Tectonic Style in Western Albania Thrustbelt and Its Implication on Hydrocarbon Exploration*

Telo Velaj[1]

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[1]Retired, Warminster, PA, United States (telovelaj@verizon.net)

Abstract

A conventional Thrustbelt-Platform system and relationship between them characterize the present architecture of Albanian Thrustbelt.

The Thrustbelt in Western Albania consists of some tectonics zones (Ionian and Kruja zones), which are westward overthrusted with a large amplitude (50-100 - 100 km) over the South Adriatic basin and Apulian platform. This overthrusting process is mainly developed due to the compressional regime (J3 - N2) and it has helped by the presence of the Upper Triassic evaporite sheets under the carbonate section (T3-Pg2). In the Thrustbelt are distinguished two main tectonic styles: imbricate and duplex style. Sometimes triplex style is encountered as well.

The Ionian zone consists of some anticlinal belts (Berat, Kurveleshi, and Cika) which are overthrusted westwards (20 - 30 km). The Thrustbelt consists of the supra-salt complex, while the autochtonous (Apulia Platform and South Adriatic Basin) consists of subsalt complex. The supra-salt complex is characterized by a development of the tectonics features (thrust, overthrust, strike-slip etc.) which developed during the collision (J3-N1) and postcollision stage causing:

1. The structural anticlinal belts are founded, which in their western side have the overthrusting faults. These faults are related with detachment horizon of evaporites which mask folded structures in subthrust depicted by drilling (Shpiragu-1, Dumre-7, Kanina-1, Delvina, Ardenica etc.) and seismic data.

2. The overthrusting of the tectonics zone of the orogenetic front above the western autochtonous (Apulian platform and South Adriatic basin) has masked the structures with perspective. These structures belong to duplex and triplex styles.

3. The overthrusting of the anticline units have local character and are more developed in Kurveleshi belt and less in the Kruja zone. Its magnitude is about 3-10 km. As a result of these overthrusting several imbrication and duplexes structures are formed. The masked structures of the subthrust complex are of high interest such as in Delvina and Kremenara prospects (buried duplex).

Subsalt complex is very important for oil and gas prospective. This complex has the form of a regional monoclinal, folded in its eastern part (under the Thrusbelt) and unfolded in its western one. Over this is set the Periadriatic depression and South Adriatic basin.

Introduction

Albania (The Albanides) belongs to the Dinar-Albanic-Hellenic arch of Alpine progeny. It is located between the Dinarides in North (Montenegro) and Hellenides in South (Greece). This range included in the North-Eastern edge of the African plate, which has already undergone orogeny (Figure 1). As a result of a collision of the African and Eurasian plates, the Albanides are folded and displaced from East to West, as thrusts and overthrusts. Due to the continuous and impulsive overthruting from East to West, there are some tectonic napes whose amplitude are reduced and which become younger westward.

In Albania territory there are three main geological units (Figure 2):

1. The autochtonous foreland Apulian platform (Sazani zone) that is extended in Adriatic and Ionian Sea and partly underthrusted orogen units (Figure 3). The Sazani zone is characterized by slope-to-platform carbonate facies of well-bedded rudist-bearing Cretaceous biocalcarenites. Wells have even locally reached Jurassic and Triassic dolomites. Unconformable Burdigalian clastics attest to a relatively late flexurial subsidence for the Sazani zone.

2. Albania orogen that is divided into two parts:

a). Internal Albanides with two tectonic zones: Korabi (Pelagonia in Greece and Golia in Serbia) and Mirdita (Subpelagonia in Greece and Serbian in Serbia), which are characterized by the presence of ophiolites (Upper Jurassic), by many folding phases (Upper Jurassic, Eocene etc.) and total allochtony (Figure 3).

b). External Albanides includes the tectonic zones: Krasta-Cukali (Pindi in Greece and Budva in Montenegro), Kruja (Gavrovo in Greece and Dalmate in Montenegro), Ionian (Ionian in Greece), and Albanian Alps (Parnaso-Kiona in Greece and High Krast in Montenegro). There is an overthrusting of all of the tectonic zones westward, partly masking each-other. The overthrusting scale may be 50 - 100 km (Figure 3). The stratigraphic section of the external zones (Ionian and Kruja zones) consists of Upper Triassic evaporite, carbonate of Upper Triassic to Eocene, flysch and flychoides of Oligocene-Aquitanian as well as Premolasse and Molasses of Neogene (Burdigalian to Pliocene).

3. The Periadriatic depression represents a basin between the External Albanides Thrustbelt (Ionian and Kruja zones) and Sazani zone. The whole postcarbonatic deposition is represented by a terrigenous sedimentation, which in itself included in South Adriatic basin. This basin overlies the Ionian zone to South - East and Kruja zone to the far East (Figure 3 and Figure 4). The Periadriatic depression molasses consists of a considerable number of sandy - clayey megasequences (going upward). In some cases sequences become more complete and begin with conglomerates and clastic limestones with lithothamnion and ends with clays coals or gypsum. From the South - East to North - East, the thickness of molasses increases, reaching 5000 – 7000 m. As a result of sedimentation condition changing in Messinian,

the clay-sandy lithofacies was formed in the Eastern sector of Periadriatic depression and clayey-gypsum lithofacies in the Western part. The tectonic regime has been developed in the context of active margin and has always been of compressive type, which observed in the more restricted sedimentation tracts beginning from Serravalian onwards. By the time the Periadriatic depression were formed and folded, the adjacent carbonate structures of the Ionian and Kruja zones, as a result of the intensive submerging of the South Adriatic basin , were "absorbed " towards the North-East and rotated anti-clockwise, increasing their tectonic complication degree. One consequence of this process is the formation of the backthrust tectonics incident encountered in the Eastern and South-Eastern edge of Periadriatic depression.

General geological setting of the External Albanides: Ionian and Kruja zones

A conventional thrustbelt-platform system and relationship between them characterize the present architecture of Western Albanian thrust belt. The tectonic setting shows a complex ecological model, where the main characteristic is the westward thrusting of different units and in some cases eastward thrusting as a backthrust feature. The Albanian thrust belt consists of some tectonics zones (Figure 2), which are westward overthrusted with a large amplitude (50 - 100 km) over the Apulian platform and Adriatic basin. The overthrusting process is mainly developed due to the compressional regime (J3 - N2) and it has helped by the presence of the Upper Triassic evaporite sheet under the carbonate section (T3 - Pg2), which constitutes major detachment level beneath the Ionian and Kruja allochthons. The evaporites have also yielded huge diapirs (Dumre, Delvine, Kardhiq, Xare etc.), some of which are interpreted to be without root. In the thrust and subthrust complex of the thrust belt are distinguished two main tectonics styles: imbrication and duplex styles. Sometimes triplex style is encountered as well (Figure 3 and Figure 4). All thrusts of different tectonic units lie almost horizontally in depth, becoming of listric type.

In the Western Albania there are two major tectonics complexes: The thrust belt (Ionian and Kruja zones) consists of the supra-salt complex (Figure 3, Figure 4, and Figure 5), while the autochthonous (Apulia platform and South Adriatic basin) consists of subsalt (subthrust) complex. The Ionian zone is represented by basin facies. Based on the structural criteria this zone is divided into three major anticlinal belts (Figure 1): Berati, Kurveleshi, and Cika anticline belts which are overthrusted in a significant amplitude (20 - 30 km). These structural belts consist of carbonate anticlines which outcrop in most areas and have their regional thrusting faults in their western side. These faults are related with detachment horizon of evaporites which mask folded structures in subthrust (Figure 3, Figure 4, and Figure 5) depicted by drilling and seismic data. These subthrusting structures are with high perspective of hydrocarbon exploration. The great scale of thrusting associated frequently with the backthrust, the approaching of the belts and masking of the other adjacent western structures are joint arguments for prognostic of new hydrocarbon prospects in three mentioned belts. According to surface geology, in the western wedge of all the structural belts of the Ionian zone there is a narrow flysh belt, rather folded that associated with thrusting faults, which show the presence of underlying structures. However, on the other hand this flysh has lost its connection with the carbonate root (Figure 3, Figure 4, and Figure 5). Berati anticline belt is the eastern belt of the Ionian zone. The general characteristic of the Berati belt structures is their western asymmetry due to westward thrusting. Sometimes, their western flank is missing on the surface (Figure 5 and Figure 8). In its southern part, large scale fan types have been formed, with backthrust in the eastern flanks. The structures of the northern sector are characterized by the smaller dimensions, but their density is larger in the surface unit (Figure 2). The structural lines within the belt do not have thrust faults and because of this, only the western side is perspective. In this belt there are two evaporitic diapirs

on the surface: Dumrea in its northern part and Zavrohoni in south (Greece) (Figure 2 and Figure 4). The Dumrea diapir has a cupola form on the surface, whereas in the subsurface it is a large diapir (Figure 5). This overthrust amounts to 20 - 30 km and it is masking one large anticline structure perspective. The presence of this structure (Figure 5), its continuation southward with Shpiragu anticinal structure where oil and gas is depicted by drilling.

(Shpiragu - 1) (Figure 6) and the presence of the surface structure (Kasidhiaris-Kurenton-Thesprotikon anticlinal line in Greece) (Figure 2 and Figure 4), in southern part of this belt, show the existence of a structural line with great perspective under overthrust of Berati belt.

The Kurveleshi anticlinal belt is characterized by structures with heterogeneous dimensions, predominating those of great dimensions and linear type. Brachy anticline and dome ones are also present. The Western thrusting of the structural units is in range of 8 - 10 km, whereas for the belt it is about 15 - 20 km. The diapirism features are associated everywhere with fault planes westward thrust faults of backthrust nature. The backthrust feature at the eastern flank of the units created space for new prospective structures. Besides the main thrusting faults of the belt, there are separated overthrusted units, which must be predicted with perspective for oil and gas bearing. Two oil fields (Delvina and Karbunara) were discovered in buried duplexes, beneath Mali i Gjere anticline (Figure 7) and Kremenara anticline respectively.

The Cika anticline belt is a more western unit of the Ionian zone. Westward is the Apulian platform and its transitory part, which have been folded into big structural units which would be very significant oil prospects. In the western side it is limited by an regional thrusting fault by which is realized the total westward thrust of External Albanians with amplitude about 50 - 100 km over the western autochthon (Figure 3, Figure 4, Figure 5, and Figure 8).

From the South to the North, the number of structural line of the Cika belt is decreased (Figure 2). The evaporitic diapirisim is very intensive especially in the Southern part, where it presents the principal character of geological feature (the Filati, Xare-Mursi, Corfu etc.). In the north part and particularly in the structures opposite to Sazani zone (Appulia platform) the backthrust development is the most typical. The duplex model is expected to occur in the South of Vlora exploration area.

The Kruja zone extends in eastern part of Ionian zone (Figure 2) and is composed mainly of carbonate neritic deposits. The character of these carbonate sequence changes from neritic to mixed facies (pelagic and neritic) westward. From tectonic point of view it is represented by some structural lines, complicated by a regional fault westward. This regional fault of overthrust type separates Kruja zone from South Adriatic basin (Figure 3). This phenomenon is more distinguished in North part of Kruja zone, where the amplitude of this fault is up to 80 km. In this region, the Kruja zone consists of linear anticline structures and constitutes two surface trends i.e. the Makareshi trend and Dajti mountain. There are also two additional buried structures westward, Fushekruja and Ishmi. But Southward two structures are evidenced (Kozani and Letani). In the South part smaller structures are developed and structural line decreased (Figure 2). In this region the Kruja zone is divided by a tectonic fault of overthrust type, with throw smaller than that in North. The evaporite of Lower Cretaceous (?) in the Montenegro region is encountered, which has been more active in developing of thrust tectonic style.

Subsalt complex is very important for oil and gas exploration. Seismic work of deep registration (3 - 5 sec.) using more effective techniques

need to be carried out for more detailed data. This complex has the form of a regional monoclonal, folded in its Eastern part (under thrust belt overthrusting) and unfolded in its western side. Over this is set Periadriatic depression and South Adriatic basin (Figure 3, Figure 5, and Figure 8).

Thrust tectonic role in architecture of External Albanides

From the genetic point of view, thrust and overthrust faults, have taken place during the collision stage (J3- $N1^{2s}$) time, in which Ionian and Kruja zones, structural belts (Berati , Kurveleshi , Cika), and individual tectonic units (anticlines, synclines etc.) have taken less or more their final form (Figure 9 and Figure 10). The tectonic faults took place together with sedimentation and fold formation processes. These faults represent the reactivation of the normal faults of the rifting stage (T3- $J\ 1^{3}$). The fact that the Noegenic basins ($N1^{3}$ -$N2^{p}$) of Tirana, Kucova, and Marinza (Figure 6 and Figure 10) are not affected by the tectonic of the carbonate structures, structural belts, or tectonic zones, show that the main compressional phase happened before Serravalian ($N1^{2s}$). The westward thrust processes of all structural units continued in the post collision stage ($N1^{2t}$ -Q). This is expressed by several interformation new faults (faults within flysch). As a result of their action, flysh deposits of the folded subthrust complex are brought in western margins of the thrust units, exposed in the form of rootless folds (Figure 5, Figure 6, Figure 8, Figure 9, and Figure 10). Their roots represent perspective structures of the subthrust. The thrust tectonic of several structural units took with them Neogene piggyback basin. They did also cause of the folding of Neogene deposits of Periadriatic depression and South Adriatic basin. These folding are SE-NW trend, showing similarity of carbonate structures, which gives evidence for their formation - mechanism from the compressive regime of the carbonate orogenic front.

Backthrust phenomenon is secondary and has taken in both supra-salt and subsalt complexes in the postcollision stage. Also, the phenomenon is present in South Adriatic basin and Periadriatic depression. Generally are Eastward thrust fault of structural units with amplitude of 5 - 10 km. They mask the geological structures at the depth, which compromise perspective objects. On the conditions of a compressive regime the triangular zones are formed, which expose themselves as folded synclinal zones (Figure 8). The backthrust faults are a result of evaporitic diapirism and of reaction to thrust process of Eastern tectonic units.

Classification of backthrust faults based on their features:

Backthrust faults of local character, which are developed in the Eastern limb of different anticline structures of Berati belt (Nemercka, Kucova, Goliko anticlines), Kurveleshi belt (Kurveleshi, Fterra, Krongji anticlines), and Cika belt (Cembel, Saranda, Tragjasi anticlines).

Backthrust fault of regional character. They are two types:

a). Backthrust fault of the thrust of platformic units above the supra-salt complex of the Ionian zone (Figure 8), fault which have a classic features on the South of Vlora city (Qafa e Llogorase). The backthrust fault here has a regional character developed in the contact between Apulian platform and South Adriatic basin. Karaburun peninsula appears as a regional backthrust over the transition zone from the platform to basin. On the South of Vlora is visible the development of a triangular zone, where the Dukati synclinal (Ionian zone) are entirely covered

from the Karaburuni backthrust and Cika overthrust (Figure 8). This backthrust developed from Eastern side of the Sazani Island and continues toward the South.

b). Backthrust fault in the Eastern margin of the South Adriatic basin, in surface contact with Neogene piggyback basins. This backthrust type has a regional character beginning from Tirana depression (Kepi i Rodonit, Fortuzaj) to the West of Marinza piggyback basin. Westward wedge-form movement of carbonate masses of orogenetic front in the same time with sedimentation ($N1^{3t}$ -N2) has caused the formation of these backthrusts and other secondary foldings (Figure 10 and Figure 11).

The united actions of the thrust, overthrust, and backthrust faults accompanist by folding factors, sedimentation processes etc. have given shape to the Thrustbelt-Platform assemblage with their features:

a. Intensive folding of the carbonate deposits of orogenetic zones.

b. Folded local and regional complexes of the subthrust of supra-salt complex.

c. Folded regional complex of the subthrust of subsalt complex, which belongs to the transition zone from neritic facies toward basin one. All these objects mentioned above are of the first - hand importance for oil and gas perspective in Western Albania.

Reference

Ricou, L.E., and A.W.B. Siddans, 1986, Collision tectonics in the Western Alps, *in* M.P. Coward and A.C. Ries, (eds.), Collision Tectonics: The Geological Society (London) Special Publication 19, 229-244 p.

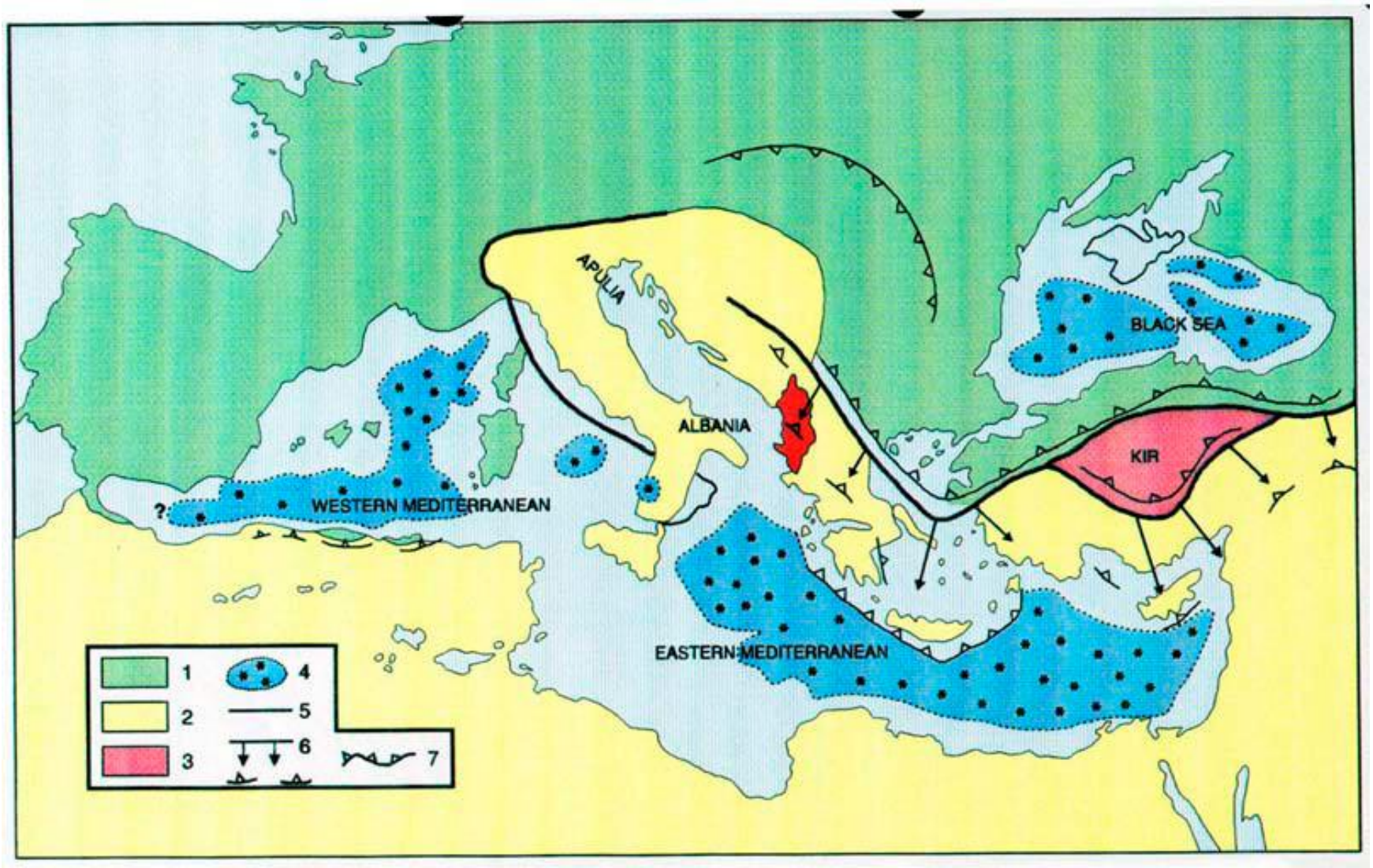

Figure 1. Schematic Map of African Plate subduction under the Eurasia (after Ricou, 1986).
Legend**:** 1-Euro-Asiatic Continent; 2-African Continent; 3-Kishir Block; 4-Present Oceanic Basins; 5-Boundaries of Mesozoic Oceans; 6-Boundaries of Mesozoic Ocean and the Main Ophiolithic Nappes; 7-Troughs of present and past subduction.

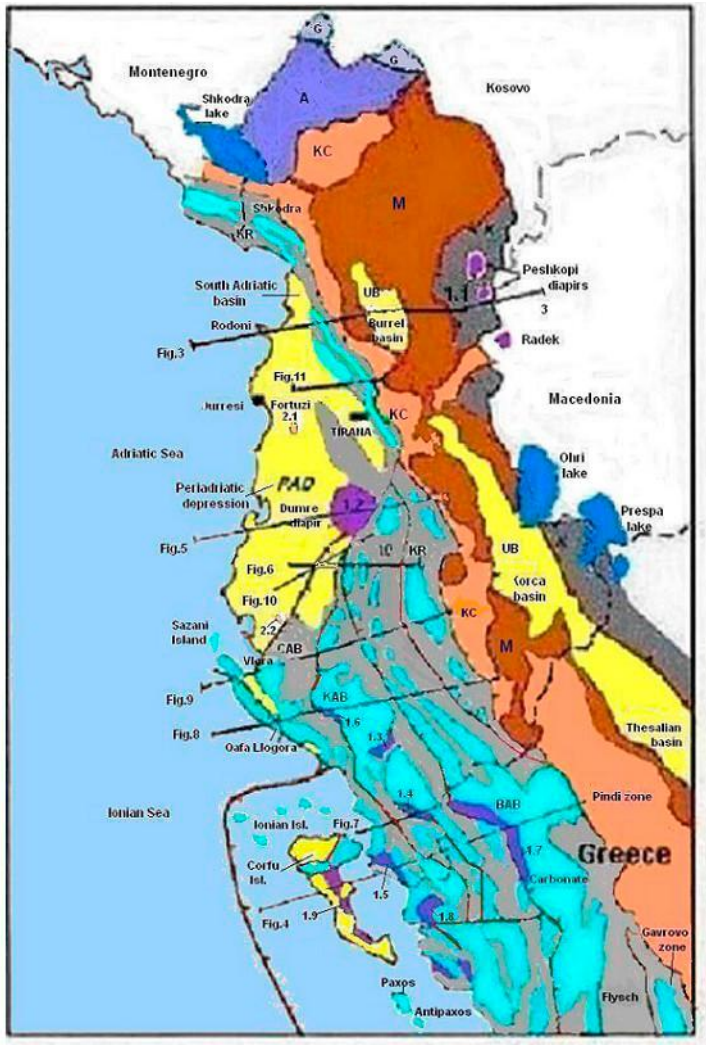

Figure 2. Tectonics map of Albanides and carbonate structures in the Ionian and Kruja zones.
Legend: Tectonics zone: S-Sazani zone, J-Ionian zone (BAB - Berati ant. belt, KAB- Kurveleshi ant. belt, CAB - Cika ant. belt), KR-Kruja zone, KC-Krata-Cukali zone, M-Mirdita zone, K-Korabi zone, A-Alpe zone, G-Gashi zone; PAD- Periadriatic depression, UB-Korca and Burreli Inter-Mountain basins.
Upper Triassic evaporites: 1.1-Peshkoppi, 1.2-Dumre, 1.3-Picar-Kardhiq, 1.4-Delvina, 1.5-Xara, 1.6–Bashaj, 1.7-Zavrohon, 1.8-Filat, 1.9-Corfu.
Upper Miocene evaporites: 2.1-Mengaj Kavaj, 2.2-Vlora.

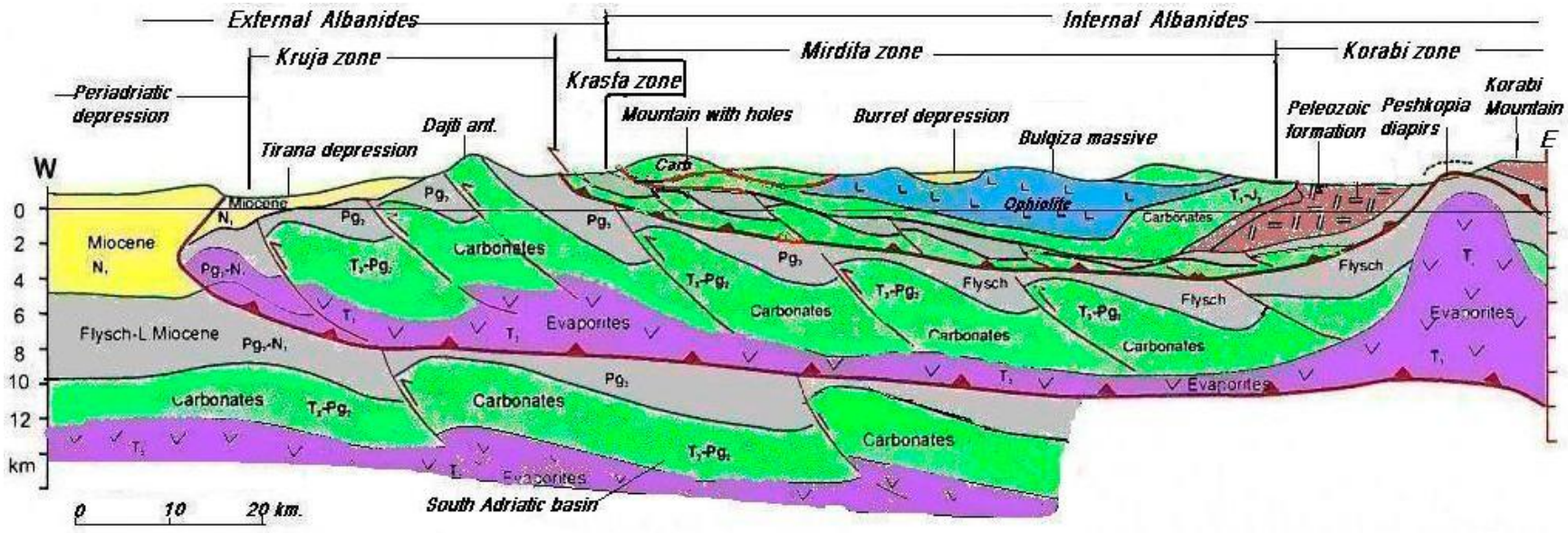

Figure 3. Schematic geological cross-section through Albanides and their relation with South Adriatic basin.

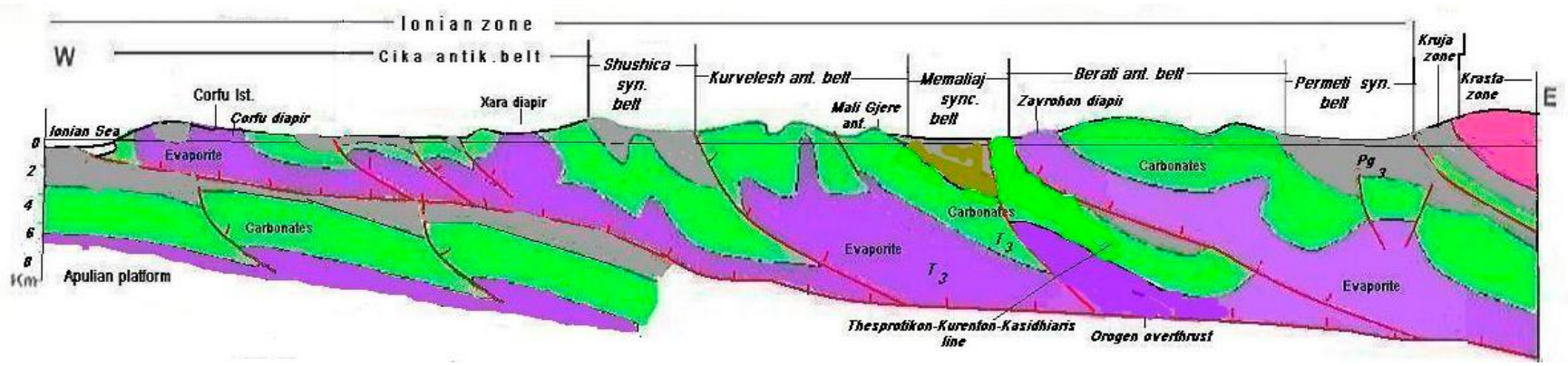

Figure 4. Geological cross-section in South part of Ionian zone.

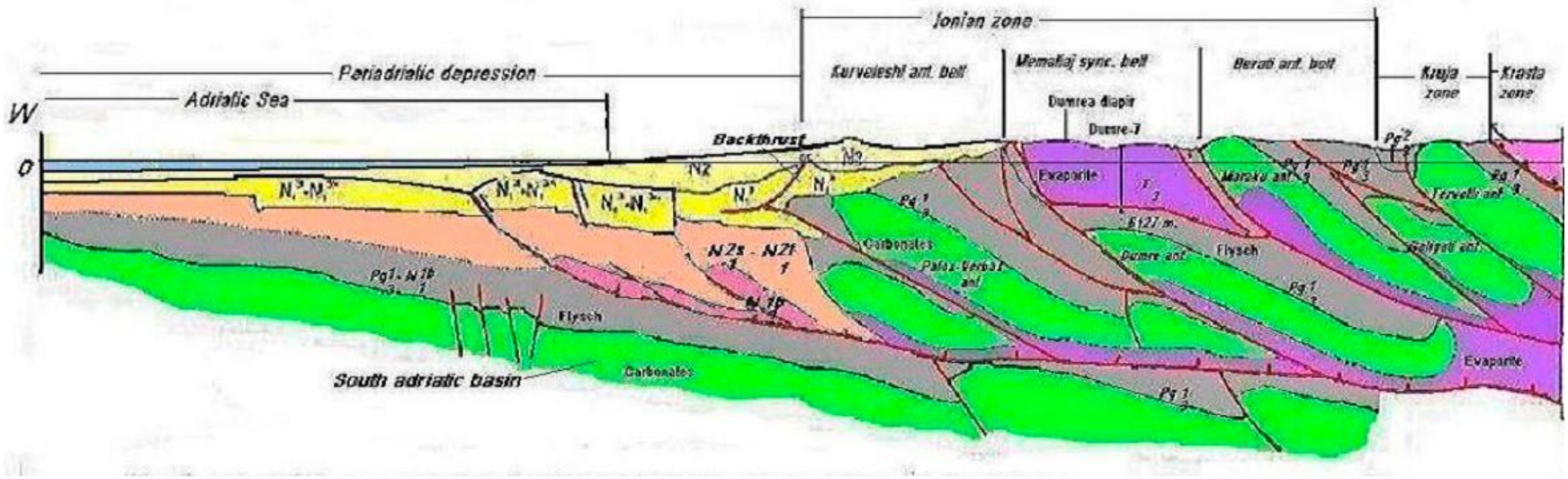

Figure 5. Schematic cross-section between the Periadriatic depression, Ionian and Kruja zones.

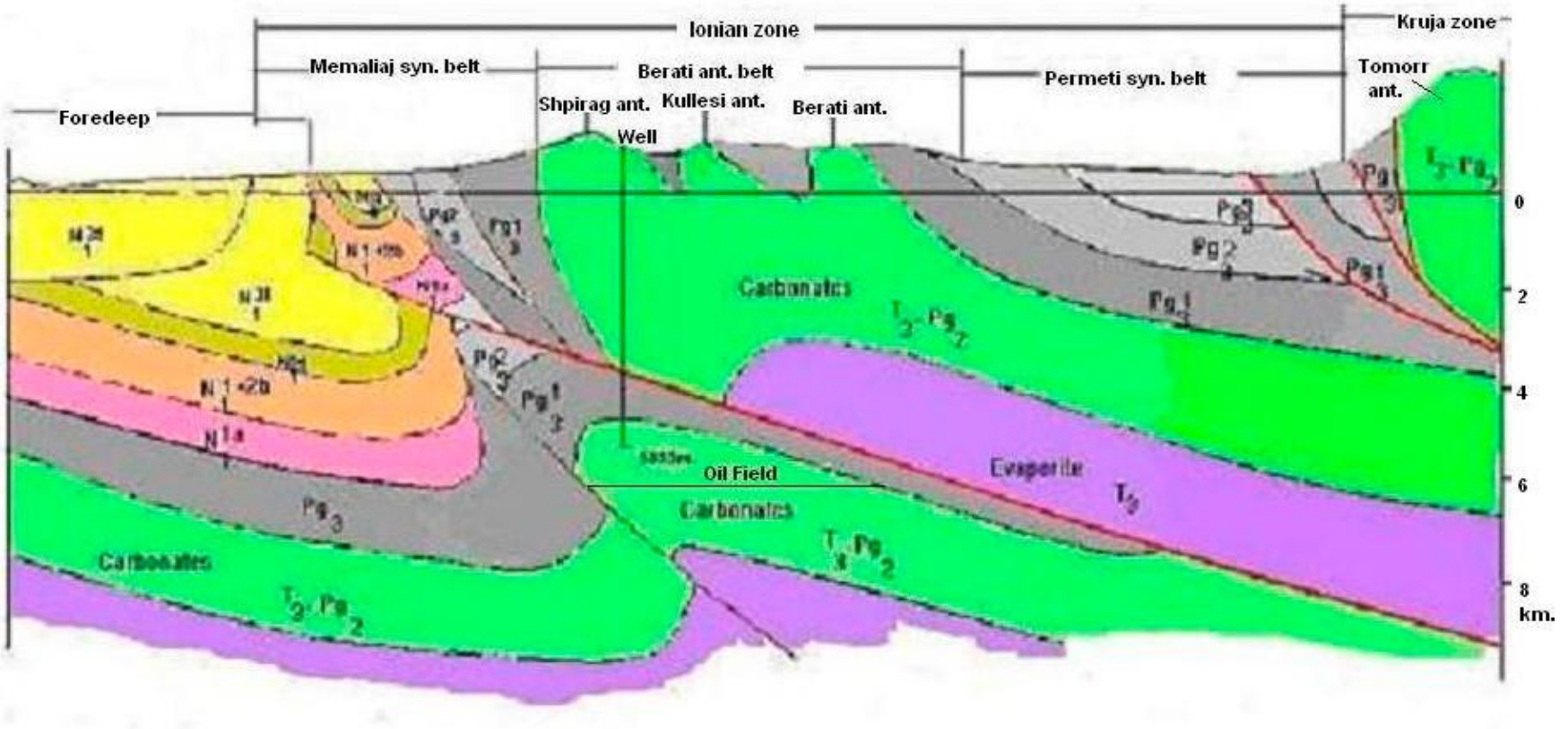

Figure 6. Geological cross- section of the Shpiragu gas condensate field.

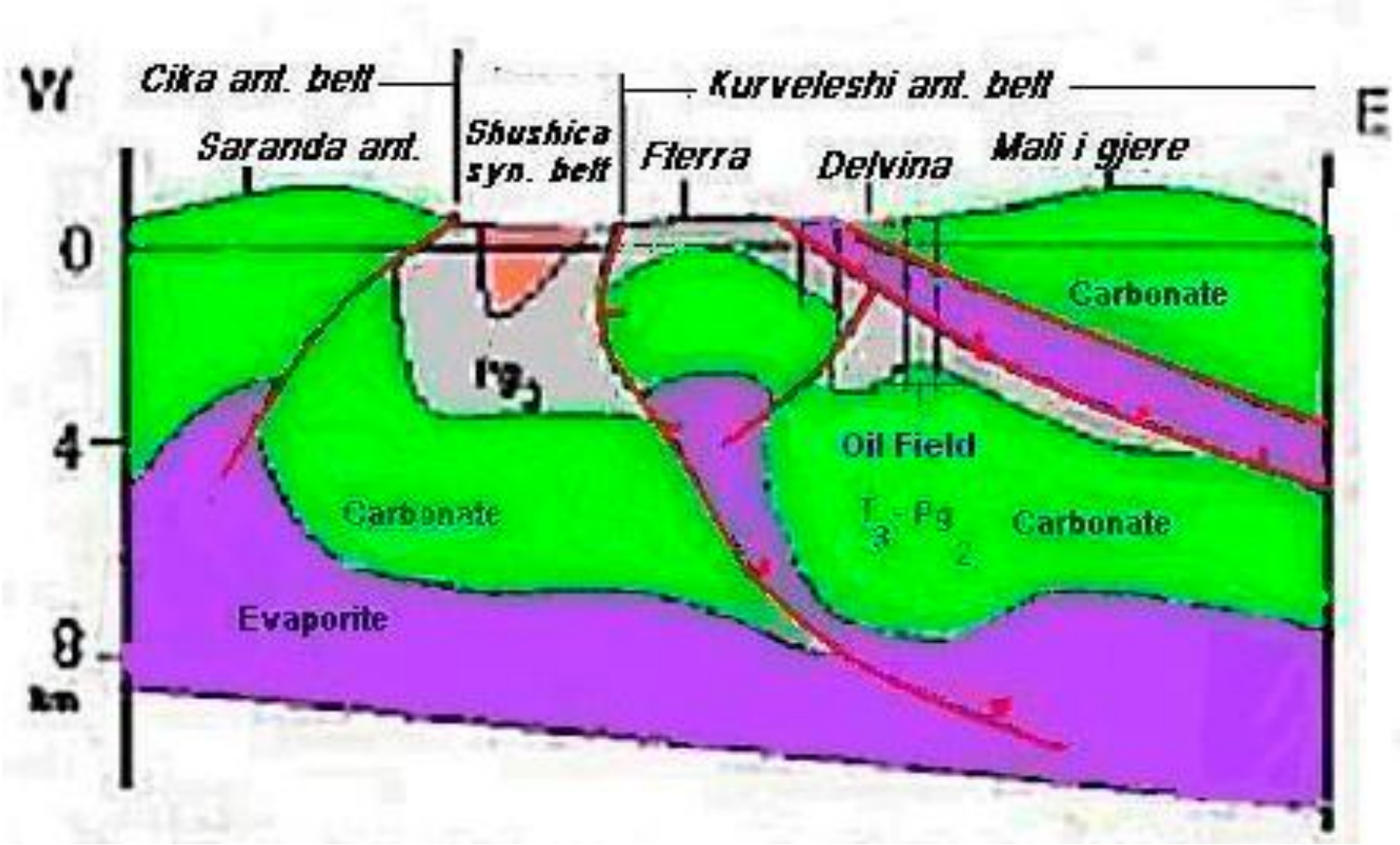

Figure 7. Geological cross-section of the Delvina gas condensate field.

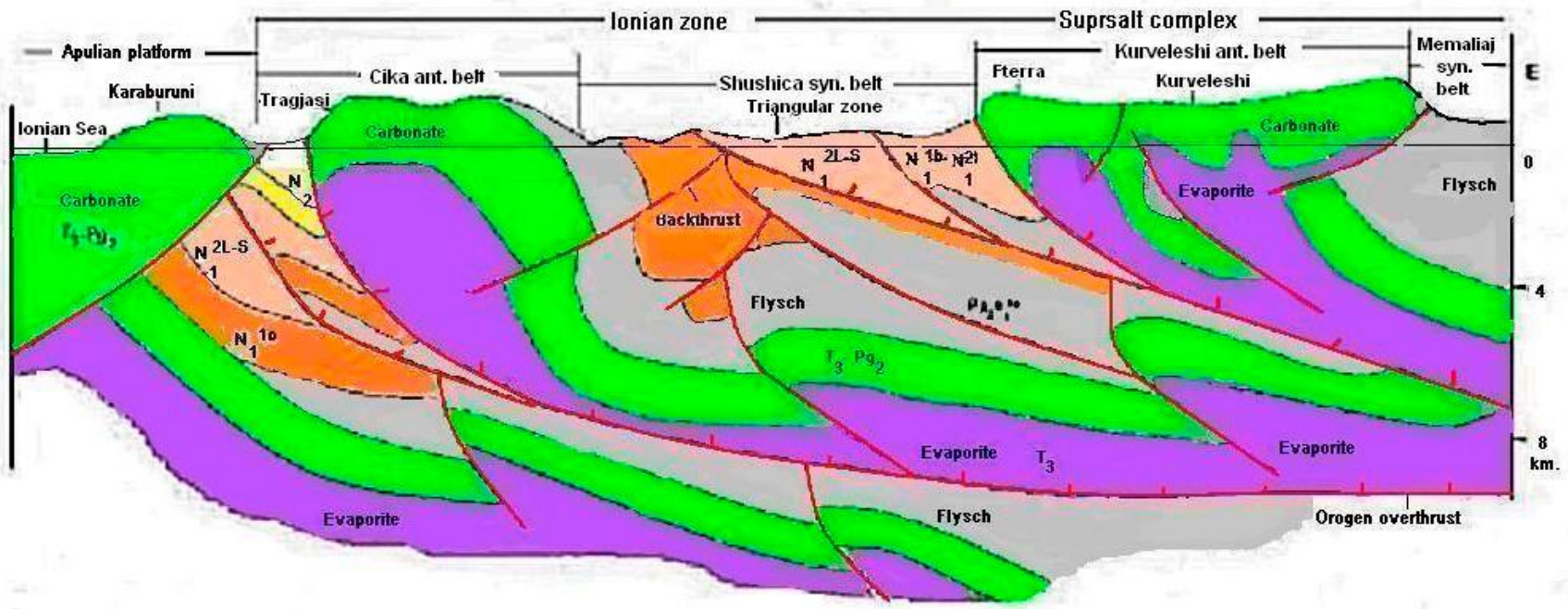

Figure 8. Geological cross -section through Apulian platform and Ionian zone.

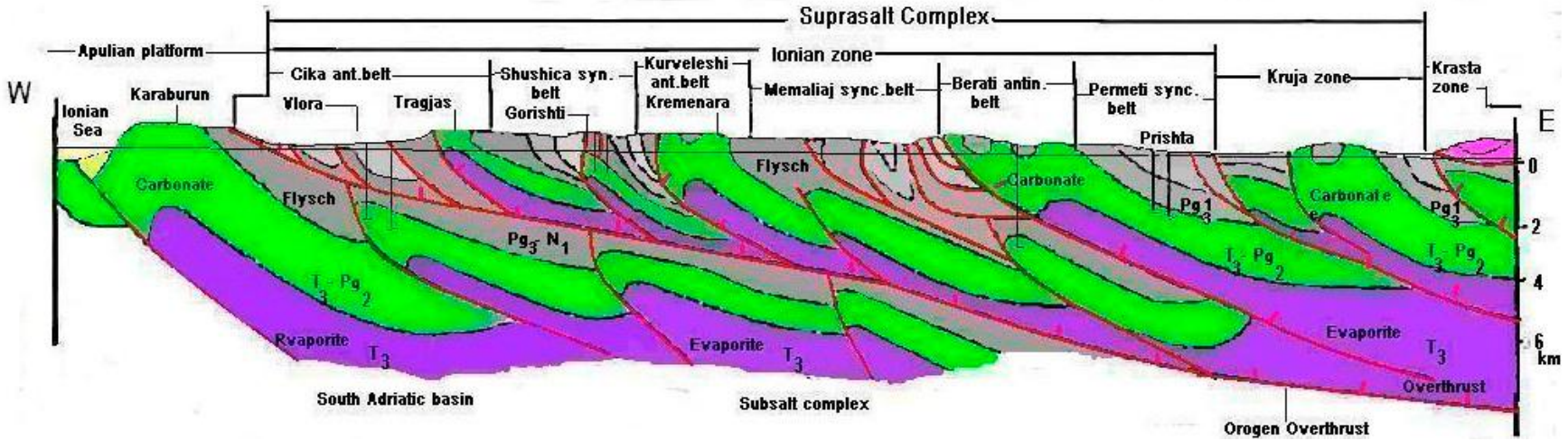

Figure 9. Geological schematic cross-section through Apulia platform and Ionian, Kruja, and Krasta zones.

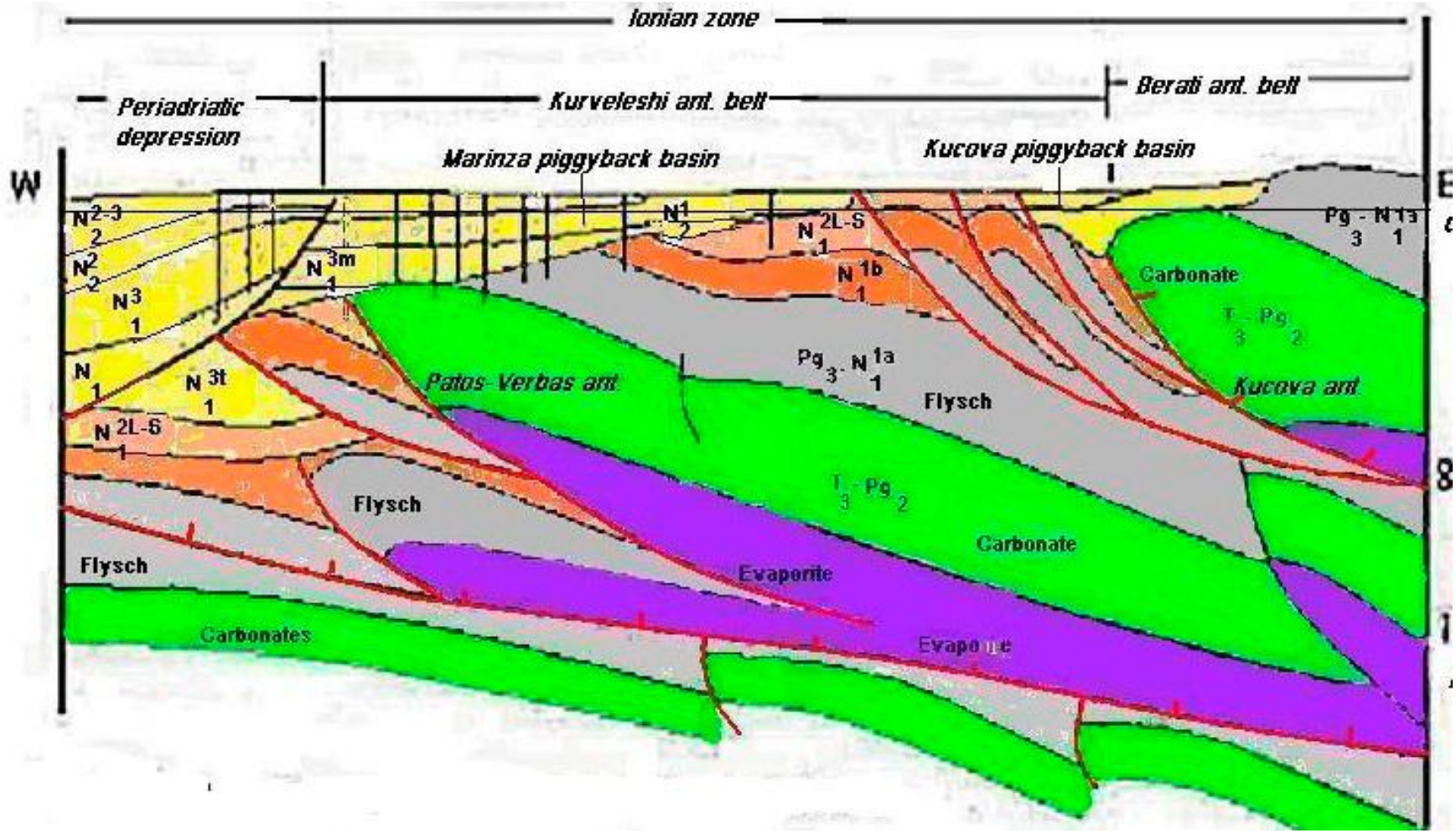

Figure 10. Geological cross-section in Marinza and Kucova piggyback basins.

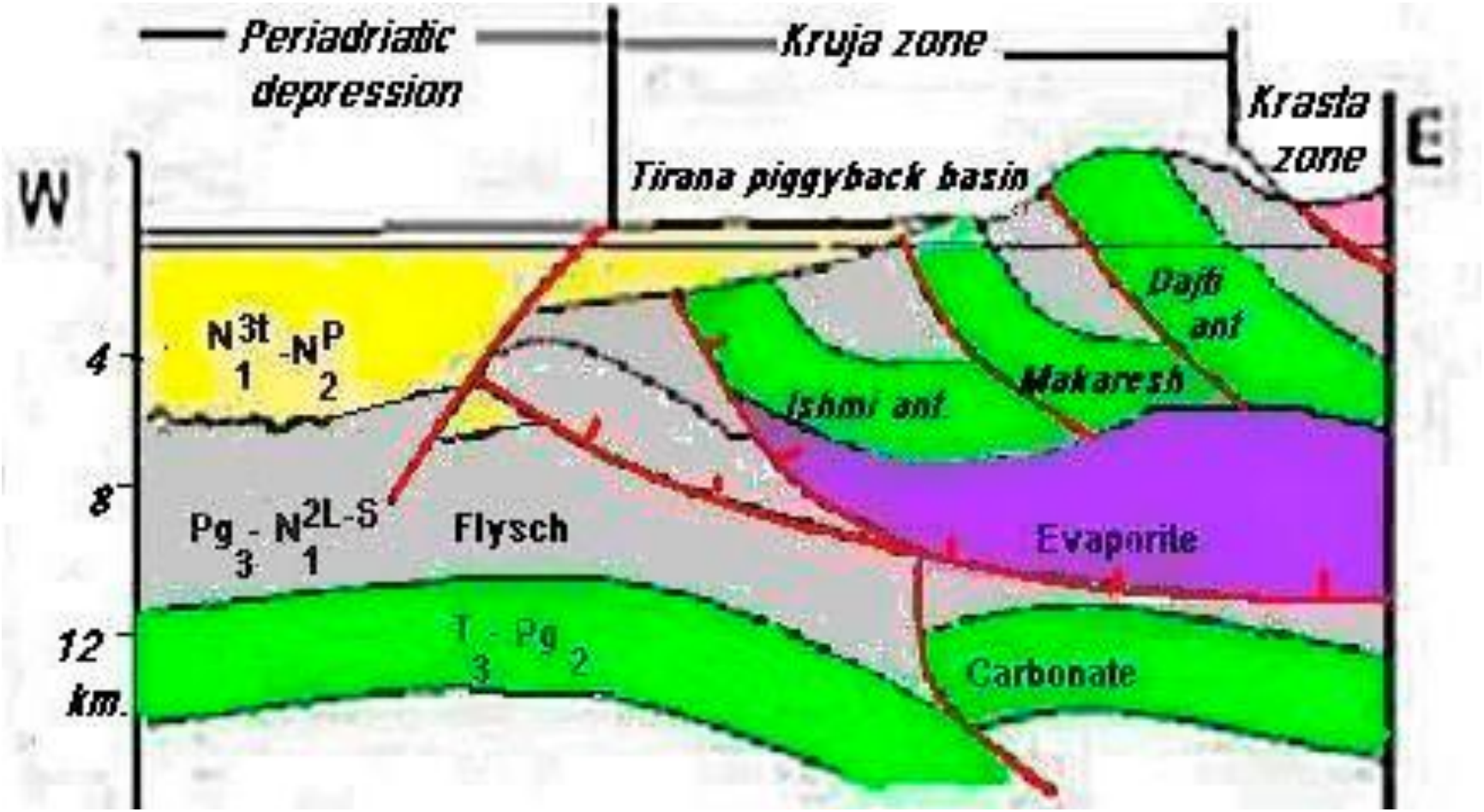

Figure 11. Geological cross-section in Tirana piggyback basin.