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INFERRED SECTION OF THE MAIN (LOW-TEMPERATURE) GEOTHERMAL SYSTEMS IN THE REPUBLIC OF MACEDONIA

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ABSTRACT

The geothermal zone in Macedonia is associated with geothermal manifestations (mainly hot springs and wells with temperature from 20-79ºC) at more than 50 localities. It is believed that only low temperature fields exist. Low-temperature hydrogeothermal systems in Macedonia can be divided into two groups depending on the mode of heat transfer, i.e. convective and conductive. This paper deals only with convective geothermal systems that develop in the surroundings of karst of Mesozoic, Paleozoic and Precambrian age. Almost all convective hydrogeothermal systems are related to an ancient subduction zone of Jurassic age along the Rodopian mass and Dinarides (known as the Vardar tectonic unit) and exhibit forced convection. The most important convective hydrogeothermal systems are in the Skopje valley, Kotchany valley, Strumica valley, Gevgelia valley and in Kezovica, Toplik-Topli dol, Toplec, Strnovec-Proevci, Sabota voda, Povisica-Kratovo.

1. INTRODUCTION

The Republic of Macedonia is situated in the east of Europe, in the central part of the Balkan Peninsula, Fig.1. It belongs to the young Alpidic-Himalayan mountain belt, but there are older tectonic blocks adding complexity to the geology and tectonics of this small country.

2. GEOLOGICAL FRAMEWORK AND TECTONIC SETTING OF MACEDONIA

In the territory of Macedonia rocks of different age occur, ranging from Precambrian to Quaternary. Almost all lithological types are represented. The Precambrian rocks consist of gneiss, micaschist, marble and orthometamorphites. The Paleozoic rocks are mostly green schists, and the Mesozoic rocks are represented by marble, limestones, and 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 of Macedonia 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.1. Our ability to distinguish these geotectonic units is based on actual terrain and geological data without resorting to geotectonic hypotheses (Arsovski, 1997).

3. GEOTHERMAL BACKGROUND

In the Republic of Macedonia there are 18 geothermal fields with more than 50 thermal springs, boreholes and wells with hot water. These discharge almost 1.400 l/s water with temperatures ranging from 20-79 ⁰ C. Some of this water is used for heating hotels and greenhouses, some for balenology purposes and some discharge without being used. The thermal waters in Macedonia mostly have bicarbonate as the dominant anion, and have essentially equal 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. The heat source is the regional heat flow, which in the Vardar zone is about 100 mW/m^2 (Milivojevic, 1993). It is a result of the reduced thickness of the earth's crust in the Vardar zone, about 32 km (Dragasevic, 1974).

4. HYDROGEOTHERMAL SYSTEMS IN MACEDONIA

The territory of the Republic of Macedonia belongs to the Alpine-Himalayan zone, with the Alpine sub-zone having no contemporary volcanic activity. This sub-zone starts from Hungary, across Serbia, Macedonia and north Greece and stretches to Turkey. Several geothermal regions have been identified including the Macedonian region that is connected to the Vardar tectonic unit. This region is characterized by a positive geothermal anomaly hosting different geothermal systems (Fig.1). The hydrogeothermal systems shown are, at the moment, the only systems that are worth investigation and exploitation. These convective hydrogeothermal systems are being used for various purposes, mainly for food production in greenhouses and less for central heating (Popovski, 1998). Conductive hydrogeothermal systems in the widespread Tertiary basins in Macedonia are not being investigated. Future use of these systems will come after the economic consolidation of the country.

5. CLASIFICATION OF MACEDONIAN HYDROGEOTHERMAL SYSTEMS

According to the type of reservoir rock porosity, as well as other lithologic features of the primary reservoirs, the hydrogeothermal systems in Macedonia have been classified into four main groups with several smaller subgroups (Gorgieva, 1996). The main groups are presented here.

5.1. Hydrogeothermal systems with karst-fractured reservoirs in marbles or other rocks of Precambrian or Paleozoic age, with block structure and covered by thick Tertiary sediments or volcanogenic sediments

The geothermal systems of the Skopje valley and the Kochani valley belong to this group, as does the geothermal system in the Kratovo-Zletovo volcanic area. The inferred section of the Skopje valley is presented in Fig.2. 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 ^{0}C and predicted reservoir temperature, by chemical geothermometers, of 80-115^{0}C (Gorgieva, 1989); the primary reservoir composed of Precambrian and Paleozoic marbles; big masses of travertine deposited during the Pliocene and Quaternary periods along the valley margins with temperature of fluid inclusions of 70-125^{0}C (Gorgieva, 1992).The Skopje geothermal system has not been examined in detail. There are only five boreholes with depths of 86m 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 geothermal anomaly and thermal waters because of their locations in Tertiary sediments with thickness up to 3,800 m (Bilibajkic, 1964).

The main characteristics of the Kochani valley geothermal system are: the presence of two geothermal fields, Podlog and Istibanja, without hydraulic connection; a primary reservoir situated in Precambrian gneiss and Paleozoic carbonated schists; the highest measured temperature in Macedonia of 79^{0}C obtained by drilling; the predicted maximum reservoir temperature about 100^{0}C. The Kochani geothermal system is the best-investigated system in Macedonia. There are more than 25 boreholes and wells with depths of 100-1.170 m.

The geothermal system in the Kratovo-Zletovo volcanic area is probably the most pervasive one in Macedonia but detailed investigations are lacking. The main characteristics of this system are: primary reservoir in Precambrian and Paleozoic marbles covered by thick volcanogenic sedimentary rocks; presence of magmatic intrusions near the surface; borehole temperature up to 42^{0}C; travertine deposits over young andesite and breccia.

5.2. Hydrogeothermal systems in the fractured granites of Paleozoic or Mesozoic age

The geothermal systems Bansko in the Strumica valley and Kezovica near Stip belong to this group. The inferred section of Bansko is presented in Fig.3. The main characteristics of this system are: the recharge and discharge zone occur in the same lithological formation-granites; there are springs and boreholes with different temperatures within small distances; maximum measured temperature is 73^{0}C; the predicted maximum temperature is 120^{0}C (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. The Kezovica geothermal systems lies in granites of Jurassic age. The measured maximum temperature is 63^{0}C and the predicted reservoir temperature is 100^{0}C.

5.3. Hydrogeothermal systems in karst reservoirs of Triassic limestones where the discharge zone occurs in the fault zone in contact with other lithological units

This group encompasses the geothermal systems in the Gevgelia valley and Toplik-Topli dol in the Kozuf mountains. The inferred section of the Smokvica field (in the Gevgelia valley) is presented in Fig.4. There are two geothermal fields in the Gevgelia valley: Negorci spa and Smokvica. The discharge zone in both geothermal fields is in fault zones bounded by Jurassic diabases and spilites. Although these two fields are separated by several km there is no hydraulic connection between them, despite intensive pumping of thermal waters. The maximum temperature is 54^{0}C, and the predicted reservoir temperature is 75-100^{0}C. The geothermal system in the Gevgelia valley has been well studied by 15 boreholes with depths between 100-800 m.

5.4. Karst, semi-open hydrogeothermal systems with reservoirs in Paleozoic marbles

This group encompasses several smaller systems such as: Proevci at the south margin of Kumanovo valley, Sabota voda near Veles, Rakles near Radovis, Toplec near Dojran etc. The inferred section of the Toplec geothermal field near Dojran is presented in Fig.5. These systems are characterized by relatively low temperatures, up to 28^{0}C, and low predicted reservoir temperatures because of lack of water-rock equilibrium and mixing of hot and cold water. Those systems are not studied in detail.

6. SUMMARY

Four main groups of low temperature hydrogeothermal systems are distinguished in Macedonia. the geothermal systems in Kochani, Gevgelia and Strumica valley have been studied in the most detail.

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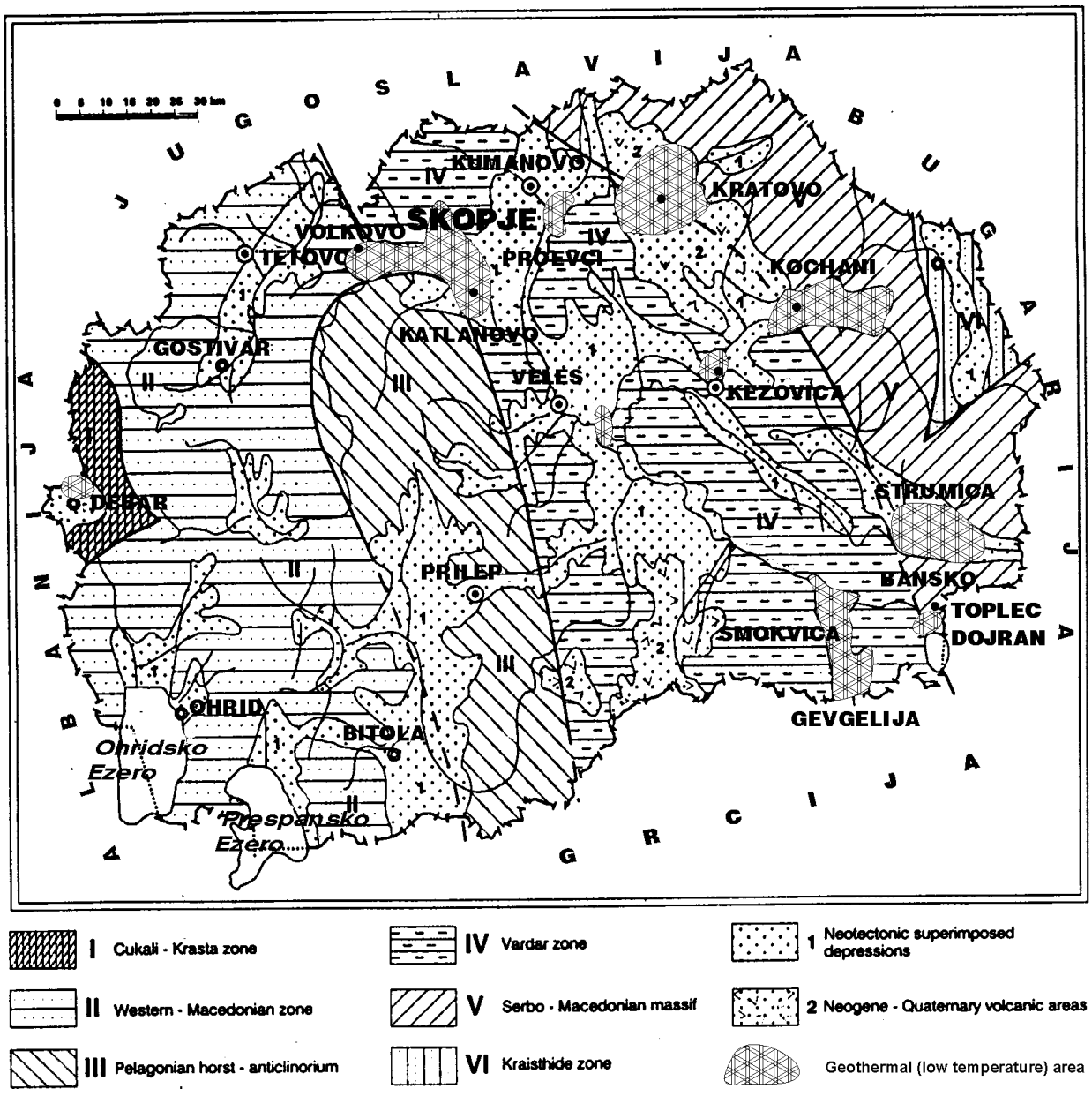

Fig.1. Map of regional tectonic setting of Macedonia (Arsovski, 1998) with main geothermal (low temperature) area

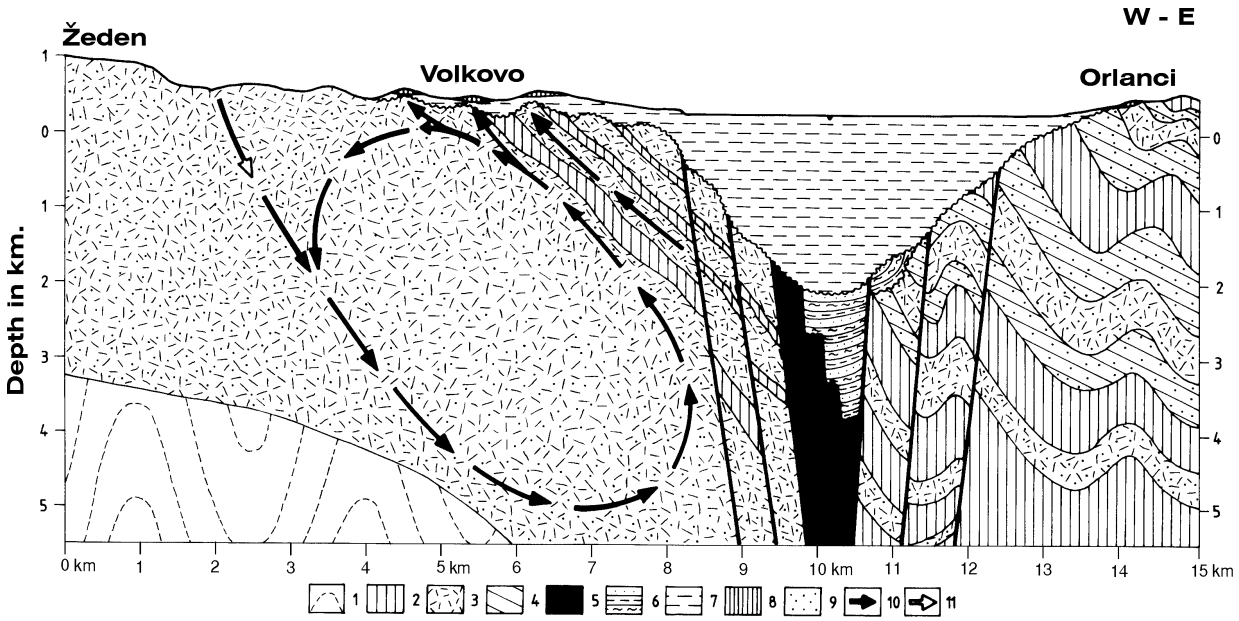

Fig. 2. Inferred sectionl of the N-W part of Skopje valley (Zeden-Volkovo-Orlanci) (1. Pt.gneiss; 2. Pt. slates; 3. Pt. marbles; 4. Pz.slates; 5.Se-serpentinite; 6. K-flysch; 7. N-sand and clay;8. Travertine; 9. Hydrogeothermal reservoir; 10. Thermal water flow; 11. Cold water flow)

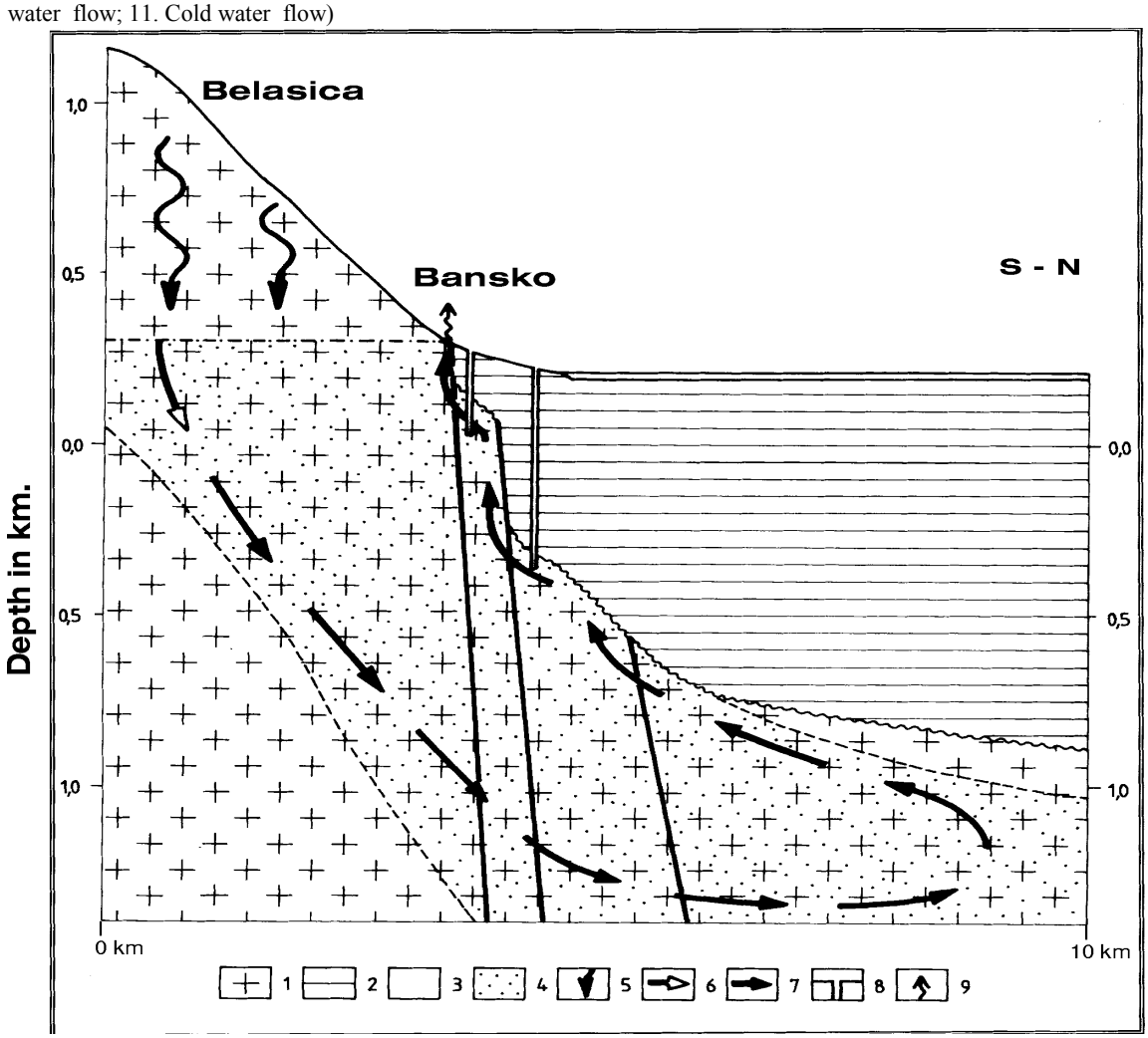

Fig.3. Inferred section of Bansko geothermal system (1. granites; 2. Ng-sediments; 3. aluvion; 4. Hydrogeothermal reservoir; 5.Cold water flow; 6. Cold underground flow; 7. Thermal water flow; 8. Borehole; 9. Thermal spring)

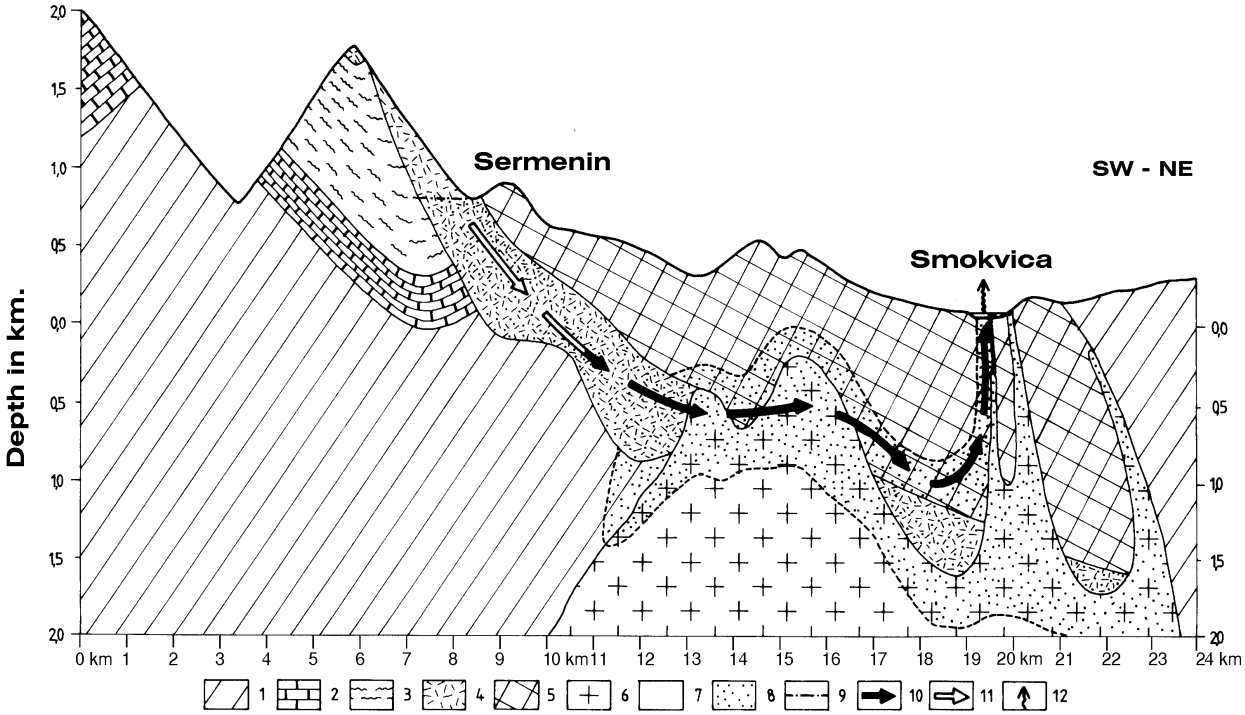

Fig. 4. Inferred section of the geothermal system of Smokvica-Negorci (Sermenin-Smokvica)(1. Pt.gneiss; 2. Pt. marbles; 3. Pz-fillits; 4. T-limestones; 5. J-gabro and diabases; 6. J-granites; 7. Hidrogeothermal isolation; 8. Hydrogeothermal reservoir; 10. Thermal water flow; 11. Cold water flow; 12. Thermal spring)

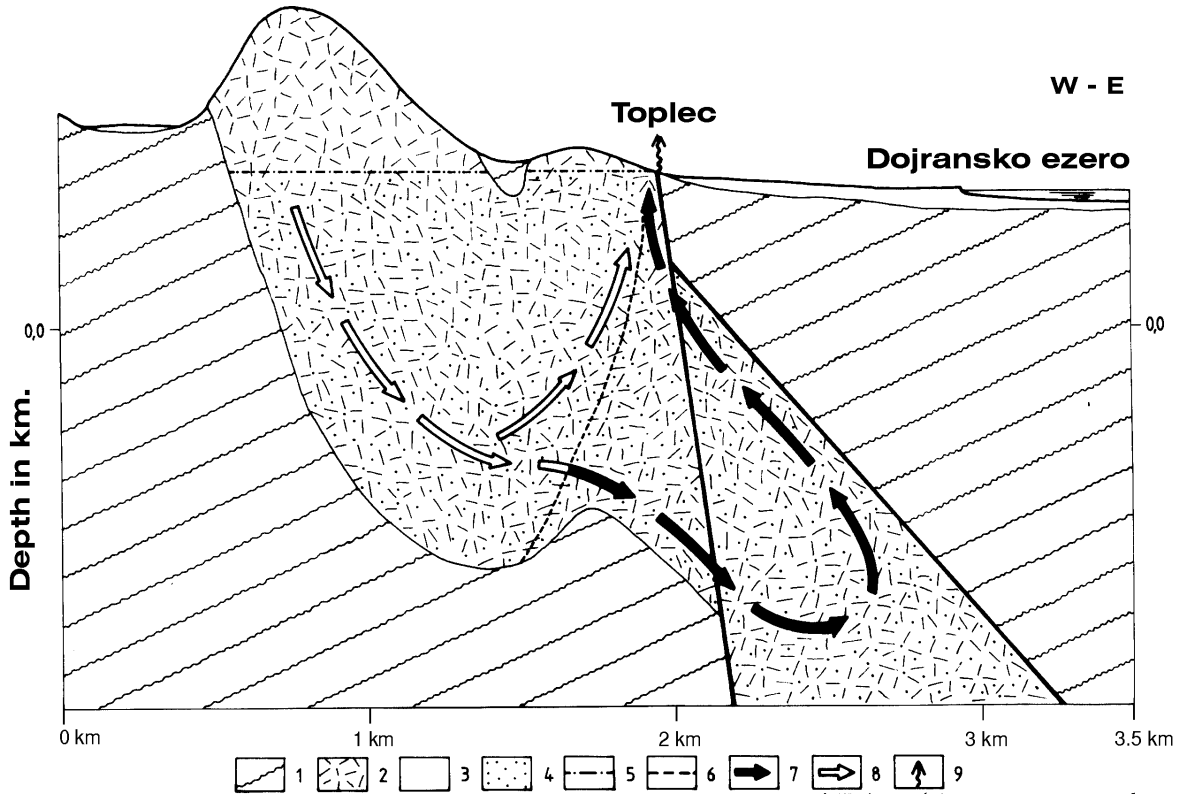

Fig.5. Inferred section of the Toplec-Dojran geothermal system (1. Pt- slates; 2. Pt. marbles; 3. Aluvium; 4. Hydrogeothermal reservoir; 7. Thermal water flow; 8. Cold water flow; 9. Thermal spring)