Variscan high-grade metamorphic rocks in Lazovo complex, Central Stara Planina Mountain

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Introduction

Up to now, not much data exist on the metamorphic evolution of the pre-Mesozoic rocks in Stara Planina Mountain, Bulgaria, connecting the intra-Alpine Variscan and Caledonian fragments in Western and Central Europe and in Turkey.

Here are presented preliminary data on some of the rocks in Lazovo complex, the easternmost exposure of the greenschist metamorphic basement of Stara Planina Mountain — the so-called diabase-phillitoid formation (DFF, Dimitrow, 1939) (fig. 1). Microstructural and geothermobarometry data suggest that the metamorphic history of Lazovo complex includes a HT-HP metamorphic event, as part of a clock-wise path in the P-T field. The metamorphic history, the protolithes origin and the preliminary $^{40}Ar/^{39}Ar$ age of the retrograde greenschist event make questionable a correlation with the low-grade metamorphites in Stara Planina Mountain or with the higher grade metamorphites to the South in Sredna Gora Mountain.

Geological setting

In Stara Planina Mountain the greenschist metamorphic event in the rocks of DFF is considered as pre-Variscan (pre-Upper Ordovician) by many authors (see Haydoutov, 1991 and references therein; Haydoutov, Yanev, 1997). The protolithes of DFF are volcanic-sedimentary island arc rocks and ophiolite fragments, metamorphosed in greenschist facies (see Haydoutov, 1991 and references therein) and granitoids metamorphosed in the same grade

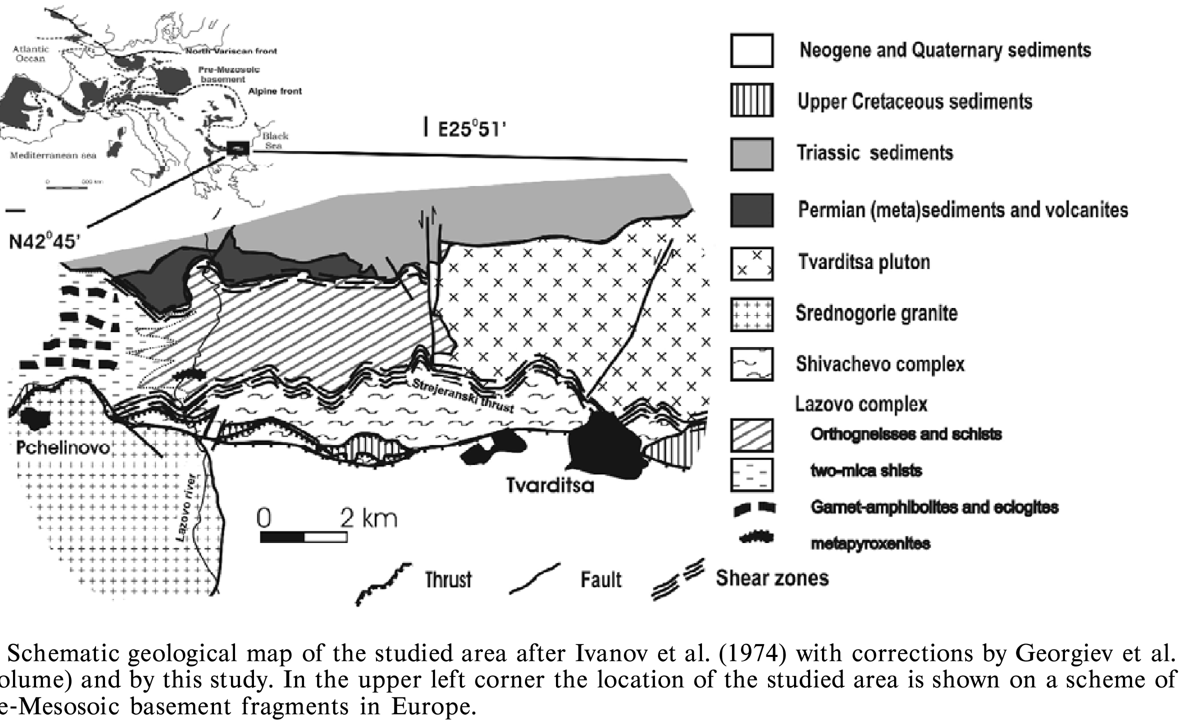

Fig. 1. Schematic geological map of the studied area after Ivanov et al. (1974) with corrections by Georgiev et al. (this volume) and by this study. In the upper left corner the location of the studied area is shown on a scheme of the pre-Mesosoic basement fragments in Europe.

(Antonov et al., 2003; Statelova, Machev, 2005). They are cut by Upper Paleozoic dykes and are intruded by Late Variscan plutons (Kamenov et al, 2002; Carrigan et al., 2005), forming large contact aureole zones.

To the South, in Sredna Gora Mountain a Variscan high grade metamorphic event (~335 Ma, U-Pb age of zircon rims in migmatite leucosomes) (Carrigan et al., 2006) is recorded in a succession dominated by metapsammites, where metapelites, garnet amphibolites, eclogites, orthogneisses and rare lenses of serpentinites are also present (Zagorchev et al., 1973). The timing of the retrograde cooling is evaluated to be at the age of ~317-305 Ma ($^{40}Ar/^{39}Ar$ age of biotites and white micas) (Velichkova et al., 2004). Late Variscan syn- to postkynematic plutons intrude these rocks at several stages (Zagorchev et al., 1973; Carrigan et al., 2005).

Lazovo complex (Ivanov et al., 1974) is exposed in a wide band with E-W extension in the southern slopes of Stara Planina to the North of Tvarditsa town (fig. 1). It is cut by Permian (?) acid dykes and overlain by Permian (?) volcanic-clastic sequence to the North. To the East Tvarditza pluton intrudes and forms thin contact aureole in Lazovo complex (Kolcheva et al., 1978). From South Lazovo complex and the pluton are overthrusted by Shivachevo complex, low-grade metagranitoids (Statelova, Machev, 2005). The pluton, the metamorphites and the volcanites are overlain by Triassic clastic sediments. Preliminary structural data indicate Early Alpine overprinting of Lazovo complex contacts and the overlaying sediments by north vergent brittle-ductile shear zones in lower greenschist facies (Georgiev et al., this volume).

Description of samples

Lazovo complex is dominated by othogneisses in its eastern parts. These include metaintermediate, metabasic to metaultrabasic rocks (as lenses and irregular bodies in the metabasic rocks), the most basic rocks being to the South (fig. 1). In its western parts, mainly two mica schists with or without garnet (up to 1.2 cm of diameter) and garnet bearing amphibolites (garnet porphyroblasts up to 1 cm of diameter) are present (fig. 1). In the northernmost parts, the amphibolites form thicker layers, and in the innermost parts of these metaeclogites are found. Layers of the eastern succession are found in the western and *vise versa*, which suggests that these are rocks of the same Lazovo complex.

Samples are collected from garnet bearing two mica schists (GBMS) and garnet-zoisite-amphibolites (GZA) from the western parts, and metapyroxenites (MP), basic schists (BS) and intermediate schists (IS) from the eastern parts of Lazovo complex. All samples are located at least 4 km away from Tvarditsa pluton.

$^{40}Ar/^{39}Ar$ age dating results (unpublished data) propose an age of ca. 338 Ma for the formation of the white micas in IS. Approximately the same ages were obtained for mineral separates of dark amphibole from IS and MP, probably due to reopening of the isotopic system in the amphiboles in agreement with mineral chemistry and the microstructural observations.

Microstructures and mineral chemistry

In the GZA garnet (Alm_{47-61}, $Grss_{21-31}$, Sps_{9-19}, Pyr_{5-15}), apatite and rutile/sphene (as abundant inclusions in garnets) are a relict mineral association, where equigranular amphibole (tchermakitic) and plagioclase (An_{25-18}) and minor zoisite, quartz, ilmenite/rutile/sphene represent the latest pervasive metamorphic event. Metamorphic foliation is defined by plagioclase and amphibole rich strips. Chlorite and calcite form matrix with no preferred orientation and fill in cracks in the minerals. Garnets have spessartine rich cores. Pyrope molecule is increasing towards the rims of the grains, where almandine shows M-like shape of zoning. Almandine has complicated correlation with spessartine and pyrope suggesting that there was a change in the stable mineral assemblage during garnet growth, involving a different ferromagnesian phase. Sphene inclusions in some garnets show shape-preferred orientation, which is not parallel to the rough matrix foliation and no orientation of the Ti- phases is observed outside the garnets. The cores of the amphiboles show the highest Mg concentrations and the lowest Na+K apfu. Element distribution in plagioclase grains shows irregular preference. Zoisite crystals are less abundant in the rock showing homogenous compositions of X_{Zo} 0.5-0.64. Chlorite has a Fe/(Fe+Mg) ratio of 0.37-0.52 with more Mg rich compositions in the matrix.

In the GBMS from the southern parts of the complex, garnets reach up to 0.3 cm and have similar composition as the garnets in GZA. Foliation is formed by layers of white micas and chloritised biotite and layers of plagioclase (An_{17-11}) and quartz. White micas are muscovite-rich phengites (Si 0.3-0.35 apfu) from the join muscovite-aluminoceladonite, with $Mg/(Mg+Fe^{2+})$ 0.68-0.75. Biotites are phlogopite-annitic with AlIV 1.22-1.36 apfu. Garnets are often fragmented and displaced along the foliation.

In the MP, clinopyroxenes (diopside) are rare relicts in the inner parts of the lenses as rounded or irregular-shaped inclusions in large amphibole grains. The rocks are composed mainly of amphibole (magnesiohornblende) and rare chlorite and epidote minerals (X_{Zo} 0.45-0.55). Amphiboles have exsolutions of opaque minerals and sphene along cleavage planes. Layers (cm scale) are observed where zoisite (X_{Zo} 0.54-0.64) forms large crystals, accompanied by slightly less Mg rich magnesiohornblendes and rare plagioclase (An_{19-11}). Quartz is very rare, filling in interstitial spaces and cracks.

The foliation in BS is defined by amphibole preferred orientation, as well as by metamorphic layering of quartz (and rare plagioclase) rich and poor layers. Fragments of garnets up to 2 mm are preserved as rare inclusions in quartz. In the transitions to IS, more epidote minerals (with allanite cores) and biotite appears, as amphibole is decreasing. White mica and epidote minerals form the foliation in the most acid IOS, where hornblende is rare as fragmented large grains, replaced by chlorite along the cracks. Rutile and opaque minerals are abundant accessory minerals. Amphibole in both IS and BS has intermediate composition between the amphiboles in GZA and MP (tschermakite and magnesiohornblende). Biotites have the same composition as the biotites in the GBMS. White micas have similar Al distribution as in GBMS, but are slightly Fe-enriched (Mg/(Mg+Fe^{2+} 0.46-0.63), probably reflecting the lack of biotite in the metamorphic association. As in GZA, plagioclase shows patchy distribution of Na in a single grain and a very large span of compositions (An_{18-7}). Epidote minerals have irregular zoning compared to the shape of the crystals seen as light and dark gray areas in BSE imaging on electron microscope. Light areas have X_{Zo} 0.42-0.49 and dark grey areas – X_{Zo} 0.24-0.31.

In all described rock types the central parts of some tschermakites and magnesiohornblendes have barroisitic amphibole compositions (Na_B = 0.505-0.802). The distribution of Na in a single grain is not well established and will be a focus of future studies.

Amphiboles in different rock types have different compositions, reflecting the different stability in the P-T field of this phase reflecting the different bulk composition. However in all rock types they show retrograde zoning towards the rims of the crystals. Based on microstructure, the most An-rich plagioclases in GZA are assumed to be in equilibrium with middle to rim parts of the amphiboles. Irregular patchy zoning of Ca-bearing phases (epidote minerals and plagioclases) probably reflects large stability fields of these minerals during fast changing local equilibrium and metamorphic fluid composition. Similar composition of micas in GBMS and IS is interpreted as due to similar PT conditions of crystallization during the retrograde metamorphism. Microstructures show that this crystallization occurred at a later stage than the garnet/amphibole crystallization. This was probably synchronous to the plagioclase final re-equilibration as micas have very narrow compositions. Garnets in GZA and GBMS are a relict mineral phase with prograde compositional zoning from core to rim areas. Re-equilibration or growth during the retrograde phase is not established along cracks or rims, but there is evidence for consumption of rims and fragments of garnet.

Conditions of metamorphism

Mineral composition and microstructures suggest a clockwise path in the P-T field for the rocks of Lazovo complex. The prograde metamorphism is marked only by garnet and its inclusions of apatite and Ti-bearing phases. Unfortunately there are no applicable geothermobarometers to this assemblage, so quantitative measurement is not possible in the studied rocks.

The retrograde path is marked by plagioclase and amphibole recrystallisation and growth. The P-T conditions, estimated based on amphibole-plagioclase pairs in GZA using the geobarometer of Fershtater (1990) and the geothermometer of Holland and Blundy (1994, the average of reaction A and B) are similar to those obtained using the amphibole geothermobarometer of Gerya et al. (1997) in the frame of 2 sigma errors of the methods. GZA recorded a retrograde path in the interval 683.9—617.0°C and 9.3—6.2 kbars. For amphiboles in BS and IS were obtained 618.9—561.9°C and 7.2—5.8 kbars. The largest interval of P-T conditions is recorded in the amphiboles from the MP, 595.9—422.3°C and 6.5—2.5 kbars, but these estimates should be treated with caution and further methods to be applied, as in these rocks quartz and plagioclase are very rare phases. However, an approximation of the P-T conditions could be assumed. As expected from mineral chemistry, amphiboles formed at different P-T conditions in the different rocks with little overlapping. The retrograde path, drown in the P-T field begins from above the amphibolite wet solidus in the Ky stability field, crosses the Ky-Sill-And point and further enters the And stability field. It has a gentle slope of simultaneous decrease in P and T, allowing re-equilibration of some phases as seen by the chemistry of the minerals. Relict mineral assemblages, showing the peak metamorphic conditions, will probably be hard to define. Further work will focus in other rock types and thicker rock “layers”, where these could have been preserved.

Discussion and conclusions

The metamorphic history of Lazovo complex is different from the history of DFF in Stara Planina Mountain. All studied rock types show evidence of a high-grade metamorphic event, which is not reported for any metabasic or metaintermediate rocks in DFF. The age of micas and amphiboles correlates better with the age of zircons in leucosomes from the high-grade metamorphic sequence in Sredna Gora Mountain, however no Alpine overprint is found in the rocks of Lazovo complex in terms of $^{40}Ar/^{39}Ar$ isotope system reopening. Structural data suggest the development of Early Alpine discrete zones as North vergent thrusts (Georgiev et al., this volume), probably preventing Late Alpine thermal overprint. According to the available data, there are differences in the protolithes between Lazovo and Sredna Gora metamorphites, as in the latter metasedimetary rocks are dominant. Thus, correlation of Lazovo complex with the basement in Sredna Gora or in Stara Planina is not possible and should be the focus of future detailed studies of these sequences.

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References

Antonov, M., S. Pristavova, V. Jelev, K. Shipkova. 2003. Deformations and metamorphism in the diabase-phillitoid complex basis in Etropole and Zlatitsa-Teteven Stara Planina. — *Ann. UMG, 46, I,* 1—6 (in Bulgarian)

Carrigan, C. W., S. B. Mukasa, I. Haydoutov, K. Kolcheva. 2005. Age of Variscan magmatism from the Balkan sector of the orogen, central Bulgaria. — *Lithos, 82,* 125—147.

Carrigan, C. W., S. B. Mukasa, I. Haydoutov, K. Kolcheva. 2006. Neoproterozoic magmatism and Carboniferous high-grade metamorphism in the Sredna Gora Zone, Bulgaria: An extension of the Gondwana-derived Avalonian-Cadomian belt? — *Precambrian Research, 147,* 404—416.

Dimitrow, Str. 1939. Ergebnisse und Problemme der Petrographischen Forschungen in Bulgarien. — *Ann. Univ. de Sofia, FPM, 3,* 225—253 (in Bulgarian).

Fershtater, G. B. 1990. Empirical hornblende-plagioclase geobarometer. — *Geokhimiya, 3,* 328—335 (in Russian)

Gerya, T. V., L. L. Perchuk, C. Triboulet, C. Audren, A. I. Sezko. 1997. Petrology of the Tumanshet Zonal Metamorphic Complex, Eastern Sayan. — *Petrology, 5/6,* 503—533 (in Russian).

Haydoutov, I. 1991. Origin and evolution of the Precambrian Balkan-Carpathian ophiolite segment. Sofia, 179 p. (in Bulgarian).

Haydoutov, I., S. Yanev. 1997. The Protomoesian microcontinent of the Balkan Peninsula–a peri-Gondwanaland piece. — *Tectonophysics, 272,* 303—313.

Holland, T. J. B., J. D. Blundy. 1994. Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry. — *Contrib. Mineral. Petrol., 116,* 433—447.

Ivanov, J., K. Koltcheva, S. Moskovski. 1974. Edification geologique d'une partie du noyau de l'anticlinal de Tvarditza. — *Ann. Univ. de Sofia, FGG, 65, 1,* 245—277 (in Bulgarian).

Kamenov, B., A. von Quadt, I. Peytcheva. 2002. New insight into petrology, geochemistry and dating of the Vejen pluton, Bulgaria. — *Geochem., Mineral., Petrol. 39,* 3—25.

Kolcheva, Kr., J. Ivanov, B. Iordanov. 1978: Metapyroxenites from the Lazovo river valley, the Central Balkan. — *Ann. Univ. de Sofia, 70, 1,* 395—405 (in Bulgarian).

Statelova, J., Ph. Machev. 2005. Metagranites from Berkovitsa Group, Central Balkan area — structural and petrographical evidence. — *Ann. Univ. de Sofia, 97,* 149—160.

Velichkova, S., R. Handler, F. Neubauer, Z. Ivanov. 2004. Variscan to Alpine tectonothermal evolution of the Central Srednogorie Zone, Bulgaria: constraints from $^{40}Ar/^{39}Ar$ analysis. — *Schweiz. Mineral. Petrograph. Mitt. (Spec. issue GEODE-ABCD), 84,* 1-2, 131—151.

Zagorchev, I., H. Dabovski, D. Chunev. 1973. On the tectonics of the western part of the Sredna Gora crystalline block (Sredna Gora proper). — *Rev. Bulg. Geol. Soc., 34, 1,* 1—10 (in Bulgarian).

Херцински високостепенни метаморфити от Лазовския комплекс, Централна Стара планина, България

Юлия Стателова

Все още не са известни много факти за метаморфната еволюция на скалите от домезозойската подложка на Стара планина, свързваща каледонските и херцинските фрагменти в Алпийския пояс в Европа и в Турция. Представени са предварителни данни за микроструктурните взаимоотношения и съставите на минералите в някои от скалите на Лазовски комплекс, считан за най-източното разкритие на зеленошистната подложка на Стара планина — т.нар. диабаз-филитоидна формация. Изведеният Р-Т ход на метаморфизма е по часовниковата стрелка и включва метаморфизъм в условия на високо налягане и температура. Метаморфната история, скалните разновидности, протолитите в метаморфния разрез, както и получените данни за възрастта на някои метаморфни минерали правят несигурни предишни корелации с диабаз-филитоидната формация. Корелацията с високометаморфния разрез от Средна гора също е невъзможна на този етап от работа, ако не се приеме, че Лазовски комплекс представлява високи нива на този разрез.