1481.5			He-72g	
	1	2	3	4	5
SiO_2	33.36	31.80	31.88	36.19	36.11
Al_2O_3	17.04	16.76	17.01	17.04	16.58
TiO_2	2.78	1.43	2.50	1.02	0.94
FeO_t	28.60	28.00	27.62	25.96	26.95
MgO	3.19	3.90	3.07	6.23	6.05
MnO	0.53	0.61	0.54	0.24	0.22
K_2O	9.09	8.52	9.04	9.95	9.76
Total	94.75	91.18	91.75	96.71	96.64
Si	5.398	5.357	5.335	5.621	5.629
Al^{IV}	0.602	0.643	0.665	2.379	2.371
Al^{VI}	2.647	2.684	2.688	0.739	0.683
Ti	0.338	1.185	0.314	0.118	0.109
Fe	3.870	3.944	3.864	3.371	3.523
Mg	0.770	0.978	0.764	1.441	1.409
Mn	0.072	0.086	0.076	0.030	0.029
K	1.876	1.831	1.928	1.971	1.946

The origin of garnet

Garnet of the type A differs from all other studied garnets by the size of its crystals, their chemical composition (higher content of the pyrope component - up to 18.9 %), as well as by the development of a reaction margin and very irregular boundaries of the grains. Even though A-type garnet is associated with relatively higher-magnesian biotite than the biotites usual in Gemeric granites, the high value of the distribution coefficient (K_D^{Bi-Gr} = = 0.61—0.63) does not indicate a coexistence of these minerals. Garnet of a similar composition has been described by Hovorka et al. (1987) in paragneisses from the Malá Fatra Mts.; the cited authors consider it to be a high-temperature garnet which originated in the upper part of the amphibolite to granulite? facies. However, no xenoliths of the primary metasediment have been found in the Gemeric granites, on the contrary, there are sporadic occurrences (mostly on the sampling sites 5 and 6) of darker enclaves with the composition of quartz diorite to diorite. According to the mentioned characteristics, garnet of the type A represents either the primary restite garnet (this suggestion can be supported by the presence of rounded inclusions of apatite and monazite in biotite which are considered to be restites - Dianiška, unpublished), or garnet formed during the crystallization of basic members of granitoid magma.

Garnet of the type B represents by its form as well as position garnet formed by the crystallization of granite magma in the early magmatic stage. Its CaO content does not exceed 1 %, which is typical of magmatic garnets (Clark, 1981). Its chemically retrogressive zoning indicates a decrease of magma temperature during its crystallization. The described garnet is in equilibrium with magmatic biotite. The value of K_D^{Bi-Ga} is 0.279 to 0.333.

The coexisting B-type garnet and magmatic served as a basis for the calculation of the temperature of magma crystallization. We used for the calculation the garnet-biotite geothermometer after Ferry — Spear (1978), with an accuracy of ± 50 °C (depending on 1 % error of the analyzed molecular quantities). Pattison et al. (1982) recommended the application of this geothermometer not only for the estimation of metamorphic temperatures, but also for the calculation of the temperatures of granitoid magma crystallization. By the use of the abovementioned geothermometer in combination with the anorthite + grossularite + Al-silicate + quartz geobarometer these authors (l.c.) obtained the temperatures 800—1100 °C and pressures 500—1000 MPa for granitoid batholiths Hepoborne and Wentzel in Canada. For Gemeric granites (coarse-grained leucogranite with biotite from the locality 1), temperatures of 754—848 °C have been calculated on the basis of the biotite-garnet geothermometer (Ferry — Spear, 1978); these values correspond to the temperatures obtained by the application of the geothermometer of Ferry and Spear modified by Essen (1982), i.e. 750—850 °C. These temperatures correspond to, or are lower than the crystallization temperatures of several granites (Whitney — Stromer, 1977; Pattison et al., 1982 and others), but they appear to be too high for the acid to ultraacid granitoids of the Spišsko-gemerské rudohorie Mts., especially when compared with the relatively not very marked contact alterations in the surroundings of the granite. The cause of such a result could be the presence of Fe^{3+} in biotite, its quantity increasing in the process of granite magma differentiation, or the high contents of Ti and Al in magmatic biotite. However, the correction of Ti and Al (by the method of Indares and Martingole, 1985) cannot be applied in the calculation of the temperatures, since the resulting values (422—553 °C) are much lower than the temperatures of minimum melting. Pattison et al. (1982) consider the temperatures obtained by geothermometry on magmatic garnet and biotite without the correction of Ti and Al to be reliable, and they justified this by the fact that they correspond to the temperatures of the formation of granite melt which is preserved by these minerals (especially garnet).

C-type garnet is characterized by a high content of the spessartite molecule. Such garnet is known to occur in leucogranites as well as in pegmatites (Manning, 1983; Bellieni et al., 1979 and others). It is mostly chemically zoned, with an MnO-rich core and overall low MgO and CaO values.

The content of the spessartite molecule attains in garnets from aplites as much as 40 mol % (Manning, 1983; Bellieni et al., 1979; Biznard et al., 1970). Garnets from aplites in the Spišsko-gemerské Mts. contain max. 31.2 mol. % of the spessartite component, and the contents of CaO and MgO are lower than 0.22 and 0.33 %, respectively. This type of garnet is in all cited works considered magmatic. The content of spessartite component in garnet is except by the physical conditions strongly affected by the chemical composition of the melt. The content of Mn, low in the primary magma, has a tendency to increase only in later stages of crystallization (Hsü, 1968). Experimental studies showed that the stability field of Fe-Mn-Ca garnets rich in Mn is in granite magma at pressures of 500 MPa (Green, 1977; Clemens — Wall, 1971), or at pressures of up to 100 MPa, meaning a depth of 5 km and temperature of 750 °C (Weisbard, 1970).

Kontak and Corey (1988) attributed postmagmatic-metasomatic origin to garnets of a composition similar to the type C (with the exception of their higher content of the grossularite component - 1.4—7.4 %) studied in South Mountain (Nova Scotia) granitioids. The conditions of its formation, corresponding to the formation of sillimanite and andalusite in aluminium-rich alteration zones (Corey, 1987), have been estimated at 500—550 °C, at 300 MPa. In the case of the depth of granitoid magma emplacement being less than 12 km the temperatures of the formation of this garnet are assumed to be higher than the abovementioned ones (Robie — Hemingway, 1984).

The group of high-spessartite garnet (of a later genesis than the type C) includes also the garnet of the type D, its content of the spessartite molecule attaing 58.5 %. Garnet with a content of the spessartite molecule of 40—85 %, but with a low content of the grossularite molecule (up to 0.5 %) has been described in aplites by Manning (1983), and in his opinion this garnet was formed in the final stage of magma crystallization. Considering postmagmatic-metasomatic origin of spessartite-rich garnets in the sense of Kontak — Corey (1988), the studied D-type garnet are most probably of the same genesis, since, in contrast to magmatic garnets this one has a high content of the grossularite molecule (15—20 %) and the Ca necessary for the grossularite could have come from plagioclase affected by these alterations.

The origin of E-type garnet is problematic. Garnet of this composition has been described on several sites in the Alps (Ackermand et al., 1972; Steck — Burri, 1971; von Raumer, 1971). The first one to describe this garnet type in Western Carpathians, in the region of Veporicum, was Vrána (1964). In accordance with the earlier cited authors, he as well considers this garnet to be the product of Alpine metamorphism. On the other hand, Korikovsky et al. (in press) consider this garnet occurring in the Veporicum region to be of magmatic origin.

From our study it follows that garnet of the type E is the youngest one from all studied garnets (Fig. 4). The space relation of this garnet (its grossularite content attaining 49.5 %) to sodium-calcium feldspar of albite-oligoclase composition (the content of An molecule varying up to 19 %) could indicate that it was formed as a result of the instability of this feldspar and the liberation of Ca in the process of its de-anorthization. This assumption is supported also by the margin-like growth of E-type garnet on garnet occurring only in plagioclase environment, i.e. only on garnets of the types A and D (B and C type garnets are intergranular). The relation to the "host" minerals is in contradiction to the assumed magmatic origin of the garnet. The considerable variability of its chemistry and the presence in various phases - or intrusive phases - of the studied granitoids indicate that E-type garnet is a product of a geological process or event of regional scale.

Metamorphic, or not postmagmatic origin of E-type garnet is supported by the following arguments:

a) in the process of tectonometamorhism, the mineral assemblage muscovite, quartz, chlorite, epidote, hydrobiotite was formed in the granitoids, indicating the beginning of metamorphism in the greenschist facies. The heating of the environment to at least 300 °C is indicated also by a redistribution of radiogenic elements (K-Ar, but also Rb-Sr) in magmatic biotite approx. 90 m.y. ago (Kantor, 1979; Kovách et al., 1986). Von Raumer (1971) and Steck — Burri (1971) described garnet of the type E in granitoids metamorphosed already in the stilpnomelane zone.

b) the marked jump in the composition of garnet grains with D-type core and E-type margin would in the case of post-magmatic origin of both types indicate either a sudden change in the composition of the fluid phase, or two independent metasomatic processes, which is less probable.

c) some garnet grains of type E were found to have progressive zoning, which is usually characteristic of metamorphic garnets and indicates temperature increase during their crystallization. Marked progressive zoning of this garnet type (Fig. 6) is documented in Veporicum (Korikovsky et al., in press).

Post-magmatic -metasomatic origin of the E-type garnet is supported by the varying intensity of tectonometamorphism in granites and by the occurrences of this garnet type on sites without marked mylonitization.

Conclusion

The recently obtained data on granitoids of the Spišsko-gemerské rudohorie Mts. shed light on some problems of granite magmatism in this region. Garnet (type A) with a content of pyrope molecule of up to 18.9 % was probably formed during the crystallization of basic members of granitoid magma, however, its origin in restite cannot be excluded.

On the basis of the coexisting early-magmatic B-type garnet and magmatic biotite, the temperatures of magma crystallization have been estimated at 754—848 °C, representing probably the temperatures attained during anatectic melting of metasediments. If we accept the relation of granite magma production (the age of magma solidification is 290 ± 40 to 223 ± 32 m.y.) to Hercynian metamorphism in Gemericum (ending before Upper Carboniferous, Faryad, in press) as supposed Grecula (1982), the depth of granite magma generation - in accordance with the geothermal gradient of Hercynian metamorphism of 40°/km determined by Sassi — Vozárová (1978) - can be estimated at minimally 21 km (580 MPa, Fig. 9). Temperatures calculated on the basis of biotite-garnet geothermometry at the pressure of 580 MPa vary then in the range of 770—860 °C. It is necessary to mention here that 40 °C/km is one the highest thermal gradients of Hercynian metamorphism determined in the region of Alps and Carpathians. However, we do not exclude the possibility of its value being lower, as indicated also by the mineral parageneses of Hercynian metamorphism (Faryad, in press).

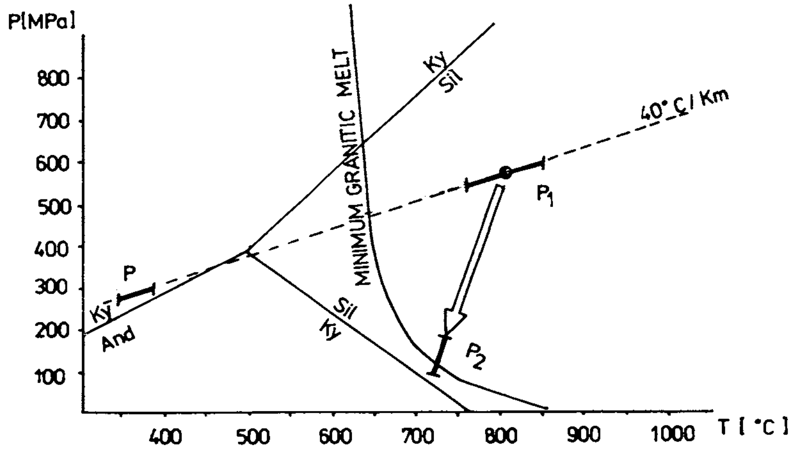

Fig. 9. P—T diagram of Hercynian metamorphism and granite magmatism not palyngenetic granite in the Gemericum region.
Explanations: P — conditions of regional Hercynian metamorphism with the corresponding thermal gradient in the region of Gemericum — Gelnica Group (Sassi — Vozárová, 1987); P_1 — possible P-T conditions of granite magma generation; P_2 — presumed conditions of granite magma solidification.

The formation of C-type spessartite garnet in accordance with experimental studies (Green, 1977; Weibaurd, 1977; Clemens—Wall, 1971) is indicated in the depth of 5 km (100 MPa) at a temperature of about 700 °C. The solidification of granite magma in a depth of 5—7 km is indicated also by the mineral paragenesis of the products of contact thermal metamorphism of metasediments in the studied region. This garnet indicates at the same time that the residual aplite melt crystallized in the depth level of displacement of magmatic matter (host granites).

Garnet of the type D is probably of magmatic origin, however, the high Mn content indicates that it is a transitional type similar to the garnet type C. The source of Ca necessary for the grossularite component could be plagioclase which became instabile in the process of post-magmatic alterations.

The existing data do not explicitly exclude the formation of E-type garnet in the process of post-magmatic alterations, but their majority supports its metamorphic origin. Assuming this, the formation of E-type garnet, in accordance with geochronological data, falls into the period of Jurassic—Cretaceous heating and tectonometamorphism.

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