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OPHIOLITIC METAMORPHIC SOLE IN KOSOVA
SHOJA METAMORFIKE E OFIOLITEVE TË KOSOVËS

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PERMBLEDHJE
Në Kosovë, formacionet ofiolitike kryesisht shtrihen në zonën e Vardarit dhe brezin ofiolitik Mirditë – Gjakovë. Në bazamentin e formacionit të ofioliteve Mirditë–Gjakovë është formuar shoja metamorfike karakteristike. Kjo përfaqëson një zhvillim regjional, e shfaqur në të dy anët e pakove të ofioliteve. Mosha e Jurasikut të Mesëm dhe shojës metamorfike përkon me moshën e ofioliteve. Këto të dhëna tregojnë se shoja metamorfike është formuar në të njëjtën kohë më proceset e formimit të ofioliteve dhe sedimentimit të radilariteve. Gjatë Jurasikut të Mesëm ka ndodhur mbivendosja ndëroqeanike bidivergjente e litosferës oqeanike të re të Jurasikut në ofiolitet e Triasikut të Mesëm – Jurasikut të Poshtëm. Ky proces ka mundësuar forminin e shojës metamorfike. Intervali i shkurtër për formimin e ofioliteve të Jurasikut, e shoqëruar me vendosjen e tyre bidivergjente në ofiolitet e Jurasikut të Mesëm Jurasikut të Poshtëm (βT_2-J_1), mbështet bindjen e ekzistencës së basenit oqeanik shumë të kufizuar

SUMMARY
In Kosova, the ophiolite formation is spread mainly in the Vardari zone and in the Mirdite-Gjakove ophiolite belt. At the basement of the Mirdita-Gjakova ophiolite formation a characteristic metamorphic sole is developed. It shows a regional development and is found on both sides of the ophiolite sheets. The Middle Jurassic age of the metamorphic sole corresponds surprisingly to the ophiolite age. These data indicate that the metamorphic soles are produced rather simultaneously to ophiolite forming processes and radiolarite chert sedimentation. During the Middle Jurassic occurred the bidivergent intraoceanic emplacement of Jurassic young oceanic lithosphere onto the Middle Triassic-Lower Jurassic ophiolites. This process led to the formation of the metamorphic sole. The very short age span of the Jurassic ophiolites, accompanied with their bidivergent emplacement onto Middle Jurassic Lower Jurassic ophiolites (βT_2-J_1) supports the suggestion on the existence of very narrow oceanic basin.
Key words: belt, Kosova, metamorphism, ophiolite, sole.

INTRODUCTION

In Kosova, the ophiolite formation is spread mainly in the Vardar zone and in the Mirdita-Gjakove ophiolite belt (Elezaj and Kodra, 2008). Small ophiolitic massifs and ophiolitic tectonic slices occur also in other tectonic zones. The Mirdita-Gjakove ophiolite belt starts in Greece, and continues several hundred kilometers through the Albania and Kosova. North to Shkoder-Peje major faults, this huge ophiolitic belt is known as Dinaride ophiolitic belt.

It should be noted that in Mirdite-Gjakove ophiolitic belt, two ophiolite complexes are distinguished: Middle Triassic-Lower Jurassic ophiolites and Middle Jurassic ophiolites (Elezaj and Kodra, 2008). In Kosove area, this belt is set very close to the Vardari ophiolites. Their relationships represent a very interesting research topic for the Mediterranean ophiolites genetic scenario.

In Kosova and Albania, both type ophiolites are closely related to the metamorphic sole rocks development at base of ophiolites. In Albania, it continues with several discontinuities for about 200 km and it is found in the western and eastern periphery of Middle Jurassic ophiolites. In several

cases its tectonic fragments outcrop within ophiolites (Xhomo et al. 2002). In Kosova, it occurs at the basement of Korishe, Lubizhde, Koxhi Ballkan, Brezovice etc., and small ophiolite massifs (Elezaj et al. 2000, Elezaj and Kodra 2008).
The soles reflect a time when the base of a hot oceanic sheet was first detached from its substratum and overrode the rocks that have been metamorphosed, commonly to green schist or amphibolite grade (Jones et al. 1991, Smith, 1993). In example of Albania, it is inferred that this formation is issued during the intraoceanic stage. Bidivergent and North-North Western thrusting and the displacement of Middle Jurassic young hot oceanic lithosphere onto Middle Triassic-Lower Jurassic old cold oceanic lithosphere produced the metamorphic sole (Kodra and Gjata 1982, Kodra et al 2000, etc.).
The metamorphic sole is an important geological indicator because it preserves a key record on the ophiolite evolution. The geological evidence of the metamorphic sole in Kosova provides ulterior alternatives on the driving forces and ophiolite emplacement in the most northeastern segment of Mirdita-Gjakove-Rahovec ophiolite belt. The paper doesn't address the metamorphic sole of Vardar Zone.

Geological evidence

In Kosova area, the ophiolite metamorphic sole is widely exposed along the edge of the ophiolites, but in several cases it is found sporadically as tectonic slices at the basement of the ultrabasic sheets. Its thickness ranges from several meters to 200 - 300 m. Generally, at the contact with ultrabasics, the metamorphic sequence is composed of amphibolites or garnet amphibolites. These facies grade downward to garnet-mica schists and green schists. Locally, a gradual transition to the underlying volcano-sedimentary formation is documented.
On the basis of several chemical analyses, the amphibolites are originated from basaltic and gabbroic protoliths, and seem to include members of high Ti series. The protoliths of mica schists were probably siliciclastic sediments with pelitic components.
At the bottom of the ophiolite massifs, a squeezed strip of serpentinites, 10 -100 m thick crops out. Upward, the ultrabasic rocks are represented of fresh and mylonitized facies corresponding to low-temperature metamorphism, probably related to the ophiolite paleo displacement onto the continental margins.
In general, two successive metamorphic sequences are distinguished: the upper and the lower sequence. The upper sequence is represented of garnet amphibolites (almandine amphibolites), amphibolites, almandine-muscovite-mica schists. The metamorphic facies belong to temperatures 500-700 ºC and pressure 6-8,2 kbar. (Dimo, 1997). The Lower sequence is composed of green schists of the temperature 300-400º and pressure 3-4 kbar.
Downward the metamorphic sole passes gradually to Middle Triassic - Lower Jurassic unmetamorphosed basalt radiolarite series.
In Albania, in several places the metamorphic sole shows a steep apparent inverted metamorphic gradient, with granulite assemblages preserved close to the contact with obducted ophiolites, going downward into almandine-amphibolite subfacies assemblages, amphibolite facies, then greenschist facies (Bebien et al. 2000). The granulites correspond to P-T conditions: 800-850 º C and 0,9- 1,2 GPa (Dimo, 1997).
In Kosova area, the ophiolite massifs set onto the metamorphic sole are represented of lithospheric metamorphosed peridotites. The peridotites show foliated porphyroclastic structure of low temperature and high pressure. Such type structures are identified also in neighboring areas (Meshi, 1995, Gjata et al. 1995, Nicolas et al. 1999).
According to Fejza, 2004, in the example of Goleshi massif, an eastern orientation displacement is documented (fig. 1). At the ophiolite massif basement, the squeezed and highly foliated serpentinite schists of several meters to 100 - 200 m thick are developed. They are widespread at the basement of the ultrabasic

sheets. In Brezovica area, thick and complete metamorphic sequences beneath the ultrabasic massifs are described by Karamata et al. (1978), Ciric et al. (1996).

Age of the metamorphic sole

The time span of the metamorphic sole is largely Middle Jurassic. The available isotopic data refer to Brezovica ophiolite massif, fig. 2 and Tab.1.

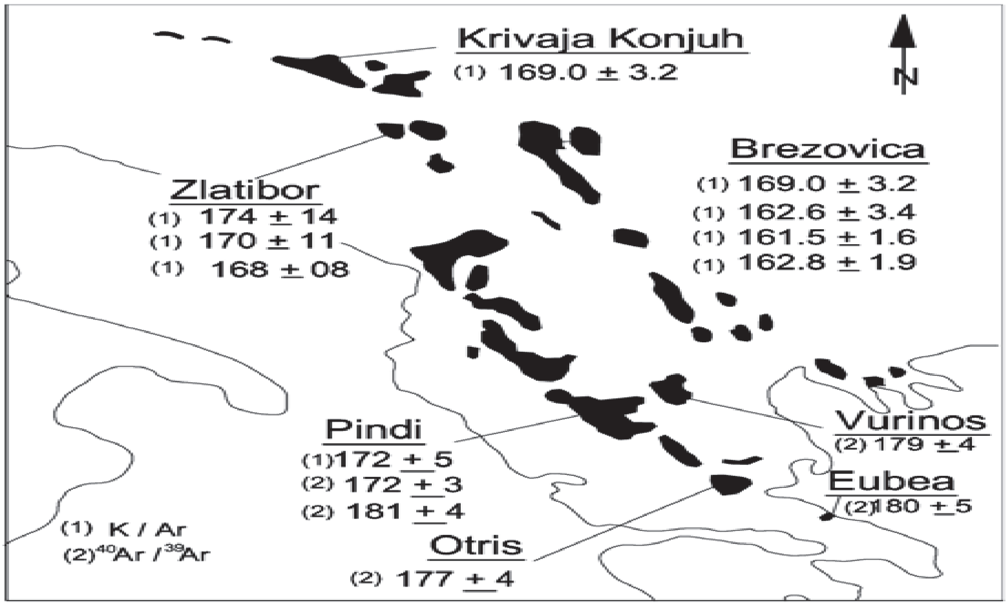

Figure 1. Metamorphic sole age in Kosova and adjacent areas

Rock	Dated mineral	Age (in mil. y.)	Method	Reference
Metapelite	Muscovite	161 ± 1.6	K-Ar	Smith A. G.1993
Metachert	“	162.8 ± 1.9	“	“
Amphibolite	Hornblende	169.0 ± 3.2	“	“
Amphibolite	“	162.0 ± 3.4	“	“
Amphibolite	Hornblende	176.± 8	K-Ar	Karamata and Lovric, 1978
“	“	176.± 9	”	“
“	“	179.± 6	“	“
“	“	176.± 9	“	“
“	“	171.± 6	”	“
Metapelite	Biotite	168.± 5	“	“
Amphibolite	Muscovite	161.± 5	“	“
“	Hornblende	172.± 8	“	“
“	Muscovite	159.± 5	“	“
“	Hornblende	161 ± 5	“	“

Table 1. Isotopic data from Brezovica massif metamorphic sole (Spray et al. 1984).

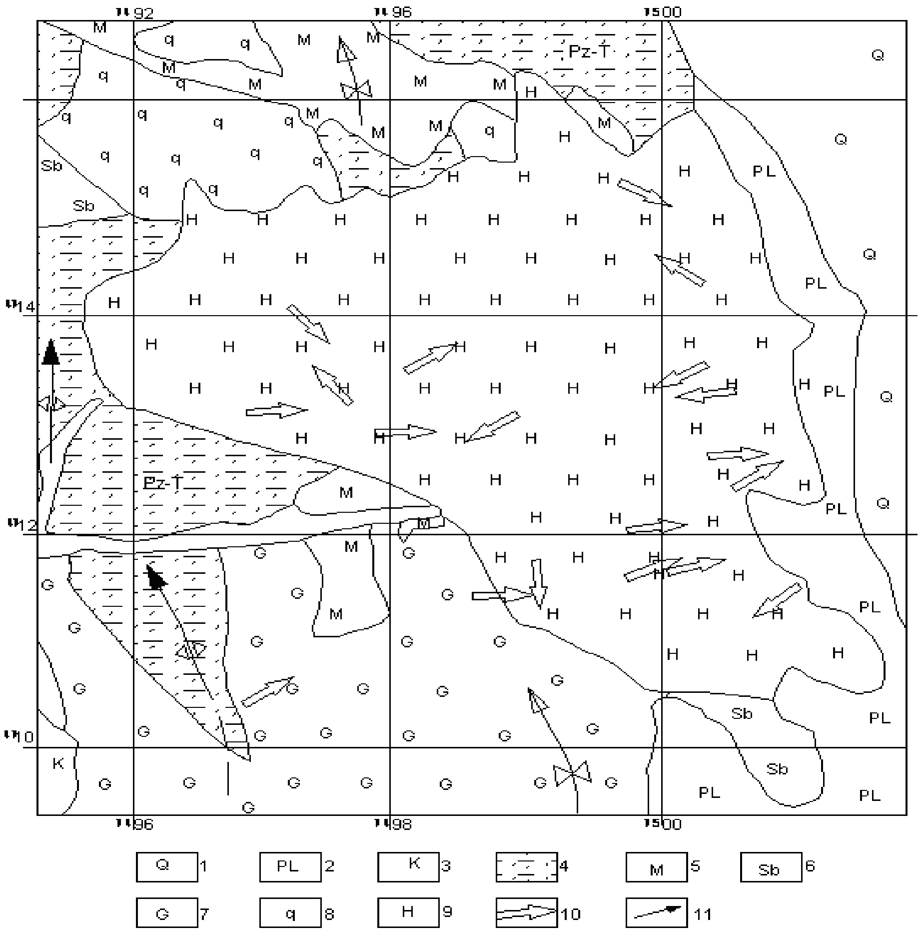

Figura. 2 Goleshi ophiolite massif and its kinematics (Fejza 2004)
1. Quaternary, 2. Pliocene, 3. Cretaceous, 4-8 Velesi series (Pz-T), 4. Schists, 5. Marbles, 6. Sericite schists, 7. Gneiss, 8. Quartzite, 9. Harzburgite, 10. Low Temperature-High pressure Lithospheric displacement trend, 11. Fold axis.

The data on the metamorphic sole of the Kosova ophiolites are still scarce. It is necessary to carry out ulterior isotopic determinations also making use of Ar^{40}/Ar^{39} method.

In Albania and other Balkan countries numerous isotopic analyses, refining the age of the ophiolite metamorphic sole are carried out. The isotopic studies of 30 samples from different sites of Albania (Ivanaj, 1992; Kodra et al., 1995; Vergely et al., 1998; Dimo, 1997), testify the Middle Jurassic age (160-174 Ma) of the metamorphic sole. This age is close to the age of the Jurassic ophiolites. Plagiogranites in the north yield 163±1, 8 Ma. (Ar^{40}/Ar^{39}) (Vergely et al., 1998). The radiolarites found within ophiolite volcanics and in the primary sedimentary chert-radiolarite ophiolite cover indicate the Middle Jurassic age: Bajocian-Callovian (Marcucci et al., 1994; Prela, 1996; Kodra et al., 1995). The very short age span of the Jurassic ophiolites, accompanied with their bidivergent emplacement onto Triassic-Liassic ophiolites (volcano-sedimentary formation, βT_2-J_1) support the suggestion on the existence of very narrow oceanic basin (Kodra and Gjata, 1982, Vergély et al. 1998, Kodra et al. 2000, 2001).

Summarizing the available results that in both sides of the ophiolite massifs the metamorphic sole age is rather the same, whereas in the northern part of Mirdita - Gjakove ophiolite massif, an accentuated contrasting diachronism in the longitudinal direction is recognized. It is expressed by the oldest ages of the metamorphic sole at the southern areas varying 169 -174 Ma and the youngest ages at the northern areas ranging 160 - 164 Ma (Kodra et al. 1995, 2000, 2001), Fig. 3.

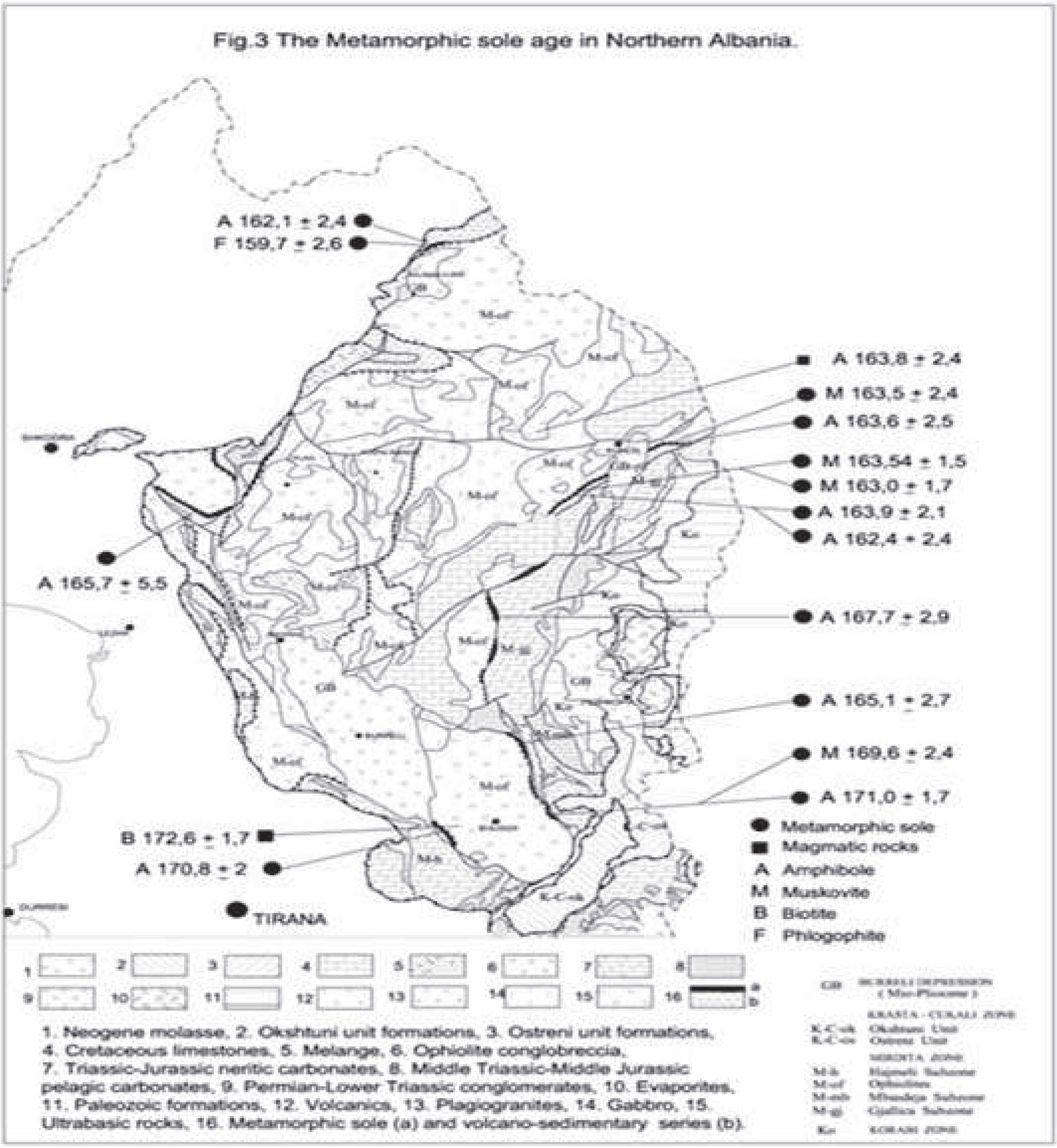

Figura. 3. Metamorphich sole age in Northern Albania

Taking into consideration the metamorphic sole ages of the Greek ophiolites, the diachronism is more noticeable. The age difference is verified also into the mafic segregations of Tropoja-Gjakova ophiolite massif. It is inferred that the diachronism is related to the advancement or the

retardation of the ophiolite forming processes and the intraoceanic paleo displacement of the different ophiolite segment limited by the transform faults largely developed into the Mirdita-Gjakove ophiolite belt (Kodra et al.1995).
In the light of the age data provided by the metamorphic sole, the radiolarite chert sequences found within the Mirdita-Gjakove ophiolite belt and by its primary radiolarite cover, a very close age span is evidenced (Kodra et al. 1995, Xhomo et al. 2002). The time span of the metamorphic soles indicates that its production is made parallel to ophiolite forming processes and radiolarite chert sedimentation.

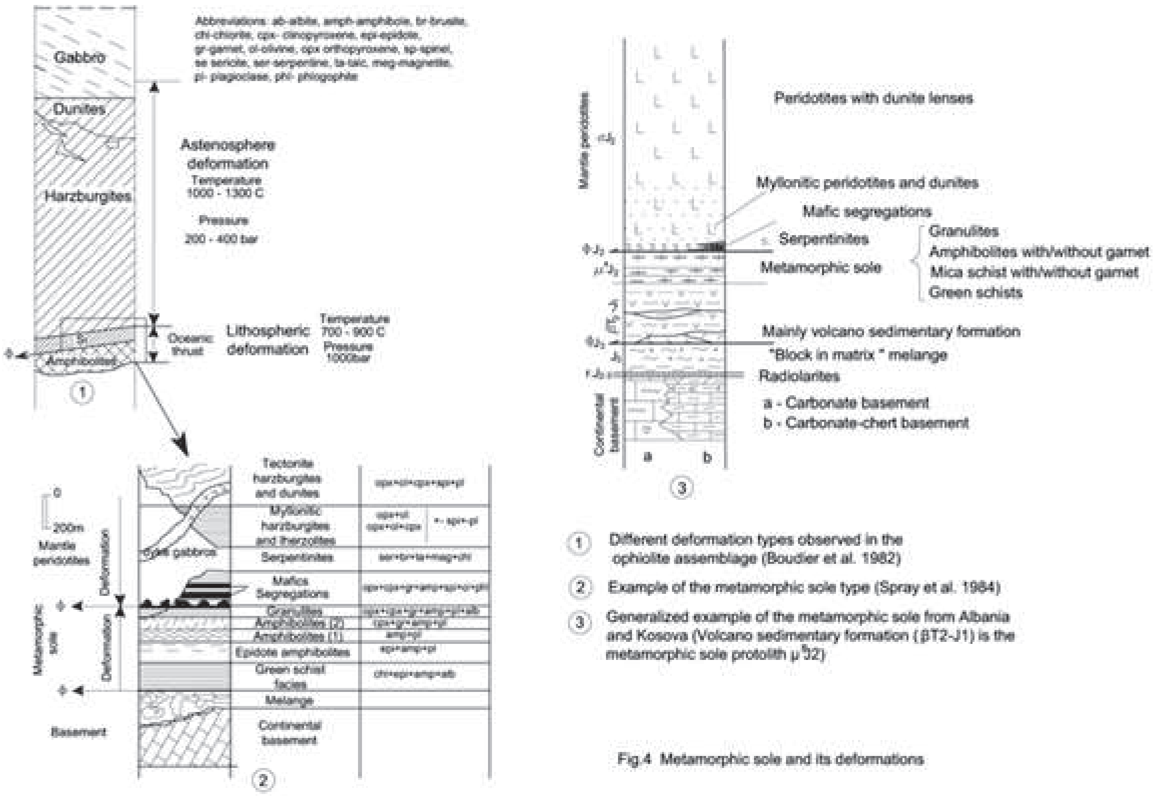

Figura. 4. Metamorphich sole and its deformations

Similar age indicate also the garnet pyroxenites enclaves in a serpentinite breccia that crosscuts the ophiolite volcanics near Derveni (Albania) (Gjata et al. 1992). According to geochemical data, the garnet pyroxenites probably originate from oceanic gabbro protoliths. Thermobarometric considerations show high temperature (1200º C) and high pressure 1.5 GPa). It s inferred that they are formed on the initiation of a subduction process or near the oceanic ridge. Analogous age span show also the plagiogranites of SSZ type ophiolites (Ivanaj, 1992).

Genetic implications

Summarizing the available data, it is inferred that the oceanic spreading producing the Jurassic ophiolites, the successive intraoceanic subduction and the ophiolite paleo emplacement onto the Middle Triassic-Lower Jurassic volcano sedimentary diabas radiolarite formation leading to the metamorphic sole generation are developed in very short time interval (Kodra and Gjata 1982, Kodra et al. 2000, Elezaj and Kodra, 2008).

It seems that in the Mirdite - Gjakove narrow oceanic basin, the ophiolite detachment and the two margins decoupling of the young oceanic lithosphere is not developed above the oceanic ridge. However, in the oceanic crust sequence is preserved the necessary thermal flux for the metamorphic sole formation. Its setting may be is close to the oceanic ridge or intraoceanic subduction zone. As consequence, the suggested scenario implies that the initial displacement of young, hot, ocean crust and mantle occur within an oceanic setting.

The petrological and structural evidence from the metamorphic sole supports also the interpretation that during the intraoceanic stage, the ophiolite emplacement (thrusting and decoupling) is developed. The Early Jurassic-Middle Jurassic young and thick oceanic lithosphere is set onto the Middle Triassic-Early Jurassic precedent oceanic lithosphere. The emplacement movement is associated with production of the amphibolites, gneisses and mica schists with or without garnet.

On the other side, the obducted ultramafics are subjected at their basement to intensive metamorphism. It is expressed by rock dehydration and the mylonitization. In more advanced phases the intensive serpentinization processes are developed. At the lowest part of the ultramafic sheets a strong serpentinization and the squeezing phenomena occurred and the shear zones are developed (Fig. 4). At the ultrabasic massif bottom the cutting deformation passes to ductile deformation, which is contemporaneous to ophiolite sole metamorphism. The last one is affected by the foliation S1, splitting schistosity S2 and multiphase micro folds (Meshi 1995, Nicolas et al. 1999).

Some time, the metamorphic sole is cross cut by the garnet, quartz-garnet etc. thin veins (from 2-5 cm, to 10-15 cm). They are considered as products related to the metamorphic processes occurred during the ophiolite emplacement.

In general, a structural concordance between the ultrabasic allochthonous massifs foliation, metamorphic sequence foliation, the structurally underlying basalt radiolarite series (βT_2-J_1) stratification and the Jurassic ophiolites emplacement plane on volcano-sedimentary series is observed (βT_2- J_1). Some time, it is difficult to retrace the boundary between the metamorphic sequence and the underlying volcano sedimentary formation, because a light metamorphic imprint is evidenced also into the volcano sedimentary members.

CONCLUSIONS

1. In the example of the Mirdita – Gjakova ophiolite, it is inferred that during the Middle Jurassic, the bidivergent emplacement of the young oceanic lithosphere onto the old lithosphere (Triassic-Lower Jurassic ophiolites) occurred. The ophiolite displacement produced the subjacent metamorphic sole developed along side the ophiolite margins.
2. The initial displacement of the oceanic and mantle crust occurs within an oceanic setting.
3. The time span of the metamorphic soles indicates that its production is made parallel to ophiolite forming processes and radiolarite chert sedimentation.
4. The very short age span of the Jurassic ophiolites, accompanied with their bidivergent emplacement onto Triassic-Liassic ophiolites (volcano-sedimentary formation, βT_2-J_1) supports the suggestion on the existence of very narrow oceanic basin suggested by Kodra and Gjata 1982, Vergély et al. 1998, Kodra et al. 1994, 1995, 2000 etc.

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