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Geothermal features of the Albanides Folded Belt

By

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With 13 figure

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Contents

Abstract

Geothermal features of the distribution of geothermal field: temperatures at different depths and geothermal gradient, heat flow density, and geothermal resources zones, in the Albanides are presented in the paper. Based on modeling results, geothermal phenomena are analyzed up to Moho discontinuity, in two profiles across the Albanides. The temperature signals from the

Albanides depth, in the framework of the integrated interpretation with geological studies results, are analyzed.

1. Introduction

The Albanides represent an assemblage of the geological structures in the territory of Albania, and together with the Dinarides at the North and the Hellenides at the South, have formed the southern branch of the Mediterranean Alpine Belt.

Integrated regional geophysical studies have been performed during exploration accros the Albanides, onshore and in the continental shelf of Adriatic Sea. Seismological studies, gravity and magnetic surveys, reflection seismic lines, geothermal studies, radiometric investigations, vertical electric soundings and well logging were applied. Interpretations of the geophysical studies results rely on the regional geological studies data.

2. Geological setting of the Albanides

Albanides tectonic setting comprises two major peleogeographic domains: the Internal Albanides in the east and the External Albanides in the western part of Albania (Aubouen & Ndojaj, 1964, Frashëri et al., 1996, I.S.P.GJ. et al., 1983, 1985, Meço & Aliaj, 2000, Melo, 1986, Papa, 1970, 1993).

The Internal Albanides are an integrated part of the Subpelagonian Trough, and are characterized by presence of the immense and intensively tectonised ophiolitic belt, displaced from east to west forming a thrust nape.

The External Albanides represent a part of South Adriatic Sedimentary Basin, developed out of the western passive margin and continental shelf of the Adriatic plate. The External Albanides are affected only by late Miocene paleotectonic stages.

2.1. Earth crust configuration

Seismological studies, seismic, gravity, magnetic and geothermal surveys depict the Earth Crust configuration (fig. 1; 2, 3), (Aliaj, 1987, 1989, Arapi, 1982, Bushati, 1987, 1988, Frashëri et al., 1996, 2003, 2004, Koçiu, 1989, Lubonja et al., 1968, Sulstarova, 1987, Veizaj, et al. 1996).

Geophysical data reveals that the Earth crust becomes thicker from central regions of Adriatic towards Albanides mainland. The regional gravity trend in Adriatic Sea area and in the Albanides reflects the configuration of the Moho discontinuity. So, in the geological-geophysical profiles Albanid -2 (Fig. 2) is presented the decreasing of the gravity force from the Adriatic Sea region toward the Albanides because of the Moho discontinuity plunges from 25 km in the central part of the Adriatic Sea (Finetti & Morelli, 1972) to 43- 52 km at eastern part of Albanides. In the Albanides are fixed four third order trends of Bouguer anomalies of the low order: two maximums two minimums (Fig. 1). Presumably these anomalies are caused by the vacillation of the depth of roof of Moho discontinuity, and reveal a block tectonic setting of the crust, which coincides fully with seismological studies data. The sedimentary crust is 15 km thick in the Adriatic seashore and increased in northwestern regions of Albania. This tectonic setting of the deep levels of the earth crust in Albanides has its reflection even in the scattering of the magnetic fields. Considering the magnetic regional anomalies brings in conclusion that the top of crystaline basement plunges toward the littoral of the Albanides up to central areas of the Albania (Fig. 2). Consequently, the Earth crust in Albanides is interrupted by a system of longitudinal fractures of NW - SE direction and transversal fractures that, according to the seismological studies, touch into the mantel (Aliaj 1989, Frasheri et al. 1996, 2003, Sulstarova, 1987). Some of them separate even the tectonic zones. Regional fractures have conditioned the presence of some heat flow anomalies and geothermal zones, where thermal springs are located.

2.2. Tectonic zones

Based on geological and geophysical regional studies and regarding the facial-structural criterion, across the Albanides are distinguished the following tectonic zones (Fig. 5):

A) Internal Albanides: *Korabi, Mirdita, Gashi tectonic zones,*

B) External Albanides: *Albanian Alps, Krasta-Cukali, Kruja, Ionian, Sazani tectonic zones, and Peri Adriatic Depression.*

Internal Albanides. The tectonic zones of the Internal Albanides lie along the eastern part of Albania.

Korabi zone (K), (analogue of the Pelagonian zone in Hellenides and Golia zone in Dinarides). In this zone outcrop the oldest formations of Paleozoic in Albania. Gravity Bouguer anomaly configuration in the Korabi zone reveals that Korabi zone structures are of low orders (Fig. 1). The contact between Korabi and Mirdita zone coincides with a deep seismogene structure (Sulstarova, 1987).

Mirdita zone (M), (analogue of the Subpelagonian zone in Hellenides and Serbian zone in Dinarides). Three tectonic stages are formed in this zone during the different orogenic phases. The lower nappe is made up of ophiolites. The ophiolitic belt is characterized by intensive Bouguer anomalies and by a magnetic field with weak and turbulent anomalies (Figs. 1, 2) (Bushati, 1997, 1998, Frashëri et al., 1996, 2003). There are three characteristics of the anomalous belt in Mirdita zone:

- The anomalies are divided in two parts, at the north and at the south of Shengjergji flysch's corridor.

- There are five gravity maximums, with epicenters set one after the other in an anomalous chain from the northeast part of Albania to its southeastern area. The anomalies have maximal amplitude up to 105 mGal and strong gradients that separate them from each other. The anomalous belt undergoes an obvious turn of 60^o-70^o toward the direction of the Dinarides ophiolitic belt in the northeastern part of Albania.
- The biggest amplitudes of the anomalies came from the northern part of ultrabasic massifs of the eastern belt.

The biggest thickness of ophiolitic belt is about 14 km at its northeastern edge, but it decreases up to 2 km towards the west and southeast. This geological setting demonstrates the allochtonous character of ophiolites belt and the covering character of their western contact onto the formation of the Krasta-Cukal zone of External Albanides. The tectonic relationships between the Internal and the External Albanides have nappe character (Cadet et al., 1980, Frashëri et al., 1996, 2003, Hoxha, 2000, Hoxha & Avxhiu, 2000, Lubonja et al,. 1968, Melo, 1986, Papa, 1993, Qirinxhi, 1970). There is presented also the autochthonous character of the Albanides ophiolitic belt (I.S.P.GJ. et al., 1983, 1985, Becaluva et al,. 1994, Gjata & Kodra, 2000, Kodra, 1998, Shallo et al., 1989, Robertson et al., 2000).

The molasses post-orogenic deposits have covered transgressively Mirdita and partially Krasta–Cukali tectonic zones in Korça and Burreli internal depressions developed during the tarditectonic-neotectonic stages.

Gashi zone (G). (analogue of the Durmitory zone of the Dinarides) at the north of Albania. It consists of metamorphic rocks, terrigeneous rocks, limestone, metamorphic volcanites, as well basic intermediate and acidic rocks.

External Albanides. The tectonic zones of the External Albanides outcrop chiefly in the western part of Albania (Aliaj, 1987, 1989, Bare et al., 1986, Dalipi, 1985, Frashëri et al., 1996, 2003, Mëhillka et al., 1999, Xhufi & Canaj ,1999, Prenjasi, 1992, Prenjasi et al., 2003).

Albanian Alps zone (A), (analogue of the Parnas zone in Hellenides and High Karst in Dinarides) at the north of Albania. Sandstone and the conglomerates of Permian are the oldest rocks, which outcrop in this zone. In general, the Albanian Alps represent limestone monoclines, as well as smaller anticlines in their background. A regional gravity minimum extends on the Alps zone (Fig. 1).

Krasta-Cukali zone (KC), (analogue of the Pindos zone in Helenides and in Budva zone of the Dinarides). It is an intermediate zone between the Internal and External Albanides, and is divided into two subzones of Cukali and Krasta:

The Cukali subzone extends in the north of the Krasta-Cukali zone. It is composed of Triassic-Cretaous carbonate rocks, some middle Triassic effusive rocks and few radiolarites at the top of Upper Jurassic, overthrusted onto the Maastrichtian-Paleocene-Eocene flysch. The Cukali subzone represents a big anticline in its background. The Alps and Mirdita zones overthrust onto this subzone.

Krasta subzone extends from Shkodra city in the North to Leskoviku in the southeast. Three formations outcrop in this subzone: the Albian-Cenomanian early flysch, Senonian limestone serie and Maastrichtian – Eocene young flysch. The latter flysch appears obviously as a tectonic window even in Shen-Gjergji corridor, between two ophiolitic belt parts.

Kruja zone (Kr), (analogue of the Dalmateian zone in Dinarides and the Gavroro one in Hellenides). The Kruja zone consists of a series of anticline structures with Cretaceous-Eocene carbonate cores of neritic limestones; dolomitic limestones and dolomites covered with the Oligocene flysch deposits. Tortonian molasses overlies transgressively the carbonate rocks of some structures of the Kruja zone, while in some other ones; the Burdigalian premolasses transgress on the flysch section.

The carbonate section of the Kruja zone is plonged down up to 10 km, where they are underlain by the Triassic evaporite formations. Anticline structures of this zone are asymmetric and some of them have their western flanks desected by disjunctive tectonics. Most of them are of linear type reaching maximum length of 52 km.

Ionian zone (Io) extends in the southwestern part of Albania, which continues in the Hellenides, too. It is the widest zone of the External Albanides, developed as a deep pelagic trough since the Late Liassic. The upper Triassic evaporites are the oldest rocks, which outcrop in this zone. Over this formation lies a thick sequence composed of upper Triassic-lower Jurassic dolomite limestone and Jurassic-Cretaceous-Eocene pelagic limestone and cherts. The limestone section passes on gradually into the Oligocene flysch, Aquitanian flyschoidal formation, and Burdigalian-Langhian and partially of Serravalian-Tortonian premolasses. Significantly flysch deposits overlie carbonate oil field and prospects, whereas the Burdigalian and Tortonian molasses often lay on them. This phenomenon has brought about a geological setting of two tectonic stages (Fig. 3).

Integrated geological-geophysical data show the presence of many anticline carbonate structures often seatled with flysch deposits along the three facial-structural belts of the Ionian zone.

Two main tectonic styles are apear in the Ionian zone: Duplex tectonics and imbricate one. The anticline structures are desected by longitudinal tectonic fault along their western flanks. Recumbent, and overthrusted-eroded structures thrusted up to of 5-6 km horizontal displacement are also present (Prenjasi, 1992). The overthrustig phenomenon has been stimulated periodically by tectonic rejuvenation of the regional faults. The backthrust faults have happened owing to retrotectonic phenomenon (Aliaj, 1987, 1989, Fezga et al., 1996, Valbona et al., 1987).

The regional reflection seismic lines across the Ionian zone show that the undethrusting limestones of the southern Adriatic basin and Sazani Zone have taken place during the structuring process of the Ionian zone (Fig. 3).

Sazani zone it is an integrated part of the Apulian platform, buldet of a thick Cretaceous-Eocene limestone and dolomite section, widely overlied by transgressive sequences of Burdigalian to Tortonian premolasses.

***Peri-Adriatic Depression*.** This unit covers transgresively considerable part of the Ionian, Sazani and Kruja tectonic zones. This is a foredeep depression filled with Miocene to Pliocene-Quaternary molasses (Fig. 3). The thickness of the molasses increases from southeast to northwest, reaching 5000 m. Ussually; the molasses deposits lay trangressively on the older ones, down to the limestone and erect a two-stage tectonic setting (Fig. 3).

The External Albanides, as a part of Albanian Sedimentary Basin, continue towards the shelf of the Adriatic Sea with carbonate and terrigene formations. The stratigrafic column of Albanian Sedimentary Basin is about 15 km thick.

3. Geothermal study method

The studies on the geothermal field and evaluation of the geothermal energy in Albania, in the cource of the preparation of "Atlas of Geothermal Resources in Albania", European Geothermal Atlas and European Geothermal Energy Resources Atlas, have performed on the basis of the temperature logs of 84 oil and gas wells and 59 shallow boreholes. The temperature was measured with either resistance or thermistor thermometers. Thermal inertia of these thermometers is respectively 5-6 seconds and 3.5 seconds. The thermal conductivity of the rocks was determined in the Laboratory of Department of Geothermics of the Geophysical Institute, Czech Academy of Sciences, Prague. Heat-flow density calculations are made for homogenous lithology of geological sections, according to several models. The temperature maps at 100, 500, 1000, 2000, 3000 meters depths below surface, average geothermal gradient map, heat flow density map and geothermal zones map, are made up by the processed data. The maps of the Albanian territory are linked with Greek and Adriatic ones.

Geothermal models rely on several regional geological-geophysical profiles. Temperature distributions up to 50 km depth, according to the modeling data are presented in two profiles: Albanid–1 (Falco Italy-Semani coastline Albania-Bilisht near of Albanian-Greek Border at SE part of Albania) and Albanid-2 (Falco Italy-Durrës-Tiranë-Peshopi NE part of Albania) (Frashëri et al., 2004). Results of these modelings are used to interpretat the Heat Flow Density Map of Albania.

Also have been performed gothermal investigatigation of the thermal water springs and deep wells, and evaluated the geothermal resources of the thermal zones. The estimation of geothermal potential of the reservoirs is based on a volumetric heat content of the model.

4. Geothermal regime of the Albanides

The geothermal regime of the Albanides is conditioned by tectonics of the region, lithology of geological section, local thermal properties of the rocks, and Earth's crust settings (Frashëri et al. 2004).

4.1. Temperature

The geothermal field is characterized by a relatively low temperature gradient. The temperature at the depth of 500 meters depth is between 21 and 24°C. The highest temperatures, up to 36 °C at 1000 meters and 105.8 °C at 6000 meters depths are measured in Peri-Adriatic Depression wells. The same values of temperatures also are measured in some boreholes in the ophiolitic belt. The lowest temperature values have been measured in mountain regions of Mirdita zone, as well as in the Albanian Alps. In these areas are present an intensive circulation of cold descendings waters, of 5-6 °C temperature. The arrangement of isotherms fits well to the structures of Albanides.

The described geothermal field, with relatively low values of temperature, is a characteristic of the sedimentary basins with great thickness of sediments.

4.2. Geothermal gradient

External Albanides as well as the Dinarides are characterized by a low geothermal gradient, (Fig. 4).

Structural and facial lithological variations of the Ionian zone and the Peri-Adriatic Depression are reflected in the distribution of geothermal field. The tectonic setting of the region, geological section lithology, and rocks thermal properties has conditioned the geothermal gradient value. The largest gradients are detected in the molassic anticline structures of the center of Peri-Adriatic Depression (Fig. 4). The highest values of the geothermal gradient of about 21.3 $mK.m^{-1}$ are observed in Pliocene clay section (Fig. 5). The gradient decreases about 10-29 % is observed at carbonate anticline structures of the Ionian zone (fig.6), whereas elsewhere along this zone the gradient is mostly 15 $mK.m^{-1}$. Extremaly low geothermal gradients values of 5 $mK.m^{-1}$ are observed in the Southern part of Albanides and in the Albanian Alps. Furthermore the gradient in these cases (Fig. 7) decreases towards the zero or becomes negative, especially wherever the cold surface waters flow into the anticline's limestones. Meanwhile the lowest values (7-11 $mK.m^{-1}$) of the gradient are observed in the deep synclinal belts of Ionian and Kruja zones.

Modeling results indicate that the gradient decrease deeper takes place at depth than 20 km, which coincids with the crystaline basement top.

In the Albanian Sedimentary Basin, geothermal gradient is stricts controlled by the lithology. Its highest values of geothermal gradient vere observed in the clay sections. Whereas increasing of sand content in geological section is associated with the geothermal gradient decrease. In the conglomerate-sandstone part of the Rrogozhina suite of Pliocene, the geothermal gradient is almost two times lower than in the Helmesi clay ones.

The influence of salt diapir is also obvious; the high thermal conductivity of salt perturbes the isotherms.

Over-pressures presence in the molasses section of the Albanian Sedimentary Basin has is dedected by a increasing of the geothermal gradient.

Deviations from the normal trend of the above-mentioned phenomenon occur in cases of lateral influences. For example in the fig.8 shown that gradient reaches its smaller values in the lower part of the section, owning to the presence of a limestone structure beside the east of the Ardenica 18 well.

Along the ophiolitic belt of the Mirdita zone, the geothermal gradient values increase up to 36 $mK.m^{-1}$ at northeastern and southeastern part of the Albania (Fig.3). In this belt is also observed the existence of a lower gradient section, up to 10 $mK.m^{-1}$. This gradient decrease is explained by the convection influence related to the infiltration of cold meteoric water.

After the geothermal modeling, decreasing of the gradient is observed even deeper than 12 000 meters under the ophiolites of Albania, at the top of the Triassic evaporate deposits.

4.3. Heat Flow Density:

The regional pattern of heat flow density in Albania is presented in fig. 9, where are depicted three particularities of the scattering of the thermal field in Albanides:

Firstly, the maximum value of the heat flow 42 mW/m^2 in the center of Peri-Adriatic Depression of External Albanides is observed. The 30 mW/m^2 isotherm is open towards the Adriatic Sea Shelf. Heat flow density values are lower than 25-30 mWm^{-2} in Albanian Alps area due to the presence of a greater thickness of sedimentary contenental crust, mainly carbonatic one in this zone.

In the ophiolitic belt of the eastern part of Albania, the heat flow density values are up to 60 mW/m^2. The contours of heat flow density give a clear configuration of the ophiolitic belt. The contours of 45 mW/m^2 in Northeast and 40 mW/m^2 in Southeast of Albania remain open toward the ophiolitic belt continuation beyond the Albanian border. While very low values of radiogene heat generation of the ophiolites means that increasing of the heat flow in this ophiolitic demonstrate heat flow transmitting from the depth. On the other hand the highes values of the ophiolitic belt heat flow density must belong to the small thickness part of the geological section down to the top of crystalline basement, and MOHO discontinuity (Fig. 2). Certainly the granites of the crystalline basement, with the radiogenic heat generation, represent the main heat source.

In the ophiolitic belt there are observed some local hearths of higher heat flow density. Heat flow anomalies are conditioned by intensive heat transmition along deep and transversal fractures (Fig. 9).

4.4. Paleotemperature estimations

Paleotemperature modeling results indicate that maximum temperatures of up to 105.3 ^{o}C were obtained during Upper Triassic-Lower Oligocene age in the Albanian Sedimentary Basin. In these paleotemperature conditions has taken place the thermal maturation of the organic matter of carbonate formation, which has entered into oil window. Upper Triassic up to the Lower Oligocene age formations of the Albanian sedimentary Basin represent the section of the first phase of the hydrocarbon generation of condensate, oil and gas. Later, during the Middle-Upper Oligocene and Miocene, the carbonate section was plunged at greater depth, where the temperature ranges maximum to 250 ^{o}C. This geothermal regime has created the thermal conditions for the phase of the methane generation.

Maximal temperatures up to 122.8^{o}C, with a geothermal gradient 1.67 mK/m and heat flow density ranges 39.8-41.2 mW/m^2 during the Middle and Upper Miocene have created the thermal conditions for maturing the organic matter of the molasses formation. Good thermal conditions for maturing of the organic matter exist also in the Pliocene section. Actually, by the general interpretation the oil of molasses section is correlated with the source rocks of the carbonate section. The molasses oil traps generally are located transgresively over the eroded top of the limestone anticlines. The hydrocarbon migration has taken place through this eroded surface. Thermal regime of the Middle-Upper Miocene, with the temperatures up to 122.8^{o}C and heat flow density 41.2 mW/m^2, creates the possibilities of molasses to entire into oil window and organic matter to be able also for the oil generation.

4.5. Geothermal Zones

Large numbers of geothermal energy of low enthalpy resources are located in Albania. Thermal waters of a temperature that reach values of up to 65.5 °C are sulphate, sulphide, methane, and iodinate-bromide types. The geothermal energy comes through seismoactive deep longitudinal NW-SE and transversal fractures of the Earth crust in the Albanides that have desected the mantel (Fig. 11). According to the calculation of different geo-thermometers, the geothermal aquifer estimated temperatures ranges from 144 to 270^{o}C, while, the geothermal modeling, suggests that thermal waters rises from 8-12 km depth section, where temperature attains to 220^{o}C.

Thermal sources are located in three geothermal zones (Fig. 10):

Kruja *geothermal zone* is the area of the biggest geothermal resources in Albania, with a length of 180 kilometers and a width of 4-5 kilometers. It starts on the Adriatic coast northwest of Tirana and continues southeast to Albanian-Greek border. The Kruja geothermal area represents an anticline structure chain. Geothermal energy resources are controlled by western regional thrust tectonics of the Kruja tectonic zone. Geothermal aquifer is represented by a karstified carbonate formation with numerous fissures and microfissures. In a regional view, limestones plunge down to 10 km, where they overlie Permian-Triassic evaporitic formation. In these depths, the temperature ranges between 120-150°C. Surface springs water temperatures in the Tirana-Elbasani northern subzone vary from 60°C to 65.5°C, and yields for long periods of time, some 3.5 to 15 l/sec. Hot water is stronglu mineralized, salt concentration range from 4.6 to 19.3 g/l.

In the southern subzone, thermal water flows out from the contact between the Eocene fissured and karstified limestones and the flysch section. Waters temperature is 27.6-29 ^{o}C and yield 70-80 l/sec. These waters are poor in H_2S and CO_2 and 7-9 times less mineralized than waters from the Tirana-Elbasani subzone.

The most important geothermal resources are located in the northern half of Kruja Geothermal Area. The heat in place (H_o) is 5.87 x 10^{18} – 50.8 x 10^{18} J, identified resources (H_i) are 0.59 x 10^{18} – 5.08 x 10^{18} J, while the specific reserves ranges between values of 38.5-

39.6 GJ/m^2. The southern subzone has lower concentration of resources 20.63 GJ/m^2, while geothermal resources amount to 0.65 x 10^{18} J.

Ardenica *geothermal zone* is located in the coastal area of Albania. It comprises several molassic-Neogenic brachyanticlines and deep carbonatic structure. At the surface, the boreholes discharge waters at temperatures of 32-67 ^{o}C. Thermal water is Ca-Cl type. The Ardenica reservoir heat in place is of 0.82 x 10^{18} J. Resources density varies from 0.25-0.39 GJ/m^2.

Peshkopia *geothermal zone* is located in the Northeast of Albania where waters of 43.5 ^{o}C flow out of a group of thermal springs. Some of the springs yield flow rates up to 14 l/s. The occurrence of these springs is condicioned by a deep fault at the periphery of a gypsum diapir of Triassic age that has penetrated the Eocene flysch. The thermal waters are of sulphate-calcium type, with a mineralization of up to 4.4 g/l, and 50 mg/l H_2S. Geothermal resources of Peshkopia Area have been estimated similar to those of Tirana- Elbasani area.

5. Geothermal phenomenon and Adriatic Sea hydrography

Epicenter of the heat flow density anomaly at the Adriatic Sea bottom (Fig. 12) (Geothermal Atlas of Europe 1992) is located at southwestern prolongation of the Scutary-Pec regional transversal tectonic accros the Albanides onshore onto Adriatic offshore. According to the paleomagnetic study results, the Scutary-Pec lineament forms the transition between two zones: the Albanian Alps and Dinarides with counterclockwise rotation to its north and the Albanides and Hellenides with clockwise rotation to its south (Mauritsch, 2000). Offshore prolongation of Scutary-Pec transversal correspond also with the "The Bridge" of continental water with high temperatures, low salt content and density of the seawaters in the Adriatic Sea observed by Albanian Oceanographic Expeditions during the wet years (Pano, 1994) (Fig. 13).

6. Conclusions

1. Heat flow density distribution arguments block character of the crystalline basement in the Albanides. Depth location of these blocks is smaller in the Mirdita zone of the Inner Albanides than in the External Albanides.

2. Albanian Sedimentary Basin by relatively low temperatures at depth is characterized. The temperature reaches only 105.8 °C at the depth of 6000 m.

3. The geothermal gradient value in the External Albanides ranges between 7 - 11 mK/m and 21.3 mK/m. This gradient increases to 36 mK/m, in the ophiolitic belt of Inner Albanides.

4. The heat flow density is about 42 mW/m^2 in the center of the Pre-Adriatic Depression and up to 60 mW/m^2, east of the ophiolitic belt.

5. Tectonics setting of the region and lithology of geological section condition their geothermal gradient value.

6. Local anomalies of the great heat flow density in some ophiolitic areas are interpreted as presence of the deep transversal fractures.

7. The geothermal reservoirs are located along the seismically active belt.

8. Afret paleotemperature investigations, depth of the Albanian Sedimentary Basin has perspective for the methane reservoir discovery.

9. Interpretation of the paleogeothermal regime of the Albanian Sedimentary Basin offers new possibilities to discover oil pools in the Miocene molasses suitable traps, which don't contact directly with the eroded limestone sections.

10. Direct use of the low enthalpy geothermal energy resources in Albania, as an alternative of the environmental friendly energy, is based on important geothermal reserves in the Albanides.

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LIST OF CAPTIONS

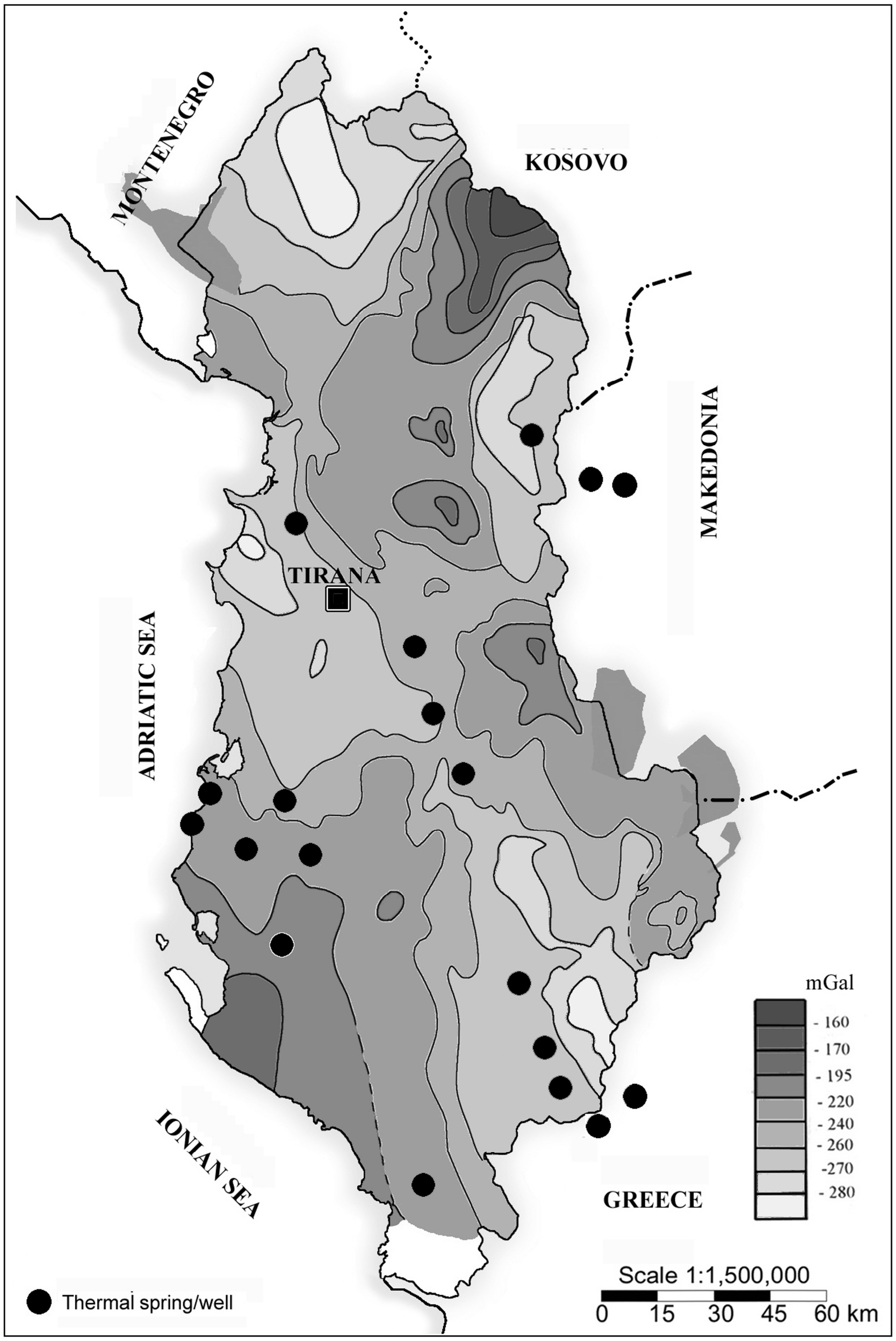

Fig. 1. Bouguer gravity map of Albania (Bushati, 1988).

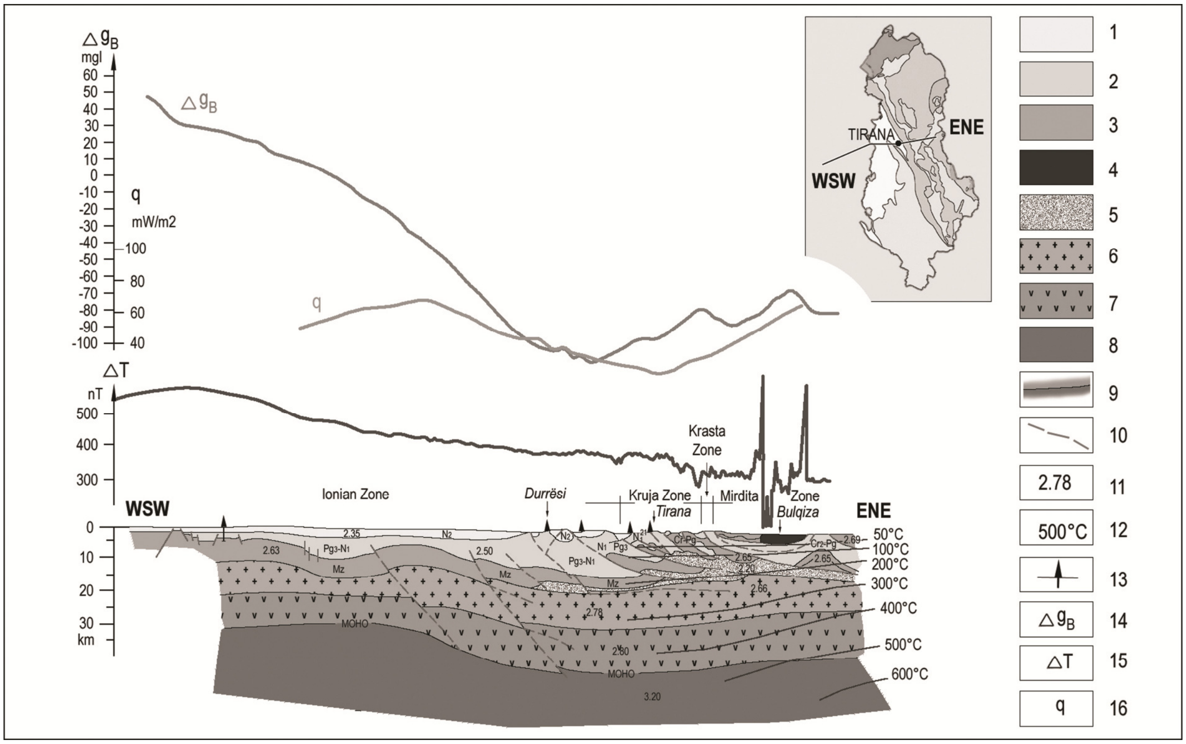

Fig. 2. Geological-geophysical regional profile Albanid-2: Falco Adriatic Sea- Durres-Tirana-Peshkopi (Gravity data for the Adriatic Sea after Richetti, 1980).

1- Serravalian- Pliocene Molasses (N_2^{2S}-N_1^{Pl}); 3- Paleogene flysch (Pg_3) and molasse; 3- Carbonate facies; 4- Ultrabasic rocks; 5- Evaporitic rocks; 6- Crustaline Basement; 7- The basalt Earth crust; 8- Upper mantle; 9- Depth up-rupt; 10- Disjunctive tectonics; 11- Rocks density, in g/cm^3; 12- Temperatures, in ^{o}C; 13- Deep well; 14- Bouguer anomaly; 15- Total magnetic field anomaly; 16- Heat flow density anomaly.

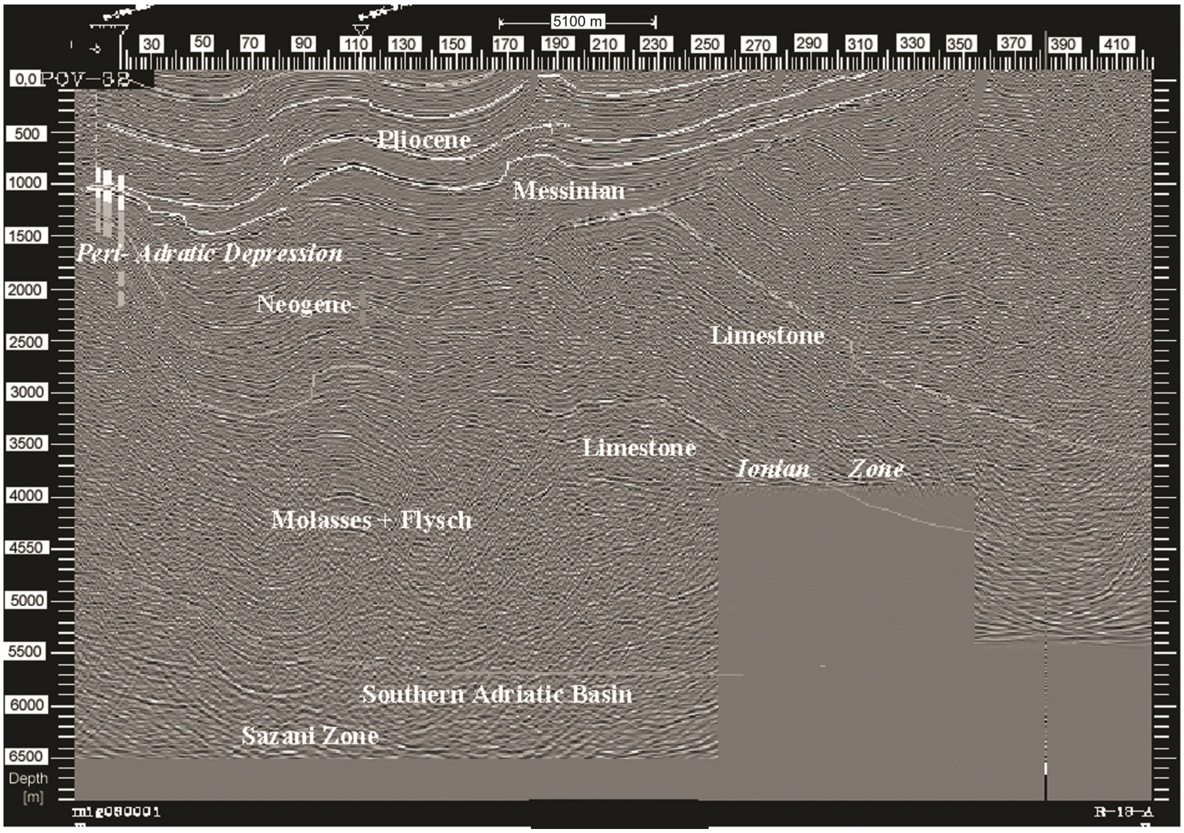

Fig. 3. Regional reflection seismic in line in Ionian and Peri-Adriatic Depression.

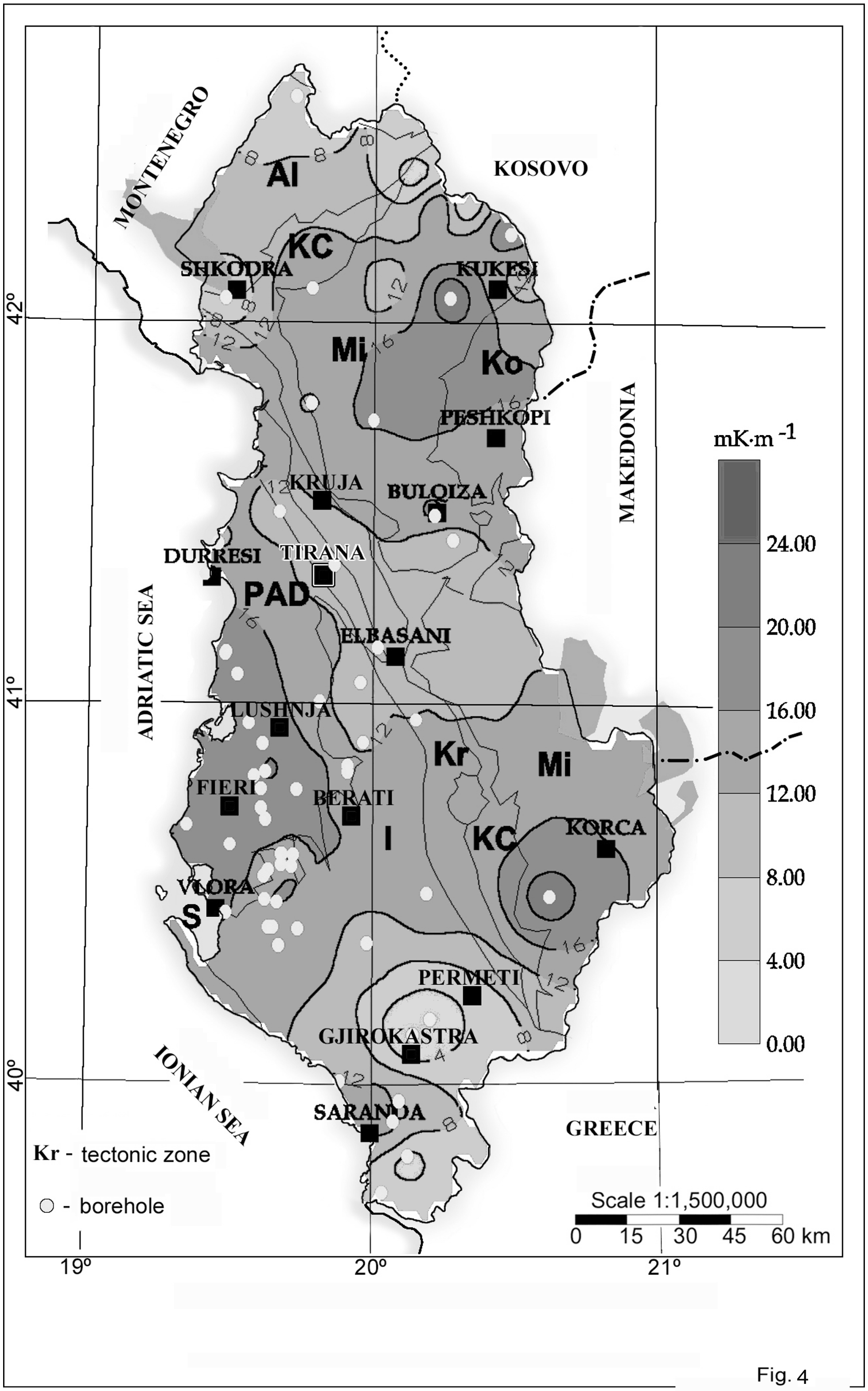

Fig. 4. Average geothermal gradient map of Albania.

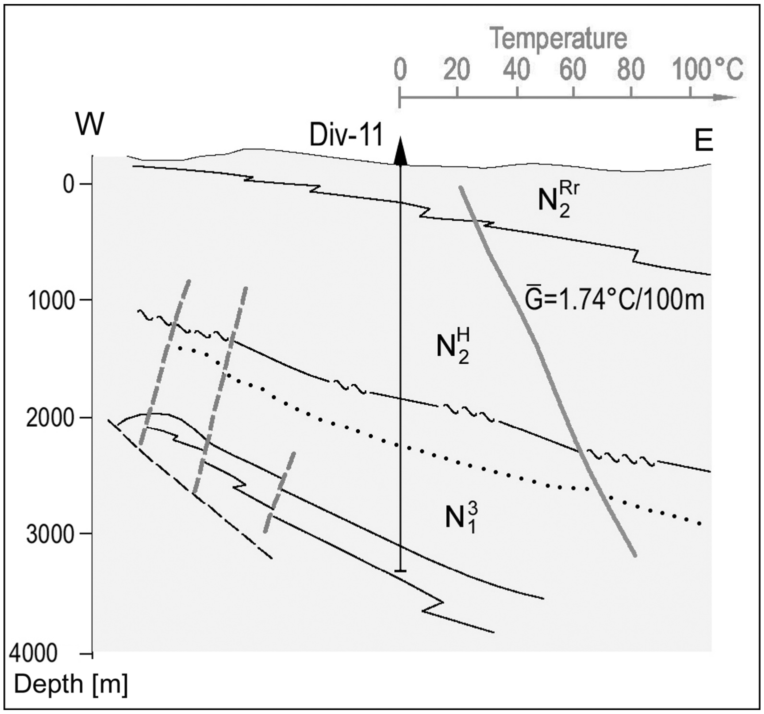

Fig. 5. Geothermal profile, Divjaka Molasse structure.

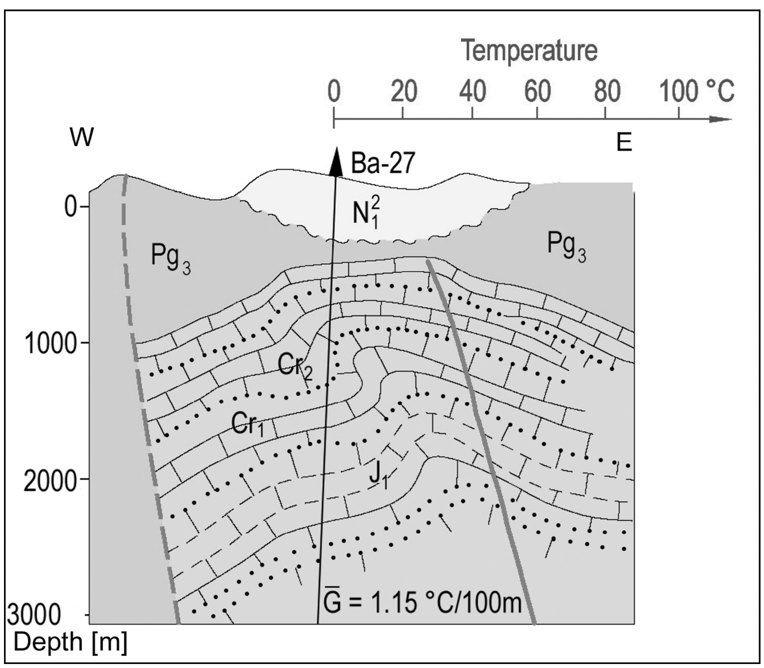

Fig. 6. Geothermal profile, Ballshi carbonate structure.

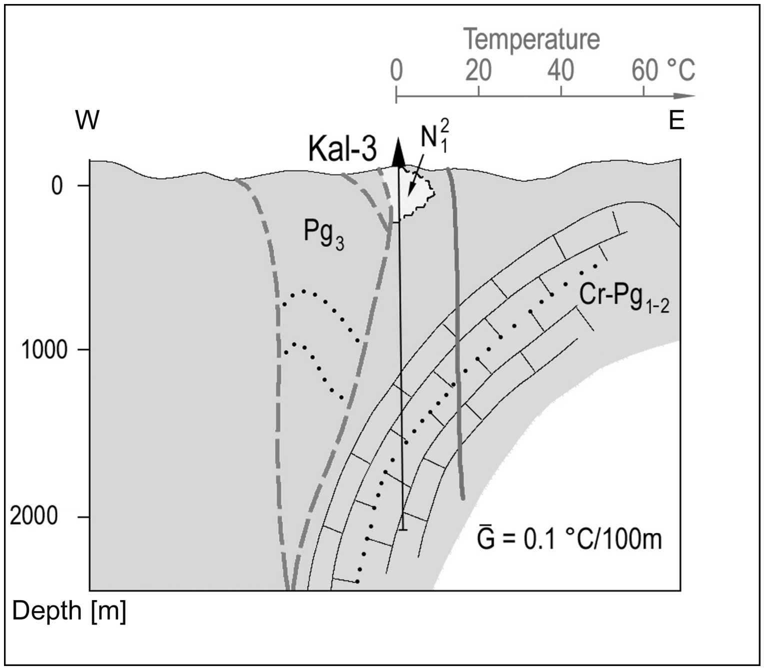

Fig. 7. Geothermal profile, Kalcati carbonate structure.

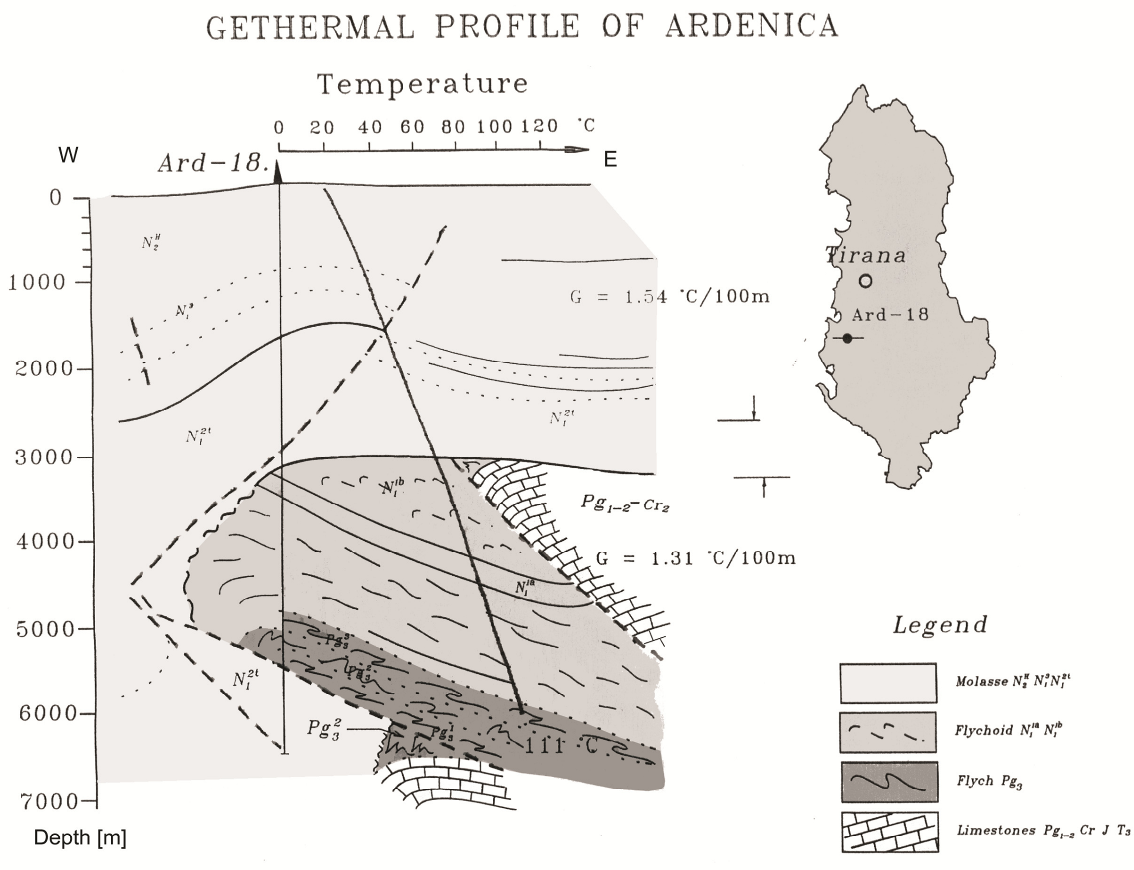

Fig. 8. Geothermal profile, Ardenica Molasse struture

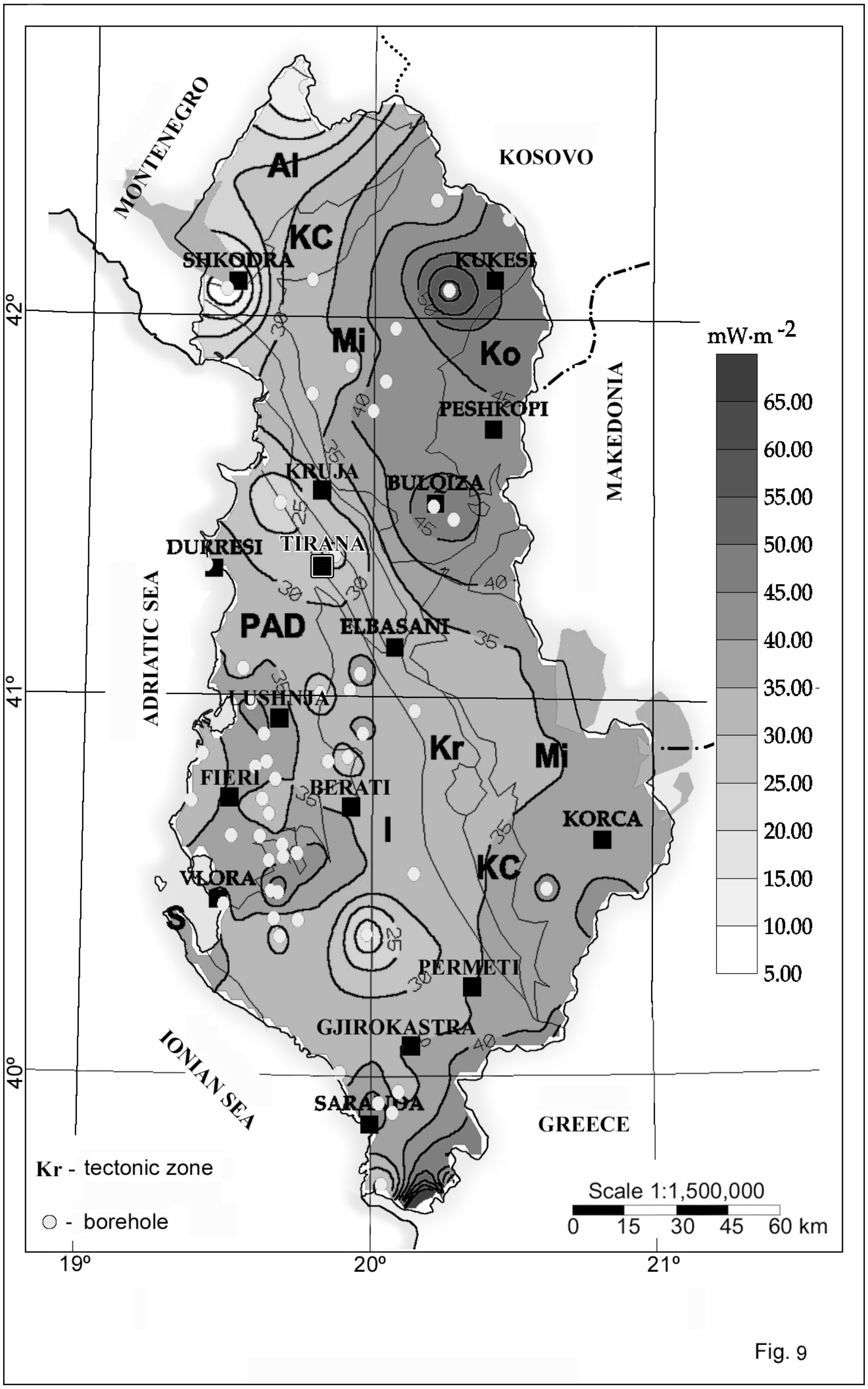

Fig. 9. Heat flow density map of Albania.

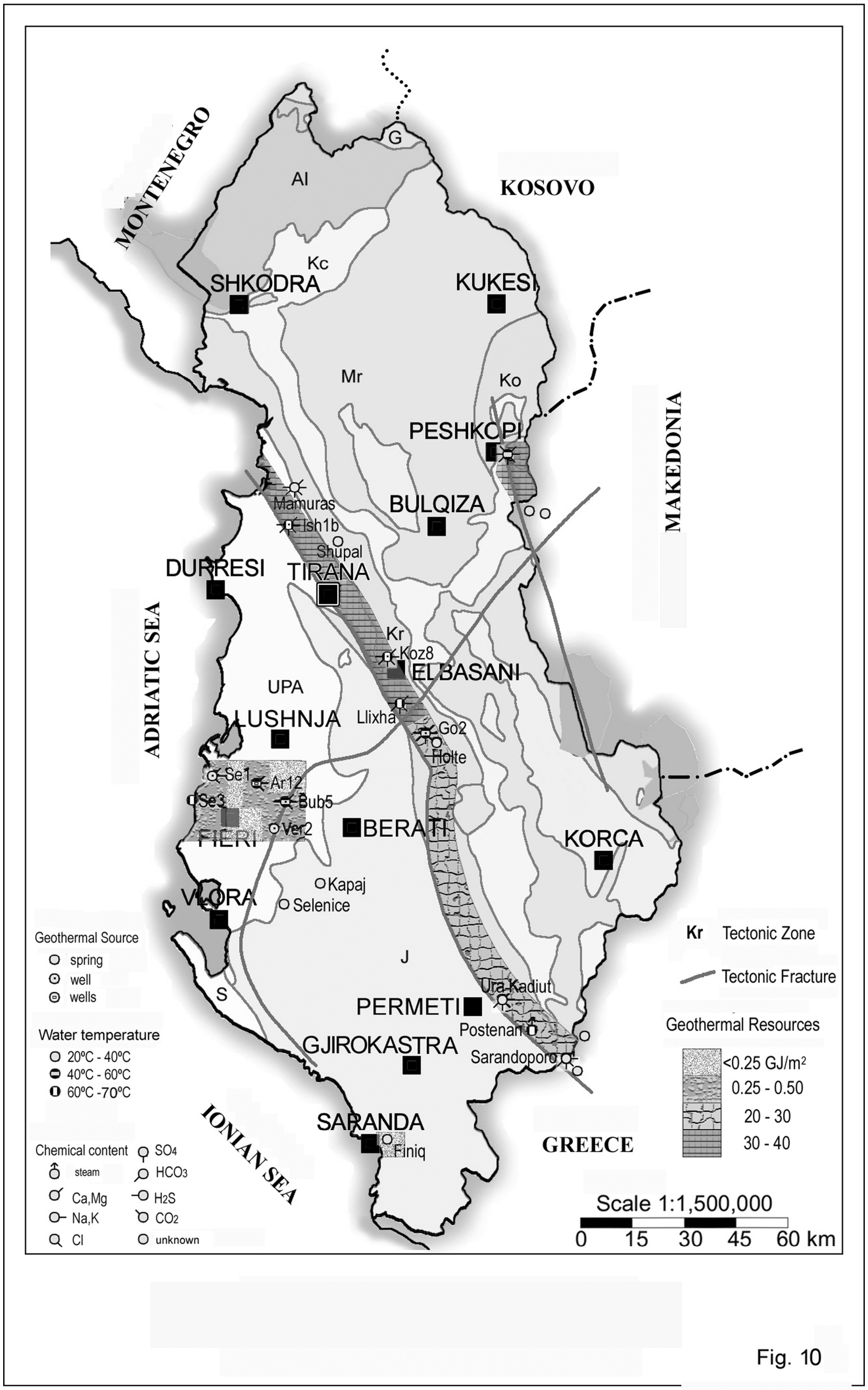

Fig. 10. Geothermal Zones Map of Albania.

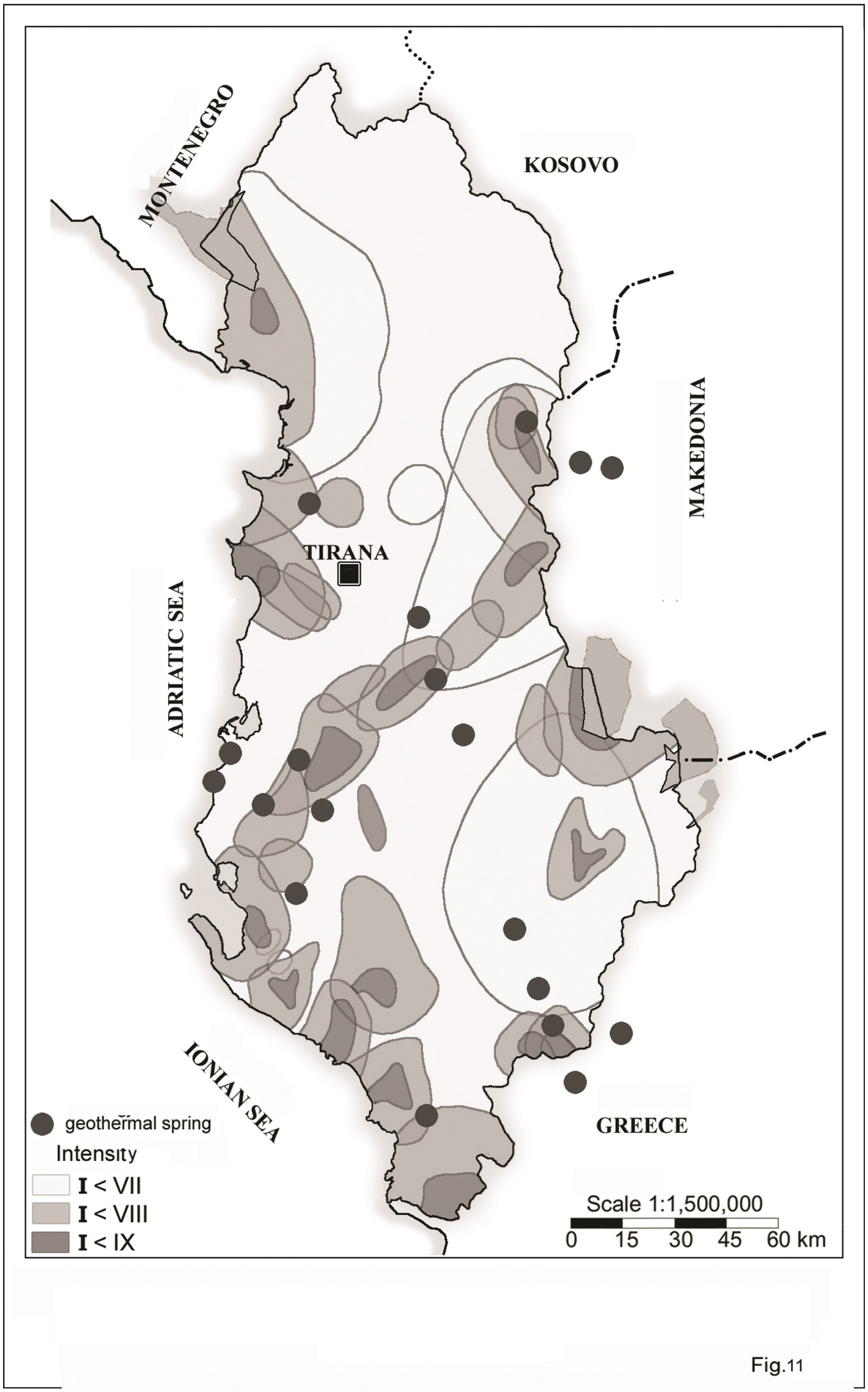

Fig. 11. Geothermal Springs and Earthquakes Isosteises Map of Albania.

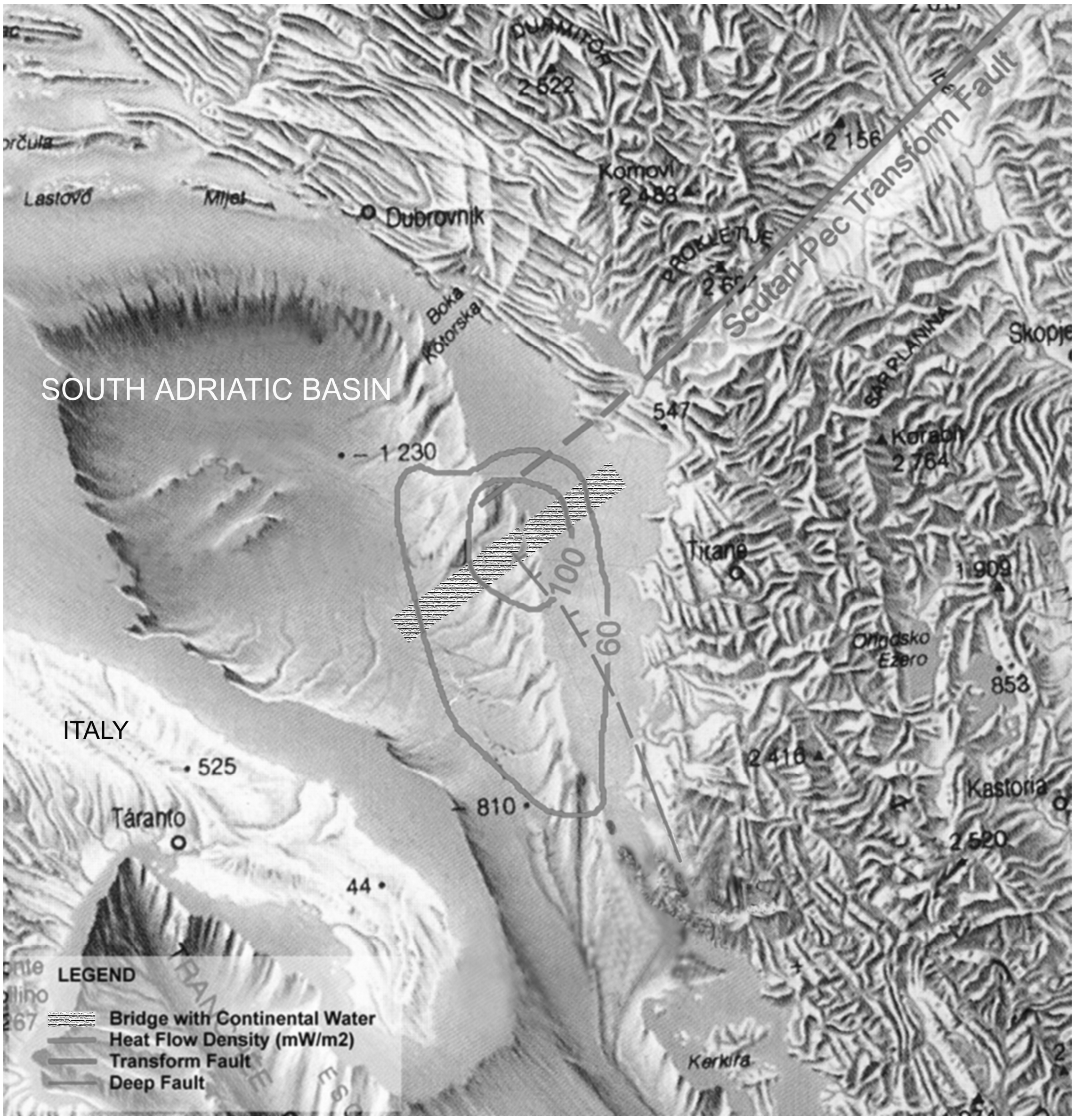

Fig. 12. Adriatic Heat Flow Density Anomaly (After Geothermal Atlas of Europe, 1992).

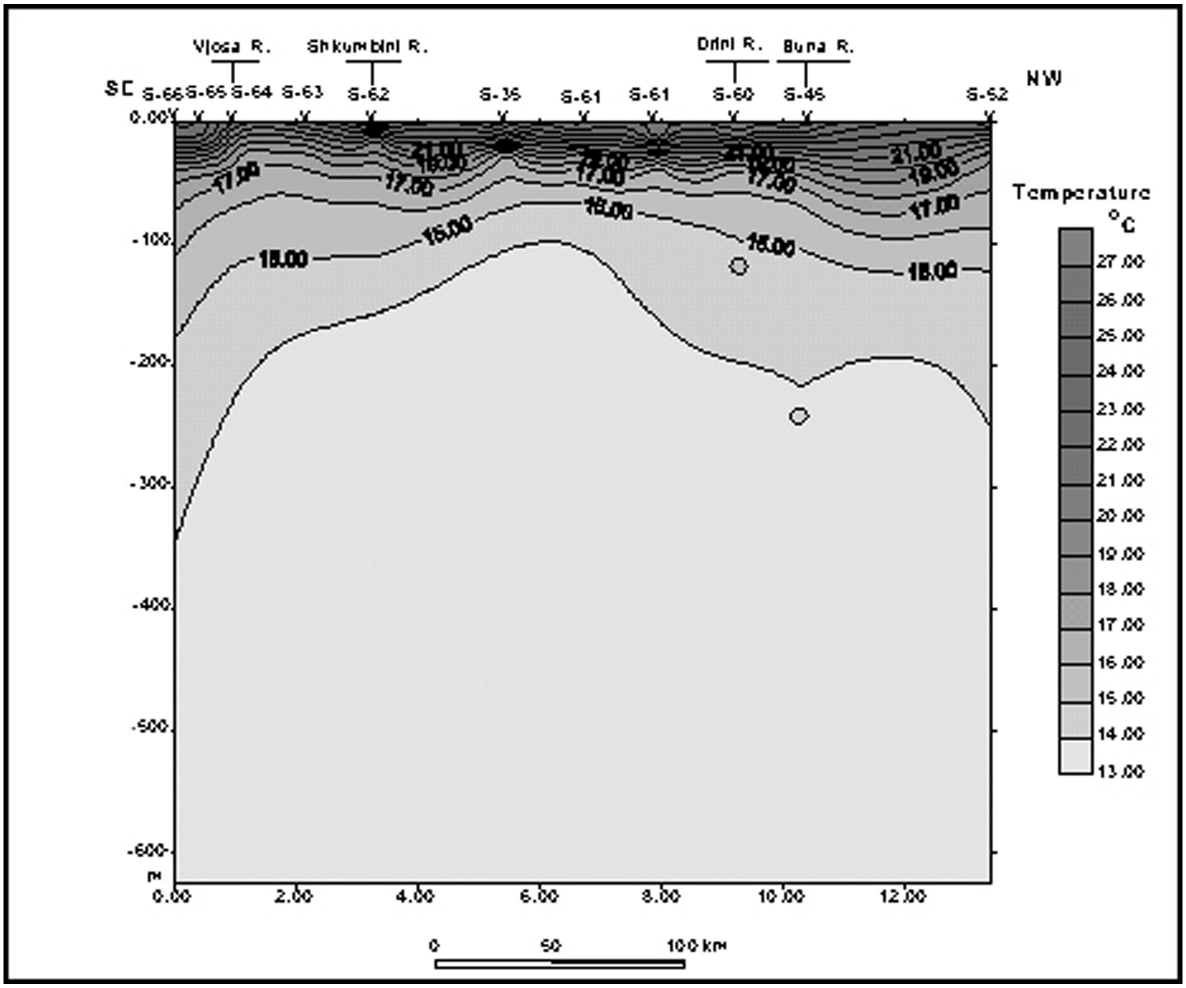

Fig. 13. Temperature in the "The Bridge" of continental water in the Adriatic Sea (Pano N. 1994).