KYANITE-STAUROLITE-GARNET-BEARING SCHISTS FROM OGRAZHDEN MOUNTAIN, SW BULGARIA – METAPELITES OR ORTHOSCHISTS?

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Key words: Ograzhden mountain, metamorphism, metapelites, orthoshists, kyanite

Introduction

In the vicinity of village Lebnitza (Ograzhden Mountain) kyanite-garnet schists with minor amounts of staurolite and chloritoid are observed. In a few previous investigations in this region (Зидаров и др., 1967; Aleksic et al., 1988) these rocks have been described as metapelites. With their wealthy mineral composition such a kind of rocks is the most sensitive indicator for reconstructing the pressure and temperature conditions of the metamorphism. By this reason we focus our attention on the metamorphic evolution of these rocks in order to provide information on the P-T path with a special regard to the number and the grade of metamorphic episodes. However, our field, petrological, geochemical and zircon typology investigations in such a kind of rocks in Ograzhden as well as in Belasitza Mountain, revealed some peculiarities leading to another interpretation of the schists, namely that they are formed in a high temperature deep crustal shear zone that transformed the granitoid rocks into aluminous orthoschists. Displaying these features is the aim of the present contribution.

Geological setting and field description

The studied area is situated in the most southwestern part of Bulgaria, in Ograzhden Mountain (Fig.1, left-bottom insertion) and is assigned to belong to the Serbo-Macedonian Massif (Kockel & Walther, 1965). The main part of the metamorphic basement in this region is built up of two facial varieties (equigranular and porphyritic after K-feldspar one) of metagranitoids overprinted by upper amphibolite facies metamorphism, heterogeneous deformation and migmatisation (Titorenkova et al., 2002). Nowadays, metagranitoids appear as augengneiss, augenlayered or layered structures. Both U-Pb (TIMS) and Hf zircon data for equigranular and porphyritic metagranitoids points to ages of 459.9±7.6 Ma and 451+18/-9 Ma, respectively, interpreted to reflect the time of the magma intrusion (Zidarov et al., 2003). Typical MME (melanocratic microgranular enclaves) meter to decimeter sized as well as concordant lenticular amphibolite bodies and boudins of a bigger size (up to tens of meters) are scattered in metagranitoids. In the vicinity of the village Lebnitza, a thin body of schists containing large kyanite- (up to 2-4 cm long) and garnet porphyroblasts (up to 4 cm in diameter) can be mapped mainly at the transition zone between the porphyritic and equigranular metagranitoids (Fig.1). At the contacts of metagranitoids with these rocks, the foliation deepens steeply (50-70^0) to NW with a remarkable almost horizontal SE lineation. Near the schist body, metagranitoids are strongly isoclinaly folded and mylonitized but more micaceous in composition and containing thin kyanite streaks elongated parallel to the foliation. At this locality, the thickness of the schist body varies from 10 to 100 m and can be traced for several hundred meters along the strike. The schist body reveals a distinct zonality (Fig 1, top-right insertion) with

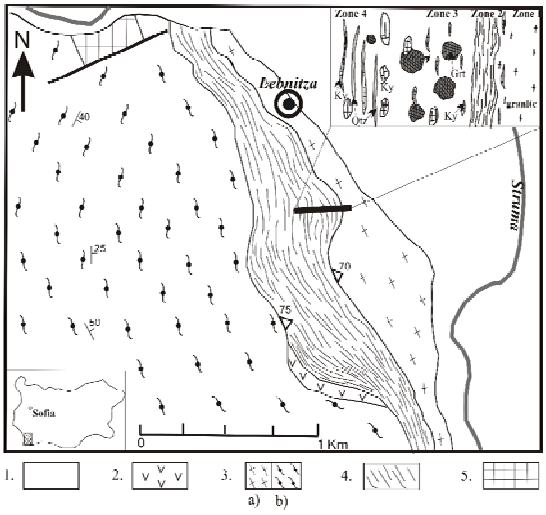

Fig. 1. Geological sketch map of the eastern slopes of the Ograzhden Mountain. 1-Quaternary; 2-Tertiary volcanites; 3a-Equigranular metagranites; 3b-Porphyritic metagranites; 4-Kyanite-staurolite-garnet-bearing schists; 5-Amphibolites. Inserted figure (top right)-schematic picture of the zonal schist body across the profile line.

variations from rocks highly resembling metagranites to high aluminous schists.

Petrography and mineral chemistry

In the vicinity of village Lebnitza four main mineralogical zones can be recognized within and adjacent to the schist body, including strongly foliated mica-rich metagranites bearing scarce kyanite streaks, noted as zone I. Zone II represents highly deformed melanocratic two-mica schists, containing small garnet and tourmaline crystals. Zone III is more coarse-grained, built up of large garnet poikiloblasts and elongated kyanite segregations both set up in a quartz-mica matrix. Zone IV (the central part of the body) is highly differentiated and built up of alternating kyanite- and quartz-enriched layers 10-15 cm in thickness. The coarse-grained kyanite with nodular appearance is stretched parallel to the foliation. In this zone, one can see finely lineated, pale-blue to white colored, almost solely kyanite comprising thin mylonite layers of a thickness up to 10 cm. They are composed of finely oriented kyanite needles.

The texture and the mineral composition of gneisses in *zone I* resemble strongly that of metagranitoids (plagioclase + biotite + white mica +K-feldspar + quartz + additional small kyanite and garnet grains as well as accessory phases including rutile, ilmenite, apatite and zircon). The kyanite and garnet grains are formed on the account respectively of sericitised mineral (most probably plagioclase) and biotite.

The mineralogy of *zone II* is substantially different from that of metagranite. It is built mainly of large flakes of biotite and white mica in addition to small amounts of plagioclase, quartz, kyanite and two garnet generations (coarse-grained, synkinematic poikiloblasts, containing white mica, kyanite and quartz inclusions and small-grained (0.1-0.3 mm) late kinematic garnet scattered in all other minerals). Accessory tourmaline is frequently observed.

Zone III is a typical aluminous rock without any feldspar. The two garnet generations are well represented together with large kyanite segregations with nodular appearance set up in a quartz-mica matrix. Kyanite nodules are made up of small radial sometimes bent crystals of a clearly pseudomorphic character (Fig. 2a). Scarce staurolite porphyroblasts are formed in kyanite nodules.

Quartz-rich layers in *zone IV* are built up of 90-95% quartz plus a minor amount of finely grained white mica, biotite, and small garnet crystals without any preferred orientation. The layers containing kyanite nodules are most intensively sericitized and rich in mica (mostly white mica) bands. The larger garnet crystals are often fully decomposed, preserving sometimes only their former contours. Differently oriented ideal prismatic staurolite and chloritoid porphyroblasts were observed, grown obviously in a static manner, at the expense of sericitised kyanite nodules (Fig. 2b). Parallel to the foliation, thin kyanite needles are formed wrapping the sericitised nodules. In this highly mylonitized zone, which is nearly monomineral (being composed of 90-95 % fine kyanite needle crystals), one observes stripes of finely grained garnet, oriented strongly parallel to the foliation (Fig.2c). Quartz bands are scarce in these kyanite layers.

The chemistry of minerals is used for obtaining information on the conditions of metamorhism. Both types of *garnet* are almandine rich (Alm_{76-86}), with small amounts of pyrope (Pyr_{7-16}), grossular (Grs_{1-7}) and spessartine (Sps_{2-7}). By using the method of Droop (1987), we recalculated the content of Fe^{3+} to be up to 4.57% from Fe_t. Most garnet profiles exhibit a plateau-like distribution of FeO, CaO and MnO, typical of the

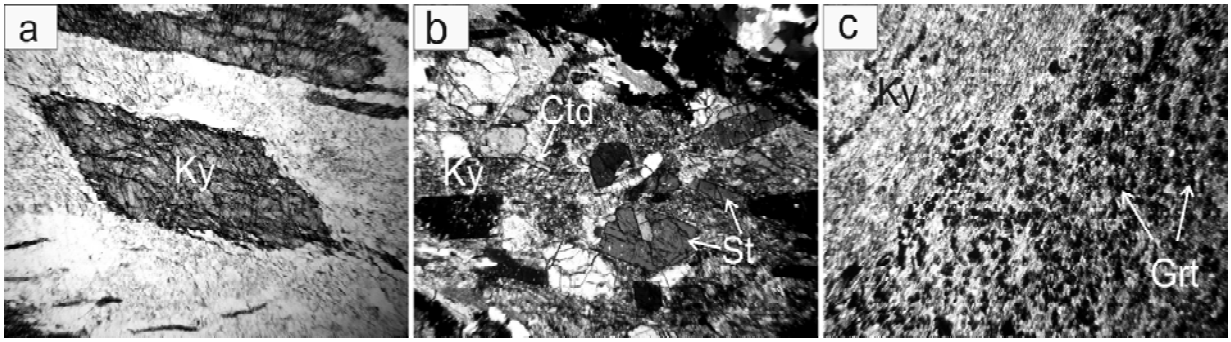

Fig.2. Microscopic images a) Kyanite nodules with pseudomorphic character; b) Staurolite and chloritoid porphyroblasts formed after kyanite; c) Kyanite mylonite – fine kyanite streaks oriented parallel to the foliation. Finegrained garnet scattered in layers parallel to the lineation. All images in crossed polars. Magnification – 40.

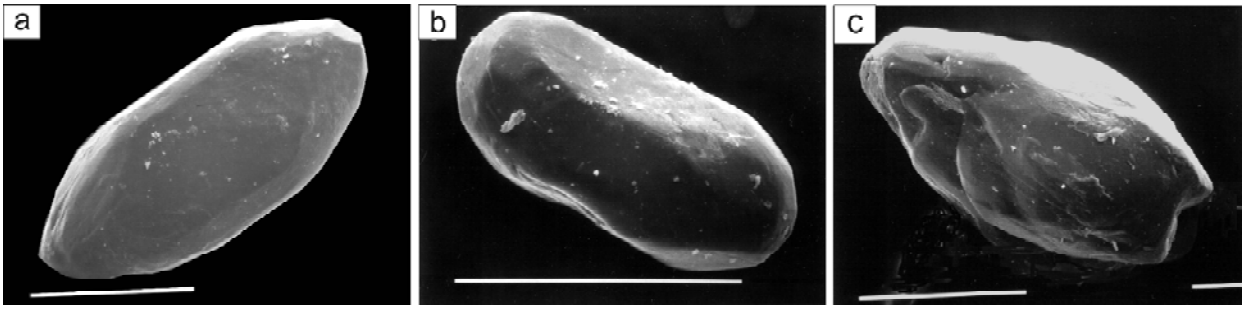

Fig.3. Zircon crystals separated from schists: a) euhedral crystal with typology identical to zircon from metagranites (S_{1-2}); b) zircon with resorbed crystal faces; c) strongly resorbed zircon grain with morphology typical for peraluminous metagranites (S_6). Marker – 100 μm.

high-grade metamorphism (Tracy, 1982). The coexisting small-grained garnet is rich in Mg and poor in Mn, chemically homogenous and of the same composition as the rims of the large-sized garnet.

Staurolite and *chloritoid* were locally observed and obviously formed at the expense of sericitized kyanite. Staurolite is unzoned, with a $Fe_t/(Fe_t+Mg)$ ratio of 0.77-0.82, Fe-rich (~13wt% FeO_t), and do not contain MnO and ZnO. Chloritoid is low magnesian (X_{Fe} =0.84-0.88), but higher magnesian than both staurolite and garnet, which is typical of the retrograde formation. Two generations of *white mica* can be distinguished on the basis of textural features: 1) an early kinematic one with a relatively high celadonite content (up to 3.34 p.f.u.), with a low paragonite component (to 0.12 p.f.u.) and with a relatively high Fe+Mg sum (to 0.42 p.f.u.) mainly at the expense of Mg.; 2) syn- to late kinematic white mica, characterized with a moderate to low Si content (3.08-3.18 p.f.u), a small Fe+Mg sum (0.11-0.18) and a relatively low paragonite content (0.13-0.22). We suppose that the early-kinematic white mica is formed at high temperatures and the second generation at lower temperatures. The biotite composition is quite uniform, with a high $Fe_t/(Fe_t+Mg)$ ratio (0.50-0.62) and an Al content of 0.40-0.51 p.f.u.

On the basis of microstructural observations and mineral chemistry the following sequence of mineral paragenesis can be distinguished: 1) HT/MP(HP?) - garnet + kyanite + quartz + white $mica_I$ + tourmaline; 2) MT/MP-LP - staurolite + chloritoid + quartz +white $mica_{II}$ ± biotite .

Metamorphic conditions

The pressure and temperature conditions are derived using two different methods, namely a selected cation exchange and net transfer reactions texturally observed on a thin section scale, and a simultaneous calculation of all possible end-member reactions within assemblages of local equilibrium using an internally consistent data set. The following results were obtained via both methods: T~670^{0}C and P_{min} = 7 kbar for the peak metamorphic conditions. The formation of kyanite porphyroblasts as well as of garnet rims around the biotite flakes in the metagranitoids infers higher pressure conditions than the calculated P_{min}. T_{max}= 550^{0}C for the retrograde staurolite and chloritoid formation are obtained. The time of the kyanite retrogression to sericite remains, however, unknown.

Zircon morphology

The zircon morphology from the schists studied resembles strongly that of zircons from metagranitoids (Titorenkova et al., 2002). Zircons with a well-preserved crystal form, identical with that of zircons from metagranitoids, are presented (Fig. 3a), although crystals with curved and resorbed surfaces dominate (Fig.3b). These peculiarities could be explained with a high fluid activity in the shear zone. Multi-faceted forms, aggregate crystals and weakly rounding of steep pyramids are typical of zircon from both rock types - metagranitoids and schists (Fig.3c). Isometric and irregularly shaped grains are also present. The obtained SEM images give evidence for secondary alteration processes. Most of the crystals are metamict or fluid overprinted.

Conclusions

Based on complex field, petrological, geochemical and zircon typology investigations, an orthometamorphic origin of the schists, cropping in the vicinity of Lebnitza village as well as in other localities of Belasitza and Ograzhden Mountains, is suggested. Peculiarities of the schist body in the vicinity of Lebnitza village, such as its zonality, the total absence of pelitic lithologies

in metagranitoids as well as the presence in the schists of finely grained melanocratic inclusions that resemble strongly MME in metagranitoids, the morphology and the inner textures of zircons from schists and their melanocratic inclusions and metagranitoids, allowed us to consider the schist body under study as a part of a deep crustal shear zone. The schist body reveals a distinct zonation that indicates a dramatic change in the mineralogical composition from granite at the wall rocks to garnet-kyanite schists with staurolite and chloritoid in the zone center. All processes of such transformations are possible only in the presence of canalized fluid flow through the deep crustal shear zone. Further U-Pb zircon ages from the schist body can give an additional evidence to support our hypothesis for the orthometamorphic character of these rocks.

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КИАНИТ-ГРАНАТ-СТАВРОЛИТОВИ ШИСТИ ОТ ОГРАЖДЕН ПЛАНИНА – МЕТАПЕЛИТИ ИЛИ ОРТОШИСТИ

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В района на с. Лебница, (Огражден планина) се разкриват кианит-гранатови шисти, съдържащи ставролит и хлоритоид, досега описвани като метапелити. Нашите теренни, петроложки, геохимични и цирконови морфоложки изследвания показват някои особености, които дават основание за друга интерпретация на протолитите на тези скали, а именно като високотемпературна дълбочинна зона на срязване, в която гранитоидите са трансформирани във високоалуминиеви шисти. Тялото от шисти в изследвания район показва ясна зоналност. От контакта с метагранитите към централната му част са отделени четири зони, различаващи се по минерален състав. Зона I включва силно нашистени, богати на слюдени минерали метагранитоиди, рядко съдържащи кианитови порфиробласти и дребни гранатови зърна; зона II - съдържа силно деформирани дребнозърнести, меланократни двуслюдени шисти с дребни гранатови и турмалинови порфиробласти; зона III е изградена от едропорфиробластен гранат и удължени кианитови нодули, включени в кварц-слюден матрикс; зона IV (централната част на тялото) – изградена от редуващи се богати на кианитови нодули и богати на кварц ивици. За сметка на серицитизираните кианитови нодули се образуват ставролит и хлоритоид в статична обстановка. Сред скалите от тази зона се наблюдават милонитни ивици, изградени почти изцяло от кианит. Получени са следните данни за P-T условията на метаморфизма: T~ 670 ^{0}C и P_{min} ~ 7 kbar за температурния пик и около 550 ^{0}C за образуването на ставролита и хлоритоида. Въз основа на проведените изследвания може да се предположи ортометаморфен произход на шистите от района на с. Лебница чрез драстична промяна в химизма и минералогията на метагранитите в дълбочинна зона на срязване с активно флуидно участие.