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Study on Dālaki Geothermal Resource in Bushehr Province, in the North of Persian Gulf

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ABSTRACT

Dālaki Geothermal Resource (DGR) is located 70 km to the northeast of Bushehr city. There is only one warm spring in DGR which its temperature is 36 ºC and its flowrate and pH is 18 l/s and 6.4 respectively. DGR is believed that relates to a salt dome. Due to the presence of salt and gypsum bearing rocks in the DGR, Cl and SO_4 ions concentration of Dālaki warm spring are very high. Based on geothermometery studies Dālaki geothermal reservoir temperature is from 66 to 146 ºC. Probably DGR heat source is normal thermal heat flow of the region. In fact, uprising of salt bodies provides high angle faults which allow rainfall waters penetrate to deeper parts of the region, absorb heat from nearby rocks and finally forming a geothermal reservoir in the region.

1. INTRODUCTION

Geothermal energy is thermal energy generated and stored in the Earth. It is in the form of pressurized steam which is able to generate electricity in geothermal power plants or in the form of hot or warm water that can also be used in a wide variety of applications such as space heating, fish farming, balneology, snow melting and so on. Many countries which are located in plate boundaries have geothermal resources including Iceland, Indonesia, Japan and etc. In Iran also there are many geothermal prospects which are distributed in different parts of the country. So far, most of the geothermal resources in Northwest of Iran have been studied. But this paper deals with Dālaki geothermal prospect in Bushehr province in southern part of the country and in the north of Persian Gulf. In this paper geological and geochemical data of Dālaki Geothermal Region (DGR) would be studied. Based on the results of the studies some information about DGR were obtained which would be explained in the text.

2. DALAKI GEOTHERMAL REGION

2.1. Location

It is located in the Northeast of Bushehr city, center of Bushehr province. DGR is about 70 km far from Bushehr city. , Figure 1. Dālaki town is located 1.6 km to the North of Dālaki warm spring.

2.2.Warm spring

According to the available data there is only one warm spring in DGR which is called Dālaki and its general information is illustrated in Table 1. In figure 1, location of Dālaki warm spring is shown too. Table 2 shows chemical characteristics of Dālaki spring.

Table 1. General Information about Dālaki warm spring (Bushehr Regional Water Company, 2013)

X	**Y**	**Elevation** (m)	**T**(c)	**Flowrate** (l/s)	**pH**	**EC** (µS/cm)
527311	3253680	110	36	18	6.4	11293

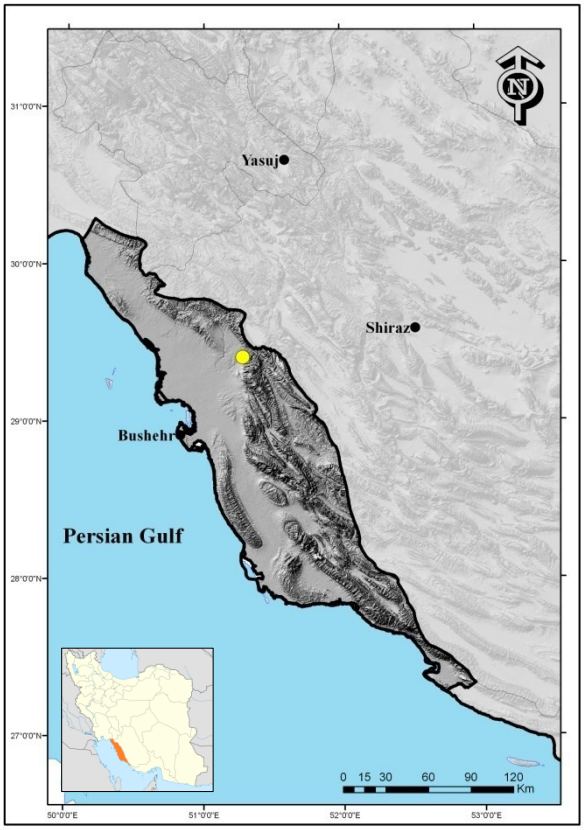

Figure 1. Location of Dalaki Warm Spring in Bushehr Province

Table 2. Chemical characteristics of Dālaki Warm Springs (Bushehr Regional Water Company)

Chemical Components	**Na**	**K**	**Mg**	**Ca**	**HCO_3**	**Cl**	**SO_4**	**SiO_2**	**TDS**
Concentration (mg/l)	2067.5	56.25	404.96	263.37	103.69	3911.4	1240.1	1.14	2345.66

2.3. Geology

Dālaki warm spring is appeared by a North-South trending fault at the northwestern corner of a salt dome whose axis is aligned in NW-SE direction. Dālaki spring flows in the contact of Gachsaran formation and quaternary alluviums.

Based on the 1:100,000 Burazjan geological map in DGR 18 lithological units are outcropped (Llewellyn and Ahdoot, 1973). Almost all of them are sedimentary and accumulated from Infra-Cambrian to quaternary time periods. There isn't any sign of young volcanic rocks in DGR, figure 2.

In order to exploration of oil reservoirs this region has been investigated carefully by many scientists. So, according to the seismic studies and oil wells data, it is found that thickness of sedimentary sequences is more than 9800 meters, (Llewellyn and Ahdoot, 1973). In figure 3 stratigraphic column of Sedimentary formations in DGR with their thicknesses are shown. Startigraphic information of different formations in DGR also is illustrated in Table 3.

There are three types of faults around dalaki warm spring. They are elongated in N-S, E-W and NW-SE directions. Dalaki warm spring is located at the intersection of the faults with different alignments, Figure 3. Dalaki spring flowrate (≈ 18 l/s) indicates that its relevant geothermal reservoir might be large in size. Moreover nearby faults are probably large and deep enough to conduct reasonable volume of water to the surface. No doubt more studies are necessary to prove those matters.

Table 3. Startigraphic Column of Dalaki Geothermal Region (Llewellyn and Ahdoot, 1973)

No.	Formation name	Formation Sign	Lithology	Thickness (m)	Age
1	Alluvium and Recent Deposits	-	Alluvium	-	Quaternary
2	Bakhtyari	Bk	Conglomerate & Sandstone	600	Upper Pliocene
3	Aghajari	Aj	Sandstone	1890	Pliocene
4	Mishan	Mn	Limestone, Marl and Limestone	294	Miocene
5	Guri Limestone	Grm	Limestone	?	Miocene
6	Gachsaran	Gs	Anhydrite, Salt, Marl	420	Miocene
7	Asmari- Jahrum	As-Ja	Sandstone, Gypsum, Limestone	540	Oligocene
8	Pabdeh	Pd	Shale and Limestone	296	Eocene-Paleocene
9	Gurpi	Gu	Marl & Shale		Upper Cretaceous
10	Ilam- Sarvak	Il-Sv	Limestone	300	Upper Cretaceous
11	Kazhdumi	Kz	Shale & Limestone	90	Lower Cretaceous
12	Dariyan-Fahliyan	Dr-Fa	Limestone	486	Lower Cretaceous
13	Hith Anhydrite	Hi	Anhydrite	126	Jurrasic
14	Surmeh	Sm	Limestone & Dolomite	720	Jurrasic
15	Neyriz- Khaneh kat	Nz-TR	Dolomite	906	Triassic
16	Permian Carbonates	P	Carbonate Sediments	900	Permian
17	Lower Paleozoic	Lpz	*	1500	Lower Paleozoic
18	Hormuz Salt Series	Sp	Evaporates (Salt), Shale, Dolomite	480	Infra-Cambrian

*No Data

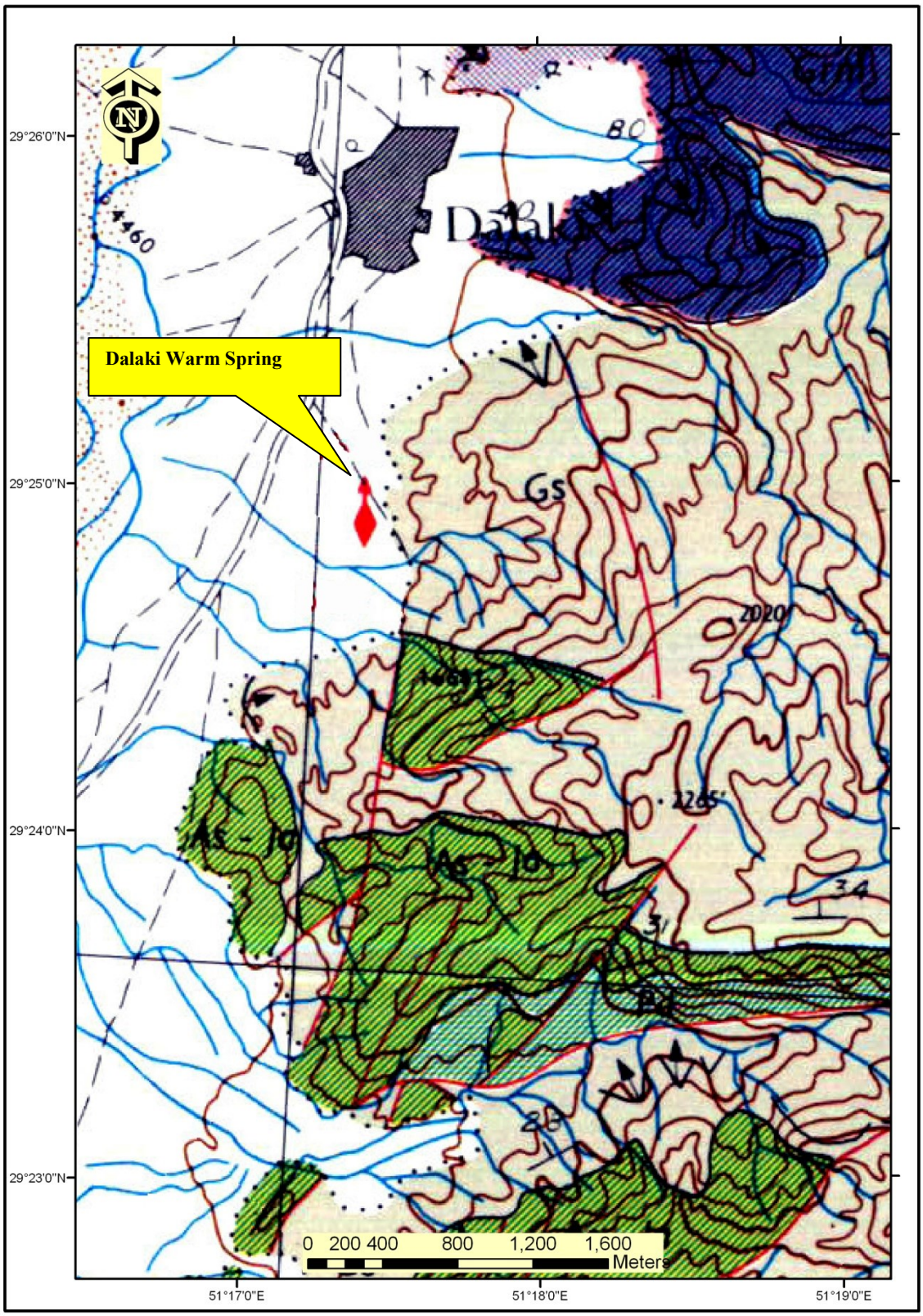

Figure 2. Geology Map of Dalaki Geothermal Region (Llewellyn and Ahdoot, 1973)

Gs (Gachsaran Fm., Anhydrite, Salt and Marl-Miocene), As-Ja (Asmari-Jahromi Fm., Sandstone, Gypsum and Limestone-OligoMiocene), Grm (Gurpi member, Marl and Shale-Upper Cretaceous)

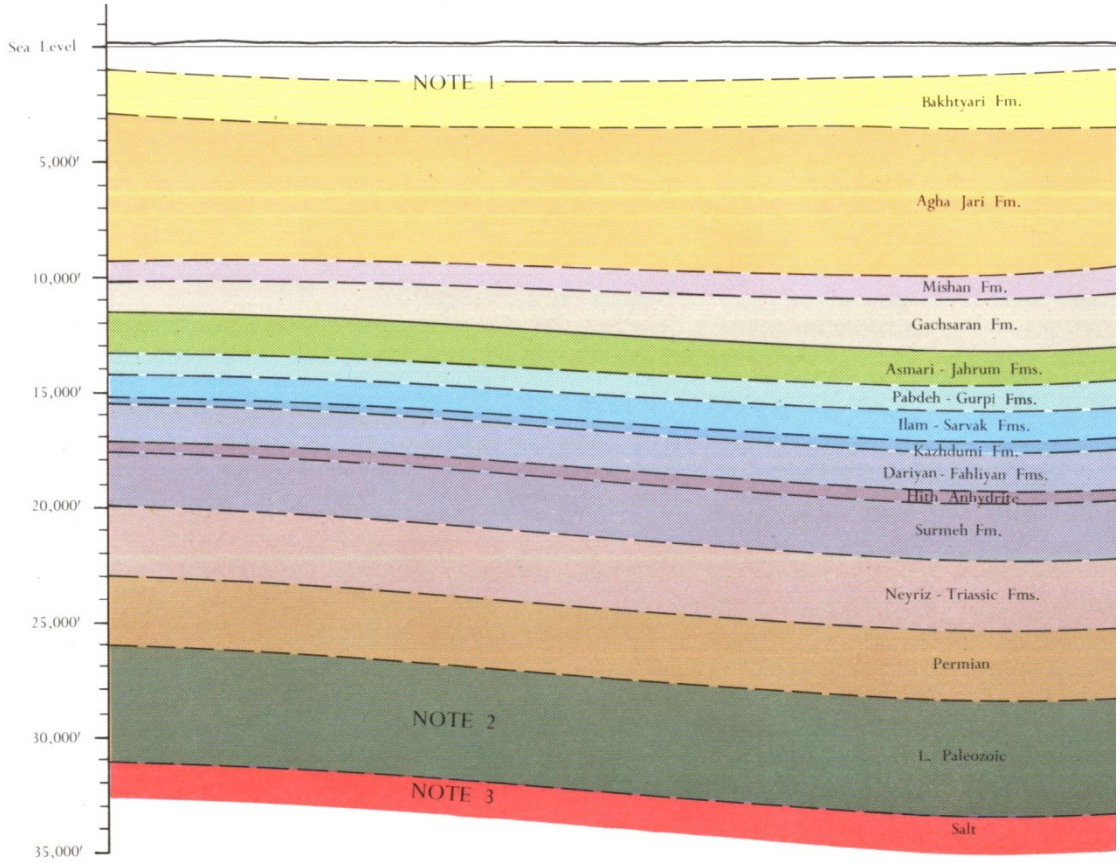

Figure 3. Stratigraphic Column of Dalaki Geothermal Region (Llewellyn and Ahdoot, 1973)

(Thicknesses are shown in feet)

2.3. Geochemistry

Due to the high concentration of Cl, Na and SO_4 ions, Dalaki warm spring has unusual chemical conditions. It's very clear that salt and gypsum layers are responsible for this phenomenon. In order to make diagrams we used spreadsheets which have been made by Powell and cumming, 2010. Based on Cl-SO_4-HCO_3 diagram, Dalaki warm spring water type is Chloride -Sulfate, figure 4. As it can be seen in the figure, there is a significant difference between Dalaki warm spring composition and some warm springs from West Azarbaijan Province in Northwest of the country. It is due to the unusual Cl and SO_4 concentration of Dalaki spring. that According to Na-K-Mg diagram, Dalaki spring belongs to the immature waters and it is plotted close to the Mg corner, figure 5. High Mg concentration could be a sign of reasonable mixing with underground water.

In order to estimate Dalaki reservoir temperature, different geothermometers were applied. Results are illustrated in Table 4. Due to the lack of silica, SiO_2 geothermometers can't be used for Dalaki spring. But based on Cation- geothermometers Dalaki geothermal reservoir temperature is 65-146 °C. However, due to the mixing of geothermal fluid with cold underground waters estimated reservoir temperatures possibly have some shift. Based on geothermometry results DGR is a very low temperature geothermal reservoir (Sanyal, 2005).

Table 4. Estimated temperature of Dalaki Geothermal Reservoir (°C)

Amorphous Silica	Chalcedony cond	Quartz cond	Quartz adiabatic	Na-K-Ca	Na-K-Ca Mg corr	Na/K Fournier	Na/K Truesdell	Na/K (Giggenbach)	K/Mg (Giggenbach)
-109	-50	-37	-6	137	-316	126	80	146	65

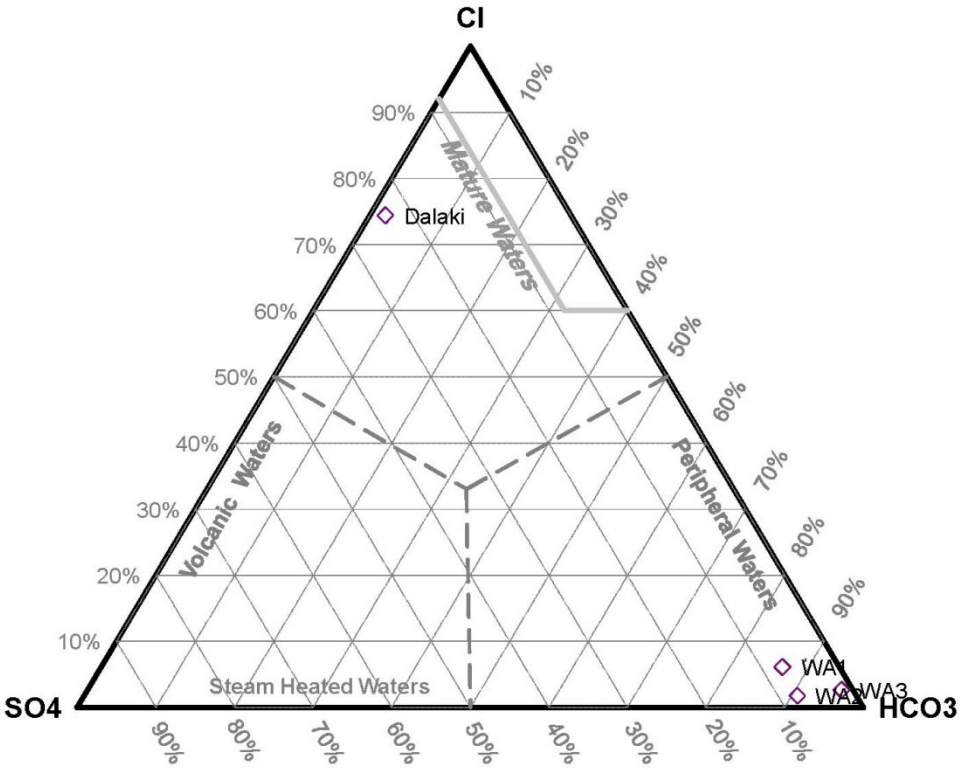

Figure 4. CL-SO_4-HCO_3 diagram of Dalaki warm spring (Giggenbach, 1988)

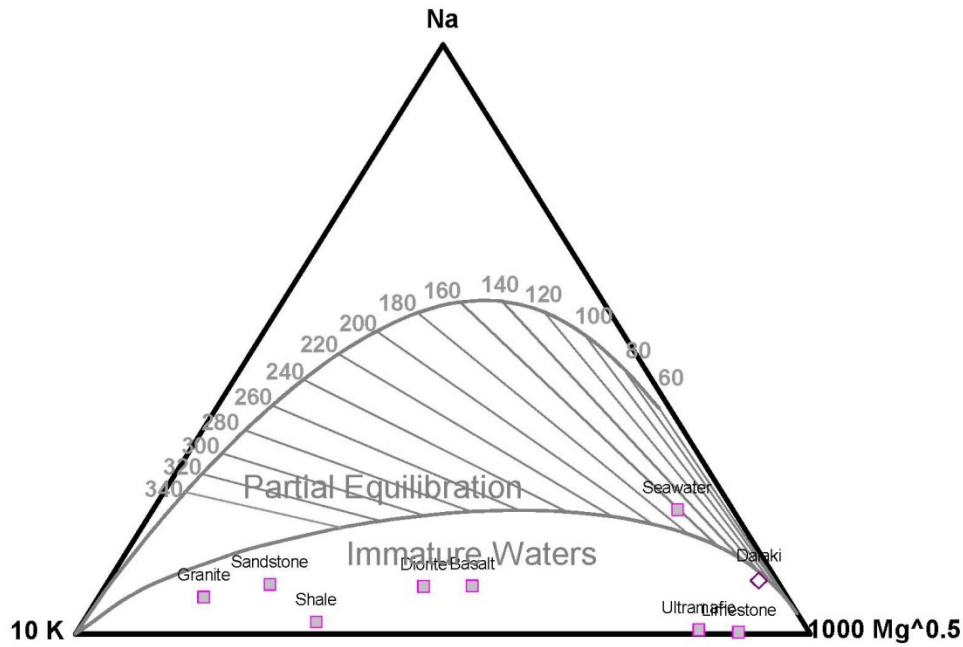

Figure 5. Na-K-Mg diagram of Dalaki warm spring (Giggenbach, 1988)

3. DISCUSSION

Dalaki geothermal reservoir is a low-medium temperature. According to the Burazjan geological map, there isn't any outcrop of young volcanic rocks around Dalaki spring. Therefore, probably in Dalaki geothermal region normal heat flow is heat source. In fact rain water penetrates to the deep parts of the region and flows through the warm rocks and geothermal reservoir is formed consequently. Stratigraphic column of the region shows that in four configurations Dalaki geothermal reservoir can be formed. They are illustrated in Table 5.

Table 5. Possible configurations for Dalaki Geothermal Reservoir

Top ▲ Bottom	Possible Reservoir Rock	Possible Cap Rock
	As (Asmari Fm.) Ja (Jahrom Fm.)	Gs (Gachsaran Fm.)
	Il (Ilam Fm.) Sv (Sarvak Fm.)	Gu (Gurpi Fm.)
	Dr (Dariyan Fm.) Fa (Fahliyan Fm.)	Kz (Kazhdomi Fm.)
	Sm (Surmeh Fm.)	Hi (Hith Anhydrite)

*For more detail see Table 3

At the present time it isn't possible to mark the most probable configuration. So, more data (especially geophysical data) is required to find real condition at the deeper parts of DGR. Dalaki spring emerges in the corner of a large salt dome. So, upward movement of salt can generate numerous faults and fissures in its upper rocks which can transfer rain water to the reservoir. Cold penetrated water reaches to deep parts of the region. Its adjacent warm rocks heat it and due to the lower density warmed water flows upward. It mixes with shallow underground water and appears at the surface as Dalaki warm spring. High concentration of Na, Cl and SO_4 reveals that geothermal fluid has been passed through salt and gypsum bearing formations. Stratigarphic column of the region confirms this task very well.

4. CONCLUSIONS

According to the geological and geochemical information of Dalaki spring it is found that there is a very low temperature geothermal system (T< 150 °C) in south of Dalaki town.

According to geothermometry results, DGR temperature varies from 65 to 146 °C. However, based on the geological environment of the adjacent areas well temperature will not be very high due to the absence of young volcanic rocks in the region.

Due to the existence of salt and gypsum bearing formations in DGR Na, Cl and SO_4 ions concentration is very high and unusual.

Possibly absence of silica in Dalaki warm spring is a sign of low temperature in the system.

Definitely in order to get more data for DGR detailed exploration program should be designed and executed. Those studies including detailed geological mapping, geochemical investigations and geophysical surveying. They would be implemented in order to understand geothermal reservoir nature and structure.

Based on the geothermometry data Dalaki geothermal reservoir is suitable for direct use applications in the future. In fact, if we consider lowest estimated temperature of the reservoir (65 °C) it is obvious that the reservoir geothermal fluid can be used in direct use projects. Other DGR data (especially geological information) prove this task too.

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