TEMPERATURE INVESTIGATIONS IN POLYANOVO HYDROTHERMAL RESERVOIR (SE BULGARIA)

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Abstract. Polyanovo hydrothermal reservoir located in the southeastern part of Bulgaria mainly consist of fractured sediment and volcano-sedimentary Upper Cretaceous rocks. Water temperature varies from 15 to 49^{o}C. Temperature depth profiles are carried out in 17 wells where varying depths are from 100 to 500m. Temperature distribution maps at three depth levels below the surface - 50, 100 and 150m and geothermal gradient map have been prepared and analyzed together with existing geophysical results of gravity, magnetic, electric resistivity and well logging. The unchanged temperature anomaly location on the three levels and high horizontal temperature gradient (at depths 100 and 150 m) are indicators for a sub vertical water heat transfer to the surface.The obtained results are base for developing a reservoir structural model.

Key words: hydrothermal reservoir, temperature-depth profiles, temperature and geothermal gradient maps

1.Introduction

Polyanovo hydrothermal reservoir represents fractured type water collectors. They are not well studied in comparison with porous and karst systems in the other parts of the country. Deep structure and its drainage system are not mapped although various geophysical and well logging investigations have been carried out. The conductivity coefficient and specific discharge data of waters, (Vlaskovski et al.,1998), are changing irregularly in a wide interval indicating a complex reservoir structure.

Thermal water is a source of renewable energy and its utilization is important for the inhabitants in the nearby-populated area. Detailed information on the conductive zones allows reassessing for exploitation of the resource, which is calculated based only on the data from two wells – 111 and 135 (temperature - 49°C and 47°C; flow rate – 5.4 l/s and 13.7 l/s), (Vlaskovski et al., 1998). With this respect an additional magneto-telluric survey (MT) will be provided by National Geophysical Research Institute, Hyderabad, India to get a better understanding of the deep reservoir structure. The aim of this article is to summarize and analyze the existing subsurface temperature, hydrogeological and geophysical information as a base and need for MT survey.

2. Study area

2.1. Geological

Polyanovo reservoir is situated in the western part of Aitos graben and belongs to Bourgas hydrothermal basin as shown on Fig.1. The reservoir is located at about 1 km southeast from Polyanovo village, Fig.2, and covers an area of about 1.5 sq. km.

This region has Quaternary and Neogene sediments and Upper-Cretaceous sediment and volcano-sediment rocks, intersected by tectonic faults, Fig.2. The Upper Cretaceous sediments consist of alternation of marls, siltstones, argillites, clayey limestone and sandstones, while the volcanic complex comprises andesites, basaltic andesites and tuffs. Quaternary and Neogene sediments are thin (from 0-59 m) and built mainly of clays and gravels. The reservoir borders to the north and northeast on the big Aitos fault, which is the major drainage system in the area. According to Ileiv-Bruchev et al., (1994) it is currently active.

2.2. Geophysical

The second well (number 111) drilled in Polyanovo area in 1988, (Fig.3), revealed thermal water of initial flow rate - 20 l/s and temperature 49.5°C. This resulted in more detailed drilling and geophysical exploration that continued up to 1992. Totally 20 wells have been drilled with a depth of 150 up to 500m (Vlaskovski et al., 1998).

Geophysical survey started in 1988 with temperature measurements carried out in 10 wells of depth up to 200m. A complex of well logging methods (electric, spontaneous potential, natural gamma ray, density gamma-gamma and temperature) have been performed in most of them. Resistivity logs are available only for 8 deeper wells. Several field geophysical surveys (electric, magnetic and gravity) were carried out later in 1990 along profile lines oriented in north-south direction. The distance between the profiles was 100 m and between measurement points – 25 m (Hristov et al., 1992). The total studied area amounts to about 1sq.km. As a result three parallel tectonic disturbances with west-east orientation have been discovered (Fig.2) and another 10 deeper wells (up to 500m) were additionally drilled. They aimed to explore these tectonic disturbances and to delineate the western reservoir border. Two of the newly drilled wells (135 and 136), Fig.2, have found out thermal water.

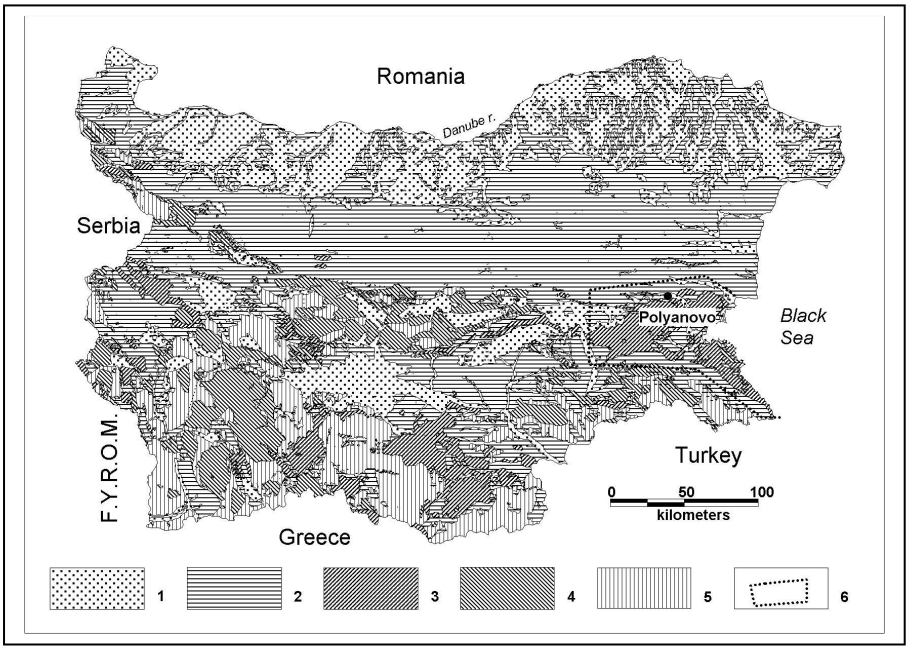

Fig.1. Location of studied area on the Geological map of Bulgaria (Cheshitev et al., 1989) 1.Unconsolidated Quaternary rocks, 2. Sediment rocks, 3. Volcanic and volcano-sedimentary rocks, 4. Intrusive rocks, 5. Metamorphic rocks, 6 – Bourgas basin

2.3. Hydrogeological

Underground thermal water is of meteoric origin and is moving mainly along faults and fractures. That results in a high conductivity and geothermal heterogeneity of the region. Water penetrates to a great depth and is heated as a result of heat exchange with the rocks. Recharge zone is associated with the small Aitos Mountain located to the north of Polyanovo reservoir and also with the hills – to the west of it.

Water conductivity coefficient was studied by carrying out airlift tests in 11 wells. The major parameters characterizing the reservoir are as follows:

Water level in the wells - from 9.85m below the surface (in well 116) up to (+44.9) m above it (well 111)

- Water temperature - from 15 to 49^{o}C
- Flow rate - from 5 to 20 l/s for the different wells
- Transmissivity - from 0.2 to 45m^2/24h
- Specific discharge - from 0.006 to 0.542 l/s.m
- pH of the water is varying from 8.3 to 9.1

Water is discovered both in Paleogene-Quaternary and Upper Cretaceous horizons. It is cold (15-18^{o}C), of CO_3-SO_4-Cl-Ca-Na-Mg chemical composition and mostly unconfined in Paleogene-Quaternary rocks. Cold and hot water is struck in Upper Cretaceous rocks and its temperature is changing in the range of 15 to 49^{o}C. Thermal water is confined and of Cl-SO_4-NCO_3-Na chemical composition. Radiochemical and microbiological tests show that hot water is not contaminated. Only two wells in the area (111 and 135) discovering hot water are taped.

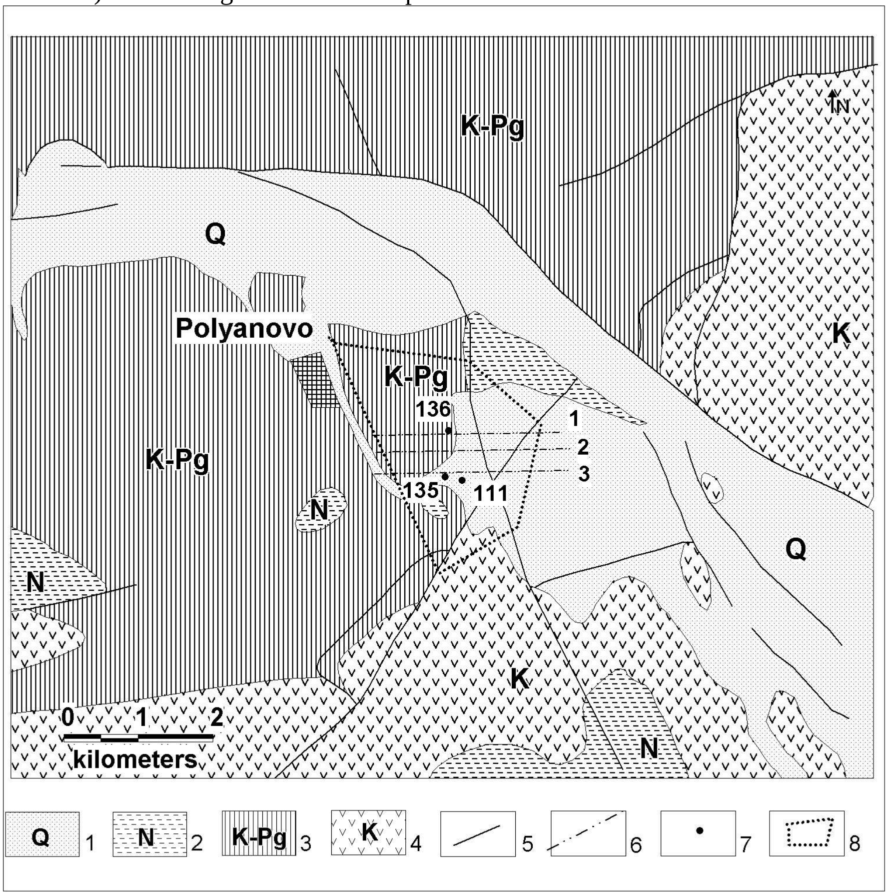

Fig.2. Schematic location map
(1. Quaternary, 2. Neogene, 3. K-Pg – Cretaceous-Paleogene, 4. K- Cretaceous, 5. Faults, 6.Assumed tectonic disturbances, 7. Deep wells, 8. Studied area)

3. Geothermal field analysis

The initially drilled 10 exploration geothermal wells in the area of Polyanovo are situated along a set of profile lines and spaced at 500 m apart from each other, Fig.3. Several temperature measurements have been carried out in one and the same well at different bottom depths. The maximum number of records (5) is available for well 114. Temperature logs were usually done three days after cessation of drilling and they represent a recovered temperature field in the wells. Measurements have reached the highest depth in wells 115 (270m) and 133 (290m), Fig.4. Geological exploration, Ltd, (town of Jambol, SE Bulgaria) has completed the entire fieldwork in the period 1988 – 1992.

3.1. Data analysis and results

Geothermal field in the region is studied by analyzing temperature-depth profiles (recorded in the wells before self-flowing) and temperature and geothermal gradient (GG) maps. The last temperature profiles recorded in all wells are plotted on Fig 4. They are divided into three groups – *A*, *B* and *C*. The first one *A*, is formed of wells discovering the highest rock temperatures in the area and of gradients above 10°C/100m – wells 111, 117 and 135 (no available data for 136). The second one - *B*, includes wells, which are of lower temperatures and gradients (5.1-6.8) °C/100m compared to the first one. The third group *C* - represents the part of the reservoir of lowest temperatures and geothermal gradients (2.4 – 4.1) °C/100m. According to (Hristov et al., 1992) wells from group *A* (111,117,135) and *B* (114, 124, 134, 136) discover thermal and sub thermal waters, while wells from group C (116, 118, 120, 133) discover cold waters.

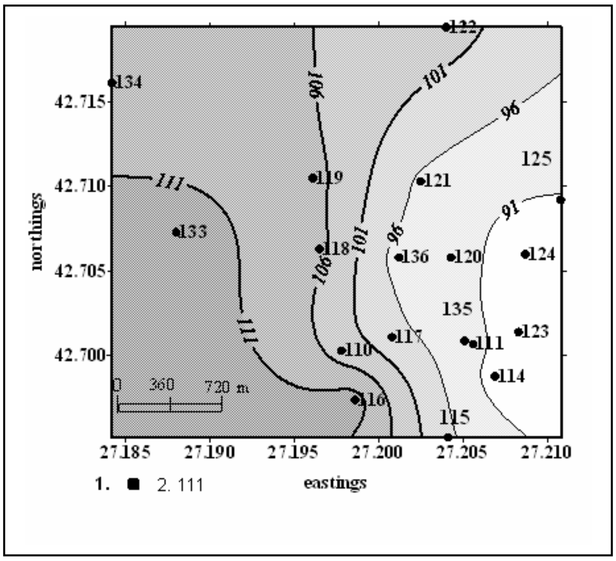

Fig. 3. Map of isohypses (in m) and location of geothermal wells (1. well location, 2. well number)

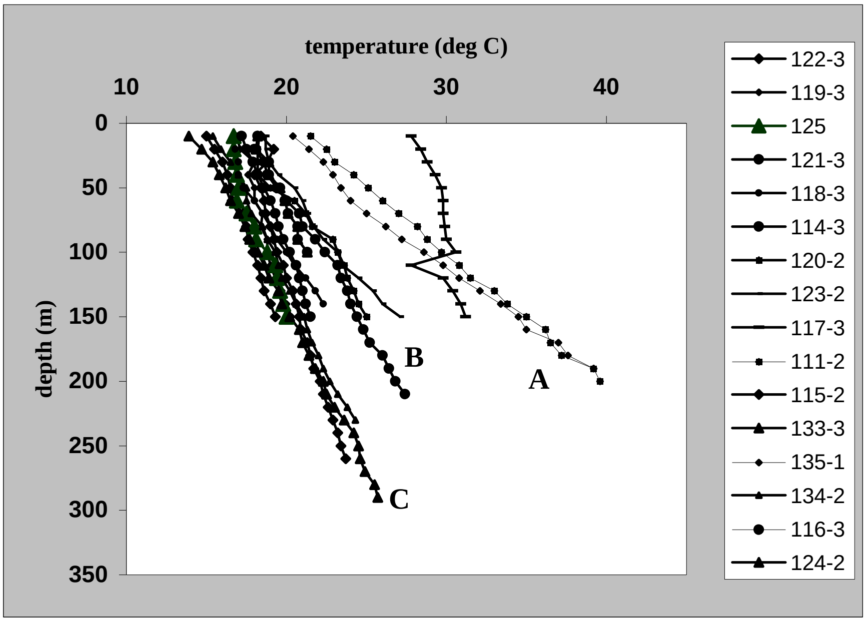

Fig. 4. Last recorded temperature profiles in the wells
(Legend: 122-3 is the third record in well 122)

Arial temperature field distribution is presented at three levels below the surface – 50m, 100m and 150m, Fig.5. Temperature data are taken from different sources (Hristov,H., et al.,1992; Vlaskovski et al.,1998; Bojadgieva and Gasharov,2001).

A closed high temperature anomaly stretched in west-east direction is outlined at the three maps. It is formed by the wells from group *A* and covers an area of about 700m in length and 200-600 in width, (Hristov,H., et al.,1992). The first depth level (50 m) is located at a highly conductive zone of cold and mixed with thermal water flows of temperature about 18-19^{o}C. The other two maps represent the deeper zone comprising thermal waters. The unchanged anomaly location on the three levels and high horizontal temperature gradient (at 100 and 150 m) are indicators for a sub vertical water heat transfer to the surface.

A vertical cross section was drawn out along a profile line with west-east direction, crossing the high temperature anomaly zone, Fig.6. It confirms that the highest temperatures are located in a narrow vertical zone around wells 135 and 111.

The map of geothermal gradient (Fig.7) represents approximately the heat flow density distribution because of the comparatively uniform lithology of rocks in the studied area. Geothermal gradient is calculated for the depth interval (100-150m) thus avoiding the influence of shallow cold-water flows. The location of high gradient anomaly and its orientation confirm the trend outlined on the temperature maps (Fig.5). Wells 117, 111 and 135 trace the major thermal water conductive zone in the structure. Thermal water probably originates from a deep-seated reservoir and moves upwards along an east western oriented fracture located between wells 110 and 123.

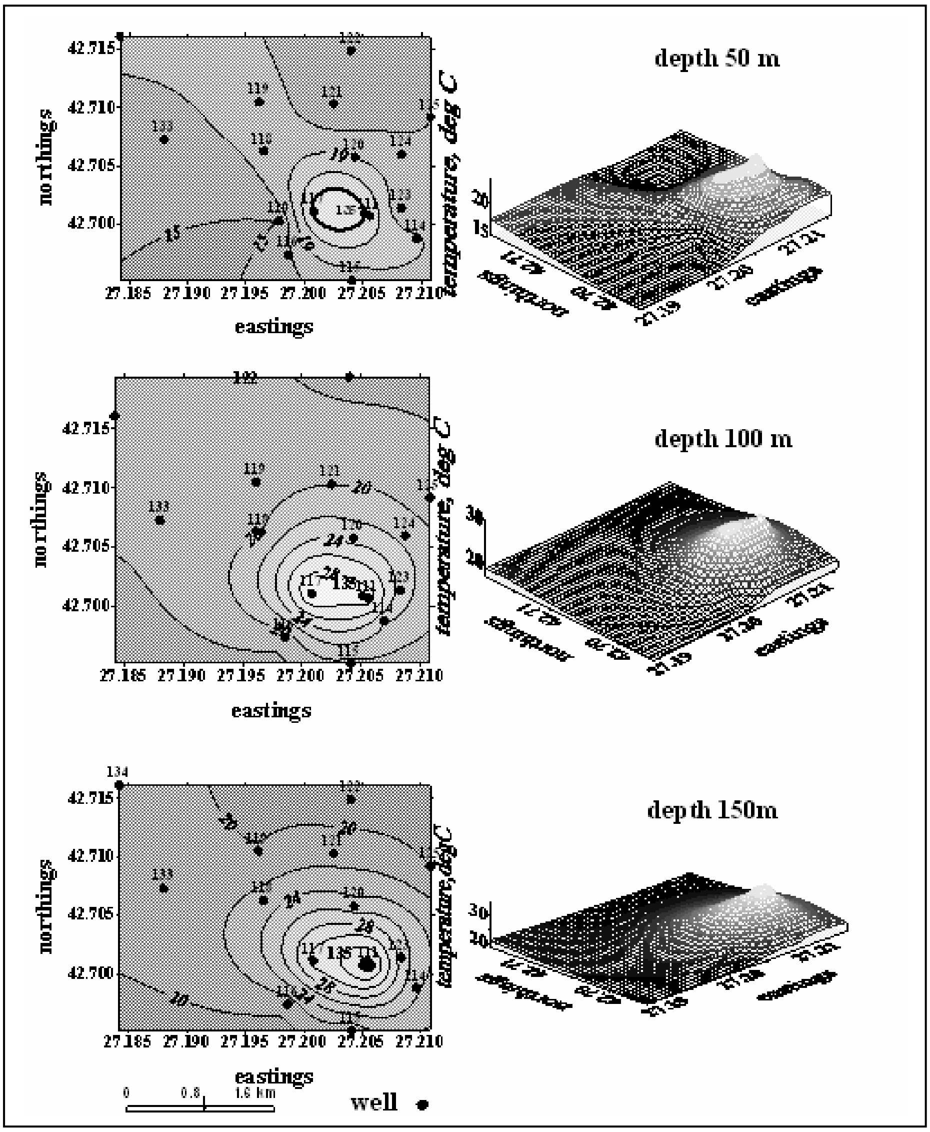

Fig.5. Maps of temperature (in ^{o}C) distribution at three levels - 50m, 100m, and 150 m below the surface, (2D and 3D presentations)

Polyanovo reservoir has been selected for performing magneto-telluric survey after providing preliminary geoelectric field exploration in the southern part of Aitos graben. These new data will be processed and analyzed together with the existing geophysical exploration data to create a hydrogeological model of the reservoir. That will reflect on reassessment of reservoir thermal capacity aiming to promote the application of its renewable energy.

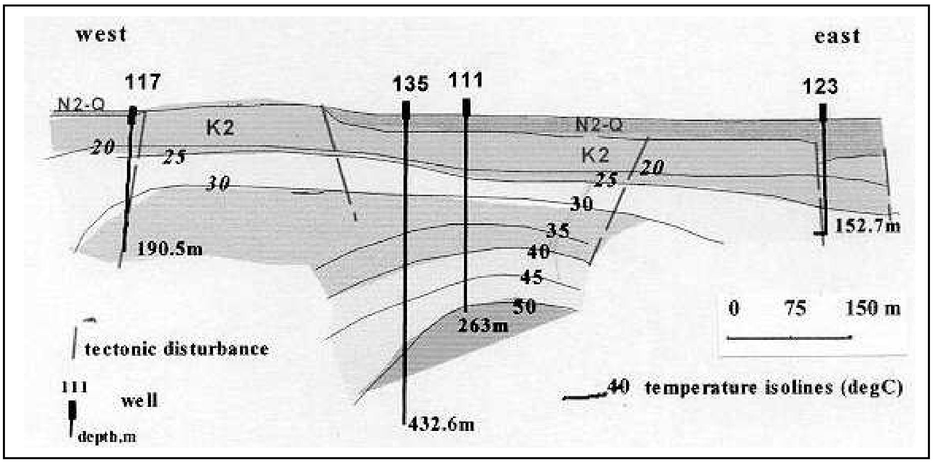

Fig.6. Vertical cross section along a profile line intersecting the temperature anomaly zone

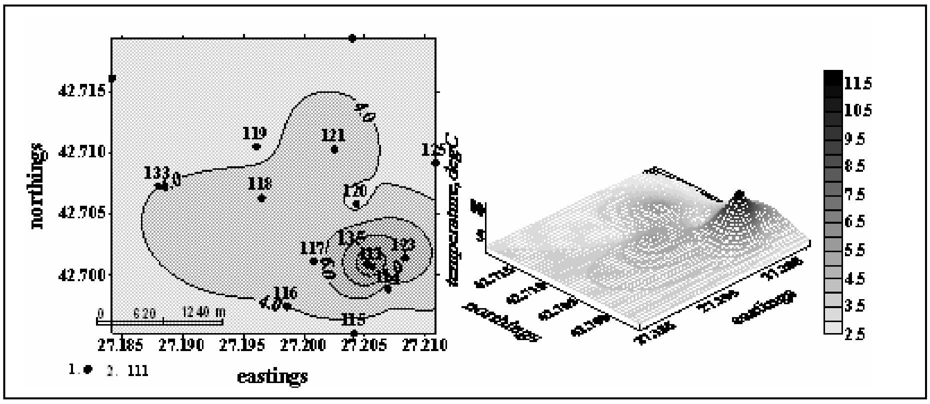

Fig.7. Map of geothermal gradient (in ^{o}C/100m), calculated for the interval (100-150)m in Polyanovo reservoir (2D and 3D presentations) 1. Well location 2. Well number

Conclusions

1. Temperature field distributions at 50, 100 and 150m below the surface and geothermal gradient calculated for the interval 100-150m have been analyzed. The unchanged temperature anomaly location at the three depth levels and high horizontal temperature variations are indicators for sub-vertical transfer of hot water. It originates from a deep-seated reservoir and moves upwards along an east western oriented fracture located between wells 110 and 123. These results are also confirmed by the geothermal gradient distribution.

2. The three tectonic disturbances revealed by the complex analysis of geophysical surveys and well logging require more detailed study.

This research is related to a bilateral Indo-Bulgarian project: NZ 1411/04 "Mapping of subsurface geo-electric structure to assess geothermal potential of Bulgaria using magneto-telluric studies" (2004-2007) between Bulgarian Academy of Science, Sofia and National Geophysical Research Institute, Hyderabad, India.

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Температурни изследвания на хидротермално находище Поляново (ЮИ България)

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Резюме. Хидротермално находище Поляново се намира в югоизточната част на България и е изградено основно от напукани седиментни и вулкано-седиментни горнокредни скали. Температурата на водата в находището се изменя в интервала от 15 до 49^{o}C. Извършени са температурни изследвания в 17 сондажа с дълбочина от 100 до 500 m. Изчертани са картите на разпределението на температурата на три нива под земната повърхност – 50, 100 и 150 m и на геотермичния градиент за интервала 100-150 m. Те са анализирани съвместно с резултатите от проведените геофизични проучвания - гравиметрични, магнитни, електрически и каротажни. В находището вероятно съществува вертикален топломасопренос по тектонски нарушения. Той формира една и съща зона на температурен максимум и на трите изследвани дълбочини, както и голям хоризонтален температурен градиент на нива 100 и 150m. Получените резултати са основа за създаването на структурен модел на находището.