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Research Paper

The Dynamic Role of Tectonic Faults in Geological Evolution of the Region in North - West Albania

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Abstract: The structural interpretation and the geological data allows us to give same consideration on the role of the longitudinal and transverse faults on the development of the structures. The object of this paper are the tectonic features and geological evolution of the north part of Albania. The study area is located in the sector between two old transverse tectonic faults of Shkoder – Peje in the north part and Vlore - Elbasan in the south. This region has very complicated geological features where combined of several facial structural zones. In the east is bounded by the Kruja (Gavrovo) tectonic zone and in the south by the Ionian tectonic zone and in the north western part by the Adriatic Sea waters. The Kruja (Gavrovo) and Ionian tectonic zones are intensively affected by orogenesis whereas Sazani (Apulia) and the Southern Adriatic Basin are partially affected. Longitudinal and transverse tectonic faults have played a very important role in facie sedimentation and in the structuring of tectonic zones and structures.

Keywords: *Longitudinal, tectonic, faults, Kruja, Folds*

Introduction

The study area is located in the north-western part of the Outer Albanides (part of the Dinarides - Albanides – Helenides structural belt). Outer Albanides are part of continental margin of the African edge and Ardia microplate) and are formed from sedimentary deposits and maybe metamorphic rocks. The study area is bordered to the east by the Kruja (Gavrovo) tectonic zone, in the south part from the Ionian tectonic zone and to the northwest by the Adriatic Sea water (Xhomo *et al,* 2020) (Figure 1). This area is located in the sector between two old transverse tectonic faults of Shkoder - Peje and Vlore - Elbasan and represents a region with complicated geological features where we have a combination of several facial structural zones. Studies made in this region have showed different opinions on the continuation of tectonic zones in north - west part of Albania and the relationships between them. This paper based on the structural interpretation and the geological data of the region, will give some consideration on the role of old and new tectonic faults in the geological evolution of the structures.

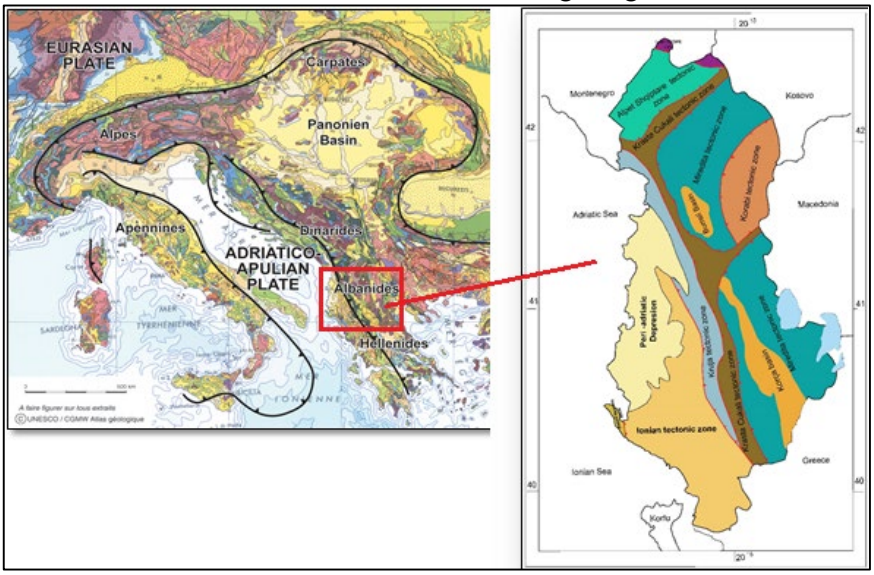

Figure 1. Location of the study area

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Characteristics and the Role of Tectonic Faults

The Structural Units in the Outer Abanides have been created as a result of the continental collision between the Ardia microplates with the European plate. The structures units have generally south - west and north – east direction. The three tectonic zones of Kruja (Gavrovo), Ionian and Sazani (Apulia) in northern part dips and in this sector has its origin in the Pre-Adriatic Depression. The longitudinal and transverse tectonic faults have played a very important role in sedimentation and in the structuring of tectonic structures in the study area (Frashëri & Nishani, 1996) (Konomi, 2000). Based on the geological settings and in the change of the deposits thickness and their lithology in the Mlik-Rodon area and surrounding regions, the tectonic faults are grouped as follows:

The Longitudinal Faults

During the rifting phases (Liassic) a series of normal longitudinal faults have separated the tectonic zones and structures from each other (Roure, et al., 2004). These faults are not uniform everywhere and have different amplitudes in combination with transverse faults give different structures forms. Due to the combination of these faults in the study area and especially in the southern and eastern parts, horsts and grabens structures have been created, bounded with longitudinal and transverse faults from each other. (Figure 2). Generally these structures or tectonic zones have a longitudinal direction and the combination of normal longitudinal with transverse faults causes significant changes in the longitudinal direction. These faults throughout the time that the Outer Albanides margin had a distinctive regime are developed sinsedimentary. Such have been the western fault of the Kruja (Gavrovo) tectonic zone and some faults that border the Dajti, Tirana structure and Ionian tectonic zone (Frashëri & Nishani, 1996). We think that these faults have existed due to the fact that the thickness and lithology of the deposits have changed in the both sides of the faults, as well as the other fact that the same faults are found fossilized in Sazani (Apulia) tectonic zone evidenced by the field survey and seismic profiles in the Adriatic Sea and surrounding regions (Milia, *et al.,* 2017; Ndreko & Nazaj, 2019*)*.

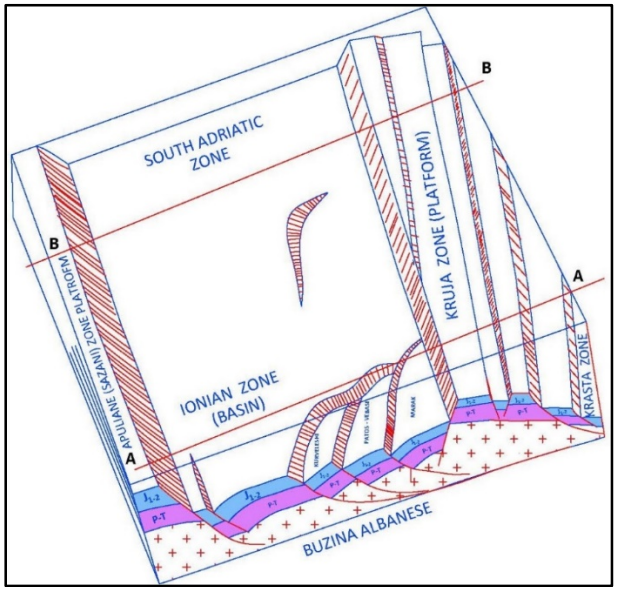

Figure 2. Scheme of tectonic zones during the rifting (Lower - Middle Liassic)

These normal faults separate the neritic deposits of the Sazani tectonic zone (Apulia platform) from the pelagic deposits of the Southern Adriatic Basin reference. Normal faults during the compression phases (orogenesis) begin to activate in the opposite direction according to these blocks and structures rotate. During the orogenesis process the compression resistance is small, so the deposits will be disconnected at their weakest point. The small resistance is exactly in the areas with existed normal fault due to this occurs inversion these faults. The amplitude of these faults depends on three factors:

The first factor: The amplitude of normal faults during lover Liassic age. The bigger the amplitude of these faults, the bigger is the overlapping amplitude of the structures, structural belts or different tectonic zones. Thus the fault of the Kruja (Gavrovo) tectonic zone in the north part has a very big overlapping amplitude of tens of kilometers (Roure *et al*., 2004). These are clearly evident in the seismic

profiles made in the Kruja (Gavrovo) tectonic zone (Figure 3). Which besides the top of limestone of this zone at 1.5-2 sec has another horizons almost parallel to the limestone top at 2.5-3 sec which dips northward direction. To the south direction this fault comes by reducing its amplitude (Nazaj & Valbona, 1990).

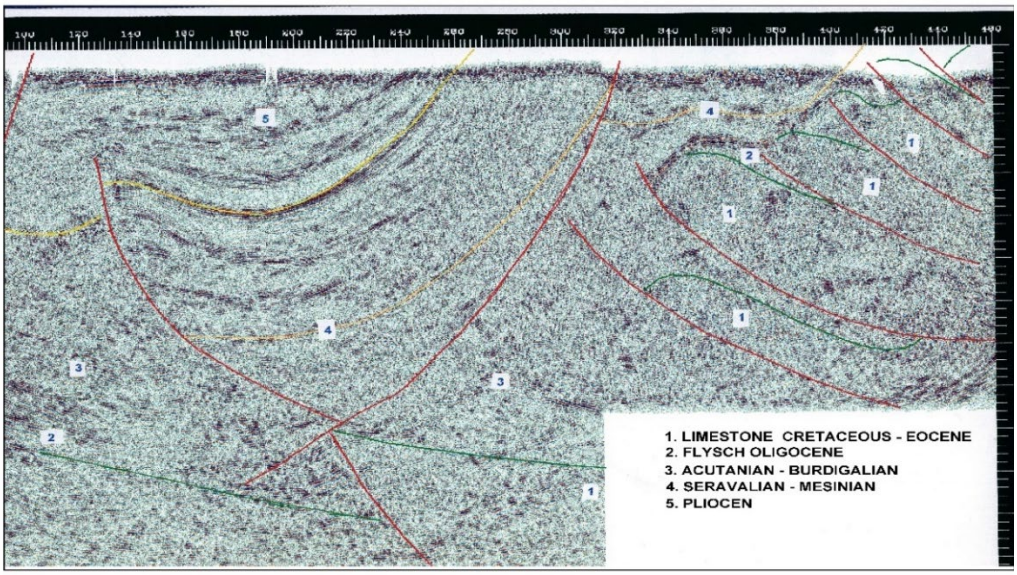

Figure 3. Seismic cross- section A-A

The second factor: The duration time of the normal fault that affect the overlapping amplitude of the structures, so how long does this normal fault continue to control the sedimentation. According to this model the tectonic inversion and overlap of the structure will occur where the normal fault has the bigger amplitude and time duration. The northern part had a bigger amplitude compared to the south part forming different structures. In the northern of the Kruja (Gavrovo) tectonic zone the folding phases is done with monoclines structure while Kozan-Tomorri structures in the south where the resistance is bigger (because the difference in deposit thickness is more gradual), the sedimentary formation responds creating structures with both arms. In some structures such as Dajti, Tirana, Rodoni perhaps and Mliku (Nazaj, 1995) where the amplitude of normal faults has been relatively small their overlapping amplitude is about several kilometers. These data show the dependence of the overlap by the amplitudes and the duration time of normal faults. At the south of the study region some structures of the Ionian tectonic zone have a very big overlapping amplitude to the north compared with the south of Ionian zone. In general, the movement direction of the structures is anti-clockwise.

The third factor affecting the structuring and the overlapping amplitude is the heterogeneity of the sedimentary formation as well as the horizons that serve as sliding horizons. The presence of incompetent horizons such as evaporate formation for the Ionian tectonic zone or different levels of the Schist of Jurassic, Cretaceous. The transition from the carbonate formation to the terrigenous formation and other horizons within the terrigenous formation play a very important role in the structuring and the overlapping amplitude. This is especially evident in the Ionian tectonic zone where most of the structures have in the west contact the outcrop of the evaporate formation (Velaj, *et al*., 1999) (Bega, 2017). These lubricating horizons have served as the basis for the sliding of the carbonate formation and fold them. It should be noted that in the northern part of the Ionian tectonic zone in the Mlik - Durres - Rodon region, based on the seismic data (Naco, *et al*., 2014), the region has flat geological construction with deep structures and small folding scale. This area forms the carbonate basement of the Southern Adriatic zone (basin). In the formation of structures in the study area has played an important role the combination of longitudinal and transverse normal faults.

Sinsedimentary Transverse Faults

In the study area other than longitudinal faults have existed and transverse faults that combined with the longitudinal faults have separated the study area into several structural blocks. Which have reacted

independently from each other during the orogenesis phases. In the study area are identified these main transverse tectonic faults:

- Transverse faults that interrupt the Ionian tectonic zone
- Transverse faults south of Durres – Fortuzaj
- Transverse faults of Rodoni area
- Transverse faults of Lezhe – Shkoder.

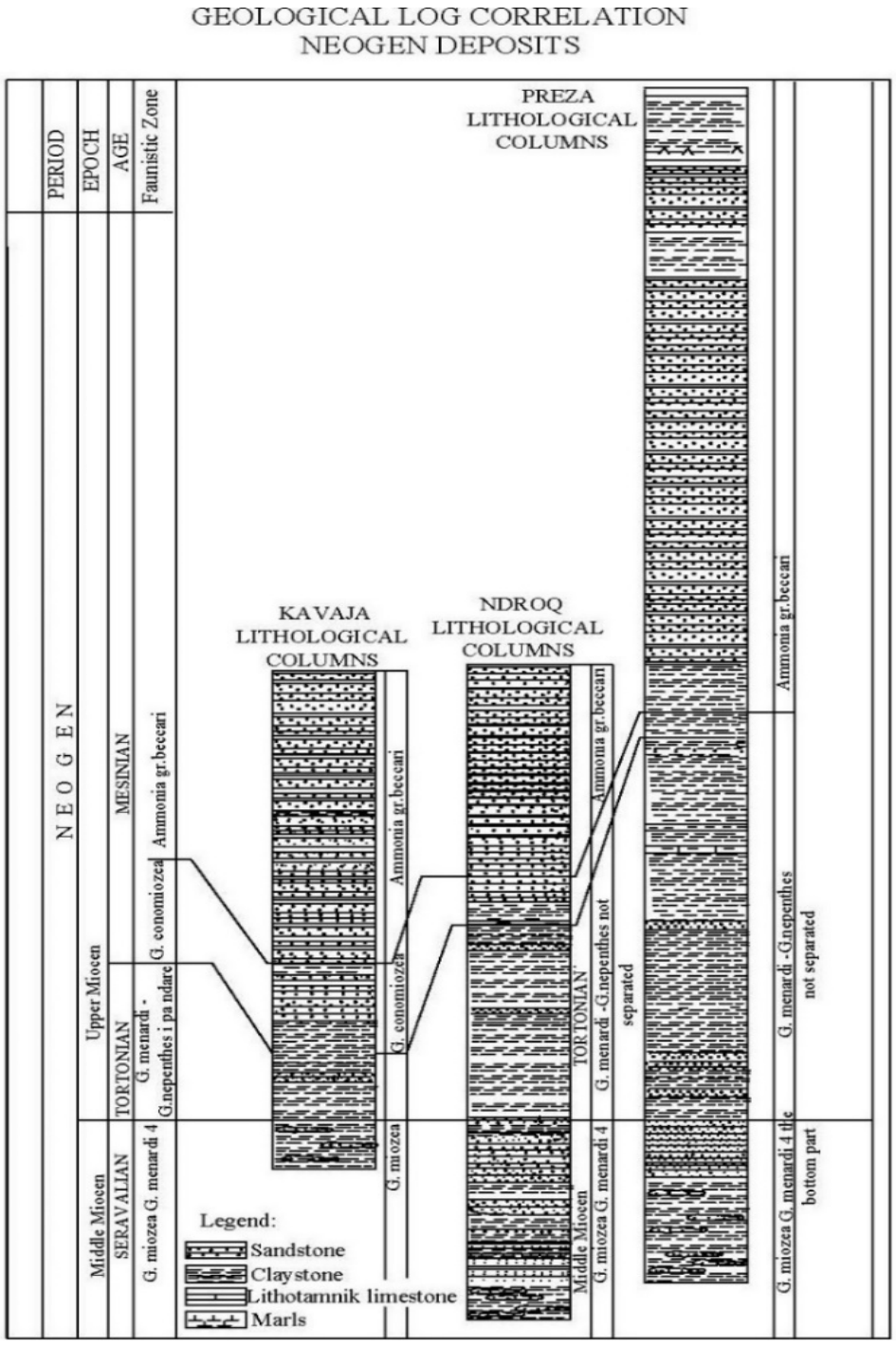

Figure 4. Geological correlation of the Kavaja, Ndroq and Preza outcrops

In these sectors is seen difference in thickness of the Burdigalian and Tortonian - Messinian deposition passing from north to the south part (Figure 4). At the same time the folding style and the rate of shortening of the structures in these sectors also changes. Transverse faults are also observed in the Kruja (Gavrovo) tectonic zone south of Tirana and in Elbasan - Tervolli sector and in the Tomorri anticline structure further to the south (Figure 5).

These transverse tectonic faults are combined with longitudinal faults. The existence of the transverse faults has made possible that today we can observe structures with different folding scale and with different dimensions. Further to the south part of the Kruja (Gavrovo) tectonic zone we have a gradual facial passing (Tomorri Structure) from neritic to pelagic facies for the Upper Cretaceous. Further to south in the anticlinal structure of Leskovik the deposition of Upper Cretaceous are pelagic facies. In this south sector of the Kruja (Gavrovo) tectonic zone the depositions are pelagic facies but belonging to the Ionian tectonic zone with the presence formation of the phosphate horizons. We think that the transition from the Kruja (Gavrovo) tectonic zone (neritic facies) to the Ionian tectonic zone (pelagic facies) e was made by some transverse paleofaults. Which combined with longitudinal faults have made the transition from neritic deposits in the northern area into mixed facies in the Tomorri anticline and in typical pelagic facies in the Melesin anticline and further in the south. As a result of these transverse tectonic faults, Kruja (Gavrovo) tectonic zone have different folding scale passing from north to south part. In the central area where the structures are monoclines (Tirana, Ishmi) and in the north and south direction the structures are anticlinal with the both arms and the number of structural belts in the south is reduced. In the sectors close to these faults as the compression resistance is smaller than is seen a greater structuring and overlapping scale. Regarding to the transverse faults that intersect the Ionian tectonic zone, is clearly seen the change of the folding style. Where the southern part is more folded and tectonically detached (Kreshpani, Verbasi and Maraku structures; Figure 5) while in the north part the structures have small folding scale for the lower tectonic level. This fault is not only one, but is a combination of western longitudinal faults of anticline belts and structures with the transverse faults. So this paleofaults has controlled in a transverse direction the sedimentation for the Triassic and Jurassic and possibly Cretaceous ages. North of the Ionian tectonic zone in Dumrea sector we have combination of longitudinal and transverse fault, we have also the outcrops of evaporate formations.

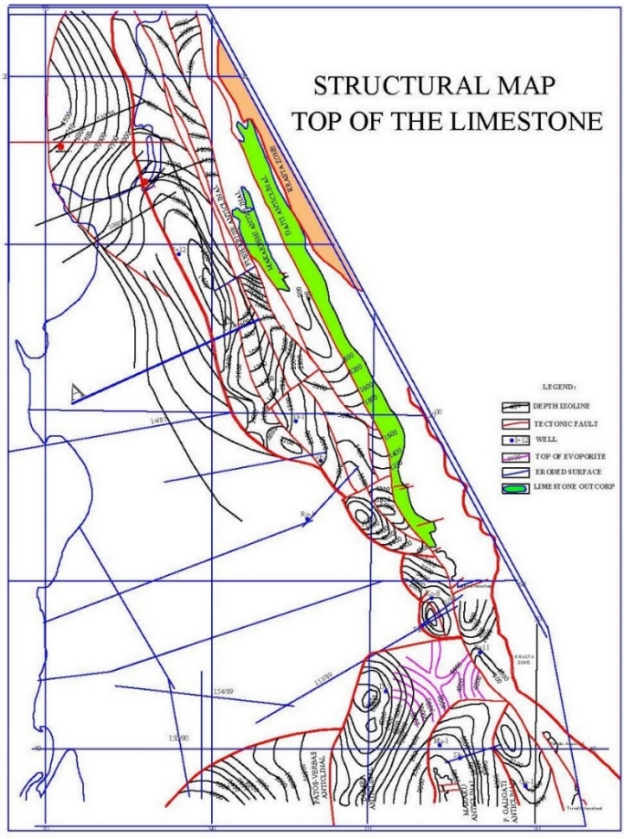

Figure 5. Structural map of the study region

Inter formational Faults and Their role in the Geological Evolution

General characteristic of the structures cover by flysch formation in the Kruja and Mlik-Rodoni structure is that in addition to the old faults that border the structures on the west arm that have continued their activity until the end of the Middle Oligocene new faults occur among the flysch formation (Nazaj, 1995). Carbonate structures are associated with flysch deposits until the Middle Oligocene and with the

continuation of the orogenesis phase cause the formation of new faults further to the west. The inter flysch faults are formed when the eastern arm of the extended structure is inserted under the handing structure. During this time the deposits fill the synclinal structure that separate the anticlinal structures. These faults have different ages in different structures. During the time of the formation of inter flysch faults which have smaller angel than older faults and usually act on the carbonate structures by moving the flysch formation of the synclines structure up to the axis of the structures. These faults are meet in Kozani, Fortuzaj and Mliku structure. In conclusion we can say that all the old structuring faults that affected the structures of the Kruja (Gavrovo) tectonic zone have ended the activity at the end of the Middle and Upper Oligocene. Then a new front of inter flysch faults has been opened in the west during the Upper Oligocene (Kugleri zone) according to these faults the carbonate structures have moved together with the flysch formation toward the west. This is seen in the big change of the thickness of the Upper Oligocene deposits (Kugleri zone) in the Kozani structure in the transverse direction on both side of the inter flysch fault. (Figure 6) (Sadiku & Nazaj, 1989) (Thomai & Nishani, 1987).

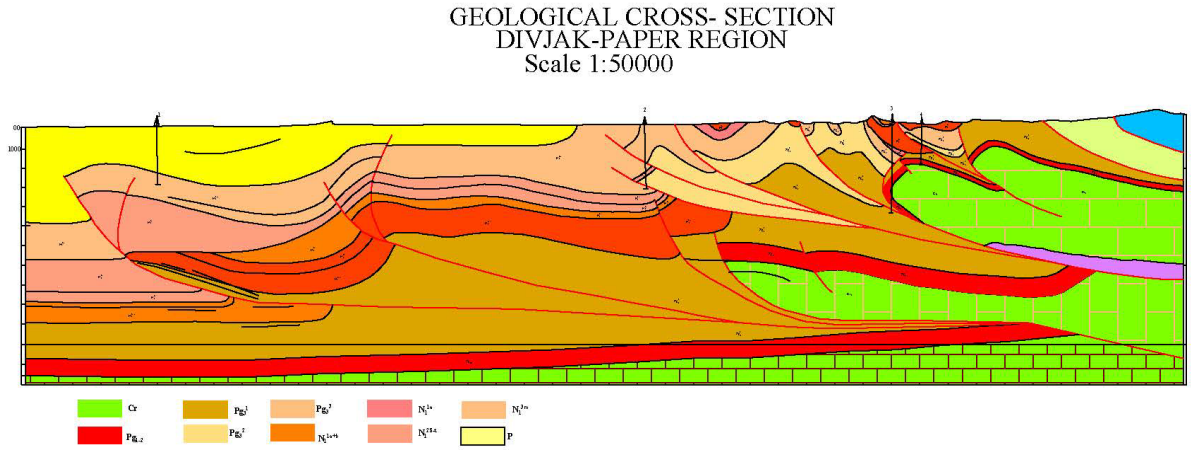

Figure 6. Geological cross- section

This phenomenon is accompanied by facial changes. During deposition of the Burdigalian sequence are formed several inter flysch faults further to the west direction in the Vrapi, Papri, Roves, and Mliku structures, all of these faults in the depth joined in one plan that dips eastward direction. Also during this sequence we have almost masked all the old faults and the new faults plan with small angles are formed further to the west. So the overlapping of the structures or the orogeny moves to the west direction according the new faults plans which in the depth join in the east direction with the old faults (Figure 6). During the Serravallian - Messinian sequence, the role of inter formational faults and their sinsedimentary character is more visible. During this time inter formational faults of Durresi, Shkoza and the Preza Monoclines are developed. In this area, from Kavaja in the south to Rodoni in the north, inter formational faults are active, this is related to the high seismic activity of this sector during the years 2019-2020. Where two powerful earthquakes with Magnitude M = 5.8 (September 2019) and M = 6.4 (November 2019) have their epicentre. This is accompanied with very high number of after aftershocks (Figure 7) (ASEM EMSC, 2019).

Characteristics for these inter formational fault is that the sedimentary prisms have large difference in depositional thickness on both sides of the faults in transverse direction and more gradual longitudinal direction. As in the Preza region where there are very large changes of depositions in transverse direction starting from the Burdigalian deposition up to the Pliocene and more gradual passage in longitudinal direction (Sazhdanaku & Thomai, 1988). This fact is important for determining the sedimentation and direction of orogeny movement. During the Pliocene sequence, the amplitude of longitudinal sinsedimentary faults continued increasing and masking of transverse faults continued. In the study area besides overlapping faults are also found faults with different direction and create the monoclines structures such as Thartori fault, Ishmi fault and Durresi fault (Figure 3). All of these faults are created as a result of orogenesis (Compression from the East) creating a triangular zones and flower structures. (Skrami, 2001). In the study area is also documented the transverse fault of Rodon which is active faults. Concerning to the origin and cause of the transverse fault of Rodon, we think that it was created as a result of the compressions forces acting differentiated in extent for the reason that to the south the

structures of the Kruja (Gavrovo) tectonic zone are shallow and passing to the north they extended excessively and as a result the resultant of the force operates at different depths. This is the cause for the creation of the shear forces of incompetent deposition and for this cause is formed the transverse fault of Rodoni and the monoclonal structure moves to the west direction. Another argument in support of this the development northward of the Neogene Adriatic uplift. There we have the intersection of the longitudinal fault of the Preza monoclines with the transverse fault of the Rodoni cape.

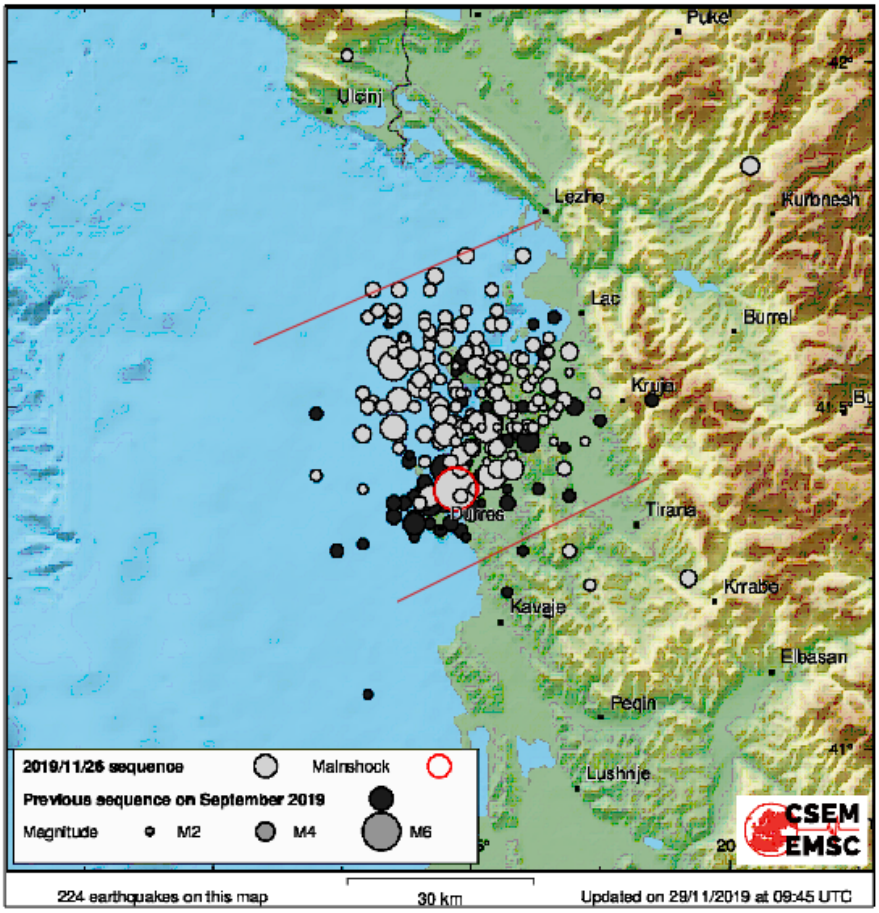

Figure 7. Durresi Earthquakes Epicentre (ASEM ESMSC, 29.11.2019)

Conclusions

1- The study region is located at the intersection of Kruja (Gavrovo), Ionian tectonic zones and Southern Adriatic zone.
2- Longitudinal tectonic faults combined with transverse faults have played a very important role in the formation of Neogene folds and have controlled the sedimentation. The facies in Kruja (Gavrovo) tectonic are neritic, while in Ionian tectonic zone and Southern Adriatic zone are pelagic facies in the southern direction (Tomorri) Kruja (Gavrovo) zone passes from neritic facies (northward) to pelagic facies (southward).
3- The tectonic style of the Southern Adriatic zone is different from Kruja (Gavrovo) and Ionian tectonic zone with big structures dimensions, low structuration scale and considerable depth.
4- The relationship between Kruja (Gavrovo) Ionian tectonic Zone with Southern Adriatic zone is tectonic where the overlap it's some tens kilometers. Some longitudinal and transversal tectonic fault are evident which combined with each other have given to the tectonic structures a certain independence in folding scale and over - thrusting.
5- The structuring tectonic fault that have reached the carbonates formation of Kruja (Gavrovo) tectonic zone have interrupted their activity during Globorotalia Kugleri time, from this time and later some new inter flysch faults have been formed in west direction. The inter flysch faults have controlled all sedimentary formation and tectonic evolution of Southern Adriatic Basin, sedimentation

environments and deposition thickness. These faults are unites and interlaced with each other and when one of them finish acting other younger fault begins to act.

6- The change of the lithology of the formation serve as sliding plans, like evaporates, different schist horizons into carbonate formation and the pass from the carbonate formation to the flysch formation.

7- The Ionian tectonic zone from the southwest to the northeast direction is tectonically faulted. So the Vlora – Elbasan tectonic fault it is not a single fault but an interlacing of western tectonic faults with transversal faults of the structures and structural belts of Ionian tectonic zone.

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