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Interactive Seminar - Workshop 26:

Geothermal Field Development

OVERVIEW OF GEOTHERMAL RESOURCES AND GEOTHERMAL ENERGY APPLICATION IN SOUTH/EAST EUROPEAN COUNTRIES

SPE International Croatian Section

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GEPTHERMAL FIELDS DEVELOPMENT

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OVERVIEW OF GEOTHERMAL RESOURCES AND GEOTHER-MAL ENERGY APPLICATION IN SOUT/EAST EUROPEAN COUNTRIES

COMPILATION OF AVAILABLE DATA AND INFORMATION OF THE INTERNATIONAL GEOTHERMAL ASSOCIATION (IGA) EUROPEAN REGIONAL BRANCH

DUBROVNIK, JUNE 2008

INTER-UNIVERSITY CENTER
DUBROVNIK, CROATIA

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Co-directors

Prof. **Kiril Popovski**

Teaching material for the
Interactive Seminar – Workshop 26

The edition shall be distributed to the participants of the Interactive Seminar-Workshop under defined financial conditions as a working material, and to the libraries of the member of Inter-University center under non-commercial conditions, i.e. free of charge.

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Dubrovnik
June 2008

Fig.1. 12 ha greenhouse complex heated by geothermal energy in Kocani (Macedonia)

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Fig.2. Geothermally heated greenhouse in Nigrita (Greece) for production of vegetables

INTRODUCTION

South East Europe is a new, still completely not defined term, like the one “West Balkan” is, i.e. that is the area of Balkan peninsula and not, for instance, the Black Sea region. Once again, the region is something “between”, something special, where things are not completely clear. Region where three strong religions are fighting to take a larger part of the living space, making it the border between them. That had and has many negative consequences, i.e. regular appearance of wars, stagnation, etc. but also positive ones. Through generations people has been under continual pressure of fight to survive, resulting with creativeness and special approach to the life values. Other Europeans and Middle East cultures were always trying to neglect these values but inter-influence was not possible to be avoided and, if it is clear that differences in culture between particular countries and regions is result of influence of differences of different religions, it is for sure that also that these differences resulted with special culture, influencing significantly the regions around.

Something similar can be transferred to the development of geothermal energy use. It is one of the regions where thermal spas are born and widely spread all over the territory from the Mediterranean See to the Panonian basin, from the Black and Marmara to the Adriatic Sea. First “thermal” heating can be identified in some of these spas already during the Roman times, by the use of flow of geothermal water below the floor surface. First geothermally heated greenhouse in the world has been completed in Bansko (Macedonia) in sixties of last century, the same with spirulina growing in Rupite (Bulgaria) or heating of large greenhouse complexes in Macedonia, drying of rice, heating of animal farms in Serbia, etc. However, and due to the “temporal” character of the political organization, this initial prospective development was stopped and recently is in a process of stagnation. A list of geothermal projects are abandoned in Bulgaria, Macedonia, Serbia …

When trying to make an overview of the situation with proven geothermal resources and application in the region, one expects that it should be a rather easy problem because most of the countries are part of an ex-country (Yugoslavia) and others with quite a quite organized professional data base, except Albania. However, very soon it becomes clear that it is not the case. Due to the political changes during the recent 20 years all the organized information and data collection was practically, more or less, lost. No new investigations are registered, not all the information about the changes is on disposal, some of the projects are abandoned, etc. Strange enough but even the present positive changes of the approach to the renewable energies, followed with new studies, development projects, etc., doesn't influence this negative situation. Simply, geothermal energy as a renewable energy source is put somewhere in the background.

In the frame of its regular data collection about the situation with geothermal resources and application all over the world, International Geothermal Association (IGA) updates the information and data on disposal each 5 years. The last one was in 2005. European Regional Branch began the same in 2007 and the action of European geothermal Energy Council (EGEC) to establish a regular data base is in flow, where anu change of the situation should be registered at least once per year. However, present situation is not positive, i.e. it is not possible to get data and information at the same level of quality. Prof John Lund tried to introduce the country updates by the use of an equal template but without success. Nobody really follows it or, better said, everybody is accommodating it according to the situation in own country, i.e. giving even unnecessary information for the parts where they are on disposal but also "jumping" the ones where there are poor information on disposal.

The above said can be followed with the information and data for the geothermal energy sources and application in the South/East (i.e. Balkan) countries. Quit a large work is necessary to be invested, if intending to reach a relevant overview, enabling clear orientation, comparisons and proper use of data. Therefore, this material cannot be counted as a serious and complete one, enabling the listed uses. This is just a trial to arrange, or better said to compile internationally available data and information on disposal and can be used only for first information purposes. Hopefully, and in the interest of all the countries in question – creating a big enough market for development, this action shall provoke interest to prepare a better and more complete one. Such an action is interesting for IGA and the World Bank, which shall support it with pleasure. I hope that all of us shall be able to organize it during the coming years.

Fig.3. Outdoor geothermally heated swimming pool in Albena (Bulgaria)

1. SOUTH – EAST EUROPEAN COUNTRIES

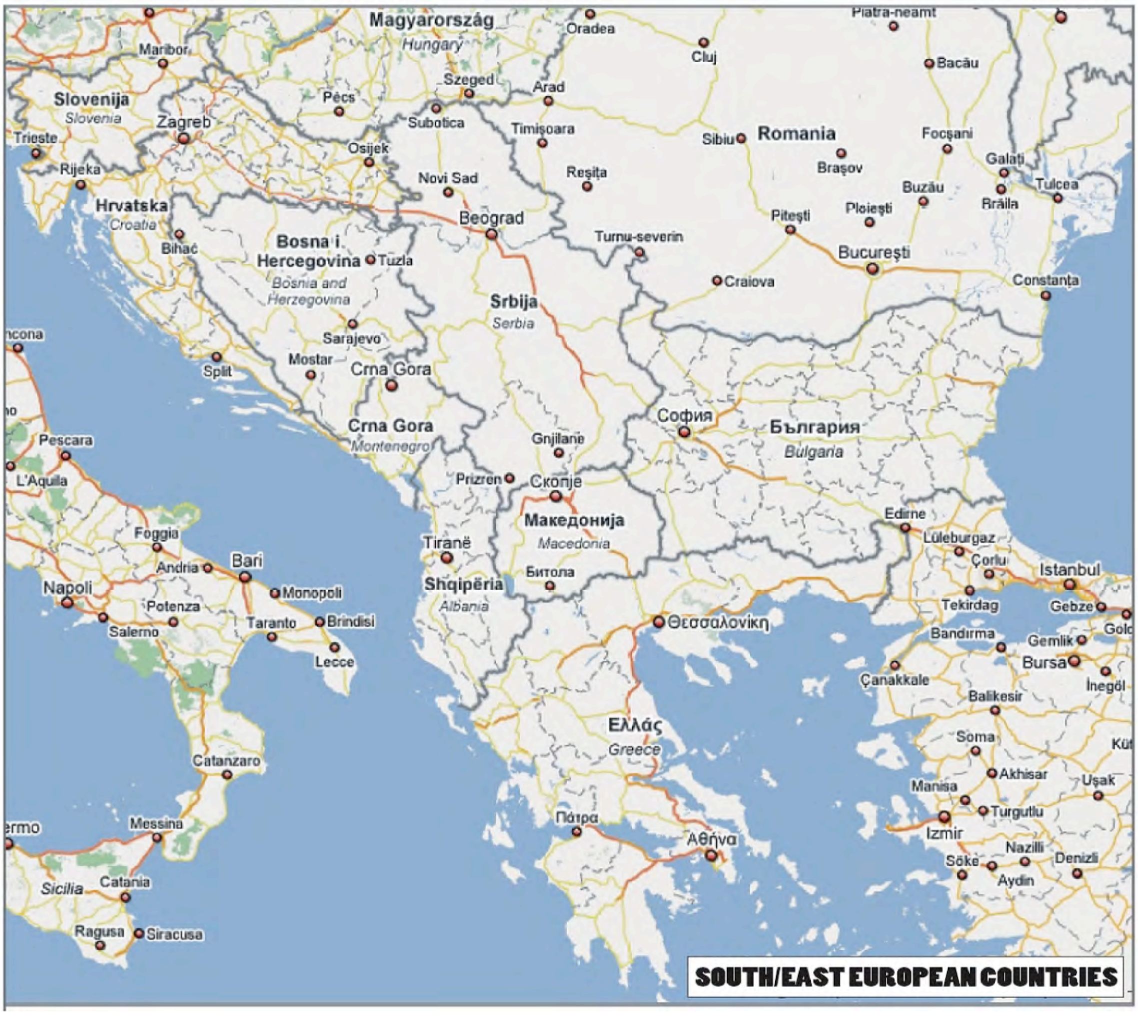


Fig.4. Map of the South/East Europe

1.1. ALBANIA

Fig.5. Map of Albania

Country (long form)
Republic of Albania
Capital
Tirana
Total Area
28,748.00 sq km
Population
3,490,435 (July 2000 est.)
Estimated Population in 2050
4,485,959

1.2. BOSNIA & HERZEGOVINA

Fig.6. Map of Bosnia and Herzegovina

Country (long form)
none
Capital
Sarajevo
Total Area
51,129.00 sq km
Population
3,835,777 note: all data dealing with population are subject to considerable error because of the dislocations caused by military action and ethnic cleansing (July 2000 est.)
Estimated Population in 2050: 3,896,902

1.3. BULGARIA

Fig.7. Map of Bulgaria

Country (long form)
Republic of Bulgaria
Capital
Sofia
Total Area
110,910.00 sq km
Population
7,796,694 (July 2000 est.)
Estimated Population in 2050: 4,478,866

1.4. CROATIA

Fig.8. Map of Croatia

Country (long form)
Republic of Croatia
Capital
Zagreb
Total Area
56,538.00 sq km
Population
4,282,216 (July 2000 est.)
Estimated Population in 2050: 4,388,085

1.5. GREECE

Fig.9. Map of Greece

Country (long form)
Hellenic Republic
Capital
Athens
Total Area
131,940.00 sq km
Population
10,601,527 (July 2000 est.)
Estimated Population in 2050: 9,208,837

1.6. MACEDONIA

Fig.10. Map of Macedonia

Country (long form)
Republic of Macedonia
Capital
Skopje
Total Area
25,333.00 sq km
Population
2,041,467 (July 2000 est.)
Estimated Population in 2050: 2,108,078

1.7. ROMANIA

Fig.11. Map of Romania

Country (long form)
none
Capital
Bucharest
Total Area
237,500.00 sq km
Population
22,411,121 (July 2000 est.)
Estimated Population in 2050: 18,340,400

1.8. SLOVENIA

Fig.12. Map of Slovenia

Country (long form)
Republic of Slovenia
Capital
Ljubljana
Total Area
20,253.00 sq km
Population
1,927,593 (July 2000 est.)
Estimated Population in 2050: 1,641,553

1.9. SERBIA AND MONTENEGRO

Fig.13. Map of Serbia and Montenegro

Country (long form)
none
Capital
Belgrade (Serbia), Podgorica (Montenegro)
Total Area
102,350.00 sq km
Population
10,662,087 (July 2000 est.)
Estimated Population in 2050: 9,771,709

1.10. TURKEY

Fig.14. Map of Turkey

Country (long form)
Republic of Turkey
Capital
Ankara
Total Area
780,580.00 sq km
Population
65,666,677 (July 2000 est.)
Estimated Population in 2050: 86,473,786

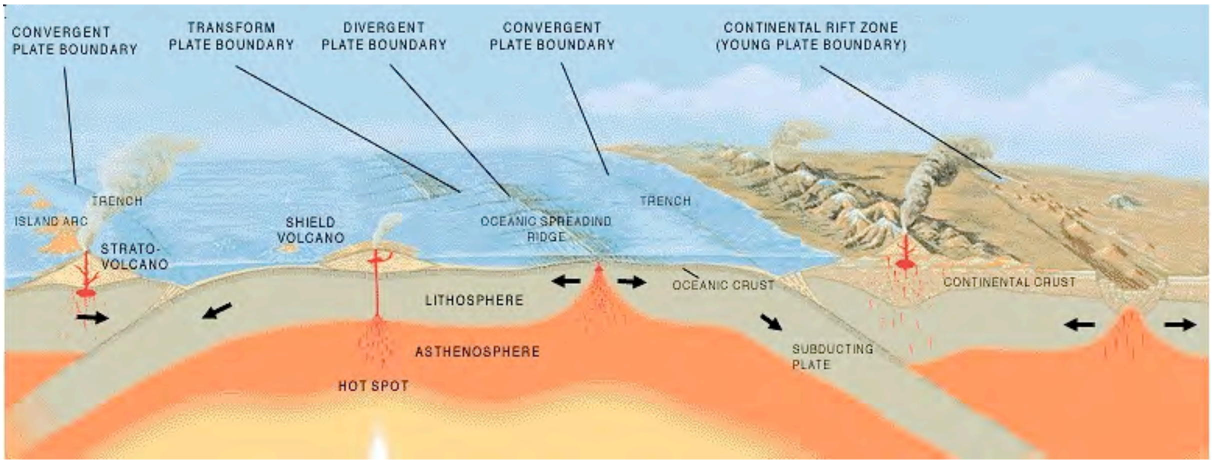


Fig.15. Geothermal energy origin

2. GEOLOGICAL BACKGROUND

2.1. ALBANIA (A. Frasheri, 2005)

The Albanides represent the main geological structures that lie on the territory of Albania. They are located between the Dinarides in the North and the Helenides in the South, and together they form the Dinaric Branch of Mediterranean Alpine Belt.

Albanides are divided in two big peleogeographical zones: the Inner Albanides and the External Albanides. Korabi, Mirdita (ophiolitic belt),presents the Inner Albanides and Gashi zones. The Alps, the Krasta-Cukali, the Kruja, the Ionian zone, the Sazani zone and the Pre-Adriatic Depression represent the External Albanides. The Depression as a part of Albanian Sedimentary Basin, continues towards the shelf of the Adriatic Sea. The geological cross-section of Albanian Sedimentary Basin is about 15 km thick and it also continues into the Adriatic Sea Shelf.

The Ionian zone developed as a large pelagic trough in the Upper Triassic. There, the evaporites of the Permian-Triassic are overlapped by a thick carbonatic formation of the Upper Triassic-Eocene. The geological section on this carbonatic formation is covered by Oligocene flysch, a flyschoid formation of the Aquitanian and by schilieres of the Burdigalian, Helvetian and particularly of Serravalian-Tortonian molasse.

Burdigalian deposits are overlapped transgressively with an angular unconformity, anticline belts. The Tortonian Age deposits have filled the synclinal belts of Ionic and Kruja tectonic zones.

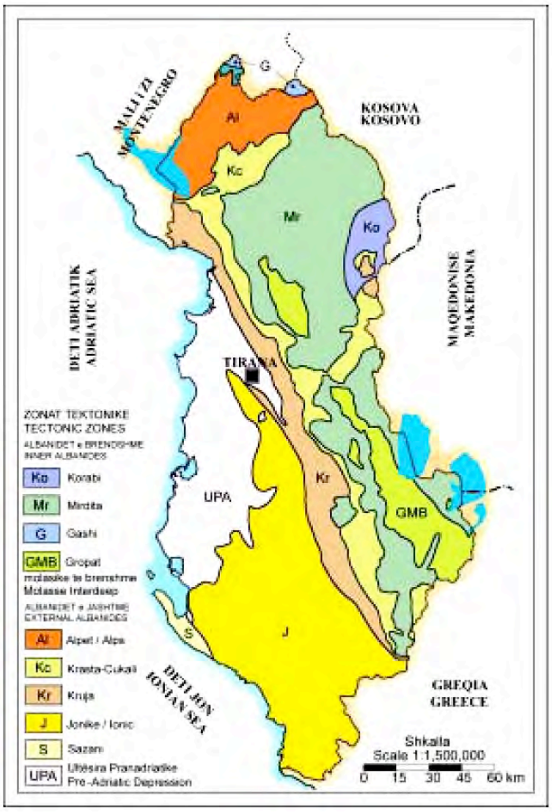


Fig.16. Geological map of Albania (Frasheri, 2005)

Miocene and Pliocene molasse of Peri-Adriatic Depression overlies the structures of northern part of the Ionian zone.

The structure of Neogenic molasses represents the upper tectonic stage of the structure of the Peri-Adriatic Depression.

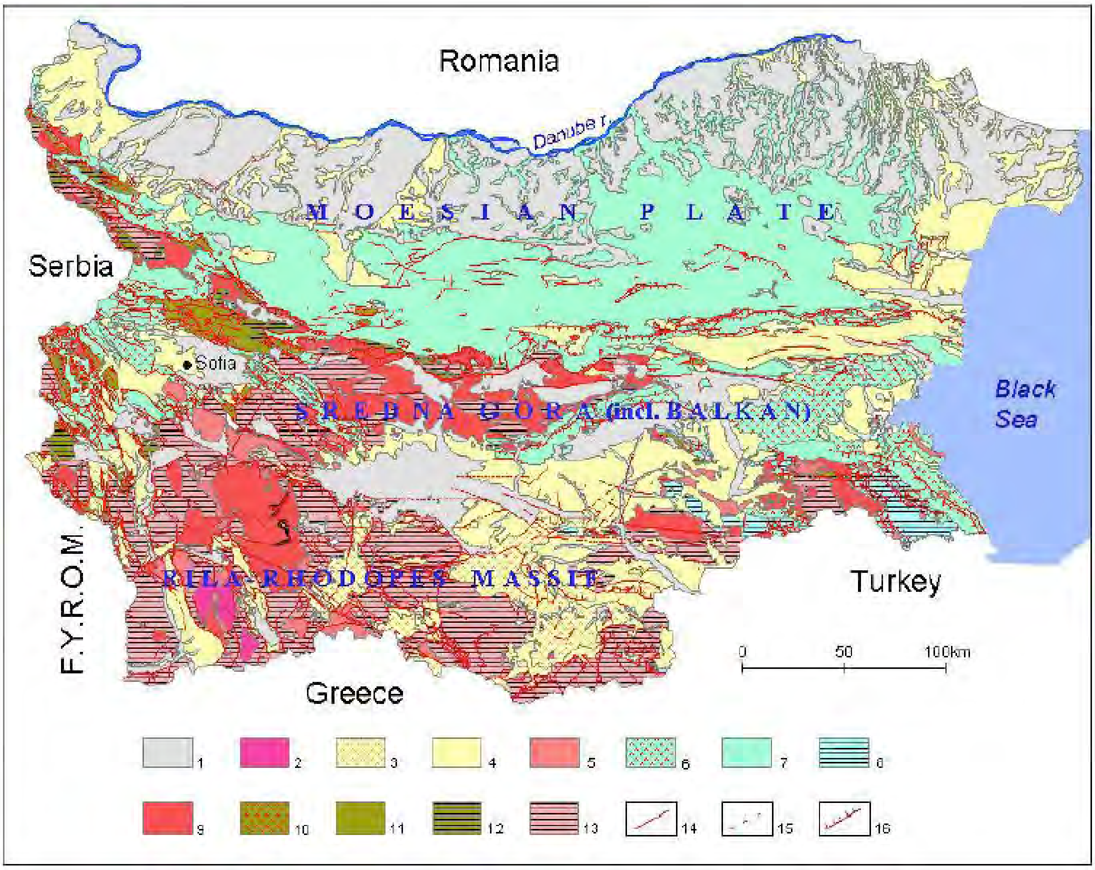
In the over part of the section of Kruja zone, the carbonatic neritic rocks of the Cretaceous-Paleogene age are overlying the

Oligocene flysch of a thickness of 5 km. The structures of the Albanides are typically Alpine ones.

The SSE-NNW directions represent their general strike. The structures are asymmetrical and have a western vengeance.

Recumbent, overthrusted and overtwisted structures are also found. Generally, their western flanks are affected by disjunctive tectonic.

2.2. BULGARIA (K. Bojadjieva, 2005)



1. Quaternary unconsolidated deposits	9. Paleozoic intrusive rocks
2. Neozoic intrusive rocks	10. Paleozoic volcanic and volcano-sediment rocks
3. Neozoic volcanic and volcano-sediment rocks	11. Paleozoic sediment rocks
4. Neozoic sediment rocks	12. Paleozoic metamorphic rocks
5. Mesozoic intrusive rocks	13. Prepaleozoic metamorphic rocks
6. Mesozoic volcanic and volcano-sediment rocks	14. Faults
7. Mesozoic sediment rocks	15. Assumed faults
8. Mesozoic metamorphic rocks	16. Line of overthrust

Figure 17: Geological map of Bulgaria (Petrov, 1997)

Bulgarian territory is characterized by a complex and diverse geological structure, (Fig17). It is built of rocks of different origin, various lithologic and petrologic compositions and of Quaternary to Archean and Proterozoic age.

Bulgaria is divided into three major hydrogeological units: Moesian plate, Sredna gora zone (incl. Balkan zone) and Rila-Rhodopes massif. The Moesian plate has a

Caledonian-Hercynian basement and a cover of Upper Paleozoic and Mesozoic sediments. Their thickness decreases from about 6-7 km in the west down to several hundred meters in the east. The main geothermal reservoirs in the platform area are situated in the carbonate strata of Malm-Valanginian, Middle Triassic and Upper Devonian age. They consist of up to 1000 m thick artesian aquifers built up of limestone and dolomite, very fractured and with high permeability. The Sredna gora zone is a rich and heterogeneous hydrothermal region where unstratifed (fault-fractured), stratified and mixed hydrothermal systems are present. Hydrothermal circulation takes place in the fractured massif of granite and metamorphic rocks and in the Upper Cretaceous volcano - sedimentary deposits.

Thermal reservoirs are formed also in many postorogenic Neogene – Quaternary grabens filled up with terrigenious deposits.

The western Rila-Rhodopes massif is mainly built of Precambrian metamorphic and granite rocks, fractured by a dense system of seismically active faults.

Unstratified hydrothermal systems with thermal waters of low salinity, meteoric origin and of highest measured temperature up to 100ºC are found in this area. The metamorphic basin contains some large bodies of marble that act as hydrothermal reservoirs. Permeable terrigenous-clastic materials in the deep Neogene and Paleogene grabens also contain thermal waters.

The eastern part of the massif is not rich in thermal waters.

2.3. CROATIA (Jelic, Kovacic, 2005)

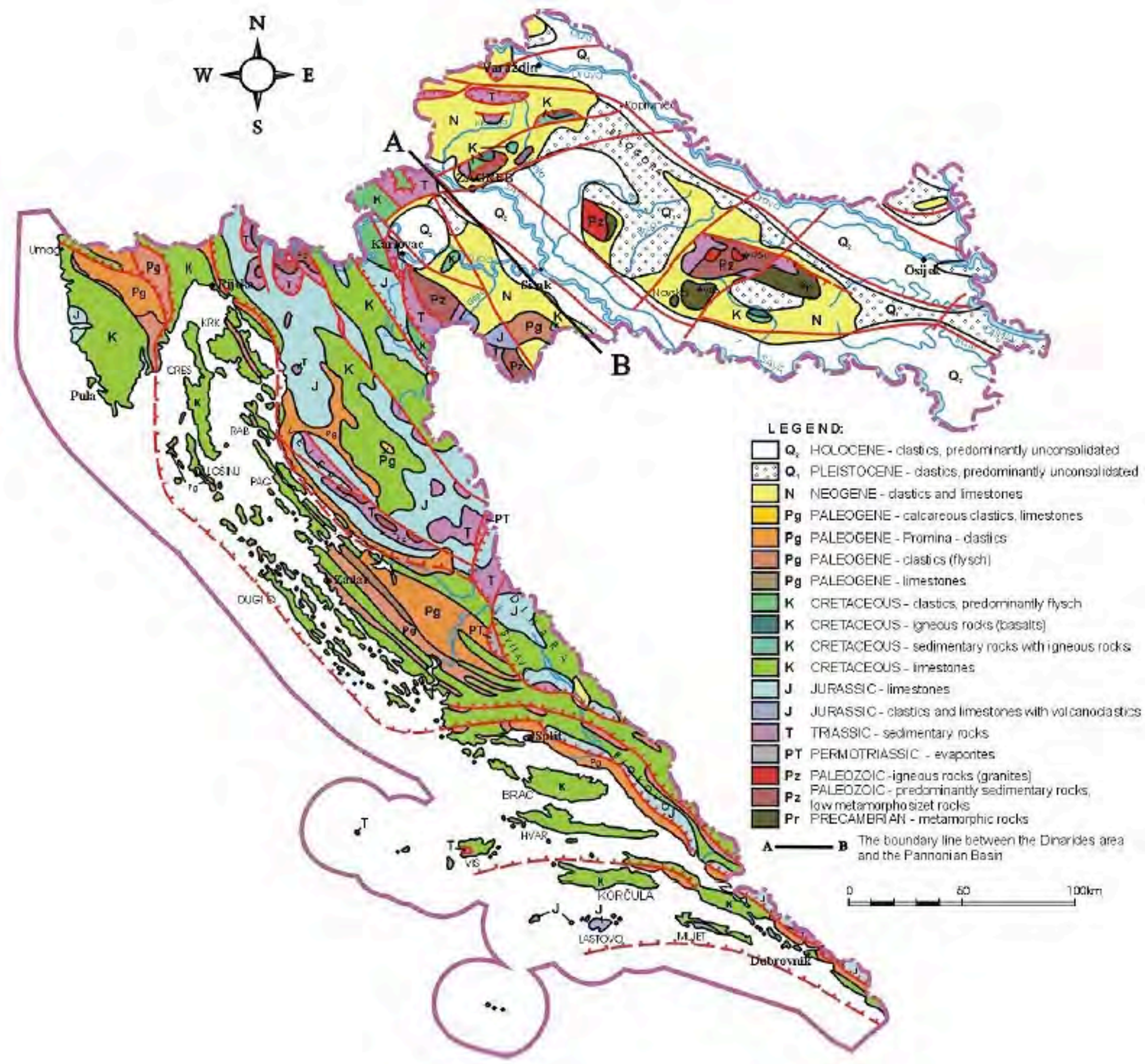


Fig.18. Geology map of Croatia (Velic&Velic, 1993)

The Republic of Croatia can be divided generally into two geologically different regions: the Pannonian Basin and the Dinarides belt. Different opinions prevail with regards to the location of the boundary line between the two regions.

The boundary on the fig.18 is based on lithological characteristics and tectonics. Southwest of the boundary is the Dinarides area where the Mesozoic carbonate rocks prevail. The northeast area of the boundary belongs to the Pannonian Basin. In this area the Quaternary and Tertiary sedimentary rocks dominate which overly the crystalline bedrock and occasional Mesozoic sedimentary rocks.

Locality of the stratigraphic unit and description of the rocks are represented on the geological map (Fig.18). The main characteristics of the tectonic pattern are tangential structures (folds, thrusts, nappes) of the northwest-southeast strike, mostly originated in Paleogene, disturbed by younger normal faults from Neogene to Quarternary (Velić,I. & Velić, J., 1993).

2.4. GREECE (M. Fytikas, 2005)

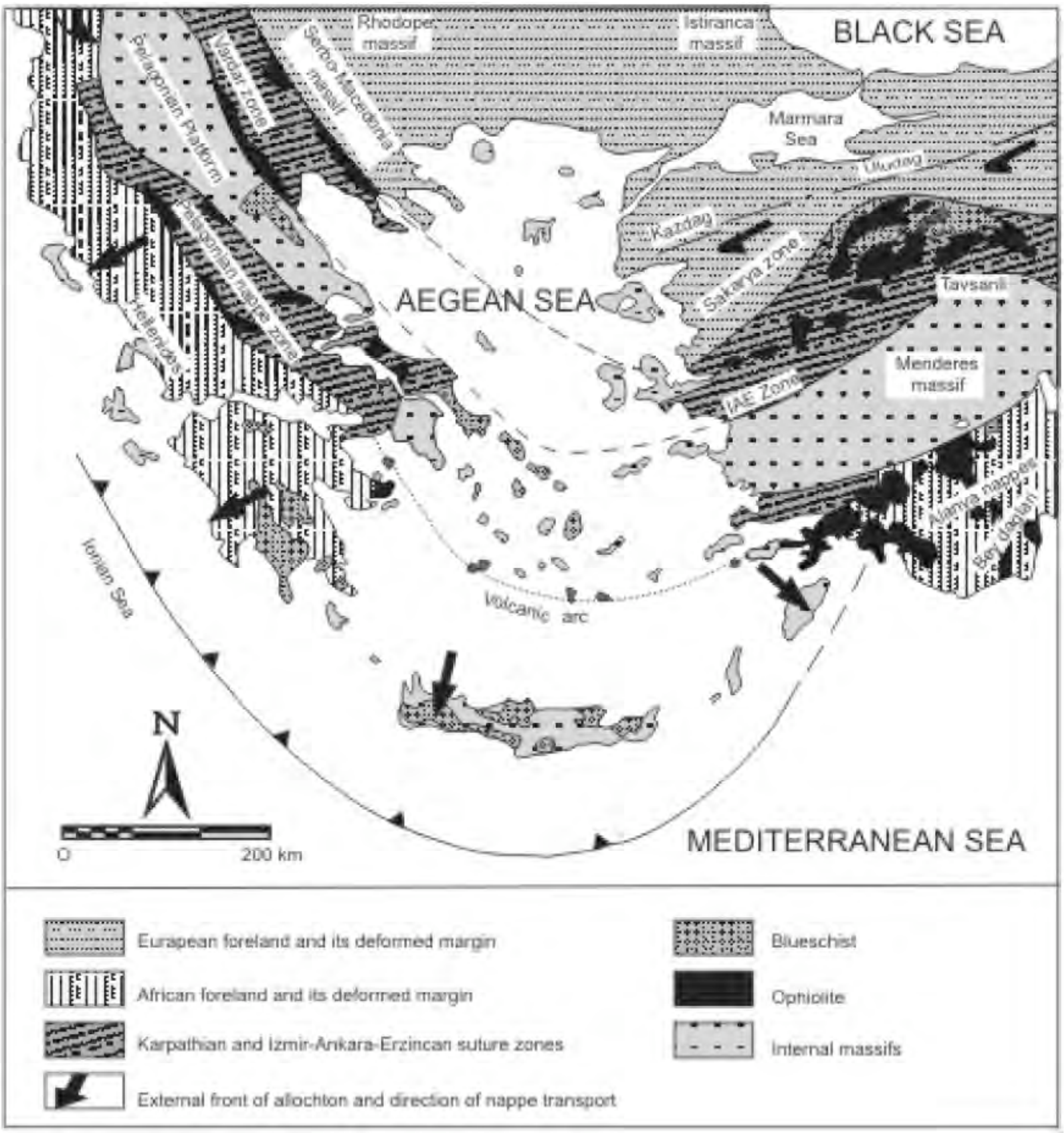


Fig.19. Major geological units and old oceanic remnants (ophiolites and blue scists) of the Aegean area. The active volcanic art is shown by a dotted curve (Kuleli et al. 1995)

The Hellenic area is characterized by high levels of heat flow higher than 80 mWm^{-2}, mainly in the internal Hellenides and the Aegean Sea. The high heat flow is due to the active tectonics and the volcanic activity, which since Tertiary is manifested in the area as result of the collision between the European and African tectonic plates. This very intense volcano-tectonic activity caused the geological conditions for accumulation of heat energy,which is manifested in many places as hydrothermal systems of low-medium and high enthalpy geothermal fields. The most important high-enthalpy geothermal fields are located in the Southern Aegean (Fig.19), along the active volcanic arc (Milos, Nisyros). Medium and low enthalpy geothermal fields are mostly associated with grabens (Central Aegean) and post-orogenic sedimentary molassic basins (southern boundaries of the Rhodope and Serbo-Macedonian Massifs).Sections and subsections should be numbered.

The magmatism and volcanic activity in Greece took place during Cenozoic. The first records come from East Macedonia and Thrace, during the Upper Eocene, and the most recent ones from Santorini Island, where the eyewitnesses of the last eruption are still alive.

After extensive research, combination and evaluation of all the obtained data, it has been concluded that several magmatic locations exist in Greece, the distribution of which –according to their age-migrate from the north to the south.

This volcanic activity in Greece has been going on continuously without any interruptions. In the islands of North Aegean (Samothraki, Agios Eftstratios, Lesvos) the intense volcanic activity took place between 23,2 and 16,2 Ma ago.

In the Central Aegean (Skyros, Psara, Euobea) the volcanic activity was not extensive and took place in the period between 17,7 and 13,2 Ma ago.

The age of the Eastern Aegean volcanism is 10,7-3,5 Ma.

During the last 5 Ma the intensive volcanism in Greece is divided in two main categories:

A scattered volcanism, which is mostly located in Mt. Vorras and in the southern coasts of Pagassitikos Gulf (6-0,5Ma ago).

The volcanism located along the volcanic island arc of Southern Aegean, from Sousaki to Nisyros Island. The oldest volcanic activity goes 4,7Ma back, while the last historical eruptions of Methana and Santorini were recorded in 282 B.C. and 1950 A.C. respectively. Hydrothermal eruptions have been also recorded in historical times in Milos (16th century) and Nisyros (19th century).

The oldest plutonic formations in North Greece have been traced in Chalkidiki (52-44Ma), Kavala (21Ma) and Samothraki (18,5Ma). The age of the Central Aegean plutonics is 17-8,5Ma, the youngest of which are located in Serifos and the oldest in Ikaria Island.

The deep exploratory oil-wells that were drilled in the Delta of Nestos river (North Greece, between Kavala and Thassos), showed that the temperatures of the sediments are over 200°C at depths less than 2000m. This has been considered as an indication of a Middle Miocene plutonic intrusion. Inbedded horizons of ignimbrites were also traced in the Upper Miocene sediments of Kavala basin.The volcanism in the islands of North Aegean (Samothraki, Imvros, Lemnos, Ag. Efstratios, Lesvos) and in the neighboring areas of Asia Minor was generated by the active subduction and the extensional decompression of the lithospheric mantle (from the collapse of the Alpine orogene), which are considered as the most suitable mechanism that generated the magmatism in this area.

In the area of Central Aegean (Cyclades Islands), a non-extensive and scattered volcanism is located in the islands of Syros, Psara and Chios, while the most extensive outcrops are found in Euobea Island.

Scattered volcanic activity has been recorded in Greece mainly during Pliocene and less in Pleistocene, in the west coasts of Pagassitikos Gulf, the North Euobean Gulf, Mt. Vorras, Strymonas Basin, Antiparos and Psathoura Islands.

The correlation between the Psathoura and Pagassitikos-Euobean Gulfs with the north branch of North Anatolia Fault is evident.

Intense volcanic activity has been taking place in the area of South Aegean Volcanic Arc. In Soussaki, Egina and Poros, the age of the volcanism is Pliocene, while in Methana, Santorini and Nisyros is Quarternary.

In the island complex of Milos, Santorini and Kos-Nisyros, big and complex volcanoes are structured (10-43km^3 above sea level), while the periodical manifestation of large explosive events caused frequent calderic collapses. On the contrary, the effusive activity prevails in the volcanic centers of Saronikos gulf and creates dome and lava flow complexes.

The general geochemical characteristics of these volcanic rocks are absolutely accordant to the products of the volcanic arcs in subduction zones.

The differences in structure and in the explosive behavior between the volcanic centers of western (Saronikos) and central-eastern arc, can be ascribed to the smaller crust thickness as well as to the more intensive extensional tectonic regime of the central-eastern part. Santorini, which is located over the thinner crust zone presents the most explosive behavior.

The volcanic centers are placed selectively along four normal faults, in Saronikos, Milos, Santorini and Kos- Nisyros.

2.5. MACEDONIA (E. Micevski, 2005)

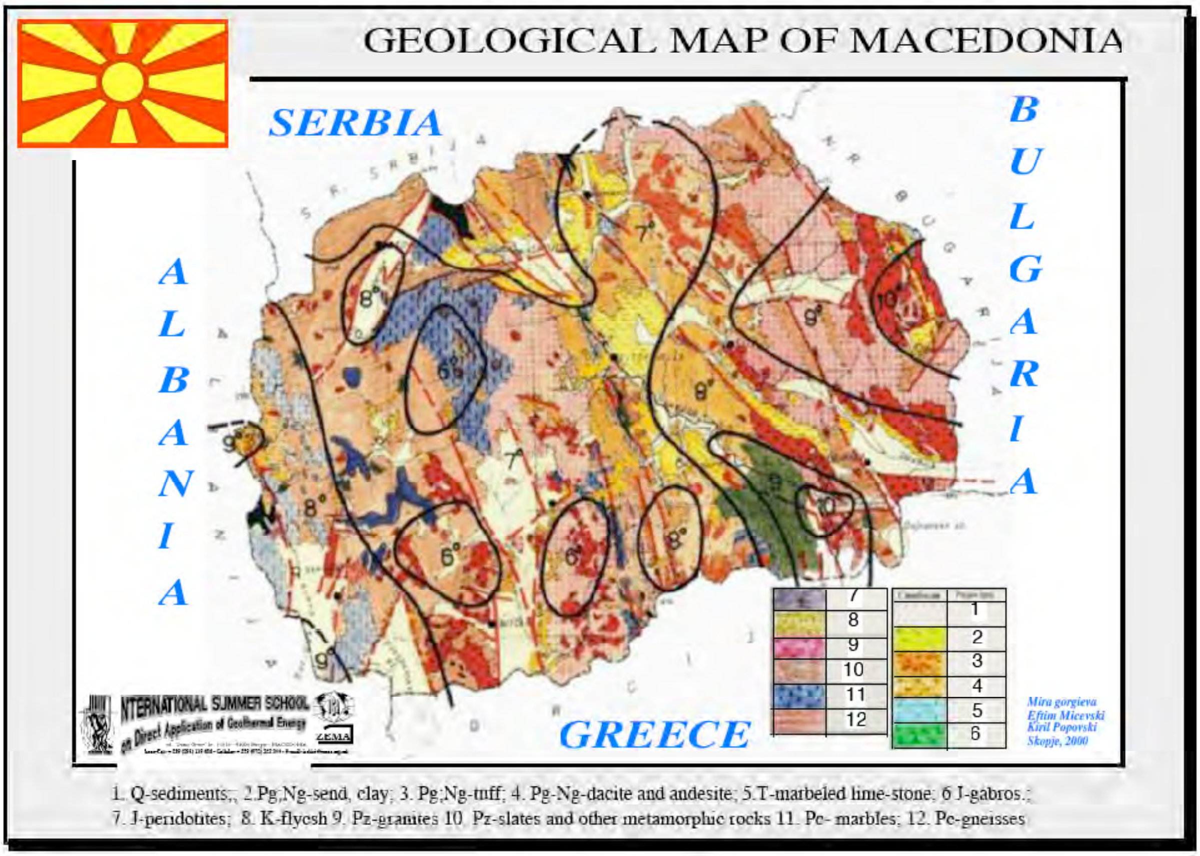


Fig.20. Geological map of Macedonia (Georgieva et al. 2000)

The geotectonic situation of the territory of the Republic of Macedonia is conditioned of its location. It belongs to the Alpine-Kaukaus - Himalyan geosynclinnian belt where the history of creation of the terrain is connected with the former geosynclinian Tethis and Alpine orogeny, but also with the primary position of the prime lithosphere of this regions, as with the effect of the pre-alpine orogeny. Many researchers were involved with the tectonic zonation of Macedonia throught examination of the tectonic complex of the whole Alpine-Himalaya orogen or onli of the Balcanian peninsula.

As a consequence of the many exsting geotectonic concept, there are many geotectonic zonations of Macedonia and its surrounding territories.

Generaly speaking, in the division of the Alpine orogen, the territory of Macedonia belongs to the two tectonic systems: the west part of Macedonia including the Vardar area, belongs to the Dinarides(Helenide), while the east Macedonian mountain terrain and valley depression are segments of the Serbo-Macedonian massif. Along the bondary with Bulgaria, a separate zone known as Karpato- Balkanides has been distinguished.

According to this geotectonic regionization, the basic part of the territory of Macedonia, in the west of the line Dojran - Strumica - Zletovo - Kumanovo, refers to the Dinaric system in which four geotectonic units are distinguished: the Vardar zone, the Pelagonian horst-anticlinorium, the western Macedonioan zone and the Korab zone known as Cukali-Krasta zone. In the eastern part of the already mentioned line, the Macedonian massif occurs, which unites with the Rhodope mass through the Ograzden complex. In the bordery part with Bulgaria, in the north from Berovo, Pehcevo, sediments from the Karpato-Balcanides occur as a wedge within the old Rhodope mass, distinguished as Strumica zone (Krajshtides- according to E.Bonchev). Each distinguished unit is a separate structural-facies wholeness, which is characterized by a special geological development, including the specific processes of the tectonic deformations as well as the manifestations of the magmatic differentiation (Fig.18.)

In the territory of Macedonia rocks of different age occur and, starting from Precambrian to Quaternary, almost all lithological types are represented. The oldest, Precambrian rocks, consist of gneiss, micaschists, marble and orthometamorphites.

The rocks of Paleozoic age mostly belonging to the type of green schists, and the Mesozoic ones are represented by marble limestones, acid, basic and ultrabasic magmatic rocks. The Tertiary sediments consist of flysch and lacustrine sediments, sandstones, limestones, clays and sands.

With respect to the structural relations the territory can be divided into six geotectonic units: The Cukali-Krasta zone, West Macedonian zone, Pelagonian horst anticlinorium, Vardar zone, Serbo-Macedonian massif and the Kraisthide zone (Fig.18). This tectonic setting is based on actual terrain and geological data without using the geotectonic hypothesis (Arsovski, 1998).

First four tectonic units are parts of Dinarides, Serbo-Masedonian mass is part of Rodops and the Kraisthide zone is part of Karpato-Balkanides distinguished on the Balkan peninsula as geotectonic units of first stage.

2.6. ROMANIA

The geothermal systems discovered on the Romanian territory are located in porous permeable formations such as Pannonian sandstone, interbedded with clays and shales specific for the Western Plain, and Senonian specific for the Olt Valley. Some geothermal systems are located in carbonate formations of Triassic age in the basement of the Pannonian Basin, and of Malm-Aptian age in the Moesian Platform.

The Pannonian geothermal aquifer is multilayered, confined and is located in the sandstones at the basement of the Upper Pannonian (late Neogene age), on an approximate area of 2,500 km^2 along the Western border of Romania, from Satu Mare in the North to Timisoara and Jimbolia in the South.

2.7. SERBIA (M. Milivojevic, 2005)

The Earth's crust in Serbia varies in thickness, increasing to the south. This thickness is uniform, about 25-29 km, in the Pannonian Basin area (Dragasevic et al., 1990). South of it, in the Dinarides, the thickness increases to about 40 km in extreme Southwest Serbia. In the Serbian-Macedonian Massif, the crustal thickness is about 32 km, and in the Carpatho- Balkanides from 33 to 38 km. Values of the terrestrial heat flow density under most of Serbia are higher than the average for continental Europe. The highest values (>100 mW/m2) are in the Pannonian Basin, Serbian - Macedonian Massif, and in the border zone of the Dinarides and the Serbian- Macedonian Massif, or the terrain of Neogene magmatic activation. These values are the lowest in the Mesian Platform (Milivojevic et al., 1992). The mentioned high heat flow densities indicate the presence of a geothermal anomaly (Milivojevic, 1992) which is certainly an extension of the geothermal anomaly of the Pannonian Basin (Bodri &

Bodri, 1982). The thickness of the lithosphere, estimated by on a geothermal model (Milivojevic, 1993), is least thinnest in the Pannonian Basin, Serbian-Macedonian Massif, and its border zone on the Dinarides, only 40 km. In the Carpatho-Balkanides and the rest of the Dinarides, this thickness is up to 150 km. The lithosphere is the thickest in the Mesian Platform - from 160 to 180 km.

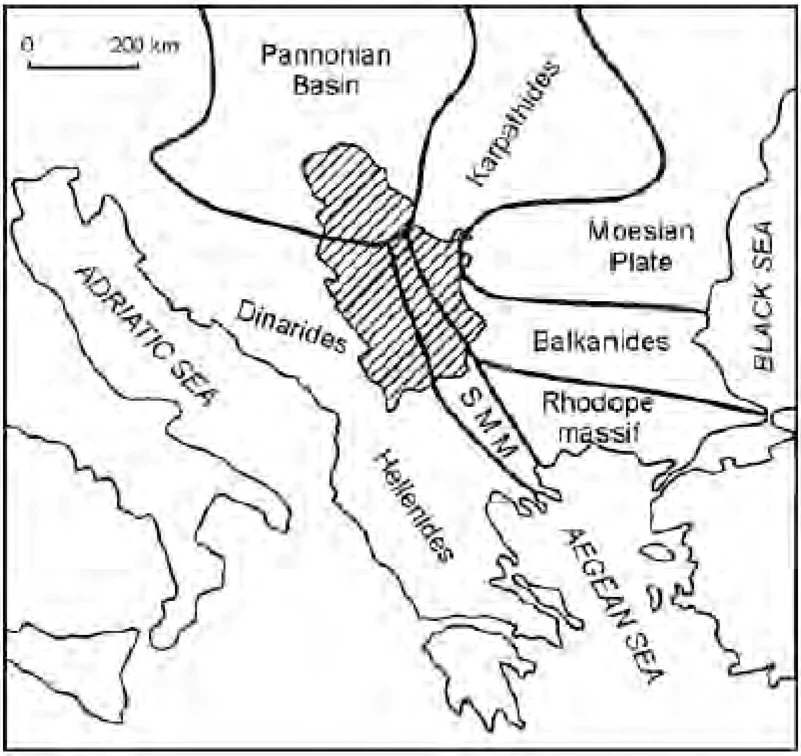


Figure 21. Tectonic map of Balkan peninsula (Milivojevic, 2005)

Figure 22. Geotectonic map of Serbia and Montenegro (Milivojevic, 2005)

The terrains in the central and western parts of the Balkan Peninsula are the consequence of subduction that occurred during the Jurassic Period (Karamata & Krstic, 1996).

According to these authors, the hydrogeothermal system of the Inner Dinarides is situated in the extreme southern section of the Pannonian Basin and the following Dinaric terraines: the Dinaric Ophiolite Belt terraine (DOBT), the Central Bosnian Mts. Terrane (CMBT), the Jadar Block terrain (JBT), and the Vardar Zone composite terrain (VZCT). The distribution of the terrains is given in Fig. 22. The Pannonian Basin, or its south part in Serbia and Bosnia and Herzegovina, consists of Paleogene, Neogene and Quaternary sediments with a total maximum thickness of about 4000 meters. The Dinarides occupy the largest part of Serbian and Montenegro territory and they consist of the following terraines: VZCT, JBT, DIT, DOBT, CMBT, EBDT and DHCT (Fig. 22.). The Dinarides are built mainly of Mesozoic rocks, most significantly the thick deposits of karstified Triassic limestones and dolomites, a Jurassic ophiolitic melange and Cretaceous flysch deposits.

The Serbian-Macedonian Massif (SMM) (Fig. 22), is composed of very thick Proterozoic metamorphic rocks: gneisses, various schists, marbles, granitoid rocks, etc. The Proterozoic complex of the Serbi-an-Macedonian Massif extends across East-ern Macedonia and northern Greece into Turkey and further eastward. This Massif includes magmatic, or intrusive-granitoid and volcanic rocks of Tertiary age. The Carpatho-Balkanides (ESCBCT on Fig. 22.) were formed in the Mesozoic as a carbonate platform separated from the Dinarides by the Serbian-Macedonian Massif. This unit is dominanted by Triassic, Jurassic and Cretaceous limestones.

The Pannonian Basin, or its South-Eastern part in Serbia, consists of Paleogene, Neogene and Quaternary sediments with a total maximum thickness of about 4000 meters.

2.8. SLOVENIA (P. Kralj, 2005)

Slovenia lies in the convergent area of the African and Eurasian tectonic plates or, more precisely, on the Adriatic microplate and on the SW part of the Pannonian basin. Slovenia extends over several tectonic units (Fig. 23): the most NE part belongs to the Pannonian basin, while the Eastern Alps (incl. magmatic rock complex), the Southern Alps, the External and Internal Dinarides and Adriatic foreland represent parts of the Adriatic microplate. The Alps and the Dinarides were formed during the collision of these two great tectonic plates that has continued from the Jurassic to the present.

Folding and thrusting occurred in several phases, and numerous deep fracture zones were formed in localized areas, enabling thermal water to circulate from depths of several kilometres to the surface, providing the zones are permeable enough. More information on geological aspects can be found in Ravnik et al. (1995) and Placer (1998) and references therein.

2.9. TURKEY (S.Simsek, 2002)

The Aegean region has been separated into major geotectonic units which are schematically outlined in Fig.25. The E-W trending geological units extending from western Turkey to Greece, associated with the area, can be identified roughly from North to South as subparallel zones.

The *Northern* part of this region is mainly formed by crystalline massifs; the Serbo-Macedonian and Rhodop massifs in Greece and Bulgaria; the Istranca, Uluda_ and Kazda_ massifs in Western Anatolia. Just below the above mentioned crystalline massifs, the suture defining the Northern boundary of the Apulian plate follows the Vardar zone in Greece to the Izmir-Ankara-Erzincan (IAE) zone in Turkey. This suture zone is known by its ophiolitic material.

Towards the *South*, the second zones of internal massifs are situated. The Pelagonian platform on the Greek mainland, the Attic-Cycladic platform and the Menderes massif in Turkey are closely related and form the Median Aegean crystalline belt. The third zone, which also coincides with ophiolitic material, is in the Pelagonian nappe zone, and the Alanya nappes are in the Lycian zone. In the southern part of the region, an orogenic belt of Alpidic origin can be traced from the Dinarides and Hellenides in the west, through to the Hellenic island arc and the Taurides (Bey da_ları) in the

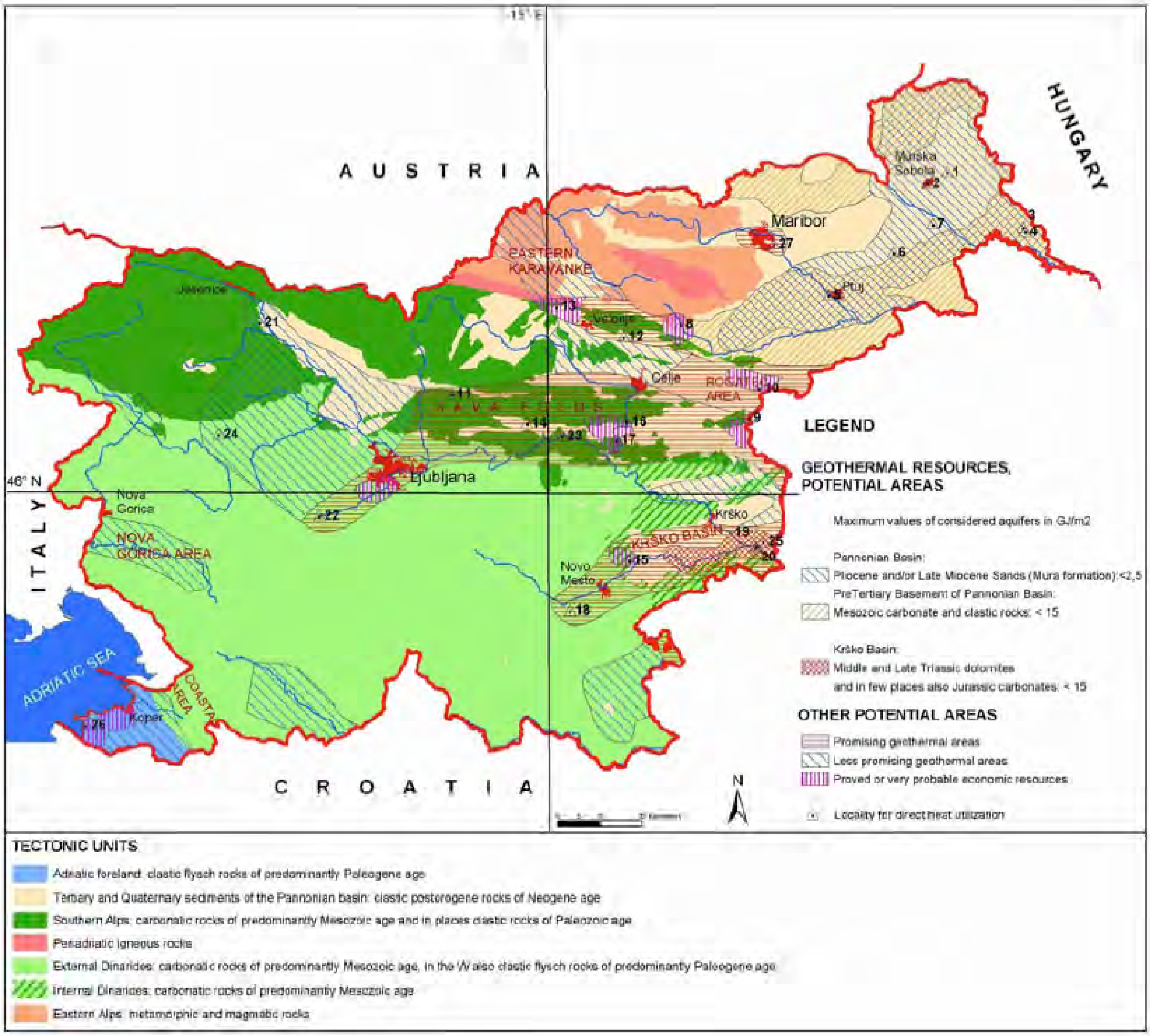


Figure 23. The main tectonic units of Slovenia with their lithological composition and geothermal resources with potential areas (P. Kralj, 2005)

East. The arc is small and highly curved (R=400 km), and marks the limit between a relatively undeformed, narrow, 3 km deep Mediterranean basin filled with up to 10 km of sediments to the South and the highly deformed, largely allocthonous Hellenic mountain belt to the North (Le Pichon and Angelier, 1979). Beneath the Hellenic arc the oceanic lithosphere is subducted through the mantle in a curve. The volcanic products cover extensive areas from the active volcanic arc in the south towards the Black Sea in the north (Fig. 25) The volcanics are located within the three zones in the region (Gülen, 1990).

The first volcanic arc mostly consists of a number of small islands stretching between mainland Greece and western Turkey. These islands are Aegina, Milos, Santorini, Nysiros and Kos. The second volcanic zone is situated along the Southern periphery of the Attic-Cycladic-Menderes metamorphic belt. This zone is referred to as the “inner arc” (Innocenti et al., 1982), and consists of Atalanta-Volos volcanics and Antiparos rhyolite. The third volcanic zone covers an extensive area in the Northern Aegean region where the Attic-Cycladic-Menderes metamorphic belt forms its Southern boundary.

The present-day deformation in Turkey is concentrated in four major structural zones: Bitlis Suture Zone, North Anatolian Fault Zone, East Anatolian Fault Zone and Western Anatolian Graben System (Fig.25).

The Bitlis Suture Zone is the manifestation of the collision between the Arabian and the Anatolian-Iranian plates which occurred in about the middle Miocene (Dewey and _engör, 1979). The diffuse seismic activity throughout eastern Turkey (Mc Kenzie, 1972; Jackson and Mc Kenzie, 1984) and the folding and thrusting of the Pliocene to recent sediments onto the Arabian platform suggest that the convergence is still in progress (_engör and Canıtez, 1982; Jackson and Mc Kenzie, 1984).

The North Anatolian Fault (NAF) and the East Anatolian Fault (EAF) are strike-slip faults (with right- and left-lateral sense, respectively) originated in response to the northward movement of the Arabian plate.

Figure 24: Main neotectonic lines and hot spring distribution of Turkey (S.Simsek, 2005)

The faults are not single continuous ruptures but are narrow zones consisting of small faults of en-echelon geometry.

Starting from the Karlıova Junction in the east, the EAF extends south-westwards where it is connected to the Dead Sea Fault (Arpat and _aroglu, 1972, 1975), whereas the NAF extends westwards and, to the west, is splitted into several branches with a dominant normal faulting component along with strike-slip component (Mc Kenzie, 1978; Dewey and _engör, 1979).

Western Anatolia is characterized by a series of grabens and comprises part of the Aegean extensional province. The province includes, together with western Anatolia, the Aegean Sea, central Greece, parts of Albania, Macedonia and Bulgaria. The NAF and its seaward extension the Aegean Trough at the North, and the Hellenic Trench together with the Pliny-Strabo Trenches at the south, constitute the major boundaries of the Aegean extensional province. Apart from the compressional trench zone where the African plate is being consumed beneath the Aegean plate, the whole province is dominated by tensional regime as is evidenced by the fault plane solutions and the presence of a number of faults with trends changing from dominantly E - W in Western Anatolia to NW-SE in the northern and central Greece (McKenzie, 1972, 1978; Dewey and _engör, 1979; Dumont et al. 1979, Angelier et al., 1981, Yılmaz, 1997).

The extension in western Anatolia is believed to be closely related to the Northward movement of the Arabian plate in the east which pushed Anatolia westwards through the NAF and EAF.

According to Dewey and _engor (1979), the southerly bending of the NAF in the Northern Aegean and Greece, prevents the escape of the Anatolian plate further westwards placing the system in a locking geometry. This creates an EW compression in Western Anatolia which is relieved by N-S extension. The driving force of extension in the Aegean, on the other hand, is believed to be the subduction along the Hellenic Trench (McKenzie, 1978). Although the amount of extension in the Aegean is poorly constrained, the estimates from geophysical and topographic data suggest that the extension is greatest in the centre of the Aegean with a _ value of about 2, and generally decreases towards the East and the west with a _ value of 1.2 to 1.5 in Western Anatolia (Makris and Stobbe, 1984).

The timing of the initiation of extension in the Aegean province is a contentious issue. Based on the initiation age of the NAF (_engör and Yılmaz, 1981), and the early works using paleontological data, the initiation of extension in Western Anatolia has long been accepted as Tortonian (~ 12 Ma). Later radiometric and palynological data (Becker-Platen et al., 1977; Seyito_lu and Scott, 1992), however, suggested that extension must have started in the region at least during the Early Miocene. The ages obtained from geophysical evidence and based on the initiation of subduction along the Hellenic Trench (which is the driving-summit calderas (Keller, 1982; Fytikas et al., 1984).

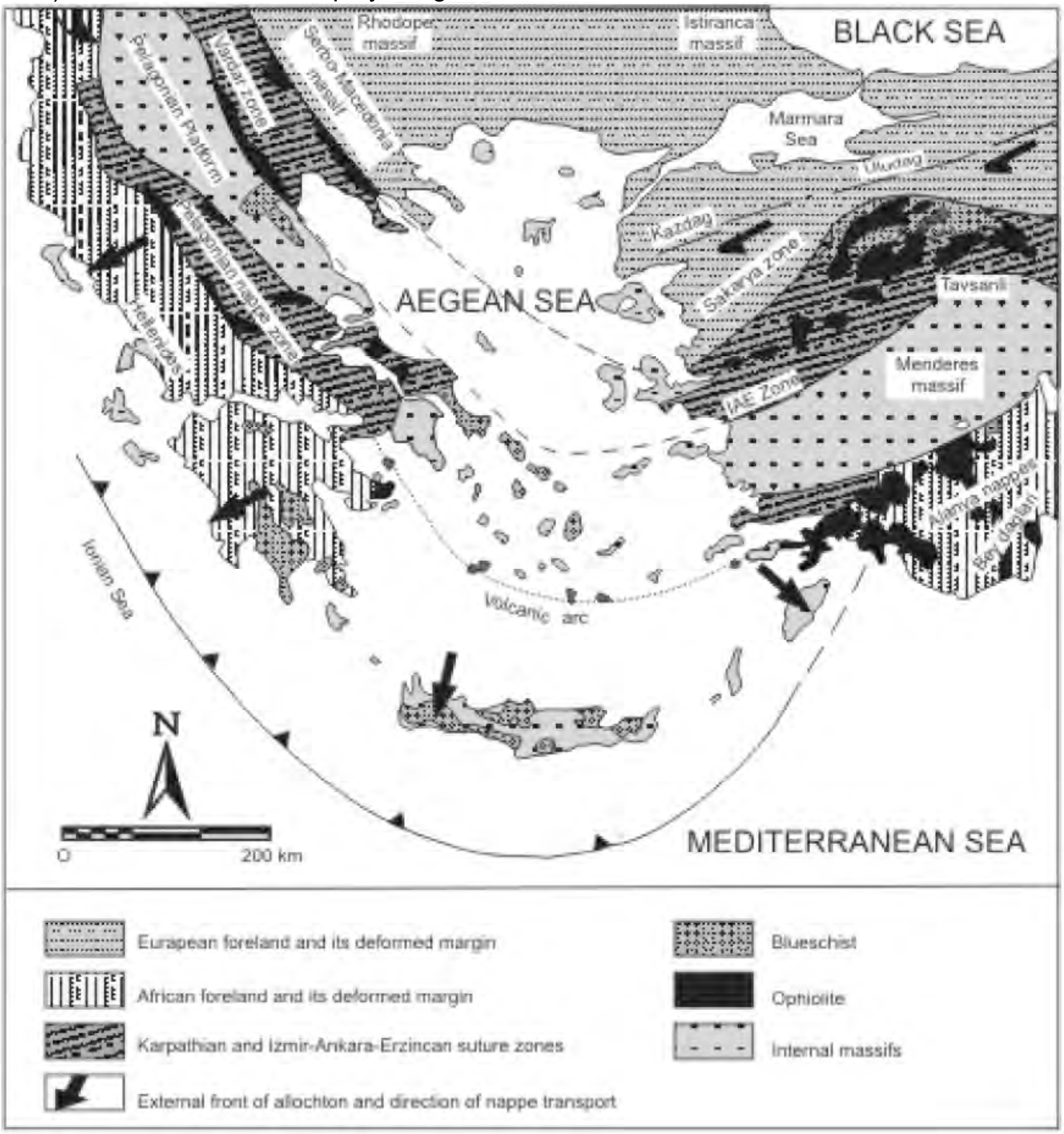


Fig.25. Major geological units and old oceanic remnants (orphiolites and blue schist). The active volcanic art is shown by a dotted curve (After Kuleli et al., 1995)

In Western Anatolia, Quaternary volcanics are observed in Kula and are represented by lava flows, cones and craters.

The volcanics are silicaundersaturated alkali olivine basalts with typical intra- plate characteristics (Ercan, 1981; Güleç, 1991).

Regarding their genesis, although the Plio- Quaternary volcanics of the south Aegean arc are clearly related to the present day subduction along. The Hellenic Trench, the origin of the Oligo-Miocene volcanism and of the Upper Miocene-Quarternary shoshonitic-alkaline volcanism are somewhat controversial. Fytikas et al. (1984) attribute the Oligo- Miocene volcanics to an early subduction zone along which the Rhodope Massif collided with the Apulian microplate.

According to Fytikas et al. (1984), the volcanism related to this subduction has migrated southwards in time as the slab became steeper, the Oligocene and the Miocene volcanics representing the Northern and the Southern sectors, respectively.

A genetic relationship to an early subduction zone is also proposed by Innocenti et al. (1982) for the Oligo-Miocene volcanics of Western Anatolia. On the other hand, basing his argument on the age given by Spakman (1989) as the initiation of subduction at Hellenic Trench (26 Ma), Gülen (1990) suggests a direct link between the Miocene volcanic activity and the subduction along the Hellenic Trench.

Figure 26. Tertiary to Quartenary volcanics of Western Anatolia and the Aegean (compiled from Fytikas et al., Ercan et al., 1985)

As to the Upper Miocene-Quaternary volcanism, Fytikas et al. (1984) suggest a genetical relationship with the active extensional regime.

According to Fytikas et al. (1984), the variations in the composition of these volcanics reflect the heterogeneities in the mantle source modified by early subduction events in the region. A subduction-modified mantle source is also proposed by Keller (1983) for the Afyon volcanics. For the back-arc volcanics of the Aegean, Pe-Piper and Piper (1989) states that the extensional regime is not the primary control on magmatism, but provides pathways (faults) for the magma to reach the surface. Contrarily, Patton (1992) states that although subduction plays a vital role in the composition of the Upper Miocene-Quaternary volcanics, extension is the primary control on magma generation. Savasçın and Güleç (1990) and Güleç (1991) regard the change in the nature of volcanism in Western Anatolia, from calc-alkaline in the Oligocene- Miocene to alkaline in the Upper Miocene- Quarternary, as a reflection of the change in the tectonic regime from compression to extension.

On the other hand, Seyitoslu and Scott (1992) - based on their work regarding the initiation age ofextension in Western Anatolia -states that the Oligo-Miocene calc-alkaline volcanism in Western Anatolia occurred during the extensional regime, without further explanation as to whether the extension played a role on (calc-alkaline) magma generation or only on their extrusion.

What is generally accepted, however, is that extension was the main control on the generation of the Quaternary alkaline volcanics (typical examples of which are seen in Kula –Western Anatolia) through the decompressional melting of an upper mantle source (Simsek and Güleç 1994).

Fig.27. Langarica-Permeti thermal spring in Albania (Frasheri, 2005)

3. GEOTHERMAL RESOURCE POTENTIAL

3.1. ALBANIA (A. Frasheri, 2005)

Geothermal studies carried out in Albania are oriented toward the study of the distribution of the geothermal field and the natural thermal water springs and wells. Geothermal studies were extended throughout the country territory.

Albanian geothermal field is characterized by relatively low value of temperatures. The temperature at a depth of 100 meters, varies from less than 10 to almost 20°C, with the lowest values in the mountain regions. The temperature is 105.8°C at a depth of 6000 meters, in the central part of the Peri-Adriatic Depression. The isotherm runs parallel to the Albanides strike (Fig. 28). Going deeper and deeper the zones of highest temperatures move from southeast to northwest, towards the center of the Peri-Adriatic depression and even further towards the northwestern coast.
Temperatures in the ophiolitic belt is higher than in sedimentary basin, at the same depth.

In the External Albanides the geothermal gradient is relatively higher. The geothermal gradient displays the highest value

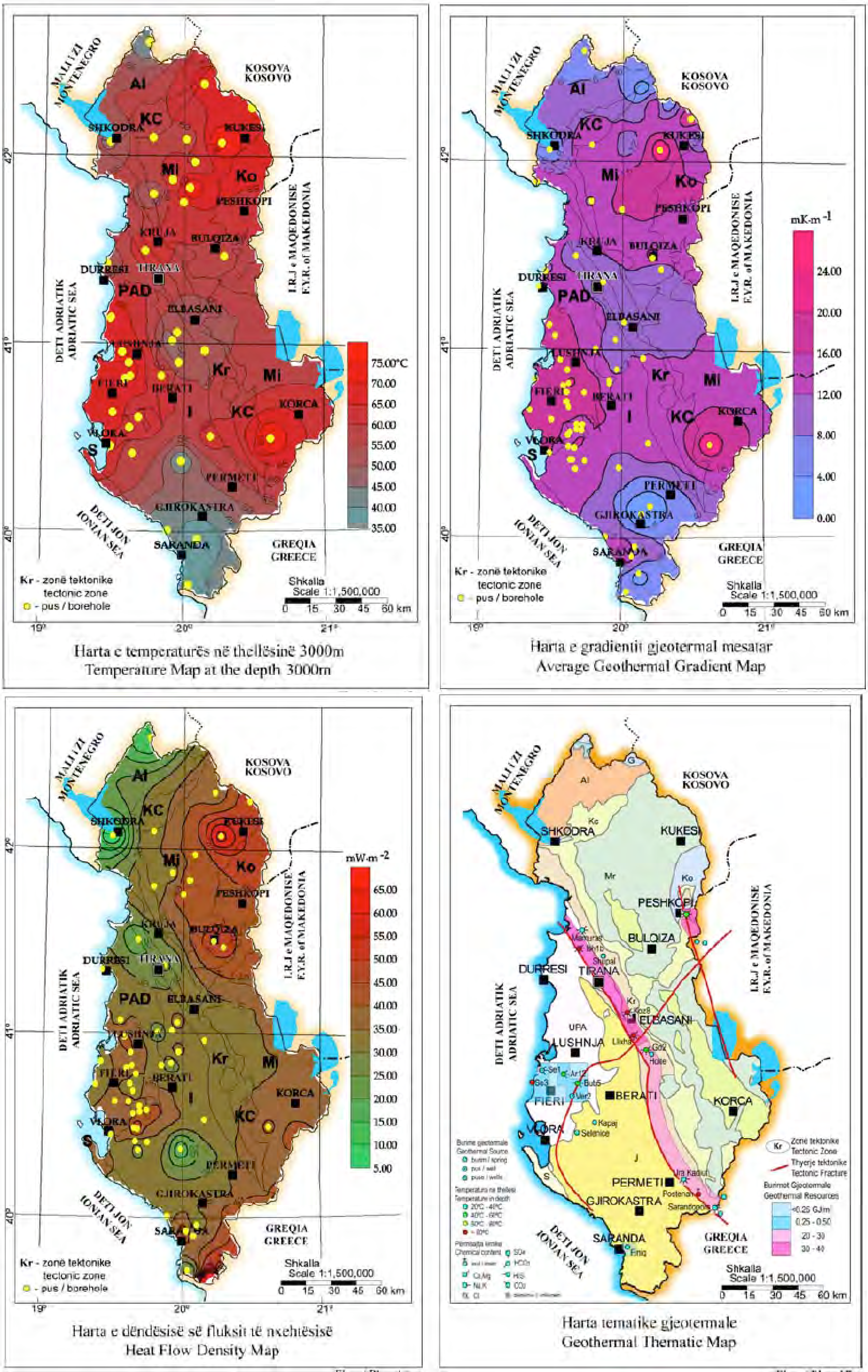


Fig.28. Heat flow density maps of and geothermal zones in Albania (Frasheri, 2000)

of about 21.3 mK.m-1 in the Pliocene clay section in the centre of Peri-Adriatic Depression. The largest gradients are detected in the anticline molasses structures of the center of Pre-Adriatic Depression.

The gradient decreases about 10-29% where the core of anticlines in Ionic zone contains limestone. The lowest values of 7-11 mK.m-1 of the gradient are observed in the deep synclinal belts of Ionic and Kruja tectonic zones.

In the ophiolitic belt of the Mirdita tectonic zone, the geothermal gradient values increase up to 36 mK.m-1 at northeastern and southeastern part of the Albania.

Regional patterns of heat flow density in Albanian territory are presented in the Heat Flow Map (Fig.28). Two particularities of the scattering of the thermal field in Albanides are observed:

Firstly, maximal value of the heat flow is equal to 42 mW/m2 in the center of Peri-Adriatic Depression of External Albanides. The 30 mW-2 value isotherm is open towards the Adriatic Sea Shelf. These phenomena have taken place owing to the great thickness of sedimentary crust, mainly carbonatic one in this zone.

Secondly, in the ophiolitic belt at eastern part of Albania, the heat flow density values are up to 60 mW/m2. The contours of Heat Flow Density gives a clear configuration of the ophiolitic belt. Radiogene 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.

Large numbers of geothermal energy of low enthalpy resources are located in different areas of Albania. Thermal waters with a temperatures that reach values of up to 65.5°C are sulfate, sulfide, methane, and iodinate-bromide types (Frasheri A. et al. 1996, 2004) (Tab. 1). In many deep oil and gas wells there are thermal water fountain outputs with a temperature that varies from 32 to 65.5°C (table 2,Fig. 27).

Albanian geothermal areas have different geologic and thermo-hydrogeological features. Thermal sources are located in three geothermal zones:

- Kruja geothermal zone represents a zone with bigness geothermal resources. Kruja zone has a length of 180 km.

Kruja geothermal zone is extended from the Adriatic Sea in the North and continues to the South-Eastern area of Albania and into the Konitza area in Greece.

Identified resources in carbonate reservoirs in the Albanian side are 5.9x108-5.1x109 GJ. The most important resources, explored until now, are located in the Northern half of the Kruja Geothermal Area, from Llixha-Elbasan in the South to Ishmi, in the North of Tirana. The values of specific reserves vary between 38.5-39.63 GJ/m2.

The Kruja geothermal area represents an anticline structure chain with carbonatic core of Cretaceous-Eocene age. They are covered with Eocenic- Oligocenic flysch. Anticlinals are linear with lengths between 20-30 km. They are assymmetric and their western flanks are separated from disjunctive tectonics. Geothermal aquifers are represented by a karstified neritic carbonatic formation with numerous fissures and microfissures.

In the Ishmi area, the Ishmi 1-b well had been drilled in 1994. It is situated at the top part of the limestone structure.

It is located 20 km North- West of Tirana, in the plain area, near “Mother Theresa” Tirana airport. It meets limestone at 1300m of depth and goes through a carbonatic coupe of 1016 m thickness.

Kozani 8 well had been drilled in 1989. It is situated 35 km South- East of Tirana and 8 km North- West of Elbasani. It is situated on hills close to Tirana- Elbasani national road. It meets limestone at 1810m of depth and goes 10m deep in them.

Since the end of the drilling to this day hot water continues to fountain from Ishmi 1-b and Kozani 8 wells.

Elbasani Llixha watering place is about 12 km South of Elbasani. There are seven spring groups that extend like a belt with 320^o azimuth. All of them are connected with the main regional disjunctive tectonics of Kruja zone. Thermal waters flow out through the contact of a conglomerate layer with calcolistolith. In this area too, the reservoir is represented by the Llixha limestone structure. The springs had been discovered before the Second World War.

Surface water temperatures in the Tirana-Elbasani zone varies from 60° to 65.5°. In the aquifer top in the well trunk of Kozani 8 the temperature is 80°C. Hot water is mineralized, with a general mineralization of 4.6-19.3 g/l.

Peshkopia geothermal zone is situated

in the Northeast of Albania. Two kilometers East of Peshkopia some thermal springs are situated very close to each other. These thermal springs flow out on the Banja river slope. These springs are linked with the disjunctive tectonic seismic-active zone Ohrid Lake-Debar, at periphery of gypsum diapir of Triassic age, that has penetrated Eocenic flysch, which surround it like a ring. The occurrence of thermal waters is connected with the low circulation zone always under water pressure.

They are of sulfate-calcium type, with a mineralization of upto 4.4 g/l, containing 50 mg/l H_2S.

The yield of some of the springs goes up to 14 l/sec. Water temperature is 43.5 °C.

The water temperature, high yield, stability, and aquifer temperature of Peshkopia Geothermal Area are similar with those of Kruja Geothermal Area. For this reason geothermal resources of Peshkopia Area have been estimated to be similar to those of Tirana- Elbasani area.

Ardenica geothermal zone is located in the coastal area of Albania, in sandstone reservoirs.

Table 1: Thermal Water Springs In Albania

N° of Springs	Location	Temperature in °C	Salt in mg/l	Artesian Spring yield in l.s-1
1	Llixha Elbasan	60	0.3	0
2	Peshkopi	5-43	9	10
3	Krane-Sarande	34		<10
4	Langarica-Permet	6-31		>10
5	Shupal-Tirana	29.5		10
6	Sarandoporo-Leskovik	26.7		>10
7	Tervoll-Gramsh	24		>10
8	Mamurras-Tirane	21	26	>10
9	Steam Postenani springs			

Table 2. The oil and gas wells that have self-discharge of the thermal Water

N°	Well Name	Temperature in °C	Salt in $mg.l^{-1}$	Self-discharge in $l.sec^{-1}$
1	Kozani	65.5	4.6	10.4
2	Ishmi	64	19.3	4.4
3	Galigati	45-50	5.7	0.9
4	Bubullima	48-50	35	
5	Ardenica	38		15-18
6	Ardenica	32		
7	Semani	35		5
8	Verbasi	29.3		1-3

3.2. BOSNIA AND HERZEGOVINA (Prasovic, 2006)

In Bosnia and Herzegovina there exist high-grade potentials of geothermal sources that can be exploited. That can be often found on numerous locations near great consumers of energy and in that sense represent a new economic categorization too, they condition a higher degree development and effect on including indifferent natural goods into economic cycle and give a chance to activities to be developed, which has not been realizable earlier.

In B&H, the degree of geothermal investigation is on low level, but it is evident, on the basis of former geological data, that it is justifiable to carry out complex investigations of geothermal potentials and initiate programs for their realization.

According to available studies, Bosnia and Herzegovina has a geothermal potential of 33 MWth. The temperature at the three known and the most important locations in Bosanski Samac (92°C), Kakanj (54°C) and Sarajevo (58°C) is too low for electricity generation, and can only be considered for heat generation.

In the following table are given view of thermal and thermo mineral water resources in Bosnia and Herzegovina with general characteristics.

3.3. BULGARIA (K. Bojadjieva, 2005)

Hydrothermal data for Bulgaria come from prospecting carried out in hundreds of exploratory and production wells and from springs. Most temperature measurements are taken in wells drilled for oil, gas, coal and minerals. The depth of wells range

Table 3. Thermal and thermo mineral waters in B&H and their physical characteristics

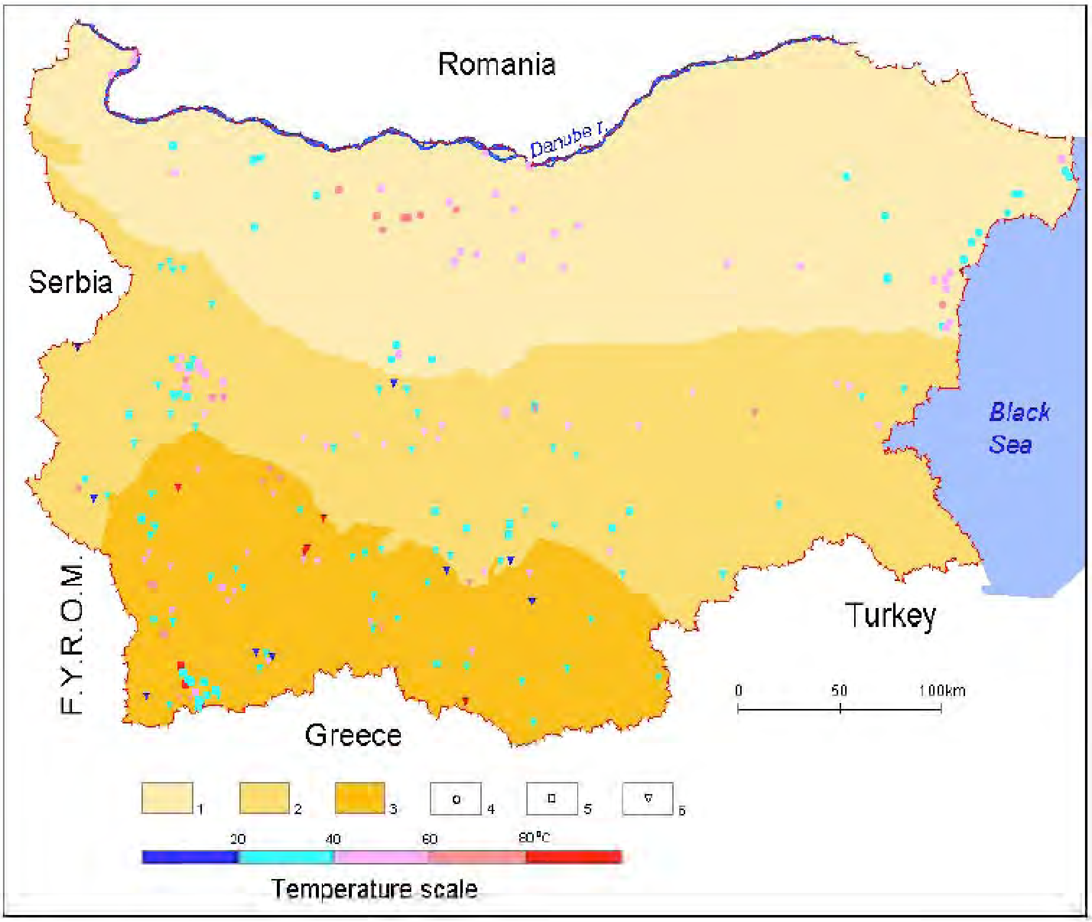
No	LOCATION	T- thermal water TM-thermo mineral water	I – one well (I) – several wells	Flow (l/s) (- well pumping; + self- erupting)	Average temperature of appearance (°C)	Power (MWth)	ENERGY	
							kWh/a x 10⁶	toe/a
1.	M. Kladuša Barake	T	(I)	60	24	3	26	3200
2.	M. Kladuša Ilidža	T	(I)	50	28	3,4	30,6	3700
3.	Gata	TM	(I)	-50	32	4,2	36,9	4550
4.	Sanska Ilidža	TM	(I)	-40	31	3,18	27,8	3500
5.	Gornji Šeher	TM	(I)	90	32	7,5	65,7	8150
6.	Slatina	TM	(I)	-70	44	9,4	82,3	10250
7.	Laktaši	T	(I)	100	30	7,6	66,6	8275
8.	Kulaši-Prnjavor	T	(I)	-20	30	1,5	13,1	1600
9.	Banja Vručica Teslić	TM	(I)	-45	38	4,9	42,9	5300
10.	Boljanić -Spreča	TM	I	+2	24	0,1	0,89	110
11.	Sočkovac Gračanica	TM	(I)	+100	39	11,5	109,75	12507
12.	Gradačac	TM	(I)	-48	29	3,4	29,8	3700
13.	Žepče	TM	I	1	20	0,03	0,25	30
14.	Tuzla Slanica	TM	(I)	-30	27	1,9	16,7	2100
15.	Toplica Spreča	T	I	230	24	11,5	101	12500
16.	Fojnica Banja	T	(I)	+162	22,6	7,2	63	7827
17.	Ilidža Sarajevo	TM	(I)	+100	58	19,1	167,4	20779
18.	Klokoti bušotina	TM	I	1	24	0,05	0,44	60
19.	Ribnica Kakanj	T	(I)	-66	28,9	4,7	41,2	5100
20.	Radići Kakanj	TM	I	+30	38	3,2	27	3400
21.	Tičići Kakanj	TM	I	+30	54	5,3	46	5800
22.	G. Vrelo Kraljeva Sutjeska	T	I	20	21	0,66	5,8	720
23.	Olovo	T	(I)	-80	34	7,4	64,8	8050
24.	Višegrad	T	(I)	+80	32	6,7	58,7	7300
25.	Domaljevac – Bos. Šamac	TM	-	+20	92	6,7	58,7	7300
26.	Srebrenik – bušotina BD-1	T		-10	28	0,67	5,8	7724
27.	Slavinovići - bušotina SL-1	TM		4	34,5	0,38	3,33	413,8
28.	Dvorovi	T	-	20	75	503	46,42	5762
29.	Bičer- Kakanj	TM	-	+1	24	0,05	0,44	60
30.	M.Kladuša - D. Šumatac	T	I	10	22	0.4	3,5	434
31.	Vedro polje	T	(I)	3	20	0,1	0,89	110
32.	Prošići	T	I	1	20	0,03	0,25	30
33.	Lješljani	TM	(I)	1,5	20	0,05	0,44	60
34.	Carakovo - Prijedor	T	I	1	23	0,14	1,22	150
35.	Kozica	T	(I)	6	21	0,22	1,9	250
36.	Grujići Laktaši	T	I	2	26,5	0,12	1,055	131
37.	Banja Vlajići	T	(I)	1	20,5	0,036	0,3	3,8
38.	Perin grad na Drinjači	T	I	2	27,8	0,13	1,1	140
39.	Medoš pod Udričem	T	I	20	25	1,09	9,4	1200
40.	Rasol Priboj Majevica	TM	(I)	3	24	0,15	1,3	160
41.	Bugojno Vruća voda	TM	I	7	25,5	0,39	3,42	420
42.	Grabovnik -	T	I	1,5	22	0,06	0,55	69
	Fojnica							
43.	Toplica Lepenica	T	(I)	25	24	1,25	10,9	1400
44.	Solun	T	I	6	26,8	0.4	3,5	434
45.	Orlja - Križevići	T	(I)	15	25	0,82	7,2	900
46.	Očevija	T	(I)	16	25,8	0,86	7,5	930
47.	Zeleni Vir	T	I	1	33	0,09	0,77	96,5
48.	Podlipnik Olovo	T	I	0,2	21	0,008	0,069	9

from 100 m to 5000 m in Northern Bulgaria and from 100 m to 1500 m in Southern Bulgaria.

The basic characteristics of geothermal water on the territory of the country have been reassessed and updated within the period 1994-1998 by extensive study carried out by the scientists from the Geological Institute under Bulgarian Academy of Sciences. The basis for resource reassessment was data taken from about 160 hydrothermal fields located all over the countries, of which 102 are state-owned.

The water temperature of the discovered reservoirs ranges between 20°C-100°C.

The total dynamic flow rate of sub thermal and thermal waters run up to 4600 l/s (Petrov et.al., 1998), of which 3000 l/s is the flow rate of the revealed thermal waters of T>25°C.



1. Moesian plate (stratified reservoirs)
2. Sredna gora, incl.Balkan zone (secondary stratified reservoirs, fractured reservoirs)
3. Rila-Rhodopes massif (predominantly fractured reservoirs)
4. Major wells and groups of wells discovering stratified reservoirs in a plate region
5. Hydrothermal sources associated with waters from fractured reservoirs located in Southern Bulgaria.
6. Hydrothermal sources associated with waters from secondary stratified reservoirs located in Southern Bulgaria

Fig. 29. Map of hydrothermal deposits of Bulgaria

About 43% of the total flow rate are waters of temperature between 40ºC-60ºC.

According to Petrov et al.(1998) a new drilling could discover about 2300 l/s of recoverable resource in addition.

Established chemical water content (TDS) varies respectively, in:

- Southern Bulgaria - from 0.1g/l up to 1.0 g/l (only for a few sites it is between 1 g/l to 15g/l)
- Northern Bulgaria - from 0.1g/l up to (100g/l - 150g/l).

About 70% of the thermal waters are slightly mineralized (<1g/l) with fluoride concentration ranging from 0.1 to 25mg/l, various metasilicic acid concentrations (up to 230mg/l) and of mostly low alkalinity. In comparison to most of the European mineral waters, the Bulgarian ones have a lot of advantages: low TDS close to the optimal one typical for potable water, high purity level especially in terms of anthropological pollution, microbiological purity and a variety of water types (Vladeva and Kostadinov, 1996).

The main hydrothermal deposits in Bulgaria are plotted on Fig.29. They are grouped in three major hydrothermal units: Moesian plate, Sredna gora zone (incl.Balkan) and Rila- Rhodope massif.

Three types of reservoirs are found out in the country - stratified, fractured and mixed (water from a fractured reservoir is secondary accumulated in a younger sediment reservoir).

The most perspective regions for geothermal application are located in the central and eastern part of Moesian plate (J3-K1 V horizon) and in Rila-Rhodopes massif.

Nowadays, thermal sources, situated on the northern Black Sea coast, are mainly utilized. Still partially used are the reservoirs of high thermal potential located in the western part of the Rila-Rhodopes massif (Southern Bulgaria). The total hydrothermal potential is defined as the thermal energy contained in the discovered thermal waters and amounts to 9 957 TJ/year (Petrov et al, 1998). It has been calculated for output temperature of 15ºC.

Table 3: Hydrothermal resource (Petrov et al., 1998)

N	Major hydrothermal units	Water temperature,degC	Total flow rate, l/s	Thermal potential, kJ/s
1	**Moesian plate (total)**	**21.5 - 71**	**1 241.6**	**101 482**
	Lom basin*	29.8 - 35.9	3.04	193
	Central Northern Bulgaria and Balkan Foreland zone*	21.5 -71	191.1	5 819
	J_3 -K_1 horizon	22 - 50	1012.9	92 891
	West Balkan	24.9 - 38	34.6	2 579
2	**Sredna gora, incl.Balkan (total)**	**20.5 - 78**	**669.4**	**85 960.5**
	West Sredna gora	23.5 - 67.5	241.7	27 058.6
	Dolna banja basin	42 - 72	47	8 846
	Central Sredna gora	20.6 - 78	211	27 402.8
	East Sredna gora	22 - 77	81	10 128.5
	Upper Thracian basin and Sakar-Strandja zone	20.5 - 51	26.5	2 763.6
	Kraishte zone	22.4 - 75	62.2	9 761
3	**Rila-Rhodope massif (total)**	**20 - 98**	**1015.8**	**128 291.6**
	Struma region	20 - 98	254.6	49 156
	Mesta region	25.5 - 55	265.93	24 331.7
	West and East Rhodopes	20.6 - 95	495.3	54 803.9

*Resource potential is assessed only for wells in exploitation

3.4. CROATIA (Kovacic, 2005)

Croatia has a centuries-long tradition of using geothermal water from natural springs for medical purposes. In the early 70es along with researches for oil and gas, the appearance of geothermal water began being observed. The calculations of temperature gradients based on the data obtained from exploration wells showed that the average gradient in the northern part of the country, belonging to the Panonian sedimentary basin, is considerably higher than the world average, while in the southern, Dinarides area its value is below that figure (0.049°C/m and 0.018°C/m respectively, compered to 0.03°C/m in the world). The temperature gradient distribution in Croatia is shown in the Figure 31.

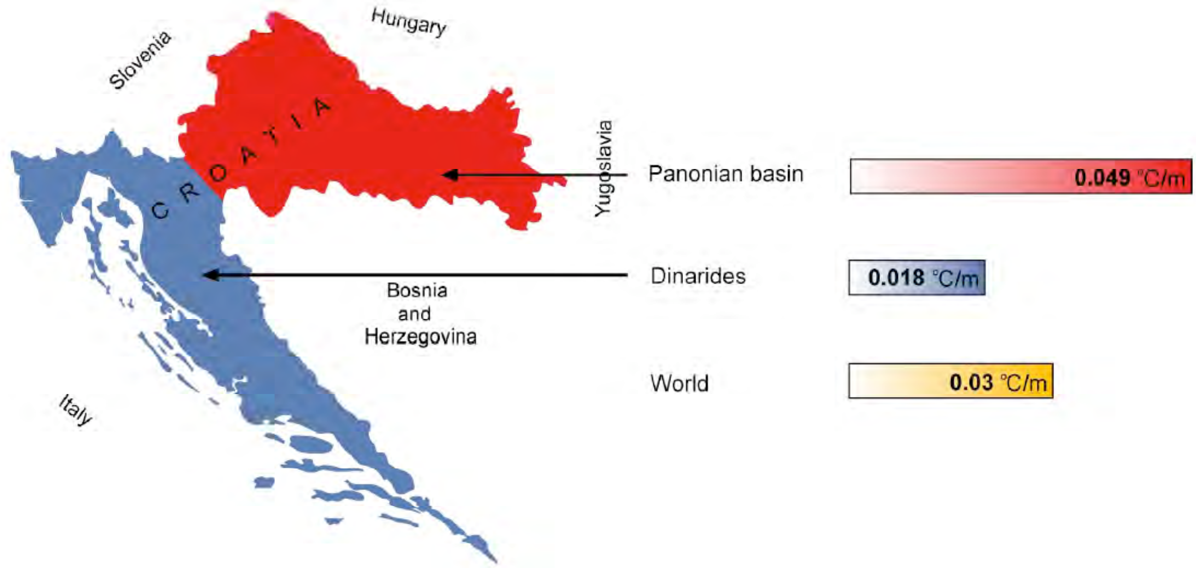


Figure 30. Temperature Gradient Distribution (Jelic, 2005)

Geothermal potential accumulated in the reservoirs of the northern part of Croatia can be a significant renewable energy resource, substantially contributing to the overall energy efficiency and the environmentally acceptable energy policy. Geothermal energy of the medium temperature reservoirs (between 100 and 200°C) can be converted into electric energy, while that of the low temperature reservoirs (below 100°C) is perfectly suitable for heating and cooling of buildings, heating of greenhouses, in various industrial processes, for medical purposes, etc. Since geothermal energy had previously been separately studied by different institutions, in the year 1997 the Government of the Republic of Croatia established the Program of Geothermal Energy Utilization GEOEN, as a part of the National Program of the Croatian Energy Sector Development and Organization PROHES. The objective of the program is unifying and promotion of the knowledge and experience in the geothermal energy field. The GEOEN Program involves all technical, technological, legislative and other measures with the aim of increasing geothermal energy use and its efficiency, as well as the implementation of the highest ecological standards. Various Governmental ministries, scientific and higher education institutions participate in the realization of the program coordinated by the Energy Institute “Hrvoje Požar”. The first phase of the program, completed in April 1998, contained an analysis of the geothermal energy potential and the legislative environment related to its utilization, defining program implementation me-asures and dynamics, and proposing five pilot projects. Results of the first phase have been included into the Strategy of the Energy Development of the Republic of Croatia. The second phase, currently in progress, deals with pilot project realization and the implementation of the geothermal energy utilization program. The figures representing geothermal energy potential from the medium and low temperature reservoirs with the water temperature above 65°C are the results of the analysis performed within the first phase of the GEOEN Program.

Most of the spas where geothermal water has been traditionally used for swim-ming, bathing and medical purposes and more recently also for heating of hotels and hospitals, having lower temperatures, have not been considered by the GEOEN Program analysis. Those localities, although contributing in a relatively small percentage to the total geothermal potential, make a significant part of the present utilization. Therefore an additional data collection activity has been performed, in order to include them into the data set necessary for completing

Figure 31. Geothermal Resources

Table 4. Geothermal Resources - Direct Heat Potential according to possible uses

	Locality	T (°C)	Thermal Power (MW$_t$)				Thermal Energy (TJ/yr)[1]			
			To 50 °C		To 25 °C		To 50 °C		To 25 °C	
			Actual	Possible	Actual	Possible	Actual	Possible	Actual	Possible
Medium temperature geothermal reservoirs	Babina Greda	125.0	31.38	31.38	41.84	41.84	494.63	494.63	659.50	659.50
	Ferdinandovac	125.0	15.69	31.38	20.92	41.84	247.31	494.63	329.75	659.50
	Lunjkovec-Kutnjak	125.0	48.95	489.53	65.27	652.70	771.62	7716.15	1028.82	10288.20
	Reèica	120.0	14.64	29.29	19.87	39.75	230.83	461.65	313.26	626.53
	Velika Ciglena	170.0	58.07	174.21	70.17	210.51	915.33	2746.00	1106.03	3318.08
	Subotal		**168.74**	**755.79**	**218.07**	**986.64**	**2659.71**	**11913.05**	**3437.36**	**15551.81**
Low temperature geothermal reservoirs	Bizovac-TG	96.0	0.58	0.58	0.89	0.89	9.10	9.10	14.05	14.05
	Bizovac-PP	90.0	3.85	46.19	6.26	75.06	60.67	728.09	98.60	1183.14
	Ernestinovo	80.0	2.89	5.77	5.29	10.59	45.51	91.01	83.43	166.85
	Madarince	96.0	1.92	1.92	2.97	2.97	30.34	30.34	46.82	46.82
	Sveta Nedjelja	68.0	3.39	6.78	8.10	16.19	53.42	106.84	127.61	255.23
	Zagreb (Mladost SC)	80.0	6.28	6.28	11.51	11.51	98.93	98.93	181.36	181.36
	Zagreb (University Hospital)	80.0	6.90	6.90	12.66	12.66	108.82	108.82	199.50	199.50
	Subtotal		**25.81**	**74.42**	**47.67**	**129.86**	**406.78**	**1173.12**	**751.37**	**2046.96**
Geothermal springs with the water temperature below 65°C	Daruvar (Daruvar Spa)	47.0	0.00	0.00	1.66	1.66	0.00	0.00	26.12	26.12
	Ivaniæ Grad (Naftalan Hospital)	62.0	0.14	0.14	0.42	0.42	2.14	2.14	6.59	6.59
	Krapinske Toplice (Krapina Spa)	41.0	0.00	0.00	4.69	4.69	0.00	0.00	73.86	73.86
	Lipik (Lipik Spa)	60.0	0.17	0.17	0.59	0.59	2.64	2.64	9.23	9.23
	Livade (Istria Spa)	28.0	0.00	0.00	0.03	0.03	0.00	0.00	0.40	0.40
	Samobor (Šmidhen SRC)	28.0	0.00	0.00	0.38	0.38	0.00	0.00	5.94	5.94
	Stubièke Toplice (Stubica Spa)	53.4	1.35	1.35	11.29	11.29	21.30	21.30	177.93	177.93
	Sveta Jana (Sveta Jana RC)	26.0	0.00	0.00	0.22	0.22	0.00	0.00	3.50	3.50
	Topusko (Topusko Spa)	62.0	6.25	6.25	19.27	19.27	98.53	98.53	303.80	303.80
	Tuhelj (Tuhelj Spa)	32.0	0.00	0.00	2.20	2.20	0.00	0.00	34.62	34.62
	Varaždinske Toplice (Varaždin Spa)	58.0	0.90	0.90	3.73	3.73	14.25	14.25	58.76	58.76
	Velika (Toplice RC)	25.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Zagreb (INA-Consulting)	55.0	0.12	0.12	0.69	0.69	1.81	1.81	10.88	10.88
	Zelina (Zelina RC)	40.0	0.00	0.00	1.88	1.88	0.00	0.00	29.68	29.68
	Zlatar (Sutinske Spa)	32.0	0.00	0.00	6.44	6.44	0.00	0.00	101.56	101.56
	Subtotal		**8.92**	**8.92**	**53.47**	**53.47**	**140.66**	**140.66**	**842.87**	**842.87**
	TOTAL		**203.47**	**839.14**	**319.21**	**1169.97**	**3207.16**	**13226.83**	**5031.60**	**18441.63**

this country update.

The north of the Republic of Croatia, in geological terms a part of the Panonian sedimentary basin, having the average temperature gradient of 0.049°C/m and vertical conductive heat flow of 76 mW/m^2 can be considered a large geothermal energy accumulator. The great majority of wells drilled for oil or natural gas, being positive or dry in terms of hydrocarbons, penetrated aquifers that, belonging to such a warm environment, could be considered geothermal reservoirs. Nevertheless, taking into account technological and economic criteria, only those producing water with the temperature above 65°C were classified as geothermal wells.

The data obtained from the hydrodynamic measurements and production testing of those wells, performed by the Croatian oil company INA, served as the basis for the reservoir engineering calculations, resulting in the defining of ten geothermal fields, one of them (Bizovac) consisting of two reservoirs. They were classified into two categories, medium temperature reservoirs with the water between 100 and 200°C, and low temperature ones, producing water having the temperature between 65 and 100°C.

Table 5. Geothermal Resources - Electricity Production Potential

Locality	T (°C)	ElectricPower(MW)		ElectricEnergy(GWh/yr)''	
		Actual	Possible	Actual	Possible
Babina Greda	125,0	1,88	1,88	14,84	14,84
Ferdinandovac	125,0	0,94	1,88	7,42	14,84
Lunjkovec-Kutnjak	125,0	2,94	29,37	23,15	231,48
Rečica	120,0	0,84	1,67	6,60	13,19
Velika Ciglena	170,0	4,36	13,07	34,32	102,97
TOTAL		**10,95**	**47,88**	**86,33**	**377,33**

Geothermal water with the temperature below 100°C is perfectly suitable for direct heat use, including space heating and cooling, various industrial processes, greenhouse heating, drying of agricultural products, medical purposes etc, by means of heat exchangers and optionally heat pumps.

Except for direct heat applications, geothermal energy from the reservoirs with the water temperature above 100°C can be effectively used for the electric power generation, employing a binary process. Basic energy data of the geothermal fields are given in the Tables, while their locations are indicated in the Figure 31. For each reservoir thermal power and annual primary energy that could be produced from the existing wells have been calculated, as well as the respective values corresponding to the situation of the complete reservoir development, i.e. after the completion and commissioning of all the projected wells. Annual thermal energy production has been calculated on the basis of a reasonable capacity factor of 50%. All the calculations have been made simultaneously for two possible energy utilization patterns. First of them refers to the application of conventional heat exchanger systems assuming outlet water temperature of 50°C. Another option that has been elaborated is based on the energy use down to the temperature of 25°C, which could be practically achieved by the implementation of heat pumps as parts of the heating systems.

For the medium temperature reservoirs the electric power and the annual electric energy production resulting from the conversion of a part of the available thermal energy into electricity have also been computed. The calculations have been made on the basis of the outlet water temperature from the electric power generation process of 80°C, the conversion efficiency factor of 10% and the capacity factor of 90%. As mentioned before, geothermal springs and wells producing water with the temperature below 65°C have not been included into the GEOEN geothermal potential analysis. However, due to the fact that they make a significant contribution to the present geothermal energy utilization, for the purpose of this work it was necessary to consider those resources of that category that are currently in use. Most of them are traditional spas, using water from natural springs and shallow wells.

Putting into relation the total geothermal energy that could be produced using conventional heat exchanging systems with the total primary energy production in Croatia of 198,4 PJ/yr , shows that an appropriate utilization of geothermal resources would ensure their contribution of 6.7%. Comparison of the same figure to the total primary energy supply, being 348.0 PJ/yr, gives the potential 3.8% coverage of the energy needs of the country. In the case of the application of heat pumps decreasing geothermal water outlet temperature to 25°C, the contribution of geothermal to the total primary energy production and the total primary energy supply would reach 9.2% and 5.3%, respectively. Installing the complete geothermal capacities available for the transformation into electricity would result in some 3.9% contribution of geothermal to the total electric energy production, and 2.9% coverage of the electric energy consumption. Nevertheless, it should be pointed out that the pre-feasibility study on combined electricity and heat production (Virkir Orkint Consulting Group Ltd., 1995) gave positive results in both technical feasibility and financial viability for the Velika Ciglena cogeneration plant, while the Lunjkovec-Kutnjak project was declared questionable in terms of financial viability. Since other potential locations still have not been seriously considered, installing of the majority of geothermal capacities available for electricity production is not probable in the near future.

3.5. GREECE (M. Fytikas, 2005)

Greece is a favored country from the geothermal point of view, since is very rich in geothermal waters and its potential has been characterized as significant. The origin of the geothermal fields is mainly associated to the wider area's geodynamic regime, with the active extensional tectonics affecting a wide area.

In Greece there are two high enthalpy geothermal fields, in the islands Milos and Nisyros, where seven deep wells identified temperatures of 320°C and 350°C respectively. Low enthalpy fields abound in Greece, mainly in the east and north parts of the country, as well as in many Aegean islands. Present data yield a low enthalpy potential exceeding 400MWt proven and 800MWt probable.

During the past years, the geothermal potential has markedly expanded through continuous research and production activities. The bulk of exploration projects were carried out mainly by the Institute of Geological and Mineral Exploration (IGME) and Universities.

The significant amount of new data and information that has been collected, revealed new low enthalpy fields, most of which are located in Northern Greece. Even in less favorable area, like West-ern Greece, new very promising data have been acquired.

The geothermal anomalies in Greece are mainly located in Tertiary-Quaternary basins with recent tectonic activity. Several exploratory wells have been constructed in these areas, some of which are already being used as productive ones, while others are planned to be utilized in the near future.

In some of the already identified geothermal areas, new, additional wells have been drilled, in order to better determine the extension of the field and the characteristics of the fluids.

Furthermore, in a number of cases (e.g. Sidirokastro and Therma Nigrita, *Strymon Basin*) complementary exploration indicated higher temperatures than the ones measured in the past.

In the following text a brief description of the most characteristic geothermal fields in Greece and the recent exploration activities is presented.

The *Strymon Basin* in East Macedonia is one of the most extensive geothermal areas in Greece, including several fields. During the past years, the Agistro geothermal field was studied, explored and delimited, the margins of the known fields of Therma, Nigrita and Sidirokastro were investigated resulting in the obtainment of new data. Recently, exploration projects were realized in the areas of **Achinos** and **Ivira**, which had shown evidence of great geothermal interest.

Figure 32. Greek geothermal fields (Hadziyannis, 2007)

Two, relatively deep (~500m) exploratory and one productive well (650m) were constructed there, establishing the great potential of the area. The geothermal reservoirs that were identified are remarkable, with temperatures that range between 40 and 75°C, while additional boreholes yields over 220kgr/sec. The production tests and the chemical analyses that took place determined the hydraulic characteristics of the aquifer and its behavior regarding the corrosion and scaling problems. The positive and stimulating new data has become the incentive for investments and further development in the area. The total extent of the geothermal area is estimated to be approximately 25km^2.

In the geothermal field of **Agistro**, the reservoir is located at the fractured metamorphic basement of the basin, which is covered by a weakly permeable cap. The exploratory and productive wells at 100-300m, showed temperatures of 40- 47°C, while the exploitable flow rate was of the order of 30kg/sec. The geothermal water belongs to the group of carbonatecalcium-sodium type, with a T.D.S. of 0,26 gr/Lt, while no corrosion or scaling problems were encountered.

The geothermal reservoir of **Sidirokastro** is also located on the top of the metamorphic basement (marble) and in the basal conglomerates of Neogene. The geothermal water belongs to the group of carbonate-calcium-sodium type.

Furthermore, in a number of cases (e.g. Sidirokastro and Therma Nigrita, *Strymon Basin*) complementary exploration indicated higher temperatures than the ones measured in the past. T.D.S. just exceeding 1gr/Lt. The known extent of this field is about 14km2.

During the past decade, additional exploration activities took place in the area of **Therma-Nigrita** area, with the construction of 9 new exploratory-productive wells at the depth of 80-370m, yielding more than 200kg/sec, 125 of which correspond to self-flowing wells. The fluids are rich in CO2 and their temperature is 40-64°C. They belong to the group of acid carbonate-sodium-magnesium type with TDS ranging between 1,5-2,5 gr/Lt. The reservoir is located in the formation of the basal conglomerates.

Two new productive wells have been drilled in the area of **Eratino**, each 670m deep, yielding about 100kgr/sec artesian flow of 75°C water. The water originates from some permeable horizons at the dept of 550-650m, in the Miocene sediments.

In the area of *Mygdonia Basin*, three important fields were found in the past and have been further explored and exploited recently. A new productive well (120m deep) was drilled in the geothermal field of **Nymfopetra**, having water of 42°C, for the heating of asparagus cultivations. In the field of **Nea Apollonia**, two new productive wells (30m each) produce more than 100kgr/sec water of 56°C. The water is being transported to a nearby Spa complex for balneological and heating purposes.

In the area of **Langadas** Spa, three new productive wells were constructed to cover the heating/cooling demands of several buildings of the town. The temperatures were 40, 29 and 20°C and the flow rate was 45, 120 and 80m3/h respectively.

The geothermal field of **Neo Ryssio** is located close to the airport of Thessaloniki, where was constructed. An interesting geothermal gradient within the Quarternary-Miocene sediments was revealed, after the drilling of a 600m deep exploratory well. Important reservoirs are expected inside the middle Miocene sediments at the depth of approximately 800m with a temperature of 60°C. A new explorationexploitation project is in progress in this area, in order to use the geothermal potential for heating purposes.

In the new Campus of Aristotle University (**Thermi**, Thessaloniki) an interesting reservoir was identified, at the depth of 300 m. The geothermal reservoir has artesian flow and its temperature is 24- 29°C. The quality of the water is excellent. The construction of the well was financed by A.U.TH., in the frame of a geothermal exploration-exploitation project.

In Chalkidiki Peninsula, in **Sani** and **Afytos** areas, exploratory wells were drilled down to 600°C and revealed an artesian aquifer of bicarbonate fluid with 40°C temperature.

Two exploratory wells in **Irinoupoli** identified a 27°C fluid of high salinity at the depth of 400m. Southwards of Irinoupoli, in the area of **Nissi**, two new exploratory wells were drilled, identifying a 35°C fluid of low salinity and high productivity at the depth of 500-580m.

Limnochori (NW Macedonia), is another interesting and promising geothermal area in Northern Greece, where the exploratory wells yield more than 30kgr/sec water of 38°C. This reservoir is located at the top of the metamorphic basement of the basin at the depth of 200m.

In Western Macedonia, near the town of **Florina**, a new area of geothermal interest was accidentally found during the drilling of irrigation wells. The geothermal area seems to follow the important fault system of the area. Two 300m deep production wells yield 110 kgr/sec of water of 27°C and rich in CO2.

In *Thrace*, the geothermal exploration expanded our knoweledge about the known geothermal areas, while two new geothermal fileds were identified (Sappes and Komotini).

The exploration that was carried out in the area of **Aristino-Aetochori**, resulted in the enlargement of the geothermal field known boundaries and the measured temperatures extended to 92°C. A new well yields more than 60kgr/sec of water from the depth of 300m.

In the area of **Neo Erasmio**, three new wells produce artesian water of significant flow rate, the temperature of which is 60°C.

Within the area of the **Traianoupolis** hot springs, two production wells were constructed for the heating system of the Spa complex. The wells yield about 30kgr/sec water of 52°C (Angelidis, 1999). The geothermal field of **Nea Kessani** was extended towards the southeastern direction, after the information obtained by two new wells at the depth of 450 m, which produce water of 38°C that is used for anti-frost protection of the artificial ponds for fish-culture.

The geothermal field of **Sappes** was discovered recently after the drilling of four exploratory and three productive wells. A very important reservoir is located in the Tertiary volcanic formations and provides fresh water of artesian flow with 40°C temperature. The total extension of the field is estimated to be 25km2.

Likewise, in **South Komotini** area, 5 exploratory wells indicated a new geothermal area of 30km2, with temperatures approximately 40°C.

In the area of *Aegean*, the recently explored geothermal fields are in Lesvos, Chios Samothraki and Kimolos islands.

Lesvos Island: The Public Power Corporation (PPC) has financed an exploration program (Koutroupis, 1999), in the frame of which nine shallow wells were initially drilled (6 in Stipsi and 3 in Argennos area). Their temperatures were 92°C (Stipsi) and 86°C (Argennos) at a depth of 200m. At a second stage, three deeper wells (600m) were additionally constructed at the same areas, confirming the anticipated results. PPC plans to start a new drilling program for deeper wells (about 2km), in order to install a Rankine Cycle power production unit, in the area between Stipsi and Petra.

Chios Island: A new geothermal field was discovered in the area of Nenita. Its reservoir is located in the Mesozoic limestones, which are covered by impermeable sedimentary formations. Five exploratory boreholes were opened, which found the geothermal reservoir at the depth of 300-400m. The temperature of the fluids is 90°C and the extension of the field more than 5km2. So far, a production well has been constructed for the evaluation of the reservoir's hydraulic parameters, the flow rate and the chemical composition of the fluids, which seem to belong to the group of sodium-chloride type with TDS>40gr/Lt.

Samothraki Island: Three new wells were drilled in the area of **Therma**, near the Spas, at the depth of 120m. The wells yield a high flow rate of high salinity fluids with 100°C temperature (Angelidis, 1999).

Kimolos Island: Two new wells were constructed in Kimolos isle, in the frame of a desalination project. The depth of the wells was 200m, the quantity of the fluids was large, while their temperature reach 60°C.

In *Western Greece*, (Epirus region) two new geothermal areas were discovered: the area of Sykies (Arta) and Konitsa (Ioannina).

Sykies: Two exploratory and one productive well at the depth of 300m were constructed, identifying a geothermal reservoir within the limestones at temperatures of 40-45°C, covering an area of more than 1km2. The geothermal water belongs to the group of Na-Ca-Mg-HCO3- Cl with TDS>4gr/Lt, containing CH4 and H2S gas. The exploration program is still under progress.

Konitsa: During the exploration program that is being held in the area, a 300m deep exploratory well has been constructed, identifying a reservoir of 38°C within the limestones. The geothermal fluids most probably belong to the magnesium sulphate water group, with a TDS of 1,3 gr/Lt.

Some interesting geothermal fields have also been explored in the mainland of *Central Greece*. To start with, close to the city of Patra, in the area of **Antirrio**, an exploratory well encountered temperatures of 38°C at the depth of 150m. Secondly, in **Kavouri** (Athens), two wells have been constructed in the past years for production-injection purposes. Each of the wells yields more than 4kgr/sec water of high salinity and 36°C.

3.6. MACEDONIA

There are 18 geothermal known fields in the country with more than 50 thermal springs, boreholes and wells with hot water. These discharge about 1.000 l/s water flow with temperatures of 20-79 0C. Hot waters are mostly of hydrocarbonate nature, according to their dominant anion, and mixed with equal presence of Na, Ca and Mg. The dissolved minerals range from 0.5 to 3.7 g/l.

All thermal waters in Macedonia are of meteoric origin.

Heat source is the regional heat flow, in the Vardar zone is about 100 mW/m2 and crust thickness 32 km.

Fig.33. Geological settings and geothermal regions in Macedonia (Arsovski, 1997)

The most known areas are listed below:

Kochani valley *(Popovski, 2002):* The main characteristics of the Kochani valley geothermal system are: presence of two geothermal fields, Podlog and Istibanja, without hydraulic connection between them. The primary reservoir is build by Precambrian gneiss and Paleozoic carbonated schists and the highest measured temperature in Macedonia of 79ºC is obtained by drilling to it. Predicted maximum reservoir temperature is about 100ºC (Gorgieva, 19 89). Kocani geothermal system is the best investigated system in Macedonia. There are more than 25 boreholes and wells with depths of 100-1.170 m.(Gorgieva, 2002).

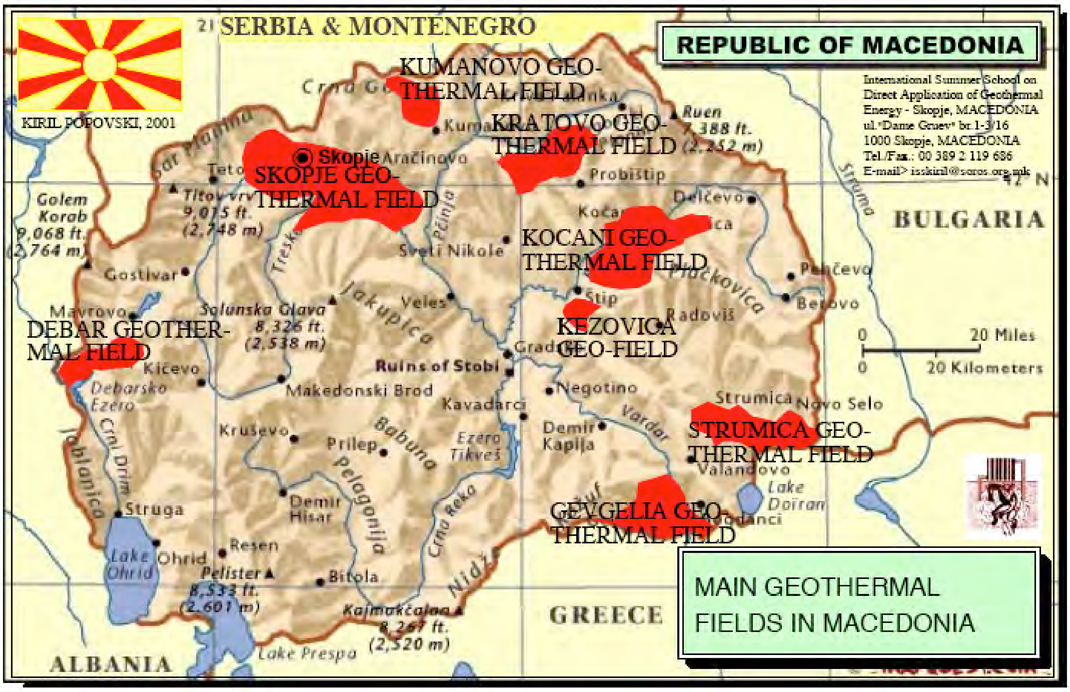


Fig.34. Main geothermal fields in Macedonia (Popovski, 2001)

Strumica valley *(Popovski, 2002)*

The main characteristics of this field are: the recharge and discharge zone occur in the same lithological formationgranites; there are springs and boreholes with different temperature at small distances; maximum measured temperature is 73^{0}C; the predicted maximum temperature is 120ºC (Gorgieva, 1989); the reservoir in the granites lies under thick Tertiary sediments. Bansko geothermal system has not been examined in detail apart the drilling of several boreholes with depths of 100-600m. (Gorgieva, 2002)

Gevgelia valley *(Popovski, 2002)*

There are two geothermal fields in the Gevgelia valley: Negorci spa and Smokvica. The discharge zone in both geothermal fields are fault zones in Jurassic diabases and spilites. These two fields are separated by several km and there is no hydraulic connection between them, despite intensive pumping of thermal waters. The maximum temperature is 54ºC, and the predicted reservoir temperature is 75-100ºC (Gorgieva, 1989). Geothermal system in the Gevgelia valley has been well studied by 15 boreholes with depths between 100-800 m. (Gorgieva, 2002)

Skopje valley *(Popovski, 2002)*

There are two geothermal fields in the Skopje valley: Volkovo and Katlanovo spa. There is no hydraulic connection between them. The main characteristics of the Skopje hydrogeothermal system are: maximum measured temperature of 54.4 0C and predicted reservoir temperature (by chemical geothermometers) of 80-115ºC (Gorgieva, 1989); the primary reservoir is composed of Precambrian and Paleozoic marbles; big masses of travertine deposited during Pliocene and Quaternary period along the valley margins. There are only five boreholes with depths of 86 m in Katlanovo spa, 186 and 350 m in Volkovo and 1.654 and 2.000 m in the middle part of the valley. The last two boreholes are without geo-thermal anomaly and thermal waters because of their locations in Tertiary sediments with thickness up to 3.800 m. (Gorgieva, 2002).

3.7. ROMANIA (I. Cohut, 2000)

The first geothermal well in Romania was drilled in 1885 at Felix Spa, near Oradea. The well was 51 m deep, with a flow rate of 195 l/s and a temperature of 49°C. This first well is still in operation. It was followed by the well drilled at Caciulata (in 1893 - 37°C), Oradea (in 1897 - 29°C) and Timisoara (in 1902 - 31°C).

Table 6. Thermal waters in Macedonia and their characteristics

No	Place Spring (i)	Occurrence Borehole (d)	Coordinate x	Coordinate y	Coordinate z	Temp. (°C)	Flow (l/s)
1	Volkovo	GTD-1 (d)	4 654 971	7 527 841	374	25	63
2		IBSKG-3 (d)	4 654 330	7 528 150	317	22	22
3	Katlanovska b	D-1 (d)	4 639 800	7 557 650	287	54,2	10
4		B-1,B-2 (d)	4 638 990	7 558 125	255	32	4
5		Nervna v (i)	4 639 225	7 558 100	250	28	2
6		Potkop	4 639 500	7 557 850	265	38	2
7		Fontana (i)	4 639 750	7 557 000	270	28	0,2
8		izvor (I)	4 639 260	7 557 910	230	38	1
9	Proevci	(d)	4 664 460	7 562 100	310	31	2
10	Strnovec	(d)	4 670 300	7 570 050	280	40	17
11	Podlog	EBMP-1 (d)	4 638 625	7 613 175	310	78	150
12		R-3 (d)	4 638 775	7 613 095	310	77,8	80
13	Krupiste	K-1/83 (d)	4 634 000	7 605 000	300	32	0,5
14		K-2/83 (d)	4 634 000	7 605 100	295	40,6	6,9
15	Kocansko pole	R-11 (d)	4 640 700	7 618 252	335	50,6	2,6
16	Kocani	Ka-1 (d)	4 641 750	7 617 200	340	22,4	6
17	Podlog	EB-4 (d)	4 639 000	7 613 000	310	79	120
18	Podlog	EB-3 (d)	4 639 025	7 613 070	310	78	350
19	Istibanja	I-5 (d)	4 643 000	7 624 350	350	66,4	12
20		I-3 (d)	4 643 100	7 624 350	350	67	5
21		I-4 (d)	4 643 025	7 624 475	350	56,6	4,2
22	Trkanje	EB-2 (d)	4 649 560	7 612 660	311	71,3	50
23		R-9 (d)	4 639 375	7 612 675	310	71,3	85
34	Banja	B-1 (d)	4 641 550	7 611 225	350	63	8,3
25		B-2 (d)	4 641 525	7 611 205	348	63,2	55,3
26		R-1 (d)	4 640 300	7 615 840	347	63	30
27		R-6 (d)	4 639 925	7 611 600	350	40	1
28	Bansko	B-1 (d)	4 583 900	7 647 225	258	68	55
29		izvor (I)	4 583 500	7 647 160	270	73	6
30	Negorci	NB-3 (d)	4 559 875	7 625 530	65,1	47,2	40
31		NB-4 (d)	4 559 750	7 625 600	64,3	53,2	40
32		B-1 (d)	4 559 100	7 625 410	65	32	3
33	Smokvica	Sied6 (d)	4 570 375	7 624 812	56,9	45,1	7,2
34		Sied1 (d)	4 570 340	7 624 800	57,5	56,7	60
35		Sied2 (d)	4 569 650	7 624 775	57,1	48,1	5,2
36		Sied4 (d)	4 570 250	7 624 815	57	56,1	35
37		Sied5 (d)	4 570 400	7 624 780	57,1	64	40
38		Sied7 (d)	4 520 369	7 624 725	57,1	68,5	60
39	Stip	Ldzi (i)	4 621 825	7 598 552	300	59	1
40		Kezovica (d)	4 621 700	7 598 360	280	57	7
41		B-4 (d)	4 621 850	7 598 630	260	32	30
42	Kozuf	Topli dol(i)	4 560 225	7 583 760	740	28	0,5
43		Toplik (i)	4 558 275	7 579 743	880	22	8
44		Mrezicko (i)	4 561 875	7 583 450	720	21	0,2
45		Gornicet (i)	4 558 425	7 619 650	220	23	0,1
46	Kratovo	Povisica (d)	4 659 035	7 590 143	443	31	4
47		Dobrevo (d)	4 654 510	7 600 300	330	28	5,5
48	Veles	Sabota voda	4 620 025	7 567 810	280	21	5
49	Rakles	dupn (d)	4 609 287	7 624 308	349	26	2
50	Dojran	Toplec (i)	4 566 550	7 642 530	161	25	2
51		Deribas (d)	4 561 580	7 643 900	240	20,5	10
52	Debar	Kosovrasti (d)	4 561 580	7 643 900	400	48,5	10
53		Banište (d)	4 561 580	7 643 900	750	40,5	5-100

The search for geothermal resources for energy purposes began in the early 60's, based on a detailed geological program for hydrocarbon resources (that had extensive budgets). There are over 200 wells drilled with depths between 800 and 3,500 m, that shows the presence of low enthalpy geothermal resources (40÷120°C), which enabled the identification of 9 geothermal areas, 7 in the Western part and 2 in the Southern part. The completion and experimental exploitation (considered as part of geological investigation) of over 100 wells in the past 25 years made possible the evaluation of exploitable heat from geothermal reservoirs. The proven reserves, with the already drilled wells, are estimated at about 200 PJ for the next 20 years.

The total installed capacity of the existing wells is about 480 MWt (for a reference temperature of 30°C). Out of this only 150 MWt is currently used, from 67 wells that are producing hot water in temperature range of 55÷115°C.

Figure 35: Location of the Romanian geothermal reservoirs

The thermal gradient is 45÷55°C/km. The wellhead temperatures are between 50 and 85°C. The mineralization of the geothermal waters is 4÷5 g/l (sodium-bicarbonatechloride type) and most of the waters show carbonate scaling, prevented by downhole chemical inhibition. The combustible gases, mainly methane, are separated from the geothermal water. The wells are produced mainly artesian, but also with downhole pumps.

The main geothermal areas are - from North to South – Satu Mare, Tasnad, Acas, Marghita, Sacuieni, Salonta, Curtici, Lovrin, Tomnatic, Sannicolau Mare, Jimbolia and Timisoara.

The Oradea geothermal reservoir is located in the Triassic limestone and dolomites at depths of 2,200÷3,200 m, on an area of about 75 km2, and it is exploited by 12 wells with a total flow rate of 140 l/s geothermal water with well head temperatures of 70÷105°C. There are no dissolved gases, and the mineralisation is lower than 0.9÷1.2 g/l. The water is of calcium-sulphate-bicarbonate type. Both aquifers, the Triassic aquifer Oradea and the Cretaceous aquifer Felix Spa, are hydrodynamically connected and are part of the active natural flow of water. The water is about 20,000 years old and the recharge area is in the Northern edge of the Padurea Craiului Mountains and the Borod Basin.

Although there is a significant recharge of the geothermal system, the exploitation with a total flow rate of 300 l/s generates pressure draw down in the system that is prevented by reinjection. Reinjection is the result of successful completion and beginning operation of the first doublet in the Nufarul district in Oradea city, in October 1992 (Lund, 1997). The Felix Spa reservoir is currently exploited by six wells, with depths between 50 and 450 m.

The total flow rate available from these wells is 210 l/s. The geothermal water has a wellhead temperatures of 36÷48°C and is potable. The annual utilisation of geothermal energy in Oradea is 415 TJ, representing 15% of the total geothermal heat produced in Romania.

The Bors geothermal reservoir is situated about 6 km northwest to Oradea. This reservoir is completely different from the Oradea reservoir, although both are located in fissured carbonate formations. The Bors reservoir is a tectonically closed aquifer, with a small surface area of 12 km2. The geothermal water has 13 g/l TDS, 5 Nm3/m3 GWR and a high scaling potential. The dissolved gasses are 70% CO2 and 30% CH4. The reservoir temperature is higher than 130°C at the average depth of 2,500 m. The artesian production of the wells can only be maintained by reinjecting the whole amount of extracted geothermal water. At present, three wells are used to produce a total flow rate of 50 l/s, and two other wells are used for reinjection, at a pressure that does not exceed 6 bar. The geothermal water is used for heating 12 ha of greenhouses.

The dissolved gasses are partially separated at 7 bar, which is the operating pressure, and then the fluid is passed through heat exchangers before being reinjected. The installed power is 15 MWt, and the annual energy savings is 3,000 toe.

The Beius geothermal reservoir is situated about 60 km South-East of Oradea. The reservoir is located in fissured

Triassic calcite and dolomite 1,870 – 2,370 m deep. The first well has been drilled in 1996 down to 2,576 m. A line shaft pump was set in the well in 1999, now producing up to 45 l/s geothermal water with 84°C wellhead temperature.

A second well has been drilled in early 2004, and a line shaft pump was being installed at the time of this writing.

The geothermal water has a low mineralization (462 mg/l TDS), and 22.13 mg/l NCG, mainly CO_2 and 0.01 mg/l of H_2S. At present, the geothermal water from the first well is used to supply district heating to part of the town of Beius (5 substations in the block of flats area, a hospital, two schools, etc.). The second well is being connected to the system and will supply 5 more substations. The company having the exploitation concession for the Beius reservoir (Transgex S.A.) intends to drill one more production well and a reinjection well in the area, and connect the entire town to the geothermal district system.

The Ciumeghiu geothermal reservoir is also located in the Western Plain, 50 km South to Oradea. The geothermal water is produced in artesian discharge, having a wellhead temperature of 105°C and 5-6 g/l TDS, with strong carbonate scaling prevented by chemical inhibition at the depth of 400 m. The aquifer is located in Lower Pannonian age gritstone, at an average depth of 2,200 m. The main dissolved gas is CH4, the GWR being 3 Nm3/m3. The reservoir was investigated by 4 wells, but only one was in use until the greenhouses in the area have been closed, with a capacity of 5 MWt (of which 1 MWt from the separated combustible gasses). There are some chances for the greenhouse to re-start operation in the future.

The Cozia-Calimanesti geothermal reservoir (Olt Valley) produces artesian geothermal water, with a flow rate of 10÷20 l/s and wellhead pressure of 16÷20 bar, from fissured siltstones of Senonian age. The reservoir depth is 1,900÷2,200 m, the well head temperature is 90÷95°C, the TDS is 14 g/l, and there is no scaling. The GWR is 2.0 Nm^3/m^3 (90% methane). Although the reservoir was exploited for 10 years, there is no interference between the wells and no pressure draw down. The thermal potential possible to be achieved from the 3 wells is 18 MWt (3.5 MWt from gases), but only 8 MWt is used at present. The energy equivalent gained in this way is 2,500 toe/year. The utilisation is mainly for space heating, but also for health and recreational bathing.

The Otopeni geothermal reservoir is located North to Bucharest. It is only partially delimited (about 300 km^2).

The 13 wells that were drilled show a huge aquifer located in fissured limestone and dolomites. The aquifer, situated at a depth of 1,900÷2,600 m, belongs to the Moessic Platform. The geothermal water has temperatures of 58÷78°C, and 1.5÷2.2 g/l TDS, with a high content of H2S (over 25 ppm). Therefore, reinjection is compulsory. The production is carried out using downhole pumps, because the water level in the wells is at 80 m below surface. The total flow rate is 25÷30 l/s. At present, only 3 wells are in production (5 MWt), for heating 1,900 dwellings (annual savings 1,900 toe), and 2 wells are used for reinjection.

The development is hampered by technical and, mostly, by financial difficulties. It is to be mentioned that there are potential users, and 6 wells are already drilled, the last 2 wells being situated near the Snagov Lake, producing water with temperatures of 75÷80°C, and significant flow rates.

Table 7: Main parameters of the Romanian geothermal systems

Parameter	U/M	Oradea	Bors	Beius	Western Plain	Olt Valley	North Bucharest
Type of reservoir		carbonate	carbonate	carbonate	sandstone	gritstone	carbonate
Area	km^2	75	12	47	2,500	28	300
Depth	km	2.2÷3.2	2.4÷2.8	2.4÷2.8	0.8÷2.1	2.1÷2.4	1.9÷2.6
Drilled wells	(total)	14	6	2	88	3	11
Active wells		12	5	1	37	2	5
Well head temp.	°C	70÷105	115	84	50÷85	92÷96	58÷75
Temperature gradient	°C/100	3.5÷4.3	4.5÷5.0	3.3	3.8÷5.0	4.6÷4.8	2.8÷3.4
TDS	g/l	0.8÷1.4	12÷14	0.46	2÷7	13	2.2
GWR	Nm^3/m^3	0.05	5÷6.5	-	0.5÷2.5	2÷2.8	0.1
Type of production		Artesian	Artesian	Pumping	Artesian+Pumping	Artesian	Pumping
Flow rate	l/s	4÷20	10÷15	13÷44	4÷18	12÷25	22÷28
Operations		11	2	1	37	2	2
Annual savings	toe	9,700	3,200		18,500	2,600	1,900
Total installed power (with existing wells)	MW_t	58	25	10	210	18	32
Exploitable reserves (for 20 years)	MW/day	570	110	52	4,700	190	310
Main uses:							
• space heating	dwellings	2,000	-	10,500	2,460	600	1,900
• sanitary hot water	dwellings	6,000	-	3,200	2,200	600	1,900
• greenhouses	ha	1.8	6	-	34	-	-
• industrial uses	operations	6	-	-	7	-	-
• health bathing	operations	5	-	-	8	3	2

3.8. SLOVENIA (D. Rajver, 2005)

The 21 thermal springs have constant temperature close to or above 20 °C, however, there are several drilled localities where no surface thermal manifestations existed. Details about the geothermal field of Slovenia and geotectonic background can be found also in papers of Ravnik (1991), Ravnik et al. (1992; 1995) and Rajver and Ravnik (2002). Geothermal resources in the Pannonian basin and the Krsko basin (sometimes called depression) have been studied and monitored in more detail (Fig. 1; Ravnik et al., 1992; Rajver et al., 2002).

The Pannonian basin is filled with Tertiary marine and fresh water sediments. Clays and marls predominate in shallow layers with intercalations of sands, while the deeper layers consist of claystones and marls with intercalations of porous sandstones, where thermomineral and thermal waters reside. The Pliocene and/or Late Miocene sand aquifer has an effective maximum thickness of 60 m, dipping down to depths of 1500 m in the east. The maximum measured permeabilities are about 2.7 darcy and the thermal waters have temperatures of up to 80 °C. Their mineralization was studied among others by Zlebnik (1979) and Kralj and Kralj (2000). In the area of about 1850 km2 the geothermal resources amount to 0.84·1015 J with a maximum resource per unit area of 2.25 GJ/m2 in the eastern part of the aquifer.

The main reservoir in the Krsko basin is a Triassic dolomite covered in some places by Cretaceous marly limestone, marl and flysch. On top of this section Miocene and Pliocene-Quaternary sediments were deposited. Borehole data and geophysical surveys confirm a total thickness of the Tertiary deposits of a few 100 m to 1700 m (see e.g. Rajver and Ravnik, 2003). Permeabilities of the Triassic dolomite reach a few darcies, and temperatures are close to 70 °C. The geothermal resources for Triassic (occasionally also Jurassic) carbonates, evaluated for a smaller region (118 km2) in the eastern Krsko basin, amount to 0.5·1018 J with a maximum of 11.2 GJ/m2, based on a conservative assessment of net aquifer thickness (400 m).

Table 8. Geothermal Energy Use in Romania (Cohut, 2000)

Locality	Type	Maximum Utilisation			Capacity		Annual Utilisation	
		Flow Rate (kg/s)	Temperature (°C) Inlet	Outlet	(MWt)	Ave. Flow (kg/s)	Energy (TJ/yr)	Capacity Factor
Satu Mare	HB	12	65	30	1.8	7	32.3	0.56
Carei	BI	5	45	30	0.3	3	5.9	0.62
Acas	GB	15	65	30	2.2	8	36.9	0.53
Tasnad	HBG	10	70	25	1.9	7	41.5	0.69
Beltiug	B	6	75	30	1.1	4	23.7	0.68
Sacuieni	HBGFI	8	80	25	5.1	12	87.1	0.54
Marghita	HB	6	65	25	2.0	10	52.8	0.83
Boghis	BH	12	45	25	1.0	10	26.4	0.83
Mihai Bravu	GF	6	65	25	1.0	0	0	0.00
Bors	G	25	115	40	7.8	0	0	0.00
Oradea	IHGBF	85	83	30	18.8	65	415.0	0.70
Livada	BF	10	88	35	2.2	5	35.0	0.50
Felix	BH	140	45	25	11.7	115	216.0	0.58
Madaras	BH	5	46	25	0.4	3	8.3	0.65
Ciumeghiu	G	12	92	35	2.9	0	0	0.00
Cighid	HBG	10	72	25	2.0	6	37.2	0.59
Beius	HB	44	83	30	9.7	15	104.9	0.34
Macea	*HGB*	*15*	*65*	*25*	*2.5*	*8*	*42.2*	*0.53*
Curtici	*HGB*	*22*	*63*	*25*	*3.5*	*14*	*70.2*	*0.63*
Dorobanti	*GB*	*18*	*60*	*25*	*2.6*	*9*	*41.5*	*0.50*
Sofronea	*HB*	*6*	*42*	*25*	*0.4*	*3*	*6.7*	*0.53*
Iratos	*IB*	*5*	*40*	*20*	*0.4*	*3*	*7.9*	*0.63*
Arad	*B*	*12*	*40*	*25*	*0.8*	*7*	*13.8*	*0.54*
Nadlac	*IHB*	*10*	*78*	*30*	*2.0*	*8*	*50.6*	*0.80*
Sannicolau	*IHBG*	*50*	*78*	*30*	*10.0*	*35*	*221.6*	*0.70*
Saravale	*HB*	*8*	*75*	*25*	*1.7*	*5*	*33.0*	*0.61*
Tomnatic	*GB*	*45*	*80*	*30*	*9.4*	*22*	*145.1*	*0.49*
Lovrin	*HGB*	*40*	*81*	*30*	*8.5*	*30*	*132.0*	*0.49*
Periam	*HB*	*10*	*70*	*25*	*1.9*	*6*	*35.6*	*0.59*
Jimbolia	*IHGB*	*50*	*82*	*30*	*10.9*	*35*	*240.1*	*0.70*
Teremia	*IHB*	*15*	*85*	*30*	*3.5*	*6*	*43.5*	*0.39*
Comlosu	*HB*	*10*	*81*	*25*	*2.3*	*6*	*44.3*	*0.61*
Grabat	*IB*	*6*	*80*	*30*	*1.3*	*3*	*19.8*	*0.48*
Beregsau	*IB*	*6*	*75*	*25*	*1.3*	*3*	*19.8*	*0.48*
Timisoara	*HB*	*15*	*45*	*25*	*1.3*	*10*	*26.4*	*0.64*
Herculane	*B*	*75*	*52*	*25*	*8.5*	*50*	*148.0*	*0.55*
Olt Valley	*HB*	*25*	*92*	*30*	*6.5*	*16*	*130.8*	*0.63*
North Bucharest	*HB*	*35*	*62*	*25*	*5.4*	*15*	*65.0*	*0.38*
TOTAL		889			156.6	659	2840.8	

Note: Data for the locations in Italics have not been confirmed by the operator (FORADEX S.A.)

Other potential areas within the Pannonian basin include deeper sandstone layers of Tertiary (Lendava) formations and the pre-Tertiary basement that is predominantly composed of Paleozoic metamorphic rocks and only locally of Mesozoic dolomites, limestones, breccias and shales, as evidenced by numerous oil wells and underground gas storage research boreholes. The Mesozoic carbonates, overlying the metamorphic rocks, are several 10 m to a few 100 m thick in some places, but their extension and permeabilities are still disputable. Seismic surveys show depths of the basement of less than 400 m to more than 5000 m. The resources in the Mesozoic aquifers, covering an area of about 1880 km2, amount roughly to 6.3·1018 J and a maximum of 15.4 GJ/m2, but they are mostly of speculative nature.

Other areas of geothermal interest are described as follows.

The Rogatec area comprises Tertiary andesites and Triassic dolomites (at depths of >1400 m and up to 70 °C). The Eastern part of the Sava folds, belongs to the Southern Alps, where Tertiary depressions and synclines form deep (1500 m) narrow wedges in the Paleozoic and Mesozoic layers along the faults. The basement consists of Paleozoic and Mesozoic carbonate and clastic sediments, where thermal waters with temperature of 20 to 48 °C are hosted, while thermal springs yield up to 50 kg/s. The Eastern Alps consist mostly of Paleozoic metamorphic rocks. Only more intensely tectonized zones are of geothermal interest (e.g. Maribor area) where deep reaching fracture networks were formed. Eastern Karavanke area is filled with Tertiary clays, sands and at deeper levels marls and sandstones, as well as Mesozoic carbonates in few places (Velenje depression) as geothermal reservoir in depths of >1000 m. In the Coastal area and around Nova Gorica thermal water with temperature of <40 °C reside in Cretaceous limestones underlying flysch sediments.

All known geothermal resources are of the low enthalpy type with the exception of the high temperature geothermal system (pre-Tertiary basement aquifers) in NE Slovenia. At present there are no new discovered resources of low enthalpy type in the past 5 years. High enthalpy resources are still not in use. Doublet schemes were in use only at Moravci for a period of 3 years in the mid 1990's, otherwise they are not yet in use but should be introduced as soon as possible, due to overexploitation. The most vulnerable locations are in NE Slovenia where thermal water is extracted from the Upper Miocene and/or Lower Pliocene sandy aquifer. In a period 1994 - 1999, the average flow rate decreased in some production wells of this area, tipically at Murska Sobota, Moravci and Ptuj, but during last 5 years only at Lendava, while at other localities it improved, perhaps just temporarily

3.9. SERBIA AND MONTENEGRO (M. Milivojevic, 2005)

Geothermal exploration in Serbia began in 1974. A year later, the first preliminary assessment was made of the national geothermal potential (Milivojevic et al., 1975; Alimpic, 1975). Then a number of pilot studies were prepared for discrete areas (Peric & Milivojevic, 1976; Milivojevic, 1979). Another, more detailed regional exploration of geothermal resources began in 1981 and ended in 1988 (Milivojevic, 1989). This regional study was conducted in parallel with the exploration of some of the previously known hydrogeothermal systems. In the Serbian part of the Pannonian Basin, the first borehole, 1454 m deep, was drilled in 1969, the second was drilled 2509 m deep in 1974. From 1977 to 1988, 58 boreholes were drilled with a total drilled depth of about 50,000 m. The overall yield of all these wells is about 550 l/s, and the heat capacity about 48 MW (calculated for dT=T-25 ºC) (Tonic et al., 1989). From 1988 to 1992, only four more boreholes were drilled. In other geothermal provinces, 45 test holes were drilled before 1992, with a total drilled depth of about 40,000 m. Only three of these as are deep as 1800 m, fourteen are 1000-1500 m deep, thirteen are 500-1000 m, and fifteen are 300-500 m deep. Most of these boreholes freeflow and are used as production wells. The total yield of these wells is about 500 l/s. Production wells have not been drilled anywhere else, because none of the hydrogeothermal systems have been well enough explored. For the same reason, the total geothermal energy reserve has not been assessed for any of the systems. The total heat capacity of all these wells is about 108 MW (thermal); the total heat capacity of all flowing wells drilled in Serbia is about 156 MW. The total heat capacity of all natural springs and wells is about 320 MW (calculated for dT=T-12 oC).

Within the territory of Serbia excluding the Pannonian Basin, i.e. the terrain comprising solid rocks, there are 159 natural thermal springs with temperatures over 15 ºC. The warmest springs (96 ºC) are in Vranjska Banja, followed by Josanicka Banja (78 ºC), Sijarinska Banja (72 ºC) Kur-

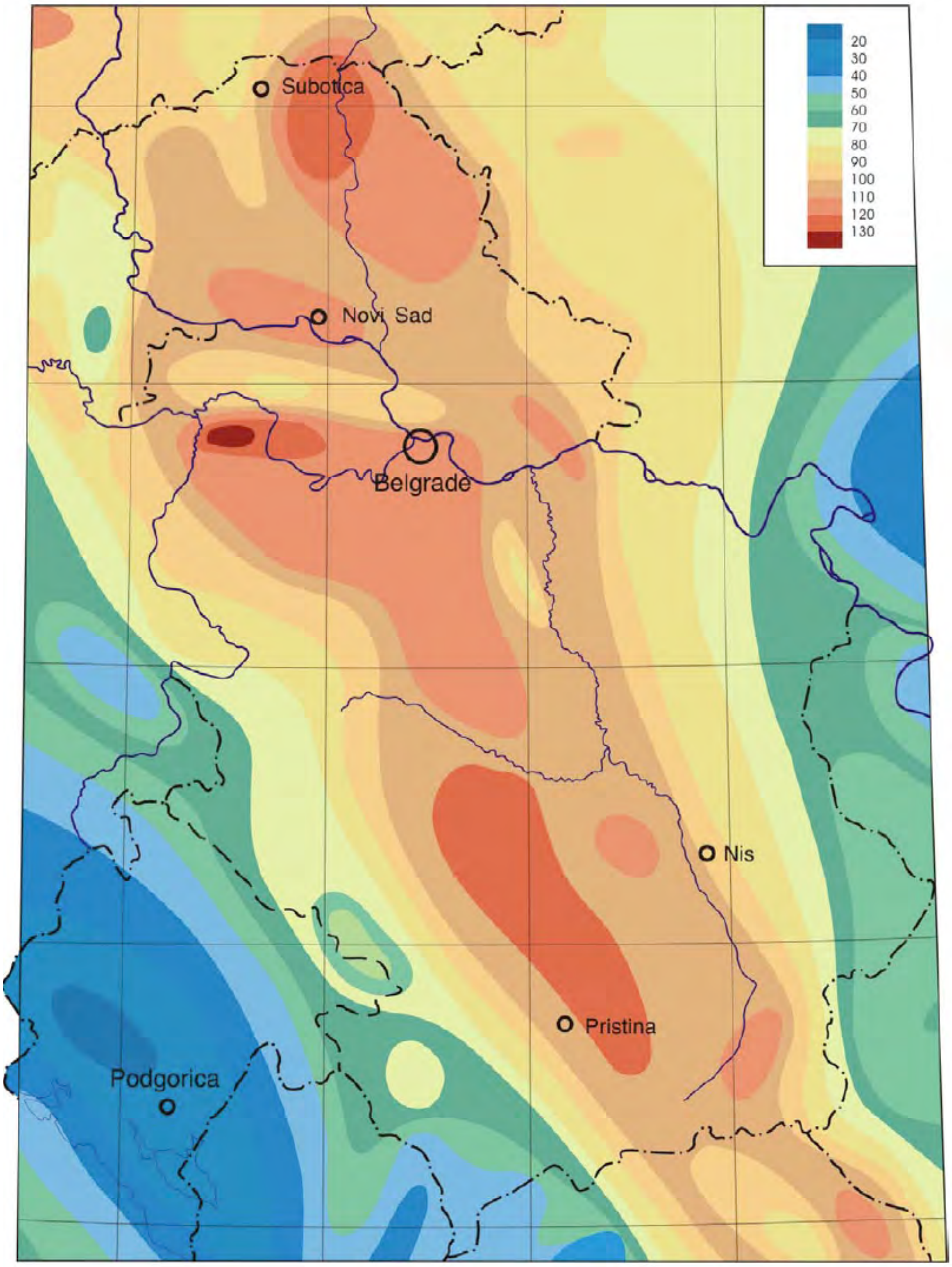


Figure 36. Heat Flow Density Map of Serbia and Montenegro (Milivojevic, 2005)

sumlijska Banja (68 ºC), Novopazarska Banja (54 ºC).

The total flow of all natural springs is about 4000 l/s. The highest flows are from thermal springs draining Mesozoic karstified limestones, and the next highest are those from Tertiary granitoids and volcanic rocks. The greatest number of thermal springs are in the Dinarides, then the Carpatho- Balkanides, the Serbian-Macedonian Massif, and the lowest, only one in each, the Pannonian Basin and the Mesian Platform. As to the elevation, the greatest number of thermal springs are within the range 200-300 m More than 90% of all thermal springs are at elevations below +600 m.

Considering the present state of our knowledge of the geologic composition and hydrogeothermal properties of rocks to a depth of 3000 m, there are 60 convective hydrogeothermal systems in Serbia. Of this number, 25 are in the Dinarides, 20 in the Carpatho-Balkanides, 5 in the Serbian-Macedonian Massif, and 5 in the Pannonian Basin under Tertiary sediments (Fig 37).

Conductive hydrogeothermal systems are developed in basins filled with Paleogene and Neogene sedimentary rocks. The

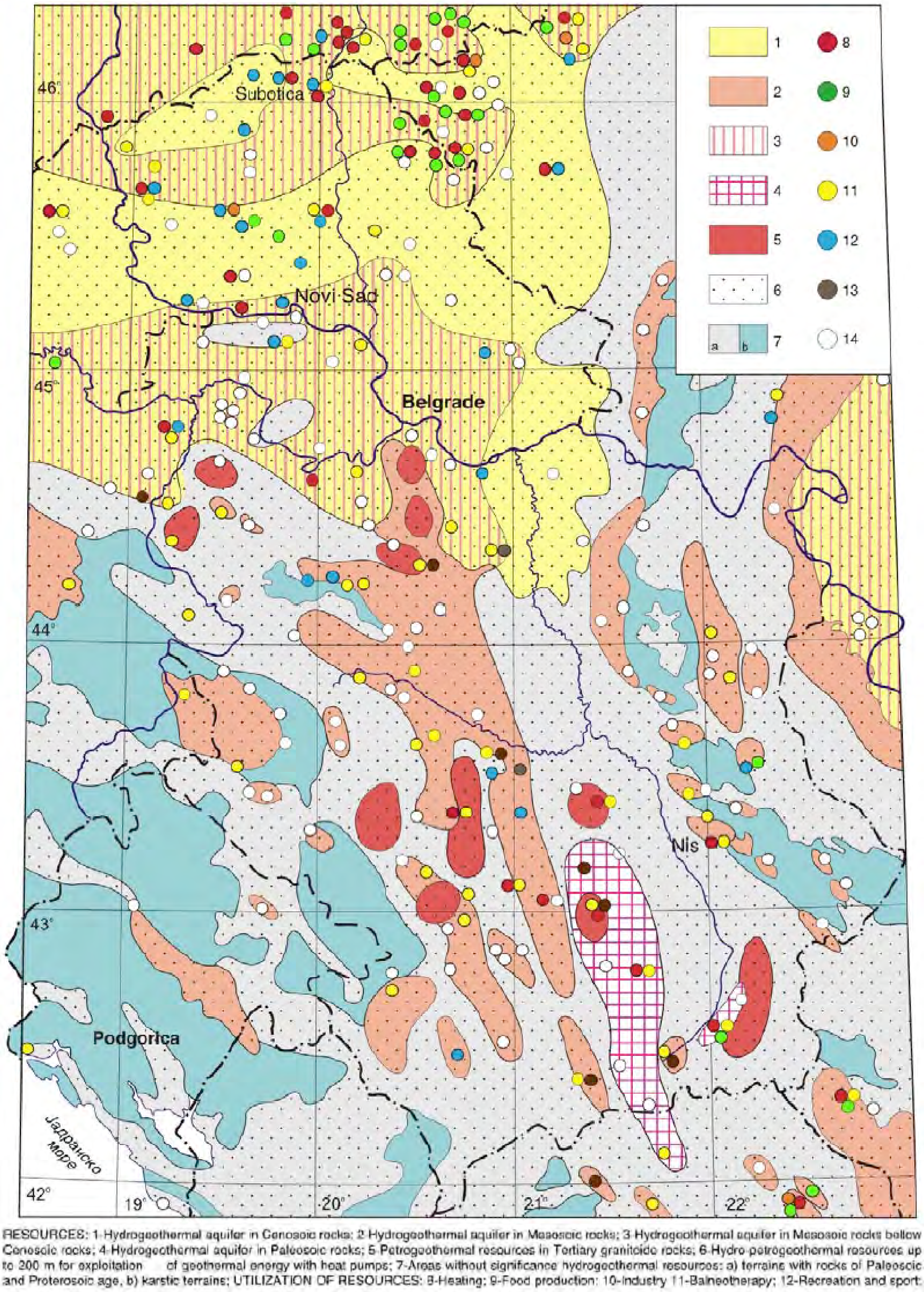


Figure 37. Geothermal resources in Serbia (Milivojevic, 2005)

majority of these are in the Pannonian Basin in Vojvodina, northern Serbia. The other 14 systems are less interrelated and less important.

Pannonian Basin

Within this geotectonic unit, which is also a geothermal province (Milivojevic, 1989) comprising a complex hydrogeothermal conductive system with a number of separate reservoirs, four groups of reservoirs are individualized by depth. The first group of reservoirs have a maximum thickness of 2000 m. The highest water temperature in the reservoirs is 120 ºC, (Fig. 37). The average flowing well yields are 1-13 l/s. Total mineralization of thermal waters is 1-9 g/kg, mostly 3-5 g/kg. Che-mically, thermal waters are of HCO3-Na type. Water temperature at well-heads are 40-55 ºC, maximum 82 ºC (Tonic et al., 1989).

The second group of reservoirs are in Lower Pliocene and Pannonian sediments, composed of sandstones of a lower porosity than the aquifers of the first group. Thermal waters in this reservoir are of HCO3-Cl-Na type and of mineralization rate 4-20 g/kg, mostly 5-12 g/kg. The maximum expected water temperature in this reservoir group is up to 160 ºC. Average yields of flowing wells are 2.5 to 5 l/s, and the well-head water temperatures are 50-65 ºC on average.

The third group of reservoirs are those at the base of Neogene or Paleogene sediments. These are Miocene limestones, sandstones, basal conglomerates, and basal breccias. Thermal water contained in these rocks is highly mineralized (to 50 g/kg), and its chemical composition is of the HCO3-Na type. Average well yields are 5-10 l/s and water temperature at well-heads are 40-50 ºC.

The fourth group of reservoirs are in Mesozoic and Paleozoic rocks under Paleogene end Neogene sediments.

The most important reservoirs of this group and of the entire Pannonian hydrogeothermal system in Serbia are Triassic karstified and fractured limestones and dolomites. Similar reservoirs extend beyond the Serbian border, in the Pannonian Basin, in Hungary and Slovakia. Far from the basin's margin, at depths exceeding 1500 m, thermal waters in Triassic limestones are of Cl-Na type. In the marginal zone of the basin, where Neogene sediments are 1000 m deep over Triassic limestones and where water-exchange is active, thermal waters are of HCO3-Na type and have mineral contents of up to 1 g/kg. Average well-yield is 12 l/s, or 40 l/s from reservoirs near the basin's margin. The water temperatures at well-heads are mostly 40-60 ºC.

Dinarides

Hydrogeothermal systems in this geothermal province differ in their types, kinds of reservoirs and their extents, etc., as a result of varying geology. Rocks that have the largest distribution are Mesozoic in age: (1) karstified Triassic limestones and dolomites; (2) ophiolitic melange including large Jurassic peridotite massifs whose origin is associated with the subduction of Dinaridic plate under the Pannonian and the Rhodopean plates; (3) Cretaceous flysch; (4) Paleozoic metamorphic rocks; (5) Paleogene and Neogene granitoid and volcanic rocks; and (6) isolated Neogene sedimentation basins, (Fig. 5).

Hydrogeothermal systems have formed in terrains of: (1) Neogene sedimentation basins with reservoirs in Triassic limestones under them; (2) peridotite massifs and ophiolitic melange with reservoirs in Triassic limestones; (3) granitoid intrusions and respective volcanic rocks with reservoirs in the same rocks; and (4) Paleozoic metamorphic rocks with reservoirs in marbles and quartzites. The best aquifers are Triassic limestones, as the thermal water contained has low mineral content (<1 g/kg) of HCO3-Na or HCO3-Ca-Mg type. Springflows are very high, up to 400 l/s, and well yields are up to 60 l/s. Maximum temperatures of waters at well-heads are 80 ºC.

The second important reservoirs are those in granitoid intrusions and their marginal thermometamorphosed fracture zones, The contained thermal waters are also low in total mineralization (>1 g/kg), of HCO3-Na type, and maximum yield to 15 l/s. The highest temperature of waters at well-heads are 78 ºC. There are few occurrences of thermal water in Paleozoic metamorphic rocks. Such springs have low flows (<1 l/s), low water temperatures (<20 ºC), mineralization rates 5-7 g/kg, HCO3-Na in type, and high concentrations of free CO2 gas.

Serbian-Macedonian Massif

There are two types of hydrogeothermal systems in this geothermal province. One is the type formed in the Proterozoic metamorphic complex, with the reservoir in marbles and quartzites up to 1500 m in thickness. Thermal waters in this reservoir have total mineral content of 5-6 g/kg. Their chemical composition is HCO3-Na-Cl type water with high concentration of free CO2. This gas is formed by thermolysis of marble at temperatures above 100 ºC in the presence of water, as verified by isotopic studies (Milivojevic, 1990). Thermal water temperature at springs is 24-72 ºC and springflow is of gas-lift type due to the high CO2 gas content. The second type of hydrogeothermal system was formed in contact with and in the marginal zones of the Neogene granitoid intrusions. The reservoir rocks are granitoids, metamorphic and contact-metamorphic rocks, heavily fractured as a result of heating and cooling.

The thermal springs of Vranjska Banja belong to this system type and have the warmest water in Serbia, 80-96 ºC. Its mineral content varies from 0.1 to 1.2 g/kg. The water type is HCO3-Na-SO4-Cl. Springflows are up to 80 l/s.

Carpatho-Balkanides

This geothermal province has many hydrogeothermal systems, most of them formed in regions of isolated Neogene sedimentary lake basins. Reservoir rocks are karstified Triassic, Jurassic or Cretaceous limestones. Thermal karst springs have flows of 60 l/s, with water temperatures to 38 ºC. Total mineralization is 0.7 g/kg and the water type is HCO3-Ca. Another type of hydrogeothermal systems in this geothermal province was formed in the Upper Cretaceous paleorift of Eastern Serbia, where Mesozoic limestones were penetrated and thickly covered with andesite lavas and pyroclastics. These water contained are up to 0.8 g/kg and the water is of SO4-Na-Cl type, or HCO3-Na-SO4-Cl type where it is in limestones. Water temperatures at thermal springs are up to 43 ºC, and springflows are up to 10 l/s.

3.10. TURKEY (S. Simsek, 2005)

In Turkey, more than 170 geothermal fields which can be useful at the economic scale and about 1500 hot and mineral water resources (spring discharge and reservoir temperature) which have the temperatures ranged from 20-242ºC, have been determined. These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions. As a result of the geological, geophysical, geochemical surveys and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal resources in geothermal fields have been increased very seriously.

These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions.

With the existing springs (600MWt) and geothermal wells (2693 MWt), the proven geothermal capacity calculated by MTA is 3293 MWt (discharge temperature is assumed to be 35 °C). The distributions of proven geothermal potential accordant to the geographic regions are given at Figure 2.

The geothermal potential is estimated as 31,500 MWt.

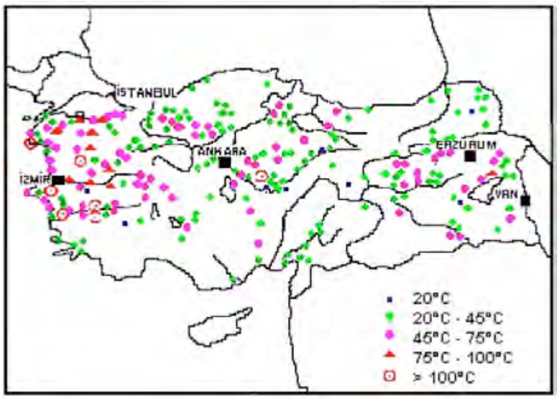


Figure 38 : Distribution of geothermal temperature records in Turkey (Mertoglu, 2007)

Up to now 500 geothermal explanatory and production wells and 200 gradient wells have been drilled in Turkey (depths up to 2398m).

As it will be considered, the number of geothermal production wells is too few if compared to the high geothermal potential of Turkey. Most of these wells have been drilled by MTA and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private (Akkus, 2002).

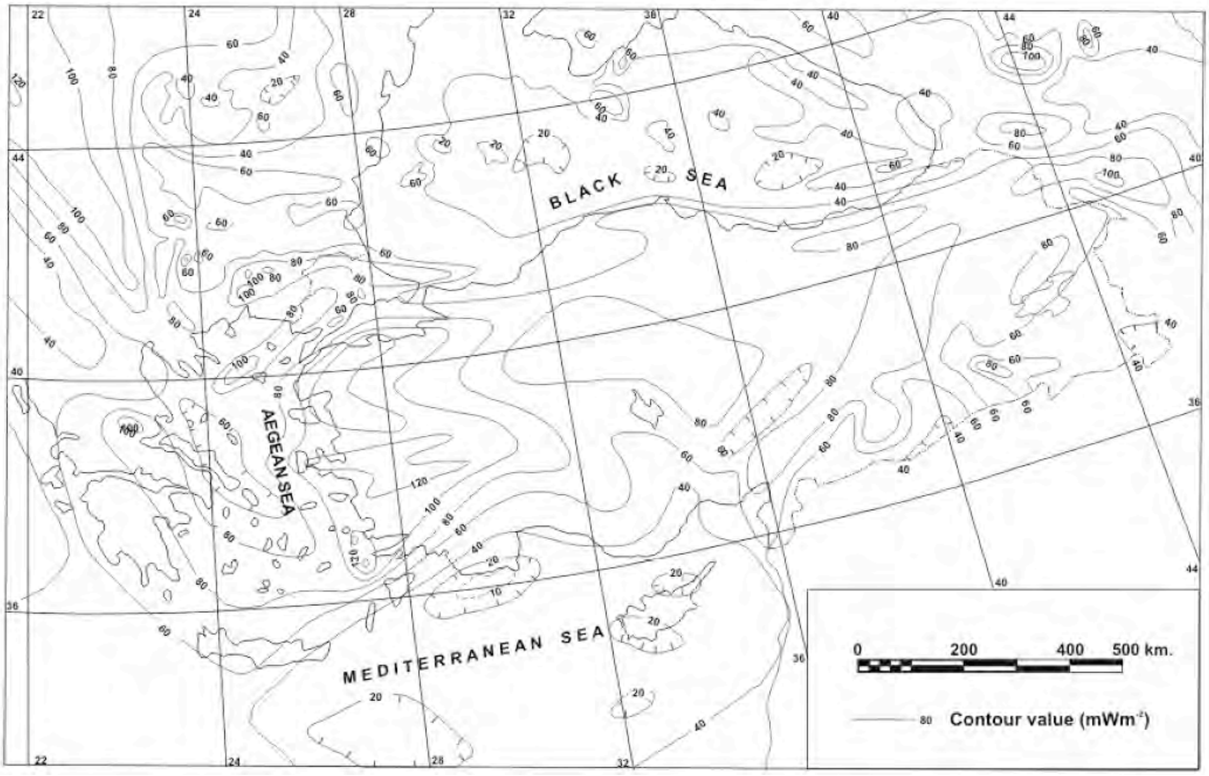


Fig.39. Heat flow in Turkey and surrounding seas (mWm^2). Compiled from Tezcan and Turgay (1992) and Heat flow Map of Europe (Cermak and Rybach, eds., 1979) (S.Simsek, 2002)

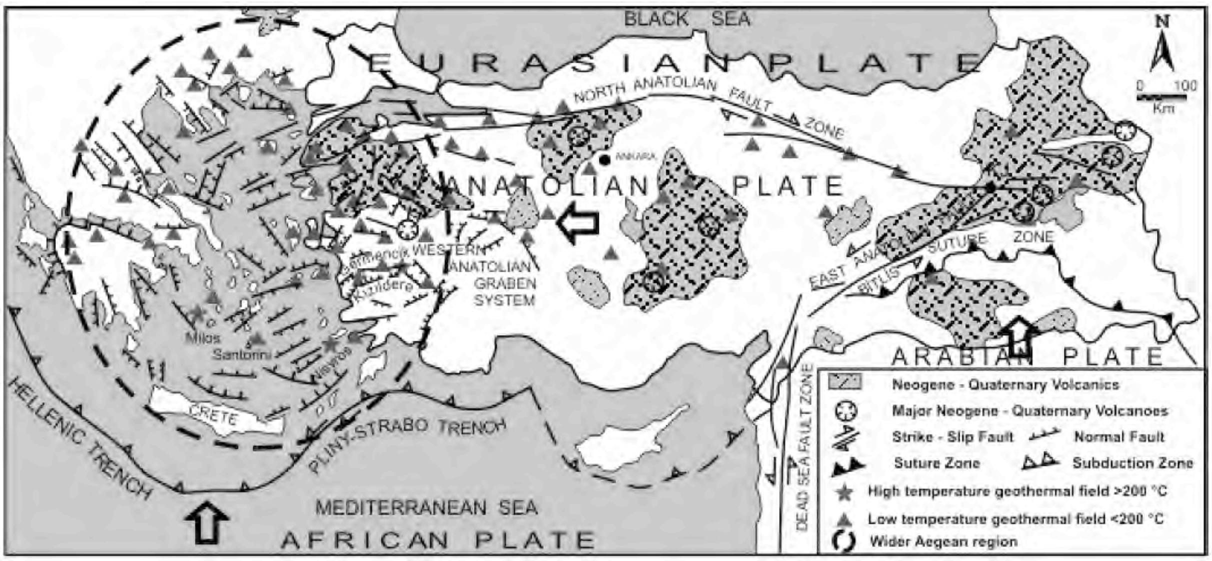
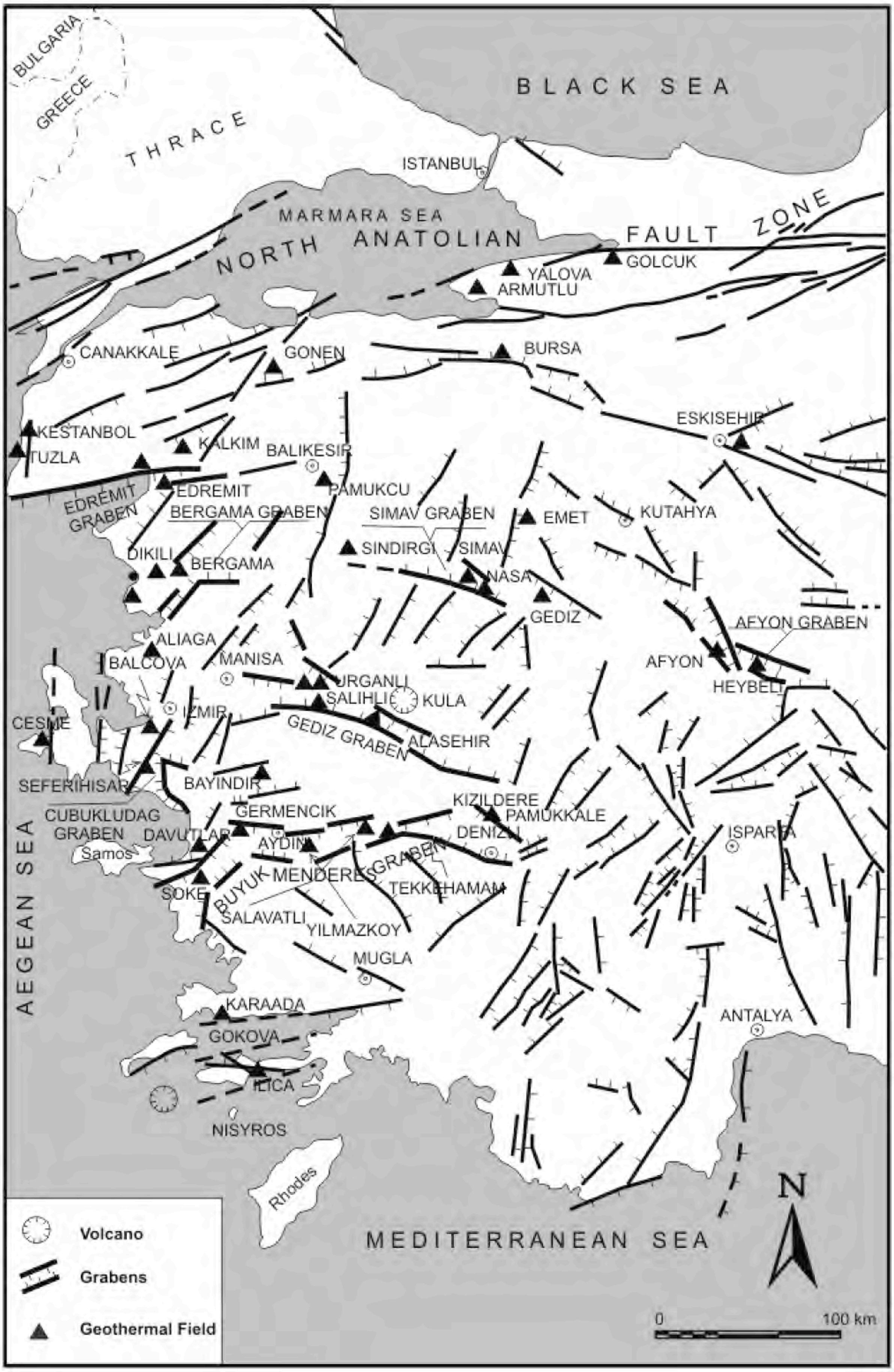


Fig.40. Major neotectonic features, distribution of Neogene to Quaternary volcanics and main geothermal fileds in wider Aegean region (compiled from Le Pichon and Angelier, 1979; Innocenti et al., 1982. Roberttson and Dickson, 1984; Fytikas et al. 2000; Simsek 2001) (S.Simsek, 2002)

Fig. 41. Geothermal fields in Western Anatolia (S. Simsek, 2002)



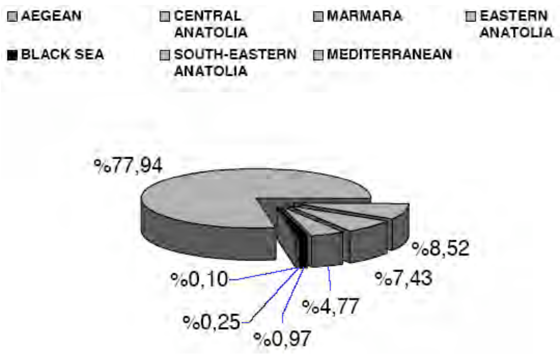


Fig. 42. Proven potential percentage for regions in Turkey

On the other hand, studies on Hot Dry Rock (HDR) systems which develop at zones included high temperature formations at shallow depths are continued very successfully. If the studies on the management of these systems will be economic, the geothermal potential of Turkey will grow up rapidly. From this point of view, especially in Central Anatolia the region of Acigol and the young volcanic fields of Eastern Anatolia are the positive fields.

Geothermal fields which their reservoir temperatures over than 140 ºC are given below.

1. Denizli-Kızıldere Field (242 °C)
2. Aydın - Germencik -Omerbeyli Field (232 ° C)
3. Manisa –Salihli-Göbekli Field (182 ° C)
4. Çanakkale- Tuzla Field (174 ° C)
5. Aydın-Salavatlı Field (171 °C)
6. Kütahya-Simav Field (162 °C)
7. Manisa- Salihli-Caferbey Field (150 °C)
8. Izmir- Seferihisar Field (153 °C)
9. Izmir-Balçova Field (142°C)
10. Aydın-Yılmazköy Field (142 °C)

It has been estimated that the Aydin-Germencik geothermal field would have 100 MWe power production capacity.

Fig.43. Indoor geothermally heated swimming pool in Hotel "Car Samuil", Bansko (Macedonia

4. GEOTHERMAL ENERGY UTILIZATION

4.1. ALBANIA (A. Frasheri, 2005)

No geothermal energy use is reported.

4.2. BOSNIA AND HERZEGOVINA (S. Prasovic, 2005)

Before the civil war an initial pilot project for a 1,00 MW plant near Sarajevo was initiated, which was designed with a volume flow of 240 l/s with water at a temperature of 58°C. However, the project was not completed.

Current activities related to geothermal energy continue to be limited to heating purposes. For example, a group of buildings in Ilidza in a suburb of Sarajevo is to be heated with geothermal energy. If higher temperatures are discovered in the course of the exploratory drilling, there are also plans for partial conversion to electrical energy. The project is being handled by a German-Bosnian company with the participation of EAN-Nord GmbH from New Brandenburg, Germany. At present the company is attempting to obtain promotional funds for further exploratory drilling.

4.3. BULGARIA

Geothermal energy in Bulgaria has various direct applications and no electricity generation so far. During ancient times thermal waters had been utilized mainly for healing, disease prevention, washing and bathing. As early as Roman times waters were used on a large scale for under floor heating in Public baths (hypocausts).

Currently thermal water application is mainly in balneology, space heating and domestic hot water supply, greenhouses, swimming pools, bottling of potable water, aquaculture (microalgae) and extraction of chemical derivatives. The total installed capacity amounts to 109.70 MWt (incl. balneology). The annual energy use is 1671.43 TJ/year (at average load factor 0.48).

Figure 44.Types of geothermal water application (for state-owned hydrothermal sources)

A small enterprise for production of iodine paste and methane extraction is in operation near Varna city (Northern Black Sea coast).

State-owned water sources have a leading role in geothermal application of the country. The different types of their utilization are presented on Figure 30. These data are based on the delivered concessions and permits by the Ministry of Environment and Water.

Balneology

A number of large spa resorts had developed in places of old Thracian or Roman residential areas on the territory of the country. Bulgarian spa resorts nowadays offer accommodation in 3 to 5 stars hotels and a built up structure of health centers controlled by the Ministry of Health. Highly experienced specialists working in spas offer treatment of a wide range of diseases (Bojadgieva et al.,2002). Currently operating health centers using thermal water sources (state-owned and municipal) amount to about 60. Mineral baths and swimming pools are common in them. Thermal waters in most of the spas also flow out of taps. This allows a free-of-charge and massive water use for drinking and disease prevention. Geothermal energy is currently used for space heating of buildings only in 12 spas as in 4 of them air- conditioning is provided in addition.

Space heating

Geothermal space heating marked insignificant progress in the last decade although it is of a high environmental importance especially in the spas mostly situated in mountainous and sea resorts. Several small new buildings using simple schemes have been heated in the last five years.

Lack of investments, some legal and organizational problems are the major obstacles for the geothermal development in the country.

Currently going process of managing water resources through concession regime has set the geothermal development on a new basis. About 26 concessions have been delivered for geothermal energy use of the stateowned sources within last 5 years. The new managers declared their intention to provide more complex thermal water application but for the time being mostly renovation of the existing systems are carried out.

Greenhouses

Geothermal greenhouses practically have no current development for the lack of investments, lost foreign markets and some land ownership problems. At the same time gas supply development is getting a strong competitor and in most cases gas heating provides cheaper greenhouse production compared to the geothermal one. The approximate total area covered by geothermal greenhouses (about 20.7ha) is close to that reported in Bojadgieva et al. (2000). Greenhouses in 11 sites are currently in operation.

Swimming pools

Reconstruction of swimming pools has marked a progress in the last years and the number of newly built outdoor pools has increased as well. Swimming pools have been built in 44 localities using state-owned water sources. This application is usually a part of complex thermal water utilization for domestic purposes, treatment and rehabilitation.

Bottling

The number of bottling companies has increased during the last ten years from 3 state-owned (before 1990) to 41 private enterprises nowadays. Their production meets mainly the demand of the local market. Several major reasons for high development rate of bottling exist due to the:

- predominant thermal waters of low TDS (<1 g/l);
- big variety of water chemical content that provides opportunity for bottling of potable water as well as of mineral water for drinking in prescribed doses; - short-term payback period.

This activity is very profitable also because the water cost is low and amounts to 2.5 USD/m3.

Ground source heat pumps

Recently the use of low-grade geothermal energy for seasonal heating and cooling has marked a significant progress.

The first installation of that kind was built in Sofia city in 1999, Hristov and Bojadgieva (2003). About 18 new installations assisted by ground source heat pumps have been recently designed and constructed by private company Geosolar V-63 Ltd., member of the European Heat Pump Association (Kolikovski, 2004). The heat pumps are made in Bulgaria including efficiency Compliant & Scroll Copeland compressors. The installed capacity varies from 7 to 45 kW. The COP is in the range of 3,5 - 4,5. Ground water temperature varies from 11 to 14 ºC. Another two installations of 60 kW heating capacity are under construction.

The existing systems are located mainly in Sofia city and provide space heating and domestic hot water supply for single apartments and family houses. About half of the installations are operating in a cooling mode.

Aquaculture

The installation for open maicroalgal mass cultivation located in Roupi region (SW Bulgaria) is a successful example for geothermal application in the county for more than 35 years.

The use of geothermal water in algal technology provides a high optimization of the cultivation process and considerable reduction in production costs, Fournadzieva et al.,(2003).

New products have been released on the local market in the last several years - pills enriched in Ca and Mg and various shampoos, face and hand creams.

4.4. CROATIA (Jelic et al., 2005)

All the localities where geothermal energy is used with the quantitative characteristics of the energetic installations are listed in the Table 9. The majority of the listed localities are spas, usually including hospitals and hotel capacities, equipped with swimming pools and other therapeutic and recreational facilities.

Except from natural springs, some of which have been used for centuries, geothermal water supply to those facilities is also drawn from shallow wells, drilled during the last few decades. While on some of the localities thermal water is used only for balneological and recreational purposes, others are heated by geothermal energy, due to water temperatures that make possible a useful amount of energy to be extracted by means of heat exchangers and heat pumps. There are also public recreational centers where geothermal water is used only in open-air swimming pools during the summer season. Obviously, the contribution of those facilities to the overall geothermal energy utilization is small.

"Mladost" Sport Centre, located in the south-western part of the Croatia's capital Zagreb, makes use of the geothermal water from the Zagreb geothermal reservoir.

The whole complex, including open-air and indoor swimming pools with all the accompanying facilities, as well as two sport halls, is entirely heated by geothermal energy, including the peak consumption.

Geothermal energy is extracted from the water flowing in a closed system, consisting of a production well, cascaded heat exchangers, injection pumps and an injection well. Pressure resulting from the density difference of water with different temperatures is used to establish so-called thermosiphon injection. Consequently, the injection system can operate without the support of the injection pumps for more than 7500 hours a year (Zelić et al, 1995).

Another locality where geothermal energy is used from deep production and injection wells is Bizovac, near the town of Osijek in the North-Eastern part of the country.

"Termia" Recreation Centre, consisting of a hotel equipped with a complex of open-air and indoor swimming pools, is heated by geothermal energy. The circulation of geothermal water is not closed like at "Mladost" Sport Centre. The outlet temperatures correspond to the average air temperatures during the year or the summer season, depending on the period of the year when a specific facility is in function. This methodology has been accepted taking into account equivalent fossil fuel energy that would be spent if water was heated from the ambient temperature.

The authors have applied this approach of energy calculation, although the alternation of such a point of view can be the object of a discussion.

Installed thermal capacities in 2000 were 113 MWt, which is not changed till today. In spite of that, annual energy usage was increased in last five years from 550 TJ/yr to 680 TJ/yr.

As can be seen from the Tables 9, the total geothermal energy used for space heating in Croatia is almost 190 TJ per year. Adding the amount of energy of 490 TJ per year relating to the balneological and recreational use, gives the total of 680 TJ per year of geothermal energy used as direct heat. Relating those figures to the total installed geothermal capacity, which is 36.7 MWt considering heating, and 77,3 MWt taking into account balneology and recreation, gives capacity factor values of 0.16 and 0.23, respectively. Small capacity factor is a clear evidence of an inadequate use of the installed geothermal capacities. As in the most cases, quantities of available thermal water are much higher than those needed to satisfy the actual demand, even taking into account peak load situations that

Table 9. Gepthermal Energy Use in Croatia (Jelic, 2005)

Locality	Type[1]	Maximum Utilization				Capacity[3] (MWt)		Annual Utilization							
		Flow Rate (kg/s)	Temperature (°C)					Average Flow (kg/s)			Energy[5] (TJ/yr)			Capacity Factor[6]	
			Inlet	Outlet											
				B excl.	B incl.[2]	B excl.	B incl.	B excl.	B only	B incl.[4]	B excl.	B only	B incl.	B excl.	B incl.
Bizovac (Termia RC)	HB	26.0	90.7	50.0	11.0	4.43	8.67	5.1	5.1	5.1	27.48	26.34	53.82	0.20	0.20
Daruvar (Daruvar Spa)	B	18.0	47.0		10.8	0.00	2.73	0.0	5.5	5.5	0.00	26.26	26.26	0.00	0.31
Ivanić Grad (Naftalan Hospital)	B	2.7	62.0		10.8	0.00	0.58	0.0	1.3	1.3	0.00	8.78	8.78	0.00	0.48
Krapinske Toplice (Krapina Spa)	HB	70.0	41.0	28.0	9.8	3.81	9.14	2.6	2.8	5.4	4.48	11.52	16.00	0.04	0.06
Lipik (Lipik Spa)	HB	8.3	60.0	55.7	10.7	0.15	1.71	4.5	4.5	4.5	2.54	26.59	29.13	0.54	0.54
Livade (Istria Spa)	B	2.0	28.0		11.3	0.00	0.14	0.0	0.7	0.7	0.00	1.54	1.54	0.00	0.35
Samobor (Šmidhen SRC)	B	30.0	28.0		20.2	0.00	0.98	0.0	4.0	4.0	0.00	4.12	4.12	0.00	0.13
Stubičke Toplice (Stubica Spa)	HB	95.0	53.4	38.0	10.1	6.12	17.21	1.7	3.7	3.7	3.49	17.58	21.07	0.02	0.04
Sveta Jana (Sveta Jana RC)	B	53.0	26.0		19.0	0.00	1.55	0.0	5.1	5.1	0.00	4.74	4.74	0.00	0.10
Topusko (Topusko Spa)	HB	124.5	62.0	50.0	19.7	6.25	22.03	30.0	1.3	31.3	47.48	7.36	54.85	0.24	0.08
Tuhelj (Tuhelj Spa)	B	75.0	32.0		10.0	0.00	6.90	0.0	75.0	75.0	0.00	217.64	217.64	0.00	1.00
Varaždinske Toplice (Varaždin Spa)	HB	27.0	58.0	39.0	10.0	2.15	5.42	5.3	5.3	5.3	13.16	20.08	33.24	0.19	0.19
Velika (Toplice RC)	B	35.0	25.0		20.0	0.00	0.73	0.0	8.8	8.8	0.00	5.77	5.77	0.00	0.25
Zagreb (INA-Consulting)	H	5.5	55.0	30.0		0.58	0.58	0.1	0.0	0.1	0.40	0.00	0.40	0.02	0.02
Zagreb (Mladost SC)	HB	50.0	80.0	50.0	10.5	6.28	14.54	6.6	6.6	6.6	26.12	34.39	60.50	0.13	0.13
Zagreb (University Hospital)	H	55.0	80.0	50.0		6.90	6.90	1.6	0.0	1.6	6.29	0.00	6.29	0.03	0.03
Zelina (Zelina RC)	B	30.0	40.0		20.2	0.00	2.49	0.0	3.0	3.0	0.00	7.83	7.83	0.00	0.10
Zlatar (Sutinske Spa)	B	220.0	32.0		19.4	0.00	11.60	0.0	1.7	1.7	0.00	2.78	2.78	0.00	0.01
TOTAL		927.0				36.66	113.90	57.5	134.3	168.6	131.43	423.32	554.75	0.11	0.15

in reality rarely occur.

4.5. GREECE (Fytikas, 2005 & N. Andritsos, 2007)

The exploitation of geothermal energy in Greece during the past decade is kept to direct uses. No electricity was produced for the sole geothermal power plant in Greece (2 MWe in Milos Island).

The installed capacity of direct uses in the beginning of 2007 reached 88 MWt, exhibiting a 18% increase compared with the capacity reported for the end of 2004 (Fytikas et al, 2005).

The greatest part of this increase is attributed to the rapid expansion of geothermal heat pump installations. All other applications do not show any clear increase in the installed capacity in the past few years. A small increase is shown in soil heating. In addition, some geothermal greenhouses and the desalination plant built in Kimolos Island are out of operation for reasons not related to the geothermal technologies. The novel desalination plant in Kimolos does not produce valuable fresh water for the inhabitants of the island because it has not been connected with a pipeline with the main water tank of the island. Furthermore, despite the significant share of balneology and open-air or indoor pool bathing to the total capacity, this sector (with some exceptions) does not show any sign of expansion or use of the hot waters heating the structures.

Finally, the completion of a 2-MW project for the heating and cooling of several public buildings in the town of Langadas, Thessaloniki, with geothermal heat pumps by utilizing shallow wells with water temperature in the range 20-40ºC was suspended due to administrative problems.

Direct heat applications in operation during the winter 2003-2004 are listed in Table 10. The installed capacity of direct uses approaches 75 MWt, giving a 42% increase with respect to the capacity reported for 1999 (Fytikas et al, 2000). Certainly, the stagnation in new greenhouse projects has lead to the above, rather modest, increase with regards to the huge potential of the country in the installed thermal capacity. Despite of this, an optimistic development in the past five years was the effective diversification of low enthalpy geothermal applications in new promising sectors, such as aquaculture, spirulina production, water desalination, fruit and vegetable dehydration and large heat pump installations.

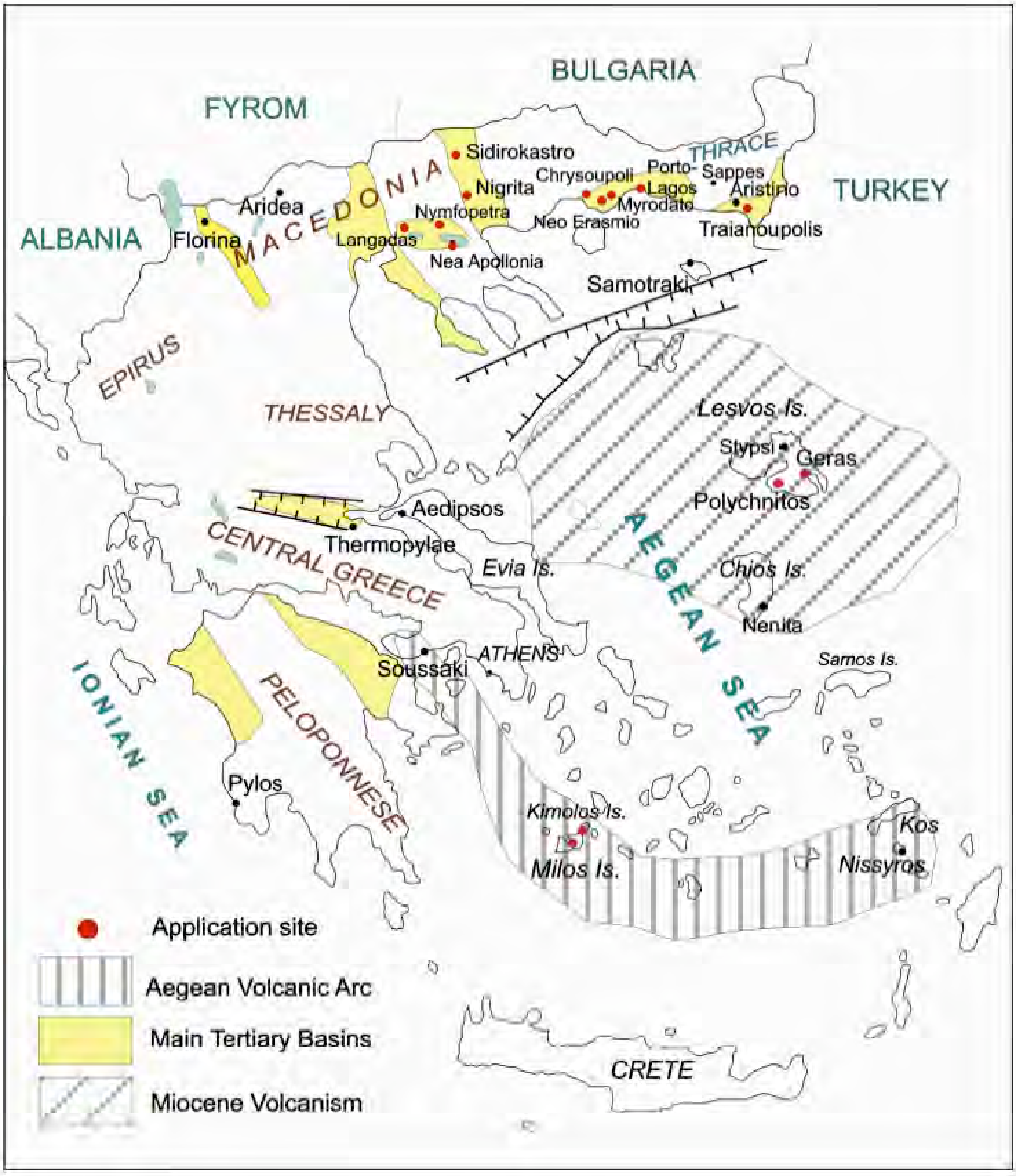


Figure 45: Geothermal map of Greece indicating the sites of direct uses (the balneology sites are not included).

Greenhouse and Soil Heating

The first geothermal greenhouses were constructed in the early 1980s in Nea Apollonia and Langadas (Perfecture of Thessaloniki), Nigrita (Serres), N. Kessani (Xanthi) and Polichnitos (Lesvos island). Currently, the covered area of geothermal greenhouses in the whole country is 18.2 ha.

Since about 1995 there is not any real increase in the covered area of geothermal greenhouses. Some new greenhouses were constructed, but greenhouses totaling about 6.5 ha have been out of operation for reasons not directly related to the geothermal energy.

Table 10. Direct application of geothermal energy in Greece (N.Andritsos, 2007)

Use	Installed Capacity (MWt)	Annual Energy Use (10^{12} J)
Space heating	1.4	16
Greenhouse & soil heating	26.5	248
Agricultural drying	0.8	4
Aquaculture*	9.3	76
Bathing and swimming	36	182
Geothermal heat pumps	14	80
Total	**88**	**606**

* Fish Farming & Spirulina Cultivation

Table 11: Greenhouse heating applications in Greece by geothermal field (2006-2007) (N. Andritsos, 2007)

Locality	Covered area (ha)	Maximum Utilization			Energy Utilization (TJ/yr)
		Flow Rate (kg/s)	Inlet Temp. (°C)	Capacity (MWt)	
Nigrita, Serres					
In operation	3.50	47.0	37-51	3.25	34.0
Inactive	4.80	39.0	45-58	2.75	
Sidirokastro, Serres					
In operation	2.70	50.1	37-63	3.20	36.9
Inactive	0.40	10.1	45	0.60	
Langadas, Thessaloniki					
In operation	2.20	14.4	35-37	0.82	8.6
Inactive	0.42	6.0	36	0.55	
Nea Apollonia, Thesssaloniki					
In operation	5.50	83.0	32-46	5.51	64.6
Eleochoria, Chalkidiki					
Inactive	0.20	5.6	30	0.23	
Neo Erasmio, Xanthi					
In operation	0.30	4.0	60	0.42	5.1
Nea Kessani, Xanthi					
Inactive	0.60	25.0	72	2.30	
Islands (Lesvos and Milos)					
In operation	3.95	31.0	46-85	5.10	45.7
Total					
In operation	18.2	230.0	32-85	18.30	195
Inactive	6.40	85	30-72	6.40	

Open field heating

Almost a decade ago, the use of geothermal water for soil heating was developed in Neo Erasmio, Xanthi, for off-season asparagus production. Soil heating usually starts in mid January and off-season asparaguses are produced between February and April, with higher prices that in-season produced asparaguses. This attempt was the first geothermal application world-wide in non-covered intensive cultivations (twenty years after unsuccessful one in France with corn production). The soil heating is accomplished by the direct flow of the geothermal water through corrugated polypropylene (PP) pipes with an outside diameter of 28 mm, laid underground. Soil heating can raise the soil temperature by 4-10ºC, depending upon the ambient conditions (temperature, moisture, winds, precipitation), the water flow rate and temperature, the presence of the foil coverage etc.

The total cultivated area with soil heating in the beginning of 2007 was 20 ha.

A 3.5 ha field in Nigrita stopped operating in 2003. In the meantime, the Nymfopetra unit was expanded by 2.0 ha, currently totalling 7 ha. A new 2.0-ha soil-heating unit was installed in Myrodato, Xanthi, in 2005. Originally, it was designed for off-season production of watermelons, but the next year the cultivation was turned to asparagus. Finally, a novel and promising effort has been carrying out during the past year in Chrysoupoli, Kavala, with the soil heating of an area of 1.0 ha for off-season asparagus production with an open (ground water) geothermal heat pump system. This installation will expand by 1 ha next year.

Dehydration of Agricultural Products

A tomato dehydration unit has been operating since 2001 in N. Erasmio, 25 km south of Xanthi, and produces “sundried” tomatoes (Andritsos et al, 2003). The unit uses lowcost geothermal water to heat atmospheric air to 55-56°C through finned-tube air heater coils. During the first six years of operation more than 37 tn of high quality dried tomatoes have been produced. The unit has been modified two years ago to double the drying capacity and a new expansion is planned for the next year. The unit can be easily modified to dehydrate many other vegetable products (e.g. peppers, onions, mushrooms and asparagus) or fruits. In fact, more than one ton of peppers, figs and apricots have been dried so far. With this application, geothermal energy undergoes one of the most appropriate and efficient tools for high quality and energy saving drying process.

Aquaculture

Anti-frost protection/heating of aquaculture ponds in Porto Lagos and Neo Erasmio (both in Perfecture of Xanthi) is practiced since 1998. It concerns mainly the heating of wintering ponds (earth channels) with giltheads, a very delicate fish which is very sensible to the abrupt drop of temperature in winter time. In Porto Lagos, the water comes from two production wells near the farming ponds. The protection of a 0.48 ha wintering pond against freezing requires a flow rate of up to 40 m3/h of geothermal fluids with a mean temperature of about 34ºC. The water in the pond (about 20,000 m3) is constantly replaced, receiving water either from the sea or from the neighboring shallow Lagos Lagoon. The injection of warmer fluids into the pond not only protected the fish stock from bad weather, but also increased fish production (Gelegenis et al, 2006).

In the N. Erasmio installation, the water, at a flow rate of 60 m3/h and temperature of 60ºC, is transported from a distance of 4.5 km through insulated plastic pipes (HDPE). Due to the high water temperature, geothermal water is initially mixed with seawater. The final mixture is injected into the ponds with a mean temperature of 30°C. The installed thermal capacity of both installations exceeds 8 MWt. The use of geothermal energy in these fish farms

Space Heating

There are not any new major developments in this sector. The use of geothermal energy for space heating is practiced only in a spa complex in Traianoupoli, Thrace, in a hotel in Milos, in several individual houses in Macedonia and Thrace and in a high-school building in Thrace, as seen in Table 11. The heating of several houses in Milos is accomplished by a kind of "downhole heat exchanger". These systems consist of a metallic U-tube submerged in a swallow (20 m) geothermal well with 60ºC water, which is directly connected to house radiators. The method uses a system of pipes placed inside a well and a working fluid (usually 'clean' water) is pumped through the pipes or allowed to circulate by natural convection to extract heat from the well water. The installed capacity of the space heating units in the country has been estimated to 1.2 MWt.

Bathing, Spas

There are 56 thermal spas and bathing centers operating in Greece today, mostly operated during the traditional balneological period (June-October). It is interesting, though, that more and more spas remain open all year.

Only recently there has been an interest for systematic work to assess the thermal use in the spas and bathing centers in Greece and to record the problems related to the geothermal waters (scaling, corrosion). The total water flowrate from the Greek spas exceeds 1000 kg/s, while the water temperatures range between 18 and 90ºC. A conservative estimate (assuming the water leaving the bathing centers has a temperature of 30ºC) of the total thermal capacity of the Greek spa resorts is 36 MWt, with a mean load factor of 0.16. These figures include the open and closed pools heated by geothermal waters (Aedispos, Loutraki-Pella, Milos Island etc.).

Industrial Uses

Industrial use involves a desalination plant in Kimolos Island, one of the numerous islands in the Aegean Sea facing severe problems of water supply, especially in the summer. The plant, based on the multiple effect distillation (MED) method, utilizes low-enthalpy water (60- 70°C) from shallow bores, 50-200 m (Karytsas et al. 2002b). In this plant, a geothermal stream flows through a low-pressure vessel containing several chambers or stages, each operating at a slightly lower pressure than the previous one. As the water enters each stage, a portion of it "flashes" into steam and is then condensed using sea water to produce a pure distillate product, which is pumped into the freshwater tank.

Spiroulina Cultivation

Cultivation of the green-blue algae spirulina is practiced in Nigrita, utilizing the geothermal waters both for their heat and for the dissolved CO2. The local geothermal waters contain about 4 kg of pure CO2 per cubic meter of water produced. The cultivation is taking place in shallow, covered, temperature-controlled ponds.

Geothermal Heat Pumps

As stated in abstract, the use of geothermal heat pumps in Greece is not as widespread as in some other countries, despite the significant increase of the installed units in the past five years. Depending upon space limitations, favorable geothermal conditions, local climatic conditions and the size of the installation, these units consist of earth coupled heat pumps (horizontal heat collectors, vertical heat exchangers), or low-temperature geothermal or ground water heat pumps. In the past five years a significant increase in seawater cooling (but also heating) has been also observed, especially for large hotels cooling.

The exact number of geothermal heat pump units presently installed in Greece is not known exactly, but the authors have been recorded about 100, mostly small (10-20 kWt), as well as some larger (100-500 kWt) units (e.g. the 550 kWt system at the Technical University of Athens, Karytsas proved indispensable during the heavy frosts in the 2001- 2002 and 2002-2003 winter periods and averted severe damage of the fish stock that has occurred in other farms of the region. It is estimated that both investments were repaid during the first three years of operation.

4.6. MACEDONIA (K. Popovski, 2007)

Fig.46. Location of geothermal projects in Macedonia

Present state-of-the-art of geothermal energy use in Macedonia is mainly a consequence of the process of the political and economic changes in flow. The economy collaps of the country, unsolved problems with the privatization of production capacityes of the geothermal energy users, a list of legal constraints, absence of a strategy for development, absence of the state support for the necessary explorations and investigations and very hard conditions for financing necessary reconstructions and new investments in the sector resulted with a complete stagnation for the period of more than 10 years. Real change of the situation cannot be expected before resolving the problem of listed constraints. Therefore, even the process of elimination of them is already in flow (new laws for energy, for mineral and water resources, and for concessions, etc.), it is not possible to expect serious changes during the period of next 5 years.

Thermal waters utilization consists of 7 geothermal projects and 6 spas. All are completed before and during the 80es of last century. Present state of the projects is as follows:

Istibanja (Vinica) Geothermal Project

Project consists of 6 ha greenhouse complex heating in combination with a heavy oil boiler for covering the peak loadings. It has been one of the worst completed projects before the crisis, however after the

Table 12. Geothermal projects in Macedonia (Popovski, 2005)

GEOTHERMAL LOCATION	GEOTHERMAL FIELD	APPLICATION	HEAT POWER (TOTAL, kW)	HEAT POWER (GEOTH., kW)	HEAT USERS
Istibanja (Vinica)	Kocani	Heating of a greenhouse complex	17.500	7.480	Aerial pipes and vegetative heating, plus heating of benches
Bansko	Strumica	Geothermal District Heating System	10.350	10.350	Heating greenhouses: - Aerial steel pipes in combination with corrugated plastic pipes - Soil heating Space heating: - Aluminium radiators - Air heating system - Sanitary warm water preparation - Swimming pool
Podlog	Kocani	Geothermal District Heating System and balneology	40.700	40.700	Heating greenhouses: - Aerial steel pipes Space heating: - Aluminia radiators - Iron radiators
Smokvica	Gevgelia				Abandoned
Negorci	Gevgelia	Space heating and balneology	250	250	Space heating: - Aerial steel pipes - Aluminia radiators Sanitary warm water preparation
Katlanovo	Skopje	Balneology			
Kumanovo	Kumanovo	Balneology			
Kezovica	Stip	Balneology			
Kosovrasti	Debar	Balneology			
Banjiste	Debar	Balneology			
Banja	Kocani	Balneology			Abandoned
TOTAL			**68.800**	**58.780**	

privatization in 2000 it has been reconstructed and optimized with Austrian and Dutch grants and now properly covers the heat requirements of the roses production for export. Owners are interested to follow investigations in order to enable geothermal heating of additional 6 ha of greenhouses.

Kocani (Podlog) Geothermal Project ("Geoterma")

That is the presently largest geothermal project in Macedonia, consisting of 18 ha greenhouse complex heating, and space heating in the center of the town. Due to the economic crisis in the country, paper industry, vehicle parts industry and rice drying have been lost as consumers of heat during the last 10 years. However, thanks to one Austrian grant, an additional borehole has been drilled, partial reinjection of used water completed and monitoring system introduced in the system. Presently, activities to finalize the completion of reinjection of the effluent water and connection of public buildings in the center of the town is in flow.

Project works as a public utility and its organizational structure is good covered by the existing team. Onliest problem in work is the price of supplied heat, which is kept very low by the State Regulatory Committee and doesn't consist funding for all necessary maintenance works and system development.

Bansko Geothermal Project

The bankrupt of ZIK "Strumica" and slow process of its privatization resulted with the collaps of organizational structure and proper use of the system, particularly during a period of three years when heating of the greenhouse complex was out of work. That was used by the other uses (existing and new ones) with the increase of "agreed" geothermal water flows. Three yeas ago, when again the greenhouse heating started with work, a trial for introduction of new organizational structure has been made but without success because not consisting centralized governing of the system exploitation. Introduction of centralized governing of the geothermal system and new exploitation boreholes are an absolute need for its proper work, due to the increased number of users and escorting not covered peak loadings. Also, a list of reconstructions and optimizations are necessary is necessary in order to put it in proper technical order.

Smokvica (Gevgelia) Geothermal System. Once the largest geothermal system in Macedonia covering the heat requirements of 22,5 ha glasshouses and about 10 ha plastichouses is now out of exploitation. Unproper privatization resulted with division of the property to 10 entities and they cannot find a common language for covering the costs of the system exploitation. Meanwhile, also the biggest exploitation borehole has been lost. Renewal of the system exploitation is nearly impossible because conditioning large investments with doubtful economy due to the present production capacity of the users.

Negorci (Gevgelia) Spa

Reconstruction of the heating installations has been finalized and now all the hotel and therapeutical projects are heated with geothermal energy. However, undefined property doesn't allow realization of necessary reconstructions and improvements of heating and sani tary installations.

4.7. ROMANIA (M. Rosca, M. Antics, 2005)

Due to the difficulties encountered by the economy, only three new geothermal projects were completed during 1999-2004: one for direct use and two for bathing and swimming. Most of the geothermal operations completed before 1999 continued to operate, with some exceptions where the users closed their operations (mainly greenhouses, the total area decreasing by almost 50%). The geothermal energy utilisation as of 31 December 2004 is shown in Table 12.

Out of the 96 wells operated in 38 locations, 37 are exclusively used for health and recreational bathing, with a total maximum flow rate of about 890 kg/s. The total capacity of the utilised wells is about 145 MWt, which produces annually 2,841 TJ. The operations in Mihai Bravu, Bors and Ciumeghiu (Table 13) have been closed in the last years because the greenhouses in the area have been closed, but these are expected to resume in the short or medium term future. The greenhouses in Bors have been purchased by a private company and operation started in 2005. For this reason, these three locations have not been removed from Table 13, and their installed capacity has been added in column 6, giving therefore a total of 156.6 MWt.

Table 12. Types of direct geothermal heat use in Romania

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr)	Capacity Factor
Space Heating	57.2	1129	0.62
Air Conditioning (Cooling)			
Greenhouse Heating	28.3	486	0.54
Fish and Animal Farming	3.1	65	0.66
Agricultural Drying			
Industrial Process Heat	14.1	246	0.55
Snow Melting			
Bathing and Swimming	42.2	915	0.68
Other Uses (specify)			
Subtotal	144.9	2841	0.62
Geothermal Heat Pumps			
TOTAL	144.9	2841	0.62

The main direct uses of geothermal heat are: space heating 39.7%, bathing and swimming including balneology 32.2%, greenhouse heating 17.1%, industrial process heat 8.7%, and fish farming and animal husbandry 2.3%, the capacity factor being 0.62. By type of utilisation, the actual situation in Romania is shown in Table 12.

4.8. SERBIA

In Serbia, geothermal energy is scarce-ly used in regard to its geothermal potential. The use of geothermal waters is mainly done for balneological purposes. In Serbia there are 60 spas where geothermal waters are used for balneology, sports and recreational purposes.

The total installed energy use is 74 MWt out of which 36 MW, in balneology, and 38 MWt for other ways of energy use. According to Freeston (1995) Yugoslavia takes 17 th place in the world as far as the use of geothermal energy is concerned. That makes just about 10% of its real potential, which is estimated to about 800 MWt.

Table 13. Geothermal direct heat use projects in Romania

Locality	Type	Maximum Utilisation			Capacity		Annual Utilisation	
		Flow Rate (kg/s)	Temperature (°C) Inlet	Outlet	(MWt)	Ave. Flow (kg/s)	Energy (TJ/yr)	Capacity Factor
Satu Mare	HB	12	65	30	1.8	7	32.3	0.56
Carei	BI	5	45	30	0.3	3	5.9	0.62
Acas	GB	15	65	30	2.2	8	36.9	0.53
Tasnad	HBG	10	70	25	1.9	7	41.5	0.69
Beltiug	B	6	75	30	1.1	4	23.7	0.68
Sacuieni	HBGFI	8	80	25	5.1	12	87.1	0.54
Marghita	HB	6	65	25	2.0	10	52.8	0.83
Boghis	BH	12	45	25	1.0	10	26.4	0.83
Mihai Bravu	GF	6	65	25	1.0	0	0	0.00
Bors	G	25	115	40	7.8	0	0	0.00
Oradea	IHGBF	85	83	30	18.8	65	415.0	0.70
Livada	BF	10	88	35	2.2	5	35.0	0.50
Felix	BH	140	45	25	11.7	115	216.0	0.58
Madaras	BH	5	46	25	0.4	3	8.3	0.65
Ciumeghiu	G	12	92	35	2.9	0	0	0.00
Cighid	HBG	10	72	25	2.0	6	37.2	0.59
Beius	HB	44	83	30	9.7	15	104.9	0.34
Macea	*HGB*	*15*	*65*	*25*	*2.5*	*8*	*42.2*	*0.53*
Curtici	*HGB*	*22*	*63*	*25*	*3.5*	*14*	*70.2*	*0.63*
Dorobanti	*GB*	*18*	*60*	*25*	*2.6*	*9*	*41.5*	*0.50*
Sofronea	*HB*	*6*	*42*	*25*	*0.4*	*3*	*6.7*	*0.53*
Iratos	*IB*	*5*	*40*	*20*	*0.4*	*3*	*7.9*	*0.63*
Arad	*B*	*12*	*40*	*25*	*0.8*	*7*	*13.8*	*0.54*
Nadlac	*IHB*	*10*	*78*	*30*	*2.0*	*8*	*50.6*	*0.80*
Sannicolau	*IHBG*	*50*	*78*	*30*	*10.0*	*35*	*221.6*	*0.70*
Saravale	*HB*	*8*	*75*	*25*	*1.7*	*5*	*33.0*	*0.61*
Tomnatic	*GB*	*45*	*80*	*30*	*9.4*	*22*	*145.1*	*0.49*
Lovrin	*HGB*	*40*	*81*	*30*	*8.5*	*30*	*132.0*	*0.49*
Periam	*HB*	*10*	*70*	*25*	*1.9*	*6*	*35.6*	*0.59*
Jimbolia	*IHGB*	*50*	*82*	*30*	*10.9*	*35*	*240.1*	*0.70*
Teremia	*IHB*	*15*	*85*	*30*	*3.5*	*6*	*43.5*	*0.39*
Comlosu	*HB*	*10*	*81*	*25*	*2.3*	*6*	*44.3*	*0.61*
Grabat	*IB*	*6*	*80*	*30*	*1.3*	*3*	*19.8*	*0.48*
Beregsau	*IB*	*6*	*75*	*25*	*1.3*	*3*	*19.8*	*0.48*
Timisoara	*HB*	*15*	*45*	*25*	*1.3*	*10*	*26.4*	*0.64*
Herculane	*B*	*75*	*52*	*25*	*8.5*	*50*	*148.0*	*0.55*
Olt Valley	*HB*	*25*	*92*	*30*	*6.5*	*16*	*130.8*	*0.63*
North Bucharest	*HB*	*35*	*62*	*25*	*5.4*	*15*	*65.0*	*0.38*
TOTAL		889			156.6	659	2840.8	

Note: Data for the locations in Italics have not been confirmed by the operator (FORADEX S.A.)

The commonest use of geothermal energy in Serbia are the traditional ones: balneology and recreation. Certain archeological evidence indicates similar uses by the ancient Romans in the localities of the presently known spas: Vranjska Banja, Niska Banja, Vrnjacka Banja and Gamzigradska Banja. There are today in Serbia 59 thermal water spas used for balneology, sports and recreation and as tourist centers. Thermal waters are also bottled by nine mineral water bottling companies. The direct use of thermal energy for space heating or power generation is in its initial stage and very modest in relation to its potential capacity. In the hydrogeothermal system of the Pannonian Basin, thermal water is used from 23 wells. This direct use began in 1981. Water from two wells is used for heating greenhouses, from three wells for heating pig farms, from two for industrial process in leather and textile factories, from three for space heating, and from thirteen wells for various uses in spas and for sport and recreation facilities. The total heat capacity of the wells presently in use is 24 MW (Tonic et al., 1989). Thermal waters outside of the Pannonian Basin region are used for heating in several localities. Spaceheating started in Vranjska Banja forty years ago. Thermal water is used there to heat flower greenhouses, a poultry farm, a textile workshop, premises of a spa rehabilitation center and a hotel. A large hotel and rehabilitation center with a swimming pool is heated in Kursumlijska Banja. In Niska Banja, a heating system is installed for the hotel and rehabilitation center, including heat pumps of 6 MW, which directly use thermal waters at 25 °C. Thermal direct use in Sijarinska Banja is for heating the hotel and recreation

Fig.47. Geographical position of greenhouses heated by geothermal energy in Serbia

Figure 48. Locations of major spas in Serbia and Montenegro.

center. A similar use is practiced in Ribarska Banja. Thermal water in Lukovska Banja is used in the carpet industry. A project has been completed for geothermal direct use at Debrc for drying wheat and other cereals. Another use at Debrc is for space heating.

Geothermal energy is used for heating of greenhouses only in three localities in Yugoslavia: Vrnjacka Banja, Srbobran and Knjazevac (Fig. 33). The biggest greenhouse is in Vranjska Banja, and the smallest in Knjazevac. 8 ha is heated by geothermal energy while the whole surface of other greenhouses heated by crude oil and gas occupies around 64 ha.

Thermal waters are also bottled by 10 mineral-water bottling companies.

Table 14. Direct heat use geothermal projects in Serbia

		Maximum Utilization							Annual Utilization	
Locality	Type[1)]	Flow rate	Temperature °C		Enthalpy[2)] kJ/kg		Capacity	Average Flow rate	Energy use[3)]	Capacity Factor
		kg/s	Inlet	Outlet	Inlet	Outlet	MWt	kg/s	TJ/yr	
Kanjiza - 1	D/B	5.0	41	26			0.314	5.0	9.89	
Kanjiza - 2	D/B	14.0	65	26			2.284	14.0	72.02	
Kula - 1	B	9.5	50	25			0.994	9.5	31.33	
Kula - 2	I	8.3	53	25			0.972	8.3	30.65	
Kula - 4	I	8.5	51	26			0.889	8.5	28.03	
B. Petrovac - 1	G	16.7	46	25			1.467	16.7	46.26	
B. Petrovac - 2	A	7.8	45	24			0.685	7.8	21.61	
Prigrevica	D/B	21.0	54	25			2.548	21.0	80.33	

Srbobran	G	11.7	63	24			1.909	11.7	60.19	
Kikinda - 1	D	6.2	50	27			0.597	6.2	18.81	
Kikinda - 2	F	15.2	51	26			1.590	15.2	50.12	
Mokrin	F	10.5	51	26			1.098	10.5	34.62	
Vrbas	B	4.3	51	23			0.504	4.3	15.88	
Temerin	B	20.0	41	25			1.339	20.0	42.21	
B. P. Selo	F	10.0	43	26			0.711	10.0	34.29	
Becej	D	19.4	65	24			3.328	19.4	104.91	
Vranjska Banja	I/D/B/G	77.0	96	50			14.820	77.0	467.19	
Sijarinska Banja	D/B	7.4	76	25			1.579	7.4	49.78	
Josanicka Banja	D/B	17.0	78	40			2.703	17.0	85.21	
Lukovska Banja	D/B	12.0	67	35			1.607	12.0	50.65	
Kursumlija	D/B	20.0	68	25			3.598	20.0	113.43	
Mladenovac	B	19.0	53	25			2.226	19.0	70.17	
S. Palanka	B/O	13.0	56	25			1.686	13.0	53.16	
N. Pazar	B	10.0	52	28			1.004	10.0	31.66	
Mataruge	D/B	47.0	43	24			3.736	47.0	117.79	
Ribarska Banja	D/B	37.0	44	25			2.941	37.0	92.73	
Pecka Banja	B	4.0	36	25			0.184	4.0	5.80	
Ilidza (Pec)	B	17.5	48	26			1.611	17.5	50.78	
Bujanovacka Banja	D/B/O	7.0	43	24			0.556	7.0	17.54	
Gamzigrad	D/B	10.0	42	24			0.753	10.0	23.74	
Ovcar Banja	D/B	50.0	38	27			2.301	50.0	72.55	
Vrnjacka Banja	B	5.0	36	25			0.230	5.0	7.25	
Niska Banja	D/B	60.0	37	25			3.012	60.0	94.97	
Pribojska Banja	B	70.0	36	30			1.757	70.0	55.40	
Klokot	B	15.0	34	25			0.565	15	17.81	
Koviljaca	B	130.0	30	24			3.264	18.0	14.25	
Brestovacka Banja	B	3.0	40	30			0.126	3.0	3.96	
Rajcinovica Banja	B	8.0	36	28			0.268	8.0	8.44	
Bukovicka Banja	B	15.0	34	28			0.377	15.0	11.87	
Prolom Banja	B/O	15.0	31	24			0.439	15.0	13.85	
G. Trepca	B	20.0	30	24			0.502	20.0	15.83	
Debrc -1	G/D	30.0	53	30			2.887	15.0	45.51	
Vrdnik	B	12.0	32	25			0.351	12.0	11.08	
Kravlje	B	10.0	33	25			0.335	5.0	5.28	
Rgoste	B	70.0	31	25			1.757	15.0	11.87	
Radalj	B	8.0	29	25			0.134	8.0	4.22	
Zvonacka Banja	B	18.0	30	25			0.377	13.0	8.57	
Ljig	B	7.0	32	25			0.205	7.0	6.46	
Debrc-2	G/D	30.0	52	22			3.766	15.0	59.36	
Total								82.887	2379.27	

Table 15. Summary of geothermal energy uses in Serbia

4.9. SLOVENIA (Rajver, 2005)

At 27 localities direct use of geothermal energy is implemented. There are no new locations so far, and new investigations with production drilling (i.e. at Benedikt, NE Slovenia) haven't given any reliable results. The main type of use is for bathing and swimming (incl. balneology) and for space heating. A certain percentage of the energy used annually goes through geothermal heat pumps (GHPs) for space heating, sanitary hot water and heating of swimming pools.

Bathing and swimming

This is the most important type of direct use of geothermal energy in Slovenia. There are 24 thermal spas and recreation centres where swimming pools with a surface area of about 36,000 m2 and volume of about 50,750 m3 are heated by geothermal water directly or indirectly through heat exchan-gers and GHPs. Thermal spas and recrea-tion centres are predominant geothermal localities for direct heat use. Water tem-peratures in thermal spas range from 22 to 68 °C. The total geothermal energy used for bathing and swimming is estimated at 245 TJ/yr in comparison with 246 TJ in 1999.

Table 16. Geothermal energy uses in Serbia

	Installed Thermal Power[1)] MW$_t$	Energy Use[2)] TJ/yr
Space heating	19.7	575
Bathing and swimming	36.0	1150
Agricultural drying	0.7	22
Greenhouses	15.4	256
Fish and other animal farming	6.4	211
Industrial process heat	4.6	121
Snow melting	-	-
Air conditioning	-	-
Other uses (specify)	-	-
Subtotal	82.8	2335
Heat pumps	6.0	40
Total	88.8	2375

Table 17. Geothermal heat pumps in Serbia

Locality	Ground or water temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type2)	COP3)	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Niska spa	25	180	6	W	3	4320	79.0	-
Belgrade	22	65	1	W	3	4320	10.7	-
Nis	22	60	1	W	3	4320	11.0	-
Knjazevac	22	65	1	W	3	4320	11.4	-
TOTAL			9				112.1	

New developments of facilities have been completed at Mala Nedelja and Snovik during the last 4 years. At some localities flow rates decreased and at some others only temperature slightly decreased as a consequence of overexploitation with no reinjection (Lendava, Moravci, Murska So-bota, all NE Slovenia), and at others both temperature and flow rate decreased just due to lower utilization or maybe also da-maged boreholes (Olimpia, Rogaska Slati-na, Dobrna, Topolsica). At some other loca-lities improvements were managed chiefly by bo-reholes' repair or new pumps, such as at Ptuj and atBanovci, while in Maribor and at Lasko with lower outlet temperature, and at Rimske Toplice with improved flow rate.

Space heating and district heating, air conditioning

This second most important type of di-rect use is mostly implemented at thermal spas, and at most of them directly.

The heating of sanitary hot water there is also included. The users have GHP units installed only in the case when the thermal water temperature is too low. At Murska Sobota 300 dwellings are heated geother-mally through heat exchangers, especially from October to April. Lower flow rates are the case at Olimia, while at Moravci higher flow rate but lower inlet temperature. Consequently the total geothermal energy used for space heating is about 224 TJ/yr as compared with 263 TJ in 1999. At Moravci a small amount of 17 TJ/yr is now dedicated to district heating and 23 TJ/yr to air conditioning.

Greenhouses

The heating of greenhouses with geothermal water began in 1962 at Catez (E Slovenia). It is performed there by the Flowers Catez Co. (total area under glass 4.5 ha) for production of flowers mainly for the domestic market, while at Moravci (1 ha under glass) for tomato production.

The total geothermal energy used in the greenhouses is about 100 TJ/yr and is lower compared with the use in 1999 (137 TJ). The active period of Terme Catez is during warmer months, while that of Flowers Catez during colder part of the year, therefore, they do not interfere much with each other despite their closely spaced localities at Catez. They both exploit the same geothermal fractured dolomitic aquifer, where the average annual flow rate is only 20 kg/s.

Industrial process heat

Industrial use of geothermal energy is active only at Vrhnika, where it amounts to 14.2 TJ/yr. There thermal water of 24 °C is heated to about 55 or 60 °C for the leather industry, while at Trbovlje thermal water is used for cooling at the cement works, and therefore, is not considered as energy use. Only small amount is utilized for the swimming pool in winter months.

Geothermal heat pumps

The GHPs are used in an open loop system at five thermal spas and /or recreation centres, predominantly for raising the thermal water temperature for further use in swimming pools and for space heating. The geothermal energy used for GHPs amounts to about 36.3 TJ/yr in comparison with 27 TJ in 1999 and 64 TJ in 1994. Small increase in recent years is due to slight improvements in temperature difference in Maribor, in Rimske and Smarjeske Toplice.

There are at least 102 GHP units on water source that extract at least about 36.8 TJ from shallow groundwater and 101 closed loop ground coupled GHP units (87 horizontal and 14 vertical) that extract additional 16 TJ/yr, while at least 1.37 TJ/yr of heat is rejected to the ground in the cooling mode. Altogether at least 203 units extract 52.83 TJ/yr. Very probably the real number of GHP units is not much higher. There was low interest in GHPs in 1990's due to high initial costs and high price of electricity and low prices of gas and oil in comparison with the situation before 1990 when GHPs were more popular. The number of closed loop (ground coupled) geothermal or ground-source heat pumps in Slovenia has increased in recent years as a consequence of governmental funding and good promotion of some private companies involved in their installation about their advantages. This increase will hopefully continue.

The annual energy use from geothermal for space heating has increased in a period 1994-1999 and decreased slightly during last 5 years (a certain amount is now dedicated to district heating and air conditioning). The energy use for bathing and swimming has decreased drastically in a period 1994-1999, and since then has decreased again by 14.5 TJ/yr. The greenhouses' energy use has increased in a 1994-1999 period and decreased substantially in 2000-2004, while that of industrial process heat has faced only small increase.

Table 17. Summary of geothermal direct uses in Slovenia (Rajver, 2005)

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] ($TJ/yr = 10^{12} J/yr$)	Capacity Factor[3)]
Individual Space Heating[4)]	16.07	224.12	0.44
District Heating [4)]	0.94	17	0.57
Air Conditioning (Cooling)	1.43	23	0.51
Greenhouse Heating	7.92	99.79	0.4
Industrial Process Heat[6)]	0.75	14.2	0.6
Bathing and Swimming[7)]	17.57	245.28	0.44
Subtotal	44.68	623.39	0.44
Geothermal Heat Pumps	3.94	89.11	0.72
TOTAL	48.62	712.5	0.46

It is worth mentioning that the number of GHPs units (open and closed loop) has increased as well as their energy use during the last 5 years. They contribute 52.8 TJ/yr and, together with those GHPs that are installed at thermal spas, about 89 TJ/yr. It is believed that good promotion of the advantages of shallow geothermics will help increase its use in future also due to unstable oil prices.

4.10. TURKEY (S. Simsek, O. Mertoglu, 2007)

The operational capacities of the city based geothermal district heating systems (GHDS) existing in Turkey are as the following: Gönen (Commissioned: 1987, 3400 residences, geothermal water temperature is ~ 80 °C), Simav (1991, 3200 residences, ~120 °C), Kirsehir (1994, 1800 residences, ~57 °C), Kizilcahamam (1995, 2500 residences, ~ 80 °C), Izmir (1996, 10.000 residences, ~ 115 °C), Sandikli (1998, 1600

Table 18. Direct heat utilization projects in Slovenia (Rajver, 2005)

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate (kg/s)	Temperature (°C)		Enthalpy[2] (kJ/kg)		(MWt)	Ave. Flow (kg/s)	Energy[4] (TJ/yr)	Capacity Factor[5]
			Inlet	Outlet	Inlet	Outlet				
1. Moravci	C,H,D,B,G	78	61	32			9.41	34.7	139.7	0.47
2. Murska Sobota	H,B	18	48.5	33			1.17	10	20.44	0.55
3. Terme Lendava	H,B	14	56	29			1.60	4	14.28	0.28
4. Lendava Elizabeta	H	14	64	44			1.17	3	7.91	0.21
5. Ptuj	B	16	34	26			0.54	13.2	13.7	0.81
6. Mala Nedelja	B	7	43	28			0.44	0.7	1.39	0.1
7. Banovci	H,B	20	68.4	33			3	5.1	23.8	0.25
8. Zrece	H,B	27	30.7	25.7			0.57	15	9.89	0.55
9. Olimia Atomske T.	H,B	20	38	28			0.84	15	19.8	0.75
10. Rogaska Slatina	B	8	48	28			0.67	1.5	3.96	0.19
11. Snovik	B	15	30.4	28			0.15	5	1.58	0.33
12. Dobrna	B	8	35	31			0.13	1.6	0.84	0.2
13. Topolsica	B	25	28	15			1.36	5	8.57	0.2
14. Medija	H,B	35	23	20			0.42	14	5.8	0.44
15. Smarjeske Toplice	H,B	40	32	17			2.51	30	59.4	0.75
16. Lasko	B	18	34	25			0.68	18	21.4	1
17. Rimske Toplice	H,B	20	40	32			0.67	6	6.34	0.3
18. Dolenjske Toplice	B	19.6	34.2	32			0.18	9	2.41	0.43
19. Terme Catez	H,B	80	62	30			10.71	41	173.05	0.51
20. Flowers Catez	G	60	54	28			6.53	20	68.59	0.33
21. Bled	B	12	21.7	20			0.09	10	2.24	0.83
22. Vrhnika	I	20	24	15			0.75	12	14.2	0.6
23. Trbovlje	B	11	27	23			0.18	0.2	0.1	0.02
24. Cerkno	H,B	29	27.6	24.5			0.38	8	3.27	0.28
25. Dobova	H,B	15	63	38			1.57	7	23.1	0.47
26. Portoroz	B	0.8	23	16			0.02	0.5	0.46	0.6
27. Maribor	H,B	2.5	39	13			0.27	1.75	6	0.7
TOTAL		650.9					47.18	301.3	672.7	0.45

Table 19. Geothermal heat pumps installed in Slovenia (Rajver, 2005)

residences,~ 70 °C), Afyon (1996, 4000 residences, ~ 95 °C), Kozakli (1996, 1000 residences, ~ 90 °C), Izmir-Narlidere (1998, 1075 residences, ~ 98 °C), Diyadin (1999, 400 residences, ~70 ºC), Salihli (2002, 3000 residences, ~94 ºC), Edremit (2003, 500 residences, ~60 ºC). Today, 40-45 °C temperatured geothermal waters are used for space heating in Turkey without heat-pump.

Most of the development is achieved in geothermal directuse applications by 1077 MWt. 750 MWt (which equals to the heat requirement of 65000 residences equivalance) of this potential is being utilized for geothermal heating, including district heating, thermal tourism facilities heating and 635000 m^2 geothermal greenhouses heating. The remaining potential of 327 MWt of

Locality	Ground or water temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
open loop:								
water - water	13	10.6/unit=212	20	W	2.4 - 3.4	900-2520	8.86	
water - water	11	18/unit=540	30	W	3	1400-2300	8.24	
water - water	11	25/unit=50	2	W	3	2200	1.44	
water - water	1 to 16	623	50	W	2.4 - 4.5	220-2520	18.27	
Total open loop		1425	102	W	2.4 - 4.5	220-2520	36.81	
closed loop:								
ground coupled	0 to 39	706.8	87	H	2.9 - 4.5	1200-2520	9.88	
ground coupled	2.5 to 14	198.3	14	V	3.0 - 4.8	1800	6.14	1.37
Total closed loop		905.1	101		2.9 - 4.8	1200-2520	16.02	
TOTAL		2330.1	203		2.4 - 4.8	220-2520	52.83	1.37

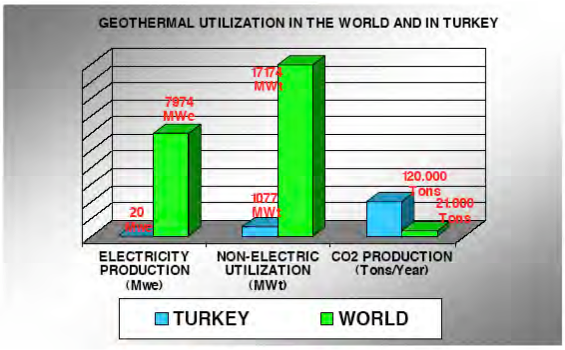


Fig.49. Participation of Turkey in whole geothermal energy utilization in the world

this potential is being utilized for balneological purposes (There exists 195 thermal facilities (Balneology) in Turkey).

Additionally, engineering design of more than 300,000 residences equivalence geothermal district heating has been completed. By summing up all these geothermal utilizations, the geothermal installed capacity is 1077 MWt for direct-use and 20.4 MWe for electricity production in Turkey. Moreover, a liquid carbon dioxide and dry ice production factory (120.000 tons/year) is integrated to this electricity production power plant.

Table 20: Capacities in Geothermal Utilization in Turkey (S.Simsek, 2005)

Geothermal Utilization	Capacity
District Heating	750 MWt
Balneological Utilization 195 Spa	327 MWt
Total Direct Use	1077 MWt
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

Table 21. Present and planned production of electricity (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2002	17.50	104.6	19568.5	95558.9	12249.45	44388	-	-	18.9	48	31854.35	140099.50
Under construction in December 2002					3338	10845						

5. FUTURE DEVELOPMENT

5.1. ALBANIA

The geothermal situation of low enthalpy in Albania offers three possibilities for the direct use of geothermal waters energy, i.e. geothermal energy utilization must be realized by an integrated scheme of geothermal energy, heat pumps and solar energy, and the cascading use of this energy (Frasheri A. 2001, Frasheri A. et al. 2003, 2004).

Firstly, the *ground heat* can be used for space heating and cooling by the Borehole Heat Exchanger-Geothermal Heat Pumps modern systems.

Secondly, *thermal sources of low enthalpy* and of maximal temperature up to 65.5°C. Thermal waters of springs and wells may be used in several ways:

1. Modern SPA clinics for treatment of different diseases and hotels, with thermal pools, for the development of ecotourism. Such centers may attract a lot of clients not only from Albania, because of the curative properties of waters and springs are situated near the seaside, the Gjinari mountains or Ohrid Lake pearl. The oldest and most important thermal springs are at the Elbasani Llixha SPA, located in Central Albania. By national road communication, the Llixha area is connected to Elbasani. These thermal springs are known from about 2000 years ago, and are near to the old road "Via Egnatia" that was passing from Durresi-Ohrid- to Constantinople. All seven groups of the springs in Llixha Elba-sani and Kozani-8 well, near to the Saint Vladimir Monastery at Elbasani, have the possibilities for modern complex utilization. Ishmi 1/b geothermal well is located in the beautiful Tirana field, near the Mother Theresa- Tirana Airport, close to the Adriatic coastline and the Kruja - Skenderbeg Mountain.

Peshkopia SPA was constructed by modern concepts as a balneological geothermal center. There are thermal pools, for medical treatment and recreation. Construction of the Peshkopia SPA must be a good example for new SPA construction in Albania.

2. The hot water can be used also for heating of hotels, SPA and tourist centers, as well as for the preparation of sanitary hot water used there. Near these medical and tourist centers it is possible to build greenhouses for flowers and vegetables, and aquaculture installations.

3. From thermal mineral waters it is possible to extract very useful chemical micro-elements as iodine, bromine, chlorine etc. and other natural salts, so necessary for preparation of creams for treatment of many skin diseases as well as for beauty treatments. From these waters it is possible to extract sulphidric and carbonic gas. Earth Heat Probe". The geothermal gradient of the Albanian Sedimentary Basin has average values of about 18.7 mK·m-1. At 2 000 m depth the temperature reaches a value of about 48°C. In these single aban-doned wells a closed circuit water system can be installed. Greenhouses can be built near these wells.

Consequently, the sources of low enthalpy geothermal energy in Albania, which are at the same time the sources of multi-element mineral waters, represent the basis for a successful use of modern technologies for a complex and cascading utilization of this environmentally friendly renewable energy, thus achieving economic effectiveness. Such developments are use-ful for the creation of new working places and improvements to the standard of living for local communities near the thermal sources.

5.2. BULGARIA (K. Bojadgieva, 2005)

A new project funded by the World Bank ("Identification of key barriers for the utilization of the national geothermal resources in Bulgaria and site case studies for Velingrad, Sapareva bania and other geothermal heating systems") has just started. The project achievements would form a base for promotion of systematic use of geothermal energy and to mitigate technical, legal and implementation risks.

The application of ground source heat pumps and air-towater pumps would continue to grow particularly concerning private and business buildings. Spa centers located in the mountains and on the Black sea coast would also develop towards achieving higher standards in treatment, services and tourism.

Table 22. Summary table of geothermal direct uses in Turkey (S. Simsek, 2005)

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	74	816,8	0,35
District Heating [4]	645	6015,45	0,35
Air Conditioning (Cooling)			
Greenhouse Heating	131	2478,7	0,6
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	327	10312,2	1
Other Uses (specify)			
Subtotal	1077	19623,2	
Geothermal Heat Pumps			
TOTAL	1077	19623,2	

Table 23. Utilization of geothermal energy for direct heat in Turkey (S.Simsek, 2005)

Locality		Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
			Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
			(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Afyon-Çobanlar(Ç-1)	2000	B+D	32	55				2,68			
Afyon-Çobanlar(Ç-2)		B+D	50	56,4				4,48			
Afyon-Sandıklı(AFS-3)		B+D	25	40				0,52			
Afyon-Sandıklı(AFS-4)		B+D	60	68				8,29			
Afyon-Sandıklı(AFS-5)		B+D	58	68,5				8,13			
Afyon-Sandıklı(AFS-6)		B+D	60	68				8,29			
Amasya-Terziköy(T-2)		B+D	32	40,1				0,68			
Aydın-Yılmazköy(Y-1)		B+D	30	142				13,44			
Balıkesir-Bigadiç(BH-1)		B+D	0,5	42				0,01			
Balıkesir-Edremit(ED-1)		B+D	75	60				7,85			
Erzurum-Pasinler(PS-4)		B+D	50	43				1,67			
Erzurum-Pasinler(PS-5)		B+D	65	39				1,09			
Kayseri-Erciyes(KB-1)		B+D	110	38				1,38			
Van-Erciş-Şorköy(ZG-2)		B+D	6	85				1,26			
Van-Erciş-Şorköy(ZG-3)		B+D	20	92				4,77			
Balıkesir-Bigadiç(BH-2)		B+D	60	98				15,82			
Balıkesir-Bigadiç(BH-3)	2001	B+D	60	98				15,82			
Balıkesir-Edremit(ED-2)		B+D	2	55				0,17			
Afyon-Bolvadin(H-4)		B+D	31	56,5				2,79			
Denizli-Gölemezli(DG-1)		B+D	15	88				3,33			
Manisa-Urganlı		B+D	22	61				2,39			
Balıkesir-Bigadiç(BH-4)		B+D	2	57				0,18			
Balıkesir-Edremit(ED-3)		B+D	18	59				1,81			
Balıkesir-Pamukçu		B+D	11	58,5				1,08			
Afyon-Bolvadin(H-1/A)		B+D	73	56,3				6,51			
İzmir-Çeşme-Ilıca(I-2)		B+D	57	57				5,25			
Kırşehir-Çiçekdağı(ÇB-1)		B+D	4,5	41				0,11			
İzmir-Balçova(BD-8)	2002	B+D	55	128				21,41			
Denizli-Yenicekent(YK-1)		B+D	20	57				1,84			
Denizli-Yenicekent(YK-2)		B+D	140	67				18,75			
Uşak-Banaz(HB-3)		B+D	34	71,7				5,22			
Kırşehir-Terme-KT-12		B+D	105	56				9,23			
Sivas-Şarkışla-Ortaköy		B+D	24	36				0,10			
Denizli-Yenicekent(YK-3)		B+D	4,5	36,5				0,03			
Denizli-Gölemezli(DG-2)		B+D	140	75				23,44			
Uşak-Banaz(HB-4)		B+D	44,00	62				4,97			
Bursa-Kaynarca(BK-1)		B+D	10,00	49				0,59			
Elazığ-Karakoçan-Golan		B+D	25	41				0,63			
Denizli-Gölemezli(DG-3)	2003	B+D	110	70				16,12			
Kütahya-Yoncalı (YON-6)		B+D	7	41				0,18			
Afyon-Sandıklı (AFS-7/A)		B+D	85	70,1				12,49			
Afyon-Sandıklı (AFS8)		B+D	40	54				3,18			
Kütahya-Harlek(HR-2)		B+D	45	37				0,38			
Afyon-Sandıklı (AFS10)		B+D	105	68				14,50			
Denizli-Gölemezli(DG-4)		B+D	45	70				6,59			

Locality		Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
			Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
			(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Bursa-Kaynarca(BK-2)		B+D	50	88				11,09			
İzmir-Balçova(BD-9)		B+D	50	136				21,14			
Denizli-Gölemezli(DG-5)		B+D	30	62				3,39			
Manisa-Demirci		B+D	5	42				0,15			
Balıkesir-Gönen-6		B+D	30	84				6,15			
Van-Özalp(VS-1)		B+D	30	87				6,53			
Balıkesir-Gönen-7		B+D	50	70				7,33			
Çanakkale-Çan-Etili		B+D	8	62				0,90			
K.Maraş-Ilıca	2004	B+D	25	47,6				1,32			
TOTAL											

5.3. CROATIA (Jelic et. Al., 2005)

The future development of the geothermal energy use in Croatia has been forecasted within the GEOEN Program, according to three possible scenarios. Key factors defining those scenarios are economic and technological development of the country, energy sector reform and government measures, international energy market development and global environmental limitations.. The first scenario is based on the assumption of a slow introducing of new technologies and insufficient government activities in the energy sector reform and restructuring. Basic characteristic of the second scenario is the implementation of new technologies, made possible by the technology transfer resulting from the joining of Croatia to the European Union and supported by state incentive mechanisms. The third scenario is a compilation of highly technological and ecological features, characterized by a strong influence of the environment protection concept to the global economic and energetic development. Table shows the forecasted geothermal energy utilization development dynamics according to three scenarios, based on the figures from 1995 as reference values. Bathing, swimming and balneology have not been included into the forecast of the geothermal energy use development

In accordance with the general orientation towards ecologically acceptable renewable energy resources proclaimed in the Strategy of the Energy Development of the Republic of Croatia, a significant growth of the geothermal energy usage is planned. In the first phase the growth will be based on the total exploitation of the existing geothermal wells and the increase of the capacity factors of the installed capacities. As the next step, the complete geothermal field development by means of newly drilled wells is planned.

Beside development in the direct heat segment, the planned construction of the geothermal power plant in Velika Ciglena by the year 2010 would bring Croatia into the group of countries producing electricity from geothermal sources. The initial power of 4.4 MWe obtained from the existing well should be increased to the value of 13.1 MWe by the construction of two additional production wells by the year 2015. As mentioned before, the pre-feasibility study on combined electricity and heat production in Velika Ciglena showed that such an energy generating plant could operate under economically acceptable conditions.

5.4. GREECE (Andritsos, 2007)

Very important geothermal projects are under development or planning, particularly in Northern Greece. The most important projects are as follows:

Macedonia airport: Heating and cooling of a 80.000 m2 total covered area of new Thessaloniki Airport buildings using geothermal water and heat pumps. The required heat energy quantities can be served by geothermal waters at a flow rate of 40 kg/s with temperature 45-55°C. For this purpose a production well will be drilled at a depth of 1000 m.

Prefecture of Imathia: Heating of a cactus greenhouse (1.0 ha) and asparagus cultivations (8.0 ha) will be ensured by a production well already performed at a depth of 800 m in the Alexandria region (36°C, 33 kg/s). In the same region low depth (150-200 m) aquifers with temperatures at 18-20°C will be used for heating and cooling purposes, by means of heat pumps, of public buildings (1000 m2), a swimming pool and a small (0.1 ha) greenhouse. The new central building of the city of Veria (12.000 m2) will be heated and cooled by means of geothermal heat pumps.

Langadas: Production and reinjection wells, distribution networks and heat pumps units are already installed to offer heating and cooling to a greenhouse, two public schools, the courthouse and the health center of the city of Langadas in a cascade mode.

Prefecture of Xanthi: Anti-frost protection and heating of open type aquacultures (for farming giltheads) will be extended over 5 ha of earth ponds. Soil heating for asparagus earliness will be implanted in 5 ha, totalizing 12 ha by the end of 2006. This heating mode will be tested for earliness purposes in watermelon and lettuce cultivations under low plastic film covering (3.0 ha). In the Porto-Lagos area geothermal waters of 35°C will be used for heating growing water of a gilthead hatchery.

Electric Power generation: As it is known, a double flash 2 MWe power plant was installed in 1985 in Milos and operated intermittently till 1989. The plant was shut down because mainly of the environmental protests due to H2S emission to the atmosphere. Because of the unfortunate fate of the Milos electrical plant, a renewal of interest for power generation in Milos and Nisiros with flash cycle units is not probable. On the other hand, the installation of small Organic Rankine Cycle (ORC) units cannot be excluded. In the past few years the Public Power Corporation has started exploratory work prospecting for the installation of a binary ORC unit in Lesvos Island. The construction of a small binary unit is also scheduled for construction to supply electricity for the Milos desalination plant. The potential for electrical generation using ORC units in several Aegean islands (Milos, Nisyros, Lesvos and possibly Chios) is large and a preliminary estimate is ~20 MWe. The substitution of fossil fuel derived electric power by a "green" power from ORC units, which may be located away from the coast, will undoubtedly have a positive impact on the environment (reduction of CO2, NOx and CO emission), will reduce the noise associated with conventional power plants and avert possible oil spill during oil shipment.

The prospects of using geothermal energy in a variety of applications in the wider region of Aegean Sea appears to be large due to the enormous geothermal potential of the region. Some drawbacks in this development is the large discrepancy in energy demand between summer (due to tourism) and winter, the relative isolation of some islands that makes almost impossible the electricity transmission and increases the transportation cost of greenhouse products, the aggressiveness of some geothermal fluids (very saline waters in Kimolos, Samothraki, Sousaki, Methana and Aedipsos and dissolved H2S in Sousaki and Methana) and, finally, the mild weather conditions of most islands rich with geothermal energy.

The new uses or the expansion of current geothermal applications in the island areas of Greece can be summarized as follows:

1) *Greenhouse and soil heating*. There are 7.5 ha of geothermal greenhouses in Lesvos (Polychnitos and Geras), Milos and Nisyros Islands with an installed capacity of ~8 MWt. The potential of expanding greenhouse geothermal heating is rather greater in the colder islands of Northern Aegean (Lesvos, Chios and Samothraki) as well as in Evia Island. In Lesvos Island, apart from the Polichnitos geothermal field, other locations for possible greenhouse and soil heating are Argennos, Stipsi-Kalloni and Lisvori, where a geothermal greenhouse was in operation several years ago.

2. *Space heating including DHE.* District heating is rather difficult to be implemented in because of the way the houses are built in Greece and of cultural reasons. It has been suggested the use of geothermal energy for heating the district of Sousaki, but the high content of the fluids in dissolved solids and gases (and especially H2S, Andritsos et al, 1994) makes the project rather costly. Individual houses and residential buildings can be heated by geothermal energy, especially in Northern Aegean.

In an interesting example, the heating needs of a house in Milos are provided by the recirculation (by natural convection) of 'clean' water through a "downhole heat exchanger" (DHE). The system consists of a metallic U-tube submerged in a swallow (20 m) geothermal well with 60ºC water, which is directly connected to house radiators. The DHE eliminates the need of the geothermal fluid disposal, which may be costly in small systems. The method uses a system of pipes placed inside a well and a working fluid (usually 'clean' water) is pumped through the pipes or allowed to circulate by natural convection to extract heat from the well water. The warm fluid then passes through the house heating system. In general it can be applied in cases where shallow wells (10- 50 m) contain hot water. These areas are not many (e.g. Klamath Falls - USA, New Zealand), but some Greek islands satisfy this criterion (Milos, Kimolos, Santorini and even Lesvos).

3) *Aquaculture.* The potential of using geothermal energy for fish farming appears to be significant especially in the islands and the coastal areas of Northern Aegean Sea and especially in Lesvos, where several fish farms are in operation.

4) *Bathing and balneology*. Thermal spas and bathing centres operate at 56 locations in Greece, almost half of which are located in coastal or island areas. Twelve spas are in operation in the Aegean islands. In the 90's new bathing complexes were constructed or (e.g. in Kyllini, Polichnitos, Kythnos), while others were expanded or renovated (e.g. Aedipsos, Sidirokastro). Certain swimming pools are also heated by geothermal fluid (Aedipsos-Evia island, Aridea). There is large potential in expanding the number of spa facilities in the Aegean region and in using geothermal water to heat swimming pools.

5) *Agricultural drying.* Drying or dehydration of fruits and vegetable under the sun is a traditional method for food preservation in Greek islands. Low- and moderate temperature geothermal energy can be efficiently used in fruit and vegetable dehydration and can be partially substitute the traditional 'sun-drying' process. Recently, it has been demonstrated in Thrace that geothermal energy can be successfully used in drying tomatoes (Andritsos et al, 2002). Geothermal drying can reduce some of the quality problems of the dried products associated sun-drying, like dust and insect contamination and enzymic activities. Geothermal water, with temperature as low as 55ºC, can be used to heat atmospheric air in finned tube air heater coils. In case that the geothermal water is corrosive, as is usually the case with the saline geothermal waters encountered in the Aegean region, a second water-water heat exchanger may be required. Cherry-tomato is almost the only agricultural products that can be dehydrated in Cyclades islands (Santorini, Milos). On the other hand, in the islands of Northern Aegean with richer crop production several crops can be dried: peppers, onions, apricots, figs and prunes.

6) *Water desalination*. Desalination technology has been available for decades. Two are the most important technologies: thermal desalination and membrane desalination (mainly reverse osmosis). The former is employed for large seawater desalination, especially in countries and industries with low fuel cost. Two refineries in Greece, in Aspropyrgos and Thessaloniki, apply this technology for brine water desalination. In general, the thermal technologies for seawater desalination systems are the multistage flash distillation (MSF) process and the multiple effect distillation (MED). Membrane technology has been used widely during the recent years for small or large systems. In the Aegean Sea there are numerous islands facing severe problems of water supply. Water needs are partially covered by wells, small dams, collection of rain and ship transportation. There are reverse osmosis membrane desalination plants in several islands (e.g. Syros and Myconos), but several hotel businesses have also installed desalination units. The major drawback of both desalination technologies is the large energy requirements in the form of oil or electricity. The large amounts of energy required for the desalination process is opening the way to the use of other energy resources, among them geothermal energy, in the Greek Islands.

Two desalination projects have recently commenced in the islands of Kimolos and Milos. The Kimolos project has been completed last year and a detailed description can be found in Karytsas et al (2002). The

Milos project is implemented through a THERMIE programme and it is in the stage of well drilling. Both plants use a MED process and utilise (or will utilise) low enthalpy water (60-100oC) from shallow bores (50-200 m). In a MED geothermal plant, a stream of geothermally heated seawater flows through a low-pressure vessel containing several chambers or stages, each operating at a slightly lower pressure than the previous one. As the seawater enters each stage, a portion of it "flashes" into steam and is then condensed to produce a pure distillate product, which is pumped into the freshwater tank. The concentrated brine remaining at the end of the process is rejected to the sea.

Geothermal Heat Pumps. Recently a geothermal heat pump (GHP) system was installed in a municipal building in Rhodes city (140 kW rated power), used for both heating and cooling. In addition, a heat pump (coupled with ground heat storage uniformly distributed below the building basement) is in operation for heating and cooling an office building of 6000 m2 by utilising the warm water (36ºC) of a nearby well. The heat pump rating is 220 kW. The GHP are similar to ordinary air-conditioners and heat pumps, but it utilises the ground instead of the outside air to provide air-conditioning, heating and hot water. There are several types of GHP systems. The most common type is the earth-coupled GHP, which uses sealed vertical or horizontal pipes as heat exchanger through which water is circulated to transfer heat from the ground to the house. In the second type, the groundwater typ, the heat pump extracts heat from the water produced in a shallow well. The mild climatic conditions prevailing in most island and coastal areas in Greece seem to make rather uneconomical at a first glance the investment in such units, although the combination of the system with air-conditioning using seawater may turn out to be attractive.

5.5. MACEDONIA (Popovski, 2005)

According to the information and data on disposal, in can be expected that the following activities and projects realization shall be realized during the period of the next five years:

- Preparation of the "Geothermal Atlas of Macedonia"
- Preparation of the feasibility study "Strategy of Geothermal Development of Macedonia"
- Preparation of the feasibility study "Geothermal District Heating of Kocani" and partial realization of the town district heating system
- Preparation of the feasibility study "Geothermal Potential of the South/West Macedonia"
- Completion of the second phase of the reinjection system of the Kocani geothermal system
- Recompletion of the Bansko geothermal system
- Reconstruction of the existing heating installations in Hotel "Car Samuil" in Bansko and their orientation towards geothermal energy use in Katlanovo Spa, Kezovica Spa, Debar Spa and Kosovrasti Spa, and probably
- Beginning of development of the Kratovo geothermal field. Real realization shall mainly depend on the finalization of the privatization process of the users and success of collection of foreign financial funds for financing the necessary investments.

5.6. ROMANIA

In 2003, the Romanian Government approved the "Strategy for the development of renewable energy sources", which sets short and medium term targets in accordance with the EU principles and directives. The Kyoto objectives imply for the European Union, between 2008 and 2012, a reduction by 8% of the greenhouse gases emission compared to the 1990 level (corresponding to about 600 million tons per year of CO2 equivalent). The European Council Resolution on renewable energies of 8 June 1998 seeks a doubling of the share of renewables from 6% at present to 12% in 2010. These targets are also assumed by Romania, as it intends to join the European Union in 2007.

5.7. SLOVENIA (Rajver, 2005)

The government funding for efficient energy use has improved in recent years. For example, the Public Fund for Regional Development will support three projects in 2004/05 for exploration and exploitation of thermal and thermomineral waters, dedicated for further development of balneology at tourist centres. This is connected with activity of the Ministry of Economy which invites tenders for the funds of the »European Fund for Regional Development« that will stimulate the further development of touristic activities, especially balneology. Therefore, few new localities for geothermal energy development are proposed in northeastern and southern Slovenia, at Janezovci near Ptuj and at Metlika, respectively.

5.8. SERBIA

Exploration to date has shown that geothermal energy use in Serbia for power generation can provide a significant component of the national energy balance. The prospective geothermal reserves in the reservoirs of the geothermal systems amounts to 400 x 106 tonnes of thermal-equivalent oil. The prospects for use of heat pumps on pumped ground water from alluvial deposits along major rivers are very good. For intensive use of thermal waters in agro- and aquacultures and in district heating systems, the most promising areas are west of Belgrade westward to the Drina, i.e. Posavina, Srem, and Macva. Reservoirs are Triassic limestones and dolomites >500 m thick, which lie under Neogene sediments. The priority region is Macva, where reservoir depths are 400-600 m, and water temperatures are 80 ºC. The economic blockade (1991-2000) of Serbia stopped a large project in Macva: space-heating for flower and vegetable green-houses over 25 ha (1st stage). The completed studies indicate that thermal water exploitation in Macva can provide district heating system for Bogatic, Sabac, Sremska Mitrovica, and Loznica, with a population of 150,000. In addition to the favorable conditions for geothermal direct use from hydrogeothermal reservoirs in Serbia, geothermal use can also be made from hot dry rocks, as there are ten identified Neogene granitoid intrusions. Geothermal exploitation programmes have been prepared, but they have not been brought into operation.

The total discharge amount of thermomineral water in Serbian spas is about 1200 l/s, an indicator of favorable hydrogeological characteristics up to a depth of 2000 m.

Thermomineral water can be utilized for balneotherapeutic purposes from aquifers at the depth of 3000 m.

The total extent of aquifers with thermomineral water is very different. It varies from several kilometers up to several thousand kilometers. The thickness varies from several meters up to 2000 meters maximum. Because of this, the total volume varies significantly, from several hundreds up to several millions m3.

Isotopic investigations of thermomineral waters from Serbian spas show that water ages vary from 1,350 years in the Prolom Spa—the youngest—up to 40,000 years in the Bujanovacka spa—the oldest. (Milivojevic, 1989, 2003).

Results of the completed hydrogeological exploration show possibilities for increasing the discharge amount of thermomineral water from two to ten times, generally four to five times.

According to the current hydrogeological investigations, it is possible to increase the temperature of the thermomineral water type when it is in limestone. Water temperatures at thermal springs reach 43 ºC, and spring flows reach 10 kg/s from present springs. Geothermometers, temperature loging and terrestrial heat-flow measurements show that the maximum temperature at a depth of 2000 m should be 100 ºC. The expected thermomineral water temperature in Vrnjacka spa is 120 ºC, in Mataruska spa 100 ºC, in Josanicka spa 135 ºC, in Ribarska spa 130 ºC, in Novopazarska spa 110

°C, in Pribojska spa 60 °C, in Koviljaca spa 40 °C, in Ovcar spa and Bogutovacka spa about 60 °C, in Bukovicka spa about 100 °C, in Mladenovac spa about 90 °C, in Trepca spa about 50 °C, in Prolom spa 60 °C, in Vranjska spa about 150 °C, in Kursumlijska spa about 120 °C, in Sijarinska spa about 100 °C in Niska spa and Soko spa up to 50 °C, in Brestovacka spa up to 100 °C and in Gamzigradska spa up to 50 oC.

Present results show possibilities for significantly increasing the temperatures of thermomineral waters in Serbian spas. The geothermoenergetic potential for thermomineral water could be increased by several times according to present geothermal indicators—it could be at least 1.200 MWt.

Recent hydrogeological investigations discovered several aquifers of thermomineral waters with favorable possibilities for balneo-tourism.

Thus, Serbia has favorable balneo- and hydogeothermalresources that, with other geologic and tourist resources, could develop the tourist economy significantly.

5.9. TURKEY (O. Mertoglu, 2007)

Table 24: Year 2013 projections for different types of geothermal utilizations, export and employment and required investment amounts to fulfill the State Planning Organisation 2013 Geothermal Goals for 2007 – 2013 period

Geothermal Utilization	Year 2013 Projections	MW	Total annual Energy
Electricity Production		550 MWe	4 Billion kWh/Year
District Heating	500 000 Residence equivalence	4000 MWt	
Balneological application	400 Thermal Facilities equivalence	1100 MWt	
Greenhouse	5.000.000 m²	1700 MWt	
Cooling	50.000 Resid. equivalence	300 MWt	
Drying	500.000 tonnes/year	500 MWt	
Fish Farming + other appl.		400 MWt	
Total Direct Use		**8000 MWt**	**35.040.000* MWt/Year**
Total Geothermal Direct Use (non-electric) + geoth. electricity production utilization projection fuel-oil saving (substitution) for the year 2013			3,88 Billion Ton/Year = 4,24 Bill. USD/year
The prevented CO_2 emission amount by reaching the 2013 geothermal utilization goals (550 MWe+ 8000 MWt)			10 Million Ton/Year
	Year 2005		**Year 2013**
Geothermal CO_2 Production (gross)	120.000 ton/year		200.000 ton/year
	Year 2005		**Year 2013**
Created Employment (Direct and Indirect)	40.000 persons		200.000 persons
	Year 2005		**Year 2013**
Export (greenhouse products)	15 Million USD		250 Million USD

*Load Factor is 50 %.

According to the Turkish Prime Ministry State Planning Organisation 9th Development Plan the year 2013 goals for different types of geothermal utilizations have been specified as follows (Tables 24, 25):

Table 25: Year 2013 Projections for geothermal electricity production in Turkey

Geothermal Field Name	Temp. (°C)	2010 Projections (MWe)	2013 Projections (MWe)
Denizli-Kizildere	200-242	75	80
Aydin-Germencik	200-232	100	130
Manisa-Alasehir-Kavaklidere	213	10	15
Manisa-Salihli-Gobekli	182	10	15
Canakkale-Tuzla	174	75	80
Aydin-Salavatli	171	60	65
Kutahya-Simav	162	30	35
Izmir-Seferihisar	153	30	35
Manisa-Salihli-Caferbey	150	10	20
Aydin-Sultanhisar	145	10	20
Aydin-Yilmazkoy	142	10	20
Izmir-Balcova	136	5	5
Izmir-Dikili	130	30	30
TOTAL		**455**	**550**

The required investment amounts to fulfill the State Planning Organisation 2013 Geothermal Goals for 2007 – 2013 period are shown in Table 26:

The economical activity created by reaching the goals in 2013 for geothermal electricty production, heating (residences, thermal facilities etc.), thermal tourism, greenhouse heating, drying, fish farming and similar direct use applications would be 16 Billion USD/year.

Table 26. The required investment amounts to fulfill the State Planning Organisation 2013 Geothermal Goals for 2007 – 2013 period

Geothermal Application	Goals for the year 2013	Required Additional Investm. Difference (USD) (until 2013)
Electricity production	550 MWe (4 Billion kWh/year)	1 Billion USD
District Heating (residences, thermal facilities etc.)	4000 MWt (500.000 residences equivalence)	800 Million USD
Greenhouse heating	1700 MWt (5.000.000 m^2)	350 Milion USD (production wells included)
Drying and other applications	500.000 tonnes/year	100 Million USD
Thermal Tourism (Balneological Utilization)	400 Thermal Facilities equivalence	800 Million USD
Cooling	50.000 Residences equiv.	200 Million USD
Total		**3.25 Billion USD**

6. LEGAL BACKGROUND AND POLICY

6.1. ALBANIA (R. Aleti, 2005)

The legislative framework on energy in Albania comprises a relatively large number of different pieces of legislation at present. However, it has to be emphasized that until today there is no existent umbrella law that covers the primary objectives of the Albanian energy policy and basic principles for the whole energy sector in long-term. Albania also lacks legislation in the field of renewable energy sources, as well as energy conservation. However, the Albanian Government has indicated awareness of this situation and is preparing the Energy Law, as well as Energy Efficiency Law. Specific energy related legislation, not covered elsewhere, includes the Law on Electricity and the Law on Regulation of Power Sector.

6.2. BOSNIA AND HERZEGOVINA (S. Prasovic, 2005)

There is no specific State energy policy or strategy. The Federation of Bosnia and Herzegovina did develop a framework for an energy sector strategy in 2002, but it has yet not been turned into an adoptable strategy.

6.3. BULGARIA (Bojadgieva, 2005)

Until 1990 the geothermal systems were entirely financed by the state. Bulgaria has no specific legislation for geothermal energy. Regulations exist however for obtaining permits and concessions, and there are guidelines in place for geothermal exploration. Thermal waters as a product of the bowels of the Earth are under the jurisdiction of the Constitution and the Water Law. The following laws govern the use of geothermal waters for energy purposes: Law on Waters, Law on Concession, Energy and Energy Efficiency Law, Law on Territorial Structure and Municipality Property Law.

The Law on Waters states that the sole right for the use of waters is owned fully by the State and may be delivered via concession only for mineral waters when the use is for bottling, energy generation and extraction of chemical elements and derivatives.

Permits issued by the Minister of Environment and Water are required for state-owned thermal waters used for treatment, rehabilitation and prevention, swimming pools, thermal water supply for domestic, technical and industrial aims.

The Law on Concessions regulates the conditions and order for delivery of concessions. They are awarded on the basis of a tender and are issued for up to 35 years.

The Consul of Ministers issues geothermal licensing. Energy and Energy Efficiency

Law states that electricity produced by renewable energy sources or combined-heat power plants (CHP) may be purchased at a preferential price, which is defined by regulations accepted by Energy Regulation Commission under the Council of Ministers.

A fund called “Energy Efficiency and Renewables” has been set up under the supervision by the Minister of Energy and Energy Resources in order to promote these energies.

Major current barriers for geothermal development in the country are:

- Lack of administrative and practical expertise in geothermal development under the new social and economic conditions in Eastern Europe after 1990.
- The procedure for obtaining a concession for water use is very complicated and time consuming. In some cases, the investors have to finance complex preliminary geological and hydrogeological study without having guarantee for gaining the concession after completing the procedure.
- The investor who intends to utilize geothermal energy is expected to develop simultaneously other geothermal applications. The Government policy is encouraging customers for a cascade use but these requirements increase additionally investor’s expanses often change their business plans.
- Local taxes and fees are important but very insufficient source of funds for the Municipalities budgets. The Municipalities are also not allowed to influence on the size of these taxes.

6.4. CROATIA (J. Domac, 2005)

In Croatia legal treatment of RES and cogeneration has started only a few years ago. Due to generally high production costs from RES and cogeneration, and due to the existence of so called incremental costs, the legislator envisaged introduction of financial support to RES and cogeneration. At the same time, supply companies are obliged by law to use certain portion of renewables and cogeneration in the energy mix they are selling. This portion (or share) of RES is not yet defined (September 2005.), but the law obliges the Government of Croatia to define this share by the *Decree on minimum share of RES and Cogeneration*. The role of an intermediary between renewable producers and supply companies is given to a re-cently established independent market operator. The market operator is responsible for contracting with renewable generators on one side, and remunerating them at price determined by the law5, and with suppliers on the other, ensuring that they fulfill their legal obligation.

As regards heat, the Law on Production, Distribution and Supply of Heat regulates in a systematic and comprehensive manner all activities related to production, distribution and supply of heat, including the rights and obligations of energy subjects (heat producers), the rights and obligations of customers, the measures to provide financial means for building up of plants and facilities for production, distribution and supply of heat, and others. The Law specifically envisages the stimulation of RES utilisation for heat production by introducing two new sublaws which will define incentive measures as well as the targeted quota of RES in heat production.

Except regulated tariffs for RES and co-generation (fixed price or feed-in) and minimum share obligation, there is another strong instrument for promotion of RES in Croatia. It is the Fund for Environment Protection and Energy Efficiency, established by special law in 2003. The aim of the Fund is to ensure additional financial sources for projects and programs in the field of protection, sustainable use and improvement of the environment. Further, the Fund takes part in financing projects, programs and measures (including National Energy Programs) aiming to increase energy efficiency and use of renewable energy sources.

6.5. GREECE (Fytikas, 2005)

In order to reinforce private investments for, among other things, in the geothermal sector and other RES production and electricity generation from RES, the Development Law was decreed in 1998 (Law 2601/1998). By this law, a RES project can be subsidized up to 40% of the total budget, depending on the level of development of the region. Besides this, there are tax deductions up to 40% or 100%.

The legislation for the exploration of geothermal energy was always a sub-division of the Mining law of Greece.

At 1984 there was a separate geothermal legislation (law 1575/84) again under the general framework of Mining law.

The last change was at 2003 with the law 3175/2003 which replaced the previous one. Up to the end of 2005 a series of Ministerial Decisions were published and further specified some topics. The character of the new law remain that the geothermal energy is a kind of "ore" and the Mining law remains its main umbrella. The main new features introduced are the following:

- The concept of the " field" management is introduced
- The whole field can be hired in order to achieve the sustainable management of it.
- Selling of geothermal energy is allowed.
- Geothermal fields are classified in three categories according to the degree of their knowledge:

a. Proven fields
b. Possible fields
c. Unknown or no-explored fields.

- According to the temperature of the geothermal fluid two types are distinguished:
- High temperature when it exceeds 90 ºC.
- Low temperature when it lies between 25 ºC & 90 ºC.
- Permits for the exploitation of low temperature proven and possible fields are provided by the Regions (local governments). License for exploration of Unknown fields is provided by the Ministry of Development.
- Permits for electricity generation from high temperature fields are provided by the Ministry of Development and Regulative Energy Agency (RAE).
- Licensing of GSHPS is provided by the Regions after the submission of a complete report including all the necessary reports (geological, engineering, techno-economic and environmental).

6.6. MACEDONIA (Popovski, 2005, 2007)

It is difficult to state that there are significant changes in the development of RES policies in Macedonia. Thanks to the efforts of different NGO's problematic is continually under attention of the press and tv, however there is no serious activity illustrating that it is finally accepted as one of the development priorities of the country.

In 2007 some initial activities have been completed or began, such as are:

a) Establishment of State Energy Committee, with the initial financial support of GEF, through the World Bank. It shall be followed by establishment of a special Fund for sustainable energies, through which new projects for RES application shall be co-financed;

b) Establishment of the first ESCO com-

pany, also with the initial financial support of GEF, through the World Bank;
c) Initialization of preparation of the study for the Renewable Energies Development in Macedonia, with the financial help of the Swiss Federation. In the frame of the study also an estimation for the influence of European legislation in the part of renewables shall be made;
d) Support to introduction of electricity of produced by small hydro and wind plants by definition of particular tariff systems was made and concrete actions for implementation, enabling to begin with planning their development and introduction in the state energy balance during the coming years.
e) Obligation of using biodiesel (4,5%) has been put in force, resulting with completion of the first biodiesel production plant and, in that way, introduction of it in the energy balance planning of the country.

Anyhow, all the listed activities are only a beginning step towards more serious treatment of renewables as an energy source whose development should be carefully planned and supported by necessary changes of existing legislative and different supporting measures.

Basic frame for the energy sector of the Republic of Macedonia is consisted in the Energy Law from 1997 and latest improvements from 2005. This law regulates the conditions and organization of the work in the field of energetics, protection of energy projects, plants and devices, environmental protection from negative impacts resulting from exploitation of energy production and use.

Other laws related to specific parts of energetics, are: Law for transformation of ESM for production, transport and distribution of electricity in state property, accepted in 2004 – accommodated to the request for division of vertically integrated energy entities, consisted in the Directive 2003/54/EEC; Law for foundation of the Energy Agency of the Republic of Macedonia; Law for Energy market of 2005.

According to the existing Energy law, following sub-acts have been accepted:

- Methodology for pricing different types of energy (electricitym heat, geothermal energy and oil derivates (Off.gaz. of RM Nº42/98; 08/2001);
- Conditions for supply of energy from different energy systems (Of.gaz. of RM Nº06/01): electricity (Of.gaz. of RM Nº06/01), natural gas (Of.gaz. of RM Nº36/89), heat (Of.gaz. of RM Nº28/89), 47/89);
- Tariff system for selling different types of energy: electricity (Of.gaz. of RM 45/82, 15/83, 22/88, 29/89, 28/92, 24/99), heat 45/82, 15/83, 22/88, 29/89, 28/92, 24/99), and geothermal energy (Of.Gaz. of RM Nº07/01);
- Regulatory Committee (Off.gaz. of RM Nº94/02 and 38/03);
- Decisions for criterias and conditions for limitation of consumption of different types of energy (electricity and oil derivates – Of.gaz. of RM Nº22/83).

Pursuant to the existing Energy Law the following secondary legislation was adopted:

- Methodology on Pricing of Individual Types of Energy (electricity, thermal energy, geothermal energy and oil derivatives), ("Official Gazette of RM" No 43/98 and 08/01),;
- Conditions on delivery of appropriate energy type to the energy systems: electricity ("Official Gazette of RM" No 06/01), natural gas ("Official Gazette of RM No 36/99), thermal energy ("Official Gazette of RM" No 28/89 and 47/89).

Recently, some improvements in policy definition, legislation and supporting measures have been made, as are:
a) Decision for introduction of new tariff system for electricity, produced from small hydro power plants (Off. Gazette of RM Nº63/06)
b) Decision for introduction of new tariff system for electricity, produced from wind power plants (Off. Gazette of RM Nº63/06)
c) Decision for introduction of new tariff system for heat produced from geothermal energy sources (Off. Gazette of RM Nº47/07)

Engagements for contracting preparation of the Strategies for Energy Sector Development and RES Development are in flow. It's expected that both shall be contracted until the end of 2007.

New Energy law is under preparation in order to reach a complete accomodation to European legislative.

There is no particular legislation concerning the support of geothermal energy explorations, investigations, development and exploitation except the law for concession and Decision for pricing the heat from geothermal origin.

6.7. ROMANIA (Rosca, 2005)

The current Romanian legislation relevant to geothermal development is harmonized with European Union principles and supports renewable energies, among which geothermal is specifically mentioned. The mineral resources (including geothermal) are owned by the State, their exploration and exploitation being regulated by the Mining Law issued in 1998. The National Agency for Mineral Resources is the Governmental institution in charge with issuing exploration and exploitation permits (long term concession).

In 2003, the Romanian Government approved the “Strategy for the development of renewable energy sources”, which sets short and medium term targets in accordance with the EU principles and directives. The Kyoto objectives imply for the European Union, between 2008 and 2012, a reduction by 8% of the greenhouse gases emission compared to the 1990 level (corresponding to about 600 million tons per year of CO2 equivalent). The European Council Resolution on renewable energies of 8 June 1998 seeks a doubling of the share of renewables from 6% at present to 12% in 2010. These targets are also assumed by Romania, as it intends to join the European Union in 2007.

At present, except for hydro, all other renewable energy sources have minor contributions to the Romanian energy mix. The main energy sources are still fossil fuels.

6.8. SLOVENIA

Following the Kyoto protocol the energetics policy of Slovenia shifted towards the greater use of renewable energy sources with the aim to decrease the dependancy on other imported energy sources and to increase the share of renewable energy resources to about 15 – 20 % in primary energy by 2010. The government supports the direct use of geothermal energy through different projects where few lead agencies are involved in geothermal development, such as: »Agency for Efficient energy use and Renewable energy resources« (AURE in slovene), »Ecological Development Fund of Slovenia« (EKO) which invites public tenders for regional ecological development (i.e. some 20 million US$ in 2004) and supports initiatives for private investments, and »Public Fund for Regional Development«. Also the item »Use of renewable energy resources« (EKO) is included here.

6.9. SERBIA AND MONTENEGRO

There is no enforced legislation dedicated to renewable energy sources yet. Decree on the conditions for acquiring the status of eligible producer and criteria for the estimation of fulfillment of conditions is preparing in the Republic of Serbia. This decree will promote obtaining the energy from the renewable energy sources.

6.10. TURKEY

The Geothermal Law of Turkey has been prepared and also gained a big step towards approval. The law is in the programme of Turkish Grand National Assembly and expected to be approved during this years.

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