

GEOPHYSICAL OUTLOOK ON STRUCTURE OF THE ALBANIDES

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The Albanides represents the assemblage of the geological structures in the territory of Albania. In the paper are presented the structural analysis of the Albanides according to the seismological, reflection seismic, gravity, magnetic, electrical, and geothermal surveys. Two major paleogeographic domains form the Albanides. The Internal Albanides formed part of the Subpelagonian Trough. The External Albanides was developed out of the western passive margin and continental shelf of the Adriatic plate. Regional gravity anomalies and seismological studies results are interpreted as caused by the variation of the depth of Moho discontinuity, and a block construction of the crust. The Earth crust in Albanides is interrupted by a system of longitudinal fractures in NW - SE direction and transversal fractures. Intensive Bouguer anomalies and turbulent magnetic field with weak anomalies characterize ophiolitic belt of the Internal Albanides. These data show about the allochthon character of ophiolites. The relations between the Internal and the External Albanides have a nape character, going toward S-W. A joint characteristic of structural belt of Ionian and Kruja zones in External Albanides is their westward thrusting, too. Two tectonic styles are observed in the Ionian tectonic zone: duplex and imbricate tectonic. Miocene and Pliocene molasses of Peri-Adriatic Depression cover Western part of Ionian zone.

Interpretation of the results of integrated geophysical surveys, in the framework of geological studies is presented in the paper.

INTRODUCTION

Integrated regional geophysical studies have been performed for exploration of the Albanides, on land and in the Adriatic Sea Continental Shelf. Seismological studies, gravity and magnetic surveys, reflection seismic lines, geothermal studies, radiometric investigations, vertical electric soundings and well logging are represented applied complex of the geophysical investigation. Interpretations of the geophysical studies result have realized on the base of regional geological studies. Only part of all regional geophysical and geological literature, which we have consulted, is presented in the reference paragraph.

The Albanides represents the assemblage of the geological structures in the territory of Albania, and together with Dinarides at the North and Hellenides at their South are formed the southern branch of the Mediterranean Alpine Belt (Fig. 1), (Aubouen. and Ndojaj, 1964, Aubouen 1973, Biçoku and Papa 1965, Biçoku 2000, Bushati 1988, Frasheri et al. 1998, I.G.S. 1983, 1985, Meço and Aliaj 2000, Melo, 1986, Papa 1970). In the paper are presented the structural analysis of the Albanides according to the seismological, reflection seismic, gravity, magnetic, electrical, and geothermal surveys, in the framework of the integrated interpretation with geological observations.

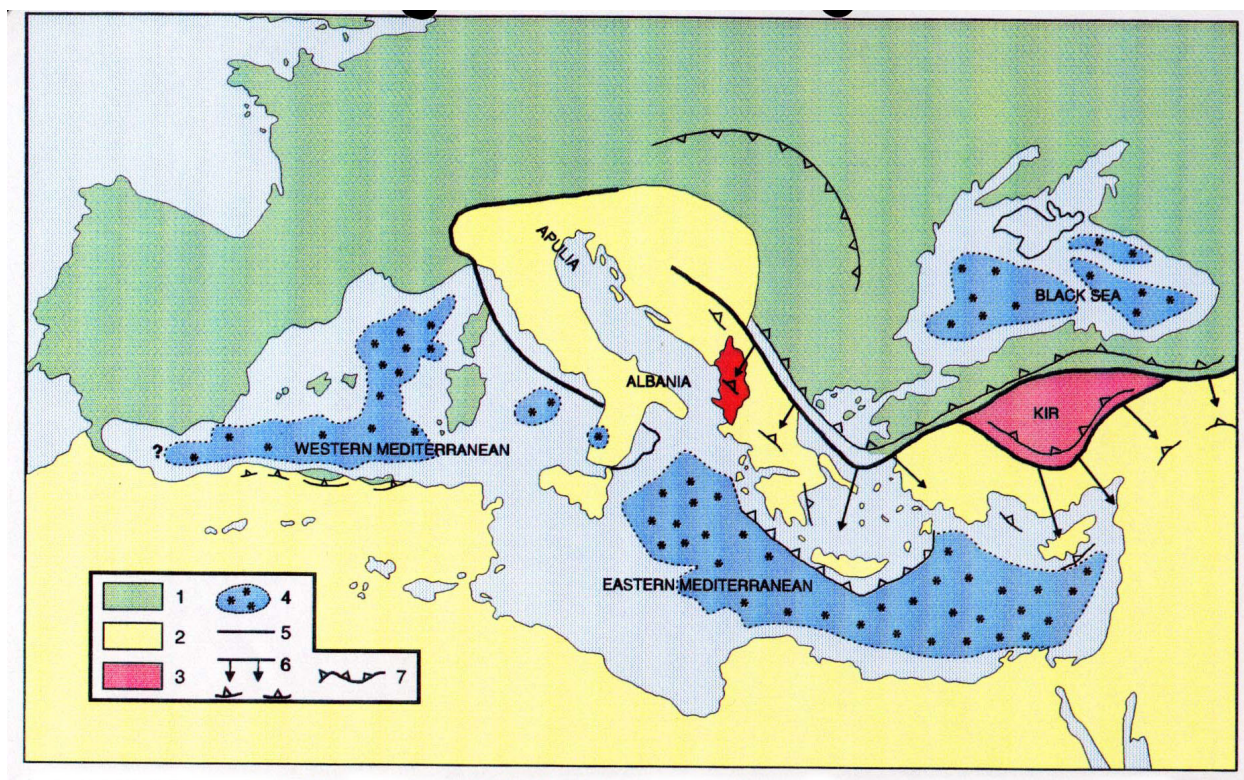


Fig. 1. Schematic Map of African Plate Subduction under the Euroasiatic one
(After Ricou, El. 1986)

- 1- Euro-Asiatic Continent; 2- African continent; 3- Kishir block; 4- Presents Oceanic Basins; 5- Boundaries of Mesozoic Oceans; 6- Boundaries of Mesozoic Ocean and the Main Ophiolitic Nappes; 7- Troughs of present and past subduction.

Two major paleogeographic domains form the Albanides: the Internal Albanides in the eastern part and the External Albanides in the western part of Albania (Fig. 2).

The Internal Albanides formed part of the Subpelagonian Trough. The Internal Albanides are characterized by presence of the immense and intensive tectonised ophiolitic belt, which is displaced from east to west as overthrust nappe. Internal Albanides has been affected by the paleotectonic stage. There are two viewpoints about the placement of the ophiolites: Allochthon character of the ophiolitic nappe (Auboin 1973, Cadet et al. 1980, Çollaku et al. 1992, Frasheri et al. 1995, 1996, Frasheri 2000, Hoxha et Bushati 1996, Hoxha 2001, Hoxha et Avxhiu 2000, Lubonja et al. 1968, Langore et Bushati 1985, Melo 1986, Papa 1993, Qirinxhi 1970, Veizaj and Frasheri 1996) and autochthon ophiolitic belt (Beccaluva et al. 1994, Gjata et al. 1999, Gjata 2000, Kane et al. 1999, Kodra 1987, 1988, Kodra et al. 1996, 2000, Robertson and Shallo 2000, Shallo et al. 1989). Tectonic development of the Internal Albanides has been during Triassic and Jurassic (Kodra A. 1987).

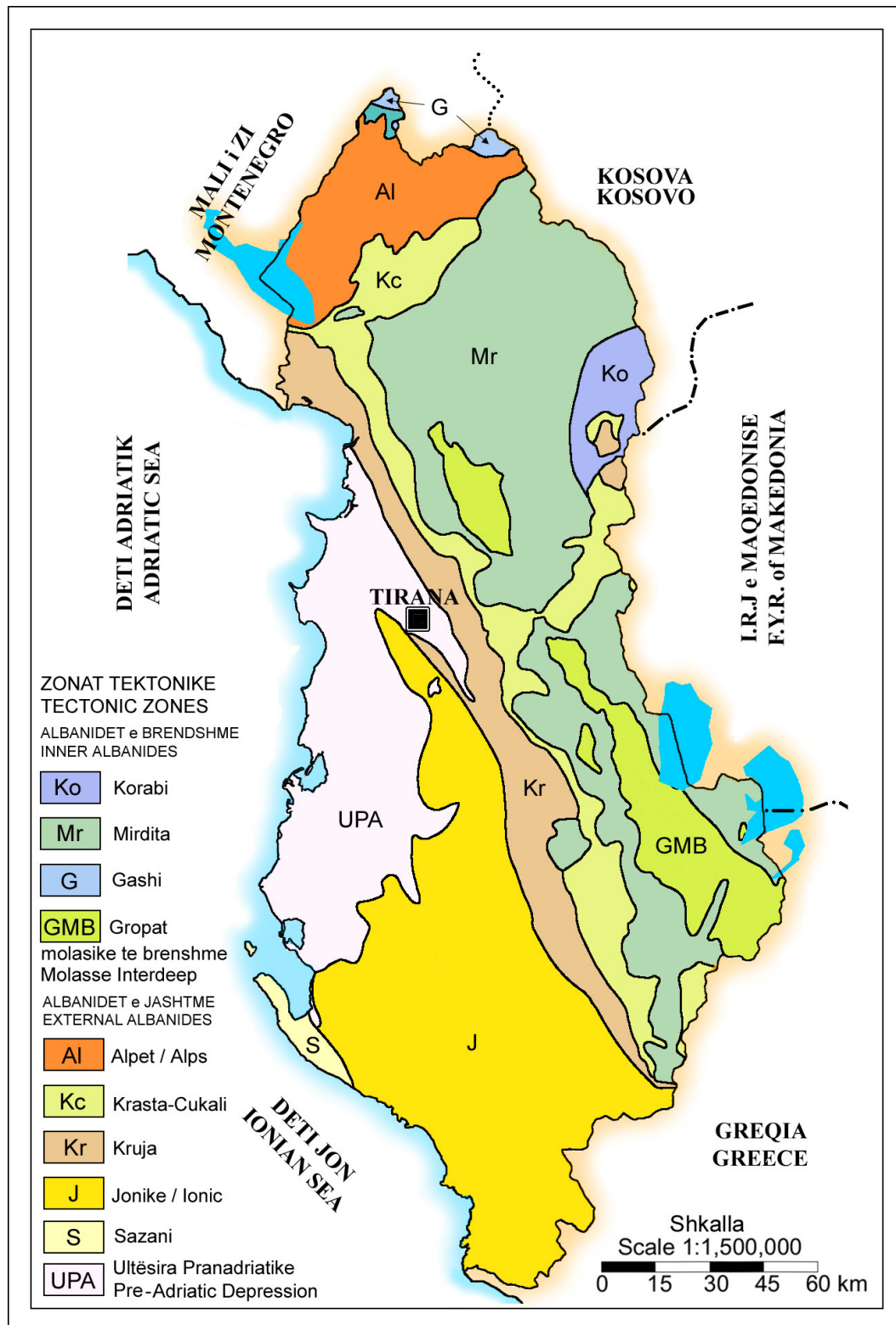


Fig. 2. Schematic Tectonic Map of Albania.

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The External Albanides was developed out of the western passive margin and continental shelf of the Adriatic plate. The External Albanides are affected only by the later paleotectonic stages, and are characterized by regular structural belts, which are associated with thrust and over tectonic. Geophysical data reveal that the Earth crust becomes thicker from central regions of Adriatic towards Albanides in land (Bare et al. 1996, Dalipi 1985, 1987, Dhima et al. 1996, Guri et al. 1996, Mëhillka et al. 1996, 1999, Nishani 1985, Papa et Kondo 1968, Seitaj et al. 1996, Valbona et al. 1997, Velaj 1999, Xhufi et al. 1999).

The sedimentary crust has 8-9 km thick in Adriatic seashore and reaches up to 15 km in northwestern regions of Albania (Fig. 3), (Fraseri et al. 1998, 2000, Koçiu 1987, Veizaj 1995, Veizaj and Fraseri 1996. The depth of Moho discontinuity is 40 -50 km. Its deepest part is in northwestern part of Albania. Regional gravity anomalies are interpreted as caused by the variation of the depth of Moho discontinuity, and a block construction of the crust, which coincides fully with the results of seismological studies (Fig. 3, 4). The Earth crust in Albanides is interrupted by a system of longitudinal fractures in NW - SE direction and transversal fractures, that touch even the mantel. Some of them separate even the tectonic zones. This tectonic construction of the deep levels of the earth crust in Albanides finds its reflection even in the scattering of the magnetic fields.

Geological and geophysical regional studies, based on facial-structural criterion, were distinguished some tectonic zones (Fig. 2):

<i>In Albanides</i>	<i>equivalent in Hellenides</i>	<i>and</i>	<i>in Dinarides</i>
<i>Internal Albanides</i>			
Korabi	Pelagonian		Golia
Mirdita	Subpelagonian		Serbian
Gashi			Durmitor
<i>External Albanides</i>			
Albanian Alps	Parnas		High karst
Krasta-Cukali	Pindos		Budva
Kruja	Gavrovo		Dalmate
Ionian	Ionian		
Sazani	Preapulian		
Peri Adriatic Depression			

Intensive Bouguer anomalies and very turbulent magnetic field, with weak anomalies (Bushati 1988, 1997) (Fig. 5, 6, 7), characterize ophiolitic belt of the Mirdita tectonic zone in Internal Albanides. These data shows as follow: Ophiolitic belt has its biggest thickness is about 14 km in its northeastern extreme, in the ultrabasic massif of Kukes (Fig. 8, 10, 11, 12). Towards west and southeast this thickness is reduced up to 2 km. This interpretation shows allochthon character of ophiolite belt and the covering character of the western contact of ophiolitic belt, under which the formation of Krasta-Cukal zone of External Albanides is laid. The relations between the

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Internal and the External Albanides have a nape character, going toward S-WW direction. The separation of the gravity and the magnetic anomalous belts in the central region of the Internal Albanides, at Shengjergji flysch corridor, are arguments the presence of Diber -Elbasan - Vlora transversal. This transversal has played a significant role in the geology of Albanides (Fig. 4; 5; 6, 7).

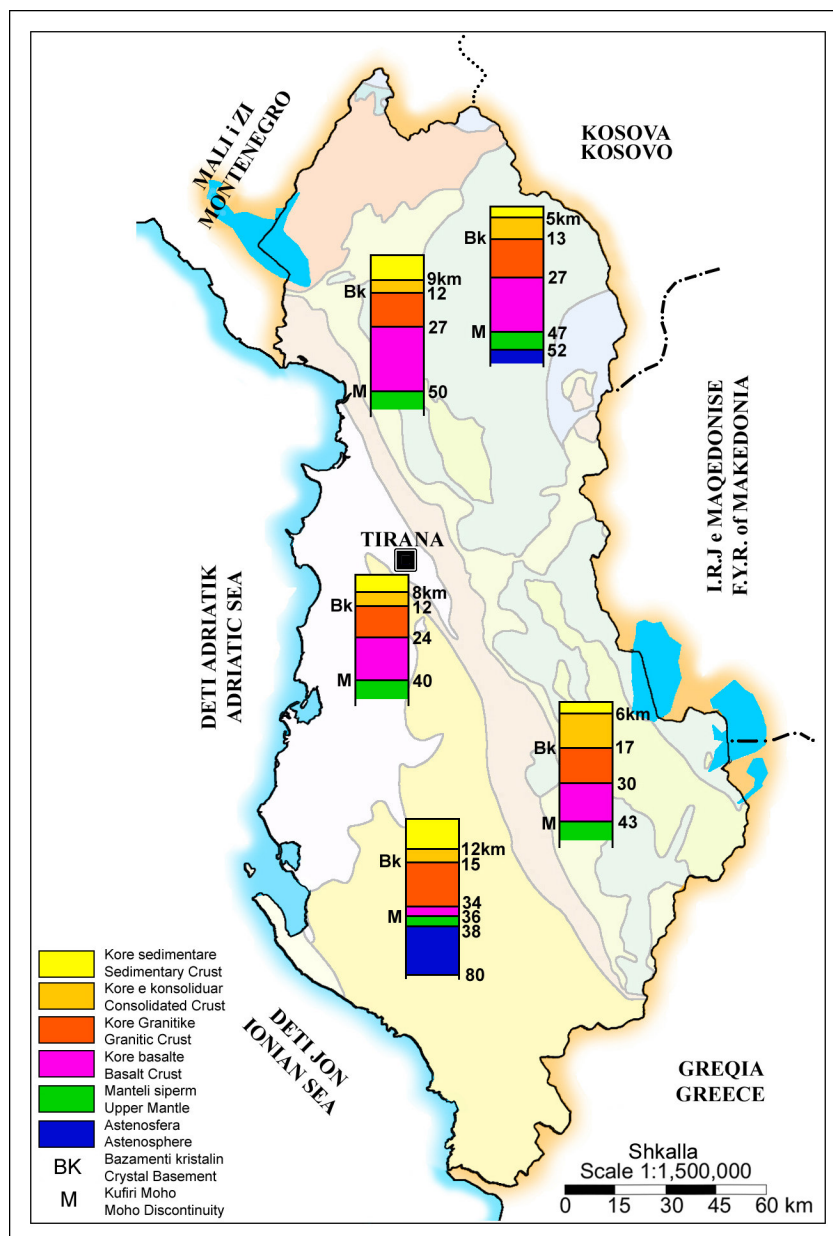


Fig. 3. Geologic structure of Earth's Crust and Upper mantle based on seismological studies (data taken from Koçiu S. 1989).

The numbers given in legen show the velocity of the seismic waves, in km/s).

- 1- Sedimentary Crust; 2- Consolidated crust; 3- Granite Crust; 4- Basalt Crust; 5- Upper mantle; 6- Asthenosphere; 7- BK Crystal Basement; 8- Moho Discontinuity.

A joint characteristic of structural belt of Ionian and Kruja zones in External Albanides is their westward thrusting too (Fig. 8, 10, 11, 12). The thrusting process is helped by the presence of the Triassic evaporite sheet under the carbonate section. According to the integrated geological-geophysical studies and deep wells data results that two tectonic styles are observed in the Ionian tectonic zone: duplex and imbricate tectonic. Traversal tectonic faults have separated the Ionian basin in several blocks. Interpreting the limestone top of the south Adriatic basin and Sazani, Ionian and Kruja zones are observed that the southern Adriatic basin limestone partly is extended under the last units. Peri-Adriatic Miocene and Pliocene mosaic deposits cover the Sazani, Ionian and partly Kruja tectonic zones. This Neogene molasses is placed transgressively over the oldest ones up to the limestone of the Ionian zone, creating a two-stage structure (Fig. 20). The molasses post-orogenic deposits were covered transgressively Mirdita and partially Krasta – Cukali tectonic zones in Korça and Burreli basins.

EARTH CRUST CONFIGURATION

Seismological studies and gravity and magnetic survey data have reflected the Earth Crust configuration (fig. 2; 3; 4, 8 and 21), (Aliaj. 1987, Arapi 1982, Bushati 1988, 1997, Chiappini et al, 1996, Duka et al, 1991, Frasheri et al. 1998, 2000, Koçiu 1989, Langora et al. 1983, Lubonja et al. 1968, Lulo et Bushati 1999, Sulstarova 1987, Veizaj 1995, Veizaj et Frasheri 1995). The structure of the Earth Crust according to the refraction seismic is presented in fig. 2. Rocks with a seismic wave velocity of 5.9- 6.2-km/sec present lower layer of the sedimentary crust. These rocks have a much consolidated structure. The regional gravity trend in Albanides is reflected in the influence of the Moho discontinuity. From Eastern part of the Albanides to the Adriatic Sea Shelf, generally it is observed an increasing of the gravity force (Fig. 5, 8 and 21). In the geological-geophysical profiles Albanid 1 and Albanid-2 (Fig. 8 and 21) is presented the decreasing of the depth of roof of the Moho discontinuity of the Adriatic Sea region. The Moho discontinuity plunges from 25 km in the central part of the Adriatic Sea (Finetti. and Morelli, 1972) to 43- 52 km at eastern part of Albanides. According to the interpretation of the magnetic regional anomalies resulted that top of the crystal basement plunged toward the littoral of the Albanides up to central areas of the Albania (fig. 8 and 24).

In the Albanides are fixed four third order trend of Bouguer anomalies of the low order: two maximums two minimums (Fig. 5, 6). Main gravity maximum is extended over the northeastern part of Mirdita tectonic zone and that of Korabi. Second maximum is located at Vlora district, in southwestern part of Albania. It is very important observation that this maximum has a strike sub-transversal with geological structures of the Ionian tectonic zone. These regional gravity maximums are attributed to a crust thinning toward the Mirdita tectonic zone and in Vlora district (Fig. 8, 21). The same phenomenon is observed in the south of ophiolitic belt of Mirdita tectonic zone to the Hellenides (Cadet et al. 1980). Main gravity minimum is extended from southeastern region of Albania to the northwestern littoral of Albania. Second minimum is located at Alps tectonic zone, by a strike in the SE-NW direction.

These anomalies are interpreted as caused by the vacillation of the depth of roof of Moho discontinuity, and reveal a block construction of the crust, which coincides, fully with the results

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of seismological studies (fig.2). This tectonic construction of the deep levels of the earth crust in Albanides finds its reflection even in the scattering of the magnetic fields (fig. 7).

The Earth crust in Albanides is interrupted by a system of longitudinal fractures in NW - a SE direction and transversal fracture that touch the mantel (fig.6). Some of them separate even the tectonic zones. With deep fractures are linked geothermal energy of the Albanides. According to the geothermometer data results that the water temperature reaches to 220-270°C, in the primary reservoir, where the water has been heated, at the depth 12 – 13 km.

Earth crust setting of the Albanides conditioned the distribution of the geothermal field and energy. In the Heat Flow Density Map of Albania are observed two characteristics (Fig. 9) (Çermak et al. 1996, Frasheri 1993, 2000, Frasheri et al. 1995; 1998, 1999):

Geothermal gradient changes from western to the eastern part of the Albania, and in the depth, too. The gradient values vary from 15-21.3 mK/m in Pre-Adriatic Depression. According to the modeling results, deeper than 20 km is observed decreasing of the gradient. This change of the gradient is coincided with the top of the crystal basement. In the ophiolitic belt of the Inner Albanides, the geothermal gradient at northeaster and southeastern part of the Albania has a value up to 36 mK/m. Decreasing of the gradient are observed deeper than 12 000 meters in this side of Albania, at the top of the Triassic salts deposits (fig. 8). In the both lines are observed that the temperatures in ophiolitic belt are higher than in the sedimentary basin, at the same depth.

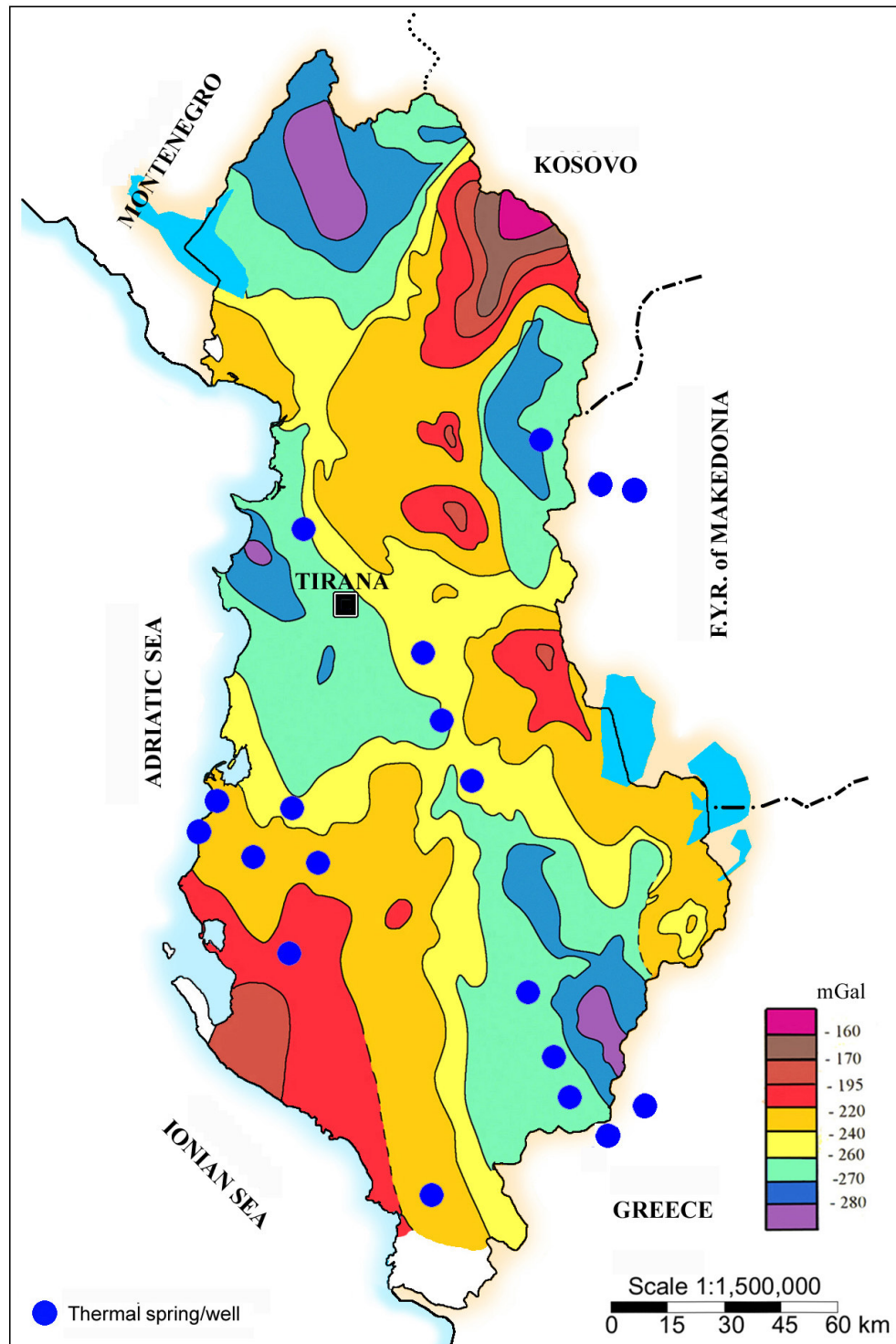
In the Heat Flow Density Map of Albania (fig. 9), is possible to observed two particularities of the scattering of the thermal field of the Albanides:

Firstly, 42 mW/m² is maximal value of the heat flow in the External Albanides. At the eastern part of Albania, the heat flow density values are up to 60 mW/m². Radiogene heat generation of the ophiolites is very low. In these conditions, increasing of the heat flow in the ophiolitic belt, are linked with heat flow from the depth. According to the Alb-1 line, the granites of the crystal basement, which have the possibilities for the great radiogenic heat generation represents the heat source. In ophiolitic belt, is observed decreasing of the Moho discontinuity depth.

Secondly, in the ophiolitic belt are observed some hearth of higher heat flow density. Heat flow anomalies are conditioned by intensive heat transmitting through deep and transversal fractures. These fractures are conditioned location of the geothermal energy sources. According to the calculation of different geothermometers, the aquifer estimated temperatures are 144 to 270°C. Based on the geothermal modeling, one can suppose that thermal waters rise from 8-12 km deep, where temperature attains to 220°C.

These arguments show that crystal basement has a blocks character. Depth of the location of these blocks is shallower in Mirdita tectonic zone. Local heat hearths show the existence of the transversal fractures and through these fractures is very high heat flow. Geothermal energy is linked with great heat flow through these fractures.

The crust setting and their dynamics are reflected in the geology of the tectonic zones of the Albanides, and their tectonic styles.



BOUGUER GRAVITY ANOMALIES MAP OF ALBANIA

(After Bushati S., 1988)

Fig. 1

Fig. 4. Bouguer Gravity Map of Albania.

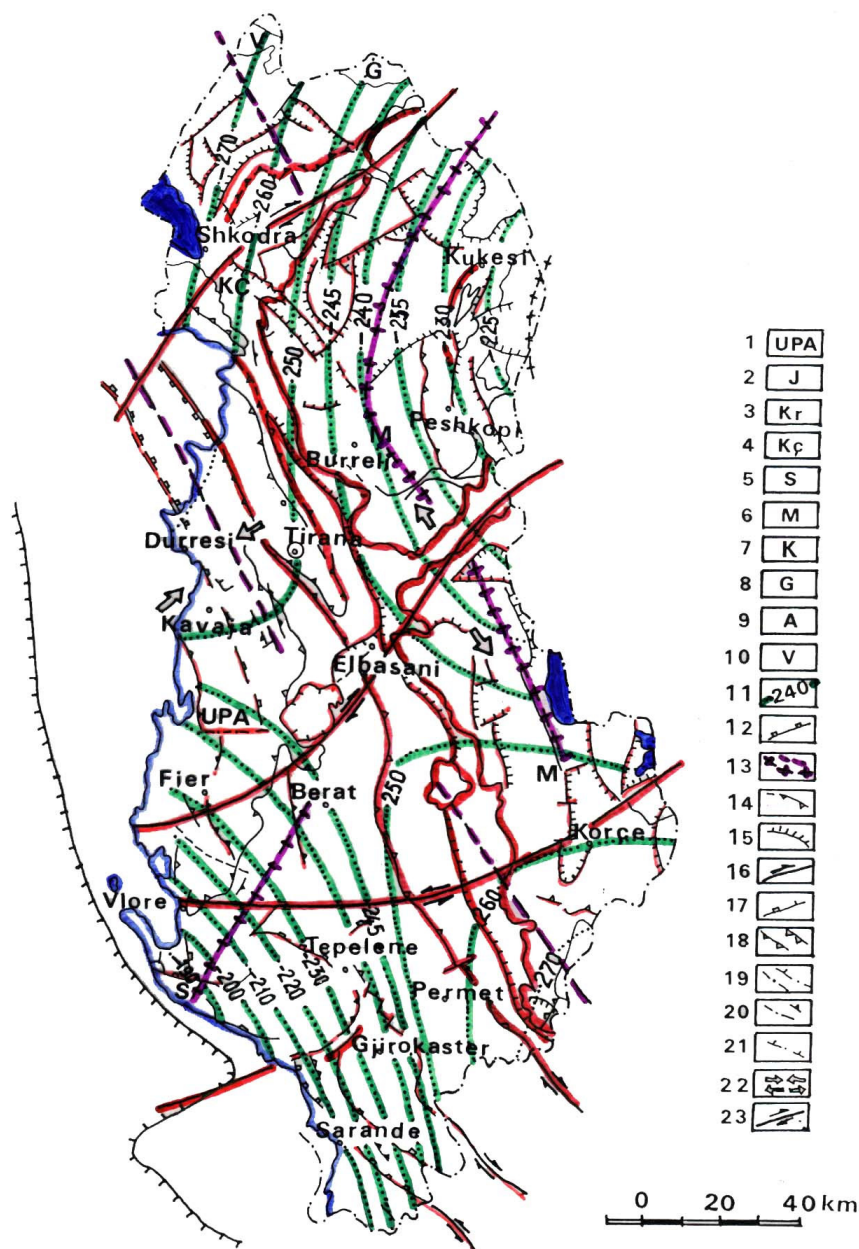


Fig. 5. The Complex Tectonic Map and map of the trend of 3rd degree of Bouguer Anomaly in the Albanides.

- 1- Peri-Adriatic Depression; 2- Ionian Zone; 3- Kruja zone; 4- Krasta-Cukali zone; 5- Sazani zone; 6- Mirdita zone; 7- Korabi zone; 8- Gashi zone; 9- Albanian Alps zone; 10- Vermoshi zone; 11- trend of 3rd degree of Bouguer Anomaly; 12- Boundary between shelf and continental slope; 13- The axes of the up-left and down-left of the Mante; 14- Boundary of the Peri-Adriatic Depression with angular discordance; 15- Normal fault; 16- Pressure; 17- Limit of deformed envelopment during the neotectonic period; 18- Overthrust; 19- Flexure; 20- Flexure and faults based on geophysical data; 21- Inactive overthrust; 22- Compression (a) and (b) extension zones; 23- Deep faults.

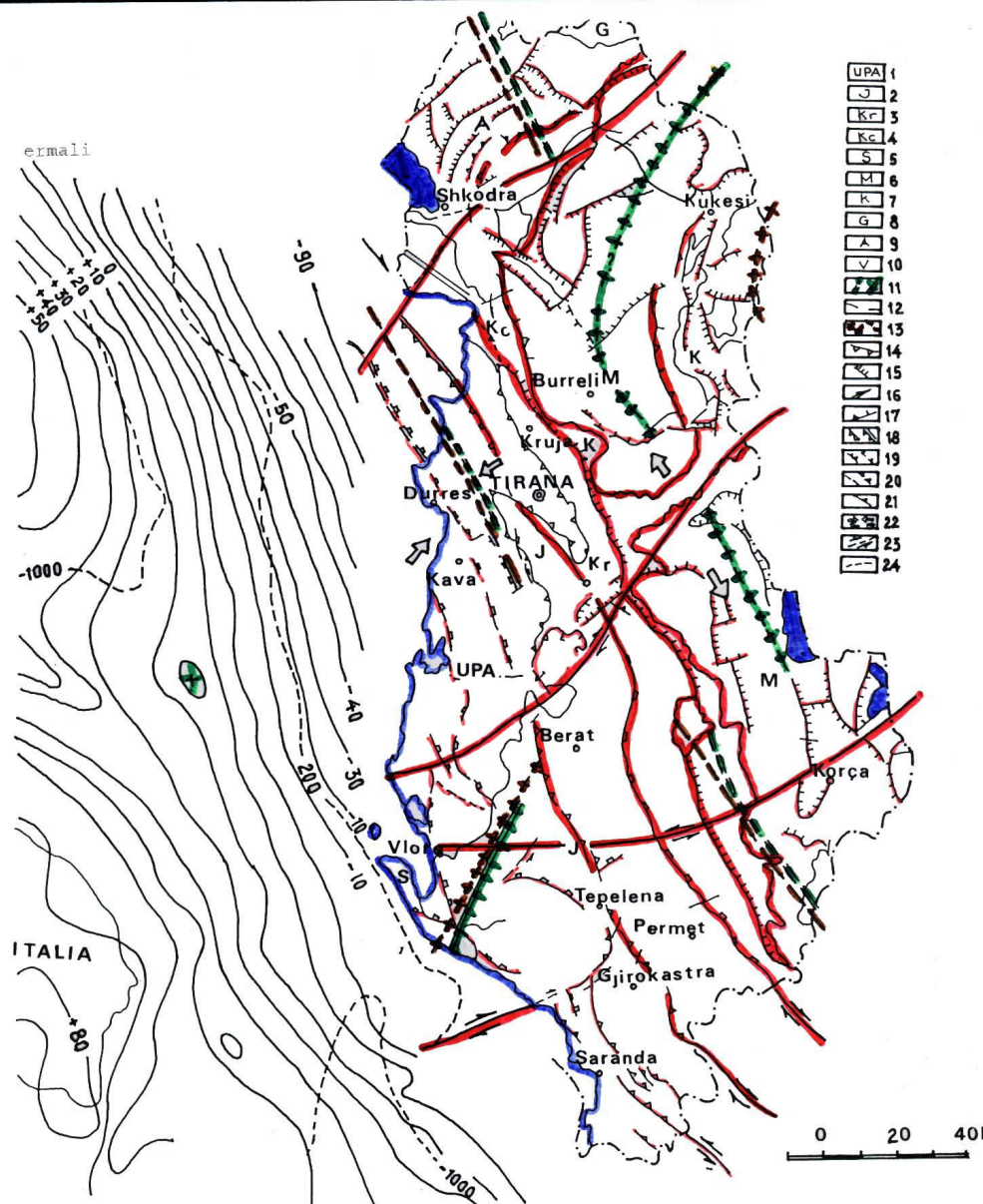
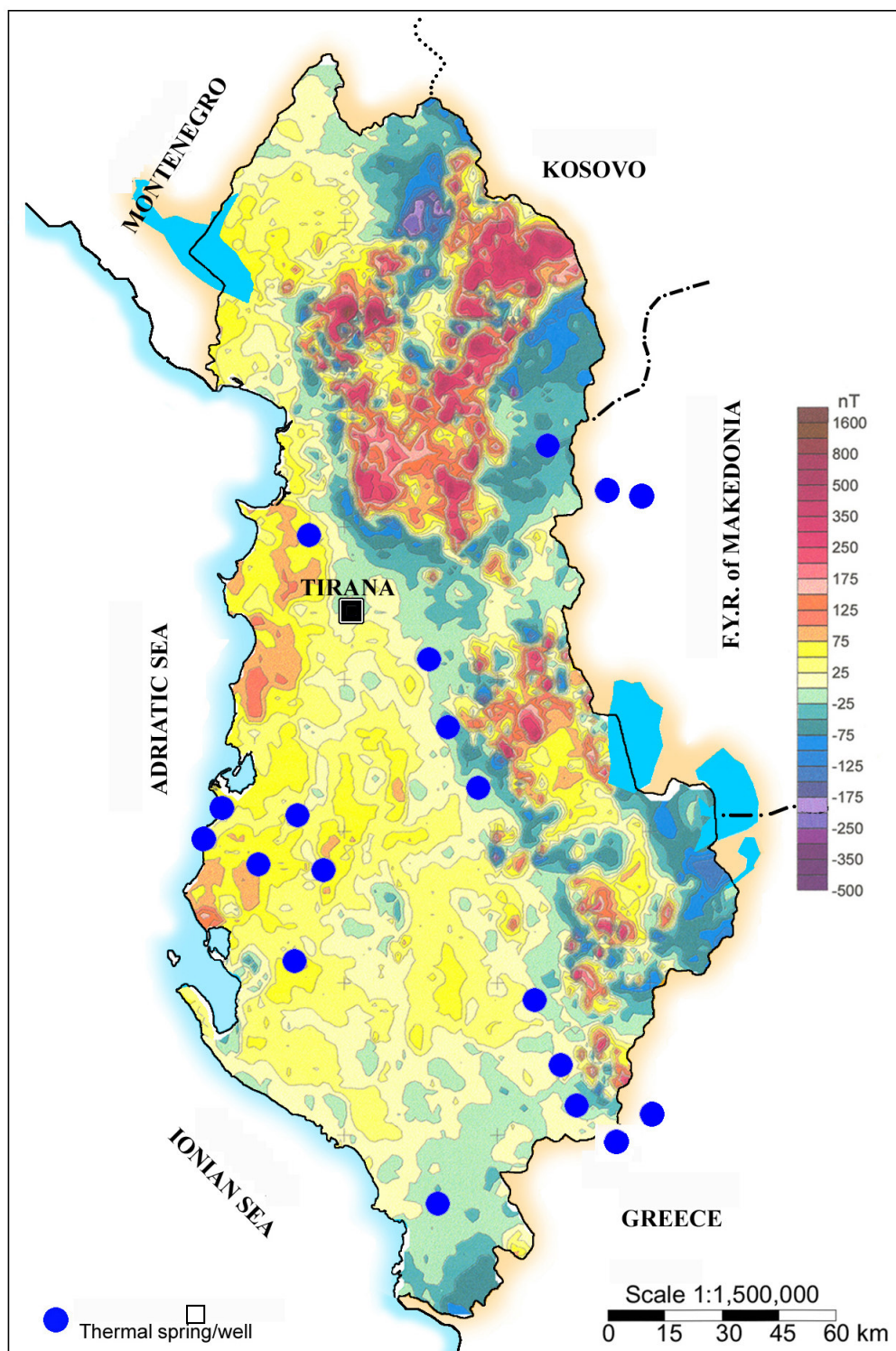


Fig. 6. The Complex Tectonic Map and axes of the Bouguer anomaly in the Albanianides and in continental plate of the Adriatic Sea.

- 1- Peri-Adriatic Depression; 2- Ionian Zone; 3- Kruja zone; 4- Krasta-Cukali zone; 5- Sazani zone; 6- Mirdita zone; 7- Korabi zone; 8- Gashi zone; 9- Albanian Alps zone; 10- Vermoshi zone; 11- The axes of the Bouguer Residual Anomalies, positive (a) and negative (b); 12- Isoanomalys of the Bouguer Anomaly in the Adriatic and Ionian Sea (after Morelli C et al. 1969); 13- The axes of the up-left and down-left of the Mante; 14- Boundary of the Peri-Adriatic Depression with angular discordance; 15- Normal fault; 16- Pressure; 17- Limit of deformed envelopment during the neotectonic period; 18- Overthrust; 19- Flexure; 20- Flexure and faults based on geophysical data; 21- Inactive overthrust; 22- Compression (a) and (b) extension zones; 23- Seismogene deep up-rupt; 24- Isobaths of the water depth, in meters.



TOTAL MAGNETIC FIELD MAP OF ALBANIA
(After Bushati S. 1987)

Fig. 7

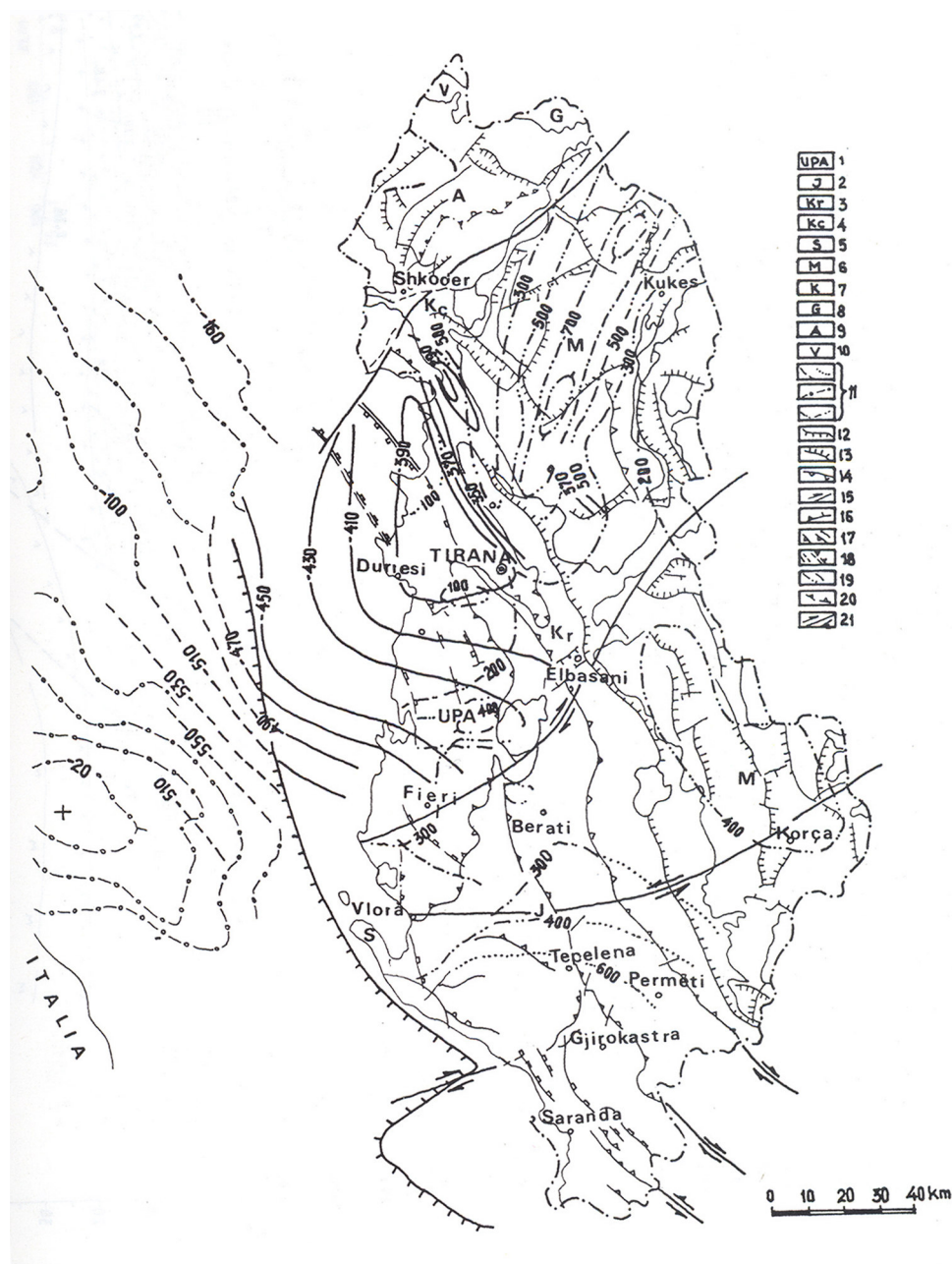


Fig. 7. The Complex Tectonic Map and Total Magnetic anomalies in the Albanides and in Adriatic Sea continental plate.

- 1- Peri-Adriatic Depression; 2- Ionian Zone; 3- Kruja zone; 4- Krasta-Cukali zone; 5- Sazani zone; 6- Mirdita zone; 7- Korabi zone; 8- Gashi zone; 9- Albanian Alps zone; 10- Vermoshi zone; 11- Isoanomals of residual total magnetic anomalies; 12- Boundary between shelf and continental slope; 13- Normal faults; 14- Boundary of the Peri-Adriatic Depression with angular discordance; 15- Pressure; 16- Limit of deformed envelopment during the neotectonic period; 17- Overthrust; 18- Flexure; 19- Flexure and disjunctions based on geophysical data; 20- Depth seismogenic up-rupt; 21- Inactive overthrust; 22- Depth seismogenic up-rupt.

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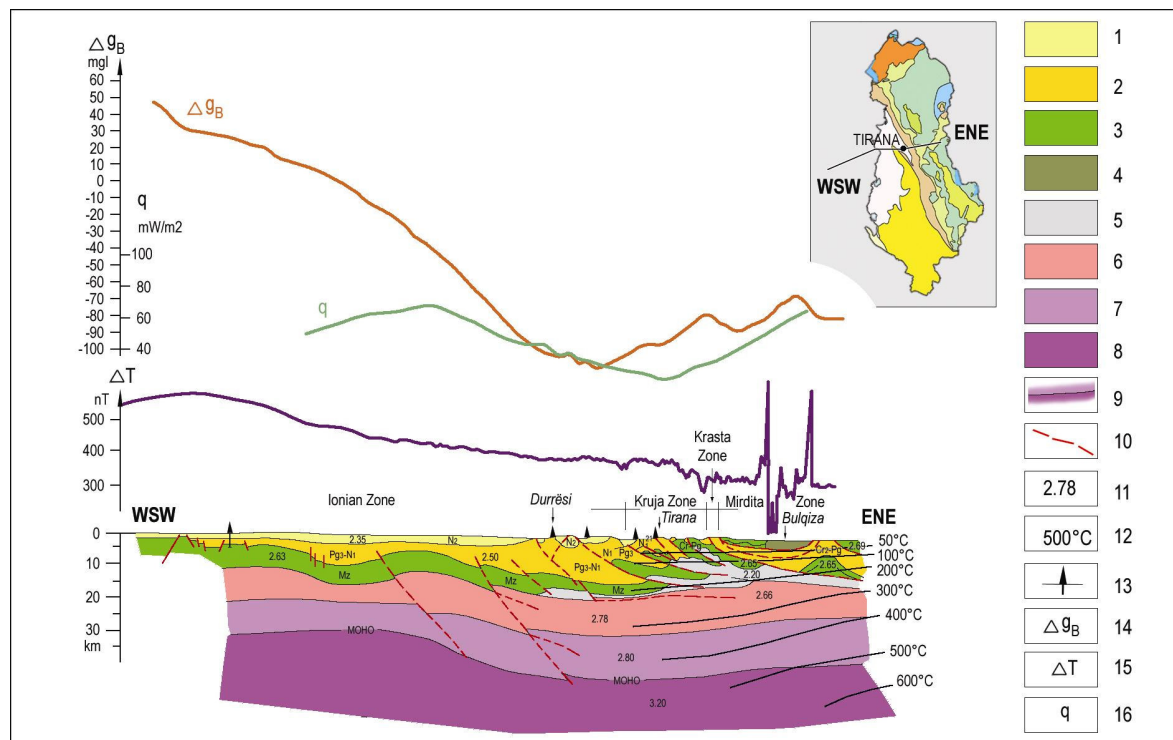


Fig. 8. Geological-geophysical profile Albanid-2: Falco Adriatic Sea- Durrës-Tirana- Peshkopi (The gravity data for the Adriatic Sea after Richetti, 1980).

1. Pliocene Sustratum; 2- Substratum of Serravalian Molasses; 3- Paleogenic flysch (Pg_3) and molasses over the limestone; 4- Flysch of the Mastrichtian (Cr^m_1), Lower and Middle Paleogene (Pg_{1-2}); Old flysch of Jurassic (J) and middle Cretaceous (Cr_2); 6- Carbonatic facies divided by the tectonic zones; 7- Ultrabasic rocks; 8- Disjunctive tectonic; 9- Depth up-rupt; 10- Top of chrystal basement; 11- The basal of the Earth Crust; 12- Moho Discontinuity' 13- Focus nodal plan of the earthquakes in the Kavaja region, western Albania; 14- Seismic reflection; 15- Deep well.

$G_{B,t}$ - Trend of 2nd degree of Bouguer anomaly; $G_{B,r}$ - Residual Bouguer anomaly;
 T_t - Trend of the 2nd degree of total magnetic anomaly; T_r - Residual of the 2nd degree of total magnetic anomaly; T_o - Observed magentic anomaly;

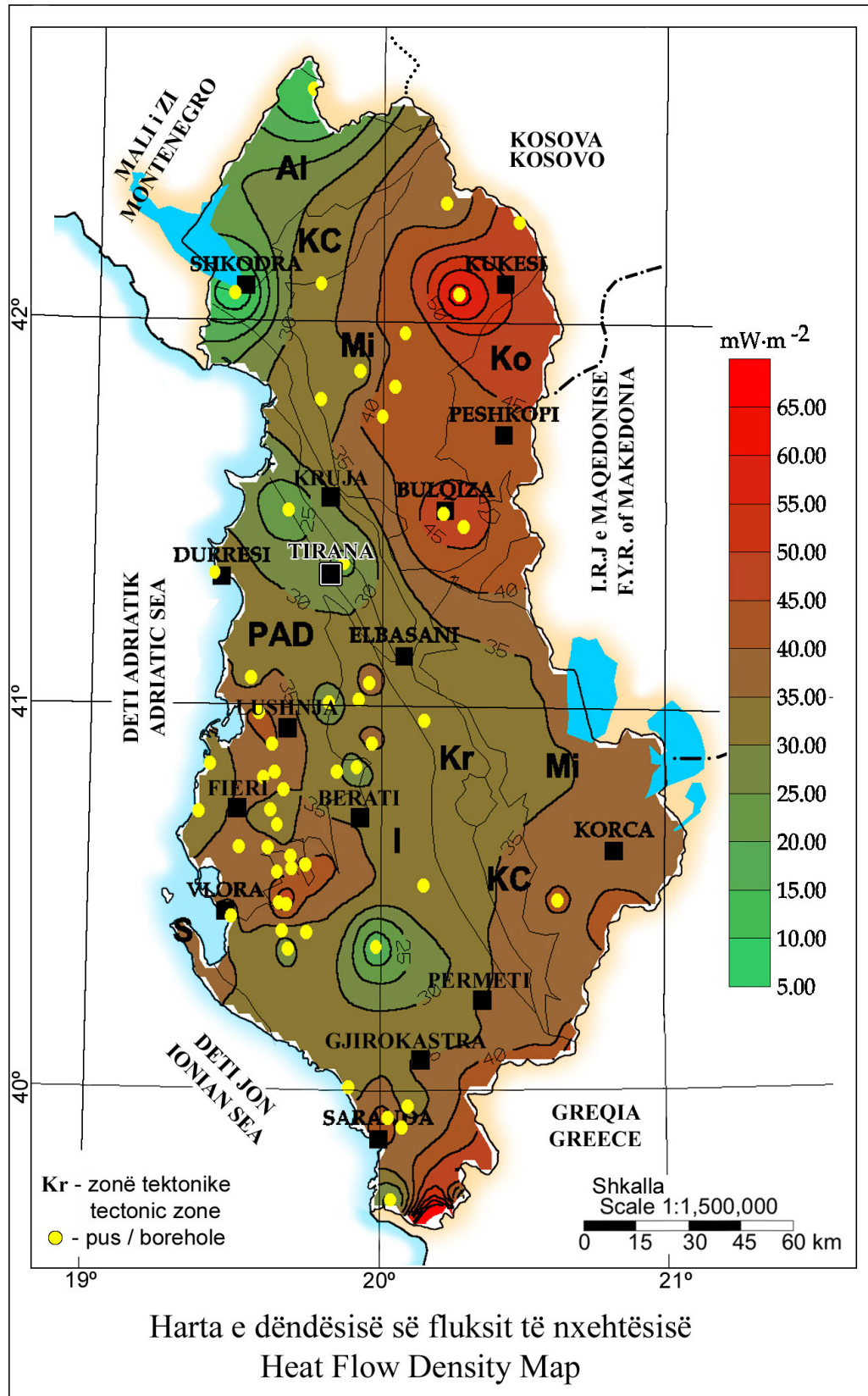


Fig. 9

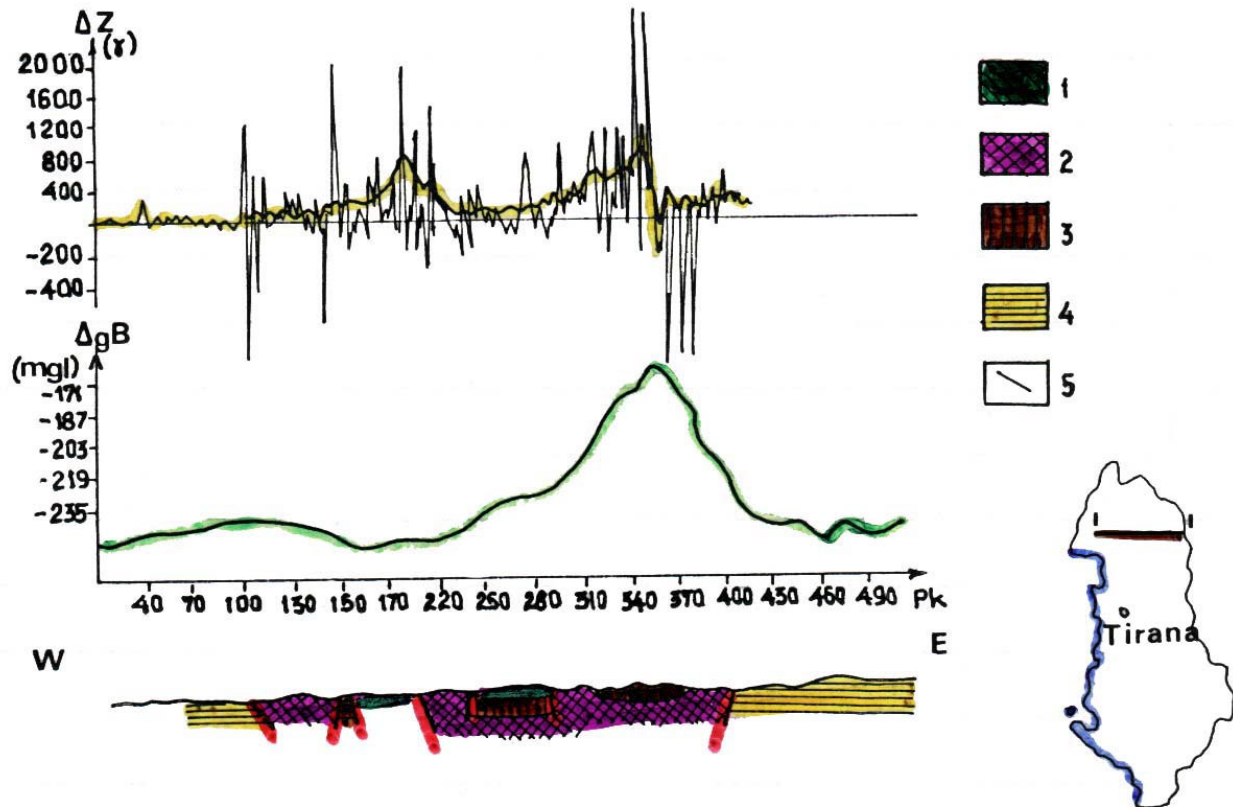


Fig. 10. Geological-geophysical Shkodër-Kukës profile.
1- Effusive rocks; 2- Ultrabasic rocks; 3- Gabbro; 4- Sedimentary formation; 5- Disjunctive tectonic.

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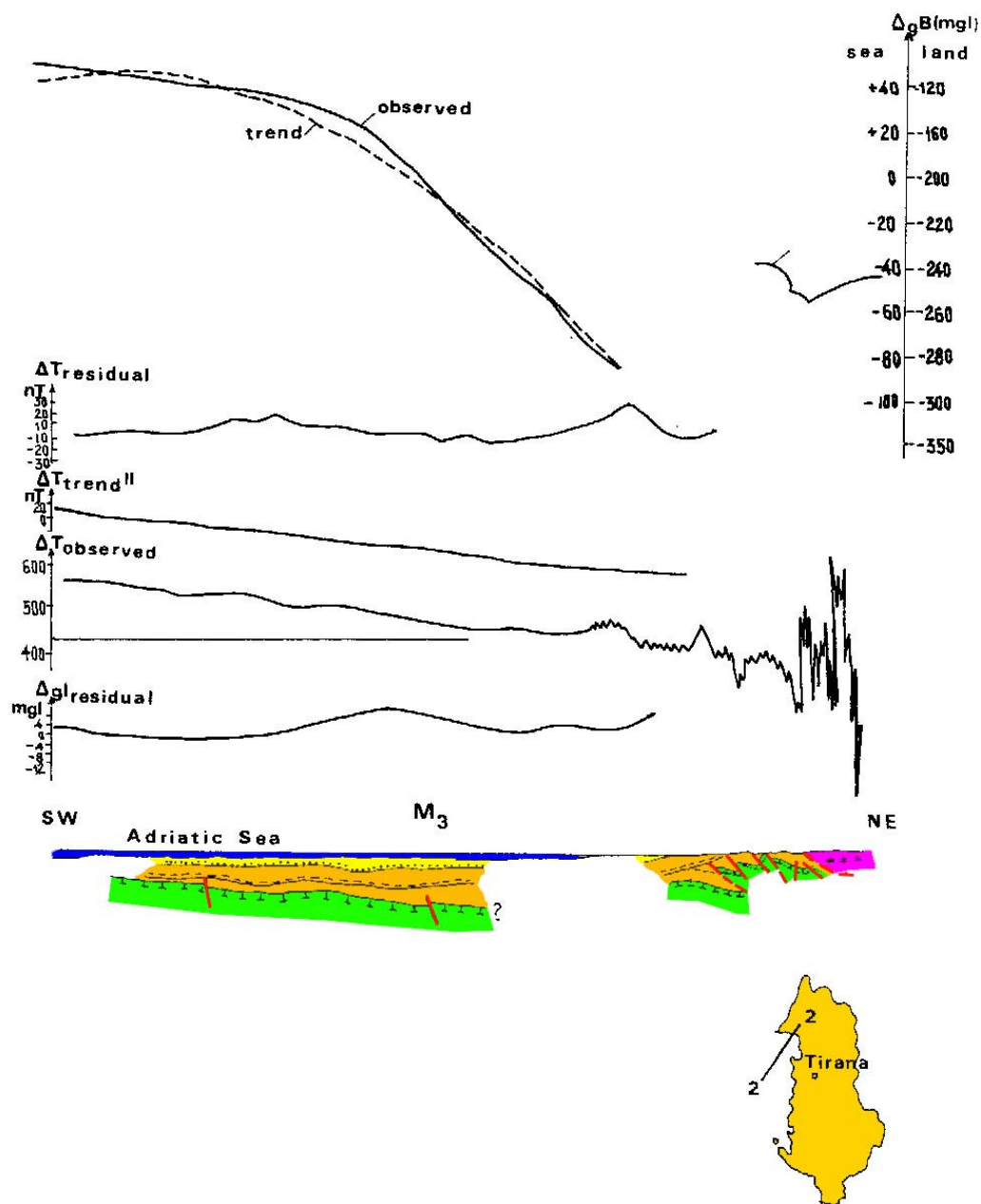


Fig. 11. Geological- geophysical profile: Adriatic Sea- Vrith

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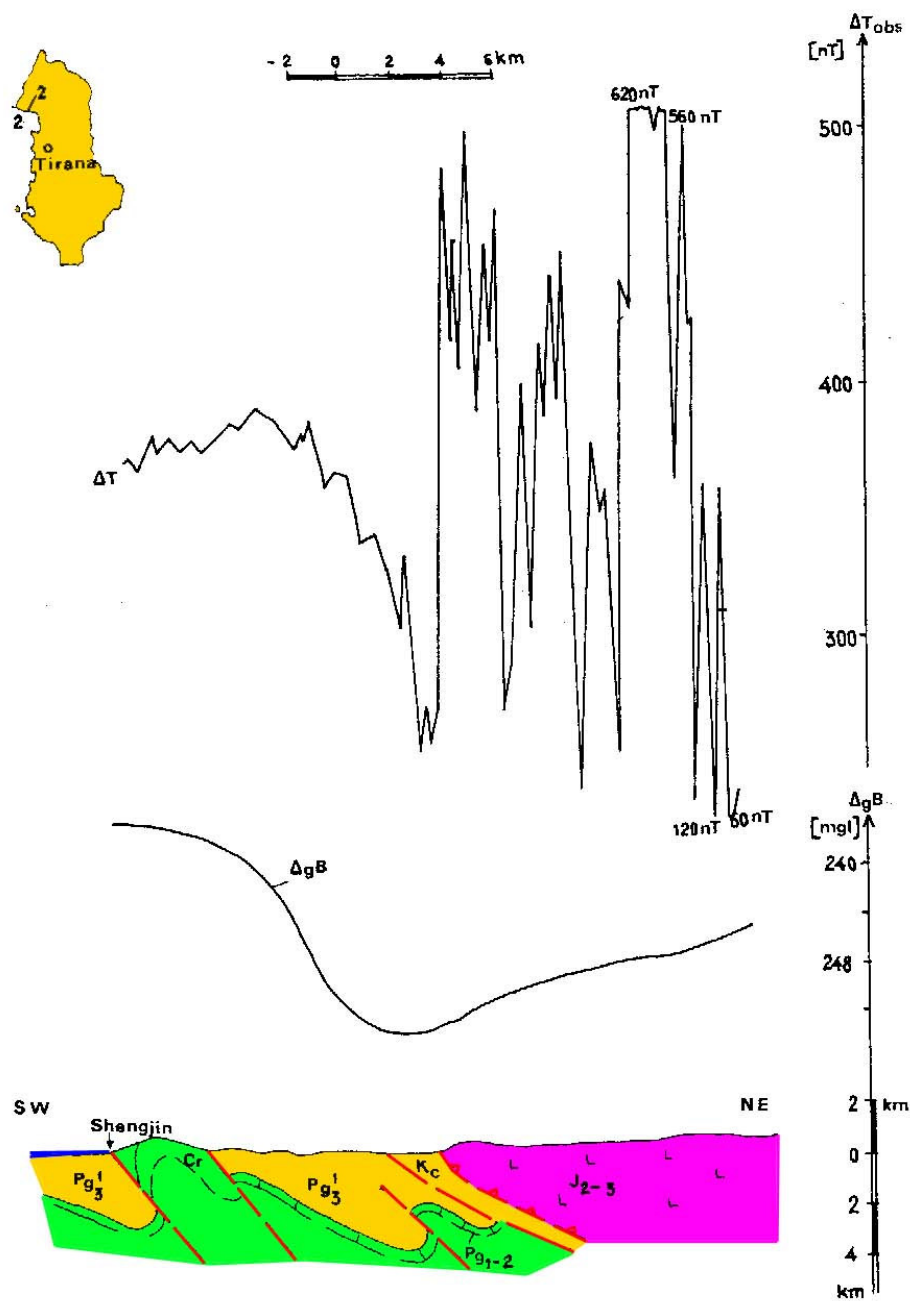


Fig. 12. Geological-geophysical profile: Shengjin- Vrith.

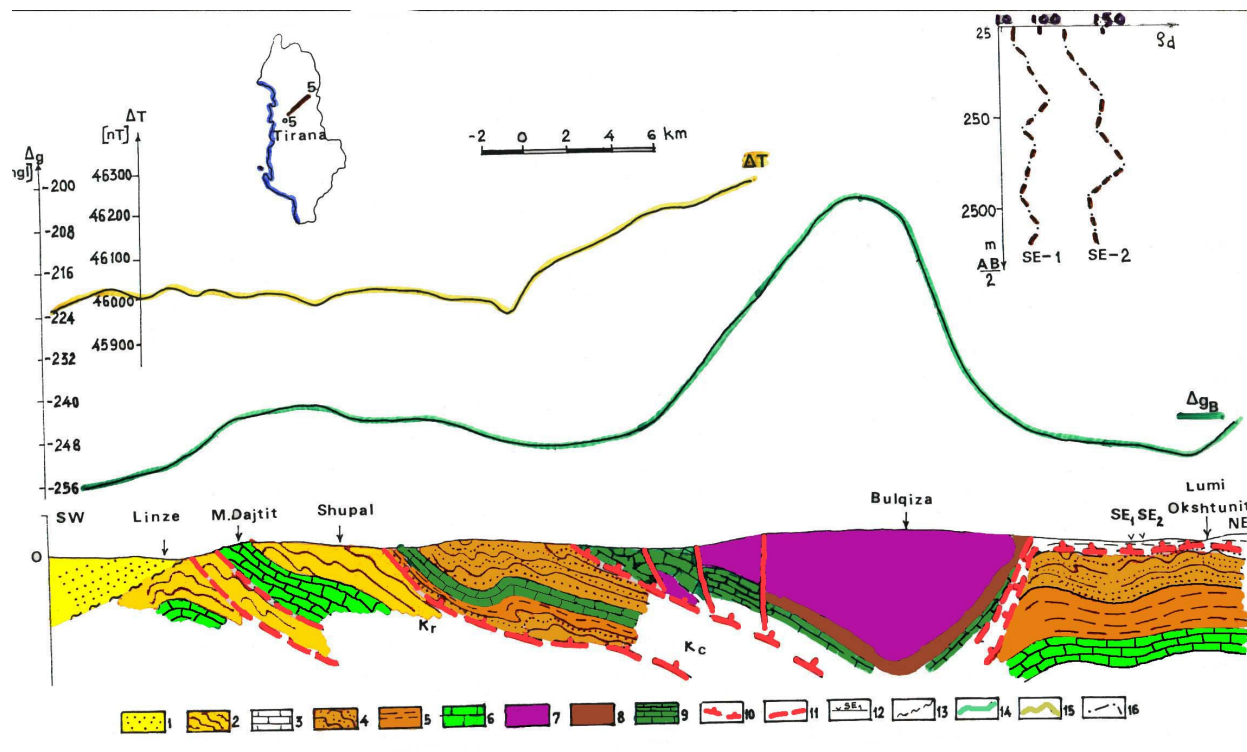


Fig. 13. Geological-geophysical profile: Tirana- Bulqizë- Shupenzë.

- 1- Terrigenous Tortonian Deposits; 2- Paleogene flysch deposits; 3- Upper Cretaceous-Paleogene Limestone; 4- Tithonian- lower Cretaceous flysch deposits; 5- Upper Triassic- lower Triassic limestone; 6- Radiolaritic limestone with silic radiolarities; 7- Ultrabasic rocks; 8- Effusive rocks; 9- Limestone with siliceous of middle Triassic- lower Jurassic; 10- Overthrust plane; 11- Up-rup tectonic; 12- Electrical sounding centers; 13- Unconformity surface; 14- Bouguer anomaly; 15- Magnetic anomaly; 16- Electrical sounding resistivity curve.

INTERNAL ALBANIDES

The tectonic zones of the Internal Albanides are extended in eastern part of Albania.

1. **KORABI** zone (K) continues in Pelagonian zone in Hellenides and Golia zone in Dinarides. In Korabi zone the field of Bouguer anomaly is normal and this reveals that the structures are of low orders (Fig.4). The quiet gravitational zone of Korabi in the west is in contact with the anomalous zone laid over the ophiolites of Mirdita tectonic zone. The contact between Korabi and Mirdita zone has coincided with the deep seismogenic structure Ohrid-Qariste-Qafe Murre-Kukes.

In this zone the oldest formations of Albania are present, and are represented by sandstones, schistose conglomerate and metamorphic limestone of Silurian, Devonian and Carboniferous ages,

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and sandstone-conglomerate and anhydrite of lower Permian-Cretaceous age. In some places there are also some volcanic and subvolcanic rocks with basic and acidic-alkaline contents. In the Korabi zone, some folds, thrust fault and cover rocks are presented.

2. **MIRDITA** zone continues with the Subpelagonian zone in Hellenides and Serbian zone in Dinarides. This zone represents a wide belt along the whole length of the country, from northeast to southeast. During the different orogenic phases, three tectonic units were formed in Mirdita zone. The lower tectonic stage is made up of ophiolites. Ophiolitic belt is characterized by intensive anomalies of the Bouguer anomaly and by a magnetic field with weak anomalies, that are very turbulent (fig. 5, 6, 7, 8, 10, 11, 12, 13).

There are three characteristics of this anomalous belt:

- Firstly, they are divided in two parts, in the north and south of Shengjergji flysch's corridor;
- Secondly, five gravity maximums, with epicenters which are set after one another in a chain according to the anomalous chain from Tropoja-Kukesi ultrabasic massif in the north-east part of Albania to the Morava massif at south-eastern area. The anomalies have maximal amplitude up to 105 mgal and are separated with strong gradients. In the northern part, the anomalous belt takes a powerful turn of 60°-70° in the form of northern-eastward direction going to the Dinarides ophiolitic belt.
- Thirdly, the biggest amplitudes of the anomalies are located over the northern part of ultrabasic massifs of the eastern belt. The southern part of the Albanides ophiolitic belt has a more limited thickness and it keeps developing southwards in Hellenides.

Falko-Tirana-Bulqiza profile interrupt transversally all the tectonic zones of Albanides (fig.8, 13). In this profile is presented clearly that the transversal profile of Bulqiza ultrabasic massif is asymmetrical. The thickest part of the massif, about 6 km.

The dip towards west of the eastern board of Bulqiza massif is proved by two vertical electrical soundings. According to these soundings, up to the depth of 2500 m, there are not observed high resistivity rocks, which can be identified with the ultramaphic rocks. (Fig. 13).

The separation of the anomalous belts of the gravity and the magnetic forces in the Shengjergji flysch's corridor, bringing evidence for the presence of Diber -Elbasan - Vlora transversal fracture, which has played a significant role in the geology of Albanides. In Shengjergji flysch corridor no magnetic anomalies are fixed, which would testify absence of the presence of ultrabasic rocks in the east of massif's margins and under the flysch deposits (fig. 14). The Bouguer anomaly in this region is due to the presence of limestone anticline under the flysch. Vertical electrical soundings have revealed that flysch deposits have a thickness of 2000 - 2500m.

Ophiolitic belt has its biggest thickness is about 14 km in its northeastern extreme, in the ultramaphic belt of Kukes. Towards west and southeast this thickness reduced to 2 km (Fig. 10)

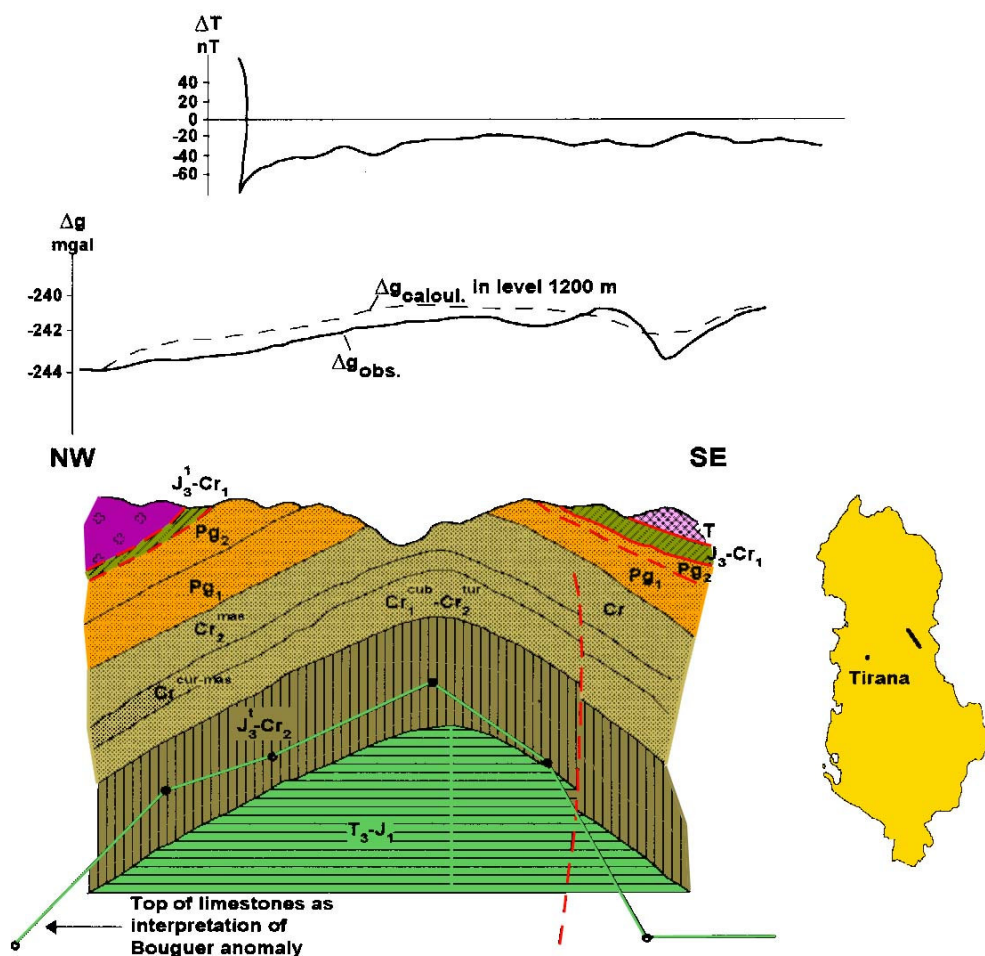


Fig. 14. Geological-geophysical profile through Paleogene and Cretaceous flysch exposures of Okshtun window.

Abbreviations: T- Triassic; J- Jurassic, Cr- Cretaceous, Pg- Paleogene.

The northwestern sector of the ophiolitic belt is extended in the east of Shkodra town (fig. 10, 11, 12). The intensity of gravity and magnetic fields forces is reduced from seashore towards the east. The amplitude of the gravitational anomaly over the Gomsiqe ultrabasic massif is 12 mGal, which is four times smaller than in the anomalies in the eastern belt of ultramafic massif. This proves the small thickness of western part of the ophiolitic belt. As it is seen from the graphic of the magnetic anomaly presented in the profile, shows that the ophiolites contact here dips in eastern direction with an angle about 45°.

This interpretation is presented the argument about the covering character of the western contact of ophiolites belt in Mirdita zone, under which the formation of Krasta-Cukal zone is laid. This geological setting of the nappe character of the ophiolitic belt explains also the fact that, between

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Mirdita and Krasta-Cukali tectonic zones, the seismological studies have not proved the presence of any deep fracture.

During the tarditectonic- neotectonic stages are formed internal neogenic depressions. According to electrical soundings, carry out in Burreli fosse; result that neogene molasses have a thickness about 1500 m in the northern part of the basin (fig. 15). Under it there lies a geoelectrical layer with high resistivity which is identified with ophiolites. Under the ophiolites there is extended a layer with resistivity 100 Ohmm and thickness 500m. This layer is placed over rocks with high resistivity. This interpretation leads to the opinion those volcanoes-sedimentary formation lies over Triassic limestone. The seismic profile through this basin shows that under neogene deposits there lays a belt without seismic reflections, which is interpreted as linked with the ophiolitic formation. Under them, there lies a section with many horizontal seismic reflections, which testifies the presence of stratified section (fig.16). The seismological studies show that is observed inversion of the waves velocity dissemination in Mirdita zone (fig. 17).

All this proves that the ophiolitic belt of the Albanides is genetically unique and tectonically split into two subbelts along its length. Geophysical data are represented the arguments for overthrust character of ophiolitic belt.

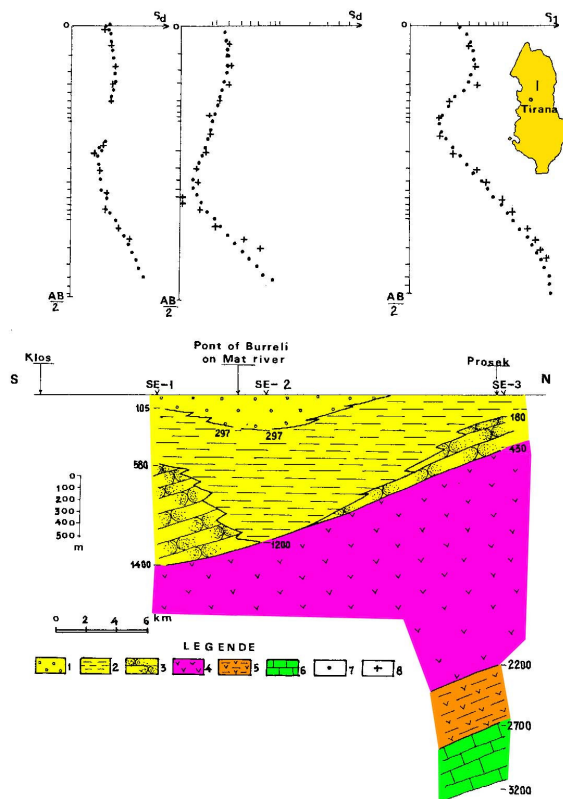


Fig. 15. Geoelectrical profile: Klos-Prosek over the Burreli Neogenic Fosse. Quaternary gravel and conglomerate; 2- Detritic-argillaceous pack; 3- Sandstone-conglomerate; 4- Volcanic rocks; 5- Volcanogenic sedimentary pack; 6- Limestone;

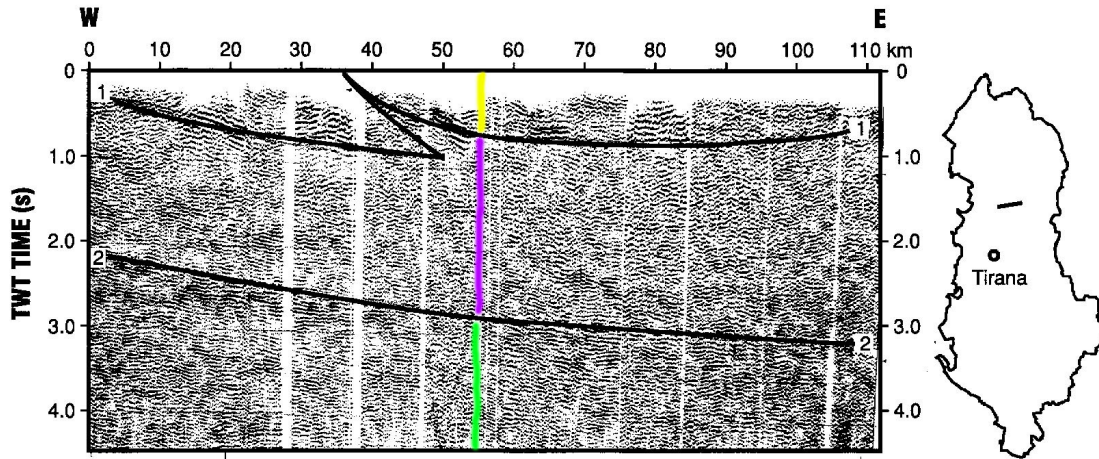


Fig. 16. Reflection seismic line in the Burreli Neogenic Fosse.

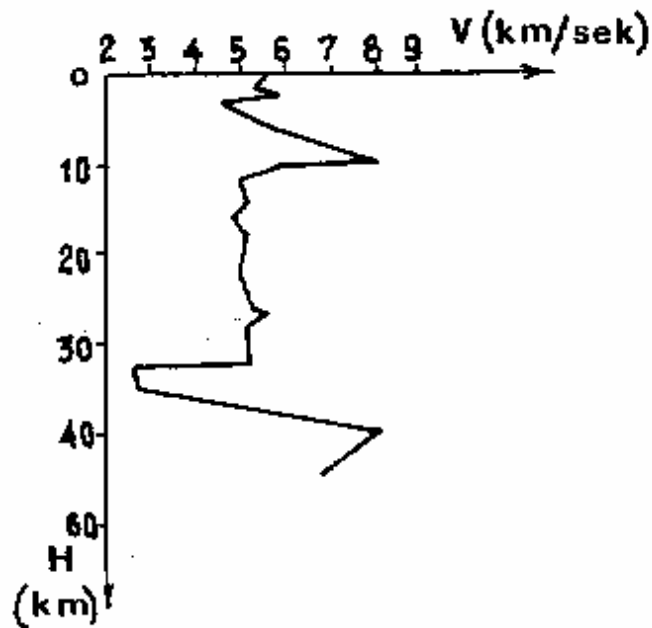


Fig. 17. Inversion of seismic P waves velocity from seismologic data (After Koçiu S., 1989).

3. **GASHI** zone (G). Beyond its border it continues into the Durmitori zone of the Dinarides. This zone includes metamorphic rocks, terrigenous rocks, limestone, metamorphic volcanites, basic intermediate and acidic rocks.

EXTERNAL ALBANIDES

The tectonic zones of the External Albanides are extended in western part of Albania.

1. **ALPS** zone (A). Analogue with Parnas zone in Hellenides and it continues with High Karst in Dinarides. In this zone the sandstone and the conglomerates of Permian are the oldest rocks. In general, Alps represents limestone monoclines, combined with smaller anticlines. A regional gravity minimum is extended in the Alps zone. Local gravity maximums are extended over the carbonatic structures (Fig. 18).

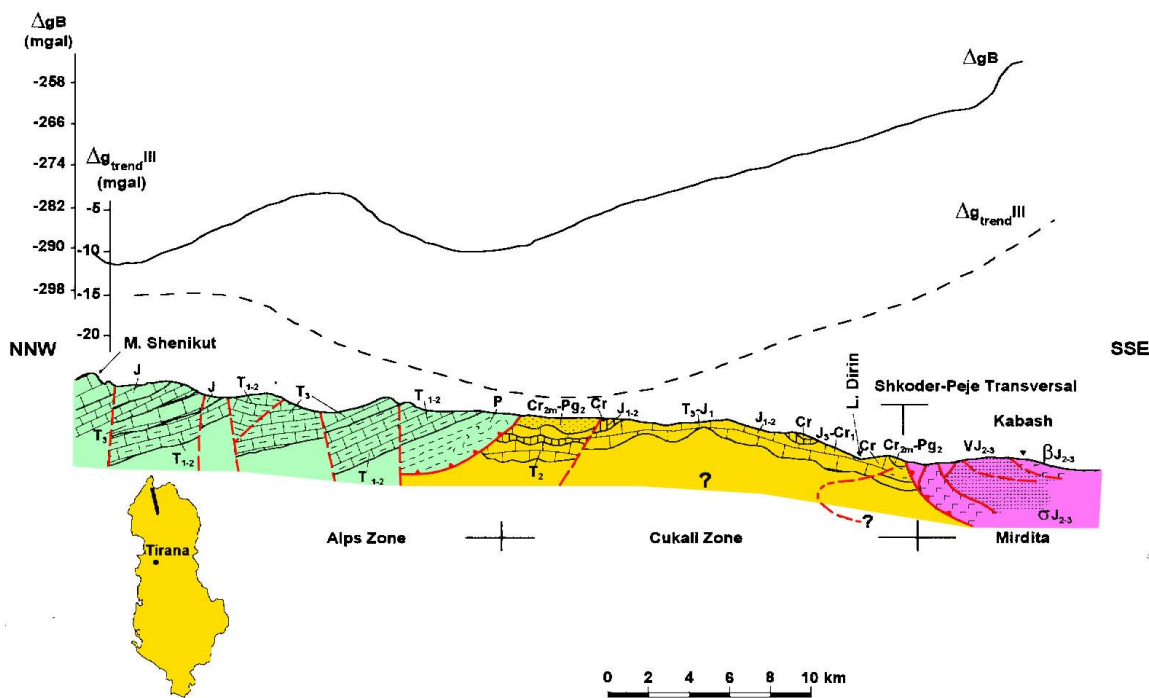


Fig. 18. Geological-geophysical profile: Alps-Cukali-Mirdita zones, over the Shkodër- Pejë Transversal.

2.KRSTA-CUKALI zone (K - C) continues in Pindos zone in Hellenides and Budva zone of the Dinarides. Krsta subzone lies like a narrow belt from Shkodra City in northwest region of Albania to Leskovik City at southeast region of Albania. This is an intermediately zone between the Internal and External Albanides. The longitudinal profile passes through the northwestern margin of ophiolitic belt, through Cukali and reaches to the Albanian Alps, interrupting Shkoder–Peje transversal (fig.18). Residual Bouguer anomaly has a monotonous increase in the southeastern part of this profile. This increase may be caused by:

Firstly, the increase of the thickness of the limestone formations of Triassic up to Cretaceous towards the border of Cukali and Mirdita zones,

Secondly the probability of existence in this zone of ophiolitic rocks covered by the formations of Cukali.

Thirdly the presence of Paleozoic formations with big density near the earth surface in this sector.

3. **KRUJA** zone (K) continues with Dalmate zone in Dinarides and in the south by Gavrova zone of the Hellenides. According to the seismic data in the central regions of Kruja zone, are noticed reflection in the seismic sections in 2.3-2.5 seconds which is partially parallel with the above reflections, identified as limestone roof of the structures of Kruja zone (fig.19). Basing on the nature of reflections and the data of the neighboring countries they may be connected with the roof of Jurassic-Cretaceous salts. Secondly, a deep overthrust regional disjunctive tectonic may pass. In this case, terrigene (flysch) section would lay under 2-2 reflection and going deeper we would expect new carbonate structures with perspectives for oil and gas discovery.

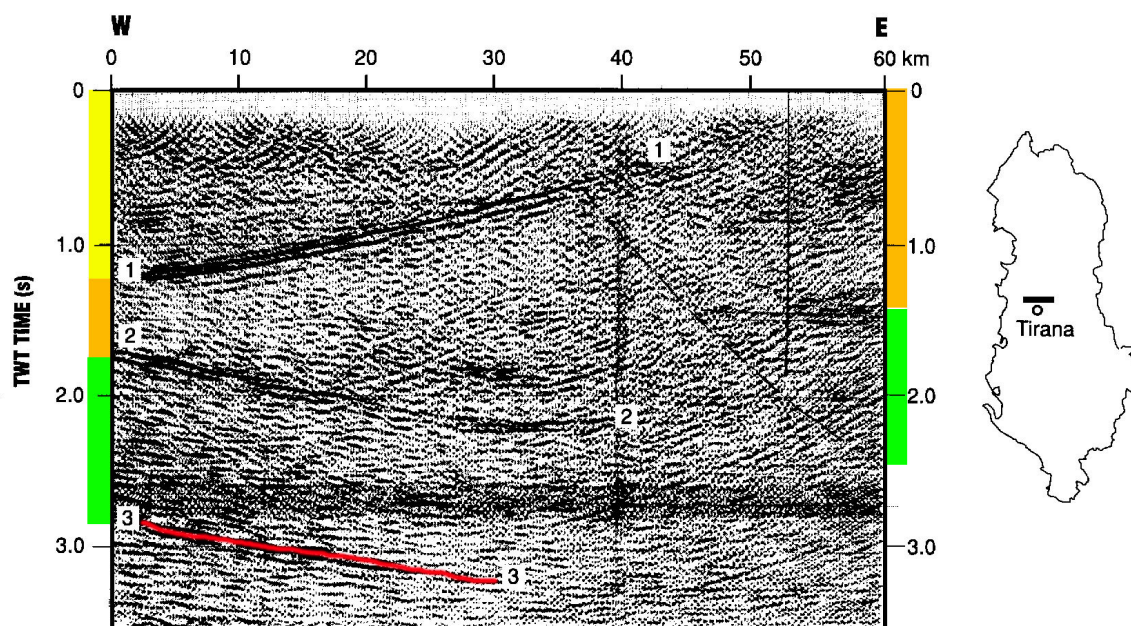


Fig. 21. Reflection seismic line in the Tirana Neogenic Depression.

4. **IONIAN** zone (Io) continues with the same name beyond borders in Greece. The Ionian zone occupies the southwestern part of Albania with SE-NW axis. This is the biggest zone of External Albanides and has been developed as a deep pelagic through since upper Triassic. The Permian-Triassic evaporites are the oldest rocks of this zone. Over this formation lies a thick deposits formed by upper Triassic- lower Jurassic dolomitic limestone and Jurassic-Cretaceous-Paleogene pelagic cherty limestone. Limestone are covered by Paleogenic flysch, Aquitanian flyschoidal formation, thin section of Burdigalian-Helvetian and partially of Serravalian-Tortonian, which mainly fill the synclinal belts. Burdigalian deposits are placed in angle discordance over anticline belts. This has brought about two- stage structure.

During the Liassic rifting affected External Albanides including Ionian zone and in this last were formed three tectonic blocks that represent the structural belts:

- a. Berati anticline belt, in the eastern margin of the zone
- b. Kurveleshi anticline belt, in the central part of the zone. According to the reflection seismic results have been compiled spatially map the carbonates.
- c. Çika anticline belt, which represents the western edge of the Ionian zone.

By the geological-geophysical data many anticline structures are delimited in the carbonate deposits inside these tectonic belts. Structures are fractured by longitudinal tectonic faults in western structure flanks.

The Berati anticline belt

The seismic acquisitions on this belt are performed in different times and by different techniques. The seismic situation in the time sections is very complicated and for the top of limestone, only some separated reflections in certain lines are recorded, especially in its central and western part, probably because limestone in this zone are deep and faulted. According to the seismic data, limestone in the central part are markedly broken.

This conclusion is well supported by the deep wells, drilled in Sqepur- Bistrovica area.

Kurveleshi anticline belt

All our conclusions are refereed mainly to carbonate formation, because those for the flysch section over the limestone, based on numerous facts, have produced wrong conclusions. The Kurveleshi belt is constructed by structures of various forms and dimensions, associated with developed tectonics up to thrusting of 5-10 km horizontal displacement, in the west of its structures as well as in eastern flanks is associated with diapiric eruptions. In regional seismic line II-II, which crosses the Ionian zone, from west to east, we can see clearly the perspective oil and gas-bearing structures.

Çika anticline belt

Çika anticline belt is constructed mainly by prolonged structures, with considerable dimensions, and associated with evaporate outcrops as in Xara, Fterra, Çika etc. Seismic works

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in this belt, date back to the start of exploration in Albania and still continue today. Earlier techniques for field acquisition have been those of one fold coverage, which continuously are improved, switching in the last years to multiple fold coverage.

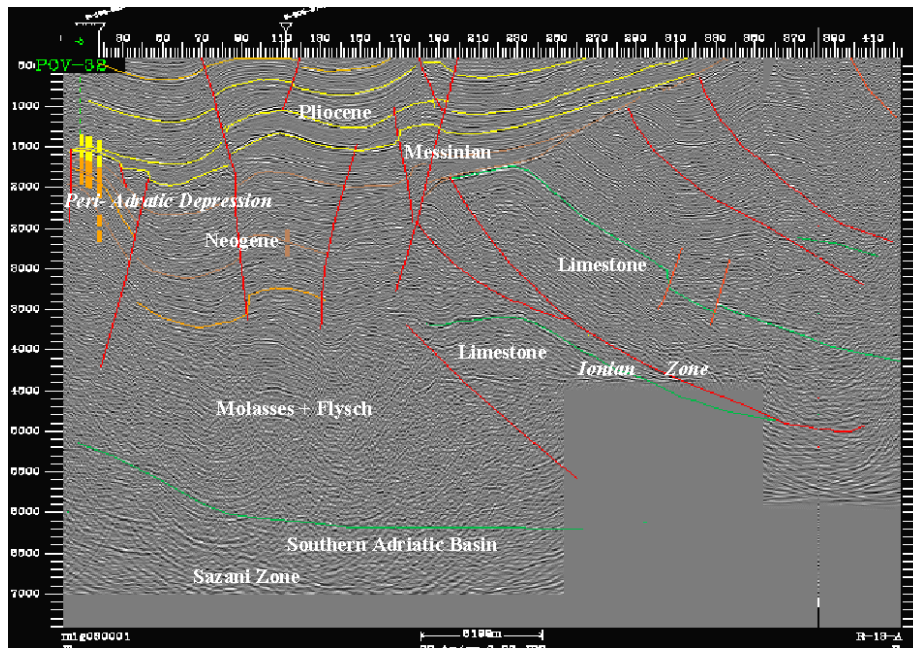


Fig. 20. Regional reflection seismic line in Ionian and Peri-Adriatic Depression.

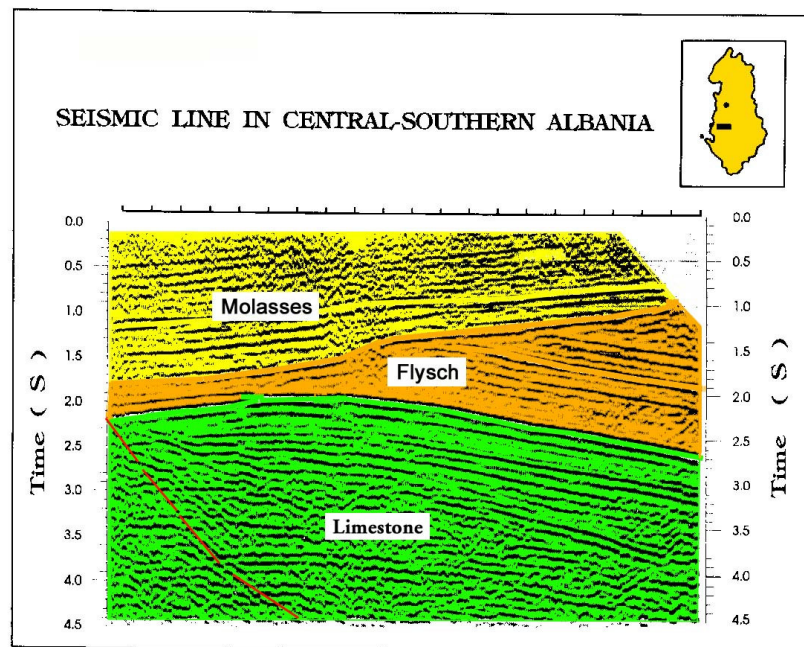


Fig. 20-a. Reflection seismic line in Ionian and Peri-Adriatic Depression.

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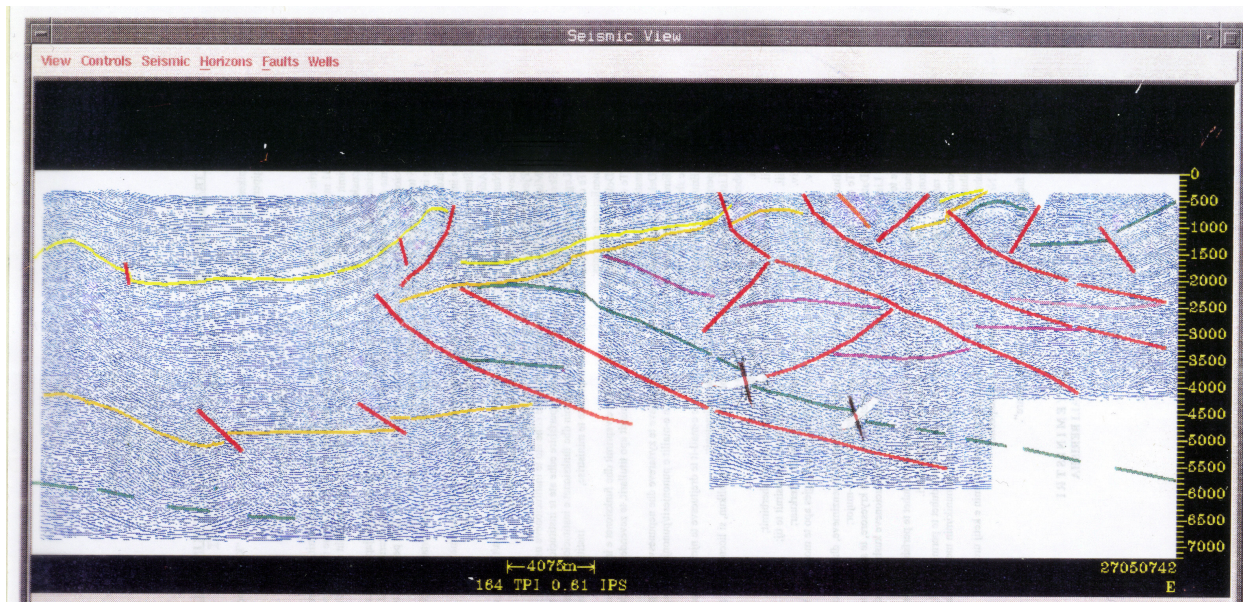


Fig. 20-b. Reflection seismic line in Ionian and Peri-Adriatic Depression (After AKH).

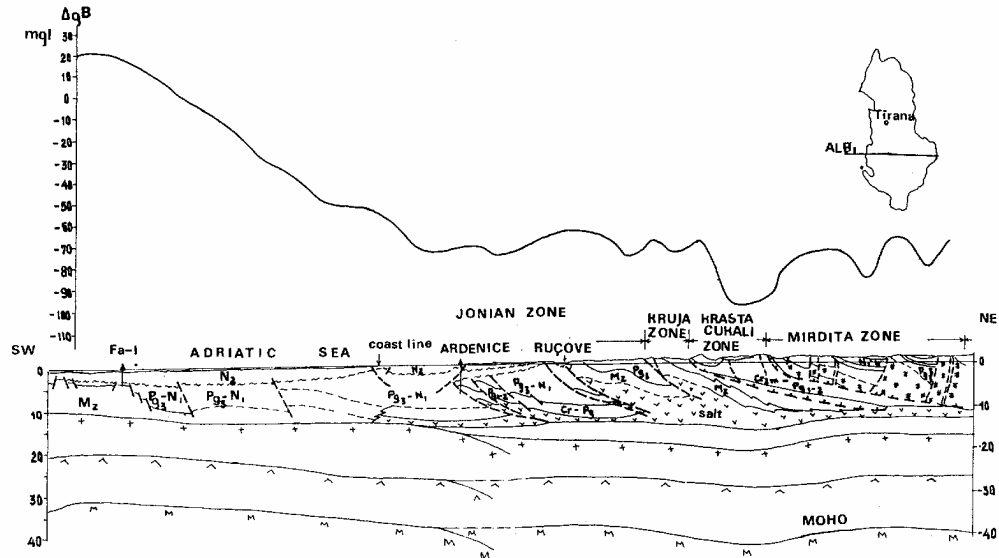


Fig. 21. Geological-geophysical profile Albanid-1: Falco Adriatic Sea- Seman-Kuçovë- Bilisht (The gravity data for the Adriatic Sea after Richetti, 1980).
Legend as in the fig. 8.

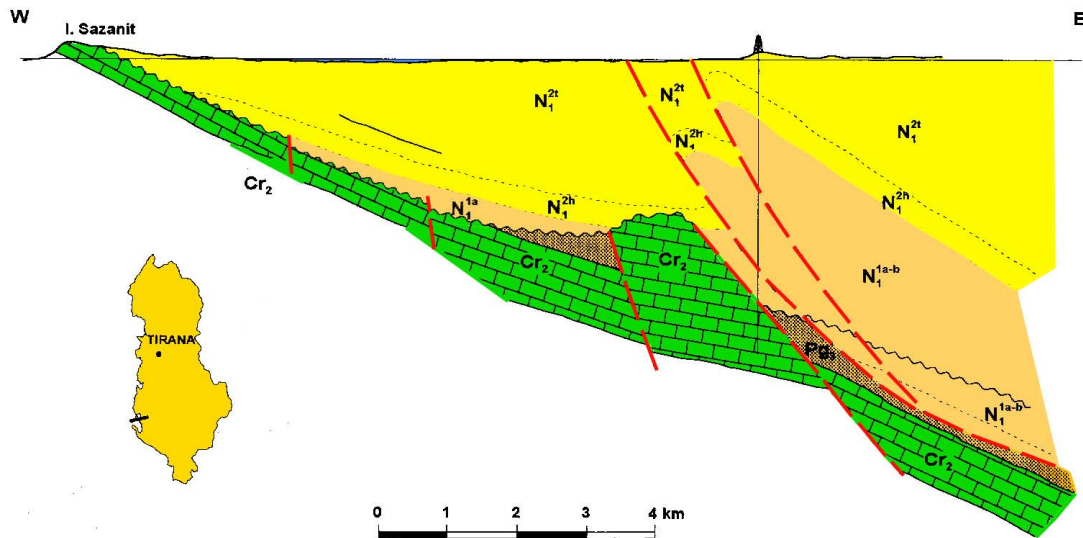


Fig. 22- Geological profile of Sazani-Zvërnec in Vlora district.

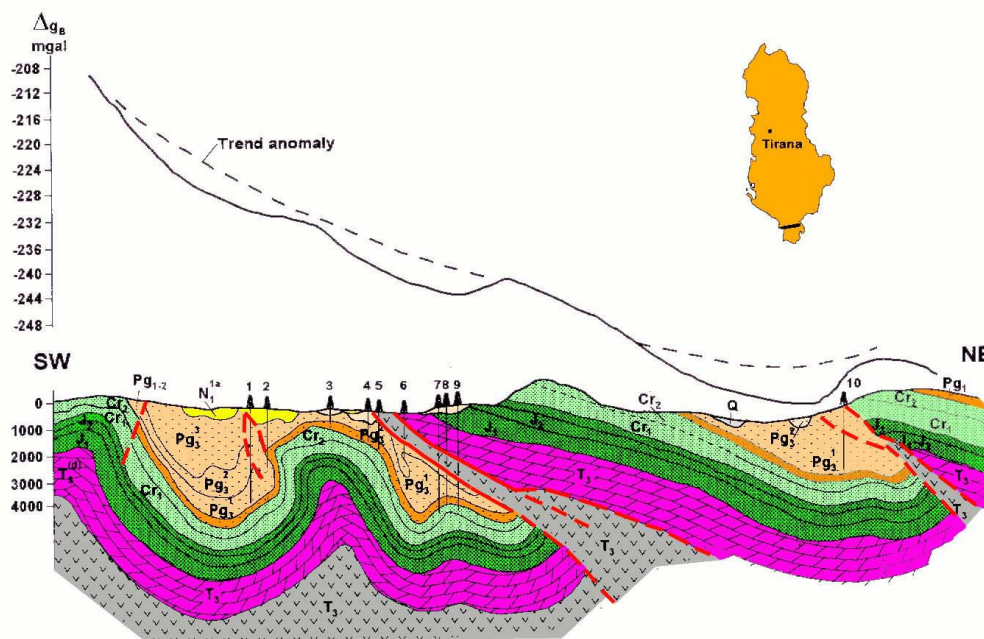


Fig. 23. Geological-geophysical profile: Saranda-Gjirokastra region.

1. Quaternary; 2- Pliocene; 3- Helevtian; 4- Burdigalian; 5- Aquitanian; 6- Upper Oligocene; 7- Middle Oligocene; 8- Lower Oligocene; 9- Lower Oligocene of suite Tomorri; 10- Eocene; 11- Paleocene; 12- Upper Cretaceous; 13- Lower Cretaceous; 14- Lower Jurassic; 15- Middle Jurassic; 16- Lower Jurassic; 17- Dolomites of the Upper triassic; 18- Upper Triassic with evaporites; 19- Paleozoic (substratum of Ionian zone); 20- Verified paleological boundary; 21- Supposed geological boundary; 22- Verified lithological boundary; 23- Supposed lithological boundary; 24- Transgressive boundary; 25- Lithological marker; 26- Verified fault; 27- Supposed fault; 28- Seismic reflector; 29- Normal attitude element; 30- Reversed attitude element; 31- Intersection of the seismic lines; 32- Trend of the Bouguer Anomaly; 33- Bouguer anomaly; 34- Depth wells.

Two main tectonic styles are distinguished in the Ionian zone: Duplex tectonic and imbricate tectonic styles. The backthrust faults have been caused by retrotectonic phenomena. The geodynamics of the Ionian zone is related with the evolution of the transversal tectonic faults. These faults have separated the Ionian basin in several blocks, since rifting time of lower and middle Jurassic. The periodical tectonic movement of the transversal faults has played an important role this overthrusting phenomenon, too.

In the regional reflection seismic lines through Ionian zone is clearly seen that during the structuring process of the Ionian zone, from upper Oligocene to Langhian, the underlying of southern Adriatic basin limestone and Sazani Zone has taken place (Fig. 22, 23).

5. **SAZANI** zone is the continuation of Apulian platform. A thick Cretaceous- Eocene limestone and dolomite section builds this). Marly deposits of Burdigalian are place transgressively over carbonatic formation (fig.22).

The interpretation of the recent geological geophysical data represents a new structural model and the tectonic styles of the External Albanides. Tectonic zones of the External Albanides are in compression tectonic regimen since upper Jurassic-Cretaceous periods. Only in western part, Apulian zone and South Adriatic basin, are in continues extension tectonic regimen. Over thrusting style of the south-eastern part of the External Albanides, with a great southwestward overthrust of the anticline chains, the presence of the old transversal faults at the present are well known. The lubrication substratum is represented by evaporites during the over thrusting movement. The regional neotectonic phenomena are also the back thrusting tectonic in the Ionian and Sazani zones. The formed structural-tectonic models are represented the results of interference of two main effects, that of southwestward over thrusting and that of secondary and newly northwestwards over thrusting.

6. PERI-ADRIATIC DEPRESSION

Overlying Peri-Adriatic Depression covers the Ionian, Sazani and partly Kruja tectonic zones. This is a fore depression filled with middle Miocene and Pliocene molasses, which are mainly covered by Quaternary deposits (fig.8, 20, 21, 24). Tortonian- Messinian- Pliocene molasses consist of a considerable number of sandy-clay mega-sequences. From south-east to north-west, the thickness of the molasses increases, reaching 5000 m. Sandstone-clay deposits of Serravalian and Tortonian are placed transgressively over the oldest ones, up to the limestone creating a two-stages structure (Fig. 20, 24).

During the molasses cycle, the structure and structural chains of the Ionian, Kruja and Sazani zones have increased the thrusting and back thrusting degree, as a result of a powerful tectonics development. This phenomenon often led to the formation of tectonic blocks, within the carbonatic section, of imbrication nature and to the partial and complete reaching of the expected anticline structures from the evaporites and the adjacent eastern structures.

The Albanian sedimentary basin continues even in Adriatic shelf with terrigene and carbonatic formations. In the different profiles (fig.8, 14) it is noticed that there exist some local Bouguer and magnetic anomalies in Adriatic shelf (Richetti, 1980). Some researches have reached the conclusion that the Apulian platform is tectonically quiet. The local gravity maximums coincide with minimums of the magnetic field: this is interpreted as due to the elevation of the top of carbonatic formation.

CROSS PROFILE BALLAJ – DIVJAKE – LUSHNJE

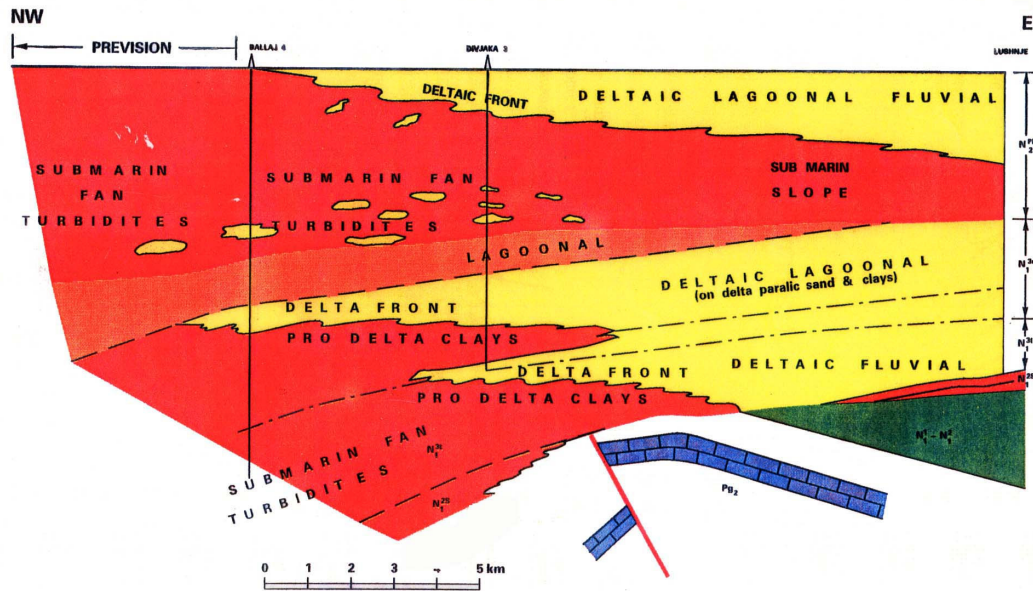


Fig. 24. Reflection seismic line: Divjaka brachianticline in Peri-Adriatic Depression.
(After Dyrnishi C).

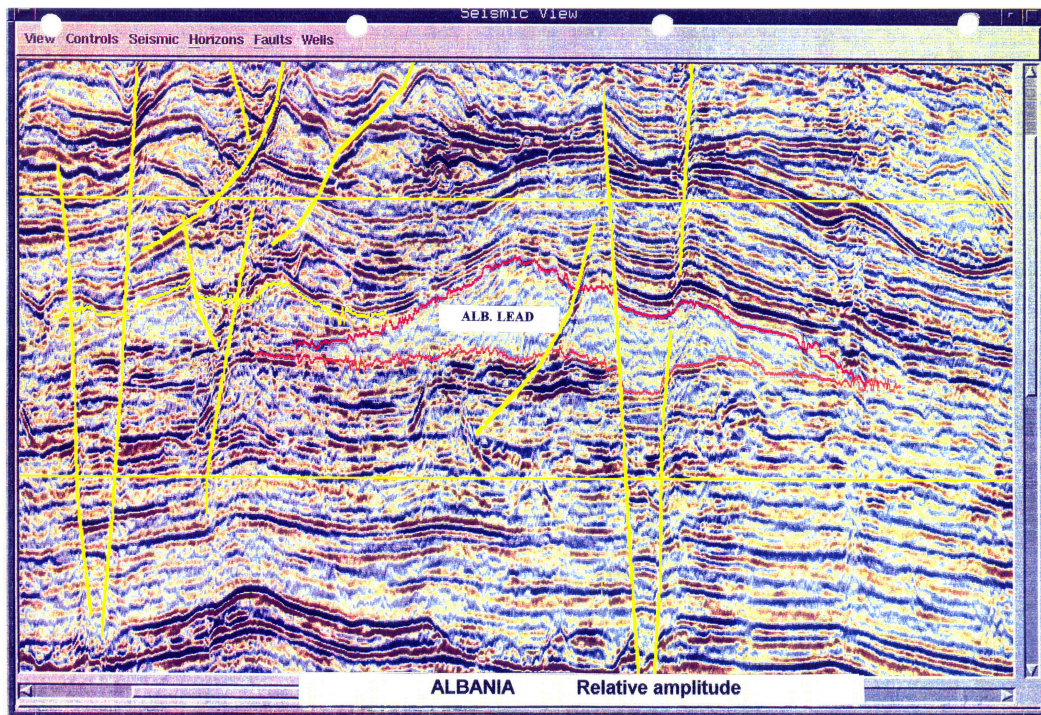


Fig. 24-b. Seismic line in Peri-Adriatic Depression (After AKH).

PALEOMAGNETIC OUTLOOK ON DYNAMIC EVOLUTION OF ALBANIDES

Dynamic evolution of the Albanides has its reflection in paleomagnetic data, collected from the paleomagnetic studies in Albania, which were performed during 90 years (Frasheri et Bushati 1995, Frasheri et al. 1995, Kane et al. 1999, Kissel et al. 1992, 1994, 1995, Mauritsch et al. 1991, 1994, Mauritsch 2000).

Paleomagnetic studies shows that Ionic and Kruja tectonic zones have support a joint clockwise rotation, with an angle $45-50^{\circ}$ during and after Eocene-Oligocene period. This rotation has been realized through two phases, by 25° every phase in the middle Miocene up to Plio-Pleistocene. Ionic and Kruja zones don't have any different rotation between each other. Vlora- Elbasan-Diber don't divided zones with different rotations of the central and northern part of the Albania. Consequently, maybe observed practically continuously evolution of the External Albanides zones from upper Eocene up to present (Fig. 25).

In the upper Miocene section in Peri-Adriatic Depression has been observed that between Oligocene and upper Miocene, the External Albanides zones have been subdued a clockwise rotation of $10-15^{\circ}$. In the clay of Pliocene section at Central Albania was observed 10° rotation, which have been supported External Albanides zones during the upper Miocene and lower-middle Pliocene. Has been evidenced also a clockwise rotation of the External Albanides and Internal Albanides younger than Tortonian, in the relation with general apparent polar displacement path from the Africa and Eurasia (Fig.26, 27). Eocene limestone anticlines of the Renz and Kakariq area, which are located in the Shkoder-Peje transversal zone, have a rotation about 31° . Consequently, these two anticlines have a declination with 18° smaller than the declination of the Eocene limestone in the Central Albania. These two anticlines maybe have superposition of two rotations with inverse sense: clockwise rotation of 50° , which has been subdued all External Albanides structures and local counterclockwise rotation by 25° , which has rotated only these two anticlines that have a Dinaride strike.

Limestone samples from Albanian Alps at Selca area, in the north of Shkoder-Peje transversal, shows a counterclockwise rotation for 20° in relation with present north, the same value as in southern Dinaride's structures.

The analogue counterclockwise rotation as in Selca area, have also Jurassic limestone at southern Shkodra lakeshore. This fact shows that both these sections appertain to the same tectonic zone, in northern of Shkoder-Peje transversal area. This lineament has great tectonic influence over Cukali subzone, where have observed changes of the sense of from counterclockwise to clockwise rotation in very short distances. In the northwestern edge of the Mirdita zone, at the Komani area of ophiolitic belt, have been observed declinations, which show the clockwise rotation of the effusive rocks and sedimentary ones.

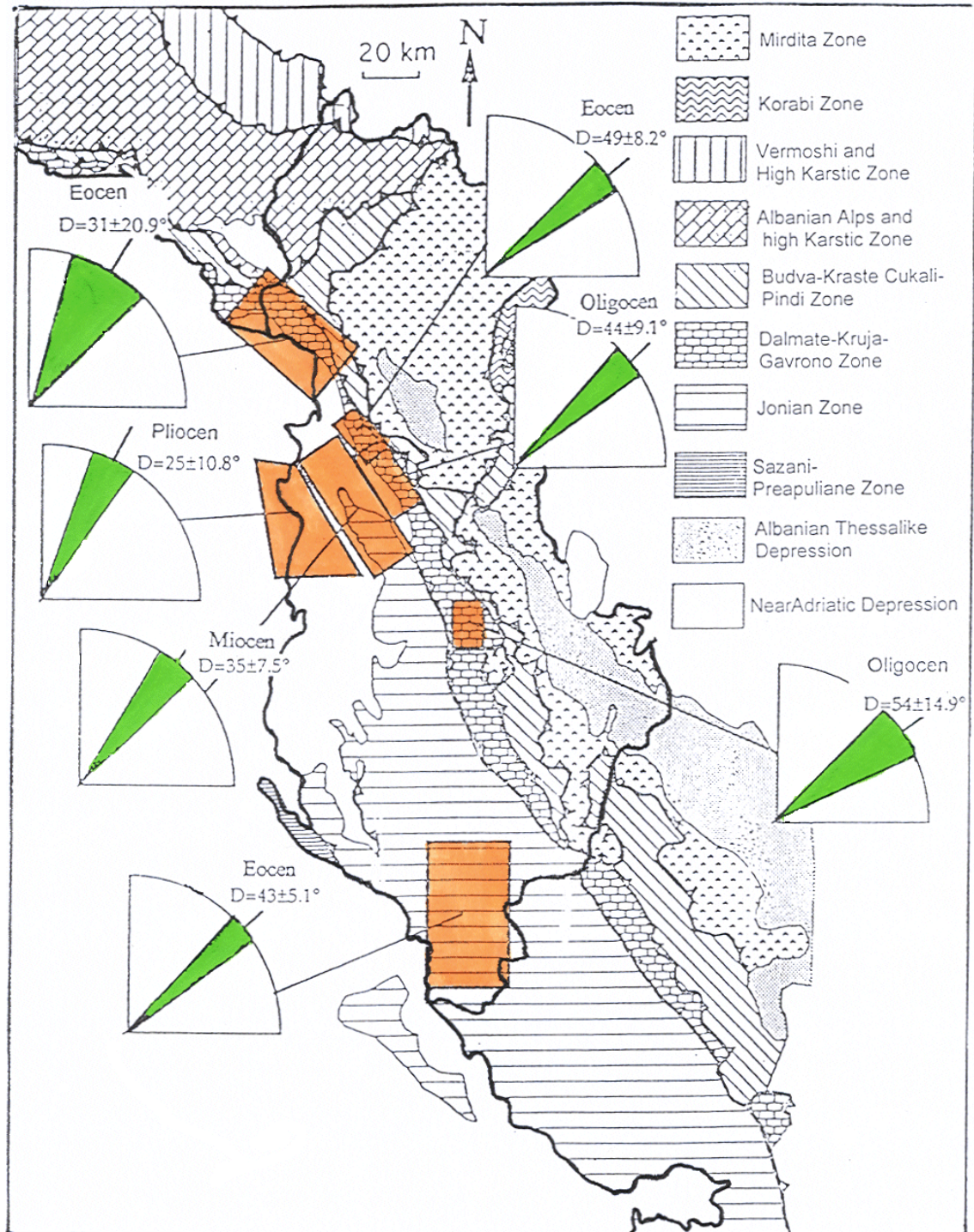


Fig. 25. Paleomagnetic Declinations Map of the External Albanides.
(After Kisel C. et al. 1994).

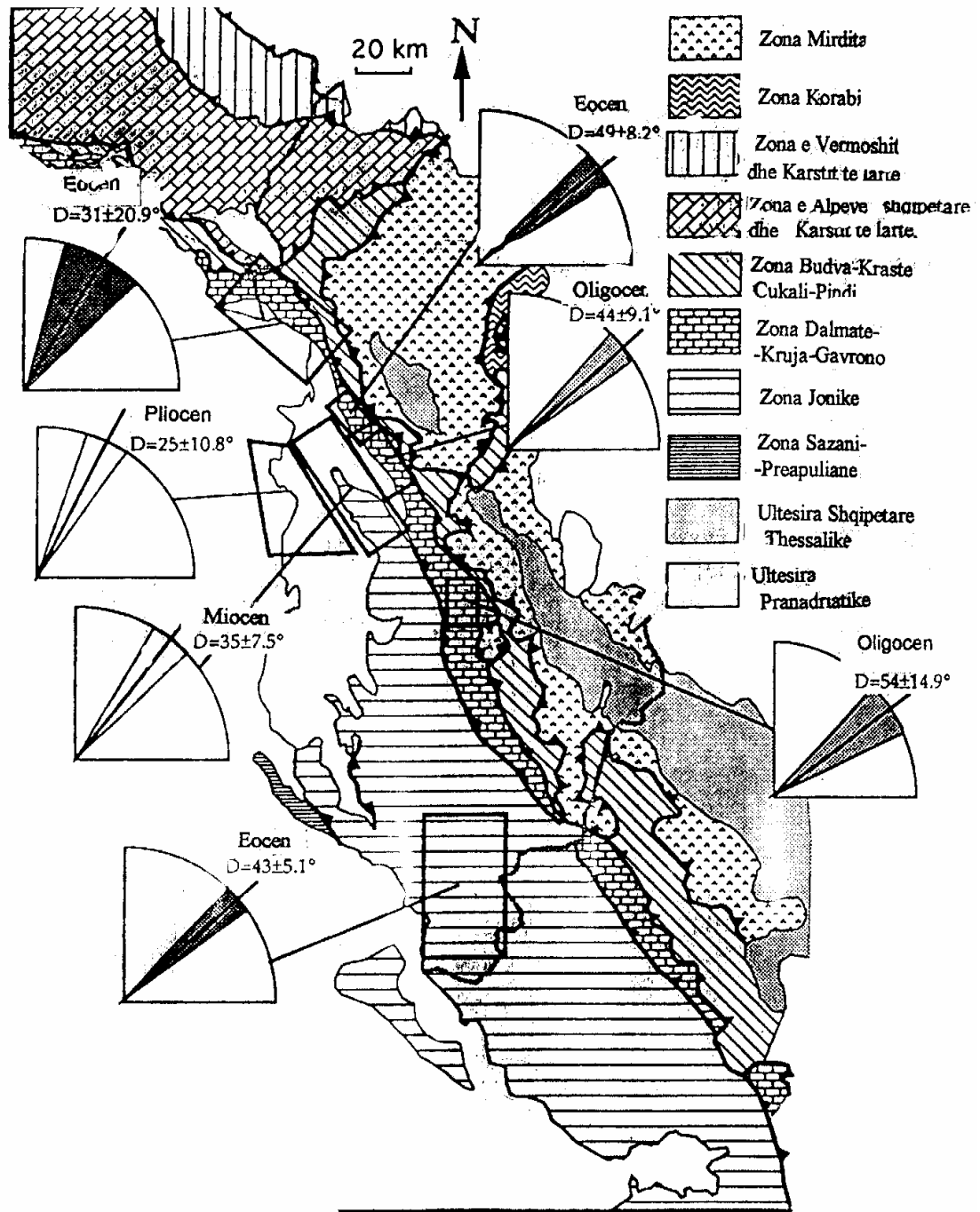


Fig. 26. Regional Paleomagnetic Declinations around Adriatic Sea and expected paleomagnetic declination for Africa during the Eocene-middle Pliocene period, (After Speranza F. 1995).

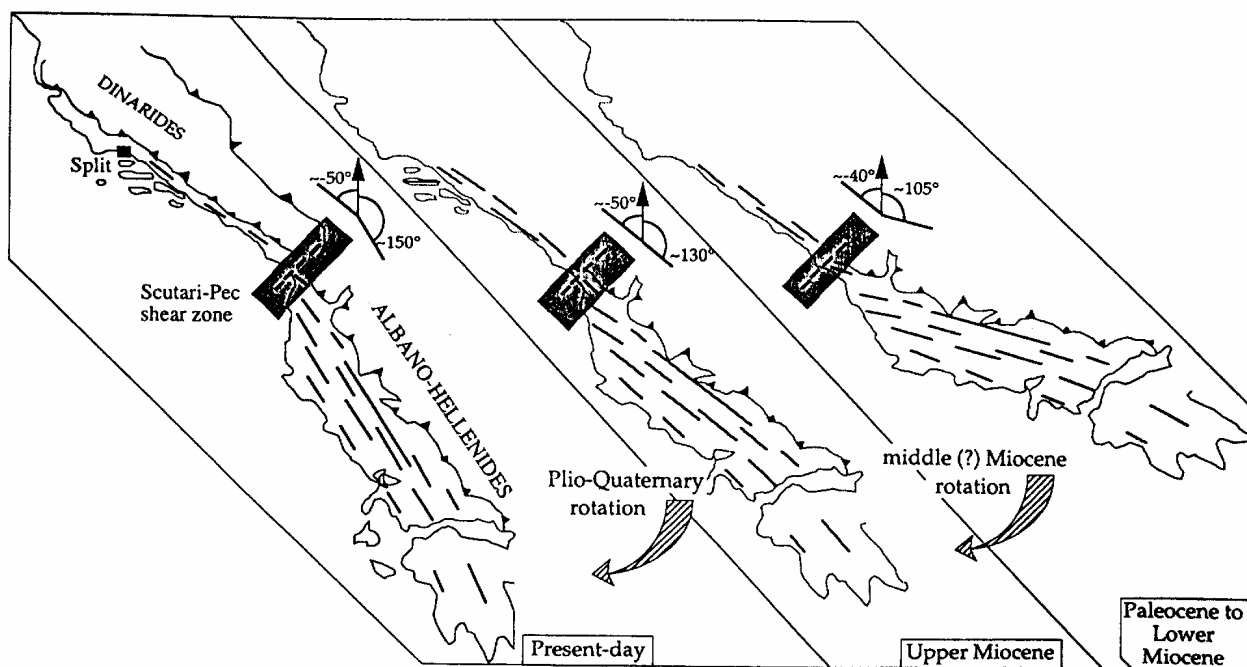


Fig. 27. Schematic evolution of the orientation of Albanides-Hellenides and Dinaride structures during the Cenozoic era, (After Speranza F. 1995).

Shkoder-Peje lineament forms the transition between two zones: of counterclockwise rotation of Albanian Alps and Dinarides to its north and clockwise rotation of the Albanides and Hellenides to its south.

Magneto-biostratigraphic studies which have been performed at Kçira area in Mirdita zone, shows that in the Spathian-Anisian section have observed alternation of normal and inverse magnetization. Kçira Pole presents affinity with Western Gondwana after restoration for the Neogene (Muttoni G. et al, 1996).

Results of paleomagnetic investigation of the samples from ophiolitic belt in Internal Albanides, from Qafëzezi in south of Korça district to the Kalimashi area in Kukësi ultrabasic massif in the north-east of Albania, shows the same declination as the Hellenides ophiolitic belt.

CONCLUSIONS

1. Albanides are presented the assemblage of geologic structures, which are extended in the Albanian territory. They are placed between Dinarides in North and Hellenides in South. The geophysical and geological studies have proved the presence of some tectonic zones, situated in two big paleogeographic zones, in the Internal Albanides and in the External Albanides.
2. Earth Crust of the Albanides has a block construction. The Earth crust in Albanides is interrupted by a system of longitudinal fractures in NW-SE direction and transversal fracture that touches the mantel. Some of them separate even the tectonic zones. With deep fractures are linked geothermal energy of the Albanides.
3. The Mirdita ophiolitic complex causes an obvious gravity anomaly chain and a turbulent magnetic field, relatively of low intensity. These data show about the allochthone character of ophiolitic belt. The interpretation of the gravity data reveals a big thickness of the ophiolitic belt of 6-14 km on the eastern belt of the ultrabasic massifs, while it is decreased up to 2 km on the West.
4. Tectonic zones of the External Albanides are in compression tectonic regimen since upper Jurassic-Cretaceous periods. Western part, Apulian zone and South Adriatic basin is in continues extension tectonic regimen.
5. The geophysical data show that the orogene front of Albanides is emplaced in Adriatic Sea. The Ionian and Sazani zones continue for a certain of distance in the Adriatic Sea Shelf. Both these zones are extended over the Apulian platform.
6. The relations between the Internal and the External Albanides have a southwestward nappe character.
7. Paleomagnetic studies have demonstrated that assemblage of the Albanides margin has supported a clockwise rotation with amplitude about 45°, after upper Oligocene. This rotation has been realized by two phases, analogue with the phases, which are observed in the western margin of the Hellenides. Shkoder-Peje transversal is represented a transition zone between the clockwise rotation of the Albanides and Hellenides and counterclockwise of the Dinarides. Horizontal displacement is about 173 km in southern Albania, for the rotation pole located at Shkoder-Peje transversal.

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$G_{B,t}$ - Trend of 2nd degree of Bouguer anomaly,

$G_{B,r}$ - Residual Bouguer anomaly,

T_t - Trend of the 2nd degree of total magnetic anomaly,

T_r - Residual of the 2nd degree of total magnetic anomaly,

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