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Features of the Structure of the Discharge Zones of Hydrothermal Systems in Certain Areas of Kamchatka and Sakhalin According to Borehole Logging Data

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Abstract

The article presents the geophysical methods for studying the discharge zones of hydrothermal systems. The importance of a detailed study and the possibility of doing this using the borehole logging (gamma-ray logging and the method of intrinsic polarization potentials) are emphasized. The application of these methods is presented on the example of studying the discharge zones of the Daginsky (Sakhalin Island) and the Karymshinskaya (Kamchatka) hydrothermal systems. The results obtained are significant for further study and practical development of these hydrothermal systems.

Keywords: Sakhalin Island, the Daginsky hydrothermal system, Kamchatka, the Karymshinskaya hydrothermal system, the discharge zone, the borehole logging.

INTRODUCTION

When studying the geological structure of hydrothermal systems, it is important to study the structure of hydrothermal flow zones in the depths and on the day surface of the system [1]. The hydrothermal discharge zone is part of the caprock. Thermal springs owe their appearance on the earth's surface to the ratio of groundwater horizons, due to the geological structure of this area, and the relief profile of this area. The zone of discharge of hydrothermal systems is located near the Earth's surface, is often observed in the form of thermal manifestations and has been penetrated by many wells [2]. This determines their greater accessibility for direct study. The subject of the study is the discharge zone of the hydrothermal system (Figure-1). The purpose of the study is the hydrogeological situation.

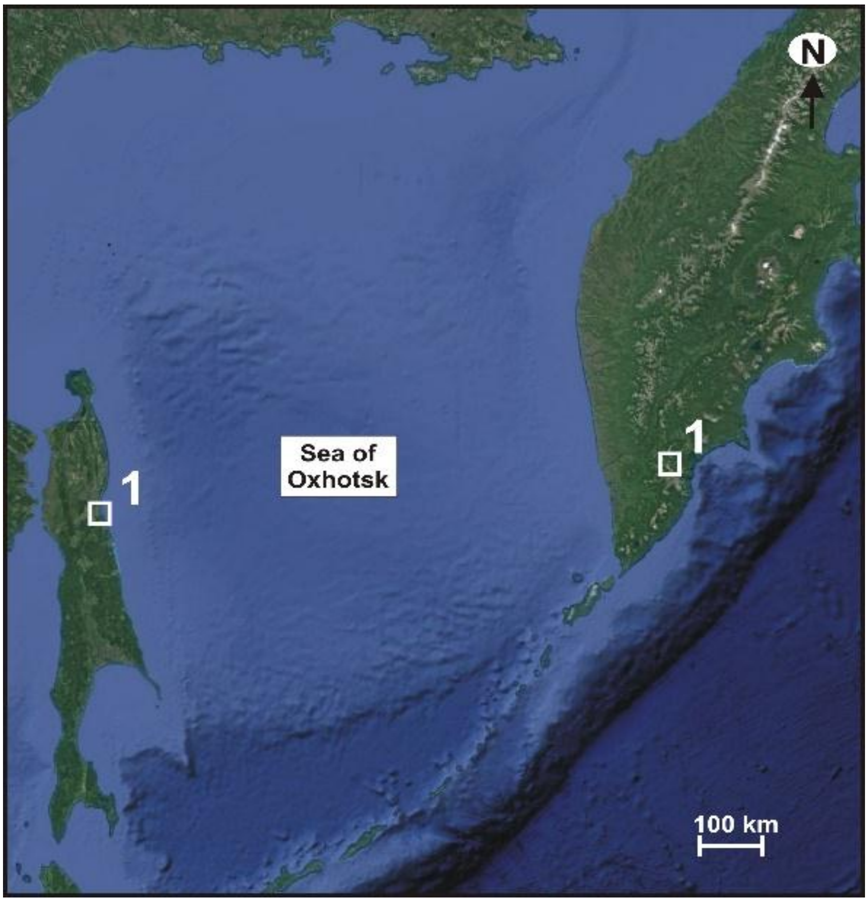

Figure-1: Location diagram: 1 - Daginsky hydrothermal system (Sakhalin), 2 - Karymshinskaya hydrothermal system (Kamchatka).

MATERIALS AND METHODS

Available logging data (gamma-ray logging, self-polarization potentials) for five wells were used as data from geophysical studies of wells [5]. All logs were available only on paper. Digitization was performed using a modern computer program. For convenience, the data were exported to the XLS format, which allowed for further calculations and processing. Gamma-logging is based on measuring the natural gamma activity of rocks, and helps in detailed geological interpretation. Advantage: gamma-activity is determined only by the radioactivity of rocks and does not depend on other factors (temperature and mineralization, humidity, etc.). The method of self-polarization potentials is one of the most common methods of electrical logging. According to the level of geological tasks and ease of execution, it is an essential part of geophysical surveys in wells. The method is reduced to the measurement of constant natural potentials arising from formations with different electrochemical activity. The method helps in identifying areas of inflow and outflow of fluid.

RESULTS AND DISCUSSION

The discharge zones of the the Daginsky hydrothermal system (Sakhalin):

The Daginskaya hydrothermal system is located in the Nogliki district of the Sakhalin region on the east coast of the northern part of the island. Sakhalin in the coastal strip of the North Sakhalin lowland, near the Mongi oil field.

Nearby is the Nyisky Bay, which is separated from the sea by sand and pebble dunes, sometimes reaching a considerable width. The discharge of thermal waters in the Daginskaya hydrothermal system is observed in places where the zone of discontinuity is exposed by erosion incisions. The first source of unloading (Southern section), 40–80 m wide, is located in the southwestern part of the study area. The springs of thermal waters come out in a small stream valley, mainly in its bed, composed of fine-grained sands. The second group outcrop of ascending springs (Central section) extends from the southwest to the northeast in the form of a strip 60–150 m wide. The springs are located in a coastal lowland densely overgrown with reeds. The outlets are concentrated in funnels of various sizes in dense clay soil, unloading is carried out in a swamp. The springs of the northeastern part (Northern section) are discharged within the littoral zone of the Nyisky Bay, covered with clayey silt, and are flooded with sea waters at high tide. The springs fill funnel-shaped cauldrons with a diameter of up to 3 m and a depth of more than 1 m. Small mud griffins are also found here. Quaternary and Pliocene deposits are widespread throughout. The predominant type of reservoir is porous. Water-bearing are peatlands, sands, rarely gravel among poorly permeable clayey rocks. Only at depths of more than 1000 m are lithified deposits with fractured and fractured-vein type of reservoir - sandstones, siltstones, mudstones, uncovered by prospecting drilling.

Interpretation of gamma ray logs (GK) and the method of self-polarization potentials (SP). Interpretation of GC diagrams was carried out for all five wells. Interpretation of PS diagrams was carried out for wells No. 2 and No. 4. For each selected layer, the arithmetic mean value of gamma activity and the arithmetic mean value of self-polarization potentials were calculated.

Well No. 5: Depth 150 m. 19 layers are distinguished in the section of the well (description by lithological composition): 1, 3, 5, 6, 8, 10, 11, 13, 16, 18 layer - silt 8.48 to 12.16 mkR/h); 2nd layer - clayey, gravel sands (average value of gamma-activity 7.35 mkR/h); 4th and 17th layer - sands with gravel and pebbles (average value of gamma-activity 7.04 and 9.12 mkR/h); 7, 9, 12, 14, 15, 19 layer - clays (the highest average values of gamma-activity from 11.15 to 15.28 mkR/h); Layers 15 and 19 are fine-grained sands (average gamma-activity is 9.51 and 10.58 mkR/h).

Well No. 4: Depth 180 m. In the section of the well, 25 layers are distinguished (description by lithological composition): 1 layer - peat; 2, 6, 13, 19, 21 - 25 layers -

clayey, gravel sands (average value of gamma-activity from 6.53 to 12.26 mkR/h; average value of self-polarization potentials -124.50 and +82.52 mV); 3, 5, 8, 10, 11, 16, 18, 20 layers – silts (average value of gamma-activity from 7.05 to 11.55 mkR/h; average value of intrinsic polarization potentials -126.63 and +74.51 mV); layers 4 and 17 - sands with gravel and pebbles (average value of gamma-activity 6.60 and 9.21 mkR/h; average value of self-polarization potentials -68.64 and -116.54 mV); 7, 9, 12, 14 layer - clays (average value of gamma-activity from 11.09 to 15.08 mkR/h; average value of self-polarization potentials from -127.50 to -121.65 mV); Layer 15 - fine-grained sands (average value of gamma-activity 10.09 mkR/h; average value of self-polarization potentials -121.76 mV).

Well No. 6: Depth 170 m. Gamma-ray logging was carried out to a depth of 120 m. 12 layers are distinguished in the well section (description by lithological composition): 1 layer - peat; 2nd layer – clayey, gravel sands (average value of gamma-activity is 3.92 mkR/h); 3, 5, 6, 8, 10, 11 layers - silts (average value of gamma-activity from 3.87 to 6.06 mkR/h); 4th layer - fine-grained sands (average value of gamma-activity is 2.22 mkR/h); 7, 9, 12 layer - clays (average value of gamma-activity from 5.89 to 7.41 mkR/h). Characterized by small values of gamma activity in comparison with other wells.

Well No. 3: Depth 150 m. In the section of the well, 18 layers are distinguished (description according to lithological composition): 1, 2, 5, 9, 10, 12, 16 layer - silt (average value of gamma activity from 5.02 to 9.70 mkR/h); 3rd, 8th, 14th, 17th layer – clays (average value of gamma-activity from 9.53 to 11.27 mkR/h); 4, 6, 15 layer - sands with gravel and pebbles (average value of gamma-activity from 6.30 to 9.12 mkR/h); 7, 11, 13 layer – clayey, gravel sands (average value of gamma-activity from 7.85 to 10.58 mkR/h); Layer 18 - sandstones (average value of gamma-activity is 10.07 mkR/h). The highest values of gamma-activity are typical for clay layers.

Well No. 2: Depth 180 m. In the section of the well, 18 layers are distinguished (description by lithological composition): 1, 2, 5, 7, 12, 16 layer - silt (average value of gamma activity from 8.84 to 10.22 mkR/h; average the value of self-polarization potentials +43.06 and +124.48 mV); 3, 8, 14, 17 layer - clays (average value of gamma-activity from 9.48 to 11.60 mkR/h; average value of self-polarization potentials +81.66 and +111.47 mV); 4, 6, 10, 11 layers - clayey, gravel sands (average value of gamma-activity from 8.00 to 10.33 mkR/h; average value of intrinsic polarization potentials +35.56 and +110.15 mV); layer 9 – fine-grained sands (average value of gamma-activity 9.75 mkR/h; average value of self-polarization potentials +108.40 mV); 15th layer – sands with gravel and pebbles (average value of gamma activity 7.12 mkR/h; average value of intrinsic polarization potentials +65.86 mV); Layer 18 - sandstones (average value of gamma-activity is 10.71 mkR/h).

Based on the analysis of gamma-ray logging for wells 2, 3, 4, 5 and 6, three zones can be distinguished. The first zone is the presence of the highest values of gamma-activity of rocks in the area of wells 5 and 4 from 5.00 to 17.00 mkR/h (Figure-2). The second zone is located near wells 5 and 4 and well 6 is located (Figure-2). This indicates the leaching of radioactive components in rocks. The third zone is in the area of wells 3 and 2, the values of gamma activity from 4.00 to 13.00 mkR/h (Figure-3). There is a good match between the lithological layers in wells 3 and 2. It is worth noting that an error was found in the available data on the lithological section of well 2. The thickness of layer 15 was incorrectly calculated. The thickness of layer 15 was indicated at 18.4 m, in fact it was 18.6. This is an important addition, because when calculating the arithmetic mean value of gamma-activity of rocks, where the thickness of the layer is taken into account, it matters.

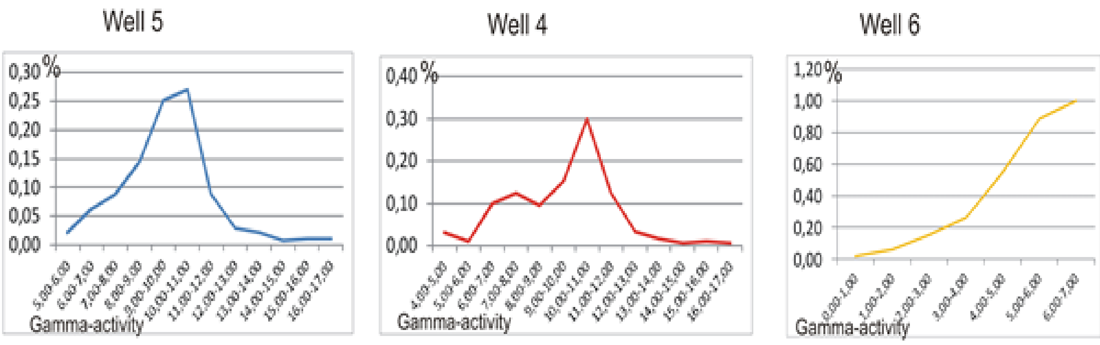

Figure-2: Graphs of the distribution of gamma-activity on the profile of 5-4-6.

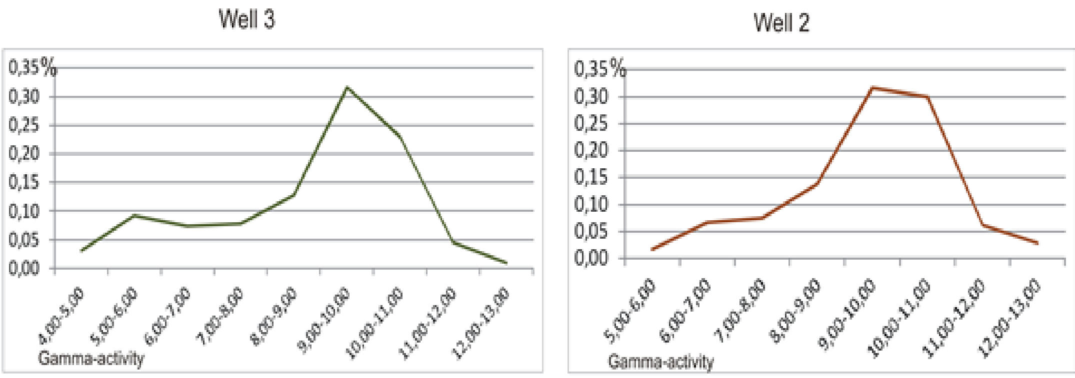

Figure-3: Graphs of the distribution of gamma-activity on the profile of 3-2.

According to the data of self-polarization potentials in the first zone (well 4) up to a depth of 40 m, only positive PS values are observed (from +3 to +95 mV), then only negative PS values are observed (up to -128 mV) (Figure-4). Negative values are probably due to the flow of fluid into the reservoir, which explains the highest values of gamma activity in this area. In the third zone (well 2), only positive PS values are observed (from +22 to +180 mV), which is possibly due to a high influx of liquid (Figure-5).

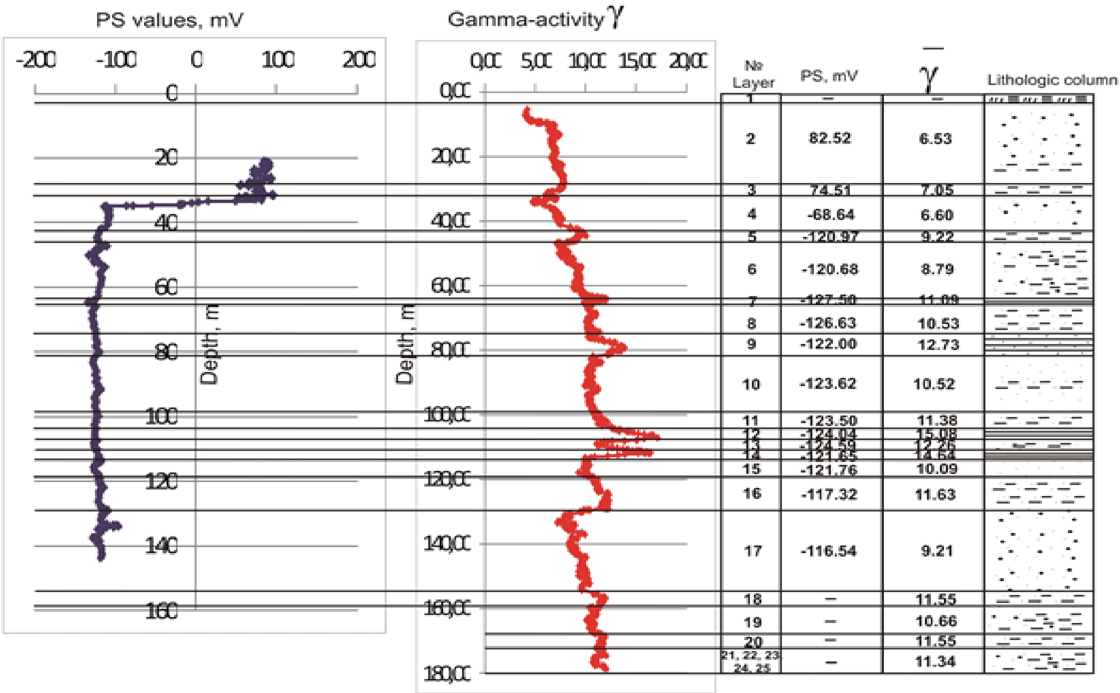

Figure-4: Well 4.

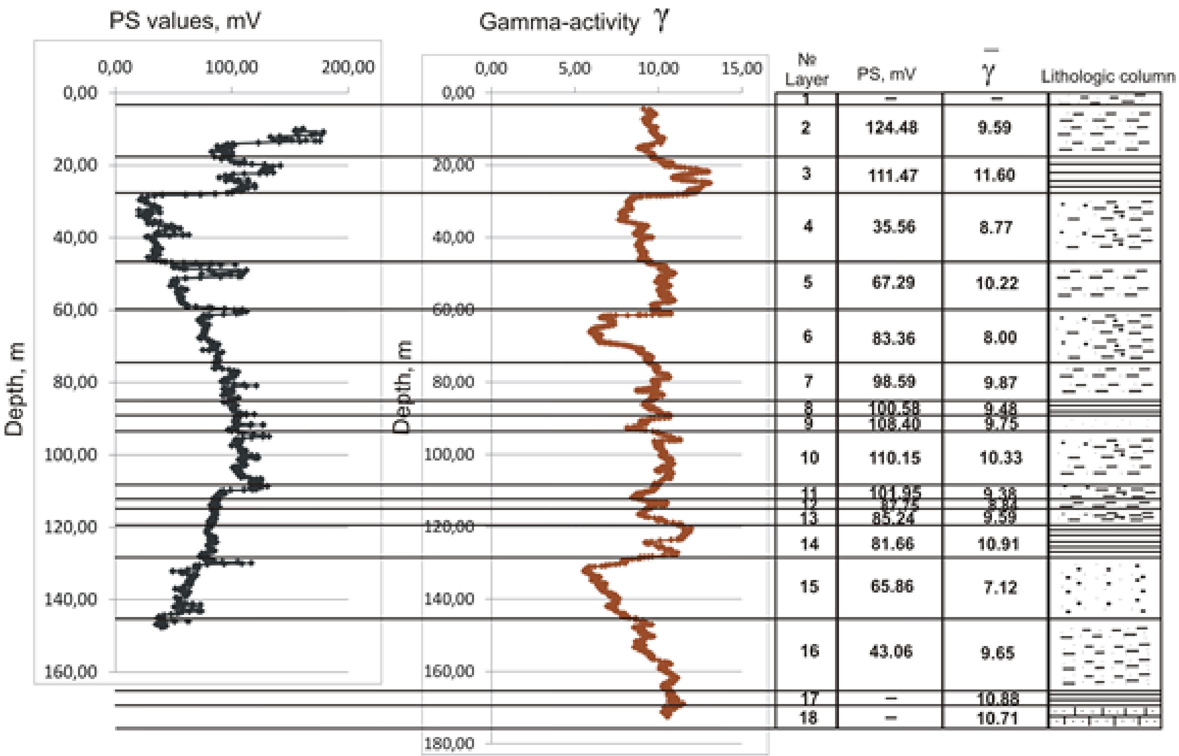

Figure-5: Well 2.

The discharge zone of the Karymshinskaya hydrothermal system (Kamchatka):

The Karymsha hydrothermal system is located to the west of the volcanoes of the East Kamchatka volcanic belt within the valley of the Paratunka and Karymshina rivers and is an integral part of the Verkhne-Paratunskaya geothermal system confined to the zone of the giant caldera of an ancient extinct supervolcano located between the mountains Yagodnoe, Tolsty Cape, Hot, Babiy stone [3].

The springs are often visited by tourists, as there are two pools filled with thermal water from the GK-5 well. Well GK-5 is one of the 4 self-flowing wells of Verkhnyaya Paratunka station. The drilling of the well was carried out from November 4, 1966 to February 17, 1967. At the end of drilling, the depth of the well was 900 m, the temperature at the mouth was 74°C, and the chemical composition of the water was hydrocarbonate-sulfate, calcium-sodium [4].

The structural position of this system is determined by the intersection of a fault-slip stretching along the axis of this valley with a fault transverse to it. Thermal waters are confined to a reservoir represented by a fissure-vein zone within the limits of volcanic deposits of the Miocene-Pliocene age (acid tuffs).

Interpretation of the diagram of the method of self-polarization potentials (PS). (Gamma-ray logging was not carried out in the well). In the GK-5 well, there is an alternation of almost equal negative (average -25 mV) and positive (average +25 mV) values of PS up to a depth of 850 m. from reservoir to well. This area is characterized by an intense zone of fracturing. According to the interpretation of the PS diagram, this is confirmed. Down to a depth of 615.4 m there are andesites, tuffs of medium-coarse clastic andesitic composition with interlayers of coarse-clastic tuffs of mixed composition. These rocks are fractured, brecciated in some areas. They are characterized by an average PS value equal to -6.23 mV. This is mainly due to a slight outflow of fluid through fractured zones. Further, to a depth of 838.5 m, there are porphyritic fissured basalts, and in the interval of 685–699 m, coarse-clastic tuffs of mixed composition are found. There are cracks ≤ 1 mm wide, rarely up to 3 mm, subvertical, subhorizontal. This layer is characterized by an average PS value of 0.73 mV. This is mainly due to a slight influx of fluid through the fractured zones. The next layer to a depth of 877.4 m is intensely fractured mudstone, and in the interval of 846.7-853.2 m - basalt. The average value of PS equal to 29.29 m is typical. A significant influx of fluid is noted at these depths. It can be assumed that further PS values will be negative, since fine porphyritic, weakly fractured andesites, subvertical and subhorizontal fractures, occur down to a depth of 900 m. And this layer is similar to the layer down to a depth of 615.4 m. (Figure-6).

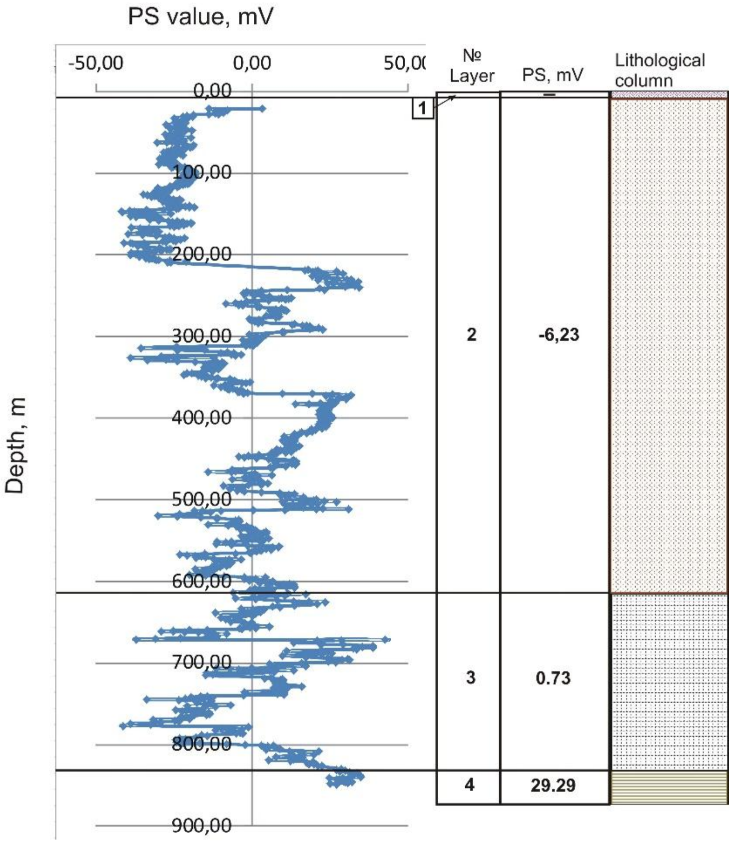

Figure-6: Well GK.

CONCLUSION

Based on the data of geophysical studies in the wells of the Daginsky hydrothermal system (Sakhalin), three zones can be distinguished, each of which is characterized by the corresponding values of gamma activity and changes in the potentials of its own polarization. All this helps in identifying permeable thermally conductive zones. The results obtained are important for further drilling design.

According to the interpretation of the diagram of the self-polarization potential method of the well GK-5 of the Karymshinsky hydrothermal system (Kamchatka), when moving from intermediate rocks (andesites) to mafic rocks (basalts), the arithmetic mean value of self-polarization potentials increases. Negative values are associated with the outflow of fluid from the well into the reservoir, and positive values are associated with the influx of fluid from the reservoir into the well.

Based on a comprehensive analysis of ground penetrating radar data, gamma ray logging and intrinsic polarization potentials, detailed information was obtained on the hydrogeological situation in the study areas of some hydrothermal systems. The applied method and data analysis can be used for other areas with a similar geological structure.

REFERENCES

[1] Rychagov S.N., Zhatnuev N.S., Korobov A.D. et al. *The structure of the hydrothermal system.* M.: Science. 1993. 298 p.

[2] Belousov V.I., Belousova S.P. *Natural disasters and environmental risks (on the example of geothermal energy)* // Petropavlovsk-Kamchatsky: KGPU, 2002. 160 p.

[3] Leonov V.L., Rogozin A.N. Karymshina - a giant caldera-supervolcano in Kamchatka: boundaries, structure, volume of pyroclastics // *Volcanology and seismology.* 2007. No. 5. Pp. 14 - 28.

[4] Boyarskaya I.D., Siritsa D.V. Assessment of the reproducibility results of measurements gas content in groundwater // *Problems of complex geophysical monitoring of the Russian Far East. Proceedings of the Second Regional Scientific and Technical Conference.* Petropavlovsk-Kamchatsky. October 11-17, 2009 / Resp. ed. V.N. Chebrov. Petropavlovsk-Kamchatsky: GS RAS, 2010. Pp. 345-347.

[5] Exploration work at the Daginsky deposit of thermal waters in the Nogliki District in 1990-1991. Performed by: I.G. Zavadsky (Yuzhno-Sakhalinsk: Sakhalingeology) Inv. No.7078 ("Rosgeolfond", Central Storage Facility). 1991. P. 281.