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Physicochemical Characteristics of Mahallat Warm Springs in West-Central Iran

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ABSTRACT

The Mahallat geothermal region is a very large region (about 50,000 km^2) that is positioned in the west-central part of the country. There are eight warm springs in this region whose temperatures vary from 32-48 °C. They are located in two different areas, Mahallat and Vartun (east of Isfahan City). Six of these springs are located northeast of Mahallat city and the other two are located in the Vartun area. In this paper, the physicochemical characteristics of Mahallat warm springs are interpreted.

These springs were visited and sampled in October 2008 in order to investigate their properties. It was found that they exhibit acid-sulfate water type and that they appeared at the surface due to the fault activity. Their heat originates from young magma bodies at unknown depths in the region. There are some large outcrops of Travertine deposits around the springs and Mahallat city. Their flowrates indicate that a large geothermal system exists in the deeper parts of the region.

1. INTRODUCTION

The Mahallat Geothermal Region (MGR) has an area of about 51,000 km^2 and includes three central provinces: Qom, Markazi and Isfahan. The geographical coordinates of MGR are shown in Table 1. The MGR is located in western and southwestern parts of the Qom Province, the central and southeastern parts of the Markazi Province, and the central and northeastern parts of the Isfahan Province, as shown in Figure 1.

Table 1. Geographical Coordinates of Mahallat Geothermal Region

Point Number	Longitude	Latitude
1	49°, 00´	34°, 41´
2	50°, 31´	34°, 41´
3	53°, 04´	33°, 00´
4	52°, 04´	32°, 13´

Due to a certain familiarity with the Mahallat warm springs (MWS) in this region, it is called the Mahllat Geothermal Region. In April 2008, a renewable energy group called Niroo Research Institute (NRI) initiated a research project to evaluate the geothermal energy potential in the MGR. As a part of that project, Mahallat warm springs were visited and sampled. The results of this study are explained in this paper.

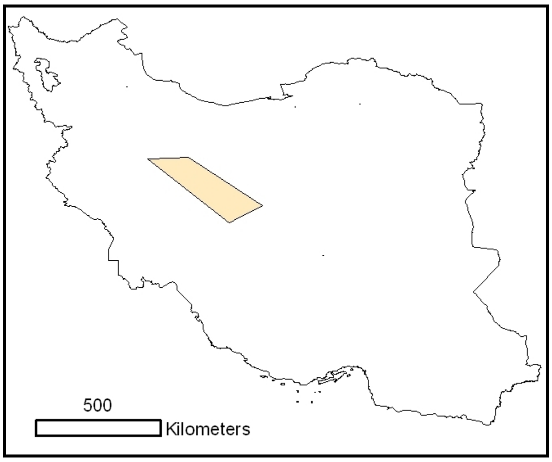

Figure 1: Location of Mahallat Region in Iran

2. MAHALLAT WARM SPRINGS

2.1 Geographical Position

Mahallat City is located in the Markazi Province. MWS are positioned 20 km northeast of Mahallat City. There is a small village called Abegarm in the vicinity of MWS, and the people there have occupations related to the warm springs.

Mountains extend in the NW-SE direction in the same area. All of them are emitted from the ground in a 3 km^2 area.

The names and geographical coordinates of the MWS are presented in Table 2. Due to high flowrate in the Shafa warm spring, a 15 room hotel was constructed 30 years ago in this area. This hotel has many private bathrooms and public pools for water therapy purposes. The location of MWS in Mahallat Geothermal Region is shown in Figure 2, and a satellite image of Mahallat warm springs location is shown in Figure 3.

Table 2. Geographical Coordinates of Mahallat Warm Springs

No	Spring Name	Longitude	Latitude
1	Abe- Donbe	50° 33´ 21˝	34° 00´ 37˝
2	Abe- Soleymanieh	50° 33´ 30˝	34° 00´ 36˝
3	Abe- Soda	50° 33´ 44˝	34° 00´ 22
4	Abe- Hakim	50° 33´ 44˝	34° 00´ 02˝
5	Sarbaz	50° 32´ 53˝	34° 00´ 24˝
6	Shafa	50° 32´ 52˝	34° 00´ 23˝

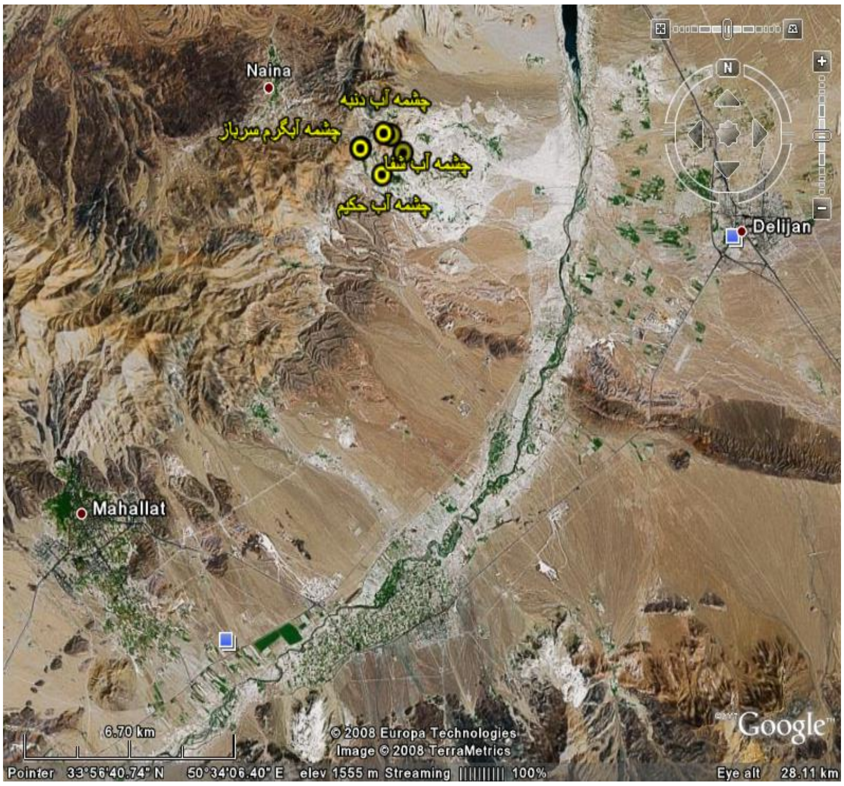

Figure 2: Mahallat warm springs around Mahallat city

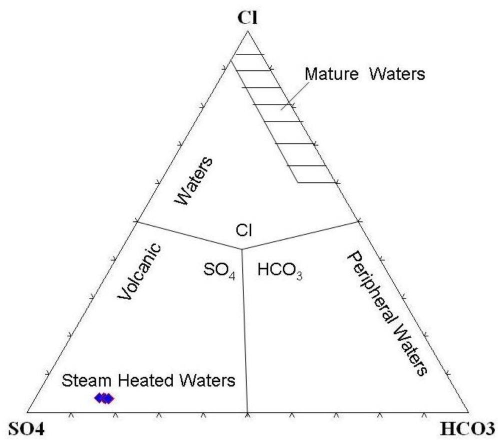

Figure 3: Cl-SO_4-HCO_3 triangular diagram of Mahallat Warm Springs (Giggenbach, 1991)

2.2. Physical Characteristics

The temperatures and flowrates of MWS are shown in Table 3. As is indicated in the table, all of the springs except for the Abe-Hakim spring have roughly the same temperature. The Shafa and Abe-Soda springs have the highest flowrates among them (14 and 10 l/s, respectively). The water in all the springs has no smell or taste. In some cases, such as in the Shafa spring, CO_2 bubbles can be seen, but they are not very distinctive.

2.3. Chemical Characteristics

Most of the MWS are acidic to some extent, as only the Abe-Hakim spring has a pH greater than 7, as shown in Table 4. The silica and chloride contents of all the springs are low, but their solphate anion concentrations are very high. Thus, they are classified as a acid-sulfate waters. The calcium content of the water is very high due to dissolution of the carbonate host rocks in the region. A Cl-SO_4-HCO_3 triangular diagram of MWS is plotted in Figure 4. As is indicated in the diagram, the chemical composition is unusual. As the diagram shows, the waters are steam-heated, and this type of water generally has a very low pH and is associated with fumaroles. However, MWS neither have a very low pH nor appear close to any fumaroles. Therefore, it is necessary to conduct a detailed geochemical survey in the region to find the reason for this.

Table 3. Temperature and Flowrate of Mahallat Geothermal Springs

No	Spring name	Temperature (°C)	Flowrate (lit/s)
1	Abe- Donbe	46.4	2.5
2	Abe- Soleymanieh	46.4	2.5
3	Abe- Soda	45.9	10
4	Abe- Hakim	33.2	1.5
5	Sarbaz	47.2	2
6	Shafa	48	14

2.3. Geology

2.3.1. Stratigraphy

Several formations have been outcropped in the region that belonged to the Quaternary period in the Cenozoic era. A geological map of the MWS region is shown in Figure 5.

Table 4. Physicochemical Characteristics of Mahallat Warm Springs

No	Spring name	Temp. (ºC)	pH	Electric Cond. (mS/cm)	Chemical Analysis Results (mg/lit)				
					SiO2	Na	K	Ca	Mg
1	Abe-Donbe	46.4	6.71	2.49	33.54	92	5.7	355.2	63.4
2	Abe- Soleymanieh	46.4	6.74	2.59	32.64	92	5.6	363.2	55.2
3	Abe-Soda	45.9	6.64	2.57	35.12	92	5.7	368	55.2
4	Abe-Hakim	33.2	7.04	2.03	35.37	98	5.7	384	54.2
5	Sarbaz	47.2	6.69	2.52	34.35	92	14.6	366.4	52.7
6	Shafa	48	6.63	2.57	34.84	92	5.7	368	54.2

Table 4 continued

No	Spring name	Chemical Analysis Results (mg/lit)					
		SO4	Cl	HcO3	B	Li	TDS
1	Abe-Donbe	1060.8	51	205	0.19	0.3	1898
2	Abe- Soleymanieh	1072	49	213.3	0.053	0.3	1857
3	Abe-Soda	1070.3	50	224.5	0.155	0.3	1851
4	Abe-Hakim	1143.6	49	202.5	0.555	0.4	1942
5	Sarbaz	1068.2	49	212.3	0.2	0.3	1855
6	Shafa	1074	50	222	0.015	0.3	1868

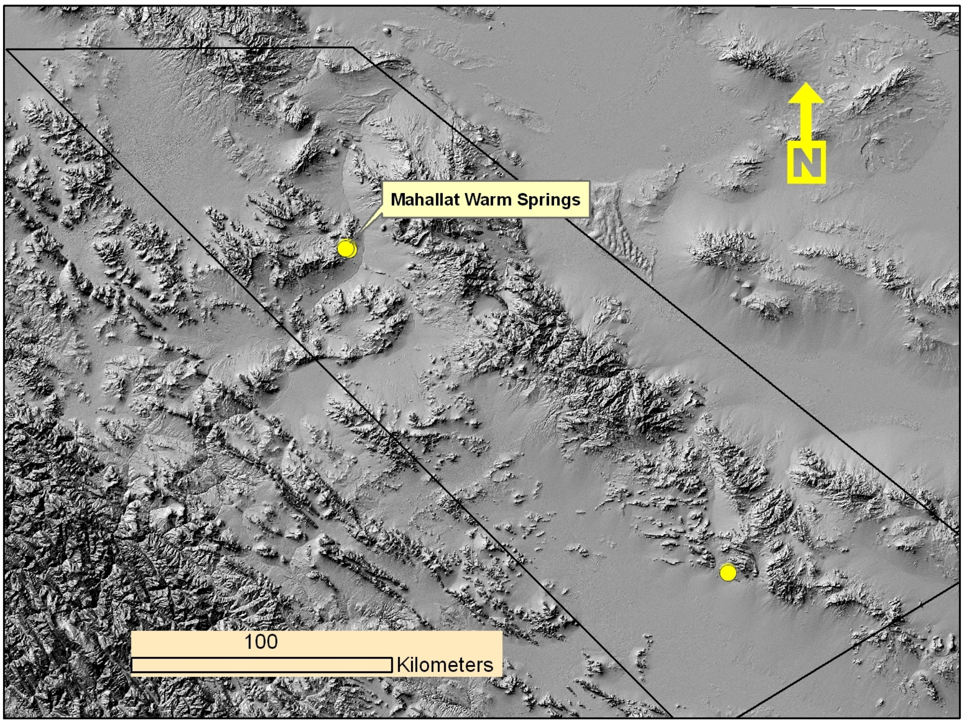

Figure 4: Location of Mahallat Warm Springs in Mahallat Geothermal Region

The oldest rocks in the region are Precambrian phylites, and the younger rocks are as follows:

Dolomits and limestones (Cambrian), Red-sandstones (Cambrian), limestone bodies (lower Cretaceous), a thick formation including shale and sandstone (Triassic- Jurassic), Red sandstone and conglomerate (Eeocene), Numolitic limestones (Eecene), Granitic- Dioritic intrusive bodies (Oligocene), Reefal limestones (Oligocene- Miocene), Travertine deposits (Quaternary) and Alluvium deposits (Quaternary)

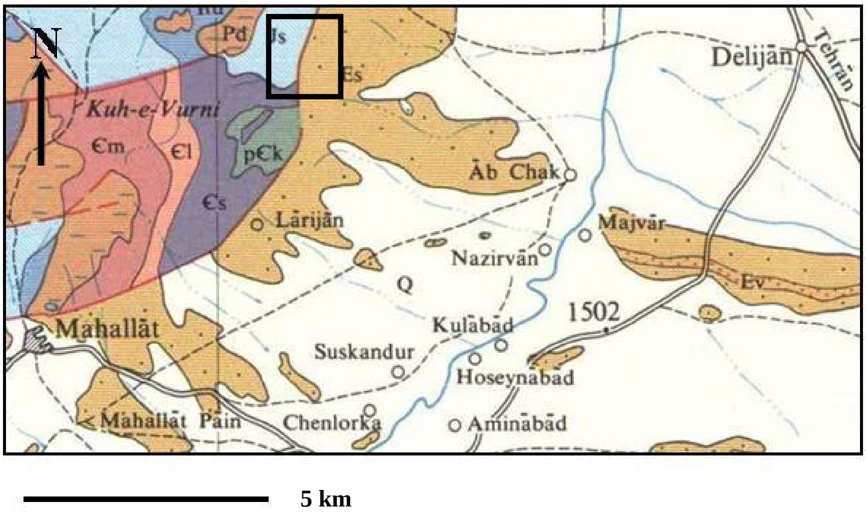

Figure 5: Geological Map of Mahallat Warm Springs

In the northern part of MWS, there are Basaltic- andesitic tuffs which are belonged to Eeocene (Thiele et al., 1968). However, these authors believe that they are much younger than the Eeocene due to presence of warm springs in the region. In fact, it is very hard to believe that Eeocene intrusive rocks can maintain sufficient heat to create warm waters in this region.

As was mentioned earlier, there are some travertine deposits which precipitated from the springs around the springs and also about 20 km northwest of them. Moreover, they are also outcropped in the southern and southwestern parts of Mahallat City, as shown in Figure 6. In some places, their area is more than several square kilometers. Their thickness is variable and in some localities exceeds 50 m (Thiele et al. 1968). At the present time, there are several travertine mines and bulding stones facilities in the region which they are use travertine deposits as a raw material.

If it is assumed that all of this travertine has precipitated as a result of the activity of the warm springs, the following conclusions can be made:

- The Mahallat geothermal system is a very old system.
- The distribution of travertine deposits reveals the fault lines.
- The precipitation of travertine has been stopped, possibly by the occurrences of natural phenomena such as earthquakes or chemical changes in the spring waters.
- CO_2 gas enters the warm waters and changes their pH to make them acidic. Acidic waters dissolve carbonate rocks while they migrate from underground to the surface. $CaCO_3$ is then precipitated at the surface as a travertine deposits, as indicated by the emission of CO_2 gas.

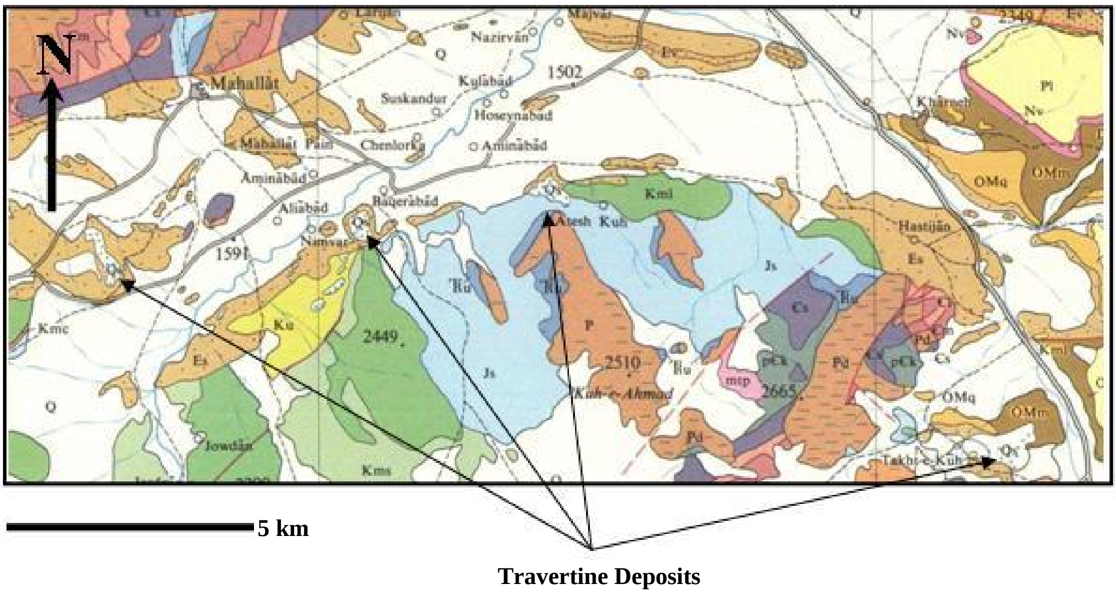

Figure 6: Distirbution of Travertine Deposits around Mahallat Springs

2.4.2. Tectonic

As can be seen in the geological map of MWS in Figure 5, the region is mainly covered by quaternary sediments, making it hard to distinguish structural features.

However, MWS is located along a distinct fault line, which can be seen in the western part of the map. It has a length of about 10 km and a NE-SW strike in the southern part, but its direction changes to N-S in its northern part. The MWS area is marked by a black rectangle on the map.

3. GEOTHERMOMETRY

As Shafa Spring has the highest flowrate among all the MWS, its chemical data was used to evaluate the temperature of the Mahallat geothermal system. Estimated temperatures according to different geothermometers are presented in Table 4. As can be seen in the table, SiO_2, Na-Ca and K-Mg geothermometers did not record suitable temperatures. However, it seems that Na-K geothermometers offer more reliable results.

According to geothermometry calculations, the Mahallat geothermal system has an approximate temperature of 165ºC.

CONCLUSIONS

The following conclusions can be made from the study of Mahallat warm springs:

- There is a favorable geothermal resource in the deeper parts of the Mahallat region.
- According to Na-K geothermometery, the Mahallat geothermal resource temperature is about 162ºC.
- The Mahallat geothermal resource has a reasonable volume and permeability due to the flowrate of all warm springs (32.5 l/s)..
- Based on the temperature of the warm springs, outcropped volcanic rocks in the region are probably younger than the Eeocene, which is mentioned in available geological maps.
- Large and thick travertine bodies reveal that the Mahallat geothermal resource is an old geothermal system.

RECOMMENDATIONS

- In order to determine the precise age of volcanic rocks in the Mahallat Region, they should be sampled and analyzed using radioactive dating methods.
- By conducting a detailed geological, geochemical and geophysical study in the Mahallat region, more reliable data on the nature of the Mahallat geothermal resource can be obtained.

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Table 5. Approximate Temperature of Mahallat Geothermal System

Geothermometer	**SiO** (1)	**SiO_2** (2)	**Na-Ca** (3)	**K-Mg** (4)	**Na-K** (5)	**Na-K** (6)	**Na-K** (7)	**Na-K** (8)	**Na-K** (9)	**Na-K** (10)	**Na-K** (11)	**T_{mean}**
Estimated Temp. (ºC)	54	57	86	46	134	141	179	171	150	166	197	162

(1)- Fournier (1977)

(2)- Arnorsson et al, (1983)

(3)- Tonani (1980)

(4)- Giggenbach (1988)

(5)- Fournier and Truesdell (1973)

(6)- Truesdell (1975)

(7)- Fournier (1979)

(8)- Tonani (1980)

(9)- Arnorsson et al, (1983)

(10)- Nieva and Nieva (1987)

(11)- Giggenbach (1988)