Garnet-kyanite schists from the Chepelare area, Central Rhodope Mts., Bulgaria: mineral chemistry, thermobarometry and indications for high-pressure melting

Гранат-кианитови шисти от района на Чепеларе, Централни Родопи, България: химизъм на минералите, термобарометрия и индикации за високобарично топене

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Introduction

Pelites are one of the most informative groups of metamorphic rocks because they respond rather sensitively to changes in P and T and are thus good monitors of metamorphic histories. Garnet-kyanite pelitic schists near the town of Chepelare have been a topic of extended investigations during the past century (Kostov et al., 1962), though little is known about their metamorphic evolution and no data on mineral chemistry have been reported yet. According to the latest tectonic subdivision of the Central Rhodope, the garnet-kyanite schists belong to the Arda unit that represents the lower plate of the metamorphic core complex (Ivanov et al., 2000).

Petrography and mineral chemistry

Porphyroblastic garnet-kyanite gneisses and schists comprise variable proportions of major plagioclase, biotite, quartz, minor sillimanite, staurolite, K-feldspar, chlorite, carbonate and accessory zircon, apatite, ilmenite, rutile, pyrite, graphite. The orientation of biotite, kyanite and muscovite form the rock foliation. The features of *in situ* migmatization are well visible, representing centimeter scale concordant and discordant quartz-feldspar layers and pods, which are partly deformed and dismembered.

Summarized petrographic and mineral chemistry data distinguish two mineral assemblages: garnet porphyroblasts interior with mineral inclusions (Qtz, Pl, Ky, St, Bt, white mica ± Chl); and matrix minerals (Ky, Qtz, Pl, Kfs, Bt, Ms, ± St, Sil, chlorite, carbonate and graphite).

All garnets are almandine rich. Big euhedral grains (>0.5 cm) preserve prograde zonation: bell-shaped distribution of Mn, core-to-rim Fe decrease, Mg increase and high Ca content (XMn 0.03 to 0.01; XFe 0.66 to 0.58; XMg 0.08 to 0.22; XCa 0.22–0.24). Small garnet grains and fragments (XFe 0.58–0.78, XMg 0.20–0.30 XCa 0.03–0.12 XMn 0–0.01) do not display compositional zonation and resemble the rim composition of the large garnets. An outermost zone of Mn-enrichment marks retrogression along garnet edges, large inclusions and cracks. Biotite inclusions have high XMg (0.51–0.79) and variable TiO_2 content (0.5 to 4.5 wt.%). Plagioclase shows faceted boundaries and often form polymineral aggregates with quartz, biotite and staurolite. Most plagioclase grains are reversely zoned (from An_{44} in core to An_{65} in rim). Staurolite inclusions have uniform XMg (0.32 to 0.39) and ZnO in the range 2.58–4.45 wt.%. Kyanite and muscovite (Si 6.10–6.33 a.p.f.u.) inclusions are common. Abundant small rutile grains overfill the central parts of the garnets, giving them dusty appearance. Tiny rutile needles oriented under 120° are common in almost free of inclusions garnet parts. Small polyphase inclusions (5–15 μm) of quartz, biotite, white mica, K-feldspar, apatite, rutile and zircon in the Chepelare garnets are similar to those in diamantiferous garnets from Erzgebirge (Stöckhert et al., 2001).

Matrix kyanites form subhedral grains often inclusions free or include rounded quartz, biotite, small garnets, graphite and rutile. Matrix biotite has lower XMg (0.41–0.63) that correlates positively with TiO_2 (1–4.4 wt.%). Matrix plagioclase is more acid than inclusions and reversely zoned (An_{37} in core to An_{50} in rim). The proportion of K-feldspar is variable. A film of K-feldspar (Or_{92-94}, Ab_{6-8}) around resorbed garnet envelops as well biotite, kyanite and quartz-biotite symplectites. The white mica in the matrix is Si rich (6.44–6.54 a.p.f.u.) with phengite relicts (6.60–6.67 a.p.f.u.) and lower content in the large muscovite flakes (6.21–6.31 a.p.f.u.). The later, together with staurolite (XMg 0.20; ZnO < 0.5 wt.%) and chlorite marks garnet, biotite and kyanite consumption during the retrogression. In some samples fibroid sillimanite forms bands conformable to the foliation, intergrows with lens-shaped quartz grains or envelops large garnet and kyanite porphyroblasts.

Mineral chemistry data give evidence for HT diffusion reequilibration of small garnets. It affected as well inclusions in garnet porphyroblasts, as it appears from higher XMg of biotite inclusions and high-An rims of plagioclase ones. High temperature conditions are also supported by high TiO_2 content in biotites. On the other hand high Ca content in garnets with preserved compositional zonation, rutile needles of preferred orientation and polyphase inclusions (crystallized from melt or supercritical fluid) have been reported as indicators for HP from several UHP terranes. The arguments of Kostopoulos et al. (2003) for suggesting extremely high P–T (68 GPa, >1000°C/40 GPa) are based on similar observations. More reliable are matrix microstructural observations that give evidence for melt back reactions with garnet (K-feldspar film and quartz-biotite symplectites).

The above present data suggest a prograde P-T path crossing the staurolite stability field, HT-HP stage with dehydration melting of biotite in the presence of kyanite, melt back reactions and retrogressive formation of staurolite, muscovite and chlorite. The peak matrix mineral assemblage: garnet — K-feldspar — kyanite is indicative for HP granulite facies in metapelitic rocks (O'Brian, Rötzler, 2003).

Thermobarometry

Determination of the peak metamorphic conditions by conventional thermobarometry in metapelites is often precluded by retrogression. Mineral inclusions are strongly affected by high-temperature diffusion exchange with the host garnet. They do not represent equilibrium compositions, which prevents their use for P–T calculations. We used the matrix minerals: biotite, plagioclase, staurolite, white mica and rims of the big garnets. Different calibrations of garnet-biotite and garnet-staurolite thermometers, GASP and GRAIL barometers using PET and TWEEQ software have been applied. The peak metamorphic conditions estimated range from 800–820°C/1.2 GPa to 700–750°C/0.9–0.1 GPa and subsequent decompression to 550–600°C/0.5 GPa. Although the uncertainty in the application of conventional thermobarometry, the results correlate with the petrographic observations of mineral assemblage characteristic for HP granulite facies. Reaction of fluid-absent melting in the kyanite stability field occurred at the peak temperature conditions.

Conclusions

Mineral chemistry data, petrographic observations and thermobarometry result allow us to reconstruct partly the prograde and retrograde metamorphic path of the Chepelare garnet-kyanite schists. The peak metamorphic assemblage preserved is indicative for HP granulite facies metamorphism and dehydratation melting of biotite in the kyanite stability field.

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References

Ivanov, Z., D. Dimov, S. Dobrev, B. Kolkovski, S. Sarov. 2000. Structure, Alpine evolution and mineralizations of the Central Rhodopes area (South Bulgaria). — *ABCD-GEODE 2000 Workshop, Borovets, Bulgaria, Guide to Excursion B,* 50 p.

Kostopoulos, D., I. Gerdjikov, P. Gautier, T. Reischmann, Z. Cherneva. 2003. First evidence of UHP metamorphism in the Central Rhodope Massif of Southern Bulgaria. — *Geophys. Res. Abstracts, 5,* 08327.

Kostov, I., I. Ivanov, S. Petroussenko. 1962. Kyanite deposit near town of Chepelare, Smolian area. — *Trav. géol. Bul., sér. géochim., minéral., pétrogr., 3,* 69—91.

O'Brian, P., J. Rötzler. 2003. High-pressure granulites: formation, recovery of peak conditions and implications for tectonics. — *J. Metamorphic Geol., 21,* 3—20.

Stöckhert, B., J. Duyster, C. Trepmann, H.-J. Massonne. 2001. Microdiamond daughter crystals precipitated from supercritical COH + silicate fluids included in garnet, Erzgebirge, Germany. — *Geology, 29,* 391—394.