Hydrochemical Properties of the Thermal Waters of Mahalat Abgarm, Iran

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ABSTRACT

Thermal waters are mainly SO_4-Ca type, with high TDS, while cold waters are mostly SO_4-Ca and HCO_3-Ca type respectively. Hydrogeological parameters affecting spring waters include dissolution, hydrolysis and alteration. In the thermal waters, high Ca, Mg, Na and K interpreted to be due to leaching of cations in the rocks by water. High SO_4 and high Ca+Mg and low Cl suggested a carbonate source with anhydrite. Chemical changes of the cold water samples were highly influenced by water-rock interaction.

1. Introduction

Springs can be classified into different water types based on the compositions of their major ions (Minissale et al., 1997; Mariner et al., 2003). Major ions in spring waters include HCO_3^-, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} which mainly originate water – rock interation (Davisson et al., 1994; Minissale et al., 1997). Therefore the water quality of springs is highly associated with their geological conditions and evolution, and hydrochemical composition of spring water can indicated the geological origin (Sanada et al., 2006; Tarits et al., 2006). Furthermore, temperatures and pH of the springs exhibit high variability, resulting in significant difference in species and quantities of hydrochemical parameters. For instance, bicarbonate ions which stem from the dissolution of carbonate-rich rocks are controlled by pH in water and are present within the pH range of 4 to10 (Chen and Sung, 2009). Zhu and Yu (1995) documented that high temperatures in spring waters tend to increase dissolution quantities of certain ions, such as K^+, Na^+, Cl^- and SiO_2.

2. Geology of Study Area

The study area is situated in the central part of Iran in Markazi Province near Mahalat City. The study area is located in the central Iran volcanic zone. Formation of the basin begun on Paleozoic time. The dolomite and limestone of Permian age can be observed. The geomorphology of the region is mountainous. Sediments of Eocene age consist of marl, sandstone, shale and conglomerate (Araghi, 2009) (Fig. 1).

3. Field Work of Springs and Laboratory Analysis

Water samples were collected from thermal and non-thermal springs in 1995, 2009, June 2010 and September 2010 (20 thermal

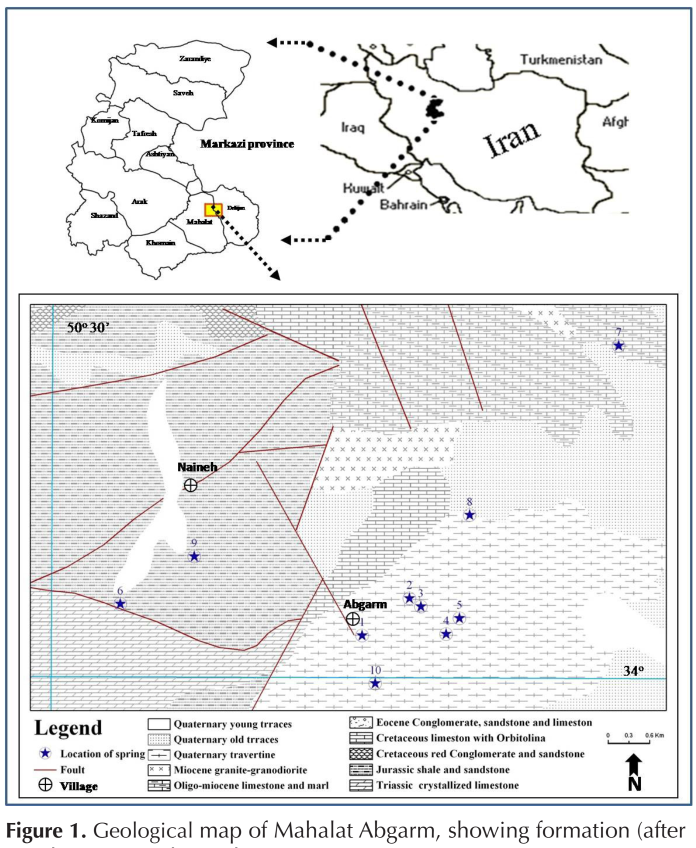

Figure 1. Geological map of Mahalat Abgarm, showing formation (after Araghi 2009) and sample points.

Table 1. Chemical data average for thermal and non-thermal waters.

No.	Name	Tem	pH	EC	TDS	Na	K	Ca	Mg	SO_4	Cl	HCO_3	SiO_2	$\delta^{18}O$	δ^2H
		°C		µs/cm	mg/l									‰	
1	Shafa	47.3	6.7	1783	1137	131	4.6	257	44.7	735	50.2	222	40	-9.40	-66.5
2	Dombeh	46	6.7	1782	1142	131	4.2	253	48.6	904	50.4	198	41	-9.47	-68.4
3	Solimani	46	6.8	1781	1131	130	5.5	263	48.4	889	50	207	42	-9.29	-66.6
4	Soda	45.1	6.8	1786	1140	126	3.5	262	49.7	969	49.5	209	35	-9.25	-63.9
5	Naineh	19.9	8.2	652	362	47	2.2	112	21.3	170	55.4	171	40	-9.42	-64.4
6	Abgarm	35.8	7.1	1782	1146	125	4.7	252	53	889	49.4	203	37	-9.11	-64.3
7	Ziaratghah	18.4	8	332	572	10	2.7	64	15.1	47	21.4	140	13.1	-8.97	-56.8
8	Siagohar	18.2	7.3	1612	912	133	3.5	271	42.9	905	67.7	187	32.4	-8.80	-63.3
9	Talkheh	25	8.1	2470	1434	184	4.29	350	96	1634	76	138	22.2	-7.20	-54.4
10	Biname	19.8	8.1	2170	1259	166	4.29	318	78	1318	63.5	215	37	-8.52	-61.3

and 10 samples of non-thermal springs). The discharge rates of these springs vary from less that 5 to 0.5 l/s and their fluid temperatures range between 18.2°C and 47.3°C. Physico-chemical parameters of the waters, such as temperature, pH and electrical conductivity (EC), were measured in the field, while Ca, K, Mg, Na, HCO_3, SO_4 and Cl ions were measured in the laboratory using standard titration and inductivity coupled plasma (ICP) methods. Silica was determined using a HACH/2000 spectrophotometer. The results of the chemical data are present in Table1. Each element was above detection limit.

4. Hydrochemical Features of Springs

The hydrochemical data are shown on the piper diagram (in Fig. 2). The central diamond-shaped figure indicates that most spring waters concentrate in the high SO_4 water. All of the thermal springs and three non-thermal springs fall into SO_4 regions but two springs of non-thermal springs with relatively high bicarbonate are distant from the above group, Table 2. Lists hydrochemical parameters in thermal and non-thermal springs. Thermal spring temperatures and pH of discharging water range from 35.8 to 47.3°C and from 6.7 to 7.1, respectively. The spring water is reach in SO_4^{2-}, Ca^{2+} ions and contains small amounts of Cl^-, Mg^{2+}, Na^+, K^+, HCO_3^- ions except spring 7 and 5. Spring 7 is in HCO_3^- and Ca^{2+} ions and spring 5 is rich in SO_4^{2-} and Mg^{2+} ions.

All of the springs are close to the hydrothermal source, therefore, are rich in $SO_4^{2-}$and springs emerged from lime-

Table 2. Statistics associated with hydrochemical parameters of thermal and non-thermal springs.

Statistical parameters		Temp	pH	EC	TDS	Na	K	Ca	Mg	SO_4	Cl	HCO_3	SiO_2
		°C		µs/cm	mg/l								
Thermal Springs	**Average**	43.8	6.82	1782	1139.2	128.6	4.50	257.4	48.9	877	49.9	207	39
	Maximum	47.3	7.10	1786	1146	131	5.50	263	53	969	50.4	222	42
	Minimum	35.8	6.70	1781	1131	125	3.50	252	44.7	735	49.4	198	35
Non-Thermal Spring	**Average**	20.3	7.94	1367	907.8	108	3.40	223	50.7	815	56.8	170	28.9
	Maximum	25	8.20	2470	1434	184	4.29	350	96	1634	76	215	40
	Minimum	18.2	7.10	332	362	101	2.20	64	15.1	47	21.4	138	13.1

stone, have abundant Ca^{2+} ions. Spring 7 is non-thermal and has abundant HCO_3^-. Rocks of all springs are limestone and have abundant Ca^{2+} ions.

Thermal springs have Ca^{2+}> (Na^++K^+)> Mg^{2+} and SO_4^{2-}> HCO_3^-> Cl^- and have high SiO_2 concentrations. SiO_2 contents of thermal springs range from 35 to 42 mg/l. EC values for thermal springs are 1783 µs/cm. Non-thermal springs have Ca^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-}, and SiO_2 less than thermal springs except Mg^{2+} and Cl^-. EC values for these springs are 908 µs/cm and SiO_2 values change from 13.10 to 40 mg/l.

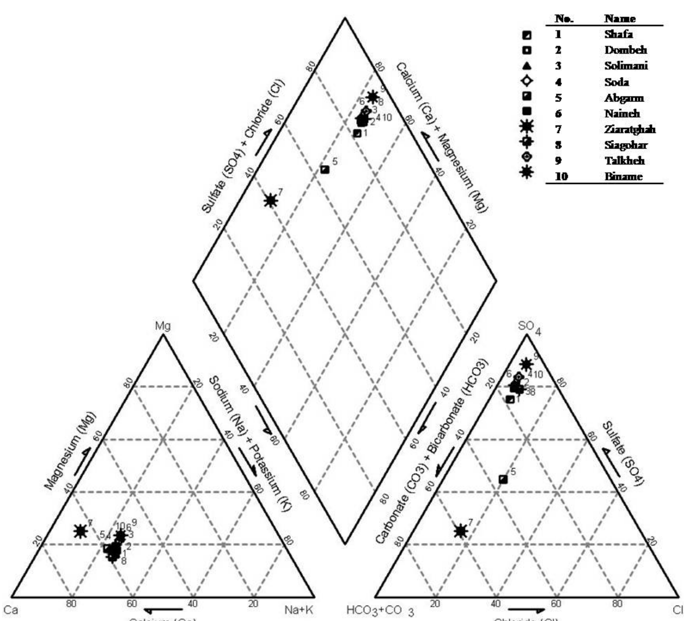

Figure 2. Piper diagram of spring water of Mahalat Abgarm.

5. Water Chemistry

Major ion composition can record of water-rock interaction during flow (Moller et al., 2007). The hydrochemical characteristics of various waters can be seen from physico-chemical data (Table 1) and Piper plots (Fig. 2). The thermal and non-thermal springs plot in distinct fields. Thermal spring samples are SO_4-Ca in chemical. TDS, EC, Na^+, K^+, Ca^{2+}, HCO_3^-, SO_4^{2-} and SiO_2 concentrations with a mean TDS of 1139 mg/l are higher than in non-thermal springs. Mg^{2+} and Cl^- concentrations are lower in the thermal springs than non–thermal water. Higher TDS in the thermal springs probably reflect longer circulation and residence times. The thermal springs of Mahalat Abgarm flow through karst aquifers. This is likely responsible for the higher Ca^{2+} and SO_4^{2-} in this water. Non-thermal springs are mainly SO_4. HCO_3-Ca type with mean TDS of 908 mg/l, which are close to the thermal region. (Han et al., 2010).

The cations of these solutes can be derived from rock dissolution by chemical weathering. The typical rock composition in this area was calculated on the basis of a pervious study (Hatafi et al., 2009). The result showed that calcite, quarts, goethite, gypsum, plagioclase, orthoclase, biotite, illite, muscovite and clay minerals such as montmorillonite and vermiculite occupies the all minerals of Mahalat Abgarm area. This composition suggests that the leaching rate of Ca, K, Mg and Na should be significant in the initial stage of water interaction process, according to the Goldich series (Goldich, 1938). Experimental works also demonstrate that calcite, plagioclase and orthoclase dissolution affect the initial water formation by water- rock interactions (Tamari et al., 1988) and the neutralized of acidic water is completed within several days.

Samples are very high SO_4 contentsand high Ca+Mg and low Cl suggest a carbonate source with anhydrite.The high HCO_3 of the water from thermal waters after SO_4 is typical of meteoric waters forming at the margins of major up flow zones through conversion of dissolved CO_2 to HCO_3. Water-rock interaction at decreasing temperature favors the formation of HCO_3 (Giggenbach et al., 1995).

The high CO_2 values result from volatiles escaping from a deeper limestone aquifer (Baitollahi, 1995), that interact with shallow waters of meteoric origin; meteoric origin is the clearly shown by the fact that the samples lie close to the GMWL on the δ^{18}O-D plot (Fig. 3). The main rock for thermal water is Permian limestone in the Mahalat Abgarm and there is thick travertine deposit around of thermal springs (Araghi, 2009) that verify degassing of CO_2 from springs (Ghorbani, 2009). In cold water, hydrochemical parameters (cations and anions) are the major solutes leached from rocks or discharged from rocks by dissolution from rocks such as marl, sandstone, and conglomerate host rocks (Araghi, 2009).

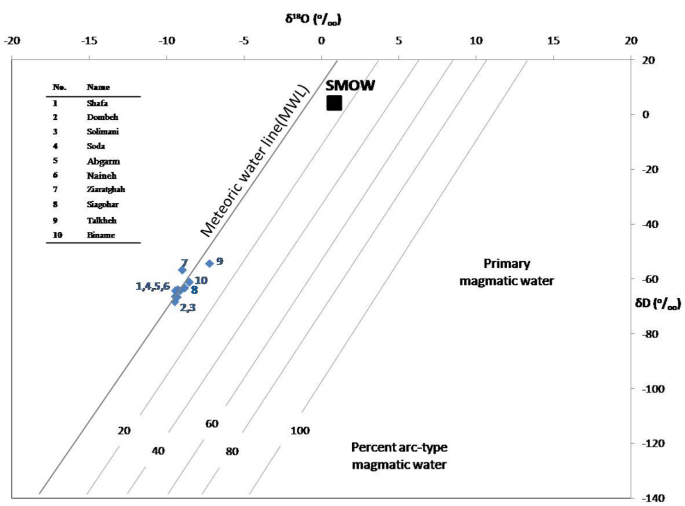

Figure 3. δ^{18}O vs. D Plot in thermal water from Mahalat Abgarm area (Giggenback, 1997).

6. Conclusion

Mahalat Abgarm spring waters of resualts leaching of cations in the rocks by meteoric/ thermal waters. High SO_4, Ca, Mg and low Cl suggest a carbonate source with anhydrite. Dissolved HCO_3 and the high CO_2 values result from volatiles escaping from a deeper limestone aquifer that interact with shallow water of meteoric origin.The cold spring waters of Mahalat Abgarm was contributed by water-rock interaction; Na, K, Ca, Mg, SO_4, and Cl dissolution from marl, sandstone, limestone and conglomerate rocks of process of thermal waters causes over HCO_3 and SiO_2 in cold waters.

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