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PETROLOGICAL AND STRUCTURAL CHARACTERISTICS OF THE LOW GRADE METAMORPHIC ROCKS FROM THE VALLEY OF GABROVNITSA RIVER, WESTERN STARA PLANINA

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ABSTRACT
New data of the petrologic features and structures of the low-grade metamorphic Lower Paleozoic rocks from the Gabrovnitsa river between the villages of Ossenovlak and Elenovdol are discussed in the present paper. These rocks are referred to the Diabase-phyllitoid Complex. The metasedimentary sequence is represented by irregular alternation of siltstones, siltshales, mudshale, sandstones and conglomerates metamorphosed in the condition of green schist facies. Four formations and four mark levels are divided in the studied rocks as well as three fold generations as a result of polyphase deformation

INTRODUCTION

Dimitrov (1930) made the first and the most detailed petrographic and stratigraphic study of the low grade metamorphic Lower Paleozoic rocks from the Gabrovnitsa river between the villages of Ossenovlak and Elenovdol. He divided one arkose-graywacke complex and another one of grey-greenish schist situated above it that are separated by “discordance between them” or “secondary discordance”. In the same work he emphasized that in the Iskar Gorge their position is opposite. Later for these metamirphic rocks, referred to the so called Diabase-phylitoid Formation or Diabase-phylitoid Complex (DPhC), are proposed various startigraphical schemes by Chunev, Kozhouharov (1968), Ivanov (1970; 1972), Gorshkov, Dzhelepov (1970) and Dzhelepov (1983). Only two of them by Ivanov (1970; 1972) and Dzhelepov (1983) could be compared with the complexes, divided by Dimitrov because they are accompanied by correlation tables and geological maps. After Ivanov (1970, 1972) the Lower Paleozoic section is discontinuous and includes three superpositionally disposed formations – volcano-terrigenous (later characterized by Ivanov, 1983 as olistostrome), aleurolite-quartzitic and clayey. Dzhelepov(1983) detached three formations – sandstone-argillitic, conglomerate-qurtzitic and volcano-argillitic. He supposes, that the rocks from the two upper formations are “deposited in the condition of a new sedimentary cycle, because in the base of the second formation “basal polygenous conglomerates” are situated with angular or parallel discordance above various levels of the sandstone-argillitic formation. The author correlates the low and the medium formations respectively to Dimitrov’s schist and arcose-greywacke complex and the upper one with the clay formation (Ivanov, 1972). The Dzhelepov’s scheme is accepted by Haydoutov (1991) who used it with slight changes in the preparing of the Bulgarian Geological Map on scale 1:100 000 (Angelov et al., 1992; 1992a; Tzankov et al., 1991; Yanev et al., 1992). In the map the sandstone-argillitic formation is referred to the Berkovitsa Group and the two upper formations to the Dalgidel Group.

During the clarifying of the structures connected to the rare-earth mineralisation in the Iskar Gorge region one of the authors (M.A.) carried out geological and structural investigations in the region of the Gabrovnitsa river and the results were partly published (Antonov, 1989).

In the present paper on the base of additional field works and laboratory studies, more detailed characteristic of the petrologic and structural features and metamorphism of the low-grade metamorphic rocks is made.

GEOLOGICAL SETTING

The Lower Paleozoic low-grade metamorphic rocks with the cross cutting Upper Paleozoic intrusive bodies and dykes built up the basement of the so-called Berkovitsa unit, according to the Alpine structure setting (Angelov et al., 1992; Tzankov et al., 1995)

During the present study it was found out that the Lower Paleozoic section in the valley of the river Gabrovnitsa is continuous but differs from those of the Iskar Gorge. It could be subdivided into four formations and a few mark levels. The surface distribution, vertical and lateral interrelations between the lithostratigraphic units are presented in fig. 1, 2, 3. The names of these units correspond to the protolith composition. The lowest sandstone-siltstone-argillite formation is set up of rhythmic alternation of fine to medium bedded low metamorphosed fine-grained sandstone, siltstones, mud stones, mudshales and argillites. It comprises fast wedging out fine packets of fine-grained polygenic conglomerates, gravelites, coarse-grained sandstones, marls and limestones.

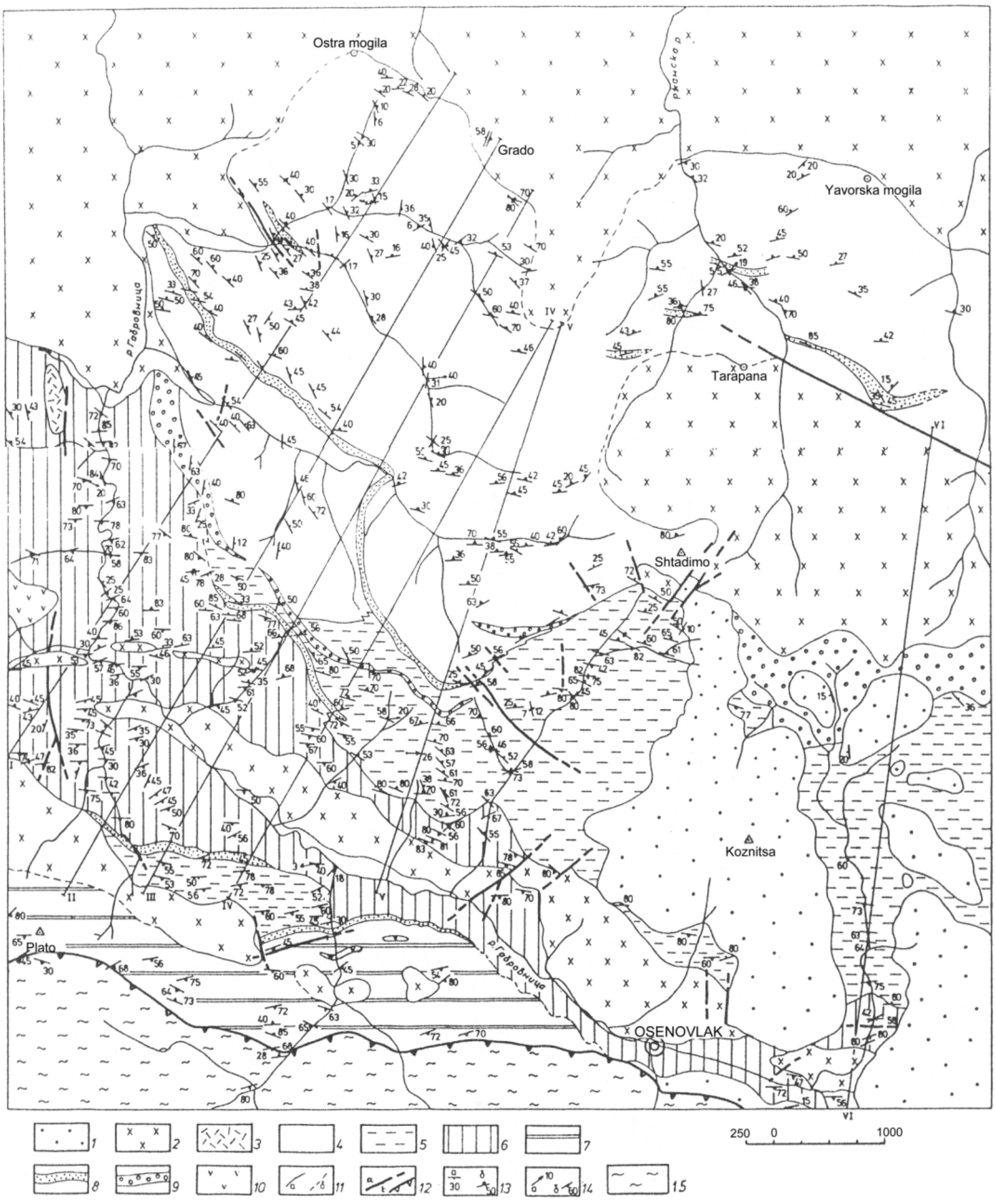

Figure 1. Geological map of the studied area
1 – Mezozoic cover; 2 – untrusive granitoide bodies; 3 – bodies and dykes of granite porphyre; 4 – siltstone –argillite formation; 5 – argillite formation; 6 – sandstone-siltstone –argillite formation; 7 – contact metamorphosed rocks of the DPhC; 8 – sandstone-quartzite and quartzite marl level; 9 – conglomerate mark level; 10 – diorite porphyrites; 11 – geological boundaries: a – established; б – probable; 12a- fault of unclear character 12б – reverse-slip fault; 13 – bedding strike and dip: a – normal; б – overturned; 14a – fold hinge direction and plunge ; 14б – foliation strike and dip; 15 – Grohoten Formation.

Argillite formation is built up of mudstones and mudshales with singular fine interbeds of siltstones. Its lower boundary is gradual transition and to the NW direction it laterally joins with sandstone-siltstone-argillite and siltstone-argillite formations. *Siltstone-argillite formation* consists mainly of siltstones and mudstones building up packets of various thicknesses. Single beds and thin packets of fine-grained conglomerates, sandstones and quartzites are presented there. *Conglomerate formation* mainly includes conglomerates and small quantity sandstones, siltstones and argillites. The low boundary with the argillitic formation is a sharp lithological contact and to the NNW direction it laterally joins probably with the siltstone-argillite formation. Single fragments of metagabbro-diabase, metadiabase and its tuffs are common in the three formations. The mark levels (*sandstone, sandstone-conglomerate and quartzite*) are situated often between formations and partly are included in them.

The above-described lithostratigraphic units take part in the formation of a relatively large anticlinal fold, known as Gabrovnitsa anticline (Maljakov, Cholakov, 1971; Gorshkov, Dzhelepov, 1980).

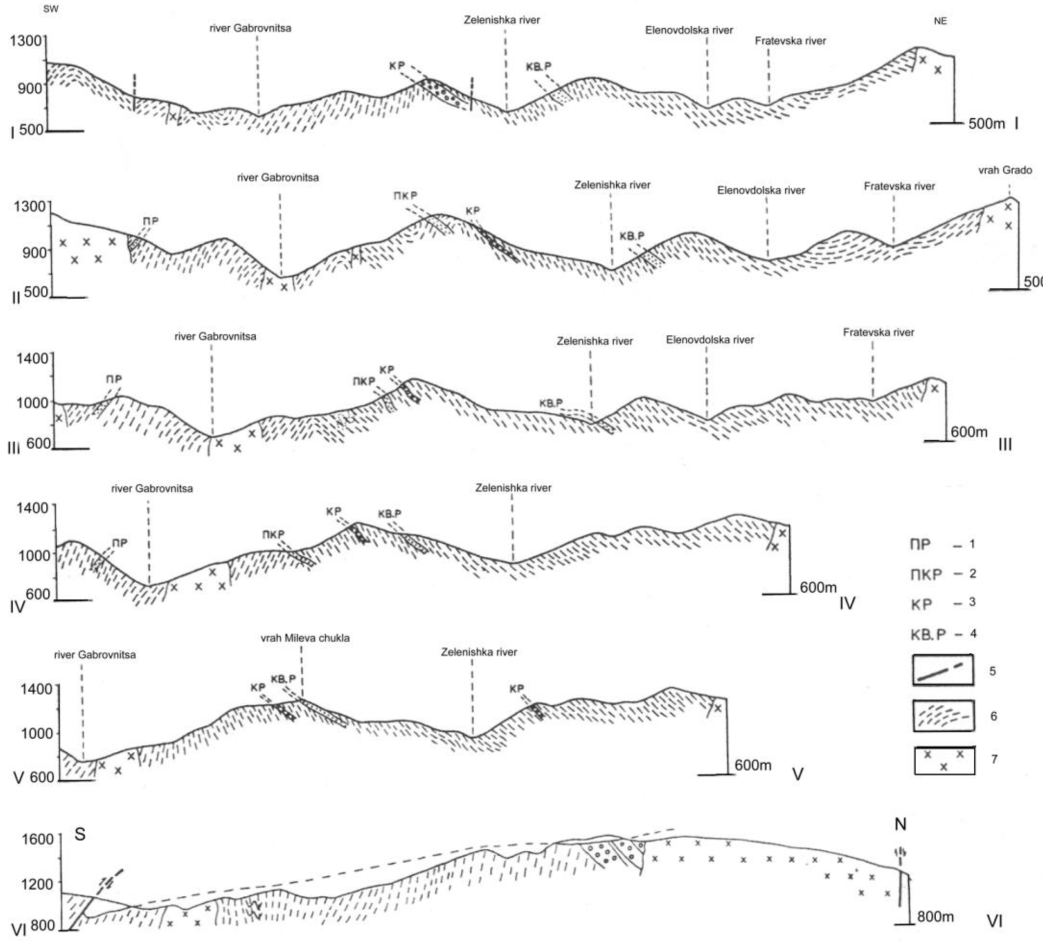

Figure 2 Geological cross-sections
1 – sandstone mark level; 2 - sandstone-quartzite mark level; 3 – conglomerate mark level; 4 - quartzite mark level; 5 – fault; 6 – axial foliation; igneous rocks

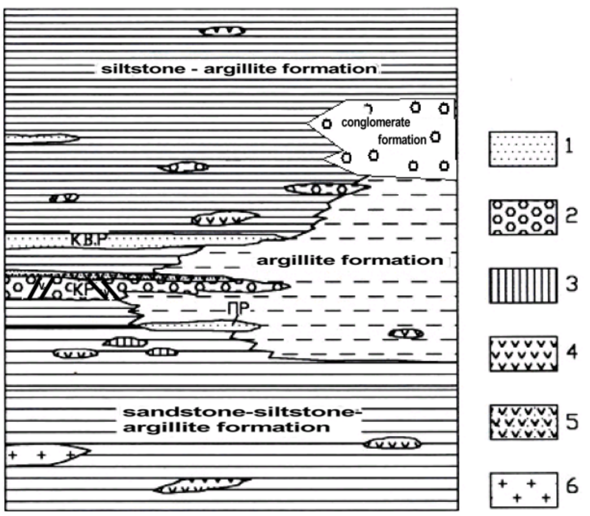

Figure 3 Scheme of the interrelations between the lithostratigraphic units: 1 – sandstones and quartzites; 2 – conglomerates; 3 – calc-silicate rocks and marbles; 4 – diabase and diabase tuffs; 5 – dykes of diabase; 6 – gabbro, gabbrodiabase; ПР – sandstone mark level; КР – conglomerate mark level; КР – quartzite mark level

PETROLOGIC CHARACTERISTIC

The rock spectrum of DPhC in the studied area includes chiefly metasedimentary rocks with protoliths: argillites, mudstones and mudshales, siltstones, sandstones – arcose wackes and lithic greywackes; conglomerates, single thin interbeds of limestones and a small quantity of metagabbro-diabases, metadiabases and their tuffs.

The classification scheme by Potter at al. (1980) was used for fine-grained terrigenous rocks (Table 1). Determination of the psammitic rocks was made according to the classification scheme by Pettijohn et al.(1976) (after Dott, 1964).

Siltstones and argillites are the dominant fine-grained rocks in the studied section. Pure silty and clayey rocks are absent – mudstones and mudshales are the most abundant rock types. About ¼ of the fine-grained clastic rocks are set up of alternation of silty and argillitic laminae (varves) with thickness 0,5-3,0 mm. Argillites show microflaked texture and oriented microstructure. They consist of 70-95% clay minerals altered to chlorite and sericite and 5-30% quartz, feldspars and single flakes of terrigenous muscovite of fine to medium silty size. Siltstones have similar composition with domination of quartz and feldspars. They are fine to medium grained with irregular grained texture. The transitional varieties (mudshales and mudstones) are the most common. Laminated argillites (varves) comprise an alternation of mudshales and mudstones varying in their silt composition. *Sandstones* are presented mainly of arkose wackes and lithic greywackes and insignificant amount of arkose arenites. Wackes and greywackes consist of about 65-75% clastic component and 35-40 % matrix. Arkose waskes are fine-grained with relict irregular graned texture. Clastic grains are semi-rounded to rounded and contacts between them are loose and pointed. The matrix type is pore-filling and basal. The composition of clastic part is mainly of quartz, less feldspar. The primary matrix was probably clayey later altered of chlorite and sericite. Numerous newly formed ore products (sphene – leucoxene) are present too. Lithic greywackes are fine grained with relict irregular graned texture. Clastic grains have irregular distribution and are represented of quartz, less feldspars and rock fragments. The matrix is of clay minerals altered of the chlorite and sericite. Ilmenite and leucoxene grains are common. *Conglomerates* from the lens-like structure consist of clasts with sizes from 4.0 – 8.0 mm up to a few cm. There are also conglomerates with abundance of clasts with sizes 2.0 – 4.0 mm transitional to the gravelites. The clasts shape is semi-rounded to rounded, corroded by the matrix. Their composition is mainly of rock fragments - micro to fine grained quartz, metadiabases, metaultramaphites(?), argillites and siltstones. The matrix was originally clayey-sandy altered of the chlorite-sericite mass with quartz and feldspar grains. The conglomerates from the conglomerate mark level accepted by Dzhelepov (1983) as “basal” are specific without analog in the studied section. Macroscopically they are grey-greenish to gray-pinkish, medium to thick bedded. They are significantly different from the above mention along to their clast composition and the presence of numerous dykes of diabase. The last ones cut conglomerates and they are not observed in the another rocks from the section (Table I, a, b). The clasts show semi-rounded to rounded shape and sizes from 1.5 – 3.0 mm up to 8 – 10 cm. The clasts are composed of arkoses, greywackes, lydites, quartz grains, two types diabases (grained and variolitic-like) in the most abounded and in a small quantity metasilstones, metagravelites, chlorite schist (table I, c, d). The matrix is sandy to gravel consisting quartz, plagioclase, K-feldspar, epidote – terrigenous component and chlorite-sericite cement enriched of iron-titan dusty products. Diabase dykes, which are observed only in the conglomerate mark level have various thickness from 1 – 2 cm to a few dm. They are grey-greenish in color, dense with massive texture. Two generations of dykes could be described, here. The first one (probably earlier) is represented by fine-grained metadiabases with micro-diabase structure – chaotic situated long prismatic plagioclase crystals (up to 0.3 – 0.4 mm along long axis), patchy albitized, with fine grano-lepidoblastic mass of chlorite (mainly), sericite, epidote, sphene, quartz, calcite and ore minerals in their angular spaces (table I, e). This type of dykes are the thickest ones. The second generation of diabase dykes is represented by meta-hyalodiabases with thickness up to 5.0 cm that cut both the conglomerates and the previous dykes. They are composed of very fine plagioclase microlites (traces) among chlorite - epidote - amphibole (?) - albite cryptocrystalline ground mass (table I, f). Porphyritic generation of plagioclase and fully altered mafites is rarely observed.

Carbonate rocks are represented by marbles, built up of about 95% calcite and 5% terrigenous component - quartz, plagioclase and clay minerals. Calcite is irregularly recrystallised to fine- medium grained. Texture is granoblastic. Clay minerals are completely altered to chlorite and sericite.

Diabases and their tuffs have limited distribution in the studied section as conforming to the parametamorphite lenses and boudinage structures. They are intensively metamorphosed and the most part of them are presented as green schists and actinolite schists

Table 1. Classification of shales (Potter et al., 1980)

<table>
<tr><th colspan="3">Persentage of clay-size constituents</th><th>0-32</th><th>33-65</th><th>66-100</th></tr>
<tr><td rowspan="2">INDURATED</td><td>BEDS</td><td>> 10 mm</td><td>BEDDED SILTSTONE</td><td>MUDSTONE</td><td>CLAYSTONE</td></tr>
<tr><td>LAMINAE</td><td>< 10 mm</td><td>LAMINATED SILTSHALE</td><td>MUDSHALE</td><td>CLAYSHALE</td></tr>
<tr><td rowspan="3">METAMORPHOSED</td><td rowspan="3">DEGREE OF METAMORPHISM</td><td>LOW</td><td>low grade metamorphosed QUARTZ ARGILLITE</td><td colspan="2">low grade metamorphosed ARGILLITE</td></tr>
<tr><td></td><td>QUARTZ SLATE</td><td colspan="2">SLATE</td></tr>
<tr><td>HIGHT</td><td colspan="3">PHILLITE AND/OR MICA SHISTS</td></tr>
</table>

Metamorphism. All rocks from the studied area are metamorphosed in conditions of low-grade regional metamorphism in the limit of green schist facies. Depending on the type of protoliths they form different low-grade metamorphic rocks. The grade of metamorphic change is assessed according to the following criteria: 1) mineralogical – processes of dissolution and regeneration, recrystallisation, degree of the matrix alteration in the clastic rocks; processes of mineral formation; 2) structure changes – conform-regeneration, lens-like, segregation and strip structures of oriented corrosion and recrystallisation under stress and 3) textural changes.

Depending on the intensity of the metamorphic alteration, the following parametamorphites are described: *low grade metamorphic argillites and siltstones, slates, quartz-slates, phyllites, quartz-sericite schists* (protoliths – argillites and siltstones); *metaarkoses and metagreywackes* (protoliths – psammites); *metaconglomerates* (protoliths – psephites); *green schists, actinolite schists, metadiabases, metagabbro-diabases* (protoliths – diabases and their tuffs, gabbro-diabases). The mentioned above variety of the parametamorphites is a result of the intensity of the metamorphic recrystallisation in the terrigenous rocks and the degree of alteration according to the protolith’s composition. Any differences in the grade of metamorphism are not observed in the different levels of the studied section. The anisotropy of the metamorphic alterations in the conditions of the low-grade metamorphism (green schist facies) is a result of two main factors – the protolith's composition and irregular distribution of the synmetamorphic deformations. Argillites and siltstones are the most intensively metamorphosed rocks with end metamorphic members – phyllites (table II, c, e) and quartz-sericite schist, respectively. Lower metamorphosed their analogues are low metamorphosed siltstones and argillites, slates and quartz slates. The rocks enriched in the terrigenous components (siltstones) are more resistant to the low-grade metamorphism and they show better-preserved relicts of sedimentary structures and minerals (table II, a, b). It is very clear in the frame of the thin-sections where alternation between above described laminae is observed (table II, b). The low-grade metamorphic quartz slates and phillites are the most widespread in the investigated area. (fig. 4). The psammitic rocks are affected by low-grade of metamorphic alteration and the clastic grains are well preserved and the matrix is intensively metamorphosed with formation of sericite and chlorite (table II, d). The metamorphic changes in the conglomerates are only in the matrix analogous to the psammites. The intensity of the metamorphic alteration in the different protoliths and their quantity are generalized in fig. 4.

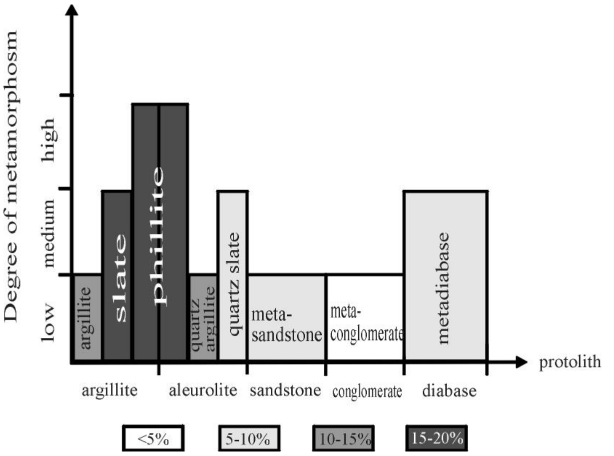

Figure 4. Scheme about intensity of the metamorphic alteration in the different protoliths and their quantity

The most intensively metamorphosed rocks: phyllites, quartz-sericite schist (parametamorphites) and green schists and actinolite schists (metadiabase and their tuffs) are typical members of the low-grade metamorphic rocks in green schist facies which are the main elements of the DPhC. Relict structures and minerals in these tocks are not present. The last ones are characteristic features for all the rest para- and ortometamorphites in the region.

The described rocks have clear polymetamorphic character in locally expressed zones. They are affected by contact metamorphic alterations close to the contacts with Paleozoic granite bodies and dykes and are changed in spotted and knotted schists. In the narrow shear zones they are turn to typical mylonites and blastomylonites. These types of metamorphic alterations are not a subject of the present study.

STRUCTURAL CHARACTERISTIC

Geometrical and age relationships between the different types of planar and linear structural elements indicate that their formation was accomplished during the four deformational stages, designated conditionally as D_1, D_2, D_3, and D_4.

D_1 structures. Early folds F_1 on the primary bedding, axial plane foliation S_1 and few morphological types of lineations are developed during the earliest stage in the conditions of low-grade metamorphism. The spatial position of the mark levels, the orientation and the asymmetry of the mesoscopic folds on the bedding show that the hinge of the Gabrovnitsa anticline has a direction 100-110° and plunges about 15° to ESE. Its northeastern limb has average dip 45-55° and the southwestern - 30-40°. Mesoscopic folds F_1 are isoclinal and tight with centimeter and meter sizes. The shape of the folded bed surfaces is parabolic or hyperbolic and folds are most of the classes 1C and 3. Diagrams about the orientation of bedding, fold hinges and the lineation $L_{ss/ss1}$ (Antonov, 1989, fig. 1c) evidence for the general subequatorial orientation of the fold hinges with the dominating plunge about 25° to ESE. The axial plane-foliation S_1 is a dominating structure in the silty and pellitic rocks where it almost obliterates primary bedding. The different morphological types and mechanism of the axial plane foliation are published by Antonov (1989). According to their morphological features, the secondary lineations formed during the earliest deformational stage are mineral lineation, lineation along to the axes of mullions and rodes, elongated conglomeratic clasts, crenulation and intersection lineation. The last two types are widespread.

D_2 structures. The formation of a new superposed fold generation F2 and synchronic to it crenulation lineation are connected to the second regional deformation. The folds of the second generation are formed on the surfaces of the axial plane foliation S_1. The notion about their morphology and dimensions could be obtained from the cross-sections (fig. 2). They are imposed coaxially upon F_1 folds, determining in mesoscopic scale the presence of the interference pattern of type 3 after Ramsay (1967). The second crenulation lineation is expressed as fine undulation on the folded cleavage surfaces S_1. Its orientation is subparallel to the orientation of the fold hinges.

D3 structures. The third deformational stage is characteristic by the development of the locally expressed ductile-brittle shear zones thick 40-50 m and up to few hundred meters long. Small asymmetrical kink-folds and kink-zones with disjunctive cleavage S_2 parallel to their axial planes are superimposed on the structures of the previous stages. The dominating zone orientation is in SE direction and rarely in EW or NE direction.

D_4 structures. The numerous local faults with insignificant amplitudes as well as a few larger faults (fig. 1) that cut crosswise or oblique the three fold generations are connected with the fourth stage.

CONCLUSIONS

The results of the present study could be resumed as follows:

1) the diabase-phylitoid complex from the valley of the Gabrovnitsa river is built up of terrigenous sedimentary rocks - manly siltstone and agrillite and in less quantity sandstone and conglomerates ;

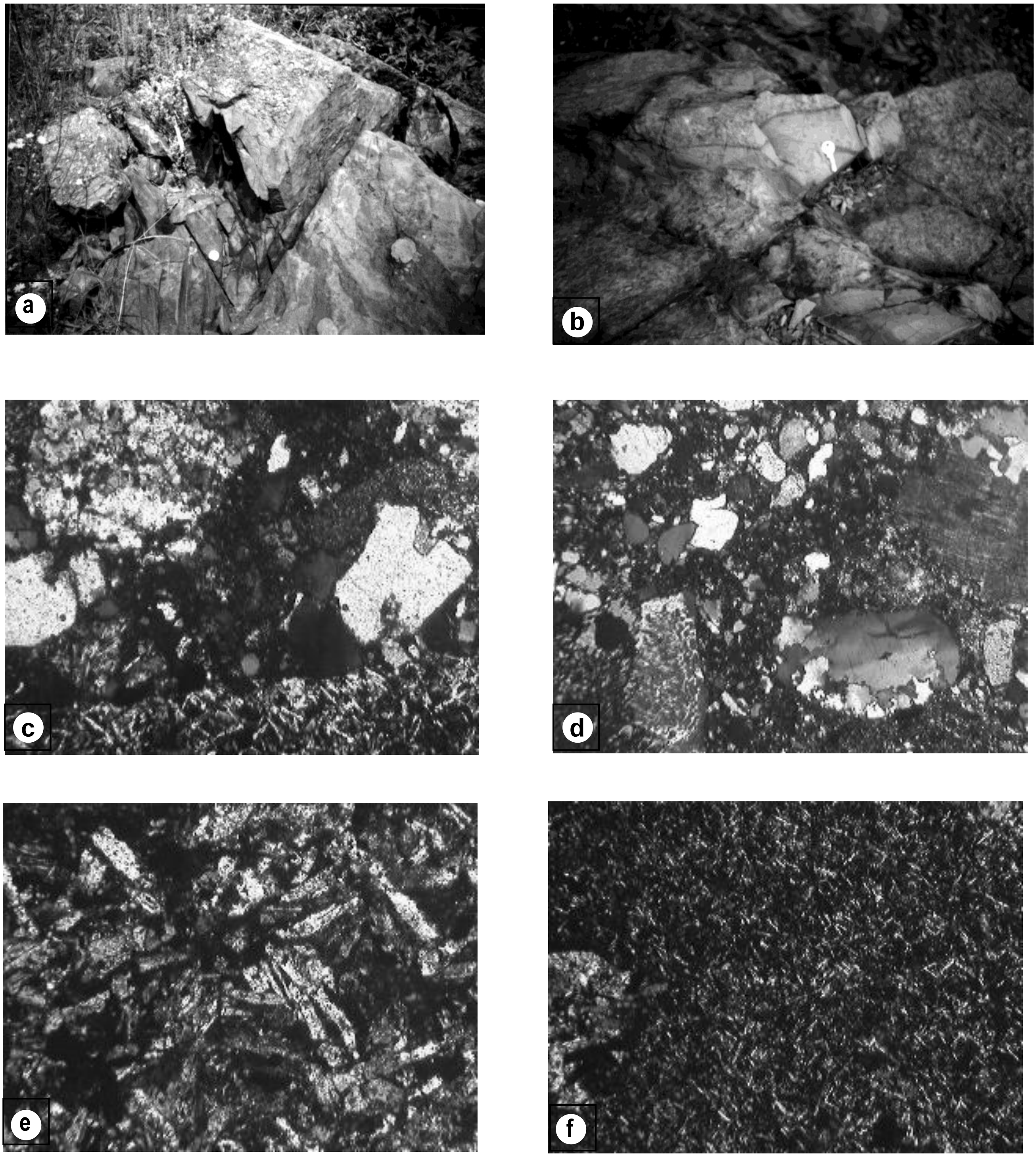

TABLE I

***a**– field's photos of the rocks from the conglomerate mark level;*
***b** – field's photos of the diabase dykes cross cut the conglomerate mark level;*
***c** – micro-photo of the conglomerates from the mark level. X 50; N +;*
***d** – micro-photo of the conglomerates from the mark level. X 50; N +;*
***e** – daibase texture in the fine grained diabase dyke. X e 100; N +;*
***f** – graund mass and plagioclase microlites in the hyalodiabase dayke. X 50; N +.*

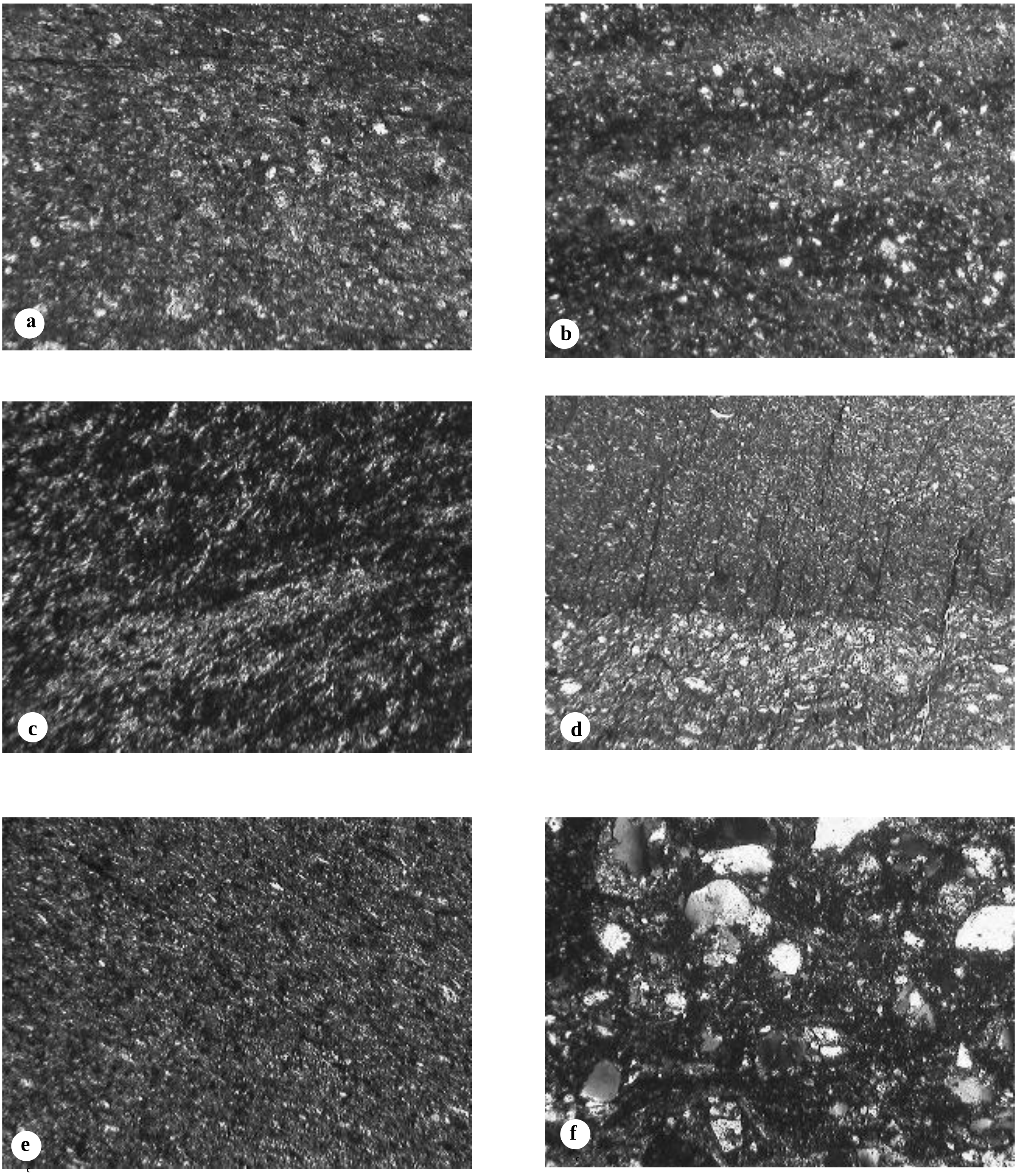

TABLE II

a *– low metamorphosed argillite. X 100; N +;*
b *– alternation of laminae of low metamorphosed quartz argillite and arhillites. X 100; N +;*
c *– phyllite with two crystallisation cleavages. X 100; N +;*
d *– crenulation cleavage in the argillite laminae. X 100; N +;*
e *– phyllite. X 100; N +;*
f *– arkose wacke. X 50; N +.*

2) on the basis of specific features of the protoliths a new scheme for lithostratigraphic subdivision of the complex is proposed. The vertical and lateral interrelations between the separated mark levels and formations as well as structural data give reason for the continuity of the section. This result requires a new point of view on the proposed correlations to the Berkovitsa and Dalgidel Groups.

3) the fragments of the basic igneous rocks among sediments from the all formations obviously are with allochtone genesis and the biggest ones are probably olistotrimes. The conglomerate mark level is probably allochtonous (olistoplake) as well;

4) the structure evolution includes four deformation stages and three fold generations are formed during them;

5) the variety of the low grade parametamorphic rocks from the studied region is a result of two factors – different resistance of the protoliths in the conditions of the low-grade metamorphism (green schist facies) and different intensity of synmetamorphic deformations.

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