

## DEFORMATIONS AND METAMORPHISM AT THE BASE OF THE DIABASE-PHYLLITOID COMPLEX IN ETROPOLE AND ZLATITSA-TETEVEN MOUNTAIN (CENTRAL BULGARIA)

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### ABSTRACT

The low-grade metamorphic rocks exposed on the southern slopes of Etropole and Zlatitsa-Teteven Mts. are the object of present study. At first these rocks have been referred to the "diabase-phyllitoid formation", renamed later "diabase-phyllitoid complex". During the last decade they have been correlated with Berkovitsa Group or Dalgidel Group. The present investigations do not support the reliability of this correlation. According to petrologic and structural criteria, the complex is divided in two lithostructural units: lower one, represented mainly by tectonically stratified orthometamorphites and upper one, built up predominantly of metapelites and metaaleurolites. On the case study of several sections of the lower lithostructural unit, the sequence of the structural and metamorphic events as well as the metamorphic environment is determined.

### INTRODUCTION

Along the southern slopes of Etropole and Zlatitsa-Teteven Stara Planina Mts., between the rivers of Brevene and Sanur Dere (Fig. 1), there are almost uninterrupted exposures of the diabase-phyllitoid complex, immediately above its boundary with migmatized gneisses referred to the so-called Arda Group (Cheshitev et al., 1995). They are very suitable for detailed study of the composition and the structure of its lowermost part, comprising mainly metabasitic rocks. It is designated here as lower lithostructural unit. The clarification of its metamorphic and structural evolution will allow more substantial interpretation of the nature of the boundary between the high-grade and low-grade rock complexes. The previous ideas concerning the composition and the structural peculiarities of these complexes as well as the character of their boundary could be found in a previous article (Antonov et al., 2001).

This paper aims to analyze the petrologic and structural data taken from 6 sections, intersecting different parts of the lower lithostructural unit of the diabase-phyllitoid complex. The study focuses on two aspects: 1) petrologic characterization of the rocks and morphological features of the deformational structures in microscopic and small mesoscopic scale and 2) determination of the structural sequence, the environment and grade of the metamorphic processes. The results from the detailed areal study of the lower lithostructural unit are to be discussed in another article.

### GEOLOGICAL SETTING

With respect to the Late-Alpine structural setting, the studied region is situated in the embrace of the so-called Chelopech unit (Angelov et al., 1995; Cheshitev et al., 1995), which possesses fold-thrust structure (Fig. 1). Its northern boundary is traced along several subequatorial reverse faults-thrusts (Kashana, Mechesh, Jemina), and its recent southern boundary is along the Sub-Balkan normal fault, which

separates the unit from the Neogene Zlatitsa semi-graben. Part of fold limb, built up of Upper Cretaceous sedimentary rocks, is represented in the region. Northeast of Tsarkvishte village, these rocks overlay transgressively and discordantly both the migmatized gneisses and the metamorphites of the diabase-phyllitoid complex. The boundary between the two metamorphic types is subparallel to their dominating planar structures, trending generally east-west and dipping from 40° to 60-75°/S. In Plevnyaka place as well as along the southern slope of Kaleto locality, it dips to north, northeast or northwest with different angles, due to local folding.

### TECTONOSTRATIGRAPHY OF THE LOWER PART OF DIABASE-PHYLLITOID COMPLEX

In the previous articles about the geological structure of the region, the rocks of the complex are initially considered as Paleozoic "schist complex" (Toula, 1882; Zlatarski, 1883; Bonchev, 1908) or "Silurian shales" (Mandev, 1942). Later, they are assigned by Trashliev (1964) to the "diabase-phyllitoid formation" defined by Dimitrov (1946) and renamed by Boyadjiev (1970) in "diabase-phyllitoid complex". Belev (1967) refers the metabasites of the lowermost part of the green-schist complex to the so-called amphibolite formation of the "Precambrian high-grade serie" and the phyllites – to the "diabase-phyllitoid formation". According to Ivanov et al. (1987), this "formation" represents a "complicated rock unit, in which, due to tectonic reasons, mixing of fragments of oceanic and continental crust with comparatively deepwater epicontinental sediments has taken place". Haydoutov (1991) assumes that the diabase-phyllitoid complex in the region is an analogue to the Berkovitsa Group.

During the initial stage of the present study, a "marker level" was separated at the base of the diabase-phyllitoid complex. It comprises mainly metabasites (Antonov et al., 2001) and its thickness varies from 50 to 500 m.

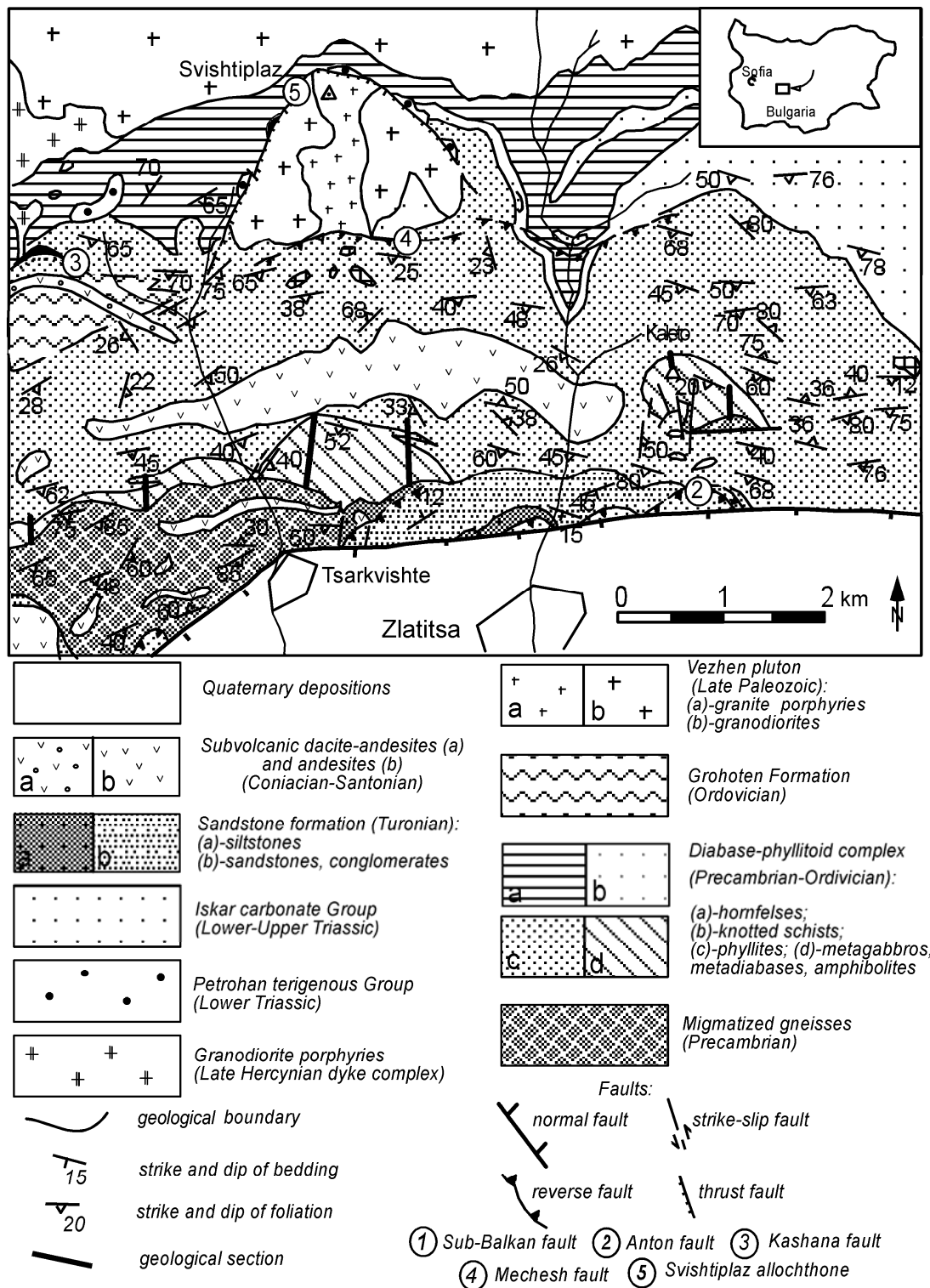


Figure 1. Geological map of the southern slopes of Etropole and Zlatitsa-Teteven Stara Planina

The new data about the petrographic composition and the structural features of this "level" as well as of the upward following association of parametamorphic rocks do not support its correlation with the Berkovitsa Group in the embrace of the region under consideration (Cheshitev et al., 1995). This is because of the lack of volcano-sedimentary and turbidite sequences, lydites and marbles, characteristic for the "island arc association" of the West Balkan. There are no grounds for its correlation with the "olistostrome" Dalgidel Group

(Cheshitev et al., 1995), due to the insignificant presence of coarser terrigenous sediments as well. That is why, proceeding from the contrast differences in the rock composition, the character of metamorphism and the deformation style, two mappable lithostructural units at the lower part of the diabase-phyllitoid complex could be defined, which we provisionally designate lower and upper.

The lower lithostructural unit is built up only of metamorphosed igneous rocks – mainly metabasites

(metagabbros, amphibolites, amphibole schists, green schists) and subordinate quantity of metagranitoids (metaplagiogrinites, metafelsites and metapegmatite-aplite). The lower boundary of this unit with the migmatized gneisses is a sharp metamorphic contact (Table. I; d), but its upper boundary is delineated along its contact with metapelites (mylonitized phyllites). Its total thickness in the region varies from 80 to 450 m.

As a result from the intensive syn-metamorphic ductile and brittle-ductile deformations, all of the rock varieties are featured by distinct SL-fabric. Dominating planar structure in mesoscopic scale is the tectonic stratification, resulted from isoclinal folding and transposition of an early foliation (metamorphic banding) in regime of heterogenous simple shearing. This foliation is determined by repeatedly alternation of homogeneous and/or heterogeneous "layers", which thickness varies from several mm up to 1-1,5 m as well as of sheets, from several meters to 30-40 m thick. Planes or narrow zones of ductile and brittle-ductile shearing always represent the boundaries between the "layers" and/or the sheets. The deformation style is unchangeable both in vertical and horizontal direction. The distribution of the rock varieties in the tectonostratigraphic section is irregular but in some localities (e.g. Kaletso) it could be subdivided in superpositionally situated sub-units: amphibolite-metafelsite, of the banded and massive amphibolites, metaplagiogrinite with orthoquartzite marker and amphibolite with thin sheets of metaplagiogrinites (Fig. 2).

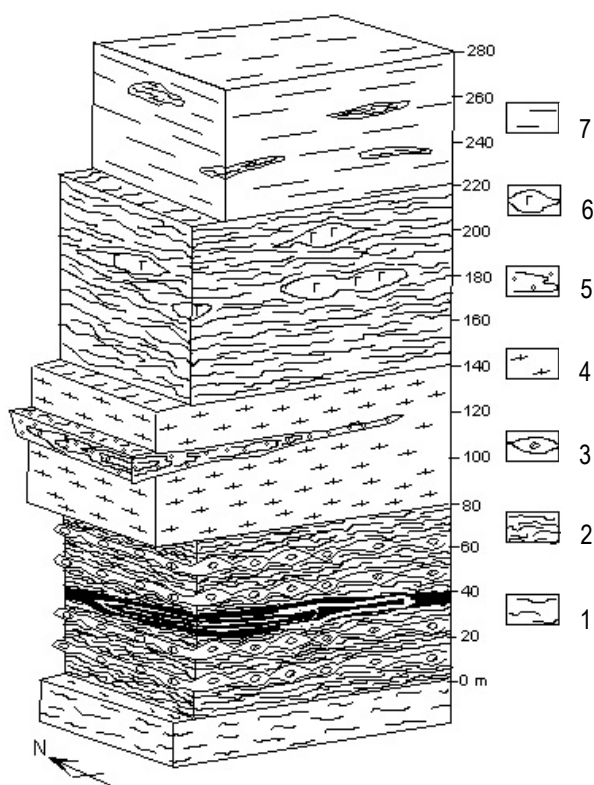


Figure 2. Generalized block-diagram demonstrating the rocks distribution of the lower lithostructural unit  
1 – migmatized gneisses; 2 – amphibolites; 3 – metafelsites; 4 – metagranitoids; 5 – quartzites; 6 – metagabbros and metagabbrodiorites; 7 – phyllites.

The upper lithostructural unit includes metamorphosed in green-schist facies sedimentary rocks (pelites, aleurolites and aleurolites), comprising allochthonous fragments of different size and composition – metabasites (ophiolithoclasts), granitoids, aplites and quartzites. Its lower boundary is traced along the first appearance of strongly mylonitized phyllites. To the north of the region, they are altered in hornfelses and knotted schists. The dominating planar structure of the metasediments is the axial cleavage, formed during the metamorphism and folding of the primary bedding. It is parallel both to the boundaries and to the foliation of the allochthonous fragments.

## PETROLOGICAL CHARACTERIZATION

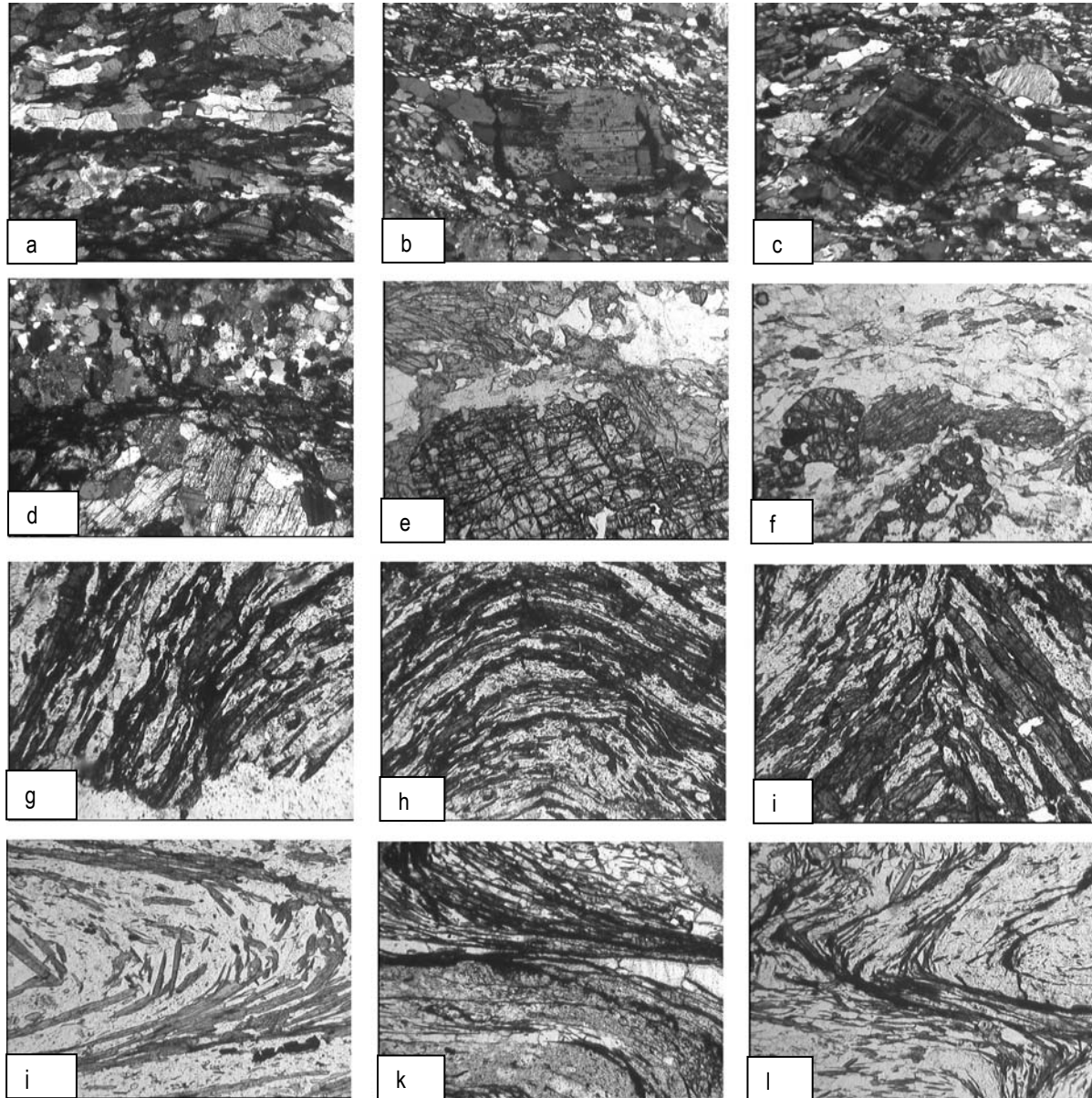
The lower lithostructural unit defined by the authors is built up only of metamorphosed igneous rocks. The detailed studies allow the separation of several petrographic varieties as follows: metabasites represented by massive metagabbros to metagabbrodiorites, massive amphibolites with or without garnet, banded amphibolites, amphibole schists and green schists as well as metagranitoids, comprising metagranites, metagranodiorites, metafelsites and metapegmatite-aplites.

**Metabasites.** *Metagabbros to metagabbro-diorites* could be observed along the entire section of the lower lithostructural unit. They form lenses and boudins varying from 0,8 up to 1,5 – 2,0 m. It strikes, that some of them are concentrated in the middle part of the unit and they are always present next to its contact with the upper lithostructural units. These rocks comprise large crystals and possess massive and/or spotty structure. Moreover, they have very well preserved gabbro to hypidiomorphic-grained texture. Although that all of the primary minerals are metamorphosed, they could easily be recognized after their forms. Their mineral composition includes two parageneses: magmatic (plagioclase, amphibole and pyroxene – only like relict "spots") and metamorphic (plagioclase, amphibole, quartz, rutile and epidot minerals). The minerals of the metamorphic paragenesis are represented by plagioclase (An45) and two types of calcium amphiboles – ferrohornblende and actinolite hornblende. The first one forms well crystallized grains, but the second one is developed along the cleavage planes of the magmatic pyroxene. *The banded amphibolites* are referred to this group of metabasites. They possess fine to rough banded structure, determined by alternation of femic and salic component. They are built up of relict magmatic association – plagioclase (An60), amphibole (edenite type) and metamorphic association including amphibole (magnesianhornblende), zoisite and plagioclase (An30). *The massive amphibolites* are represented along the entire section. In some places they comprise garnet in other ones they do not. The latter ones are always in boudinage structures. Microscopically, the amphibolites possess heterogranoblastic structure, porphyroblastic after the garnet (Table I; e). They are built up of amphibole (magnesianhornblende), garnet (Alm<sub>60-56</sub>; Pyr<sub>25-27</sub>; Gross<sub>9-10</sub>; And<sub>4,4-5</sub>; Spess<sub>1,66-1,87</sub>), plagioclase (An20), quartz and rutile. Along the boudins periphery these rocks are blastomylonitized (Table I; f) and form new mineral paragenesis comprising amphibole (actinolite hornblende), garnet (Alm<sub>62-63</sub>; Pyr<sub>17-18</sub>; Gross<sub>10-11</sub>; And<sub>4,5-5</sub>; Spess<sub>3-3,2</sub>), plagioclase (An25) and chlorite. *The amphibole schists* are small-grained with fine-schistous character and micro-

granonematoblastic texture. They consist of amphibole (magnesian- and ferrohornblende, ferroactinolite hornblende and ferroactinolite), plagioclase (An0-7), quartz, epidot, brown mica, apatite and ore minerals (ilmenite). *The green schists* are very rare in the studied lithostructural unit. They consist of fine granolepidoblastic mass of chlorite (up to 80%), epidot, rutile, titanite, plagioclase (albite), quartz, white mica, titanium-leucogene products and ore minerals (ilmenite). Larger part of them is strongly blastomylonitized (Table I; l).

**Metagranitoids.** Metamorphosed magmatic rocks of acid compositions are referred to this rock group – plagiogranites, granodiorites, felsites and pegmatite-aplites. They are small- to

coarse-grained, gray-whitish with very distinct banded structure. They possess mark of clear cataclasis and blastomylonitization. These rocks are featured by cataclastic to mylonitic and blastomylonitic texture, porphyroclastic after the plagioclase crystals (Table I; b, c). In the more slightly deformed districts it is blastogranite, blastoporphry (e.g. with the felsites) and blastoaplite. All of them possess very well preserved magmatic mineral association comprising plagioclase, potassic feldspar, quartz, amphibole and biotite. The metamorphic association of these rocks is represented by plagioclase, quartz, epidote and zoisite, chlorite and amphibole. More detailed petrographic characterization of the metagranitoids is made by Antonov et al. (2001).



**Table I**

a – contact between migmatized gneisses (down the arrow) and metagranitoids (up the arrow); b, c – porphyroclastic after the plagioclase texture in metagranitoids; d – tectonic contact between massive amphibolites and metafelsites; e – garnet amphibolite; f – blastomylonite on garnet amphibolite; g, h – transposed foliation in the limb (g) and the hinge (h) of fold in amphibole schist; i – shearing in hinge zone of fold in amphibole schist; j – two amphibole generations in a narrow fold in amphibole schist; k, l – reduction of the “layers” in the limbs of isoclinal folds. X50.

## STRUCTURAL CHARACTERIZATION

The presence of gneisses ("crystalline") in the valley of Sanar Dere river and along the massive of Kaleto peak is at first marked by Mandev (1942). It opines that they are slipped to north over the Paleozoic schists, which as a result from the stress related to the thrusting, have been metamorphosed up to amphibolites. The assumption of Belev (1967) is similar. He thinks that these gneisses and amphibolites build up a "tectonic klippe".

During the present study it was established that a fragment from the core and the recumbent northern limb of a relatively big antiform fold is preserved in Kaleto locality. It is broken by longitudinal, transversal and oblique faults (Fig. 1). The fold core comprises migmatized gneisses, which crop out in a narrow strip to the north of a subequatorial normal fault. The relatively competent rocks of the lower lithostructural unit form the recumbent limb. Its general trend is subequatorial but the dip varies from 20° to 40°/S. The migmatized blastomylonite gneisses, situated immediately to the contact with the green-schist rocks, are diaphthorized. Due to insignificant areal distribution and lack of relevant outcrops, their structural peculiarities are characterized in more details to the west of the region, along the southern slope of Plevnyaka hill.

**Planar structures.** In the strongly metamorphosed rocks of the lower unit, several morphological types of foliation could be distinctly recognized: metamorphic banding, schistosity, mylonite foliation, transposed foliation and crenulation cleavage. *The metamorphic banding* is manifested in the metabasite rock varieties. It is determined by the alternation of strips of different composition and/or color. *The schistosity* is determined by the plan-parallel trend of the prismatic minerals and mineral aggregates in the metabasites (the banded amphibolites, amphibole schists and green schists). *The transposed foliation* is the dominating planar structure in microscopic and small mesoscopic scale (Table I; g, h). It resulted from the intensive isoclinal folding and refolding of the preceding foliations. In larger mesoscopic scale, the repeated transposition is expressed as tectonic stratification, which most frequently is subparallel to the other foliations. *The mylonite foliation* is developed everywhere parallel to the transposed foliation (Table I; k, l). *The crenulation cleavage* is locally manifested in relatively narrow zones up to 10-15 m thick. According to morphological peculiarities it is most frequently represented by fracture-like crenulation cleavage, related to kink-folds and crenulations, deforming the transposed foliation.

**Linear structures.** Intersection lineation, stretching lineation, slickenside lineations and crenulation lineation are observed on the planes of the different morphological types of foliation. Boudinage structure could be met in all levels. *The intersection lineation* is almost everywhere manifested on the surfaces of the "layers". It resulted from the intersection of the metamorphic banding or schistosity with the tectonic stratification. It is parallel to the fold hinges developed after this banding. *The stretching lineation* could be surely identified only in the metafelsites. It is determined by the elongated mineral aggregates. Moreover, on the surfaces of the transposed metamorphic banding are observed slickenside lineations of different trends compared to the fold hinges. *The crenulation lineation* is locally manifested in relatively narrow zones of

brittle-ductile shearing. It is marked by the crenulations of the transposed foliation. *The lineation after the long axes of the boudins* formed by relatively more competent «layers» of metafelsites, coarse-grained metagabbros and metagabbrodiorites could be met in all parts of the lower unit.

**Folds.** The fold structures have got significant importance for characterization of the deformation style of the lower lithostructural unit. During the present study, several fold generations have been recognized. The earliest generation comprises isoclinal micro- and small mesoscopic folds (Table I; g-l), which morphology can not be characterized due to later refolding and transposing. Only intrafoliation hinge zones pictured by the metamorphic banding are preserved from them. The folds of the second generation are coaxially superimposed on the folds of the earliest generation. They are also represented by small mesoscopic isoclinal or narrow folds of big amplitude and insignificant wavelength, formed after the transposed foliation. The third generation includes kink-folds and kink-zones after the transposed foliation, which are superimposed crosswise or oblique on the earlier folds. Mesoscopic and relatively larger open and undisturbed folds of local distribution, formed after the tectonic stratification, refer to the fourth generations.

**Metamorphism.** In the published literature prevails the opinion that the rocks of the separated here lower lithostructural unit are regionally metamorphosed in green-schist facies environment (Antonov et al., 2001). The data obtained during the present study give grounds to suppose that this unit unites rocks both with contrast protolithic composition and with different metamorphic evolution. For example, part of the separated varieties of *metabasites* brings clear marks of polymetamorphism. This could be best seen in the massive amphibolites and amphibole schists. Their metamorphic paragenesis (magnesiocornblende – garnet – plagioclase) is typical for the rocks of the amphibolite facies. The superimposed on it paragenesis of ferroactinolite – chlorite – plagioclase possesses clear diaphthorite character. It is in close relation to the transposition of the early foliation (Table I; g, h) and/or is localized in the zones of blastomylonitization of these rocks. The green schists have got a mineral paragenesis, featured for the green-schist facies, which in the zones of transposition recrystallizes in the same mineral phases. Metabasites of very well preserved relict magmatic minerals and structures are also an element of the composition of the level studied. On the other hand, the exposed *metagranitoids* possess the marks only of the typical dislocation metamorphism and all of them could be united in the general term - blastomylonites.

**Structural sequence.** The relationships of the structures allow determination of the supposed sequence of the structure-forming process. Several stages are recognized which are provisionally designated D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, and D<sub>4</sub>. *The deformation stage D<sub>1</sub>* comprises syn-metamorphic formation of the metamorphic banding, early isoclinal folding and initial banding transposition; coaxial superimposing of the second generation of isoclinal and tight folds and repeated transposition of the foliation. The similar trend of the fold hinges and axial planes of the two generations as well as of the intersecting lineation demonstrates that they resulted from two episodes in the framework of one deformation event. The deformation

represents heterogeneous simple shearing. The deformation stage  $D_2$  is related to the formation of boudinage structures and oblique shear fractures, resulted from flattening and shearing in pure shear conditions. Slickenside lineations develop on the surfaces of the transposed foliation. During the deformation stage  $D_3$ , in relatively narrow zones of brittle-ductile shearing, kink-folds, crenulation cleavage and crenulation lineation form. During the deformation stage  $D_4$ , open and uninterrupted folds of subequatorial trend are established.

## CONCLUSIONS

The most important results of this study are as follows:

1) According to petrologic and structural criteria, the lower part of the diabase-phyllitoid complex is divided in two lithostructural units, provisionally noted as lower one and upper one. The lower unit comprises tectonically stratified ortho-rocks – mainly metabasites and subordinate quantity of metagranitoids. The upper unit is built up of metapelites and metaaleurolites with fragments of metabasites, granitoids etc. Lithologically, this part of the diabase-phyllitoid complex can not reliably be correlated with the Berkovitsa Group or Dalgideltsi Group, defined in the West Balkan.

2) The planar, linear and fold structures of the lower lithostructural unit are interpreted according to their trends and geometrical relationships as a result of four deformation stages.

3) The data about the mineral composition, micro- and meso-structural peculiarities, the grade and type of the metamorphic processes of the rocks in the embrace of the lower lithostructural unit give grounds to assume, that this unit “unites” rocks of both contrast protolithic composition and different metamorphic evolution.

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