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ZONED GARNETS AND THEIR EQUILIBRIA IN MICA SCHISTS AND GNEISSES OF KOHÚT CRYSTALLINE COMPLEX, HNÚŠŤA REGION, WESTERN CARPATHIANS

(7 Figs., 5 Tabs.)

Abstract: The metamorphic rocks of phyllite, schist to paragneiss type occurring in the SE part of Veporicum represent the content of the Hladomorná Valley, Ostrá and Klenovec complexes. The intensity of progressive (Variscan) metamorphism in the above-mentioned complexes reached the conditions of garnet subfacies of the greenschist facies, increasing slightly in SE-NW direction up to the staurolite- chloritoid subfacies. The application of Ferry's and Spear's biotite-garnet geothermometer confirmed the results of the study of mineral parageneses; temperatures determined in various samples varied between 431—451 °C. Prograde zoning in the whole profile is typical of the majority of garnets; on the other hand, the typical features of retrograde alteration zones are retrogressive zoning and the presence of grossularite margins as a result of retrograde exchange isochemical reactions in the mineral couple garnet-plagioclase in the course of which the Ca-content in garnets increased and in plagioclases it decreased.

Резюме: В ЮВ части вепорикума встречаются метаморфические породы типа филлитов, сланцев и парагнейсов которые являются частей комплексов Гладоморной долины, Острой и Кленовецкого. Интенсивность прогрессивного (варисцийского) метаморфизма этих комплексов достигла условий гранатовой субфации фации зеленых сланцев, с небольшим повышением в направлении ЮВ-СЗ до ставролит-хлоритоидной субфации. Применение геотермометра Ферри и Спира подтвердило результаты изучения минеральных парагенезисов: температура определенная для отдельных образцов колебалась между 431—451 °C. Для большего числа гранатов типичной является прогрессивная зональность вдоль всего профиля, и в зонах ретроградных изменений регресивная зональность и гроссуляровая оторочка как результат обменных ретроградных изохимических реакций в минеральной паре гранат-плагиоклаз, в течении которых содержание Ca в гранатах возрастало и в плагиоклазах понижалось.

The studied territory is a part of the Kohút Zone of Veporicum, its geological setting, tectonic and metamorphic evolution being in their complexity one of the greatest problems in the geology of Western Carpathian crystalline complexes.

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A decisive turn in the history of studies of the geological structure of Veporicum was brought about by the determination of nappe position of granitoids lying on the metamorphic complex (Klinec, 1966). Some of the authors (Máška — Zoubek, 1960; Kamenický, 1977; L. Kamenický — J. Kamenický, 1983) suggested that Precambrian regional metamorphism affected these rocks, while in the opinion of a majority of workers only the manifestations of Variscan and Alpine metamorphic cycles have been proved. According to Vrána (1964) the first cycle of regional metamorphism (Variscan, Assyntic?) reached the conditions of "quartz-albite-epidote-biotite" and "quartz-epidote-almandine" subfacies of the greenschist facies (biotite and garnet zone). Vrána (1966, 1980) was the first one to describe the new-formed metamorphic assemblage with almandine-grossularite garnets in granitoids affected by Alpine metamorphism which led him to the assumption that the Alpine cycle took place in the conditions of biotite and garnet zone. He suggested the same metamorphic grade also for the zone of tectonic contact with Gemericum where he found kyanite and chloritoid in Al_2O_3-rich rocks (Vrána, 1964).

Except regional metamorphism the studied terrane was affected also by the contact effects of the Rimavica Granite (Kamenický, 1977). There are two opinions on the age of the above mentioned intrusion: - it is a Variscan granite (Kamenický, 1977; Cambel et al., 1988), - the granite is of Alpine (Cretaceous) age (Kantor, 1960; Varga, 1963; Vozárová — Vozár, 1979, 1982). Bezák (1982) suggested the existence of a so-called "Rimavica Complex of granitoids" formed by varieties of Variscan as well as Alpine age.

Geological mapping in the seventies led to the distinguishing (Bezák, 1982) of the Klenovec Complex and Sinec Complex (Fig. 1). The Klenovec Complex is represented by biotite "albitic" gneisses with layers of graphitic schists and light gneisses. Palynologically it was classified with Lower Paleozoic. The Sinec Complex consists of two parts — the basement with a prevalence of chlorite-muscovite schists with layers of chlorite schists, amphibolites, graphitic schists and metacarbonates, and the overlying part containing metaconglomerates, or metaarkoses, and metaquartzites.

The studied region (Fig. 1) is formed further by schists of the Hron Complex (Klinec, 1966) with amphibolite and metaquartzite intercalations. Metamorphism reached in this complex the conditions of garnet zone. The thermal climax in these rocks determined by Shengeliya et al. (1978) on the basis of graphite thermometer was at 400—450 °C. Bezák (1988) distinguished the schists occurring around Hnúšťa as a part of a separate complex which he called Ostrá Complex. NW of this complex lies the Kráľovohoľský Complex represented by a large body of hybrid granites and migmatites; this complex belongs nevertheless already to the Kráľovohoľská Zone.

Phyllites of the Hladomorná Valley Formation, Lower Paleozoic in age, occur in the SE part of the studied territory (Klinec et al., 1982). Planderová — Vozárová (1978) determined palynologically the presence of the Upper Carboniferous in these rocks. Later Klinec and Planderová (1981) confirmed in the rocks from the drillhole KV-3 (Rochovce) the presence of palynomorphs indicating Lower Paleozoic age and they suggested that the formation is stratigraphically heterogenous. Vozárová — Vozár (1982) distinguished in the basal part of the southern Veporicum mantle the

Revúca Group consisting of the Upper Carboniferous Slatvina Formation and the Permian Rimava Formation. They classified a substantial part of the Hladomorná Valley Formation - in a belt from Ľubeník to Poltár - with the Slatvina Formation. The rocks of the Revúca Group are according to their opinion contact-metamorphosed by the Lower Cretaceous Rimavica Granitoid. The inner part of the contact aureole is characterized by almandine-biotite isograde and the outer part by chlorite isograde (V o z á r o v á — V o z á r, 1988). J. K a m e n i c k ý (1977) described cordierite occurring inmediately next to the contact, in association with garnet and in places sillimanite. He estimated the temperature on contact at 500 °C.

Garnet-containing assemblages of gneisses and schists

Garnet is one of the principal rock-forming minerals in all rock types of the Kohút Crystalline Complex in the Hnúšťa region: in the mica schists of the Ostrá Complex, in paragneisses and schists of the Klenovec Complex and in phyllites and schists of the Hladomorná Valley Complex. The associations of garnets are rather monotonous: they are biotite-chlorite-muscovite-garnet, muscovite-garnet and muscovite-chlorite-garnet schists and paragneisses with quartz and variable content of acid plagioclases, ilmenite, frequently also with graphite. A characteristic feature of all garnet-mica schists of the Kohút Zone is the constant presence of zoisite or low-iron clinozoisite. This allows to classify them with the group of rocks saturated simultaneously with calcium and aluminium. The increased content of Ca in garnet-mica schists and carbonaceous phyllites (primarily pelitic sediments or clays) is rather unusuall. The whole alumina surplus in these rocks is bound to calcium in the form of clinozoisite, which explains the almost total absence of such alumina-rich minerals like chloritoid, staurolite or aluminium silicates in the metapelites. On the other hand, Ca-surplus in garnet-mica schists leads sometimes to the appearance not only of clinozoisite but also of calcite. Such rocks occur in the Hladomorná Valley Complex.

Garnet forms porhyroblastic grains 0.2—3 mm in size in quartz-mica groundmass. Its grains have round contours, with not very marked, but sometimes well-discernible dodecahedral shapes.

Garnet-bearing rocks are intercalated by biotite-chlorite-muscovite, muscovite, chlorite-muscovite schists. The Ostrá Complex contains a considerable amount of hornblende-epidote and hornblende-chlorite-epidote orthoamphibolites with metaporphyric textures, as well as hornblende-epidote ± carbonate-biotite paraamphibolites of tuffogenic-sedimentary origin.

The critical paragenesis of the progressive stage of metamorphism is in all theree complexes (Fig. 1) garnet + biotite + chlorite + muscovite + quartz, all of the minerals being in complete equilibrium. Their compositions, as we intend to show later, vary in very narrow ranges, indicating a uniform, single-stage character of metamorphism in the complexes of Ostrá, Klenovec and Hladomorná Valley in the Hnúšťa region.

The garnet-mica schist are intercalated by biotite-chlorite-muscovite, biotite-muscovite and chlorite-muscovite schists. Thus, the following parageneses are stabile in the rocks of the Kohút crystalline complexes in the Hnúšťa region:

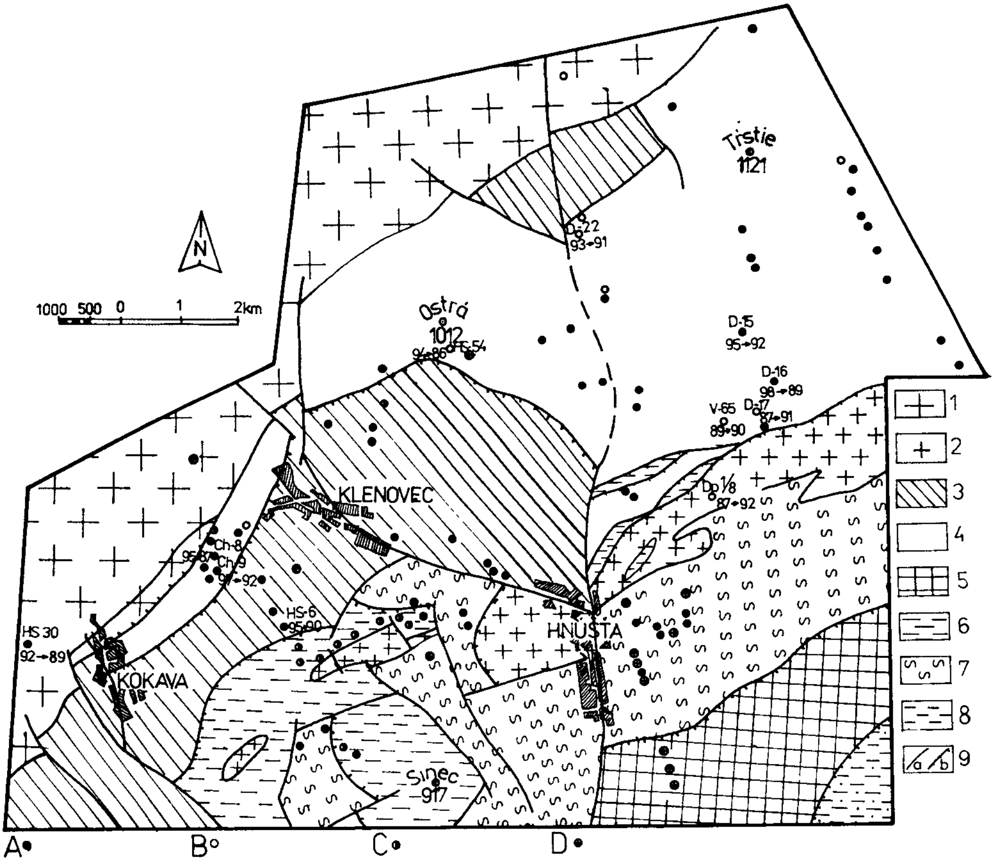

Fig. 1. A scheme of the distribution of rock complexes in the middle part of the Kohút Complex (B e z á k, 1982).
Legend: 1 — Kráľovoholský Complex (hybride granitoids, migmatites); 2 — Rimavica Complex (leucocrate granitoids); 3 — Klenovec Complex (biotite albite gneisses); 4 — Ostrá Complex (garnet schists, amphibolites); 5 — Rimava Formation (schists, metaarkoses); 6 — Sinec Complex (schists, magnezites, metaconglomerates); 7 — Hladomorná Valley Complex (phyllites, gneisses); 8 — Dobšiná Group (phyllites — Gemericum); 9 — tectonic lines (a — faults, b — overfaults, overthrusts). Mineral associations of the studied samples: A - Gr + Chl + Mu ± Bi; B - Gr + Bi + Mu; C - Bi + Chl + Mu; D - Chl + Mu (no Bi).

mica schists, phyllites and paragneisses

Bi + Gr + Chl + Mu + Clz ± Pl + Q ± Grph + Ilm*

Gr + Mu ± Chl ± Clz ± Pl + Q ± Grph + Ilm .

Bi + Chl + Mu + Clz ± Pl + Q ± Grph + Ilm

Mu + Chl ± Clz ± Pl + Q ± Grph + Ilm

Bi + Gr + Cc + Chl + Clz ± Pl + Q ± Grph + Ilm

amphibolites

Hrb + Ep ± Chl ± Cc + Pl + Q +Sph

Hrb + Bi + Ep ± Chl + Cc + Pl + Q + Sph

Secondary retrograde processes have been fixed in some rock varieties. They are the following processes: partial substitution of biotite (rarely of garnet) by secondary fine-flaked chlorite with sagenite inclusions; substitution of oligoclase by albite with inclusions of clinozoisite and sericite; silicification along layers.

In such retrograde-altered rocks garnets are frequently surrounded by a secondary margin which can be frequently optically well distinguished (Fig. 2). The trend of composition changes in the margins of garnet is contrary to that observed in the prograde stage.

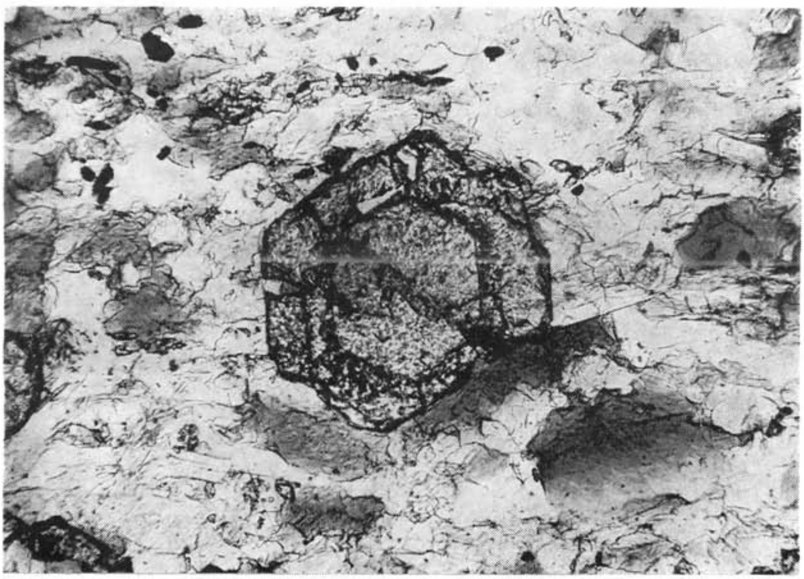

Fig. 2. Retrograde margin of Ça-rich garnet around almandine-pyrope-spessartite garnet. Sample Dp-1/8, enlarg. 120. Mica schist of the Hladomorná Valley Complex.

* *Symbols of minerals:* Ab - albite, Als - aluminium silicate, An - anorthite, Bi - biotite, Cc - calcite, Chl - chlorite, Chld - chloritoid, Clz - clinozoisite, Gr - garnet, Gros - grossularite, Grph - graphite, Hrb - hornblende, Ilm - ilmenite, Ky - kyanite, Mu - muscovite, Pl - plagioclase, Pr - pyrope, Q - quartz, Spes — spessartite, Sph - sphene, St - staurolite.

Prograde-zoned garnets

The prevailing majority of garnets from schists and paragneisses of the Hron, Klenovec and Hladomorná Valley complexes are prograde-zoned. As shown by detailed microprobe profiling of these garnets, carried out on

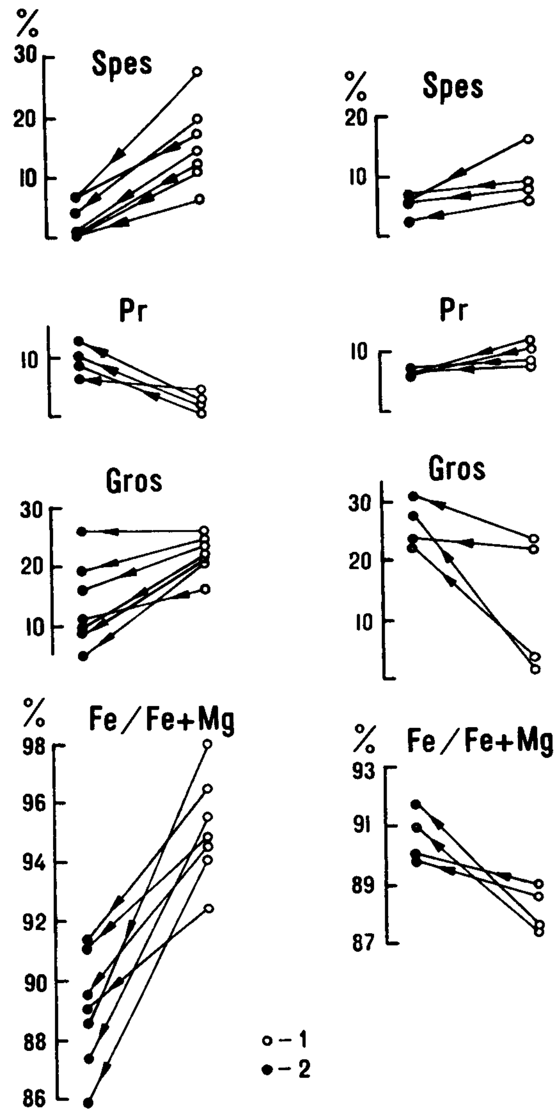

Fig. 3. Change of the contents of spessartite, pyrope, grossularite and the value of Fe/Fe + Mg in garnets with progressive (1) and retrograde (2) zoning according to data from Tabs. 1—4 (1 — centre, 2 — rim of garnet grains).

Table 1

Results of detailed profiling of garnets with progressive type of zoning from paragneisses and schists (component compositions, %)

CH-9	Diameter of grain 2700 μ, probe step ~17 μ															
	left edge							centre			right edge					
No. of point on profile	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Alm	82.3	79.0	77.3	74.9	72.5	70.7	67.6	61.2	63.2	63.4	64.3	65.9	69.4	74.8	78.3	81.4
Spes	—	—	1.4	2.4	4.5	6.5	8.2	10.0	11.7	11.7	11.0	9.3	6.9	2.4	2.1	0.3
Pr	7.6	6.9	5.8	4.2	3.8	3.7	3.7	1.8	3.1	2.8	2.4	3.1	3.4	4.5	4.5	5.5
Gros	10.1	14.1	15.5	18.5	19.2	19.1	20.5	27.0	22.0	22.1	22.3	21.7	20.3	18.3	15.1	12.8
$\frac{Fe+Mg}{Fe}$, %	91.5	92.0	93.0	94.7	95.0	95.0	94.7	97.1	95.3	95.8	96.4	95.5	95.3	94.3	94.6	93.6
D-16	Diameter of grain 2800 μ, probe step ~200 μ															
	left edge						centre		right edge							
No. of point on profile	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
Alm	73.8	78.2	78.1	71.5	71.3	67.8	66.4	67.4	68.6	72.8	75.9	79.3	77.9	80.3		
Spes	—	—	0.3	2.8	6.2	9.3	11.1	10.8	7.4	4.8	1.7	0.7	1.0	—		
Pr	9.0	6.2	3.8	4.5	3.1	2.1	1.7	1.4	2.7	2.4	3.8	3.9	7.6	10.0		
Gros	17.2	15.6	17.8	21.2	19.4	20.8	20.8	20.5	21.3	20.0	18.3	16.5	13.5	9.7		
$\frac{Fe+Mg}{Fe}$, %	89	92.6	95.3	94.0	95.8	97.0	97.4	97.9	96.2	96.8	95.2	95.3	91.1	88.8		

Continuation of Tab. 1

D-22	Diameter of grain 1600 μ, probe step ~100 μ													
	left edge						centre				right edge			
No. of point on profile	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Alm	76.5	74.9	71.6	69.7	73.1	74.0	67.7	69.0	71.9	68.4	66.5	76.2	75.6	76.9
Spes	—	—	0.7	5.2	2.4	1.4	5.8	4.9	3.8	6.5	5.2	1.0	—	—
Pr	7.2	6.6	6.9	4.1	5.6	4.1	3.8	4.9	4.4	4.1	5.2	7.6	7.9	7.1
Gros	16.3	18.5	20.8	21.0	18.9	20.5	22.7	21.2	19.9	21.0	23.1	14.5	16.5	16.0
$\frac{Fe+Mg}{Fe}$, %	91.3	91.9	91.2	94.3	92.8	94.7	94.7	93.4	94.2	94.3	92.8	90.9	90.5	91.5

HS-30	Diameter of grain 300 μ, probe step ~25 μ											
	left edge					centre				right edge		
No. of point on profile	1	2	3	4	5	6	7	8	9	10	11	12
Alm	62.8	54.6	53.8	52.4	52.1	49.2	50.5	49.9	50.0	53.6	56.5	62.2
Spes	3.9	11.3	13.7	15.7	17.5	18.7	18.9	20.2	19.3	16.0	12.0	4.5
Pr	7.0	6.1	6.5	4.9	4.4	5.0	4.1	4.9	4.5	4.8	4.8	7.6
Gros	26.3	28.0	27.0	26.9	26.0	27.1	26.5	25.0	26.2	25.6	26.7	25.6
$\frac{Fe+Mg}{Fe}$, %	89.9	90.0	90.7	91.5	92.1	90.7	92.4	91.1	91.8	91.8	92.2	89.1

Paragenesis: CH-9 — Gr + Bi + Chl + Mu ± Clz + Ilm + Q; clinozoisite grains occur in the form of inclusions in garnet but they are absent in the mesostasis of the schist.
D-16 — Gr + Mu ± Bi ± Chl ± Clz + Tour + Ilm + Q; clinozoisite inclusions are only in garnet, but not in the mesostasis.
D-22 — Gr + Bi + Mu + Chl + Clz + Ilm + Pl + Q; (retrograde saussuritization of plagioclase). HS-30 — Gr + Bi + Mu + + Chl + Clz + Pl + Ilm + Q; relics of metapsammite texture.

Table 2

Representative compositions of garnets with progressive zoning and of associated minerals (wt. %) from paragneisses and mica-schists

Sample No.	HS-6				CH-8					HS-54		
Mineral	Gr		Bi	Chl	Gr	Gr	Chl	Gr	Chl	Gr		Chl
Part of grain	centre	rim			centre	left edge		right edge		centre	rim	
Analysis No.	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	38.42	39.20	38.84	28.64	36.68	38.69	27.29	36.68	25.07	37.73	38.57	27.51
TiO_2	0.18	0.08	1.49	0.11	0.15	0.07	0.12	0.12	0.12			
Al_2O_3	21.60	21.57	19.99	24.27	19.92	21.19	24.36	19.68	22.64	21.21	21.87	25.93
FeO	24.14	28.99	17.49	21.63	24.09	32.56	26.49	31.41	27.94	27.21	36.07	25.69
MnO	7.66	2.47	0.10	0.14	12.51	2.69	0.28	2.90	0.25	5.91	0.28	0.14
MgO	0.78	1.89	10.41	15.67	0.68	2.62	14.29	1.47	12.53	0.95	3,32	13.60
CaO	8.27	6.47	0.04	—	5.86	3.95	0.08	6.47	—	7.32	1.79	0.08
Na_2O			—	—			—		—			
K_2O			8.97	0.01			—		0.2			
Total	101.05	100.67	97.33	90.47	99.89	101.77	92.91	99.00	88.57	100.33	101.90	92.95
$\frac{Fe}{Fe+Mg}$, %	94.6	89.6	48.5	43.6	95.2	87.4	51.0	92.3	55.5	94.1	85.9	51.4
Components of garnet:												
Alm	55.0	67.2			53.0	72.4		68.9		61.5	80.9	
Spes	17.7	5.8			27.9	6.0		6.4		13.5	0.6	
Pr	3.2	7.8			2.6	10.4		5.7		3.8	13.3	
Gros	24.1	19.2			16.5	11.2		19.0		21.2	5.2	

Paragenesis: HS-6 — Gr + Bi + Chl + Zs + Grph + Ilm + Pl + Q; (slight retrograde substitution Gr → Chl, Pl → Ser); CH-8 — Gr + Chl + Mu + Clz + Ilm + Q; HS-54 — Gr + Chl + Mu ± Clz + Ilm + Tour + Q; clinozoisite inclusions only in garnets.

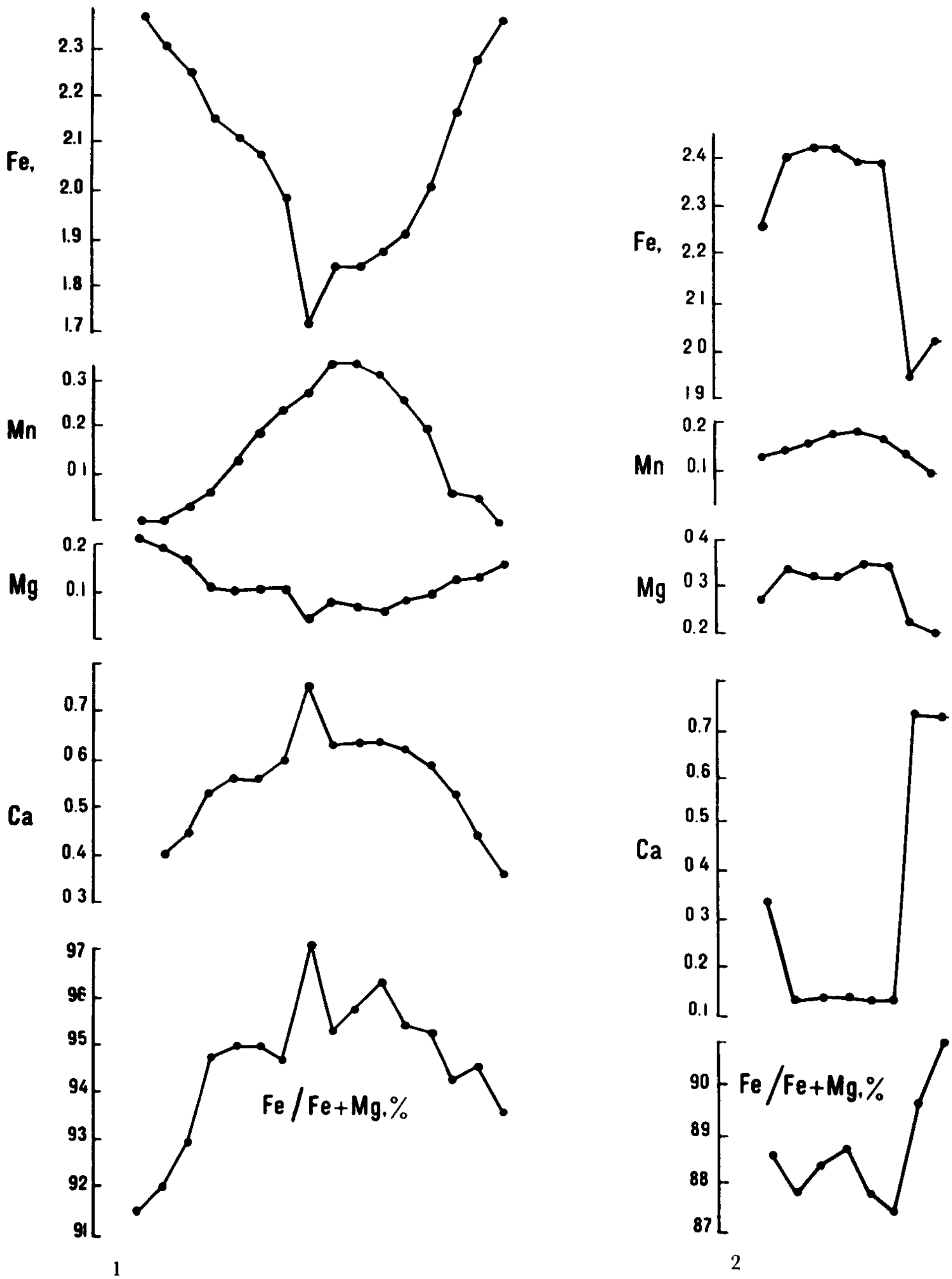

Fig. 4. Characteristic types of zoning in garnets, mica-schists and paragneisses. *Explanations:* 1 — progressive (Sample CH-9) and 2 — retrograde (Sample D-17), according to data from Tabs. 1 and 3.

the apparatus CAMSCAN-4 DV with the LINK spectrometer at the Moscow University, the contents of Mn and Ca (spessartite and grossularite) decrease and the contents of Fe and Mg (almandine and pyrope) increase from centre to rim, and at the same time the ratio Fe/Fe + Mg decrease due to the increase of Mg-content (Tab. 1, Fig. 3, 1). However, the ferruginity of central as well as peripheral parts of garnets remains very high — in samples from the complexes of Ostrá, Klenovec and Hladomorná Valley it never falls bellow 86 % (Tabs. 1 and 2).

As a rule the changes of garnet composition from centre to rims are relatively gradual (Sample CH-9 and D-22 — Fig. 4, 1), but sometimes we can observe a perhaps more rapid, even abrupt increase of Mg-content and thus a decrease of the value of Fe/Fe + Mg (Sample D-16, Tab. 1). The change of the content of Mn is always smoother, and manganese frequently disappears altogether in the marginal zone (CH-9, D-16 and D-22).

An increased content of Ca (16—28 % of grossularite) in the central part of garnet or along the whole profile (Sample HS-30) is characteristic of all garnets.

The increased admixture of grossularite is usually due to the increased calcium content of the rocks themselves, since zoisite or clinozoisite is present in all studied samples. However, with increased temperature Ca was redistributed from garnet to plagioclase as a result of which oligoclases are formed in place of early low-temperature albites. This leads to the depletion of garnets in Ca - a typical feature of prograde zoning in garnets of low and medium metamorphic grades (A l b e e, 1965; B r o w n, 1969; C r a w f o r d, 1971).

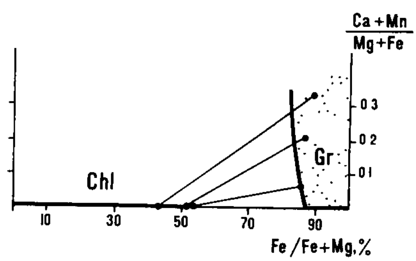

Fig. 5. Relations of ferruginity of coexisting garnets and chlorites in proportion to the contents of Mn and Ca in garnet.

Prograde-zoned garnets are coexisting (Tab. 2) with biotites which have moderate TiO_2 contents as well as with chlorites with a ferruginity of 44—55 %. The distribution of Fe and Mg in the pair garnet-chlorite, as it is usually characteristic for rocks of the garnet subfacies (A l b e e, 1965; K o r i k o v s k y et al., 1973), is controlled by the contents of Ca and Mn in garnet: the higher the contents, the more magnesian is the coexisting chlorite (Fig. 5).

Facial conditions of progressive metamorphism

The stability of the paragenesis Gr + Chl + Mu + Q ± Bi on the whole studied territory (see Fig. 1), the narrow variations of mineral compositions in it — these features are determinative for the classification of all three complexes of the Kohút Zone in the Hnúšťa region with either garnet, or staurolite-chloritoid subfacies (K o r i k o v s k y, 1979). The garnets in high--temperature conditions - in staurolite-chlorite or staurolite-kyanite-biotite subfacies - are higher-magnesian, prograde-zoned crystals change into more homogeneous ones and the paragenesis Gr + Chl + Mu + Q decomposes and it is substituted by the association St + Bi ± Ky(Andl). This paragenesis has not been observed in the studied section of the Kohút Zone and thus metamorphic temperature did not reach medium stages of the staurolite facies.

Regardless of the presence of the association Gr + Chl + Mu + Q, the relation of the compositions of the external margins in prograde-zoned garnets and of the coexisting biotites and chlorites indicates a not very marked thermal gradient in the studied territory, the temperature increasing from south--east to north-west. This is indicated by two facts.

The first one is that the limits of magnesium content in garnets of the paragenesis Gr + Chl + Bi + Mu + Q attain their highest values in north-east of the studied territory. Thus, in Sample HS-54 (Tab. 2) from a site 3 km NNE of Klenovec the ferruginity of garnet is 86 % (pyrope content 13 %) and at the same time, on the rest of the territory the ferruginity is nearer to 90 %. Garnet ferruginity of 86 %, as observed in many regions (A l b e e, 1972; F o x, 1971; S c h r e y e r — C h i n n e r, 1966; B a l t a t z i s, 1979; K o r i k o v s k y, 1979), is characteristic of rocks of the staurolite-chloritoid subfacies. North of Klenovec was the metamorphic grade perhaps even higher, since chlorite disappears from the paragenesis Gr + Bi + Mu + Q (see Fig. 1).

The second direct evidence of the pertinence of the north-western part of the territory to the staurolite-chloritoid zone is the discovery of staurolite--chloritoid-chlorite-garnet schists in the Klenovec region by K r i s t; the equilibria in these rocks have been discussed in a special work (K o r i k o v s k y — K r i s t — B o r o n i k h i n, 1989).

The ferruginity of outer margins in prograde-zoned garnets from the rocks of the eastern and south-eastern part of the territory (Hnúšťa region and the left bank of the river Rimavica) does not fall bellow 87 %, usually it is between 89—90 % (Tabs. 1—5). Similar compositions of garnets and micas in the pair garnet-chlorite are characteristic of the upper stage of the garnet subfacies (A l b e e, 1965; B r o w n, 1969; C r a w f o r d, 1966; K o r i k o v s k y et al., 1973). The relatively low-temperature character of metamorphism of the rocks from the three complexes of the Kohút Zone - not only in the Hnúšťa region but also to the north-east, in the region of Rochovce (K o r i k o v s k y — J a n á k — B o r o n i k h i n, 1986)) - is confirmed by data obtained by biotite-garnet geothermometry.

For the determination of crystallization temperatures of schists and paragneisses from the Hnúšťa region we used the compositions of biotite and garnet from the samples HS-6 (Tab. 2), D-17 (Tab. 3) and DP-1/8. Analyses of minerals from the garnet-chlorite-biotite schist DP-1/8 collected in the Hladomorná Valley Complex, 1.5 km east of Mútnik, have been presented in another paper; here we shall only demonstrate that the ferruginity of biotite from this rock is 49.9 % and the ferruginity of the outer margin in the coexisting garnet 91.6 %.

For the rocks of the Hladomorná Valley Formation, north-east of Hnúšťa, near Rochovce, we used biotite-garnet pairs from the samples D-28 (Tab. 4) and the earlier analysed B-10 (Korikovsky et al., 1986).

Experience has shown that the most accurate geothermometer for rocks of the garnet and staurolite-chloritoid subfacies is the biotite-garnet geothermometer of Ferry and Spear (1978). According to this geothermometer the crystallization temperature of the sample HS-6 is 431 °C, of the sample DP-1/8 440 °C, the sample D-17 548 °C, the sample D-28 451 °C and of the sample B-10 442 °C.

The only evidently increased estimate among these determinations is that for the sample D-17. The other 4 values fall into the range of 431—451 °C, corresponding on the petrogenetic grid to the stability field of garnet and staurolite-chloritoid subfacies (Korikovsky, 1979).

The AKFM diagram (Fig. 6) displays the mineral assemblages of garnet-mica schists of the staurolite-chloritoid subfacies in the Kohút Zone in the region of Hnúšťa. We succeeded in determining the mineral compositions in two rock types of the staurolite-chloritoid subfacies (Fig. 6): in common garnet-biotite-chlorite-muscovite schists and paragneisses of the Ostrá and Klenovec complexes, and in high-alumina staurolite-garnet-chloritoid schists forming intercalations among paragneisses of the Klenovec Formation (Korikovsky et al., 1989). Looking on the diagram it is apparent that stabile assemblages in the most common moderate-aluminous rocks with compositions lying bellow the connode Gr—Chl are Gr + Chl + Bi + Mu + Q and Bi + Chl + + Mu + Q. Staurolite and chloritoid are in this subfacies stabile only in super-aluminous rocks the compositions of which should lie on the diagram above the connode Gr + Chl.

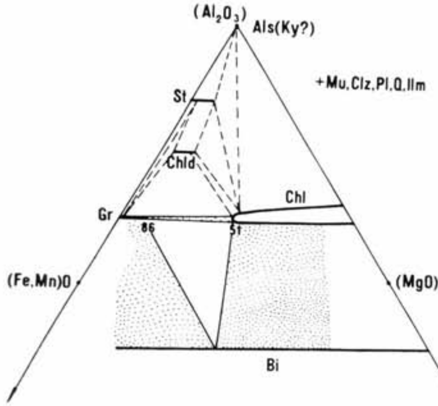

Fig. 6. Mineral parageneses of schists and paragneisses of staurolite-chloritoid subfacies on the diagram AKFM.

In rocks of the garnet subfacies (eastern and north-eastern part of the Kohút Zone) from the Ostrá, Klenovec and Hladomorná Valley complexes it was possible to study only the equilibria in garnet-mica schists, i.e. moderately aluminous rocks. Super-aluminous rocks do not occur here. However, if they would be present in one of the complexes, chloritoid, chlorite and aluminium silicate (kyanite or andalusite), analogically with other regions (Albee, 1965; Korikovsky—Boronikhin, 1976), would be stabile in these rocks. Possible associations of such rocks in the garnet subfacies would lie on the diagram above the connode Gr + Chl (Fig. 6).

In this place we cannot avoid to make a note of the fact that on the eastern flank of the Kohút Zone, in the Rimava Formation including except the Hladomorná Valley Complex also the Revúca Group (Vozárová — Vozár, 1982), there is an elongated horizon of chloritoid, garnet-chloritoid and kyanite-chloritoid schists which have been studied in detail by Vrána (1964). Metamorphic grade of these rocks - judging from the stability of kyanite and garnet - corresponds to the garnet subfacies. Such coincidence of metamorphic grade of the schists from the Hladomorná Valley Formation and aluminous rocks of the Rimava Formation can be hardly accidental. This shows that the geological uniformity of the Hladomorná Valley Formation and the Rimava Formation determined by Vozár (Vozárová — Vozár, 1982) confirms the uniformity of their metamorphism. Thus we can assume that rocks of the Hron, Klenovec and Hladomorná Valley complexes, together with chloritoid schists of the Klenovec region were simultaneously progressively metamorphosed in one cycle of zonal metamorphism affecting the rocks of the Kohút Zone.

It is considerably more difficult to estimate the depth of progressive metamorphism than its temperature since there is no accurate geobarometer for garnet-mica schists not containing aluminium silicates.

However, a qualitative estimate is possible. The high magnesium content of garnet in the paragenesis Gr + Chl + Mu + Bi + Q (13 % of pyrope in the sample HS-54, Tab. 2), the considerable admixture of grossularite in pyrope-almandine garnets from mica schists (16—18 %, Tabs. 1—2) are characteristic, according to a comparison with other regions, only of complexes with kyanite-sillimanite type of metamorphism, corresponding to the pressure of 4 kbar (Albee, 1962, 1972; Korikovsky — Fedorovsky, 1980). The stability of kyanite and not of andalusite in chloritoid schists of the Rimava Formation confirms this conclusion.

The age of progressive metamorphism can be estimated on the basis of the age of magmatic zircon from the synmetamorphic Rimavica Granites which are cutting on the studied territory through the schists of the Hladomorná Valley Formation. Prismatic magmatic homogeneous zircon in which scannig has shown neither old cores nor outer, yonger regeneration rims gives a concordant age of 350 ± 5 m.y. (Bibikova et al., 1988). The isotopic composition of the zircons did not preserve any signs of their thermal recrystallization in the Alpine cycle. Therefore we conclude that zonal metamorphism of garnet and staurolite-chloritoid subfacies is in all complexes of the Kohút Zone of the same age corresponding to the Lower Carboniferous.

Retrograde-zoned garnets

In contrast to progressive metamorphism, retrograde processes — chloritization, sericitization, albitization, silicification, formation of retrograde rims on garnets — affected the studied rocks unevenly. They were most intensive in the exocontacts of the Rimavica Granites, or along faults and zones of secondary schistosity which were the conductors of low-temperature fluids.

When determining the age of these processes it is necessary to take into consideration that retrograde sericitization (muscovitization) and albitization of schists near granites is according to its mineral manifestations and chemical trends (acid leaching) identical with autometasomatic processes in the Rimavica Granites. This could be an indication of genetic correspondence of both processes. The similarity of retrograde metamorphism of schists and autometasomatism in granites is even more marked in the view of the fact that metamorphic garnets as well as magmatic garnets in the Rimavica Granites were affected by the same type of retrograde recrystallization — the formation of outer rims enriched considerably in grossularite (G r e g u š, 1982; K o r i k o v s k y — D u p e j — Z i n o v i e v a, 1989).

The first one to determine grossularization of pyrope-almandine garnets in metamorphic rocks of Veporides was G r e g u š (1982). The scanning carried out by the cited author made it possible to explain the fact that grossularite--enriched parts form the outer rims of garnets or they penetrate into the crystals in the form of veinlet-like segregations. G r e g u š related these phenomena to the retrograde stage of the Variscan metamorphic cycle pointing out at the same time the more intensive manifestations of these processes on the periphery of migmatitic granitization zones.

Our data confirm the fundamental conclusions of G r e g u š and they allow to determine new details of the process.

Tab. 3 lists data on the profiling in garnet from retrograde-altered garnet--mica paragneisses (Sample D-17). The study showed that the central part of the garnet preserved elements of prograde zoning — i.e. a certain increase of Mg contents towards the edges, a decrease of Mn contents and of the ratio Fe/Fe + Mg (Tab. 3 and Fig. 4, 2). However, in the 30—80 microns wide outermost zone there is a sharp change in the composition of the garnet and its zoning. It shows in the abrupt increase of grossularite contents (from 4—4.5 in the centre of the grain to 11—24 % in the margin), as well as in the considerable decrease of Mg content and increase of the value Fe/Fe + Mg.

Simultaneously there was strong saussuritization of primary oligoclase which was replaced by albite No. 2—5 with sericite inclusions. Thus, the connection of these processes — deanorthization of plagioclase and grossularization — is evident.

At the same time, it is interesting that there is no retrograde increase of Mn content in the marginal zone and its quantity continues to decrease gradually, similarly as in the central, prograde part of the garnet.

Similar type of retrograde zoning, as shown by the results of profiling in other garnet grains from gneisses and schists, is typical of the Kohút crystalline complex.

Corresponding data have been obtained from retrograde-altered garnets occurring in the group of extraordinary calcite-bearing garnet-mica schists of the Hladomorná Valley Complex (Tab. 4). These rocks have been selected with the purpose of determining the upper limit of grossularite content in pyrope-almandine garnets of the prograde and retrograde stage. The content of grossularite in garnets from calcite-bearing schists (Sample D-28 and V-65) increases by 2—8 % - from 22—23 % in the centre to 24—31 % in the marginal zone (which, as it turned out, almost does not differ from the content of grossularite in garnets from common clinozoisite-bearing schists — compare with

Table 3

Composition of garnet with retrograde zoning and associated minerals (wt. %) from garnet-mica gneisses (sample D-17)

Sample No.	D-17										
Mineral	(transverse profile)								Bi	Pl	
Part of grain	left edge			centre		right edge					
Analysis No.	1	2	3	4	5	6	7	8	9	10	11
SiO_2									36.57	66.61	66.99
TiO_2									1.01		
Al_2O_3									19.85	20.37	19.71
FeO	32.72	35.16	35.52	35.59	35.03	34.80	29.14	30.17	21.67		
MnO	1.75	1.83	1.87	2.28	2.39	2.20	1.63	1.16	0.14		
MgO	2.34	2.79	2.60	2.53	2.79	2.85	1.91	1.72	7.41		
CaO	3.90	1.45	1.54	1.46	1.42	1.46	8.59	8.28	0.08	1.30	0.56
Na_2O									0.13	12.68	12.63
K_2O									9.56	0.10	0.10
Total									96.42	101.06	99.99
$\frac{Fe}{Fe+Mg}$, %	88.6	87.8	88.4	88.7	87.6	87.3	89.6	90.9	62.1		
Components of garnet:										5.4 % An	2.4 % An
Alm	74.9	80.2	80.8	80.4	79.2	79.2	64.4	67.0			
Spes	4.1	4.3	4.2	5.2	5.5	5.1	3.7	2.6			
Pr	9.5	11.2	10.5	10.2	11.2	11.5	7.5	6.7			
Gros	11.5	4.3	4.5	4.2	4.1	4.2	24.4	23.7			

Paragenesis: D-17 — Gr + Bi + Mu + Tour + Pl + Q; (retrograde substitution Gr →Chl, Pl-- →Ab+Ser.

Table 4

Composition of garnets with retrograde zoning and associated minerals (wt. %) from calcite-bearing garnet-mica gneisses

Sample	D-28							V-65m				
Mineral	Gr	Chl	Gr	Chl	Bi	Pl	Cal	Gr		Chl	Pl	Cal
Part of grain	centre		at outer edge					centre	edge	at outer edge		
Analysis No.	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	38.05	26.44	37.63	27.59	38.29	67.80		39.40	38.84	26.82	65.92	
TiO_2	—	0.07	0.15	0.07	1.52			0.08	0.08	0.07		
Al_2O_3	20.88	23.61	20.68	23.83	20.02	20.01		20.64	20.54	21.24	22.89	
FeO	27.43	24.85	27.64	23.02	17.98			26.89	25.66	28.26		5.48
MnO	3.80	0.26	3.27	0.17	0.10		0.27	3.59	3.11	0.18		0.65
MgO	1.87	13.61	1.69	15.04	9.23		0.43	1.91	1.56	12.35		3.33
CaO	7.60	0.13	8.53	0.08	0.14	1.00	57.37	7.81	11.16	0.38	2.91	46.11
Na_2O		0.13		0.27	0.38	11.43				0.12	9.58	
K_2O		—		—	9.26	0.04				0.01	0.06	
Total	99.63	98.04	99.59	99.01	96.91	100.28		100.32	100.95	89.43	101.36	
$\frac{Fe}{Fe+Mg}$, %	89.2	50.6	90.2	46.2	52.2			88.8	90.2	56.2		
Components of garnet:												
Alm	61.9		61.6			4 % An		61.2	55.9		14 % An	
Spes	8.7		7.4					8.3	6.9			
Pr	7.5		6.7					7.7	6.0			
Gros	21.9		24.3					22.8	31.2			

Parageneses: D-28 — Gr + Bi + Chl + Mu + Cal + Pl + Q; retrograde substitution Pl→Ser. V-65m — Gr + Bi ± Chl + Cal ± ± Clz + Mgt + Pl + Q; retrograde substitution Bi→Ser, Pl→Ser.

Table 5

Important constants of analysed minerals and their parageneses in garnet-mica schists and gneisses of Kohút crystalline complexes (according to data from Tab. 1—4)

Sample No. part of garnet grain	Gr					Chl	Bi	Pl	Paragenesis
	Alm	Spes	Pr	Gros	$\frac{Fe}{Fe+Mg}$, %	$\frac{Fe}{Fe+Mg}$, %	$\frac{Fe}{Fe+Mg}$, %	An, %	
1	2	3	4	5	6	7	8	9	10
I. Rocks containing prograde-zoned garnets									
HS-6									Gr + Bi + Chl + Zs + + Grph + Ilm + Pl + + Q
centre	55.0	17.7	3.2	24.1	94.6				
rim	67.2	5.8	7.8	19.2	89.6	43.6	48.5		
CH-8									Gr + Chl + Mu + + Clz + Ilm + Q
centre	53.0	27.9	2.6	16.5	95.2				
left edge	72.4	6.0	10.4	11.2	87.4	51.0			
right edge	68.9	6.4	5.7	19.0	92.3	55.5			
HS-54									Gr + Chl + Mu ± ± Clz + Ilm + Tour + + Q
centre	61.5	13.5	3.8	21.2	94.1				
rim	80.9	0.6	13.3	5.2	85.9	51.4			
CH-9									Gr + Bi + Chl + Mu ± ± Clz + Ilm + Q
centre	61.2	10.0	1.8	27.0	97.1				
left edge	82.3	—	7.6	10.1	91.5				
right edge	81.4	0.3	5.5	12.8	93.6				
D-16									Gr ± Bi ± Chl + Mu ± ± Clz + Tour + Ilm + + Q
centre	67.4	10.8	1.4	20.5	97.9				
left edge	73.8	—	9.0	17.2	89.0				
right edge	80.3	—	10.0	9.7	88.8				
D-22									Gr + Bi + Chl + Mu + + Clz + Ilm + Pl + Q
centre	67.7	5.8	3.8	22.7	94.7				
left edge	76.5	—	7.2	16.3	91.3				
right edge	76.9	—	7.1	16.0	91.5				

Continuation of Tab. 5

HS-30									Gr + Bi + Chl + Mu + + Clz + Ilm + Pl + Q
centre	50.5	18.9	4.1	26.5	92.4				
left edge	62.8	3.9	7.0	26.3	89.9				
right edge	62.2	4.5	7.6	25.6	89.1				
II. Rocks containing retrograde or prograde-retrograde zoned garnets									
A. *Calcite-bearing garnet-mica schists*									
D-28									Gr + Bi + Chl + Mu + + Cal + Pl + Q
centre	61.9	8.7	7.5	21.9	89.2	50.6			
rim	61.6	7.4	6.7	24.3	90.2	46.2	52.2	4	
V-65m									Gr + Bi ± Chl + Cal ± ± Clz + Mgr + Pl + Q
centre	61.2	8.3	7.7	22.8	88.8				
rim	55.9	6.9	6.0	31.2	90.2	56.2		14	
B. *Garnet-bearing schists*									
D-17									
centre	79.2	5.5	11.2	4.1	87.6				
left edge	74.9	4.1	9.5	11.5	88.6				Gr + Bi + Mu +
right edge	67.0	2.6	6.7	23.7	90.9		62.1		+ Tour + Pl + Q
Dp-1/8									Gr + Bi + Chl + Mu + + Clz + Ilm + Pl + Q
centre	70.4	16.3	10.0	3.3	87.6				
rim	60.5	6.4	5.4	27.7	91.8	47.4	49.9		
VL-3/9.5m									Gr ± Bi + Chl + Mu + + Clz ± Pl + Q
centre	73.0	8.6	10.9	7.5	87.0				
left edge	66.2	3.5	6.2	24.1	91.5		44.5		
right edge	68.7	1.8	6.2	23.3	91.7		57.4	1.4	

Tab. 1). In the retrograde rim the content of Mg decreases and the value Fe/Fe + Mg increases. However, in these samples the content of Mn in the retrograde rims does not increase, as it is usual, but it decreases.

The grossularization of peripheral parts of garnets is similarly as in mica schists accompanied by a decrease of the An-content of coexisting plagioclases to No. 4—14 (Tab. 4).

It is impossible to estimate the temperature and pressure of the retrograde stage on the basis of geothermobarometry because of reactional, disequilibrium relations between minerals. However, the very high content of grossularite in the outer margins of pyrope-almandine garnets shows that the pressure of the retrograde stage was not less than 4 kbar.

All data on garnets with prograde and retrograde zoning and on the composition of coexisting minerals are listed in Tab. 5.

Interpretation of the origin of grossularite-rich retrograde margins of garnets

The indications of retrograde recrystallization of garnets in the metamorphic rocks of the Kohút crystalline complex are: the increase of the value Fe/Fe + Mg in the outer margin, the abrupt increase of Ca content with simultaneous decrease of Mn contents (Fig. 2, 2).

The first trend — decrease of Mg contents and increase of the value Fe/Fe + Mg in the margin is the most typical manifestation of retrograde processes and it can be explained by exchange reactions between garnet and biotite flakes from the surrounding mesostasis in the course of temperature decrease.

Far more interesting is the second trend — strong retrograde increase of Ca contents in the peripheral zone. The relationship of the changes in the composition of coexisting garnets and plagioclases indicates clearly a redistribution of Ca from plagioclase to garnet proportional to the decrease of temperature — a trend contrary to the one in the prograde stage (see Fig. 2). It can be observed petrographically that retrograde processes as a whole take place on the background of a supply of only K (sericitization of biotite and plagioclase) and not Na.

The retrograde exchange reaction between two minerals of the progressive stage — oligoclase and almandine-pyrope-spessartite garnet (the peripheral zone of which is due to prograde reactions strongly depleted in Ca) can be expressed the following way:

$$Gr_{Fe\text{-}Mg\text{-}Mn} + Pl_{30} \longrightarrow Gr_{Ca\text{-}Fe\text{-}Mg\text{-}Mn} + Ab$$

The reaction is isochemical as far as Ca, Al, Mg, Fe and Mn are concerned. This can be seen very well on Fig. 7, 1: the change of the prograde paragenesis $Gr_{Fe\text{-}Mg\text{-}Mn} + Pl_{30}$ into the retrograde $Gr_{Ca\text{-}Mn\text{-}Mg\text{-}Fe} + Ab$ does not alter the bulk composition of the garnet-plagioclase pair, only the composition of both minerals and their relative quantity in the rock are changed.

The latter can be estimated on the diagram 7, 1 on the basis of the "rule of lever". E.g., if the relationship of $Gr_{Fe\text{-}Mg\text{-}Mn}/Pl_{30}$ in any garnet-plagioclase

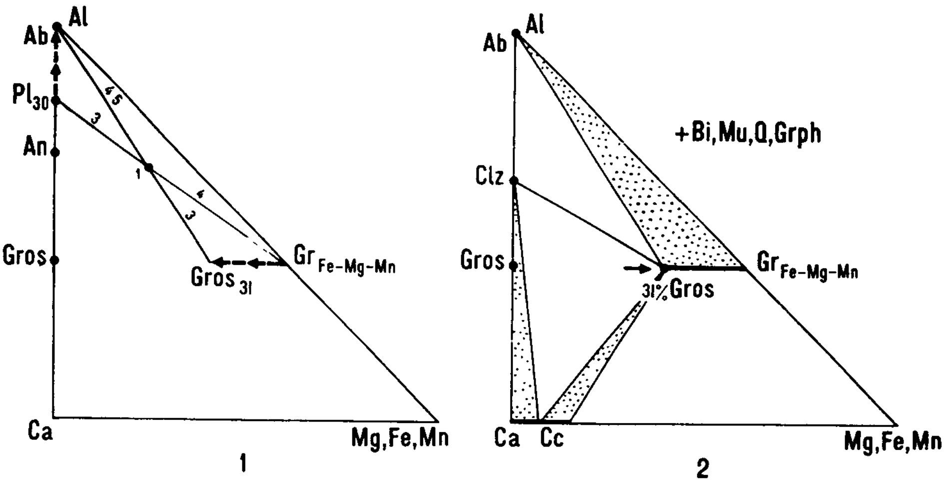

Fig. 7. Diagrams Al-Ca-(Mg, Fe, Mn) for equilibria with garnets having varying calcium contents in schists and paragneisses of the Kohút Zone.
Explanations: 1 — simultaneous change of the compositions of plagioclases and garnets (shown by arrows) in the course of the retrograde process, 2 — mineral equilibria of calcite-bearing garnet-mica schists of the Kohút Zone in the samples D-28 and V-65m, according to data from Tab. 4. The arrow shows the change of the content of grossularite molecule with P_{CO_2} increase.

mixture with the composition I were 3 : 4, the ratio of $Gr^{31\,\%\,Gross}_{Ca\text{-}Fe\text{-}Mg\text{-}Mn}$/Ab would, proportionally to the albitization of plagioclase and grossularization of garnet, attain the value 4.5 : 3, i.e. the amount of garnet increases and that of plagioclase decreases. At the same time, nucleation of new garnets is not necessary: they can grow on the existing garnet of the progressive stage. This practically means that the size of garnet grains should grow proportionally to the growth of the outer grossularite-rich retrograde margin. This trend can be actually observed in the retrograde-altered schists of the Kohút Zone.

Fig. 2 shows that retrograde Ca-rich rim can increase the width of the primary garnet grain by 1/10—1/5 of its original diameter, while garnet frequently acquires the form of a new dodecahedron. Similar "grossularite" type of retrograde recrystallization of garnets with an increse of its grain-size is relatively rare since the usual trend is opposite: the appearance of retrograde rims with increasing contents of only Mn and Fe in the peripheral zone is accompanied by resorbtion of the edges, by the loss of dodecahedral forms and often by a decrease of grain-size.

The discussed mechanism of retrograde recrystallization allows to explain also the third, very unusual feature of garnets from the Kohút Zone — the decrease (and not increase) of Mn content in the retrograde margin. It is well known that Mn does not occur in any considerable quantity in other coexisting silicates (biotite, chlorite, muscovite) and thus the resorbtion of garnet in retrograde stage leads to reversed diffusion of Mn into the crystal and followingly to the increase of Mn contents in the peripheral reaction zone of garnet (common variant).

If garnet increases in size during the retrograde stage, the original amount of Mn is redistributed on a large surface of the crystal and its absolute content in the outer zone should decrease, as it is the case in progressive growth zoning (the discussed variant).

This mechanism allows to explain the not wholly common features of the composition of retrograde margins in garnets from garnet-mica schists of the Kohút crystalline complexes.

What is the maximal limit of grossularite solubility in pyralspite garnets at the P-T conditions of the retrograde stage in the Kohút Zone? This question is interesting when inspected in the view of the fact that grossularite rims are formed not only around garnets from retrograde-metamorphosed gneisses and schists, but also around magmatic garnets from autometasomatically altered Rimavica Granites. At the same time, the content of grossularite in the outer margin of garnets from calcite-clinozoisite mica schists, where the Ca-content of garnets should be maximal, is 31 % (Tab. 4). In analogous garnet types from muscovitized and saussuritized Rimavica Granites it attains 55 % (Vrána, 1980; Korikovsky—Dupej—Zinovieva, 1989).

What is the cause of such difference in the solubility of grossularite in pyrope-almandine garnets at apparently similar P-T parameters of the process?

Fig. 7, 2 shows the assemblage of minerals from the sample V-65m. As in all parageneses with calcite, the compositions of all minerals are controlled not only by T and P, but also by partial pressure of CO_2 in fluids.

From the diagram on Fig. 7, 2 it follows that the coexisting minerals are bound by a reaction of the type

$$\mathrm{Gr}^{31\,\%\ \mathrm{Gross}}_{\mathrm{Ca\text{-}Fe\text{-}Mg\text{-}Mn}} + CO_2 \longrightarrow \mathrm{Gr}^{<31\,\%\ \mathrm{Gross}}_{\mathrm{Ca\text{-}Fe\text{-}Mg\text{-}Mn}} + \mathrm{Clz} + \mathrm{Cc}$$

The higher the partial pressure of CO_2 in retrograde metamorphism, the lower is the content of grossularite in garnet of the paragenesis Gr + Clz + Cc, and the more to the right is shifted the composition of garnet in this association — this shift is indicated on Fig. 7, 2 by an arrow.

In the case of a low partial pressure of CO_2, like e.g. in postmagmatic fluids in granites, the limit of grossularite solubility in pyralspite garnets is considerably increased and the content of grossularite in secondary margins around magmatic garnets can reach 55 %.

Conclusions

1. Progressive metamorphism of the Ostrá, Klenovec and Hladomorná Valley complexes in the Kohút Zone was a one-act process. Its intensity changes in north-western direction from garnet to staurolite-chloritoid zone.

2. In the majority of samples garnets are characterized by prograde zoning in the whole profile of grain, with a decrease of Mn and Ca contents and of the ratio Fe/Fe + Mg and increase of Mg contents from centre to rims.

3. Retrograde zoning occurs in garnets in the zones of retrograde alterations (sericitization, chloritization, saussuritization), with a reversed increase of Ca contents and of the value Fe/Fe + Mg and decrease of Mg and Mn contents towards the rims.

4. The analysis of exchange retrograde reactions in the pair garnet-plagioclase shows that plagioclase loosed Ca and garnet was enriched by this element. Grossularite margins growed on prograde-zoned garnets causing an increase of the grain-size of garnet.

Translated by K. Janáková

LOCALIZATION OF THE STUDIED SAMPLES

D-16 — Road-cut of the forrest road from Kvakov Hill (862.8 m) to Polom (approx. 3 km NE of Hnúšťa) 800 m S from the elev. point 862.8 m. Garnet schist of the Ostrá Complex. Gr + Mu ± Bi ± Chl ± Clz + Tour + Ilm + Q.
D-22 — Wall outcrop in the cut of the railway line Tisovec-Hnúšťa, approx. 100 m E of the cooperative Hačava. Muscovite-chlorite garnet gneiss to schist-gneiss of the Ostrá Complex. Gr + Chl + Bi + Mu + Clz + Ilm + Pl + Q.
D-17 — Wall outcrop approx. 800 m N of the village Polom near the mountain-ridge path from the Kvakov Hill to Polom. Two-mica garnet gneiss of the Ostrá Complex. Gr + Bi + Mu + Tour + Pl + Q.
D-15 — Rocky basement of the path approx. 100 m S of the elev. point 862.6 m (Kvakov Hill) 2 km N of the village Polom. Biotite-muscovite garnet schist of the Ostrá Complex. Gr + Bi + Mu + Chl + Clz ± Pl + Q.
D-28 — Road-cut of the forrest road to the ridge of the Ostrý Hill across Hladomorná Valley approx. 5 km N of the village Chyžné. Two-mica garnet schist-gneiss. Gr + Bi + Mu + Chl + Cal + Pl + Q.
Dp 1/8 — Cut of the forrest path approx. 1.5 km E of the deposit Mútnik and 200 m W of the elev. point 569.0. Garnet-chlorite-biotite schist of the Hladomorná Valley Complex. Gr + Bi + Chl + Mu + Clz + Ilm + Pl. + Q.
C-8 — Road-cut of the road Klenovec-Kokava nad Rimavicou, approx. 500 m from the memorial in the pass Chorepa in the direction to Kokava. Chlorite-muscovite garnet schist of the Ostrá Complex. Gr + Chl + Mu + Clz + Ilm + Q.
CH-9 — Road-cut of the road Klenovec-Kokava, approx. 600 m from the memorial in the Chorepa pass in the direction to Kokava. Chlorite-muscovite garnet schist of the Ostrá Complex. Gr + Mu + Chl + Bi ± Clz + Ilm + Q.
HS-6 — Wall outcrop on the left side of the path from the Chorepa pass to Bodnárka (833.2 m) approx. 100 m E of the lonely house Petošovo (1.5 km SE of Klenovec). Chlorite-biotite schist of the Klenovec Complex. Gr + Bi + Chl + Zs + Grph + + Ilm + Pl + Q.
HS-30 — Wall outcrop in the road-cut of the road Kokava-Hriňová approx. 1.5 km E of Kokava. Enclave of muscovite-biotite paragneiss in a complex of granitoids and migmatites (Kráľovohoľský Complex). Gr + Bi + Mu + Chl + Clz + Ilm + Pl + Q.
HS-54 — Wall outcrop 2 × 1 m in a road-cut of the forrest road from Klenovec to Ostrá approx. 250 m SW of the elev. point 897.1 m. Chlorite-muscovite garnet schist of the Ostrá Complex. Gr + Mu + Chl ± Clz + Ilm + Tour + Q.
V-65 m — sample from the borehole carried out by Ore Mines Hnúšťa in a road-cut of the road from Mútnik to Polom approx. 800 m NW of the village Polom, in overlying beds of the deposit Mútnik. Garnet-biote-carbonate schist. Gr + Cal + Bi ± ± Clz ± Cl + Mgt + Pl + Q.
VL-3/9.5 m — Sample from the borehole carried out by Ore Mines Hnúšťa approx. 400 m E of the village Polom. Garnet muscovite-biotite schist. Gr + Bi + Mu + + Pl + Ilm + Q.

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