THERMAL AND MINERAL WATERS OF ALBANIA AND THE PLATFORM FOR THEIR INTEGRATED AND CASCADE USE

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1. Summary

Based on geological conditions, as well as on the hydrochemical and thermal characteristics, four provinces of thermomineral waters are has been distinguished in Albania. In the paper, for each province are described geological-structural, thermal and hydrochemical characteristics. Most important province in terms of the thermomineral underground water resources results Kruja province, very reach on high temperature H_2S groundwater. The platform for the integrated and cascade use of these thermomineral waters represent an important part of the study.

.2 Introduction

In Albania the presence of some high mountain chains and of active fault systems favors the rise of deep waters that discharge at the surface as thermomineral springs. Some important thermomineral springs are widely used for their excellent curative properties like those of well known spa of Peshkopia, Llixha Elbasan and Leskoviku. The results of some deep wells confirm, also the presence of important thermomineral water resources particularly in the Adriatic basin. Some good chemical analyses has been performed for the most important thermomineral springs, while for deep wells only some general chemical analyses have been performed during the oil prospecting. The goal of this paper is to summaries all the existing data and to estimate the thermomineral groundwater, as part of deep regional groundwater flow system and thermal springs as their discharge features.

3. Geological setting of the Albanides

The Albanides represent the assemblage of the geological structures in the territory of Albania, as a part of southern branch of the Mediterranean Alpine Belt. Two major peleogeographic domains consists the Albanides: the Internal, and the External Albanides (Fig. 1). The earth crust is characterized by a system of longitudinal fractures in NW - SE direction and transversal faults that touch even the mantle. The thickness of Albanian sedimentary basin is 8-9 km in Adriatic seashore and reaches up to 15 km in northwestern regions of Albania.

The tectonic zones of the *Internal Albanides* extending in eastern part of Albania are: 1. *Korabi Zone*, which continues in Golia Zone in Dinarides and Pelagonian Zone in Hellenides, is represented generally by terrigene and metamorphic limestone of Paleozoic ages. *2. Mirdita Zone* continues as Serbian Zone in Dinarides and Subpelagonian Zone in Hellenides. The lower tectonic unit of Mirdita Zone is presented by the overthrusted ophiolitic belt thickness 2-14 km. In Mirdita zone lies also Korça-Librazhd and Burreli depressions, filled by the Neogene molasses. 3. *Gashi Zone* continues as the Durmitori Zone of the Dinarides. The representative formations there are metamorphic terrigene, limestone, and volcanic rocks.

The tectonic zones of the *External Albanides* extending in western part of Albania are: 1. *Alps Zone* is analogue to High Karst in Dinarides and Parnas Zone in Hellenides. The lower part of this zone consists of Permian sandstone and the conglomerate while the upper part of the zone consists mainly of Mesozoic limestone forming some monoclines, combined with smaller anticlines. 2. *Krasta-Cukali Zone* continues in Budva Zone of the Dinarides and Pindos Zone in Hellenides. Krasta subzone consist a narrow belt filled with flysch formations and represents an intermediately zone between the Internal and External Albanides. 3. *Kruja Zone* continues with Dalmate Zone in Dinarides and in the south by Gavrova Zone of the Hellenides. Generally, the Cretaceous-Eocene limestone and Paleogene flysch formation, covered by Neogene formations are representative rock of this zone. 4. *Ionian Zone* continues beyond borders in Greece at south-western part of Albania. The Permian-Triassic evaporates, the oldest rocks of this zone, are covered by thick deposits of Mesozoic-Paleogene limestone. Carbonate formations are covered by Paleogenic flysch and of Neogene deposits. They

form three anticline belts often cut by longitudinal tectonic faults in western structures flanks. 5. Sazani zone is the continuation of Apulian platform. A thick Cretaceous-Eocene limestone and dolomite section, trangressively covered by marly deposits of Burdigalian builds this zone. 6**.** *Preadriatic Depression* covers the Ionian, Sazani and partly Kruja tectonic zones. This depression is filled with middle Miocene and Pliocene molasses, which are mainly covered by Quaternary deposits. Molasses consist of a sandy-clay mega-sequence. The Depression plunge to north-west, to Adriatic Sea and the molasses thickness increases up to 5000 m. Sandstone-clay deposits of Serravalian are placed trangressively over the oldest ones, up to the limestone, creating a two-stages structure.

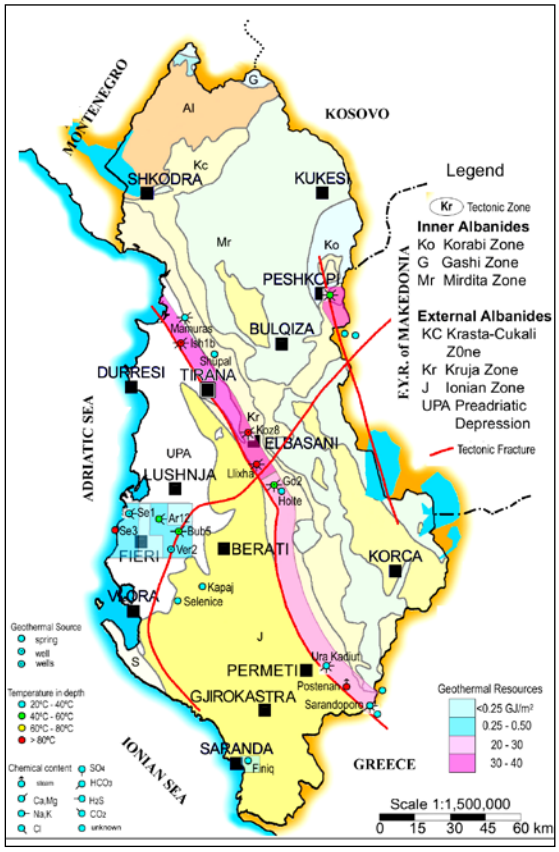

Fig. 1: Geothermal resources of Albania

Fig. 2: Geothermal Kozani-8 deep well

4. Mineral water basins

Although Albania is a small country, his regional hydrogeological picture is very heterogeneous. The complex geological-structural and geomorphologic conditions of Albania have resulted in aquifer's heterogeneity concerning their resources, hydrodynamics and hydro-chemical characteristics (Eftimi 2010). The thermal and mineral waters of Albania are located in four thermo-mineral provinces: a) Peshkopi province; b) Kruja province; c) Preadriatic basin province, and d) South Ionian province.

Peshkopi province represents the central part of Korab zone which is characterized by the presence of two tectonic windows where gypsum dome structures outcrop. Two important sulfur thermo-mineral springs known as Peshkopia spa, appear at south western tectonic contact of gypsum with surrounding Paleogene flysch formations (Table 1). The formation of the springs is related to the deep fault developed along the Black Drin River. The thermal waters are of sulfate-calcium type, the temperature varies about 35° C to 43.5° C and the upward flow of the springs is about 13 l/s.

Kruja province is most interesting in terms of thermomineral waters in Albania. In the northern part of this province is developed the Tirana artesian basin hosting two deep aquifers containing thermo-mineral waters: a) the aquifer of Mesozoic-Paleogene carbonate rocks related to some deep anticline structures, and b) the aquifer of Neogene molasses rocks. Many deep oil wells have tapped the aquifer of carbonate rocks, but among them the most important is Ishmi-1/b. The water temperature is 60° C, the water chemical type is Cl-Na and the H_2S gas content is more than 1000 mg/l (Table 1). The aquifer of molasses contains mediocre water quantities with the temperature usually lower than 30° C. Kruja province hosts some big thermomineral springs like Uji Bardhe-Mamuras, Llixha and Hidraj near Elbasan, Holta, Langarica and Leskoviku. Only the Uji Bardhe spring, which temperature is about 22.5° C, is of Cl-Na type; the other above mentioned springs and wells have temperatures varying from 24.0° C to 58.0° C and the waters are characterized by the high content of SO_4 ion and H_2S (Table 1). A particular geothermal phenomenon is the Postenan steam spring issuing from a tectonic fault crossing the Postenan limestone structure. Some deep thermo-mineral water wells, like deep well Kozan-8 free flowing about 10.3 l/s with a temperature 65.5°C (Fig. 2) are located in province, also. The groundwater of Kruja province are widely used for their excellent curative properties, particularly those of well known Llixha and Hidraj spars, as well as Loskoviku spring. Identified resources of Kruja geothermal province in carbonate reservoirs are $5.9x10^8$-$5.1x10^9$ GJ.

Preadriatic basin province hydrogeologicaly represent an artesian basin. In this basin three aquifers are identified: a) the deep aquifer of carbonate rocks; b) the intermediate aquifer of sandstone Neogene molasses, and c) the upper aquifer of Pliocene sandstone-conglomerate formations. The evidences about the groundwater of the deep carbonate rocks aquifer confirm the presence of high temperature and high mineralized of Cl-Na type groundwater. Some oil wells have free flowed high temperature and high mineralized water from Neogene molasses aquifer. Particularly important are the free flowing thermomineral water from the deep wells of Ardenica and Seman structures. The groundwater temperature at surface of Ardenica structure is about 32° C; the total mineralization varies about 38-55 g/l, and the chemical type is Cl-Na. In the groundwater of Seman structure these components are accordingly 67-83° C, about 20 g/l and the chemical type is also Cl-Na. The thermomineral waters of Adriatic basin province are rich also in CH_4 gas.

South Ionian province is the widest geothermal province of Albania, but not the richest. This province consists of some carbonate anticline, and some syncline chains filled mainly with flysch formations, dipping to the north-west under the Preadriatic basin. In this province is not known the presence of thermomineral springs. From the carbonate rocks, only big fresh water spring issue. Some deep wells have free flowing high temperature and highly mineralized groundwater. The well Grekan-4, situated near the Dumre gypsum dome, at the depth about 1200 m fountain the groundwater with temperature 35° C, mineralization about 325 g/l, and brome content of about 768 mg/l; the last parameters being the highest measured in the groundwater of Albania. Some deep wells drilled in Delvina syncline, in South Albania, have fountain also high mineralized groundwater of Cl-Na type.

Thermal springs and deep wells in Albania

Table 1

Spring (s) or well (w)	Province	Discharge l/s	Temperature ° C	Mineralization g/l	H_2S mg/l	Br mg/l	J mg/l	Chemical type
Llixha, Peshkopi - s	Peshkopi	23	35-43.5	3.5-4.0	50	2.1	0.6	SO_4-Ca
Uji Bardhe - s	Kruja	20-100	18.5-22.5	5.0-6.0	350	-	-	Cl-Na
Llixha, Elbasan - s	Kruja	28	46-58	6.8	408	5.5	1.1	Cl-SO_4-Na-Ca
Holta - s	Kruja	50-70	24.1	2.2	?	?	?	SO_4-Mg-Ca
Langarica - s	Kruja	70-150	24-30	1.2-1.6	2.0-5.8	-	-	Cl-Na-Ca
Leskoviku - s	Kruja	15	25.6-26.7	1.0	2.2-7.0	-	-	Cl-Na-Ca
Ishmi-1 - w	Kruja	3.5	57	12.6	1220	-	-	Cl-Na
Kozan-8 – w	Kruja	10.3	65.5	4.1	?	-	-	Cl-SO_4-Ca-Na
Ardenica 12 –w	Adriatic basin	18.0	32.0	53.6	?	109.7	21.2	Cl-Na
Seman-7 - w	Adriatic basin	30.0	67.0	20.7	?	25.0	30.0	Cl-Na

5. Geothermal regime

Earth crust setting of the Albanides conditioned the space distribution of the geothermal field and energy. (Frashëri et al. 2004). The gradient values vary from 15-21.3 mK/m in Preadriatic Depression. According to the modeling results, deeper than 20 km are observed decreasing gradient. The change of the gradient coincides with the top of the crystal basement. In the ophiolitic belt, the geothermal gradient reaches a value up to 36 mK/m. The maximal value of the Heat Flow Density is 42 mW/m^2 in the External Albanides. At the eastern part of Albania, the heat flow density values are up to 60 mW/m^2. Increasing of the heat flow over the ophiolitic belt, are linked with heat flow from granites of the crystal basement. There are some heat flow anomalies, which are conditioned by intensive heat transmitting through deep faults. These fractures are conditioned location of the geothermal energy sources. According to the geothermometers, the aquifer estimated temperatures vary 220 to 270^oC. Based on the geothermal modeling, one can suppose that thermal waters rise from 8-12 km deep, where temperature attains to 220^oC. The temperature at a depth of 100m ranges 6.7 to 18.8°C, in average 16.4^oC and at a depth of 500m from 21 to 27.7°C. The temperature ranges up to 105.8°C at a depth of 6000m (Frashëri A. et al. 2004).

6. Platform for integrated and cascade use of the mineral and thermal waters

The geothermal situation in Albania offers three directions for the exploitation of geothermal energy (Frashëri A: & Kodheli N. 2010): Firstly, the integrated uses of the heat flow of shallow geological section for space heating/cooling; Secondly, thermal sources of low enthalpy in a wide territory of Albania represent the basis for a successful *complex and cascade use* of their energy, achieving an economical effectiveness: a) modern SPA-Wellness for recreation and treatment of different diseases, with thermal pools, for development of eco-tourism; b) the hot water for space heating, for sanitary water, greenhouses and aquaculture installations; c) extract very useful chemical microelements as iodine, bromine, chlorine etc., other natural salts, and H_2S and CO_2 gases, as well as for bottling of mineral waters. Thirdly, the use of deep doublet abandoned oil and gas wells and single wells for geothermal energy, in the form of a "Vertical Earth Heat Probe". Near of these wells can be build greenhouses.

7. Conclusions

In Albania four provinces of thermomineral waters are distinguished. Based on the chemical data, the thermomineral waters could be classified into three most relevant types. The SO_4-Ca type, reach in H_2S gas occurs in the areas of gypsum deposits, the mixed Cl-SO_4-Na-Ca gas types reach in H_2S occurs in limestone sediments underlined by gypsum deposits of Kruja and Ionian provinces. The Na-Cl type reach in CH_4 gas underground waters are related to molasses sediments of Adriatic basin province. The highest measured temperature of thermomineral water of Albania is 83° C, but the temperature calculated by the geothermometers results more than 200° C.

The resources of geothermal energy of low enthalpy of Albania could be integrated and cascade direct use as an alternative energy. Resources of the geothermal energy in Albania are: high temperature springs (temperature up to 65.5° C), as well as shallow groundwater and bedrocks, with have an average temperature about 16.0^o C, and depth Earth Heat Flow. Installation of the space-heating system, using shallow borehole-heat exchanger-Geothermal Heat Pumps systems present the most important direction of the use of geothermal energy.

7. References

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