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STRUCTURE AND METAMORPHISM OF THE DARDANIA ZONE IN THE EASTERN PART OF GJILAN REGION (KOSOVO)

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Abstract: The Dardanian zone represents the western part of the Rhodope crystalline basement. This zone was structured and metamorphosed during the Hercynian and post Hercynian tectonic stages. The important aspects have been identified in the structure and metamorphism from this part of western Rhodopes.

The geological setting of study region has clarified the most important aspects regarding: structural geology, deformation, tectonics, and metamorphism.

The studied region represents an important node in the geology of Kosovo and beyond. In this region there is the border of the Vardar unit and the Serbo-North Macedonian tectonic unit (Dardania Massif). The Serbo-North Macedonian Massif (eastern part of Kosovo) structurally represents the upper part of Dacia and the innermost whole, compared to the Carpathian-Balkanids described above. The Crystalline belt of metamorphic rocks belongs to high-grade metamorphism. The rocks of the Upper Complex represent a volcano-sedimentary sequence that is metamorphosed only under greenschist facies conditions. The Lower Complex consisting of gneiss, micaschists and to a lesser extent amphibolites, quartzites, marbles and migmatites.

The main event of the Hercynian tectonic period that structured the rocks forming in the *Dardania zone* is associated with the regional deformation D_2. Its intensity is depending on the type of rocks, but it is noted an increase of the intensity from west to east. The associated schistosity S_2(penetrating schistosity) is an axial plane schistosity of the isoclinals folds S_0, S_1. The schistosity S_2 is homogenous, with an average strike direction of 345° and dip direction of 45°. The intersection lineation (L_2) and the fold axis (B_2) are very homogenous with the dip azimuth toward N (350°) and dip angle of 10°. The deformation D_3 is associated with the crenulations of schistosity S_3. The schistosity S_3 represents the axial plan of the kink fold and crenulation. The schistosity S_3 is very heterogeneous and it is difficult to arrive at conclusions regarding the average direction of this planar structure also to judge the kinematic aspects of the movement. Likewise, the axis of the crenulations B_3 and L_3 lineation represent relative heterogeneous linear structures.

The deformation D_4 is associated with the fracture schistosity S_4. The schistosity S_4 often show the axial plan of the open parallel folds. The schistosity S_4 is homogenous with the range East–West with

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symmetric drop (in the N and S), by proving that we are dealing with a phase of deformation with an extensional tectonic regime (with the direction N–S).

Keywords**:** *Dardania zone, metamorphism, schistosity, deformation, structural analysis*

1. INTRODUCTION

Kosovo is situated in the central part of the Balkan Peninsula. In the Southwest, it is bordered by Albania, in the West by Montenegro, in the North and East by Serbia and in the Southeast by North Macedonia. The territory extends within longitudes N41 050′58″ and 43 015′42″ and within latitudes E20 001′30″ and 21 048′02″ [2].

Kosovo covers a surface area of 10 887 km^2. It is characterized by an average altitude of 800 m above but shows considerable changes in relief and morphology of terrain (Fig. 1).

Fig. 1. Geographic map of Kosovo

The western Rhodope (Serbian-Kosovo-North Macedonian massif) composite unit is made up of a variety of relatively high-grade metamorphic rocks, some of which are of Pan African age with a Variscian overprint (Dallmeyer et al. 1996; Krstić et al. 1996; Haydoutov et al. 1996; Karamata 2006). The Serbian-Kosovo-North Macedonian massif is generally believed to have formed the northerly, Eurasian margin of the Tethyan Ocean

during Mesozoic-Early Cainozoic time. However, its setting during the Late Palaeozoic is controversial, in particular whether is experienced continental collision related to closure of a "Hercynian ocean" (e.g., Dercourt et al. 2000), or remained an active margin into Mesozoic time with ongoing northward subduction (e.g., Stamphili, Mosar 2000; Stamphili, Mosar 2001). Possible correlations with the Carpathian regionare discussed by Schmid et al. (2008). The term Vardar Zone was also established by Kossmat (1924), named by the river Vardar. Based on differences in their Cretaceous sedimentation history, Mercier (1968) subdivided the Vardar Zone into three NNW–SSE trending units (Almopias, Paikonand Peonias), where as the investigations of Kockel (1973) led to the present division of the Vardar Zone into the following five units (from W to E): The Almopias Unit; The PaikonUnit; the Guevguelije Unit; The Stip Axios Massif; The Circum Rhodope Belt (Fig. 2).

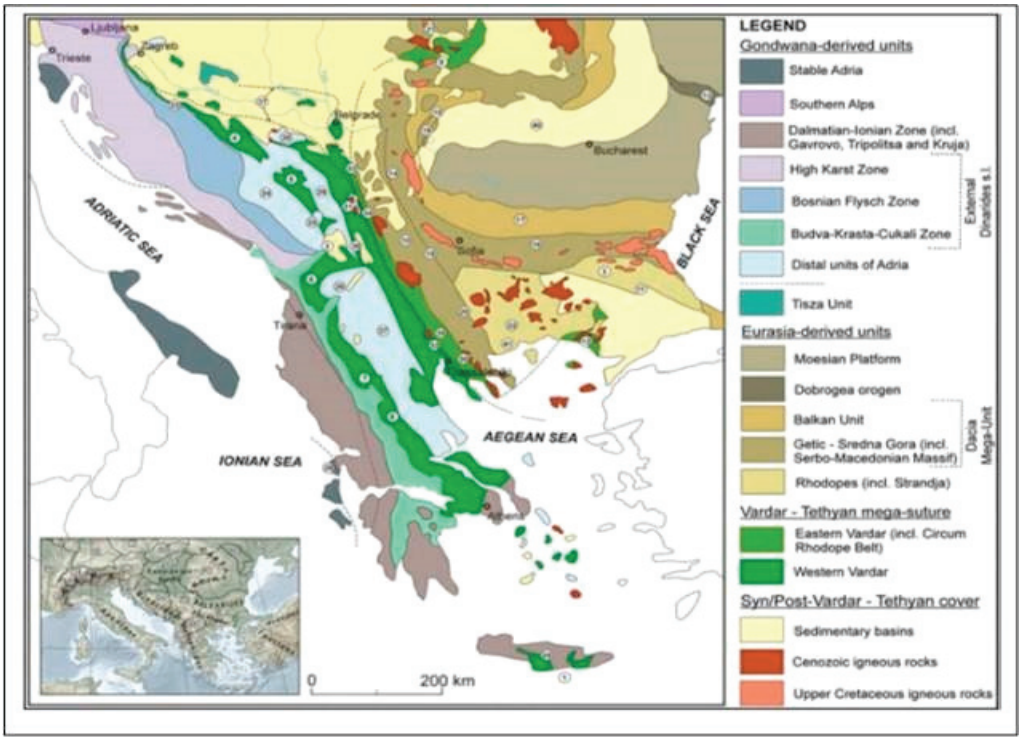

Fig. 2. Simplified sketch of the Geology of Southeast-Europe (after Cvetković et al. 2016)

Geological setting

The Serbian-Kosovo-North Macedonian and the Rhodope massif are predominately composed of crystalline rocks and are regarded as a continental slope and rise during Jurassic and Cretaceous time.

According to Jacobshagen et al. (1986) the Alpine evolution of the Hellenic orogen is dominated by four different orogenic cycles each of them is accompanied by folding, nape transport and regional metamorphism. The presence of an additional orogenic cycle during Late Cretaceous times is assumed by Jacobshagen et al. (1986).

The Palaeozoic crystalline basement (Pz)

Gneissic sequence starts from a series of gneiss and orthogneiss with the presence of tectonic banding without mapped, due to their limited size. These banding are represented by these types of rocks such as: biotite and biotite-muscovite gneiss, leptynolite, micaschists, leucogneiss, amphibolite, quartzite and migmatite. At the beginning, these rocks have represented pelagic sediments with under layers sinrift basic volcanism, accompanied with granite intrusion which then are metamorphosed in the orthogneisses facies. The grade of metamorphism increases in the sense of the top to down, representing a epidote-amphibolite facies in the deep and green schist facies above.

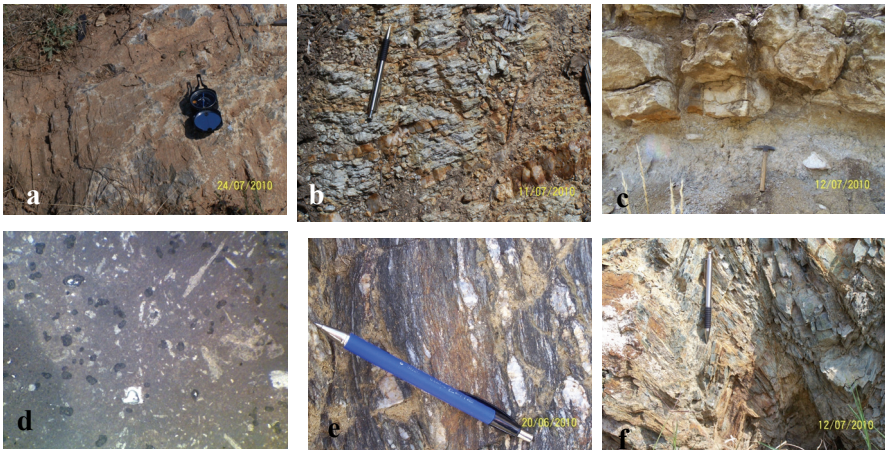

Fig. 3. Photos from study works: a) metalimestones with a strongly foliation according to calcite pressure, b) tectonic banding of calcite in the crystalline basement, c) Upper Oligocene transgression (clay, sandstone and limestone) situated onto Paleozoic metalimestones, d) fragments of bivalve and ostracoda in yellow dolomites with micrite texture (Oligocene age), e) schistosity (S_1) and boudinage of quatzite tectonic banding, f) kink band folds of deformation (D_3)

Micaschists sequence is localized in the central and western part of region and it is built by micaschists with tectonic banding of limited scale of metamorphic rock types such as: green schists (Fig. 3b), amphibolites, gneisses, leptynolites and metalimestones (Fig. 3a). According to Anonymous (1974), this sequence is named as Veles series with Palaeozoic age, as sub-unit of the Vardar zone. In this context, these authors considered this sub-unit as tectonically situated below the Neoproterozoic gneisses sequence

of the Serbian-Macedonian mass. We think that the gneiss and micaschists sequence belong to Paleozoic of tectonic unit of Dardania. These sequences are in continuity with each other, where the eastern and deeper part represents higher level of metamorphism compared with the micaschists sequence which is widespread in the center and west of study region (Figs. 4 and 5).

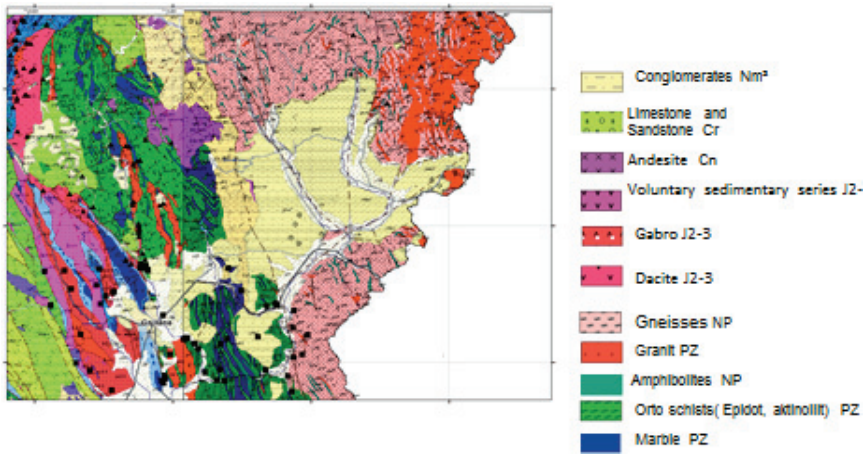

Fig. 4. Geological Map of studies region

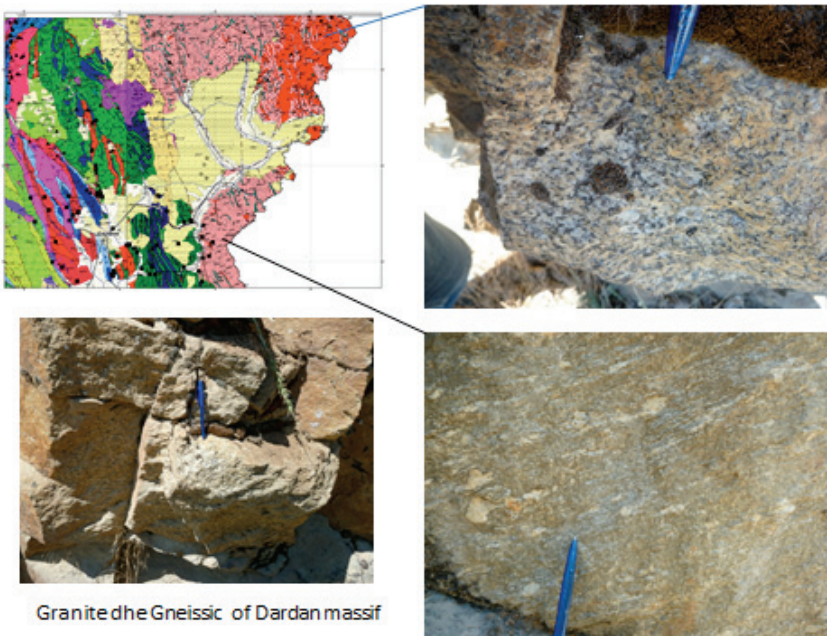

Fig. 5. Granites and Gneisses of Dardanian massif

The Upper Oligocene Transgression

Onto the crystalline basement of Paleozoic, with stratigraphic and structural inconsistencies, are placed limestones and dolomites of the upper Oligocene. Onto metalimestones is developed the karstic phenomenon in the form of cavity filled with calcite mineral, which gives rocks a breccias view. Directly onto the surface of weathering are placed sandstone with 70 cm thicknesses which gradually passes into the limestones with over 2.5 m thickness (Fig. 3c). In yellow dolomites with micrite texture (Oligocene age), are observed bivalve and ostracoda fragments (Fig. 3d).

Conglomerate – sandstone-clay-carbonate formation of meddle Miocen

This formation is placed onto the Paleozoic of the Dardania unit and occupies the central part of studied region. Formation has a thickness of about 200 m and presents alternation of conglomerate, sandstone, limestone and claystone.

Granitic intrusion

Granitic intrusion with large size are spread in the south-west of the region while some smaller sized intrusions are mainly distributed in the eastern part of the studied region. These rocks are tectonically transposed, thus presenting concordant and sub concordant bodies with metamorphic rocks structures where they are introduced. During intrusion penetration they have done migmatization and recrystallization of the surrounding schists.

Granites are fine grain and contain less colored minerals. Their color is light gray. In the mineral composition are included: microcline, plagioclase (albite), quartz, muscovite, biotite, epidote, apatite, leucocsene and metallic minerals. They have subhedral texture.

2. TECTONICS

Paleozoic of the Dardanian zone is structured during the Hercynian and Variscan tectonic phases. The study of Variscian and Hercynian tectonic phases of deformation is difficult to estimate, because post-Hercynian tectonic phases have deleted them. We can say that we have at least two pre-Jurassic deformation stages. The most visible is the schistosity of the last Hercynian stage marked with the symbol S_1. In our study are evident the distortions that have affected the entire Dardanian zone, that means the Hercynian as well as the Mesozoic and Cenozoic sediments observed in the west part of Gjilan. Thus, D_2 and D_3 refer to successive post-Hercynian stages, while S_2 and S_3 refer to associated schistosity. S_2 is a penetrating schistosity while S_3 represents the crenulation schistosity (Mesha, Fejza 2010). The fracture schistosity is also present. A structural analysis of deformation fields was possible especially for S_2 because the

field measurements show that the D_2 deformation is strongly homogenous. This structural overview provides us an analysis and an evaluation of the structural history of the post-Hercynian period, especially those related to the ophiolite obduction on the micro-block of Dardania and has had a large number of structural measurements of this schistosity (Fig. 6a). Crenulation schistosity, S_3 is heterogeneous (Fig. 6c) while S_4 represents symmetrical behaviour (Fig. 6e).

The deformation (D_2) and associated structures

The main event of the Hercynian tectonic period that structured the rocks forming the *study region* of eastern Gjilan is associated with the regional deformation (D_2). Its intensity is depending on the type of rocks, but it is noted an increase of the intensity from west to east. The associated schistosity (S_2) is an axial plane schistosity of the isoclinals folds (S_0, S_1).The schistosity (S_2) is homogenous, with an average strike direction of 345° and dip direction of 45° (Fig. 6a). The intersection lineation (L_2) and the fold axis (B_2) are very homogenous with the dip azimuth toward N (350°) and dip angle of 10°.

The folds are isoclines, inverted to the west and with generally easier dipping northward. Structural and stratigraphical regional polarity (folds with Western vergent) suggest a mega sinforme structure in the center of which is placed micaschists sequence(Mesha A, Fejza I, 2010).

The deformation (D_3) and associated structures

The deformation (D_3) is associated with the crenulations of schistosity (S_3). The schistosity (S_3) represents the axial plan of the kink fold and crenulation. The schistosity (S_3) is very heterogenous and it is difficult to arrive at conclusions regarding the average direction of this planar structure also to judge the kinematic aspects of the movement. Likewise, the axis of the crenulation (B_3) and (L_3) lineation represent relative heterogeneous linear structures

The deformation (D_4) and associated structures

The deformation (D_4) is associated with the fracture schistosity (S_4). The schistosity S_4 often show the axial plan of the open parallel folds. Stereogram (Fig. 6e) shows that (S_4) schistosity is homogeneous with strike direction from East-West with symmetric dip, sometimes in the north, and sometimes in the south, by proving that we are dealing with a phase of deformation with an extensional tectonic regime (with the direction N–S).

The first,is attributed to the late Jurassic and is responsible for main schistosity and sub-isoclinal folds of post-Hercynian units. Three other phases are expressed respectively by open oriented folds NNW–SSE, mezoscopic open folds to tight, axial plan of which is oriented NE–SW , with dipping towards NW and the last of the open oriented

folds NW–SE with an axial plan that dips to the SW. They are therefore the result of post-obduction tectonic events, always according to Moutrakis et al. (1986).

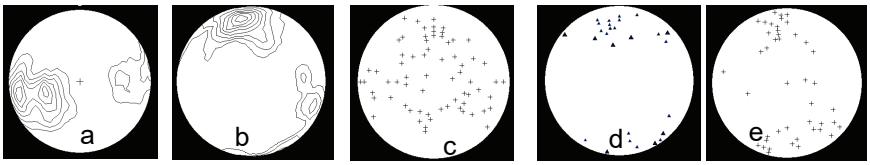

Fig. 6. Stereographic projections - lower hemisphere (after Mesha, Fejza 2010): (a) of poles of planar fabric S_2 (277 measurements), contours: 1, 2, 3, 4, 5, 6; (b) of linear fabric L_2 (94 measurements), contours: 1, 2, 3, 4, 5; 6,7,8; (c) of poles of planar fabric S_3 (84 measurements); (d) of linear fabric L_3 and β_3 (34 measurements); (e) of poles of planar fabric S_4 (53 measurements)

3. METAMORPHISM

The metamorphism of gneiss, marble and micaschists is associated with the deformation D_2 belong to the age of 150 up to 130 million years [Most, T. 2003]. The deduction of this age is based on the dating of similar metemorphic events from the neighboring regions [Most, T. 2003], [Moutrakis, D et al. 1986]. The crenulation schistosity has a heterogeneous behaviour proving that it belongs to the deformation field of ductile-brittle. The fracture schistosity presents a homogenous behaviour with extension but with a strong dip towards the N and S. The nature and the age of the metamorphism related to the deformations D_3 and D_4 are difficult to estimated. This metamorphism is associated with a regional schistosity of NNW-SSE orientation.

4. CONCLUSION

In this paper the important aspects have been identified in the structure and metamorphism of the Dardania zone – Eastern part of Kosovo.

This zone was structured and metamorphosed during the Hercynian and post Hercynian tectonic stages. The geological setting of study region has clarified the most important aspects regarding: structural geology, deformation, tectonics, and metamorphism.

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