STRUCTURAL ANALYSIS OF THE ROCKS IN THE NORTH - EASTERN PART OF GJILAN REGION (KOSOVA)

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ABSTRACT

In this paper, structural analyses show that the rocks in the North - Eastern part of Gjilani Region represent a mega-antiform reversed towards the south-west. This is accompanied by meso - and micro-isoclinal folds, with reversal towards the West, observed in the tectonic stratification with the thickness of several millimeters to several meters. These tectonic stratifications under green schist`s facies conditions, amphibolites, marbles, quartzes, etc., a result from the tectonic transposition during the deformation phase associated with a regional homogeneous schistosity Sn (Axial plan of isoclinal folds). This last one has NNW strike and dip, once to East and once to West with the angle about 70°. The associated metamorphism is the high grade to middle metamorphism, aged of 150 to 130 million years deducted from dating in neighboring regions (Most, 2003). The cinematic analyses concerning this deformation phase indicate a transport of the upper part towards the SW. Concerning this phase of deformation, the direction of displacement is deduced from the reversed polarity of the Sn, while transport sense is deduced from the cinematic analysis on field and the microscope analysis. Structural and microstructural analysis show also two successive phases accompanied by a crenulation schistosity Sn+1 and fracture schistosity Sn+2, connected to two deformations stages Dn+1 and Dn+2. The Age of metamorphism that accompanies these two stages is difficult to assess. The crenulation schistosity has a heterogeneous behaviour and is proving that belongs to the ductile-brittle deformation and depends on the facial lithology. While the fracture schistosity shows a homogeneous behaviour with wide strike with strong dip angle once north, once south.

Keywords: schistosity, structural analyses, sedimentary mélange, deformation stages.

INTRODUCTION

The western Rhodope (Serbian-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 (Most, 2003; Krstić, *et al*., 1996; Haydoutov and Janev, 1996; Karamata, 2006). The Serbian-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, 2000, or remained an active margin into Mesozoic time with ongoing northward subduction (e.g. [Stampfli, *et al*., 2000; Stampfli, *et al*., 2001; Karamata, 2006). Possible correlations with the Carpathian region are discussed by (Schmid, 2010).

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, Paikon and Peonias), where as the investigations of (Kockel, 1977) led to the present division of the Vardar Zone into the following five units (from W to E):

The Almopias Unit; The Paikon Unit; the Guevguelije Unit; The Stip Axios Massif; The Circum Rhodope Belt (Figure-1).

WORK METHODOLOGY

Field works was carried out during July-October 2012 and are focused on:

- Identify all types of rocks present in the study area.
- Taking samples from all types of rocks for preparation: petrographic mineral properties, chemical analysis, and geochemical analysis.
- Systematic measurement of structural elements (foliation and lineation) accompany with oriented samples (Figure-1(a)).

Figure-1(a). Oriented sample.

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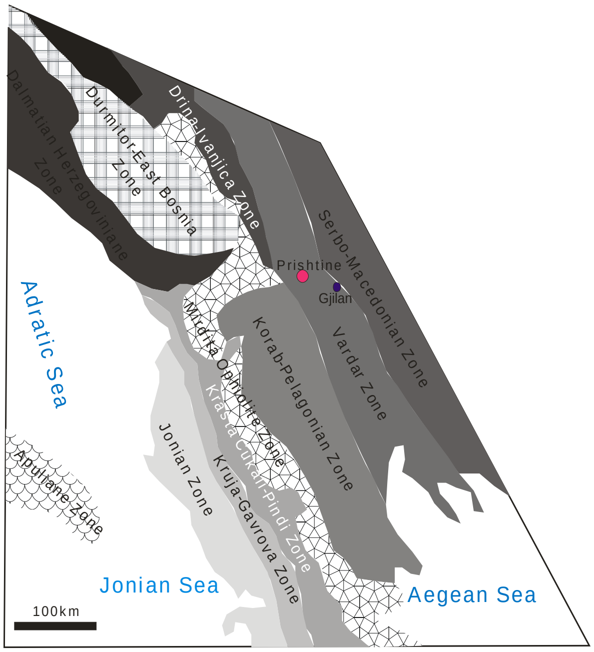

Figure-1. Geological setting of gjilani area in the per-alpine balkanic belts.

GEOLOGICAL SETTING AND FRAMEWORK

The study area is located in the Eastern part of Gjilan region and belongs to the Vardar Zone and Dardania zone (Serbian - Macedonian zone).

Boundary of these geotectonic units is marked by a fault, covered with Neogene sediments (Figure-2).

The present structure of the Dinarides and the Hellenides is the result of a Mesozoic to Cenozoic orogeny, related to the ongoing convergence between the Apulian and European plates (Figure-1). The present subdivision of the Dinarides - Hellenides into NNW-SSE trending zones (Figure-1.) is related to the structural geological and sedimentological investigations of (Aubouin, *et al*., 1976) as well as (Jacobshagen, 1986).

The Apulian platform forms the foreland of the Hellenic orogen, which is exposed on islands (e.g. Paxos) situated west of the Greek mainland. The Hellenic hinterland is represented by the crystalline of the Serbian-Macedonian and the Rhodope Massif (Figure-1). The west vergent nappe system of the Hellenic orogen comprises the following major tectonic units from W to E. (Figure-1).

One major problem of the Balkan geology concerns the tectonic setting of the Mirdita ophiolite (Albania): is it the remnant of a small oceanic basin obducted eastward and slightly thrusted over the Korabi Zone from the West? Or is it rooted into the Vardar Zone (a major intra cratonic suture of former Yugoslavia), in which case the ophiolite was obducted westward and thrusted over the Korabi Zone from the East?

The Vardar Zone (also referred to as Vardar-Axios Zone) represents the eastern Hellenic and Dinaridic ophiolite belt and comprises MORB-type oceanic crust (Triassic to Jurassic) as well as Paleozoic and Mesozoic sediments.

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

STRATIGRAPHIC UNITS

Quaternary - represents mainly of: alluvium, proluvium, slope wash, lower river terrace, higher river terrace, lacustrine, gravel and sand.

Lacustrine deposits (N_2) - placed in discordance on old Jurassic formations, specifically over the Kozniku harzburgite and serpentinites. Represent part of these basal deposits: sandy clay, marl with under a layer of gravel and conglomerates (alluvial - proluvial complex).

Andesite dykes (N_2) - Located in the southwestern corner of the exploration area, occupying about 4 km^2, near Kishnica Pb - Zn deposit.

The upper Oligocene transgression

Onto the crystalline basement of Paleozoic, with stratigraphic and structural inconsistencies, limestones and dolomites of the upper Oligocene are placed. Onto metalimestones of crystalline basement, the karstic phenomenon is developed in the form of cavity filled with calcite mineral, which gives rocks a breccias view.

Conglomerate - sandstone - clay- carbonate formation of meddle Miocene

This formation is placed onto the Palaeozoic crystalline basement of the Dardania unit and presents alternation of conglomerate, sandstone, limestone and claystone.

Granitic intrusions with large size are spread in the southwest of the region while some smaller-sized intrusions are mainly distributed in the eastern part of the studied region. These rock`s 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 coloured minerals. Their colour is light gray. In the minerals compositions microcline, plagioclase (albite), quartz, muscovite, biotite, epidote, apatite, sagenite, leucocsene and metallic minerals are included. They have subhedral texture.

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Cretaceous (K)

It represents mainly of these lithostratigraphic units: Valanginian basal conglomerates (K_1^2); Valanginian - Hauterivian silty - sandstone turbidites ($K_1^{2,3}$); Barremian - Aptian basal conglomerates ($K_1^{4,\ 5}$); Barremian - Aptian silty - marl turbidites ($K_1^{4,\ 5}$); Albian - Senomanian sandy - phillitic turbidites (K_1^6 - K_2^1); Santonian sedimentary ophiolitic melange (K_2^4).

Jurassic represents by: Serpentinised harzburgites (J_2); Schist serpentinites with granitic intrusion (J_2); Basalts with dacite dykes (J_2); Dacite (J_2); Metamorphic sole (amphibolites) (J_2); Supra ophiolitic sedimentary mélange (J_3).

The Supra ophiolitic sedimentary melange (J_3)

This melange is appeared in the south - eastern part with limited output in the form of a narrow belt of black schist's with extremely rare manganese nodules. The contact with Palaeozoic crystalline basement of the Dardanian zone is a tectonic contact. Matrix is characterized by dark gray and black schists in some places with manganese nodules sizes several centimetres. More are observed rare basalt blocks with no large scale. It is known that manganese nodules are set in the pelagic oceanic areas that represent a slight size of sedimentation (7m/y), with radiolarites sludge without turbidites. Nodules represent centimetric to increased decimetric aggregates around benthic foraminifera's. They are composed by iron and manganese hydroxide and also by silicates, which are slightly amorphous with an extremely slow growing. Facies is too metamorphosed and, despite the effort that was made; it was impossible to find fauns.

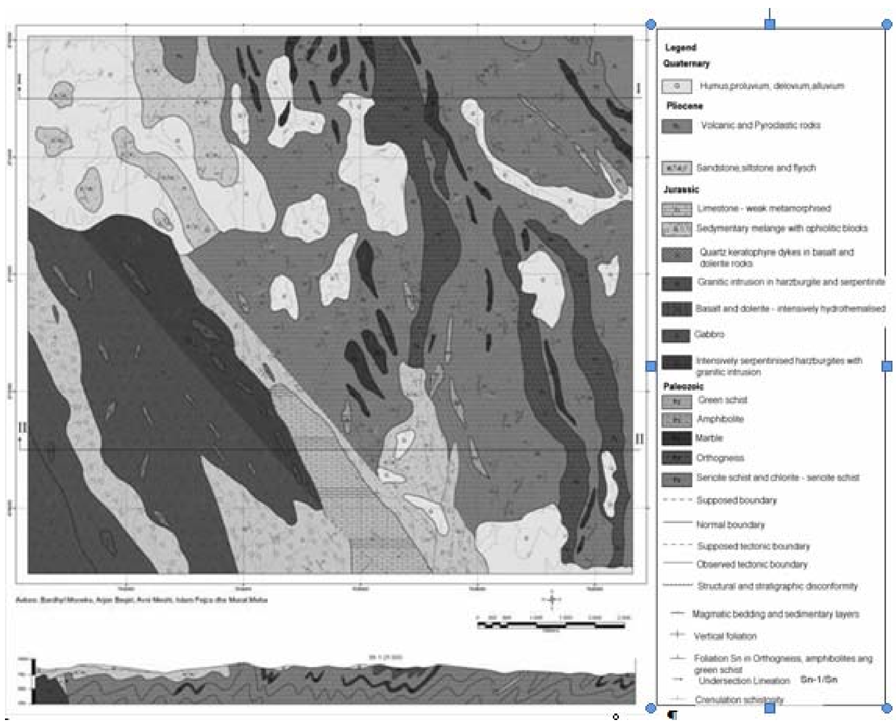

Figure-2. Geological map and cross section in the Northern - Eastern part of Gjilani region, Kosove.

Jurassic

In the western part of sheet supra - ophiolitic sedimentary melange is placed sometimes onto gabbros, sometimes onto sheeted dike complex and sometimes onto intrusive granites. The fact that this melange covers granite means that it is formed after intruded of the granite`s magma. This melange starts in this part with a schistosity of clay matrix, similar with described schists in the paragraph above, with rare sandy under layers.

The blocks are mostly basalts of several meters to several tens of meters in size. There are also limestone blocks, metasandstones etc. Transferred to a matrix melange with over 90% of sandy-clay sediments, with the folds of inverted polarity, isoclinal folds and the boudinage of sandy layers. Sedimentary material is added above until it reaches a typical sedimentation of turbidites with metaconglomerate - breccias limestones (with 90% of limestone clasts cemented by limestone of the same gray colour, then followed with limestones with thin marly underlayers, radiolarites, limestones with siliceous boudinage. In breccias limestone, clasts met the following species which dates from upper Jurassic: echinoderms, annelides, ostracodes, Tubiphites morronensis, Trocholina Charophytes. In layered limestones with siliceous met the following species which dates from the upper Jurassic:

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Pelmicrite, echinoderms, Petites foraminiferes circalittoraux.).

The sediments take a real look of a flysch with limestone layers of Upper Jurassic up to 100m thickness (Gllames limestone). This limestone is combined with thin layers of clay and marls with highly schistosity.

The Paleozoic 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 underlayers sinrift basic volcanism, accompanied with granite intrusions 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.

Micaschist`s 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 (Photo-3b), amphibolites, gneisses, leptynolites and metalimestones. According to (Anonim, 1974) this sequence is named as Veles series with Palaeozoic age, as the 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 belongs to Palaeozoic crystalline basement of the tectonic units of Dardania.

These sequences are in continuity with each other, where the eastern and deeper part represents higher level of metamorphism compared to the micaschists sequence which is widespread in the center and west of the explored area.

STRUCTURAL ANALYSES

Paleozoic crystalline basement in the Eastern part of the Gjilani region is structured during the Hercynian and Variscian tectonic phases. The study of Variscian and Hercinian tectonic phas 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_{n-1}. In our sheet are evident the distortions that have affected the entire Dardanian zone, that means the Hercynian basement, as well as the Mesozoic and Cenozoic sediments observed in the west part of Gjilan.

Thus, D_n and D_{n+1} refer to successive post - Hercynian stages, while S_n and S_{n+1} refer to associated schistosity. S_n is a penetrating schistosity while S_{n+1} represent the crenulation schistosity. The fracture schistosity is also present. A structural analysis of deformation fields was possible, especially for S_n because the field measurements show that the D_n 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.

The deformation D_n, D_{n+1}, D_{n+2} and associated structures S_n, S_{n+1}, S_{n+2}.

The main event of the Hercynian tectonic period that structured the rocks forming the *area* of northern Gjilan is associated with the regional deformation (D_n). 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_n) is an axial plane schistosity of the isoclinals folds (S_0, S_{n-1}) (Figure-3). The schistosity (S_n) is homogenous, with the simetric fold and dip direction of 70° once in north -west and once in east (Figure-4). The intersection lineation (L_n) and the fold axis (B_2) are very homogenous with the dip azimuth toward N (345°) and dip angle of 15°.

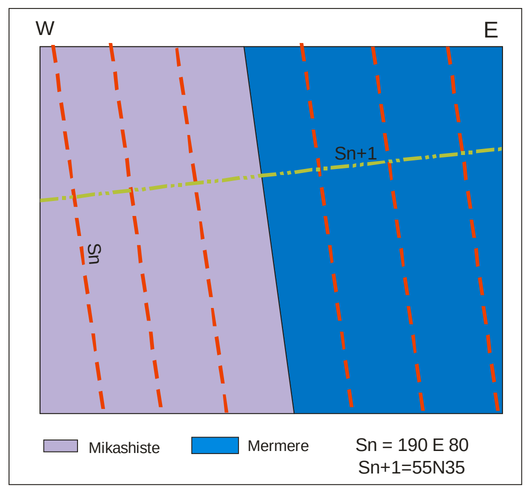

Figure-3. Foliation S_n parallel to boundary of micaschists and marble.

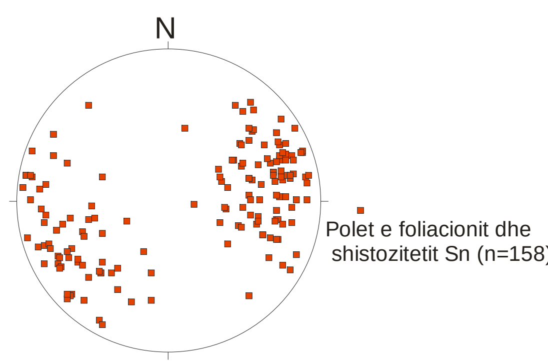

Figure-4. Stereographic projection (lower hemisphere) of Foliation Sn (158 measurements).

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The deformation (D_3) is associated with the crenulations of schistosity (S_{n+1}). The schistosity (S_{n+1}) represents the axial plan of the kink fold and crenulation (Figure-5). The schistosity (S_{n+1}) 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 (Figure-6). Likewise; the axis of the crenulation (B_{n+1}) and (L_{n+1}) lineation represent relative heterogeneous linear structures.

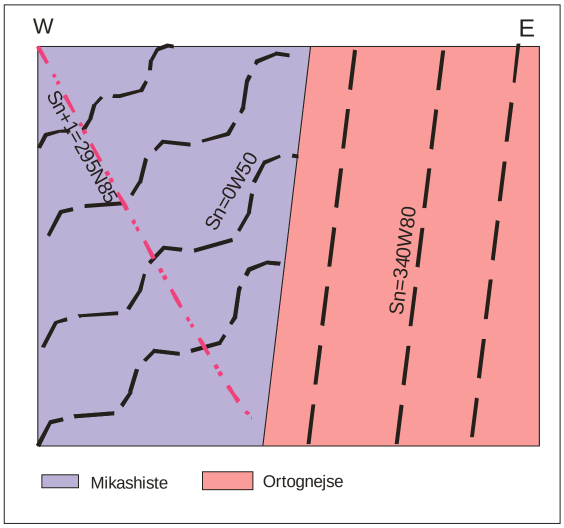

Figure-5. Crenulation schistosity S_{n+1} (axial plan of micro folds crenulation) which folded the foliation Sn inter micaschists but not attack ortogneisses.

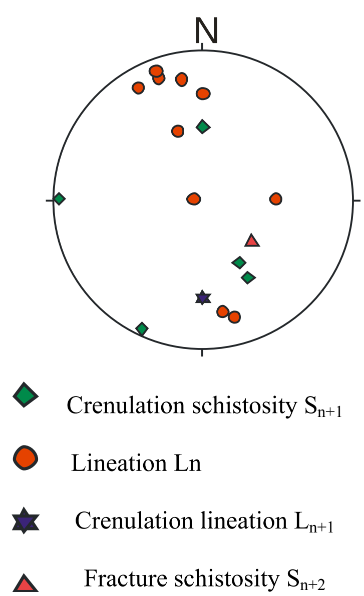

Figure-6. Stereographic projection (lower hemisphere) of Lineation Ln, crenultion schistosity, crenulation lineation and fracture schistosity.

Metamorphism

The metamorphism of gneiss, marble and micaschists are associated with the deformation D_{n+1} belongs to the age of 150 up to 130 million years [2]. The deduction of this age is based on the dating of similar metemorphic events from the neigh boring regions (Most, 2003; Moutrakis, 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_{n+2} are difficult to be estimated. This metamorphism is associated with a regional schistosity of NNW-SSE orientation.

SUMMARY

The study area is located in the North - Eastern part of Gjilan region and belongs to the Vardar Zone and Dardania zone (Serbian - Macedonian zone).

Boundary of these geotectonic units is marked by a fault, covered with Neogene sediments (Figure-2).

The present structure of the Dinarides and the Hellenides is the result of a Mesozoic to Cainozoic orogeny, related to the ongoing convergence between the Apulian and European plates (Figure-1).

In accordance with petrological-structural exploration in this region, we can distinguish the next structural stages: The entire Paleozoic crystalline basement of Dardania zone, Ophiolites and supra ophiolitic sedimentary melange, The Albian-Senonian transgression, The Tertiary transgression.

Structural analyses show that crystalline basement represents a mega-antiform reversed towards the south-west. This is accompanied by meso- and micro-isoclinal folds, with reversal towards the West, observed in the tectonic stratification with the thickness of several millimetres to several meters. These tectonic stratifications under green schists facies conditions, amphibolites, marbles, quartzes, etc., a result from the tectonic transposition during the deformation phase associated with a regional homogeneous schistosity Sn (Axial plan of isoclinal folds). This last one has NNW strike and dip, once to East and once to West with the angle about 70 °. The associated metamorphism is the high grade to middle metamorphism, aged of 150 to 130 million years deducted from dating in neigh boring regions (Most, 2003). The cinematic analyses concerning this deformation phase indicate a transport of the upper part towards the SW. Concerning this phase of deformation, the direction of displacement is deduced from the reversed polarity of the Sn, while transport sense is deduced from the cinematic analysis on field and the microscope analysis.

Structural and microstructural analysis show also two successive phases accompanied by a crenulation schistosity Sn+1 and fracture schistosity Sn +2, connected to two deformations, stages Dn+1 and Dn+2. The Age of metamorphism that accompanies these two stages is difficult to assess. The crenulation schistosity has a heterogeneous behavior and is proving that belong the ductile-brittle deformation and depends on the facial lithology. While the fracture schistosity shows a homogeneous behaviour with wide strike with strong dip angle once north, once south.

Structural similarity, the lack of a regional tectonic contact between the massive gneiss facies from the neighboring regions with the sericite-schist facies, the nature of the metamorphism increase in depth towards the East, so these are some strong facts that are taking for the structural and metamorphic continuity of these two crystalline sequences. For this reason, the Paleozoic crystalline basement was considered as the crystalline basement of Dardania and is the western extension of the Rhodope crystalline basement and Serbo-Macedonian zone. The Cretaceous transgression starts with settling the Albian-Cenomanian sediments over the Paleozoic crystalline basement. The folds are isoclinals with the axial plan parallel with schistosity.

Very homogeneous structures with SW reversal observed in the Cretaceous turbidites assume that during this deformation phase we have a transport towards the south-west. This is in accordance with the deformation phase D3 (110-90 million years) that has recorded a transport of the upper part toward the south-west under conditions of green facies in the ALMOPIAS unit (Most, 2003).

Another stage of deformation that has affected the Cretaceous turbidites is the deformation phase D4 (Campanian) that according to Most 2003 has recorded a transport of the upper part toward the NE under conditions of green facies in the West Pelagonian zone. While in the area of Eastern Pelagonian zone, the deformation occurs only under conditions of semi-ductile to be brittle. From the cinematic analysis of the major tectonic fault (see map) that separates the Paleozoic formation from the flysch and supra-ophiolitic melange, it results that this fault has functioned as a senestral strike-slip fault with an important component of the inverse movement. This has happened for reasons of a dextral transpressive tectonic with the compression direction towards NE-SW (Miocene age).

Extensional tectonic regime has installed in the region of the graben structures where Neogene lacustric deposits have settled.

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