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Geochemical Interpretation of Thermal Water Samples from Eastern Part of Mt. Sabalan, Nw – Iran

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ABSTRACT

There are several thermal springs in the eastern part of Mt. Sabalan with temperatures ranging from 16 to 47°C. The thermal waters from the eastern part of Mt. Sabalan were found to be peripheral and steam heated waters according to Cl-SO4-HCO3 ternary diagram. The Na-K-Mg-Ca diagram shows that all the thermal waters plotted far from the full equilibration curve indicating these waters are probably not fully equilibrated or high degree of mixing with cold groundwater and or re- equilibration. The Na-K-Mg triangular diagram indicates that all of the waters are immature waters with high Mg content and the application of both Na-K and K-Mg geothermometers becomes doubtful. The Mg content in most of the thermal samples is high, ranging between 8.6 -57 mg/kg. The relationship between δD and $\delta^{18}O$ shows that the waters are predominantly meteoric as they are in the meteoric trend line. The silica geothermometers provide the most reliable temperatures for this area, with predicted subsurface temperature values ranging from 96 to 147°C. The geochemical studies and field observations suggest that the study area is a low-temperature geothermal system.

1. INTRODUCTION

Geochemical exploration relies mostly on sampling and analysis of water, steam and gas from thermal manifestations in order to characterize the fluids, estimate equilibrium reservoir temperature, determine the origin, evaluate mixing scenarios, determine the suitability of the fluids for the intended use and locate recharge areas and direction of fluid flow. Mount Sabalan is located in the northwest of Iran (Figure 1) and has several geothermal fields in the north, northwest, east and south. Eastern part of Mt. Sabalan is a very special area where development of geothermal energy will be significant for socio-economic activities. There are several thermal springs in the eastern part of Mt. Sabalan with temperatures ranging from 16 to 47°C. The primary data (Samples and chemical composition table) in this research is taken from previous researches by Entes Nazionale per L'Energia Elettrica of Italy (ENEL) (1983), Tehran Berkley Consulting Engineers (TBCE) (1979) and Shahroud University of Technology (SUT) (2014). The water samples from thermal springs and few cold springs were used with the purpose of estimating and interpreting the chemical compositions of the waters, by methods as chemical and isotopic diagrams and geothermometers using Excel Spreadsheets (Powell and Cumming, 2010).



Figure 1: Location of Mt. Sabalan.

Table 1: Chemical composition of thermal and cold springs in the eastern part of Mt. Sabalan (mg/kg); * From TBCE (1979) and ** from ENEL(1983); Others from SUT (2014). SN: Sarein; VD: Vakil abad; VH: Vila darrah; JH: Jenagheyeh; EA: Erdi mousa; JL: General; PU: Pahnalu; AH: Atashgah; GI: Ghahvasuei; GS: Gozasuei; SU: Sarisuei; GU: Qarasuei; GL: Gavmishgoli; SB: Sardaba; AR: Arjestan. C in VHC and EAC shows that they are cold springs.

Sample	Temp.(°C)	pH	Li	Na	K	Ca	Mg	SiO_2	B	Cl	F	SO_4	HCO_3	Rb	Cs	Sr	Ba	Fe	Mn	$\delta^{18}O$(‰)	δD(‰)
***SN1(1003)**	16	5.60	0.01	13	2.5	42	9.8	78	0.0	5	0.4	48	140	0.02	0.05	0.07	<1.5	<1.1	<1.8	-12.4	-74.8
***SN2(1004)**	47	6.00	0.47	191	36	72	18.2	105	1.9	209	0.3	96	415	0.35	1.05	0.24	<1.5	3.16	0.38	-11.2	-74.3
***VD1(1009)**	36	4.60	0.01	23	6.3	174	8.6	84	<2.8	2	0.5	480	16	0.04	0.06	0.20	<1.5	0.02	0.47	-12.5	-74.9
***VD2(1010)**	22	4.50	0.02	20	6.3	170	8.7	68	0.4	4	0.4	442	28	0.02	0.00	0.33	<1.5	0.15	0.44	-11.6	__
****VH1(051)**	23	6.20	0.00	32	8.6	56	13.4	118	0.00	6	__	37	229	0.00	__	0.20	__	0.00	2.01	-11.5	__
***VH2(1001)**	17	5.90	0.02	25	6.6	54	13.4	106	0.00	4	0.1	35	256	0.06	0.07	0.14	<1.5	<1.1	<1.8	-12.8	-74.6
***VHC(1002)**	11	6.30	0.00	12	2.0	46	12	84	0.1	4	0.4	12	195	0.01	0.04	0.10	<1.5	<1.1	<1.8	-10.8	__
***JH(1007)**	23	5.50	0.12	62	16.8	44	12	107	0.5	29	0.7	96	250	0.12	0.10	0.10	<1.5	<1.1	<1.8	-12.4	__
***EAC(1008)**	7	7.00	0.01	17	3.9	78	12	0.00	0.2	4	0.5	41	281	0.00	0.00	0.37	<1.5	<0.54	<1.8	-12.1	__
JL(9)	42.3	7.07	0.68	210.5	35.75	79.66	18.45	__	1.41	191	__	229.44	396.5	0.17	0.14	0.53	0.09	3.16	0.40	-11.45	-69.3
PU(10)	44.5	7.03	0.68	205.6	36.86	79.23	19.17	__	1.44	187	__	360.96	311.1	0.19	0.15	0.50	0.06	3.86	0.41	-11.56	-59.1
VD3(11)	16.5	6.45	0.04	38.01	6.45	61.93	16.68	__	0.05	7	__	22.08	256.2	0.03	0.01	0.50	0.02	0.01	0.03	-11.59	-73.2
AH1(14)	16.4	6.44	0.03	42.56	10.99	99.40	18.58	__	0.05	5	__	291.84	219.6	0.04	0.01	0.50	0.01	0.01	0.05	-11.42	-73.9
GI(15)	43.5	6.84	7.07	230	182	250	57	__	0.20	213	__	235.2	402.6	0.97	0.89	9.89	0.06	1	0.17	-11.41	-73.6
GS(16)	20.6	6.23	0.24	87.40	17.32	93.61	16.30	__	0.49	80	__	337.92	201.3	0.08	0.07	0.62	0.07	0.14	0.21	-11.21	-72.5
SU(17)	44.7	6.57	0.69	210.1	35.51	79.77	18.54	__	1.42	190	__	225.6	387.35	0.18	0.14	0.52	0.09	3.64	0.39	-11.01	-62.5
GU(18)	42.5	6.41	0.69	204.5	35.51	84.82	18.64	__	1.43	187	__	255.36	405.65	0.17	0.14	0.58	0.10	3.41	0.37	-11.36	-70.5
GL(19)	45.3	6.58	0.71	210.8	36.30	80.27	18.90	__	1.46	191	__	260.16	396.5	0.18	0.13	0.53	0.07	3.01	0.36	-11.40	-67.0
SB(35)	35.6	5.33	0.02	23.60	6.62	213	10.31	__	0.05	10.65	__	916.8	18.3	0.01	0.00	0.30	0.02	0.01	0.49	-11.65	-72.5
AR(12)	16	6.40	0.02	22.49	12.45	65.43	16.06	__	0.05	10	__	99.84	231.8	0.02	0.01	0.51	0.00	0.01	0.01	__	__

Table 2: The results of the geothermometers for water samples from thermal springs in the eastern part of Mt. Sabalan (°C)

Sample	$T_{Chalcedony}$ (Conductive)	T_{Quartz} (Conductive)	T_{Quartz} (Adiabatic)	$T_{Na-K-Ca}$	$T_{Na-K-Ca}$ (Mg Corr.)	$T_{Na/K}$ (Fournier)	$T_{Na/K}$ (Truesdell)	$T_{Na/K}$ (Giggenbach)	$T_{K/Mg}$ (Giggenbach)
SN1(1003)	96	124	121	25	-14	280	271	291	39
SN2(1004)	114	140	135	207	-36	278	268	289	91
VD1(1009)	100	128	125	29	29	322	330	328	59
VD2(1010)	88	117	115	28	28	340	356	344	59
VH1(051)	121	147	141	60	-36	319	326	326	61
VH2(1001)	114	141	135	51	-37	317	323	324	55
JH(1007)	115	141	136	94	-54	320	328	327	77
JL(9)	—	—	—	123	-33	267	253	278	91
PU(10)	—	—	—	124	-38	273	260	284	91
VD3(11)	—	—	—	51	-50	267	253	278	52
AH1(14)	—	—	—	59	-7	314	319	321	63
GI(15)	—	—	—	164	-15	495	619	478	121
GS(16)	—	—	—	81	-3	284	275	294	75
SU(17)	—	—	—	123	-34	267	252	278	91
GU(18)	—	—	—	121	-28	269	256	281	91
GL(19)	—	—	—	124	-35	268	255	280	91
SB(35)	—	—	—	27	27	325	334	331	58
AR(12)	—	—	—	64	-39	426	495	419	67

2. CHEMICAL FEATURES OF THE WATERS

The chemical composition of waters from the eastern part of Mt. Sabalan is given in Table 1. As seen in the table, Mg content in thermal waters is high. The springs have quite variable bicarbonate and sulphate concentrations with the highest SO_4 occurring at the highest elevation. At lower elevations SO_4 appears to be replaced by HCO_3, possibly by the interaction with carbonate rock (and loss of SO_4 as gypsum). Also, the thermal waters of this part of Mount Sabalan are immature.

2.1 Cl-SO_4-HCO_3 Triangular Diagram

As shown in Figure 2, the thermal samples from the study area are mainly spread in the HCO_3 corner and a few plot in the steam heated waters part close to the SO_4 corner. This indicates that most of the samples are peripheral waters, where one can use geothermometers. In this case study, samples which are the steam heated waters (VD1, VD2, SB, PU, GS and AH1), are not suitable for geothermometers according to Giggenbach (1991).

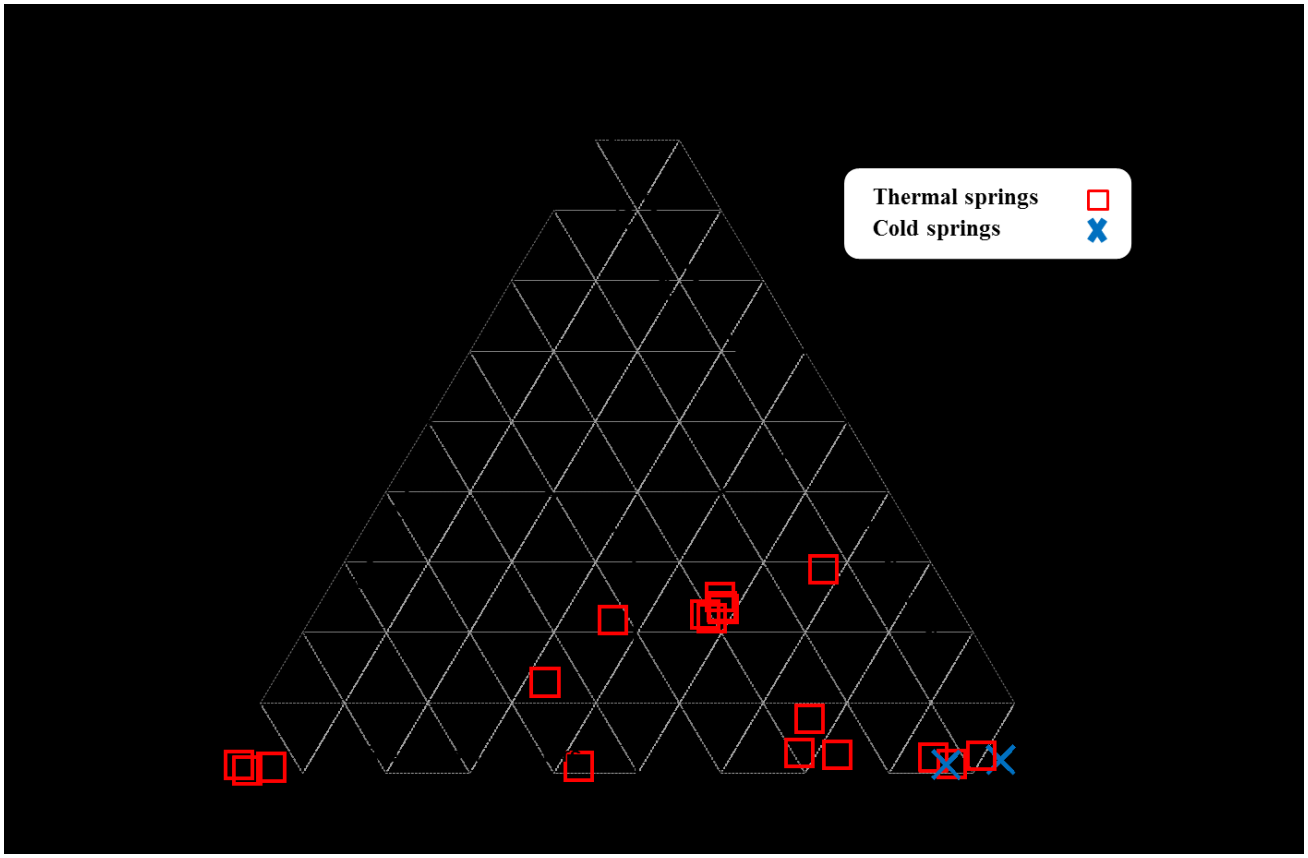

Figure 2: Cl-SO_4-HCO_3 triangular diagram for water samples from thermal and cold springs in the eastern part of Mt. Sabalan.

2.2 Na-K-Mg Triangular Diagram

Figure 3 shows that all samples are placed as immature waters with high Mg content. In this place, samples are frequently quite acid or CO_2 rich waters and therefore according to Giggenbach (1991) the application of both the Na-K and K-Mg geothermometers becomes doubtful.

2.3 Na-K-Mg-Ca Diagram

The Na-K-Mg-Ca diagram shows that all the thermal waters plotted far from the full equilibration curve indicating these waters are probably not fully equilibrated or high degree of mixing with cold groundwater and or re- equilibration (Figure 4).

2.4 Mg Level in Thermal Waters

In the high-temperature fluid, Mg is readily associated into secondary alteration minerals such as illite, montmorillonite and especially chlorite. Higher Mg concentrations in thermal fluid can either indicate leaching of Mg from the local rock and acid alteration or dilution by groundwater which has high Mg concentration. The Mg content in the thermal samples of the study area is high, ranging between 8.6 -57 mg/kg suggest the waters have either: have mixed with high Mg groundwaters or been cool for a long time or have an acidic history.

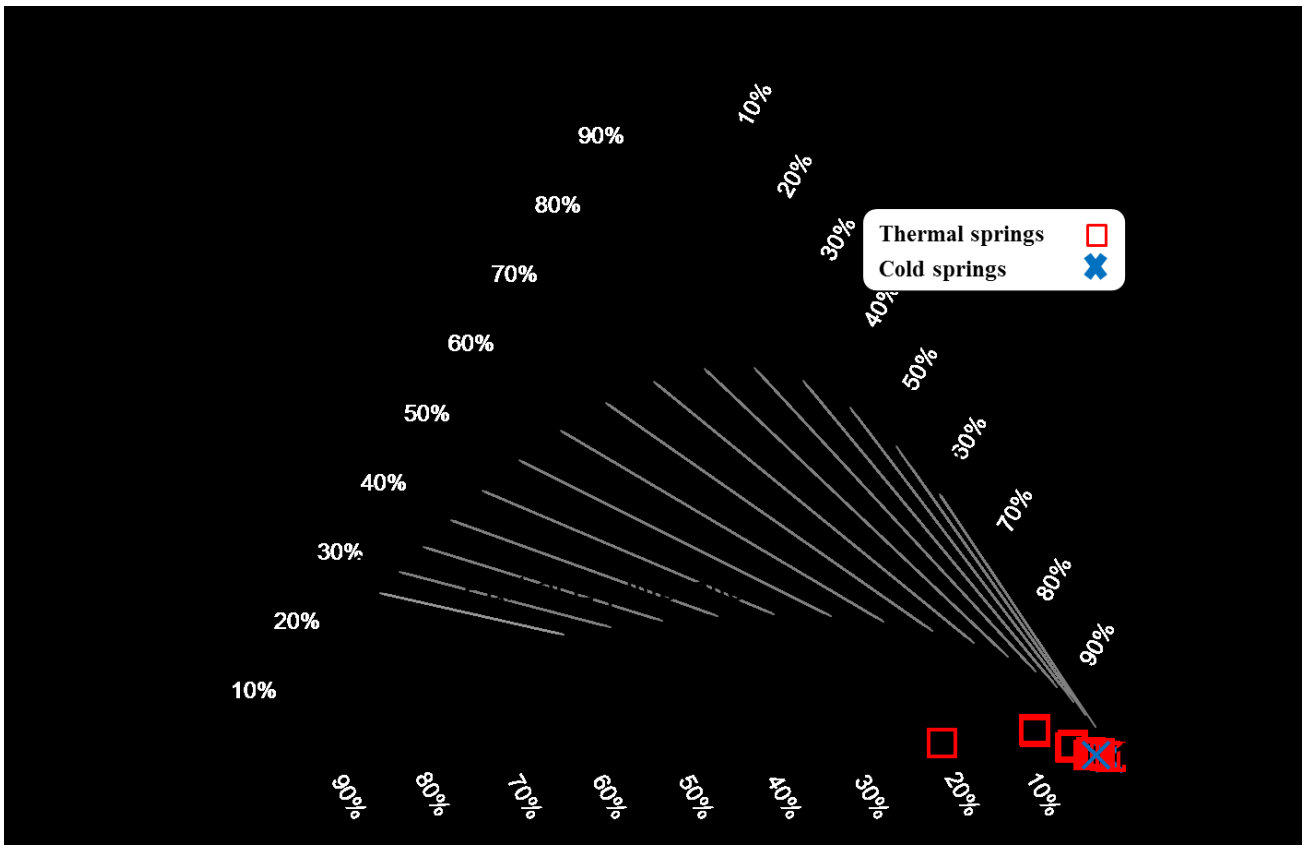

Figure 3: Na-K-Mg triangular diagram for water samples from thermal and cold springs in the eastern part of Mt. Sabalan.

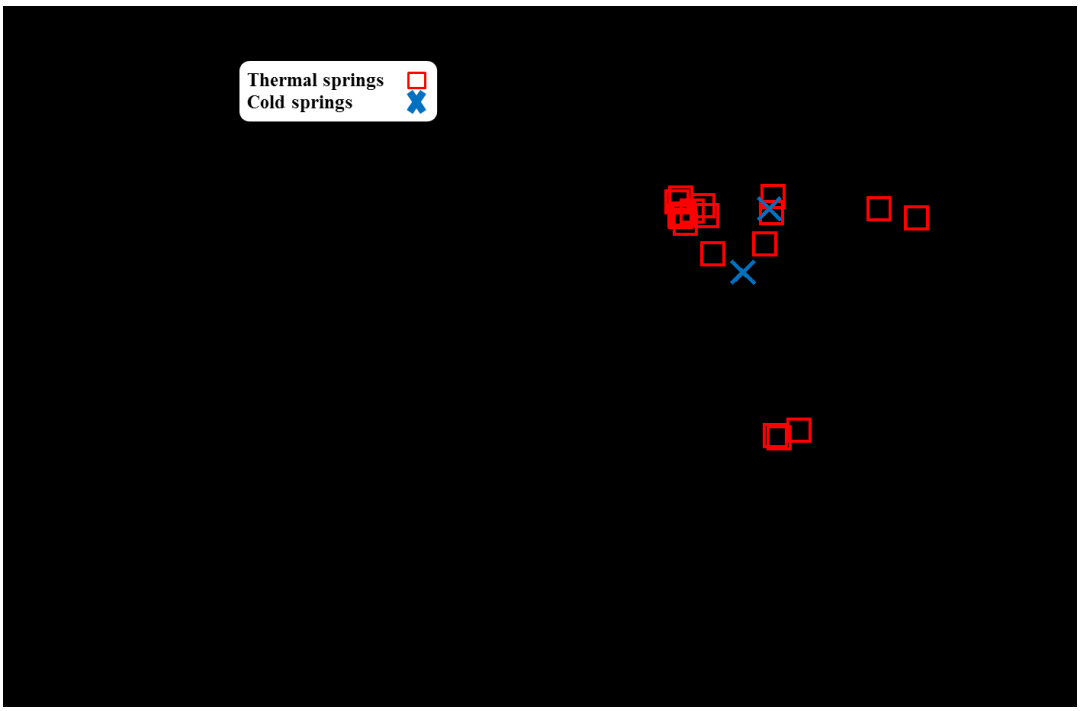

Figure 4: Na-K-Mg-Ca diagram for water samples from thermal and cold springs in the eastern part of Mt. Sabalan.

2.5 Origin of Geothermal Waters

The relationship between δD and $\delta^{18}O$ indicates that thermal waters are predominantly meteoric as they are in the meteoric trend line (Figure 5).

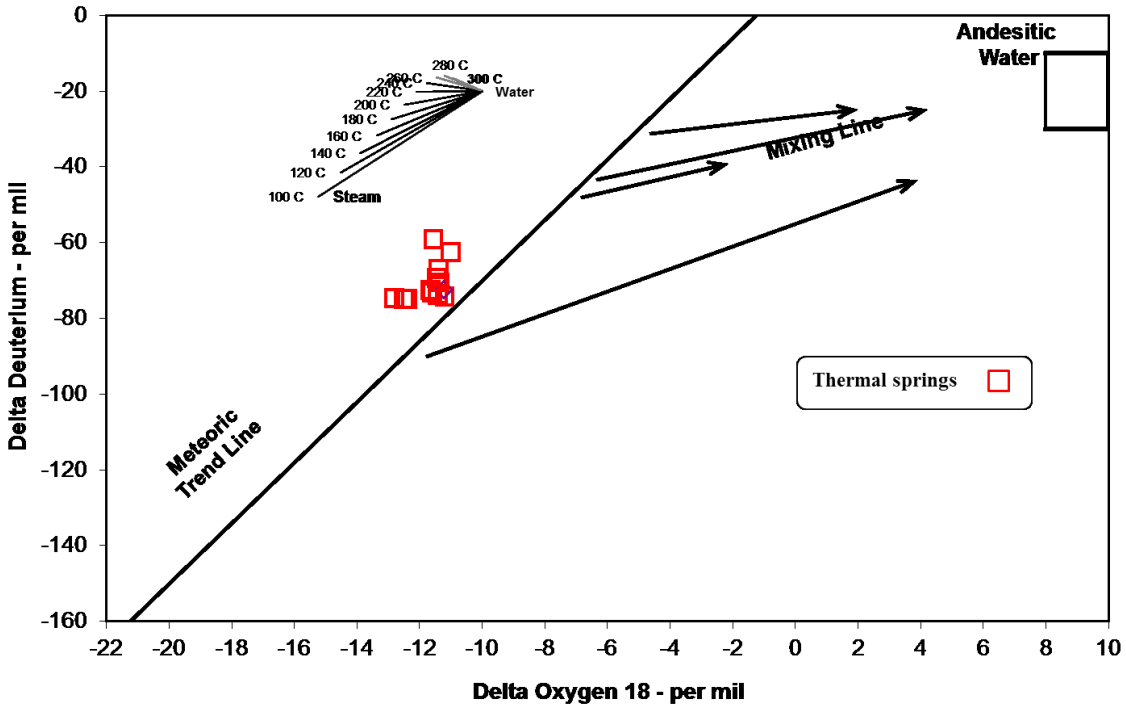

Figure 5: $\delta^{18}O$ vs. δD for water samples from thermal springs in the eastern part of Mt. Sabalan.

3. GEOTHERMOMETRY

The results of the different geothermometers are shown in Table 2.When we use the geothemometers, most of the problems in their use arise from their application to unsuitable samples. As mentioned above, samples VD1, VD2, SB, PU, GS and AH1 which are the steam heated waters are not suitable for geothermometers according to Giggenbach (1991). Due to Na-K-Mg triangular diagram which explained and according to Giggenbach (1991), application of both the Na-K and K-Mg geothermometers becomes doubtful. Moreover, the Na-K-Ca geothermometer gave very low temperatures for most samples; some of these temperatures are below or near surface temperatures. According to Fournier (1991) Na-K-Ca geothermometer is entirely empirical and will give excellent results for most water above 200°C, but also give erratic results for water at less than 200°C. The erratic results are affected by exchange reactions involving Na^+, K^+ or Ca^{+2} with additional ions as Mg (like this case study) and precipitation of calcium as carbonate where solutions boil on the way from the reservoir to the surface. Also, the calculated temperatures for the reservoir by the Na-K-Ca Mg correction geothermometer are negative for most samples and for the rest samples they are lower than the spring's temperature. So, the silica geothermometers based on chalcedony conductive and quartz conductive provide the most reliable temperatures for this area, with predicted subsurface temperature values ranging from 96 to 147°C.

4. CONCLUSION

The geochemical studies and field observations suggest that the study area is a low-temperature geothermal system. According to the water classification in the Na-K-Mg ternary diagram and also Na-K-Mg-Ca diagram, all the water samples in the study area are immature and have high Mg content so they might be mixed with cold groundwater. Most of the thermal waters in the study area are peripheral waters and some are steam heated waters and some geothermometers can be used for these waters but are not suitable for steam heated samples. The chemical properties of thermal waters in the eastern part of Mt. Sabalan showed that the cation geothermometers are not suitable to estimating subsurface temperature in this area. Therefore, Silica geothermometers appear to be the most suitable geothermometers for the waters of this area, which estimated subsurface temperatures from 96 to 147°C.The relationship of $\delta^{18}O$ vs. δD indicated that the thermal waters are predominantly meteoric.

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