

High-pressure garnet-bearing migmatites from the Chepelare area, Central Rhodope

Zlatka Cherneva^{1,2}, Milena Georgieva¹, Elena Stancheva², Ianko Gerdjikov¹

¹ Sofia University “St. Kliment Ohridski”, 1504 Sofia; E-mail: cherneva@gea.uni-sofia.bg

² Geological Institute, Bulgarian Academy of Sciences, 1113 Sofia;

(Submitted: 24.09.2007; accepted for publication: 16.11.2007)

3. Чернева, М. Георгиева, Е. Станчева, Я. Герджиков – Гранат-содержащие мигматиты, образованные при высоких давлениях (Чепеларский район, Центральные Родопы). Ассоциация гранатов с повышенным содержанием Са и плагиоклаза, обогащенного Na, является прямым индикатором плавления в условиях высокого давления. Гранат-содержащая лейкосома и аплитовидные гнейсы вершины Мечи чал (Чепеларский район Центральные Родоп) содержат ассоциацию минералов, образованных в условиях плавления при высоком давлении. Представлены: гранат с высоким содержанием Са (22–33% гроссуляра), антипертитовый плагиоклаз с повышенным Na-содержанием (An_{15–20}), пертитовый К-полевой шпат, кварц и поздний биотит, который замещает внешние зоны граната. Приблизительные условия, в которых происходила кристаллизация расплава, были в границах 1.6–1.9 GPa/800–850°C. Они значительно превышают P–T условия, вычисленные для центральнородопских мигматитов. В работе обсуждается значение плавления в условиях высокого давления при Альпийской метаморфической эволюции Центральные Родоп.

Abstract. The association of Ca-rich garnet and Na-rich plagioclase in migmatites is a proper indicator for high-pressure melting. Garnet-bearing leucosome and aplitoid gneiss from the Mechi Chal peak in the Chepelare area of the Central Rhodope comprise a mineral assemblage produced by high-pressure melting: Ca-rich garnet (grossular 22–33 %), Na-rich antiperthitic plagioclase (An_{15–20}), perthitic K-feldspar, quartz, and minor back reaction biotite replacing garnet rims. The approximate conditions of melt crystallization are in the range 1.6–1.9 GPa/800–850°C that is well above the P–T estimates available for the Central Rhodope migmatites. The study focuses attention on the key role of the high-pressure melting in the Alpine metamorphic evolution of the Central Rhodope.

Cherneva, Z., Georgieva, M., Stancheva, E., Gerdjikov, I. 2008. High-pressure garnet-bearing migmatites from the Chepelare area, Central Rhodope. — *Geologica Balc.*, 37, 1–2; 47–52.

Key words: HP-melting, garnet-bearing leucosome, Ca-rich garnet, Central Rhodope.

Introduction

Garnet-bearing migmatites refer usually to high-temperature fluid-absent melting of pelitic schists and biotite gneisses (Vielzeuf, Holloway, 1988; Gardien et al., 1995). Grossular-rich garnets in anatexitic melts argue for high-pressure conditions of dry decompression melting during exhumation of subducted

continental crust (Auzanneau et al., 2006; Lang, Gilotti, 2007). Garnet-bearing migmatites are not common in the Central Rhodope. Data available for garnet free migmatites indicate extensive fluid-present decompression melting of quartz-feldspar rocks at high-grade amphibolite facies (Cherneva et al., 1995; Cherneva, Georgieva, 2005). Recent data on amphibole-bearing leucosome crystallization at 760°C/0.8 GPa

to 650°C / 0.8–0.6 GPa however suggest higher-grade conditions of melting (Cherneva, Georgieva, 2007). The assumption for dry-melting reactions in pelitic schists (Georgieva et al., 2002) and an announcement of grossular-rich garnet-bearing leucosome in biotite gneisses (660–710°C / 1.2–1.4 GPa; Cherneva, Gerdjikov, 2004) are encouraging in finding relics of higher-pressure stage of melting. It is worth noting that Kostopoulos et al. (2003) suggested an extremely high-grade decompression melting event (>1000°C / 4 GPa) related to UHP conditions that remain unproved yet. The products of high-pressure melting could fill the data gap between the eclogite event and migmatization in the metamorphic P–T path of the Rhodope region. We present preliminary data on grossular-rich garnet-bearing anatectic melts from the Mechi Chal peak in the Chepelare area.

Geological setting and field relations

A variegated rock assemblage comprising garnet-kyanite gneisses and schists, marbles, ortho- and paragneisses, garnet-bearing amphibolites, and ultramafic rocks (Kostov et al., 1962) crop out as kilometer-scale sheet-like fragments squeezed between the migmatitic orthogneiss of the Arda tectonic unit (Fig. 1). These are well known as Chepelare Formation according to the lithostratigraphic subdivisions of the Central Rhodope metamorphic rocks (Ivanov et al., 1984; Kozhoukharov, 1984). Recently Sarov et al. (2007a) introduced the designation “Chepelare mélange” for the same rock assemblage. The largest sheet is best studied and traced in the area of Chepelare. The top of the variegated rock level is traced by compressional synmetamorphic zone in close spatial association with MORB-type eclogite bodies (Burg et al., 1990; Ivanov et al., 2000). The bottom is marked by sharp shear gradient as well (Gerdjikov et al., 2003). Another probably discontinuous sheet crops out along the crest line of the ridge Chernatitsa in the area of Mechi Chal peak. Due to the poor outcrops, the tectonic setting is not that clear, but from the analysis of the penetrative synmetamorphic fabric it seems that this fragment is also included in intensively sheared migmatitic orthogneisses.

The features of migmatization are preserved in less deformed domains, and could be observed in biotite and garnet-kyanite gneisses in the outcrops 0.5 km to the east of Chepelare along the path to the old marble quarry, the northern slope of the Sivkovska river valley, the Mechi Chal peak and the WSW neighbouring ridge (Fig. 1). The dominant leucosome type of concordant to the foliation centimetre-thick segregations is followed by discordant melt patches, which position and diffusive boundaries with the mesosome indicate melt migration. Garnets occur in both leucosome types formed in the garnet-kyanite gneisses, and on rare occasions in alternating biotite gneisses. Felsic aplitoid gneisses crop out

in close spatial relations as elongated decimeter to meter-scale lenses of uneven-grained massive to foliated structure with minor garnet or garnet + kyanite. The felsic gneiss bodies are roughly granitic in composition and could be considered as melt portions extracted from the nearby rocks.

Sample descriptions

The Mechi Chal peak poor outcrops are dominated by monotonous migmatitic biotite gneiss comprising diffusive concordant quartz-feldspar leucosome. The samples represent garnet-bearing leucosome (HP37) and garnet-bearing aplitoid gneiss (HP36) from the former military base territory (E24.666, N 41.692). The leucosome is 2–3 cm thick and concordant to the foliation of the host garnet-bearing biotite gneiss. The latter alternates with felsic aplitoid gneiss dotted with redish garnets 1–3 mm in diameter (Fig. 2). Larger garnet grains (4–5 mm) in the leucosome together with biotite clusters mark diffusive contacts with the host biotite gneiss.

The leucosome and the felsic gneiss display very similar petrography. The major minerals are K-feldspar, plagioclase, quartz, garnet, minor biotite and magnetite. The accessory minerals assemblage comprises allanite, apatite, zircon, and rutile. Equigranular fine-grained quartz-feldspar aggregates (micro-aplite, Hibbard, 1987) anastomose throughout euhedral garnets, subhedral to ovoid feldspar grains 0.5–3 mm size, and polycrystalline quartz bands, all of them in subparallel alignment. Garnets display euhedral outlines against large feldspar and quartz grains and resorption along contacts with micro-aplite aggregates (Fig. 3). Chloritized biotite and chlorite plus secondary magnetite associate with garnet grains edges, partially enveloping and replacing garnet rims or penetrating garnet grains along fractures. Fresh brown biotite is preserved along leucosome boundaries. Larger garnets contain monomineralic inclusions of euhedral plagioclase and lobate quartz, and polyphase Qtz-Pl-Kfs±Mag±Ap inclusions (abbreviations after Kretz, 1983). Some of them are in contact with micro-aplite matrix. Abundant rectangular antiperthitic exsolutions in large plagioclase (HP37) and perthitic exsolutions in K-feldspar grains (HP36) are common. Large feldspar and quartz grains display subsolidus deformation features (subgrains mainly).

The mineral relations suggest synkinematic crystallization of large plagioclase, K-feldspar, quartz and garnet, followed by remaining melt crystallization (micro-aplite) that interacted with the solid phases in particular with garnet to produce biotite, with contemporaneous or subsequent reequilibration of large feldspar compositions at solidus conditions, and subsolidus retrogressive biotite chloritization. In this scenario the back reaction between melt and solid phases (Kriegsman, 2001) could be responsible for production of biotite clusters along leucosome boundaries.

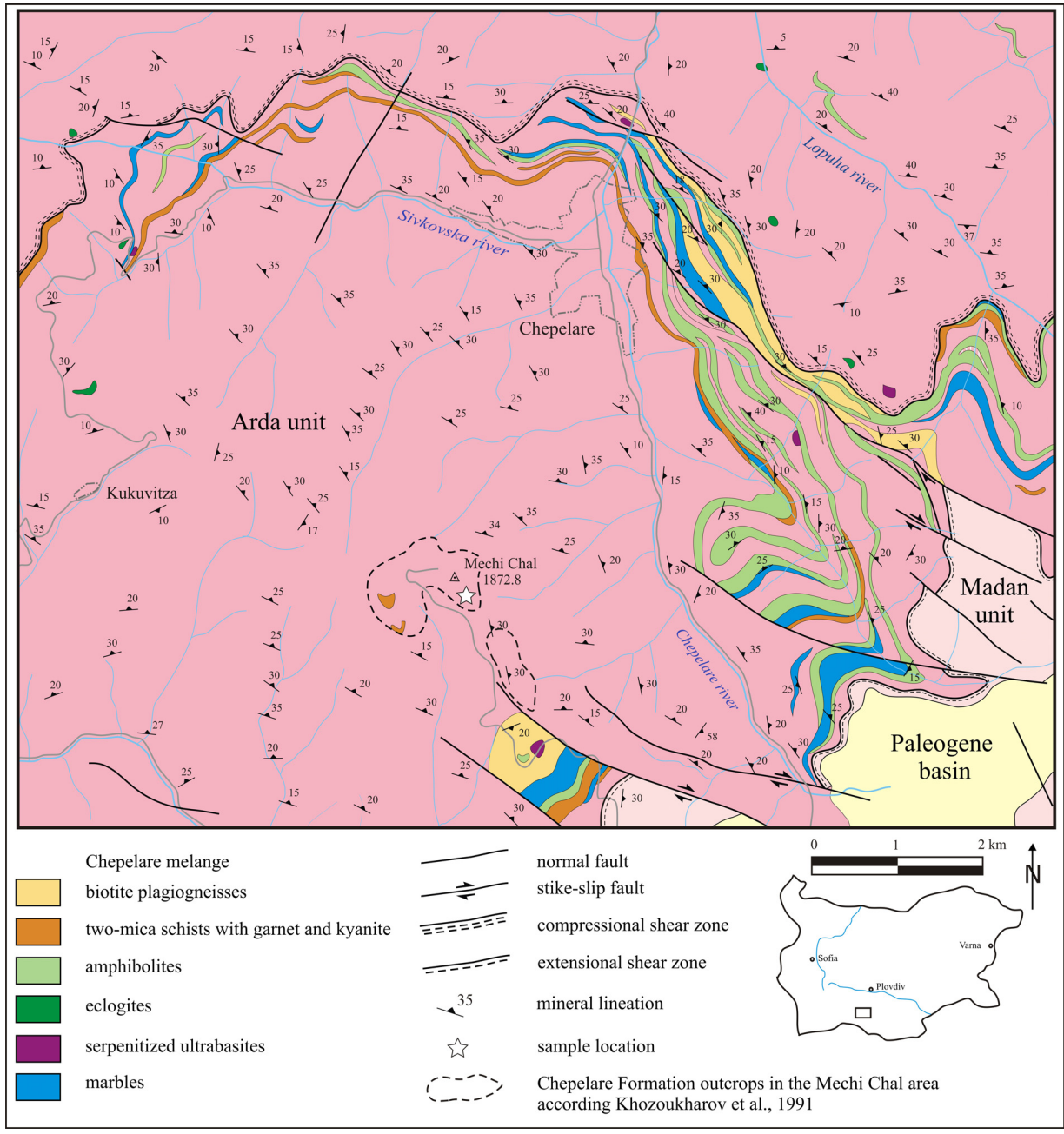


Fig. 1. Simplified geological map of the area of Chepelare after Sarov et al. (2007b) with additions after Khozoukharov et al. (1991)

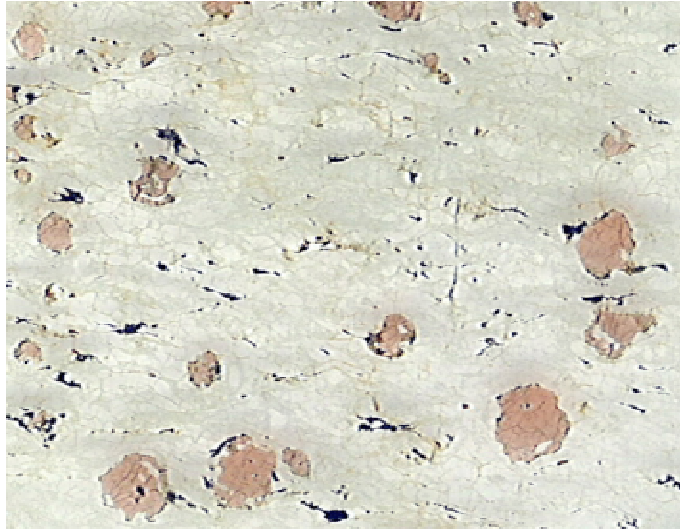


Fig. 2. High resolution scan of thin-section fragment of sample HP36. Base of picture 19 mm

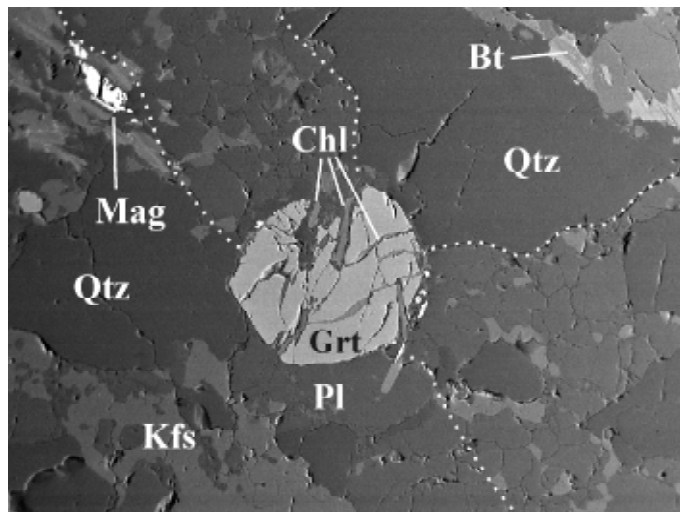


Fig. 3. Microstructural relations in leucosome (sample HP37) showing euhedral garnet outlines against large feldspar and quartz and resorption along contacts with micro-aplite (dotted lines), and secondary chlorite filled fractures. BSE image. Base of photo 1.8 mm

Mineral chemistry

Plagioclase is Na-rich (An_{15-22}). Large subhedral grains are homogeneous and slightly Ca-enriched in the leucosome (An_{19-20}), when compared with the felsic gneiss ones (An_{15-17}). Micro-aplite plagioclase (An_{16-17}) corresponds with the later in both samples. Perthitic exsolutions (An_{16}) in large K-feldspars

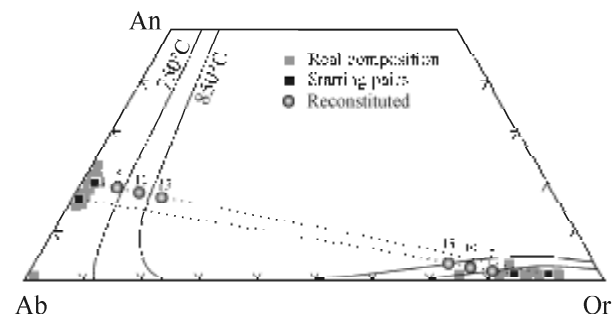


Fig. 4. Real and reconstituted feldspars compositions along with the 1.5 GPa / 750 and 850°C solvus curve deduced from the feldspar activity model of Fuhrman, Lindsley (1988). Numbers beside points of reconstituted compositions refer to proportions of Kfs (5, 10 and 15%) added to Pl and vice versa

Table 1

Selected analyses of garnet and biotite: cations at 12 and 22 O-atoms respectively; abbreviations after Kretz (1983)

Mineral	Garnet					Biotite	
	HP36		HP37			HP37	
Sample	18 c	24 r	2 c	4 r	12 r	9	11
SiO ₂	38.14	38.22	38.83	38.86	39.03	36.25	36.26
TiO ₂	0.09	0.11				3.11	2.41
Al ₂ O ₃	20.81	21.18	21.13	21.12	20.90	15.21	16.53
FeO	25.44	26.92	22.80	25.73	25.73	19.52	18.36
MnO	1.53	4.65	1.95	1.78	1.52	0.00	0.15
MgO	2.90	3.13	3.83	4.27	4.62	11.58	11.87
CaO	10.97	6.11	11.25	8.23	8.41		
K ₂ O						9.74	9.55
Total	99.88	100.32	99.79	99.99	100.21	95.41	95.13
Si ^{IV}	3.01	3.03	3.04	3.05	3.05	5.54	5.52
Al ^{IV}	0.00	0.00	0.00	0.00	0.00	2.46	2.48
Al ^{VI}	1.93	1.98	1.95	1.95	1.92	0.28	0.48
Ti ^{VI}	0.01	0.01	0.00	0.00	0.00	0.36	0.28
Fe ³⁺	0.08	0.09	0.08	0.08	0.08		
Fe ²⁺	1.60	1.70	1.42	1.60	1.60	2.50	2.34
Mn	0.10	0.31	0.13	0.12	0.10	0.00	0.02
Mg	0.34	0.37	0.45	0.50	0.54	2.64	2.69
Ca	0.93	0.52	0.94	0.69	0.70	0.00	0.00
K						1.90	1.85
XFe	0.82	0.82	0.76	0.76	0.75	0.49	0.46
Alm	53.78	58.53	48.27	55.05	54.33		
Prp	11.50	12.77	15.21	17.14	18.30		
Sps	3.45	10.78	4.40	4.06	3.42		
Grs	27.13	13.62	28.43	19.61	19.76		
Adr	4.14	4.30	3.69	4.14	4.18		

$$XFe = Fe^{2+}/(Fe^{2+} + Mg)$$

(HP36) are similar in composition. The richest in Ca plagioclase (An_{20-23}) dominates in garnet resorption rims, though strongly variable compositions as An_2 are found as well.

Large subhedral K-feldspar grains display core to rim Na-depletion from Ab_{14-25} to Ab_{7-14} . Similar to the latter with their low Ab component are K-feldspar inclusions in garnet (Ab_{8-14}), micro-aplite K-feldspars (Ab_{7-11}), and antiperthite exsolutions (Ab_{8-11}) in leucosome plagioclase. The exsolution proportions are about 10% both in plagioclase and in K-feldspar. The reconstituted compositions of the original feldspars are: $Ab_{71.5}$, Or_{11} , $An_{17.8}$, $Cn_{0.1}$ for leucosome plagioclase; and $Ab_{21.6}$, $Or_{75.2}$, $An_{2.6}$, $Cn_{0.6}$ for felsic gneiss (Fig. 4).

Garnets are relatively homogeneous almandine-dominated (Alm 46–58%) with moderate pyrope (Prp 12–15%) and low spessartine component (Sps 3–4%). High Ca content is a distinguishing feature of garnet compositions. The grossular component is 27–33% in leucosome garnets and 22–27% in the felsic gneiss ones. Thin outermost rims ($\leq 8 \mu m$ for 2 mm grain diameter) display Ca-decrease (Grs 18–19% in leucosome and 11–19% in felsic gneiss garnets, Tabl. 1). Sharp fall in Ca towards rim is balanced by increased Fe and Mg contents (Fig. 5a). The ratio

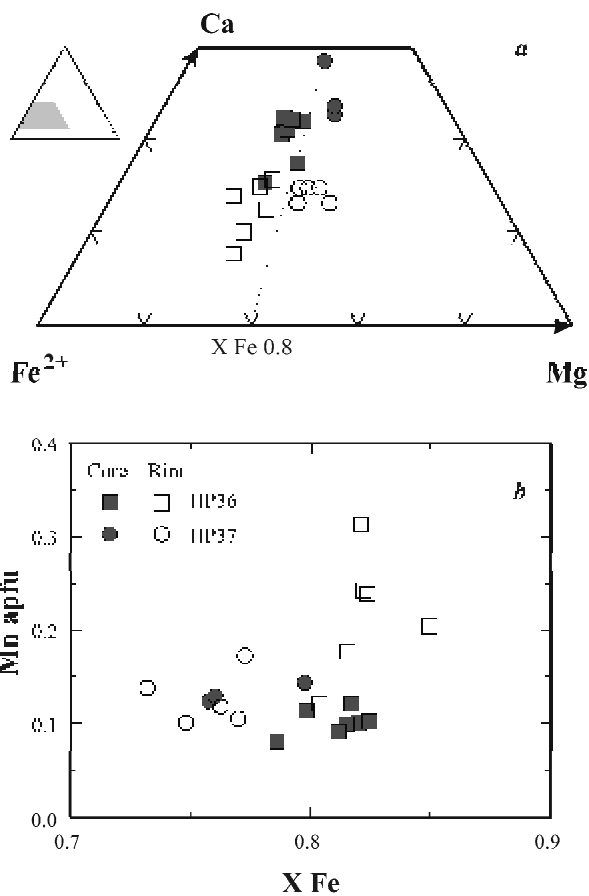


Fig. 5. Plots of garnet compositions showing: (a) Ca-rich inside and sharp fall in Ca towards outermost garnet rim in leucosome HP37 and felsic gneiss HP36; (b) retrogressive Mn increase in felsic gneiss garnet rims

$X_{Fe} = Fe^{2+}/(Fe^{2+}+Mg)$ do not show systematic core-to-rim changes (Fig. 5). In general it keeps lower values (X_{Fe} 0.73–0.80) in the leucosome garnets and slightly higher values in the felsic gneiss garnet, where Mn enriched rims (Sps 4–10%) correlate with X_{Fe} 0.81–0.85 (Fig. 5b).

Fresh biotite preserved along leucosome boundaries is enriched in Mg (X_{Fe} 0.45–0.48) when compared with biotite in Arda unit garnet-free and garnet-bearing migmatites ($X_{Fe} > 0.5$; Cherneva et al., 1997; Cherneva, Gerdjikov, 2004). The contents of TiO_2 (2.4–3.1%, Tabl. 1) suggest Ti-saturation in the presence of accessory rutile.

The mineral assemblage composed of Ca-rich garnet, Na-rich antiperthitic plagioclase and perthitic K-feldspar, together with quartz and biotite corresponds to HT/HP melting assemblage marking decompressional eclogite-amphibolite facies transition in metagreywakes (Auzanneau et al., 2006). The biotite crystallization in such melts is related to back-reaction between garnet rims and crystallizing melt

($Grt + melt \pm Kfs \rightarrow Bt + Pl + Qtz$) affecting both X_{Fe} and Ca-content of re-equilibrated garnet.

P-T conditions

The major mineral assemblage available makes accurate geo-thermobarometry problematic. Geothermometry based on back reaction biotite and adjacent re-equilibrated garnet rims from leucosome boundary parts indicates 750–850°C with different Fe-Mg exchange geothermometers (Ferry, Spear, 1978; Kleeman, Reinhardt, 1994; Holdaway, 2000). The only proper geobarometer for the assemblage $Grt-Bt-Pl-Qtz$ (Hoisch, 1990) yield pressure values between 1.6 and 1.9 GPa at 750–850°, the corresponding depth being 60–70 km.

The attempt to apply two-feldspar thermometry (after Fuhrman, Lindsley, 1988) using real feldspar compositions gave unsatisfactory results due to incomplete reequilibration. The approximate estimate

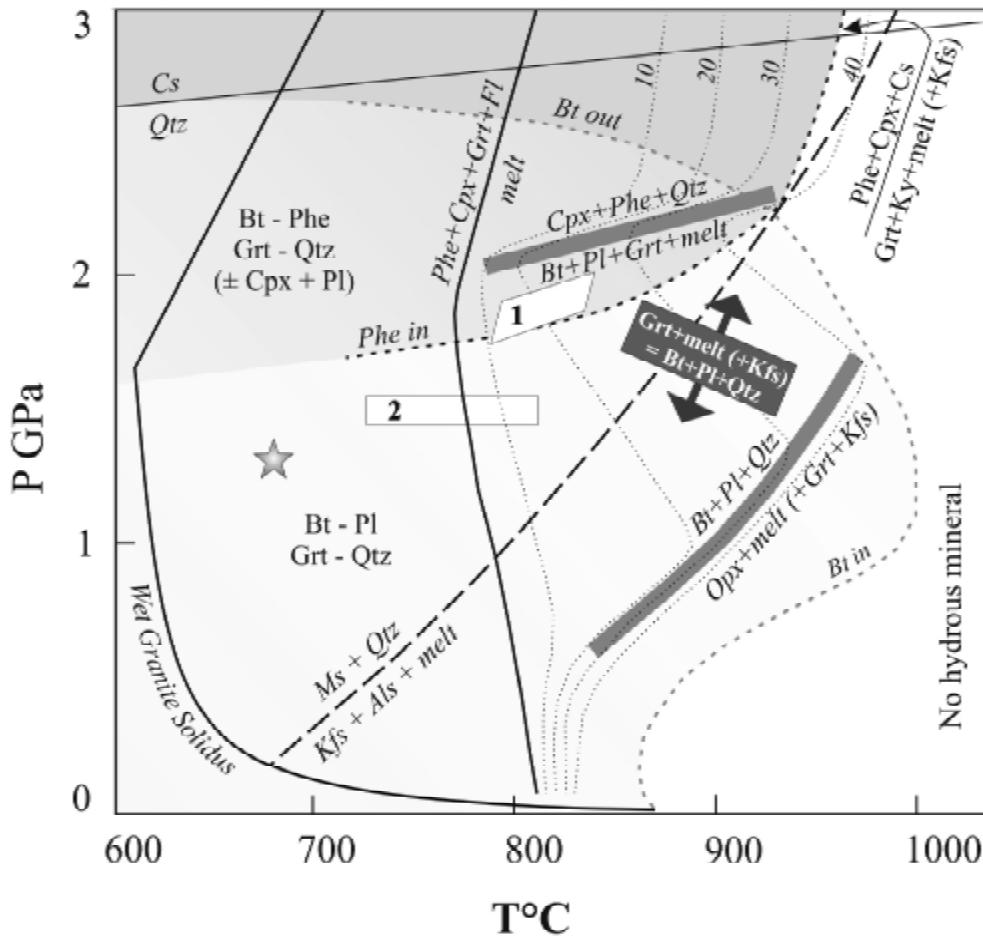


Fig. 6. Interpretative P-T diagram and location of major melting reactions in metagreywakes with dashed lines tracing melt fraction proportions (10, 20, 30, 40 %) (Auzanneau et al., 2006). Present study results are marked by rectangular fields 1 (Grt-Bt and Grt-Bt-Pl-Qtz thermobarometry) and 2 (two-feldspar thermometry). Star – P-T estimations for Erma Reka (Cherneva, Gerdjikov, 2004)

of exsolution amounts (~10 %) enables a reconstitution of large feldspar grain compositions. Model plagioclase and K-feldspar compositions plot between 750 and 850°C solvus curves at 1.5 GPa (Fig. 4) and yield concordant temperatures 725–805°C in the pressure range of 1–1.5 GPa.

Discussion

The field and grain-scale relations demonstrate that the rocks studied originated from melt crystallization. The coexistence of Ca-rich garnet and Na-rich plagioclase is a well known indicator of high-pressure conditions. The approximate thermobarometric results (Fig. 6) plot in the P–T area of a melting pulse that should happen at the eclogite-amphibolite facies transition during decompression and exhumation of subducted continental crust according to the experimental data of Auzanneau et al. (2006). Metagreywackes, metapelites and amphibolites can melt at similar conditions (Clemens, Vielzeuf, 1987; Patiño Douce, Johnston, 1991; Patiño Douce, Beard, 1995). The general high-pressure melting reaction itself ($\text{Cpx} + \text{Phe} + \text{Qtz} \rightarrow \text{Bt} + \text{Grt} + \text{Pl} + \text{melt}$; Fig. 6) operates in the stability field of phengite and marks the clinopyroxene-out curve for metagreywackes, which composition corresponds to the average continental crust one.

The mineral assemblage in our samples is kyanite free suggesting a metaluminous precursor of metapsamitic (metagreywacke) type; and phengite-, and clinopyroxene free suggesting complete consumption of such reagents except for quartz. Garnet-kyanite-bearing melts should be expected in Al-rich metasediments (Vielzeuf, Holloway, 1988). Garnet-kyanite-bearing leucosome and aplitoid gneiss lenses in the area of Chepelare are proper candidates for such melts. Preliminary data of phengite-bearing matrix and rare finds of melt inclusions in garnets from the Chepelare high-Al metapelites (Georgieva et al., 2003, 2005, 2007 in preparation) corroborate the operation of high-pressure melting reaction. According to

our field observations, garnet-bearing amphibolites (metagabbros) in close spatial associations with the metasedimentary rocks from the same area, display features of partial melting as well.

The above consideration poses a problem regarding garnet-free migmatites and spatial limits of high-pressure melting in the Arda unit. The only case of garnet-bearing migmatite comprising Ca-rich garnet and Na-rich plagioclase except for the present ones refers to the deepest parts of the Arda unit (Erma Reka area; Cherneva, Gerdjikov, 2004) (Fig. 6). The most wide-spread rocks in the unit are metagranitoids of late-Hercynian protolith age affected by late-Alpine migmatization that produced garnet-free anatectic melts (Cherneva, Georgieva, 2005 and reference therein). The question whether or not high-pressure melting ever happened in the metagranitoids could be a key point in the whole scenario of high-grade rocks exhumation. It assigns to possible preservation of UHP relics and their spatial distribution within the Arda unit (Gerdjikov et al., 2003).

Conclusions

Garnet-bearing leucosome and aplitoid gneiss from the Mechi Chal peak in the Central Rhodope comprise a mineral assemblage produced by high-pressure melting: Ca-rich garnet, Na-rich plagioclase, K-feldspar, quartz, and biotite. The approximate conditions of crystallization are in the range 1.6–1.9 GPa / 800–850°C. Ca-rich garnets in garnet-bearing migmatites are a proper indicator for high-pressure melting that happen during decompression and exhumation of subducted continental crust.

Acknowledgments

The National Science Fund of the Ministry of Education and Science in Bulgaria have supported this work, grant BY-H3-05/2005.

References

- Auzanneau, E., Vielzeuf, D., Schmidt, M. W. 2006. Experimental evidence of decompression melting during exhumation of subducted continental crust. – *Contrib. Mineral. Petrol.*, 152; 125–148.
- Burg, J.-P., Ivanov, Z., Ricou, L.-E., Dimov, D., Klain, L. 1990. Implications of shear-sense criteria for the tectonic evolution of the Central Rhodope massif, southern Bulgaria. – *Geology*, 18; 451–454.
- Cherneva, Z., Dimov, D., Stancheva, E., Daieva, L. 1995. Subsolidus and anatectic veins in migmatitic gneisses from the Vacha-river valley, Central Rhodopes. – *Rev. Bulg. Geol. Society*, 56, 3; 91–109 (in Bulgarian).
- Cherneva, Z., Arnaudova, R., Iliev, Tz., Rekalov, K. 1997. Feldspar thermometry of migmatitic formations from the Central Rhodopes. – *Rev. Bulg. Geol. Society*, 58, 3; 139–156 (in Bulgarian).
- Cherneva, Z., Gerdjikov, I. 2004. Retrograde overprint on high-grade metamorphic rocks from the deepest parts of the Arda unit, Central Rhodope. – *Proceedings of the annual scientific conference of BGS*, Sofia; 6–8.
- Cherneva, Z., Georgieva, M. 2005. Metamorphosed Hercynian granitoids in the Alpine structures of the Central Rhodope, Bulgaria: geotectonic position and geochemistry. – *Lithos*, 82; 149–168.
- Cherneva, Z., Georgieva, M. 2007. Amphibole-bearing leucosome from the Chepelare area, Central Rhodope: P-T conditions of melting and crystallization. – *Geochem. Mineral. Petrol.*, 45; 79–95.
- Clemens, J. D., Vielzeuf, D. 1987. Constraints on melting and magma production in the crust. – *Earth Planet. Sci. Lett.*, 86; 287–306.
- Ferry, J. M., Spear, F. S. 1978. Experimental calibration of the partitioning of Fe and Mg between biotite and garnet. – *Contrib. Mineral. Petrol.*, 66; 113–117.
- Fuhrman, M. L., Lindsley, D. H. 1988. Tertiary-feldspar modeling and thermometry. – *Am. Mineral.*, 73; 201–215.

- Gardien, V., Thompson A. B., Grujic, D., Ulmer, P. 1995. Experimental melting of biotite + plagioclase + quartz ± muscovite assemblages and implications for crustal melting. – *J. Geophys. Res.*, 100, B8; 15581–15591.
- Georgieva, M., Cherneva, Z., Kolcheva, K., Sarov, S., Gerdjikov, I., Voinova, E. 2002. P-T metamorphic path of sillimanite-bearing schists in an extensional shear zone, Central Rhodopes, Bulgaria. – *Geochem. Mineral. Petrol.*, 39; 95–106.
- Georgieva, M., Mogessie, A., Hauzenberger, C., Proyer, A., Cherneva, Z. 2003. P-T metamorphic path of garnet-kyanite-bearing schists: Chepelare formation, Central Rhodope, Bulgaria. – *Mitt. Österr. Miner. Ges.*, 148; 152–153.
- Georgieva, M., Mogessie, A., Cherneva, Z. 2005. Mineral needles and melt inclusions in garnet from the Chepelare area, Central Rhodope, Bulgaria. – *Mitt. Österr. Miner. Ges.*, 150; 40.
- Gerdjikov, I., Gautier, P., Cherneva, Z., Kostopoulos, D. 2003. Tectonic setting of ultrahigh-pressure metamorphic rocks from the Chepelare area, Central Rhodopes. – *Proceedings of the annual scientific conference of BGS*, Sofia; 44–45.
- Hibbard, M. J. 1987. Deformation of incompletely crystallized magma systems: granitic gneisses and their tectonic implications. – *J. Geol.*, 95; 543–561.
- Hoisch, T. D. 1990. Empirical calibration of six geobarometers for the mineral assemblage quartz + muscovite + biotite + plagioclase + garnet. – *Contrib. Mineral. Petrol.*, 104; 225–234.
- Holdaway, M. J. 2000. Application of new experimental and garnet Margules data to the garnet-biotite geothermometer. – *Am. Mineral.*, 85; 881–892.
- Ivanov, Z., Moskovski, S., Kolcheva, K., Dimov, D., Klain, L. 1984. Geological structure of the Central Rhodopes. I. Lithostratigraphic subdivision and features of the section of metamorphic rocks in the northern parts of Central Rhodopes. – *Geologica Balc.*, 14.1; 3–42 (in Russian).
- Ivanov, Z., Dimov, D., Dobrev, S., Kolkovski, B., Sarov, S. 2000. Structure, Alpine evolution and mineralizations of the Central Rhodopes area (South Bulgaria). – *Guide to Excursion B, ABCD-GEODE Workshop*, Borovets, Bulgaria, 50 pp.
- Kleeman, U., Reinhardt, J. 1994. Garnet-biotite thermometry revised: the effect of Al^{IV} and Ti in biotite. – *Eur. J. Mineral.*, 6; 925–941.
- Kostopoulos, D., Gerdjikov, I., Gautier, P., Reischmann, T., Cherneva, Z. 2003. First evidence of UHP metamorphism in the Central Rhodope massif of southern Bulgaria. – *European Geophysical Society, Geophysical Research Abstracts*, 5, 08327.
- Kostov, I., Ivanov, I., Petrusenko, S. 1962. Die Distenlagerstätte beim Dorfe Čepelare Bezirk Smoljan. – *Trav. sur geol. Bulgarie, ser. géochim.*, III; 69–92 (in Bulgarian).
- Kozhoukharov, D. 1984. Lithostratigraphy of the Precambrian metamorphics from Rhodope Supergroup in the Central Rhodopes. – *Geologica Balc.*, 14.1; 43–88 (in Russian).
- Kozhoukharov, D., Kozhoukharova, E., Marinova, R., Kazkov, N., Yanev, Y. 1991. Geological map of Bulgaria 1:100 000, Chepelare Map sheet.
- Kretz, R. 1983. Symbols for rock-forming minerals. – *Am Mineral.*, 68; 277–279.
- Kriegsman, L. M. 2001. Partial melting, partial melt extraction and partial back reaction in anatectic migmatites. – *Lithos*, 56; 75–96.
- Lang, H. M., Gilotti, J. A. 2007. Partial melting of metapelites at ultrahigh-pressure conditions, Greenland Caledonides. – *J. metamorphic Geol.*, 25; 129–147.
- Patiño Douce, A. E., Johnston, A. D. 1991. Phase equilibria and melt productivity in the pelitic system: implications for the origin of peraluminous granitoids and aluminous granulites. – *Contrib. Mineral. Petrol.*, 107; 202–218.
- Patiño Douce, A. E., Beard, J. S. 1995. Dehydration-melting of biotite gneiss and quartz amphibolite from 3 to 15 kbar. – *J. Petrol.*, 36; 707–738.
- Sarov, S., Voinova, E., Moskovski, S., Jelezarski, T., Georgieva, I., Nikolov, D., Naydenov, K., Nedkova, K., Petrov, N., Markov, N., Marinova, R. 2007a. Explanatory notes to the Geological map of Bulgaria 1:50 000, Chepelare Map sheet (in press).
- Sarov, S., Voinova, E., Moskovski, S., Jelezarski, T., Georgieva, I., Nikolov, D., Naydenov, K., Nedkova, K., Petrov, N., Markov, N., Marinova, R. 2007b. Geological map of Bulgaria 1: 50 000, Chepelare Map sheet (in press).
- Vielzeuf, D., Holloway, J. R. 1988. Experimental determination of the fluid-absent melting reactions in the pelitic system (Consequences for crustal differentiation). – *Contrib. Mineral. Petrol.*, 98; 257–276.

3. Чернева, М. Георгиева, Е. Станчева, Я. Герджиков – Високбарични гранат-съдържащи мигматити от района на Чепеларе, Централни Родопи. Асоциацията от богат на Са гранат и кисел плагиоклаз в мигматитите е индикатор на високбарично топене. Изследвани са левкосома и алпитоиден гнайс от в. Мечи чал в района на гр. Чепеларе, Централни Родопи. Минералната асоциация в мигматичните образувания свидетелства за високбарично топене: богат на Са гранат (гросулар 22–33 %), антипертитен плагиоклаз (An_{15–20}), пертитен К-фелдшпат, кварц и малко вторичен биотит, образуван при взаимодействие на остатъчната топилка с гранатовата периферия. Приблизителната оценка на условията на кристализация на топилката е 1.6–1.9 GPa / 800–850°C, което значително надвишава известните досега стойности за мигматити в Централните Родопи. Изследването насочва към ключовата роля на високбаричното топене в алпийската метаморфна еволюция на Централните Родопи.