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Chemical geothermometry studies on a geothermal system in Manza hot springs near Kusatsu-Shirane volcano, Japan

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Abstract

Changes in temperatures in shallow geothermal systems beneath the Manza area in the Kusatsu-Shirane volcano region, Japan with time, were reconstructed by using chemical geothermometers derived from long-term data on the water chemistry of three typical hot springs in the area from almost the last fifty years. The calculated equilibrium temperatures for quartz, anhydrite and alunite were helpful in understanding the state of the hydrothermal systems in the area. Although the measured water temperatures of the hot springs at their vents have decreased gradually since the 1970s, the temperatures of the geothermal systems in the area do not seem to be in a downward trend based on the geothermometry. The temperatures of the geothermal systems have probably fluctuated in response to changes in the volcanic activity of the Kusatsu-Shirane volcano. The changes in the estimated equilibrium temperatures for appropriate minerals give us helpful information on the volcanic activity that we cannot obtain directly, by monitoring of water chemistry of hot springs in the volcanic area.

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Keywords: Kusatsu-Shirane volcano; Manza hot springs; geothermometry; geothermal system; water chemistry; hydrothermal fluids

1. Introduction

The Manza hot spring area is located about 2 km southwest of the summit of the Kusatsu-Shirane volcano, which is one of the most famous active volcanoes in Japan. The hot springs of the area issue from a sulfurous alteration zone composed of siliceous and argillaceous zones originating in andesitic rock formations[1], and hot springs of different chemical types can be found in the area[2,3]. It is known that the water chemistry of some hot springs in the area shows fluctuation related to the volcanic activity of the Kusatsu-Shirane volcano[2]. In this study, we attempt to

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reconstruct the change in the temperature of the geothermal system lying beneath the Manza area chronologically based on chemical geothermometer data on the water for hot springs in the area over the past five decades.

2. Experimental

We selected the three major hot springs in the Manza area, Manza-yubatake, Oku-Manza, and Manza-karafuki, for this study. Waters of these three have been periodically sampled and analyzed for their water chemistry in our annual geochemical observations since 1969. The chemical analysis has been conducted by conventional methods[2,3]. The water chemistry results for the three hot springs since 1969 were subjected to chemical geothermometry calculations. The calculations were conducted using the geochemical code, “react”, in the software package “The Geochemist’s Workbench, Release 9”, and then the equilibrium states, i.e. saturation indices, for various minerals were computed as a function of temperature[4]. The parameters input for the computations were pH and the Na^+, K^+, Mg^{2+}, Ca^{2+}, Al^{3+}, Fe, Si, Cl^-, SO_4^{2-} and H_2S concentrations. The input data is listed in Table 1 and in a previous paper[2]. As for the Manza-karafuki hot spring, its water had originally gushed with fumarolic gasses at the boiling point at its altitude. Since 2002, however, we have not been able to sample the Manza-karafuki water, because there was a landslide in a small valley in which this water vent was located in 2001, and the original vent has been lost since that time.

Table 1. Water chemistries of hot spring water used for chemical geothermometry calculations.

Sampling location	Sampling date	WT (ºC)	pH	Cation (mg/L)							Anion (mg/L)		SiO_2 (mg/L)	H_2S (mg/L)
				Na	K	Ca	Mg	Fe	Al	Mn	Cl^-	SO_4^{2-}		
	2000-08-02	75.4	2.40	96	26.8	55.0	64.4	4.2	8.1	5.3	127	816	111	97.1
	2001-08-02	75.7	2.41	99	26.9	52.4	62.6	4.2	8.3	5.1	---	---	108	62.4
	2003-08-05	75.1	2.36	102	26.6	52.3	58.8	3.9	7.9	4.9	123	746	110	80.1
	2004-07-28	75.0	2.32	104	26.9	55.9	57.9	4.2	8.1	4.7	126	725	104	72.6
	2005-07-28	74.6	2.31	99	25.8	51.8	55.5	4.7	8.4	4.2	122	690	106	83.7
	2006-08-03	74.1	2.40	96	25.1	49.4	51.2	5.2	8.6	4.0	---	---	104	---
	2007-08-02	73.6	2.32	96	25.2	50.7	49.1	4.6	8.4	3.7	126	721	88.8	93.6
Manza-yubatake	2008-07-28	72.9	2.23	94	25.0	50.1	50.0	5.2	8.3	3.8	120	719	103	77.0
	2009-08-05	73.2	2.40	99	24.5	47.8	50.4	5.2	7.5	3.4	104	723	107	53.8
	2010-08-02	72.7	2.07	99	25.2	43.9	45.8	5.2	7.5	3.8	119	683	98.8	71.2
	2011-07-28	73.3	2.11	102	25.2	43.2	45.8	4.8	7.3	3.8	122	680	101	81.6
	2012-07-30	72.0	2.42	100	24.6	42.2	43.2	5.1	6.9	3.5	116	669	99.0	77.4
	2013-07-30	73.7	2.55	107	26.3	42.3	44.3	3.3	6.0	3.7	123	676	100	111
	2014-07-31	72.7	2.43	102	25.1	41.7	42.0	3.2	5.6	3.3	115	663	101	72.4
	2015-07-31	---	2.44	97	23.6	42.0	41.5	4.6	6.4	3.4	107	740	104	18.6
	2000-08-05	46.3	2.81	30.4	5.63	110	18.0	1.4	9.2	0.86	69.4	428	68.0	378
	2001-08-02	45.6	3.06	30.1	5.28	107	19.2	1.4	9.2	0.89	---	---	65.5	334
	2002-07-31	45.2	3.07	30.2	5.29	106	18.6	1.5	9.8	0.89	59.0	367	65.5	---
	2003-08-04	43.8	2.86	30.2	5.50	103	19.0	1.3	9.9	0.88	62.6	381	63.7	356
	2004-07-31	43.4	2.95	30.3	5.50	107	18.9	2.3	10.3	0.90	64.5	398	65.0	306
	2005-07-28	42.1	2.92	29.8	5.39	104	19.0	2.1	10.2	0.86	61.0	366	61.6	185
	2006-08-04	43.7	3.09	---	---	---	---	---	---	---	---	---	---	---
Oku-Manza	2007-08-02	43.3	3.02	31.0	5.52	107	19.9	1.4	9.7	0.84	66.0	410	59.0	216
	2008-07-28	42.8	2.81	30.7	5.45	102	18.9	1.5	9.0	0.84	61.9	411	59.0	313
	2009-08-05	42.3	3.20	31.3	6.68	111	17.8	1.7	4.9	0.73	55.6	415	62.5	237
	2010-08-02	42.7	2.93	31.1	5.45	103	17.7	1.4	11.9	0.80	65.9	575	58.0	354
	2011-07-28	41.7	2.83	31.1	6.02	99.6	18.0	1.8	8.1	0.87	66.2	477	58.6	229
	2012-07-30	41.2	3.02	31.3	5.73	97.3	17.2	1.2	7.0	0.80	64.4	421	57.8	273
	2013-07-30	40.8	3.13	30.7	5.29	101	17.8	1.1	6.7	0.79	66.3	795	59.9	302
	2014-07-31	41.6	3.03	30.3	5.26	96.2	16.8	1.2	6.6	0.75	63.5	414	58.8	337
	2015-07-31	40.9	3.13	29.8	5.37	92.9	16.9	1.2	6.8	0.71	61.1	395	58.6	275
Manza-karafuki	2001-08-02	86.2	1.44	414	138	64.6	297	6.0	47.3	22.5	756	4718	350	---