

Study on Conceptual Model of Arabdizaj Prospect in West Azarbāijan Province, NW-Iran

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ABSTRACT

Arabdizaj Geothermal Prospect (AGP) is located at 32 Km to the west of Maku city in west Azarbajian province in the most northwestern part of Iran. AGP area is 41 km² which has been determined by gravity studies. There are two types of geothermal surface manifestations in the region including young volcanic rocks and a warm spring which its name is Arabdizaj. Temperature of the warm spring is 26.7°C and its pH and EC are 6.73 and 4080 µS/cm respectively and also it is bicarbonate in water type. Based on the available geological maps, AGP heat source is cooling of quaternary basalts of Ararat volcano which outcrop close to the warm spring. Also, it is believed that in the most possible case upper Cretaceous colored Melange sediments can be reservoir and caprock of Arabdizaj geothermal reservoir. According to geothermometry Studies, estimated reservoir temperature of Arabdizaj geothermal region is from 94 to 179 °C. Based on the thermal surveying data, thermal gradient of the region is 45 °C/km.

1. INTRODUCTION

Arabdizaj Geothermal Prospect (AGP) is located 32 km to the west of Maku city in west Azarbajian Province, Figure 1. It is positioned in the most northwestern part of Iran. Its area is 41 km². There are two types of geothermal surface manifestations in AGP including young volcanic rocks and a warm spring which is called Arabdizaj. This prospect was found during a geothermal resource assessment project which has been carried out in west Azarbajian province. In fact it is one of 12 geothermal prospects that have been determined in the province. In this paper some data about Arabdizaj warm spring would be presented. Then some detailed information about geology, geochemistry and geophysical conditions of AGP would be explained. Finally, a conceptual model about Arabdizaj geothermal reservoir would be introduced.

2. ARABDIZAJ WARM SPRING

Arabdizaj warm spring is located 2 km to the east of Arabdizaj village almost in the central part of the AGP. Its temperature is 26.7 °C and its other information is illustrated in Table 1. There are some gas bubbles which emerge from this warm spring that mostly are CO₂. Arabdizaj spring is shown in Figures 2 and 3. At the present time nobody use spring's water regularly and in some cases villagers use it for washing purposes.

Table 1. General Information about Arabdizaj Warm Spring

Longitude	Latitude	Elevation (masl)	Temperature (°C)	Flowrate (l/s)	pH	EC (µS/cm)
44° 10' 11"	39° 18' 68 "	1563	26.7	0.5	6.73	4080

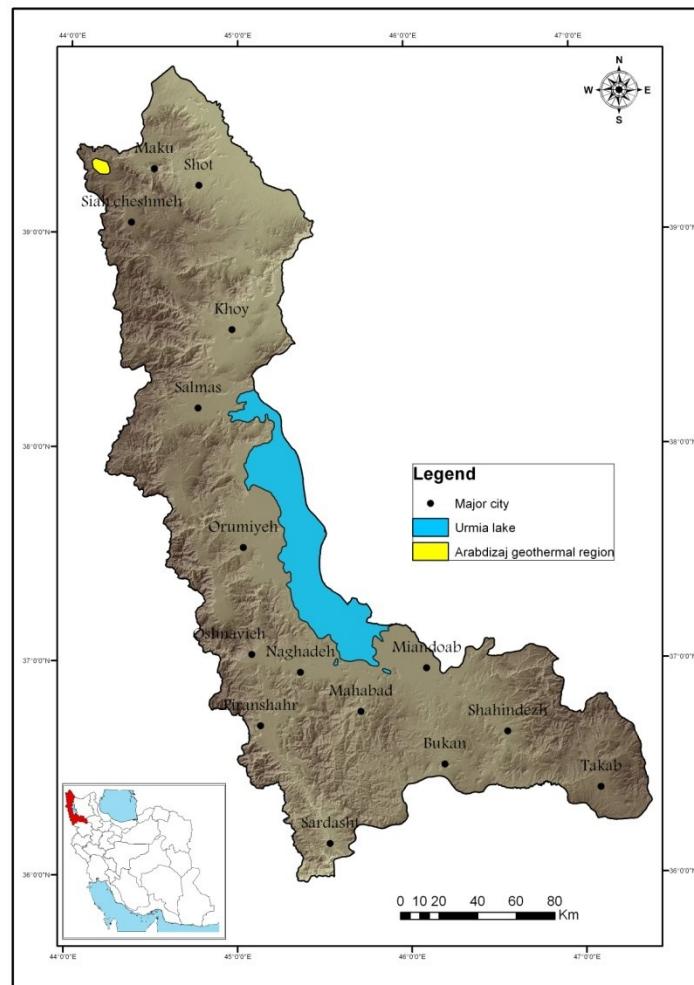


Figure 1. Location of Arabdizaj Prospect in West Azarbaijan Province



Figure 2. Arabdizaj warm spring in the north west of Iran

Physicochemical information about Arabdizaj Warm Spring is illustrated in Table 1. (The width of pH meter case is 30 cm).

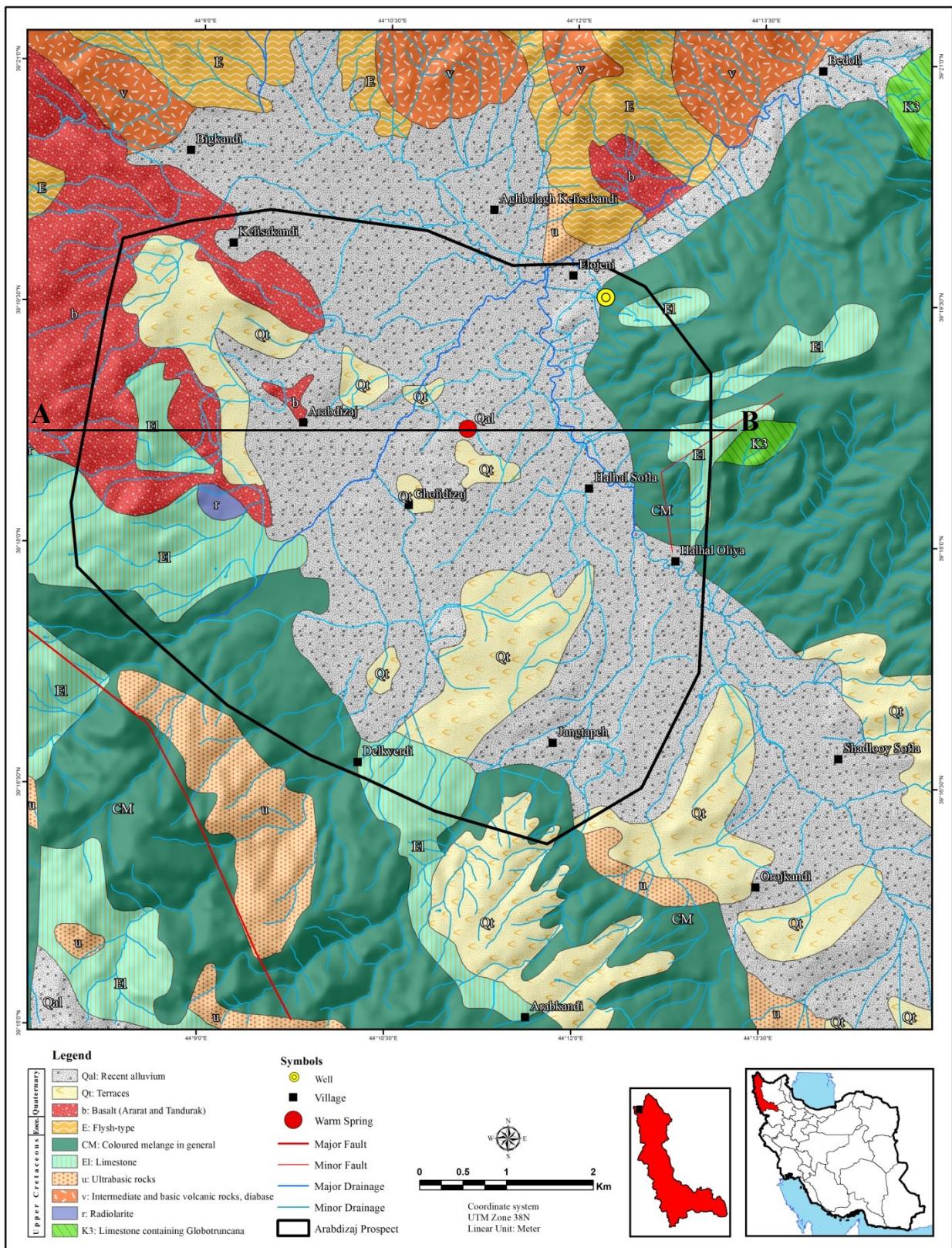


Figure 3. Geological Map of Arabdizaj Geothermal Prospect (Alavi & others, 1975)

Geological information about AGP was obtained from 1: 250,000 Maku geological Map. Due to the size of AGP and small scale of the studied geology map, it seems that the relevant data are much generalized but unfortunately there was not any other more detailed geological map. However, based on the current data, 5 lithological units are outcropped in AGP which from older to younger are as follows, Figure 3:

CM, ophiolitic melange including ultrabasic rocks, Diabas and volcanic tuffs- upper Cretaceous to middle Eocene

r, radiolarite- upper Cretaceous to middle Eocene

El, fossiliferous limestone- upper Cretaceous to middle Eocene

b, basalt- Quaternary

Qal, alluvium- Quaternary

In some parts of the Arabdizaj geothermal region, basalts show prism structures, Figure 4. According to the geology map of the area, there isn't any fault in AGP. Probably it causes by extensive alluvium outcrops that cover the AGP and hide faults in the geothermal prospect. It is believed that Arabdizaj warm spring is appeared at the surface due to the activity of a probable fault which connects warm spring to the geothermal reservoir but based on the current data there isn't any sign of fault at the surface.



Figure 4. Prism Structures of the basalts in Arabdizaj Geothermal Prospect

(The average height of the trees is about 3 meters)

3. GEOCHEMISTRY

During the implementation of geothermal resource assessment project in West Azarbaijan Province, Arabdizaj warm spring were visited and sampled. Chemical analysis data of this spring is illustrated in Table 2. Based on the chemical data it is found that Arabdizaj spring is slightly acidic (field pH and lab pH are 6.73 and 6.85 respectively) and bicarbonate in composition, Figure 5. Therefore, it is believed that the geothermal fluid has been mixed with underground water. Generally this type of warm spring isn't very useful for geothermometry calculations, (Mahon et al, 1980). In Figure 6, Na-K-Mg triangular diagram of the spring is shown. In this diagram, Arabdizaj spring is located very close to Mg point which is a clear sign of immature waters. It means that geothermal fluid hasn't equilibrated with surrounding rocks yet or has been mixed with cold underground water.

In order to calculation of reservoir temperature we used software which is written by Powell and cummung, 2010. Geothermometry calculations reveal that estimated temperature of Arabdizaj geothermal reservoir varies from 39 to 179 °C. Due to the presence of young basalts it seems that 39 °C isn't a realistic reservoir temperature. The results of geothermometry calculations about Arabdizaj

warm spring are illustrated in Table 3. It should be mentioned that the results of geothermometry calculations are the only data about geothermal reservoir because there is not any other warm spring in the region.

Table 2. Chemical characteristics of Arabdizaj Warm Spring

No	Chemical Agent	Concentration (mg/l)
1	Na	330
2	K	15.6
3	Mg	378.7
4	Ca	90
5	Al	<0.1
6	Fe	<0.005
7	As	0.1
8	Li	0.5
9	F	0.5
10	Cl	80.4
11	SO ₄	42
12	B	0.8
13	CO ₂	211.2
14	H ₂ S	<0.1
15	SiO ₂	122.5
16	TSS	25.5
17	TDS	2940

Table 3. Geothermometry Results of Arabdizaj Warm Spring (°C)

Chalcedony cond.	Quartz adiabatic	Quartz Cond.	Na-K-Mg	Na/K Fournier	Na/K Giggenbach	Na/k Truesdell	Na/K Giggenbach
123	142	149	94	160	179	119	39

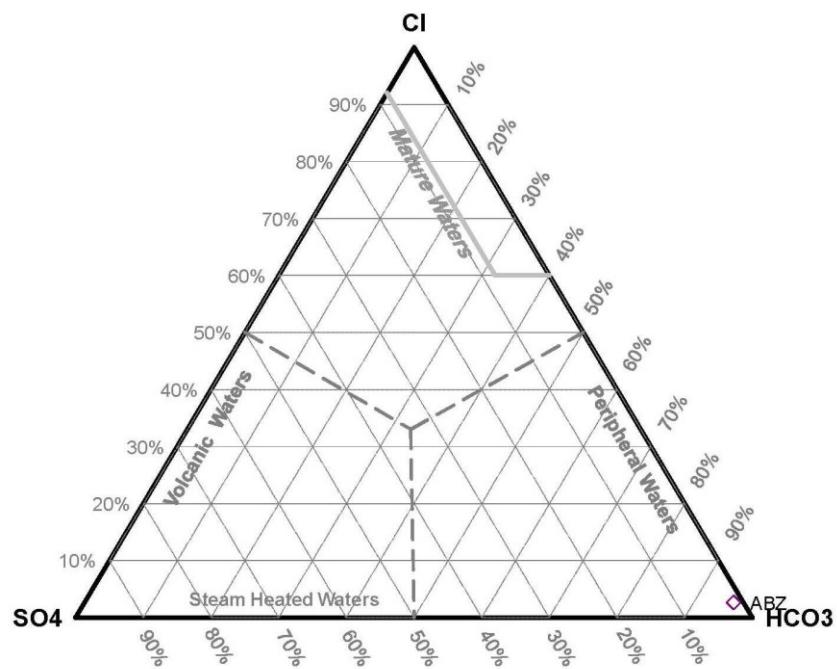


Figure 5. Cl-SO₄-HCO₃ Triangular Diagram of Arabdizaj Warm Spring (Giggenbach,1991)

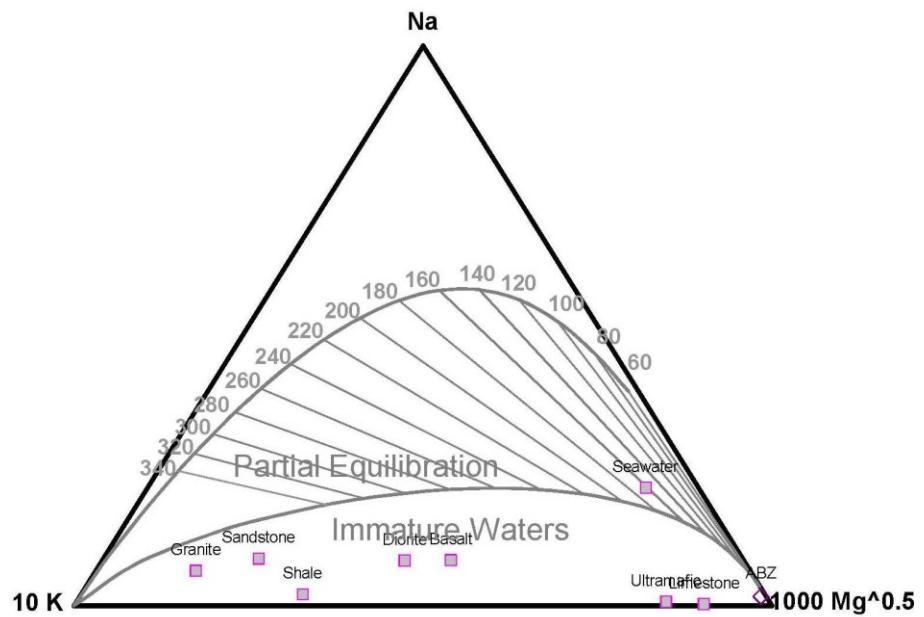


Figure 6. Na-K-Mg Triangular Diagram of Arabdizaj Warm Spring (Giggenbach,1991)

4. GEOPHYSICAL STUDIES

4.1. Gravity Studies

An Italian company (ENEL) had conducted a gravity surveying in northwestern parts of Iran including Arabdizaj geothermal region 35 years ago. Unfortunately, detailed data of gravity studies aren't available now. The only available information is a residual gravity map that has been shown in Figure 7. As it can be seen in the Figure, there is a negative gravity anomaly around the Arabdizaj warm spring. In fact, AGP area has been selected using the gravity results. Arabdizaj spring is located inside the negative gravity anomaly. Based on the gravity data, warm spring is located above the geothermal reservoir and also it is concluded that possible fault that has created warm spring is a high angle or vertical fault.

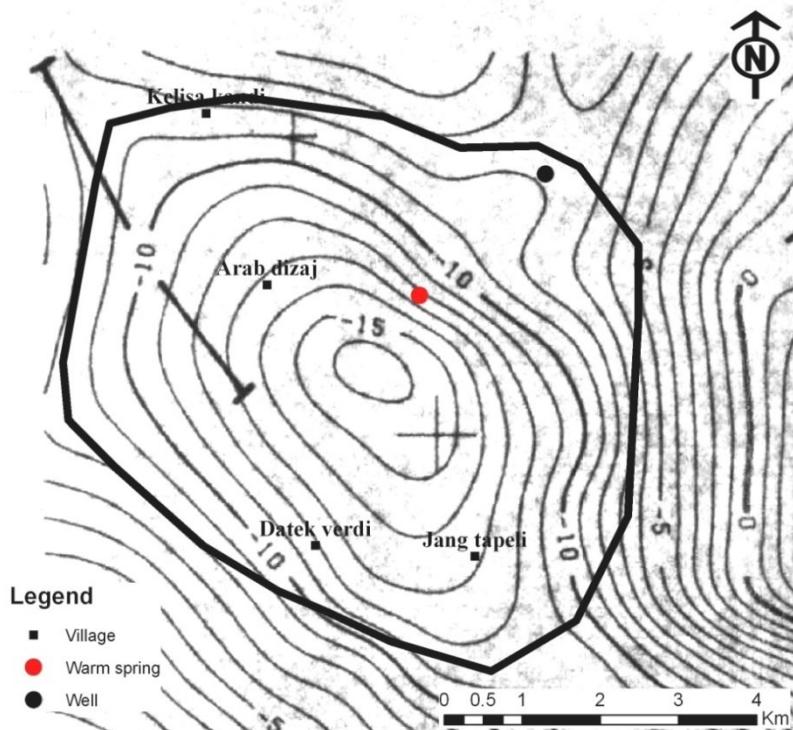


Figure 7. Residual Gravity Map of Arabdizaj Geothermal Prospect (in mgal) (Enel co., 1978)

4.2. Thermal Surveying

Also, ENEL Company had drilled a borehole in the vicinity of Arabdizaj warm spring, Figure 6. More information about the borehole is illustrated in Table 3. Based on the borehole data thermal gradient in AGP is $45^{\circ}\text{C}/\text{km}$. As it can be seen in Figure 6, there is a 2200 m distance between Arabdizaj warm spring and borehole. So, thermal gradient has been measured at the corner of AGP. Therefore, maybe thermal gradient in AGP is greater than the measured one. More studies and investigations can prove this idea.

Table 3. General Information about Drilled Borehole in Arabdizaj Geothermal Region (Enel Co., 1979)

X	Y	Elevation (m)	Depth (m)	Borehole diameter (mm)	Thermal gradient ($^{\circ}\text{C}/10\text{ m}$)	Heat flow (10^{-6} cal/cm.s)
$44^{\circ} 12' 14''$	$39^{\circ} 19' 33''$	1910	100	86-110	0.45	1.47

5. CONCEPTUAL MODEL

According to the current geological data the first conceptual model of AGP was generated. So, it is found that the most possible heat source of AGP is cooling of young basaltic rocks which have been emitted from Arārāt volcano in Turkey in 12 km to the northwest of AGP. Based on the geophysical data thermal gradient of the region isn't very high (just 1.5 times more than normal one). Therefore, probably volcanic rocks aren't very young. Of course, more data is needed to prove this theory.

Arabdizaj geothermal region has been covered mainly by colored Melange, Figure 3. This lithological unit has an extraordinary thickness (about 4000 m). So it is strongly believed that Arabdizaj geothermal reservoir is located in colored Melange. At the bottom of this geological formation there are oldest sedimentary rocks which are consisted of sandstone, shale and limestone. The thickness of those rocks seem to exceed 1200 m (Alavi et al., 1975).

Therefore, we think that above mentioned rocks are suitable for forming of a geothermal reservoir in the region. In fact, these sedimentary rocks can provide both reservoir and cap rocks for geothermal system in AGP.

AGP is located in a depression so rain water can penetrate to the reservoir from all directions. Based on the geothermometry calculations minimum estimated temperature of the reservoir is 94 °C. So, due to the measured thermal gradient in AGP probably geothermal reservoir could be in more than 2000 meters below the surface. Conceptual model of Arabdizaj geothermal reservoir is shown in Figure 8.

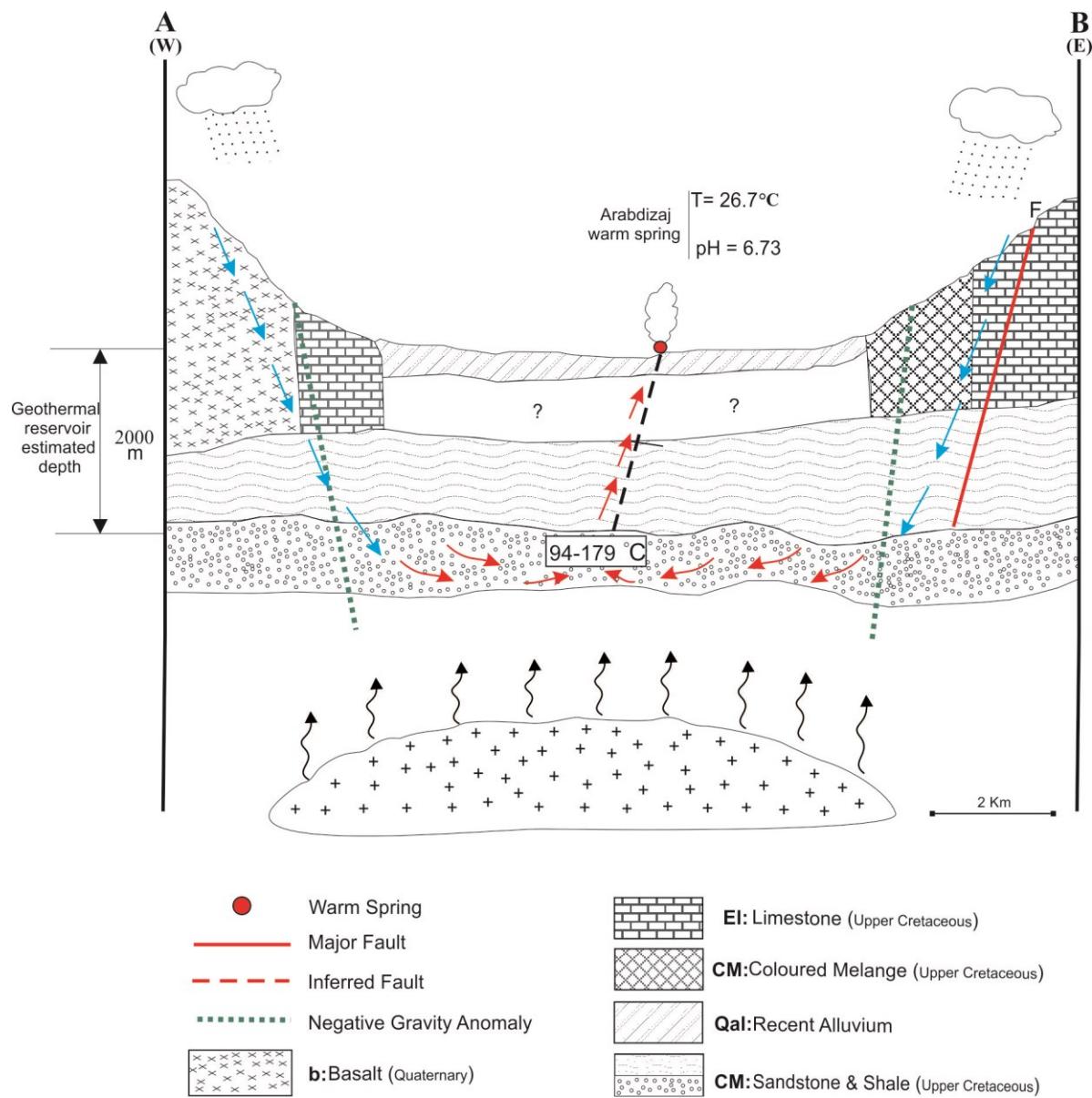


Figure 8. Conceptual Model of Arabdizaj Geothermal Prospect

See Figure 3 for location of A and B. Based on the available geology map of Arabdizaj region CM unit consists of volcanic, ultra basic and sedimentary rocks. It is believed that the geothermal reservoir is located in sandstones and limestones of CM unit.

6. CONCLUSIONS

- Due to the presence of young basaltic rocks and a warm spring there is a geothermal resource in Arabdizaj region in the most northwestern part of Iran.
- Arabdizaj region is a low temperature geothermal region. Its estimated temperature is from 94 to 179 °C.
- Thermal gradient in the region is 45 °C/km, so reservoir depth is around 2000 meters based on the minimum temperature of the reservoir.
- Cooling of young volcanic rocks is heat source of the geothermal reservoir.

- CM lithological unit in Arabdizaj geothermal prospect is very important formation in geothermal point of view. Because it is believed that both reservoir and caprock are positioned in this unit. In the bottom of CM unit there are some sedimentary rocks including sandstone, shale and limestone which can maintain suitable conditions for making a geothermal reservoir.

- Arabdizaj geothermal region is located in a basin so rain water can infiltrate to the reservoir from all geographic directions.

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