XX Congress of the Carpathian Balkan Geological Association

Tirana, Albania, 24-26 September 2014

www.cbga2014.org

submission@cbga2014.org

Form

C

GENERALIZED GEOPHYSICAL OVERVIEW

ON SHKODËR-PEJË DEEP TRANSVERSAL FRACTURE

Frashëri A[1].; Bushati S.[2]; Frashëri N.[3]; Dema Sh.[4]

1. Faculty of Geology and Mining, Polytechnic University of Tirana; alfred.frasheri@yahoo.com
2. Academy of Sciences of Albania
3. Faculty of Information Technology, Polytechnic University of Tirana
4. Albanian Geological Survey

Abstract

The article presents an attempt to generalize the complex of geophysical data: Gravity, Magnetic, Paleomagnetic, Geothermal, Seismological and Remote Sensing of Cukali tectonic subzone, where it crosses the deep transversal fracture Shkodër – Pejë, as well as marine seismic data, and hydrological observations on the shelf of the Southern Adriatic Basin. Analyses of the results of these studies are based on regional geological setting data.

Regional geological-tectonic setting of Shkodër-Pejë sector of Mediterranean Alpine Folded Belt, presents the existence of this important disjunctive deep tectonics element. The geological surveys and detailed mapping at the scale 1:25.000 up to regional ones at the scale 1:200.000, does not have traced at the Earth's surface the outcrop of this thrust. Consequently, have brought about the different concepts on it: "scharung" (1901), "deviation" (1920—1930), "an accident" (1960), "transform transversal fault" (1970-2012), "transverse fault" (1990-2012), "deep transversal fracture" (2012), and to silence about its existence, even to denial of its presence. These changes in the course of a century, not just in terms of use, were related to different geological schools over the geological setting of the Albanides. This transformation of concepts, unfortunately even in our days in some studies, related to the fact that the geological hypothesis or theories about the geological-tectonic setting of the region, were formed solely on the basis of surface geological surveys, which undertake to presented geological setting to the Moho Discontinuity without geophysical data, as necessary to known the depth.

During the last two decades, the Shkodër-Pejë region was involved in geophysical surveys polygons. Gravity Bouguer Anomaly Map, Magnetic Anomaly Map, Paleomagnetic Studies, Heat Flow Density Map, analyze of the satellite imagery, have provided important information about tectonic setting in the depth of the region. This information, interpreted in complex with the existing geological-tectonic data has cast light on the depth of the area, where it crosses the transverse Shkodër-Pejë. They argued that it represent a deep transverse vertical fracture, which affects the Moho Discontinuity. Its amplitude at those levels is about 4 km. It decreases toward the Earth's surface, until extinguished in some segments. This fracture represent a wide belt, was also interrupted by the deep regional or lowest order longitudinal thrusts.

Key Words: Mediterranean Alpine Folded Belt, Shkodër - Pejë transversal, geophysical anomalies,

deep fracture, gravity anomalies inversion.

1. Introduction as a historic review

Hellenides-Albanides-Dinarides, branch of the Mediterranean Alpine Folded Belt, are interrupted by a deep transversal tectonic fracture in the Shkodër-Pejë segments. This fracture is correlated with contact between Eurasian and African Plates in Drini Bay in Adriatic Sea (Fig. 1-a, b, c). It has been Cvijich Jovan who described this fracture, calling "scharung" (Cvijich, 1901). Later, during the first half of last century, this "scharung" is called as "deviation" by Kosmat F. (1924); Koberh L. (1929), Nopca F., (1929); Bourcart J. (1919 and 1925); Novack E. (1929), Zuber S. (1940) et al. (Kosmat, 1924; Koberh, 1929; Nopca,1929; Bourcart, 1919, 1925; Novack, 1929, Zuber, 1940), or "accident" (Aubouin. & Ndoja, 1964), as an "element inherits of the Tethyan Ocean paleogeography" (Aubouin et al. 1970), and as "Faille transversale Scutari-Pec" (Çollaku & Cadet, 1991).

For almost several decades in Albanian geological studies, this fracture had not been mentioned, because the Albanides geological setting and its geologic history had been based on geosyncline's theory (Geology of Albania, 1970). Only later, some authors, who admit the opening of the Mirdita Ocean and interpreted this transversal as oceanic transform fracture. Shkodër-Pejë transform fault is represented by the north-western front of the ophiolitic belt (Kodra, et al. 1994, Melo, 1986, Melo, et al. 1991, Peza et al. 1971, Xhomo et al. 2002), or this transversal is represented by the northern border of Cukali subzone as natural geological border between Alps Zone and Cukali ones (Papa et al. 1991). According to Qirinxhi A., the co-author of Geological Map of Albania at scale 1:200.000, is important to show that the existence of Shkodër – Pejë thrust and its position cannot being observed and mapped during geological field surveys, but, perhaps, exist in the depth (Qirinxhi et al. 1983, 1991). The seismological studies have argued the presence of an active fault zone according to the well known Shkodër-Pejë direction (Aliaj, 1988, Muço et al. 2001, and Sulstarova, et al. 1972). According to Aliaj Sh. "…the Shkodër-Pejë transverse fault dividing Dinarides from the Hellenides" (Aliaj, 1988, 2006]. The above interpretations regarding the Shkodër-Pejë fracture also have resulted in alternative of the geological opinion concerning its position.

During the last quarter century, the remote sensing study has observed some tectonic lineaments along the Shkodër-Pejë transversal zone (Chorowicz, et al. 1981).

2. Methodology of Study

Geologic-tectonic settings of Shkodër-Pejë region is included in the regional Geological Maps of Albania, by Nopça F. (1929), Novack E. (1929), and Zuber S. (1940), in the Geological Maps of Albania at the scale 1:200.000 (1967, 1983, 2002), and in the Tectonics Map at the scale 1:200.000 (1984), Neotectonics Maps of Albania, and seismicity studies (Sulstarova E. et al. 2011). Detailled geological setting of the Kiraj-Ndreaj-Brashtë in Cukali zone was presented in the Geological Map at the scale 1:25.000 (Qirinxhi A. et al. 1983). Already avalaible are the results of integrated surveys and studies, which include Shkodër-Pejë fracture zone (Frashëri A. et al 2009).

The seismicity of Albania was study by analyze of the historical and instrumental data, and the distribution in time and space of the seismic activity in Albania and surrounding areas, which covers a period of about 2000 years (SulstarovaE et al. 2011, Aliaj A. 1988, Sulstarova E.1986, Tagari Dh.1993, Muço B., 1994). The seismic hazard estimation of Albanian territory, which presents a part of the seismological studies, is accompanied and with important geological information to investigated the Earth Crust structure of Albanides.

Have been compilated the Map of Gravity Bouguer Anomalies of Albania [Bushati S., 1988] and Map of Total Magnetic Vector (T) of Albania (Bushati S., 1998) at the scales 1:200.000. For the Shkodër - Pejë area have been observed also two detailled profiles (Fig. 1-b). Gravity and magnetic surveys were accompanied with density and magnetic properties of the rock, and detailled geological studies (Qirinxhi A. et al. 1983).

The dynamic evolution of the Albanides is recorded in the paleomagnetic data, collected from the paleomagnetic studies in Albania during 1991-1995 (Mauritsch H.J., et al 1991, 1994, Kissel C. et al, 1992, 1994, and 1995, Mauritsch H.J., et al. 1995, Speranza F. 1995, Frashëri A. and Bushati S. 1995).

Geophysical investigation has provided some information related to the crystal basement of Albanides (Aliaj Sh. 2006; Frashëri A. et al. 1991, 2004, 2010; Bushati S. 1988, 1998; Koçiu S. 1989). In particular, was analyzed the propagation of the Earth Thermal Field (Frashëri A. et al. 2004). Have been observed marine currents, waves, water salinity and temperature at various depth, as well as Earth Heat Flow Density at the sea bottom in the ofshore of Drini Bay, at the south-western edge of Shkodër - Pejë fracture zone (Frashëri A. et al. 2011, Geothermal Atlas of Europe, 1992).

Remote sensing based on Landsat and Modis data was used to identify some regional geological features and analyse the ground temperatures.

3. Results and discussion

Complex methods used for studies also in northern Albania and in the Adriatic Sea have brough the new information of great value for the Albanides depth, and which throw light on the Shkodra - Peja fracture zone. Geophysical investigation results show that crystal basement of Albanides has a blocks character (Fig. 2) (Bushati S., 1988, 1998, Koçiu S., 1989, Frashëri A. et al. 1991, 2010). Thickness of the location of these blocks is shallower in Mirdita Tectonic Zone. The crust construction and their dynamics are reflected in the geological setting of the Albanides tectonic zones, and their tectonic styles. Block structure controlled by a system of NW-SE longitudinal faults as well as transverse ones. Local heat hearths put in evidence the transversal faults. Geothermal energy is related with a great heat flow through these fractures (Fig. 3) (Frashëri A. et al. 2004).

The Shkodër-Pejë deep fracture represents one of deep thrusts, which transversally divides Albanides in two parts (Fig. 3, 4). In northern part are including western-northern edge of Kruja tectonic zone, northern part of Cukali zone, Albanian Alps and Gashi zones, which follow by the Dinarides tectonic zones: Budva, High Karst, Dalmate, Durmitor, Serbian, and Golia zone. In the southern part of the Albanides, represented by Sazani, Ionian, southern part of Cukali zone, Krasta-Cukali, Mirdita and Korabi tectonic zones, which follows by the Hellenides. This deep fracture generally considered a multi phase's transversal tectonic faults zone, with a north-eastern extension of about 30^o. Consequently, Shkodër-Pejë deep fracture divides two big areas with different geological settings and developing geological history, but not only in the continent, also to the orogenic front in the Adriatic Shelf.

The Albanian orogenic thrust front is cut and displaced by the Othoni Island-Dhërmi, the north of Sazani Island, and the Gjiri i Drinit-Lezha strike-slip faults (Fig. 5) (Aliaj Sh., 2006). The orogenic front, north of the Drini Bay-Lezha town strike-slip fault, in the Adriatic offshore, belongs to the Kruja Zone. During the Tertiary phase, this strike-slip fault functioned as a right pushing, being shifted towardsthe south-western inner zones (Sulstarova E. et al. 2011). Ophiolitic Belt of the Mirdita Tectonic Zone is displaced more than 100 km south - west. In outer zones, at the transversal Drini Bay - Lezha Town, cut and displaced front thrust of the orogen (Sulstarova E. et al. 2011).

Offshore seismic surveying at the Montenegrin Adriatic shelf and deep wells (Dragasević T. 1983, Picha F.J. 2002) very well have enlightened geological setting at the depth on the western edge of Shkodër-Pejë deep thrust in the Adriatic shelf (Fig. 6, 7).

Onshore geological surveys from Adriatic coast line-Shkodër-Cukal-Tropoja have mapping two regional disjunctive tectonics in northern southern borders of Cukali subzone, divided this subzone from Alps zone and Mirdita zone, respectively (Fig. 4). For this transversal fault's zone were an alternative: as a transform tranversal fault, aligned with the overthrust tectonic in the northern boundary of the Mirdita zone (Kodra A. et al. 1994, Xhomo A. et al. 2002), or as a tectonique border between Cukali and Alps zone as natural geological border between them (Papa A. et al. 1991). Intensively folded structure of the Cukali subzone has northwest-southeast strike. From surface geological data, ranging from the Permian rocks of Albanian Alps tectonic zone, the Upper Triassic - Maastrichtian- Paleocene - Eocene rocks in Cukali subzone, and also from all magmatic and sedimentary rocks that spread of the Mirdita zone at the surface, had not been deduced any arguments which can help to accept the presence at the surface of the Shkodër-Pejë transversal fault (Qirinxhi A. et al. 1983). In contrast with surface geological surveys, the geophysical studies have provided information on the presence of the regional transversal deep thrust through Cukali subzone.

3.2. Gravity and Magnetic data

Scattering of gravity and magnetic fields have very well contoured Inner Albanides, particularly the ophiolitic belt (Fig. 8, 9). Bouguer gravity anomaly and magnetic ones have common peculiarities: a) epicenters are located over the eastern belt of the ophiolites; b) Ophiolitic belt represented in two parts: northern and southern, separated by flyschoid corridor; c) gravity and magnetic anomalies are very intensive, compared with Internal Albanides. These pecularities and anomaly configuration have argued the nape character of the ophiolitic belt [Frashëri A. et al. 1991, 2010].

According the gravity and magnetic surveing (Bushati S. 1987), Alps zone represented by a minimum of Bouguer gravity anomaly in general, with particularly a small amplitude anomaly in southern part of the Alp's zone (Fig. 8). In the northern direction there are observed the trend of the increasing of the intensivity of magnetic anomaly. This pecularity of the magnetic anomaly express overthrust character of the Albanian Alps, too. Over the Cukali subzone is observed a linear upward trend of the intensity of the Bouguer anomaly toward the Mirdita zone (Fig. 8, 10). This trend's anomaly can explained by the presence of the vertical deep tectonic thrust.

After the inversion model, thrust level resulted with amplitude about 4km in the Moho Discontinuity (Fig. 10). Thrust amplitude toward the Earth's surface is gradually reduced and, until the surface of the Earth, is almost extinguished, also according to the geological mapping. This deep thrust represents Shkodër - Pejë fracture. By analogy with the deep strike-fault in the Adrietic Shelf Crust (Fig. 7) and this, Shkodër - Pejë deep fracture, at the depth expected to be composed by several branches, occupying a wide zone of their influence and action.

3.3. Paleomagnetic surveys - an important indicator of the presence of Shkodër - Pejë deep fracture and its geodynamic evolution role in Alpine Mediterranean Foldet Belt Hellenide-Albanides-Dynarides

Dynamic evolution of the Northern Albanides has its reflection in paleomagnetic data, collected from the paleomagnetic studies in Albania, which were performed during 90 years, performed by Mauritsch H.J. et al. (1991-1995), Kissel C. et al. (1992-), Muttoni G. et al (1940), Frashëri A. and Bushati S. (1995) [Frashëri A. et al., 1995; Kissel C. et al., 1995; Mauritsch H.J. et al., 1995, 2006, Mauritsch H.J. 2000, Muttoni G. et al. 1994, Speranca F. 1995]. Paleomagnetic studies shows that Ionic and Kruja tectonic zones, located at southern side of the Shkodër - Pejë transversal, have support a joint clockwise rotation, with an angle 45-50^o during and after Eocene-Oligocene period. This rotation has been realized through two phases, by 25^o every phase in the middle Miocene up to Plio-Pleistocen. Ionic and Kruja zones don't have any different rotation between each other. Clockwise rotation for 40^o-45^o since Early-Middle Miocene is observed at Kçira site. For this rotation, the Kçira pole acquires a West Gondwana affinity [Mutoni G. et al. 1996]. A large Neogene clockwise rotation, D=40^o, I=3.8^o, is observed also in the Mirdita zone of Inner Albanides, at southern Albania, northern of Albanian-Greek border [Mauritsch et al., 1994].

Eocene limestone anticlines of the Renz and Kakariq area, which are located in southern side of the

Shkodër - Pejë transversal zone, have a rotation about 31^o. Consequently, these two anticlines have a declination with 18^o 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^o, which has been subdued all External Albanides structures and local counterclockwise rotation by 25^o, which has rotated only these two anticlines that have a Dinaride strike.

At the Komani area, in the southern side of Shkodër - Pejë transvesal, at north-western edge of the ophiolitic belt of Mirdita zone, have been observed declinations, which show the 82^o-140^o clockwise rotation of the Jurassic limestone. The same 28^o-57^o clockwise rotation is observed for ultrabasic rocks of western edge of the Gomsiqe massive, at south-western direction from Komani (Fig. 11). Gabro massive at Bozhaj, southern of Korça city have a magnetization vector with declination Do=282^o and inclination Io=60.9^o, the same direction as in the Khalkidhiki in Greece (D=240^o-312^o and I=30^o-68^o), which have demonstrated an Upper Cretaceous anti-clockwise rotation, and Upper Tertiary clockwise rotation of the Khalkidhiki [Feinberg H. et al. 1996].

Limestone samples from Albanian Alps at Selca area, in the north of Shkodër - Pejë transversal, shows a counterclockwise rotation for 20^o 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 Shkodër-Pejë transversal area.

The Kotori to the Split area, which belongs to the Dinarides in Dalmatia in the North is almost immovable for the time period being studies starting from the Eocene onwards. Dinaride's orogen in the north are characterized by the regional direction f the structures N12^o, unlike the Albanides orogen structures with a direction N150^o, as in southern Hellenides [Kissel C., 1994; Mauritch H.J. et al 1993, 1995, 2006; Mauritch H.J. 2000]. Paleomagnetic studies in the external Dinarides have shown that this orogen has no any significant counter-clockwise rotation in relation to Africa, ranking from the Eocene, such small rotation that is observed in limestone of the Albanian Alps to the southern shore of Shkodra Lake.

Paleomagnetic directions demonstrate a strong tectonic disturbance in the Central part of Shkodër - Pejë zone. In the Jurassic limestone of the northern side of Cukali subzone, about 4 km northwest of Prekali village, is observed a country-clockwise rotation for about 45^o. Only in less than 2 km south, a 60^o clockwise rotation is observed. Such result attests to the strong tectonic influence in transversal thrust zone.

Paleomagnetic studies have demonstrated that Shkodër - Pejë belt presents a transition zone between counter-clockwise rotation in the north, and clockwise rotation in the south sides (Fig. 11, 12). Consequently has a great tectonic influence over Cukali subzone. Thus, Shkodër-Pejë lineament, defines a transition zone which separates the Albanian Alps and the Dinarides (counterclockwise rotation), from Albanides and Hellenides (clockwise rotation). For the rotation pole located at Shkodër - Pejë transversal thrust, Southern Albania has undergone a horizontal displacement is about 173 Km [Speranza F., 1995].

3.4. Seismological pecularities related to Shkodra-Peja seismoactive tranversal fault zone

Seismological studies carried during the last half of century in Albania have mapping seismoactive longitudinal and transversal deep tectonic fault zones of the Albanides. Among them is situated the Shkodër - Pejë transversal fault zone (Fig. 13 and 14). (Muço B., 1984; 1991, Sulstarova S. et al. 2011). Shkodër - Pejë transversal fault zone divided in two segments the northern part of the Ionian-Adriatic thrust fault zone, which presented the longest fault zone along the Adriatic and Ionian coasts. Based on focal mechanism solution, results that in Northern littoral side of the Shkodër- Pejë fault zone, the compression strain has a P=16^0 NE-W strike, and 10^0 plunge, while the axis of expansion T = 124^0 and 79^0 dep. In the Southern side of the Shkodër- Pejë fault zone, the compression strain has a P=274^0 E-W strike, and 10^0 deep, and the axis of expansion T = 164^0 SE-NW and 64^0 deep (Sulstarova, 1988, Tagari (1993). In the internal area, region Vau i Dejes-Pukë-Tropojë, the tensional stress regime has a NWN extending (Muço B. 1994, Sulstarova 1988).

Offshore geophysical explorations have discovered a deep fractures zone in the Adriatic Sea between Buna River discharge and Kotorri Estuary, about 15-20 km from coastline, with the NW strike direction. In this Adriatic offshore area, near Albanian-Montenegrin border, at the northern side of the Shkodra - Peja fault zone, was located focus of earthquake, 15 April 1979 (Sulstarova E. et al. 2011). The analyze of the seismic P waves velocities (Vp) and ratio Vp/Vs show that exist a difference between upper part of the Earth Crust (0-30 km) in the both side of the Shkodra-Peja fault zone [Ormëni Rr., 2010].

The stress field, the fault system and the spatial distribution of the seismic activity shows that the Albanian territory and the surrounding areas is constructed by many blocks which move relatively to each other due to the collision of two great plates, the Eurasia and African ones, in the region of the Adriatic promontory of African plate [Sulstarova et al. 2011]. All seismological features indicated above argues that Shkodra-Peja transversal present a deep fracture, a relatively wide active fault zone that separates the paleogeographic units with different geological settings, and dynamic of their developments.

3.5. Heat Flow density anomalies

Geothermal studies at Northern Albania have been performed in 19 boreholes and in one deep well. Heat Flow Density anomalies axes are presented in Fig. 3. Two of them are located in the unic axis, which extends from northeast to southwest, over the overthrust tectonics in the northern border of the ophiolitic belt. Thirty axes is located in Keçel village in eastern site of the Kukesi ultrabasic massif. The heat flow density values are up to 60-70 mW/m^2. Radiogenic heat generation of the ophiolites is very low. In these conditions, increasing of the heat flow in the ophiolitic belt is linked with heat flow transmitting from the depth. The granites of the crystalline basement, with the radiogenic heat generation, represent the heat source. Heat flow anomalies are conditioned by intensive heat transmitting through deep and transversal fractures. By comparing these characteristic of the thermal field and zone geological setting with structure of the strike-fault system in southwestern side of the Shkodër - Pejë transversal in Adriatic Shelf, we assume that this thermal anomaly associated with the branches of transversal fracture.

The thermal anomaly over the Adriatic Shelf, is observed at the epicenter in Drini Bay (Fig. 15) (“Geothermal Atlas of Europe”, 1992). In the same time, this thermal anomaly epicenter is located over the prolongation into Albanian Adriatic Shelf of Shkodër - Pejë transversal deep fracture. These facts show that the Shkodër - Pejë transversal deep thrust continues even in the Adriatic Shelf, where interrupted with Adriatic longitudinal strike-slip fault system.

3.5. Remote sensing and GIS information

First study by Landsat imagery has presented a sketch of thrust tectonic in Northern Albania, which differenced clearly main segments of Shkodër - Pejë transversal fault (Fig 16) (Chorowich J. et al. 1981). According to the geophysical studies results above indicated, as well as satellite image, have paved Shkodër – Pejë tranversal fault (Fig. 17).

Based on GIS and seismological investigations were determined velocities of microplates movement in Adriatiuc Sea. Nubia (Africa) microplate is moving NW with respect to Eurasia with a velocity of 6 mm/yr, while the Adria microplate moves NE at a rate of 4-5 mm/yr (Fig. 18) (Battaglia M. et al. 2004). Adria is considered as an independent microplate within Nubia – Eurasia plate boundary one (Nocquet J.M. et al. 2001), which is divided by Gargano-Dubrovnic fault in two blocks (Oldov et al. (2002). In the frame of these interpretation data is necessary to discussed also the position of NW edge of Otranto Street, which is located in the direction of the Shkodër-Pejë deep transversal fault in the eastern Adriatic Shelf, that result parallel with Gargano – Dubrovnic fault zone (Fig. 19).

Usage of satellite imagery for identification of geological structures resulted difficult because of two factors: vegetation coverage of the area and soil coverage of rocks. Nevertheless in different band combinations from Landsat it is possible to distinguish two areas separated during the same delineation of Shkodra – Pejë fault (Fig. 20). Analysis of ground temperature from MODIS images was done calculating the average for day and night temperatures from 24 images spanned in the period 2004 – 2006. In these images it is visible a "bridge" of relatively higher temperature delineated between Shkodra and Peja (Fig. 21).

4. Conlusions

1. Earth Crust of the Albanides exhibits a block structure controlled by a system of NW-SE longitudinal faults as well as transverse ones. The blocks have different thickness.
2. According to the gravity data inversion, Shkodër-Pejë zone present a vertical deep transversal fracture, which separate two Earth crust blocks. Fracture interrupts the MOHO Discontinuity with amplitude about 4 km that decrease towards the Earth surface. This fracture represents a seismically active belt. Based on satellite image, this vertical fracture outcropped through Cukali subzone.
3. Paleomagnetic studies have demonstrated that assemblage of the Albanides margin encountered a clockwise rotation of about 45^{o}, after upper Oligocene. Shkodër-Pejë transverse fault represents a transition zone between the clockwise rotation of the Albanides and Hellenides and the counterclockwise of Albanian Alps on e and Dinarides. For the rotation pole located at Shkodër-Pejë transverse fault, the horizontal displacement is about 173 Km in Southern Albanian border.
4. Continuation of Shkodër-Pejë fracture in the Albanian Adriatic Shelf in Drini Bay passes over the epicenter of Heat Flow. This correlation argues relation of the geothermal anomaly with depth fractures of the Earth Crust in Adriatic Shelf.

References

Aliaj Sh., 1988, Features of the neotectonic structures of Albania. (In Albaniua, abstract in french) Geographical Studies, **3**, 37-53.

Aliaj Sh., 2006. The Albanian orogen: Convergence zone between Eurasia and the Adria microplate. The Adria Microplate: GPS Geodesy. Tectonic and Hazards, NATO Science Series, **IV**. Earth and Environmental Sciences, Vol.**61**, 133-149..

Aubouen, J., and Ndojaj, I., 1964, Regards sur la géologie de l'Albanie e sa place dans la géologie des Dinarides : Bull. Soc. France (**97**) **VI**, 593-625.

Aubouen J., Blanchet R., Cadet J.P., Celet P., Charvet J., Chorowicz J. Cousin M., Rampou J.P. .1970. Essai sur la geologie des Dinaride. B.S.G.F. (**7**), **VI**, 593-624.

Battaglia M., Murray M.H., Serpelloni E., and Bürgmann, 2004. The Adriatic Region: And independent microplates within the Africa-Eurasia Collision one. Berkeley Seismological Laboratory, Annual Reports. http://seismo.berkeley.edu/annual_report/ar03.

Bushati S**.,** Dema Sh. 1985. Gravity Map of Albania at the scale 1:200.000. Geophysical Center, Tirana.

Bushati, S., 1988, Regional study of the distribution of gravity field of the Internal Albanides, for tectonics and metallogenic zoning (In Albanian): Ph.D. thesis Polytechnic University of Tirana.

Bushati S. 1997. Total magnetic field anomalies of Albania, at the scale 1:200.000. Geophysical Center, Tirana.

Cadet J.P., Bonneau M., Çollaku A., 1991. Sur la position de l'Albanie dans le systeme Dinarico-Hellenique. Séance spécialisée de la Societe Geologiqiue Francese (S.G.F.) Colloque sur la "Gologie de l?Albanie", Paris, 12-13 Avril, 1991.

Chorowich J.. Cadet J.P., Stephan J.F., 1981. Le secteur tranversal de Scuari-Pec: apports de l'etude de la fracturation à partir does donne Landsat. B.S.G.F. (**7**), **XXIII,** 217-228.

Cvijiç J**.** 1901. Die Dinarics Albanische scharung-sitzba. D.Kais Ak. D. wiss. Bt.CX. Wien, 1901.

Çollaku A., Cadet J.P., 1991. Sur L'Allochtone des Albanides: Apport des donnes de L'Albanie Septentrionale. (In French, resume in Albanian). Symposium «Thrust tectonics in Albania. Bulletin of Geological Sciences, **1**, 255-271.

Dercourt J. , 1967. Sur l'accident de Scutari.Pec, la signification paléogéographique de quelque series condense en Albanie Septentrionale. Annales Soc. Gel. Du Nord, t. 98, p. 109-117.

Dietrich D., Carnevale G.F., and Orlandi P. 2002. Adriatic simulations by DieCAST. Center for Turbulence Research , Proceedings of the Summer Program 2002, 269.

Dragasević T**.,** 1983 - Oil geologic exploration in the Montenegro offshore in Yugoslavia. Nafta, **34** (**7-8**), 397-404.

Frashëri A., Bushati S., Bare V., 2009. Geophysical outlook on structure of the Albanides. Journal of Balkan Geophysical Society (JBGS), Vol. **12**, 9-30.

Frashëri **A**., Cermak.V., Doracaj M., Lico R., Safanda J., Bakalli F., Kresl M., Kapedani N., Stulc P, Malasi E., Çanga B., Vokopola E., Halimi H., Kucerova L., Jareci E., 2004. Atlas of Geothermal Resources in Albania. Published by Faculty of Geology and Mining, Polytechnic University of Tirana and Academy of Sciences of Albania.

Frashëri, A**.**, and Bushati, S., 1995, Paleomagnetic outlook on geodynamics of Albanides (In Albanian): Report Faculty of Geology and Mining, Polytechnic University of Tirana, Geophysical-Geochemical Center of Tirana.

Frashëri N**.**, Pano N., Frashëri A., Bushati, 2011. Outlook on seawaters dynamics and geological setting factors for the Albanian Adriatic coastline developments. EGU 2011, Wiena.

Feinberg H., Edel B., Kondopoulou D., Michard A., 1996. Implications of ophiolite palaeomagnetism for the interpretation of the geodynamics of Northern Greece. The Geological Society.

Geološko-Tektonska Karta SAP KOSOVO. Industprojekt-Zagreb OOUR ZA KOMPLEKSNA GEOLOŠKA ISTRAŽIVANJA , 1:100.000, 1974 ZAGREB.

Geothermal Atlas of Europe, 1992.[Eds. Hurtig E., Çermak V., Haenel R. and Zui V.], International Heat Flow Commission, Herman Haak Vertagsgesellschaft mbH, Germany, 156 and 25 Map Plates.

Institute of Geologinal &Mining Studies and Design. 1970.Geology of Albania. Explanatory text of Geological Map of Albania, at the scale 1:200.000. (in Albanian). Publishing House Naim Frashëri, Tirana, 343.

Institut**e** of Geological Studies, Faculty of Geology and Mining, Geological Intsitute of Oil and Gas, 1983. Geological Map of Albania, at scale 1:200.000.

Institute of Geological Studies, Faculty of Geology and Mining, Geological Institute of Oil and Gas, 1983. Tectonic Map of Albania, at scale 1:200.000.

Kissel, C., Speranza, F., Islami, I., and Hyseni, A., 1995, Paleomagnetic evidence for Cenozoic clockwise rotation of External Albanides: Earth and Planetary Science Letters, **129**, 121-134.

Kober L.,1914. Geological map of Balkan, at scale 1:15.000.000

Koçiu, S., 1989, On the construction of the Earth Crust in Albania according to the first onset of P waves in the seismologic stations. (In Albanian, abstract in English): Bull. of the Geological Sciences, **1**, 137-159,

Kodra A., Vergely P., Meshi A. (1994) – Tectonic evolution of the ophiolite in Albania. Geological Archive of Institute Geological Studies and Projects, Tirana.

Komatina M. and S. Komatina-Petrovic, 2009. Geodynamics af Serbia. 5th Congress of Balkan Geophysical Society, Belgrade, Serbia, 10-16 May, 2009.

Mauritsch J. H., Scholger R., Bushati L. S., Xhomo A., Pirdeni A. Paleomagnetic works in the field of the Krasta-Cukali, Alps and Sazani zones carried out in September 1993, Conference in Albanian Geological Institute of GEOALBA, November 1994, etc., publications. Tectonophysics. 1995.

Mauritsch H. J., Scholger R., Bushati S. L., A. Xhomo A. 2006. Palaeomagnetic investigations in Northern Albania and their significance for the geodynamic evolution of the Adriatic-Aegean realm. Geological Society, London, Special Publications,**260**,155-178.

Magnetic Map of Albania. Monography, Center of Geophysical and Geochemical Investigation: Albanian Geological Survey.Viti

Meço S**.**, Aliaj Sh., Turku I., 2000 - Geology of Albania. Gebrüder Borntraeger. Berlin. Stuttgart, Faqe.

Melo V., 1986. Structural Geology, Geotectonic (Geological setting and geodynamics development of Albanides. (In Albanian), Published by Faculty of Geology and Mining, Polytechnic University of Tirana, Text Books Typography, Tirana, 169.

Melo V., Shallo M., Aliaj Sh., Xhomo A. & Bakia H., 1991 – Thrust and cover tectonics in the geological structure of the Albanides. Bul. Shk. Gjeol., **1**, 7-20.

Muço B., 1994 - Focal mechanism solutions of earthquakes for the period 1964-1988. Techtonophysics, 231.

Muttoni G., Dennis V.K., Meço S., Nicora A., Gaetani M., Bahini M., Germani D., Rettori R. 1996. Magnetostratigraphy of the Spathian to Anician (Lower.Middle Triassic) Kçira section, Albania. Geophys. J. Int. **127**, 503-514.

Nopçsa F., 1929 - Geographie und Geologie Nord- Albaniens. Geol. Hungarica, S. geol., **III**, 1-704.

Nocquet J.M., Calais E., Altamini ., Sillart P., and Bounder C., 2001. Intraplate deformation in western Europe deducted from an analysis of the International Terrestrial Reference Frame 1997 (ITRF97) velocity field. J. Geophys. Rs. **106**,11,239-11,257.

Nowack E., 1929 - Geologische Ubersicht von Albanien. Salzburg.

Oldow J.S. et al. 2002. Active fragmentation of Adria, the north Africa promontory, Central Mediterranean Orogen. Geology, **30**, 779-782.

Papa A. et al., 1985. Shkodra-Peja transversal and its role in Albanides. 5th National Geological Conference, Tirana.

Papa A., Xhomo A., Aliaj Sh. , 1991. Le secteur transversal Shkoder-Peje et sn role dans l'evolution geologique des Albanides". Séance spécialisée de la Societe geologiqiue Francese (S.G.F.) Colloque sur la "Gologie de l'Albanie", Paris, 12-13 Avril, 1991.

Peza L., Xhomo A., Qirinxhi A., 1971. Geology of Albania. (In Albanian). The Publishing House of Universitary Books, Tirana.

Picha F.J. 2002. Late orogenic strike-slip faulting and escape tectonics in frontal Dinarides-Hellenides, Croatia, yugoslavia, Albania, and Greece. AAPG Bulletin, v.**86**, **9**, 1659-1671.

Qirinxhi A., Nyftari A., Bicaj Z., Tashko A., Zhegu V., Kosho P., Bushati S., Monika K., Kastrati N., 1983. Geological Setting and utile minerals of the Kçira-Ndrecaj-Brashtë region, and geochemical and geophysical surveys performed during 1981-1982. Technical rapport. Geological Archive, Geological Service of Albania, Tirana.

Qirinxhi A., Nasi V., Hyseni A., Kokobobo A., Leci V., 1991. Review on relation of Albanides tectonic zones and main featuresnof their inner structure. (In Albanian, resume in English). Symposium «Thrust tectonics in Albania. Bulletin of Geological Sciences, **1**, 129-139.

Speranza F., 1995, Evolution of Cenozoic geodynamic of Alpine Belt at Mediterranean Centrale: Paleomagnetisme contribution. Ph.D. University Pierre and Marie Curie, Paris VI, France, 294.

Sulstarova E., Koçiaj S., Aliaj Sh. , 1972. Seismic map of Popular Republic of Albania, at scale 1.250.000. (In Albania), Published by Faculty of Geology and Mining, Polytechnoc University of Tirana, 201.

Sulstarova **E**., 1988 - The seismic faults in Albania. Proceedings of first symposium on the Recent Trends in Seismology and Geophysics og Aegean Area, July 1-3, Thessaloniki, Greece, 164-180.

Sulstarova E., Aliaj Sh., Muço B., Koçiu S.. 2011. Seismicity, seismotectonics and seismic hazard esstimation in Albania. Academy of Sciences of Albania, Tirana, 310.

Tagari Dh., 1993 - Etude neotectonique et seismotectonique des Albanides: Analyse des deformations et geodynamique du Langhien a l'actuel. These de Docteur en Science. Paris-Sud, Orsay.

Shehu R., Shallo M., Kodra A., Vranai A., Gjata K., Gjata Th., Melo V., Yzeiri D., Bakiaj H., Xhomo A., Aliaj Sh., Pirdeni A., Pashko P., 1990 – Geology of Albania. Published Home "8 Nëntori" Tirana.

Shehu V**.,** 1967. On so-called Shkoder.Peje transversal and some problems of the geological setting of the Albania. (In Albanian, abstract In French), Bulletin of the State University of Tirana, Serie of Natural Sciences, **3**, 87-96.

Vranaj A., Shallo M., Xhomo A. 1997. Geology of Albania. Published Home "Universitary Books"

Xhomo A., Kodra A., Xhafa Z., Shallo M. 2002. Geology of Albania. Geological Survey of Albania, ALBPETROL, Faculty of Geology and Mining, Tirana, 171.

Zuber S., 1940 - Appunti sulla tettonica e sull'evoluzione geologica dei giacimenti metalliferi albanesi. AIPA, Publ. Sc. Techn., Fasc. **1**, Roma.

List of Captions

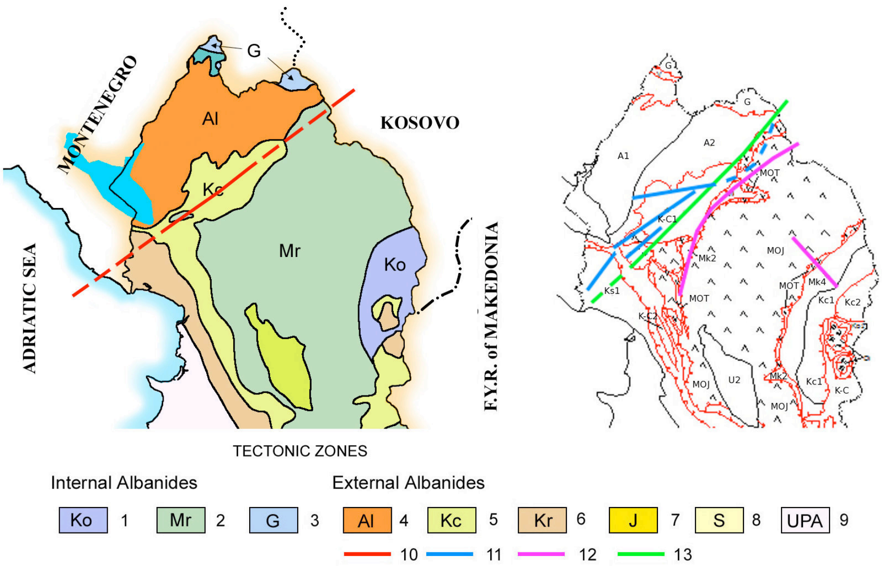

Fig. 3. Tectonic scheme of the Albanides [Xhomo A. et al. 2002].
G-Gashi zone; MOJ- Mirdita ophiolites; MOT- T2-J3 Ophiolites (Efusive-sedimentary formation): Ko, Ko1, Ko2-subzones of Korabi zone; MK4 Gjallica subzone; Ao, A1, A2 subzones of Alps zone; K-C1- Cukali subzone; K-C2- Krasta subzone; Kr1- Dajti subzone of Kruja zone.
1. The trace of the deep transversal thrust Shkodër-Pejë after gravity inversion; 2- Thermal anomaly axis of the Heat Flow Density value mW/m^2; 3- Strike-slip faults Gjiri Drinit-Lezhë.

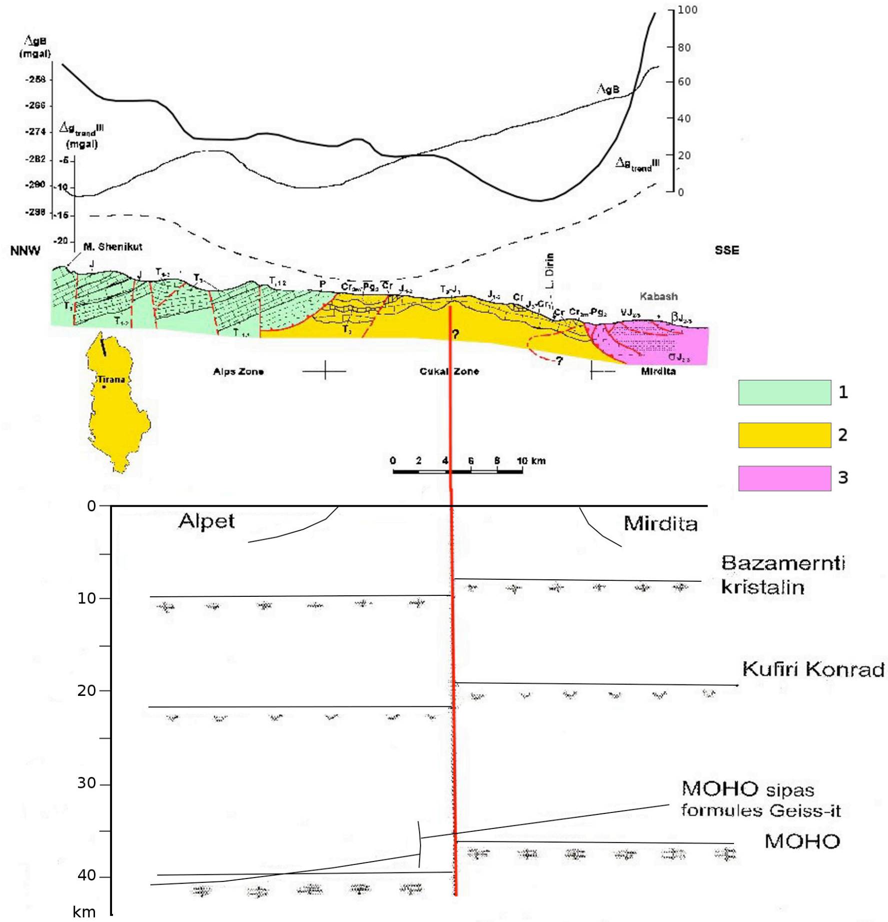

Fig. 10. Gravity Bouguer Anomaly (Δg) and Magnetic Anomaly (T) profile I-I, Mountain Sheniku at the Albanian Alps-Kabash in Mirdita zone, and gravity inversion results.

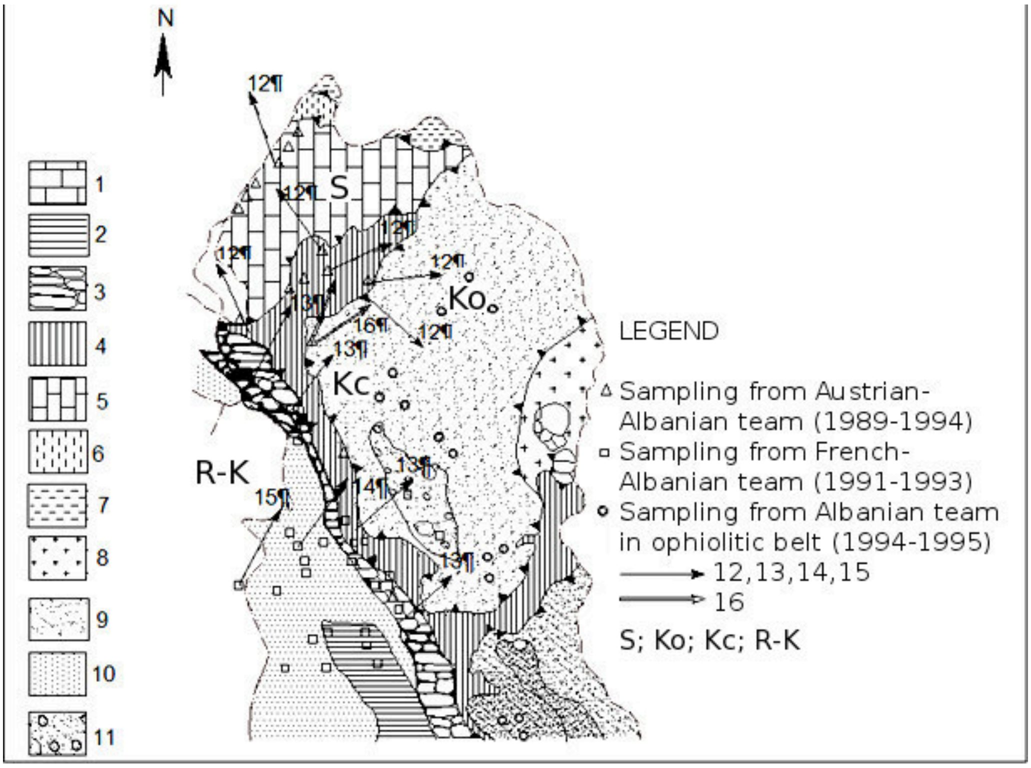

Fig. 11. Scheme of the paleomagnetic echantionage in Northern Albania, during 1989-1994.
1-Sazani Zone; 2-Ionian Zone; 3-Kruja Zone; 4-Krasta-Cukali Zone; 5- Albanian Alps Zone; 6-Vermoshi Zone; 7- Gashi Zone; 8-Korabi Zone; 9-Mirdita Zone; 10- Periadriatic Depression; 11-Mollasic depressions; 12- Jurasic limestone; 13- Upper Cretaceous-Eocene limestone: 14- Middle Neogene molasses: 15- Pliocene formation: 16- Ultrabasic rocks: 17-Overthrus tectonic.

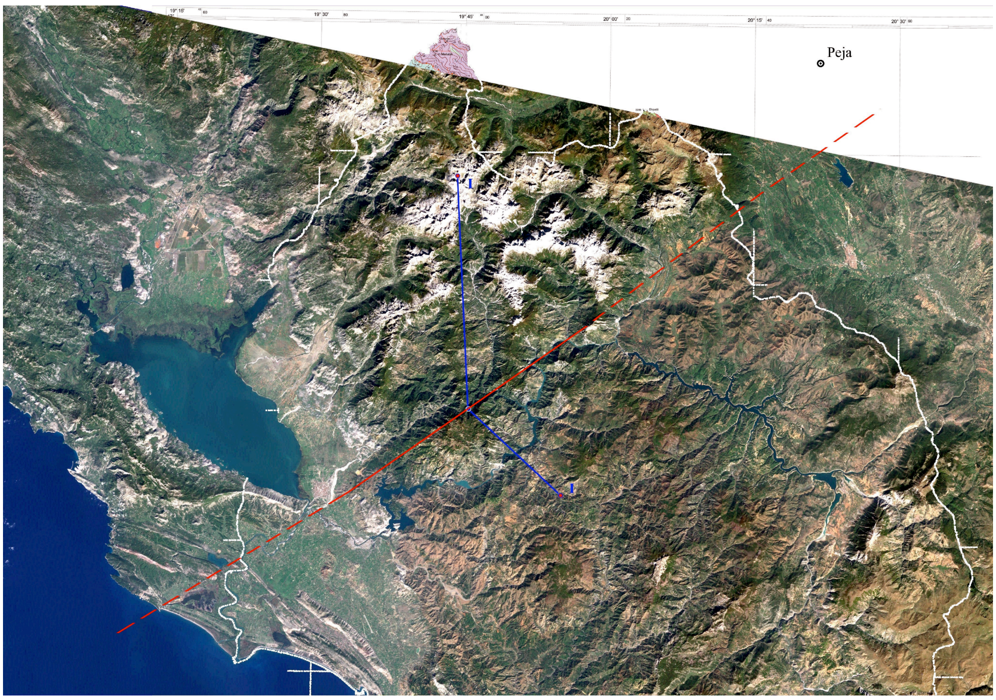

Fig. 17. Satelite image of Shkodër-Pejë transversal fault at Northern Albania.