GEOCHEMICAL STUDIES OF THE GINYU RESERVOIR IN THE KIRISHIMA GEOTHERMAL FIELD

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Abstract

This is the presentation of the result of geochemical study based on chemical and isotope data of discharge fluids and surface waters in the Kirishima geothermal area. Almost discharge waters from the wells drilled in the Kirishima geothermal area are characterized by the near-neutral pH Na-K-Cl-SO_4 type ,and these discharge fluids are provided from the water-dominated hydrothermal system. The Ginyu Fault reservoir fluids would be derived from meteoric water which precipitated to the Ginyu area and east of the Ginyu area before 1953.

Introduction

Geothermal resources explorations in the Kirishima geothermal area of Kagoshima Pref.,Japan have been carried out by Nippon Steel Corporation and Nittetsu Mining Company since 1979. The Kirishima volcano is one of the largest Quarterly volcano in Japan. On the weatern part of the Kirishima volcano, surface manifestation such as fumarol,hot spring and alteration zone caused by geothemal activity, are widely distributed.

Sixteen production exploration wells were drilled in the area in the course of the joint exploration.(Figure 1) Fifteen out of sixteen wells produced geothermal fluid. Wells KE1-7,17,19S and 22 penetrated into the Ginyu Fault at depth were found to be especially productived.

Described here in are the results of the geochemical studies. Geochemical interpretation was done by chemical analyses of discharge water,steam and non-condensable gases and isotopic analyses of discharge water,steam and surface water.

1.Chemical properties of discharge fluids

Geothermal reservoir in the Kirishima area is of deep water-dominated hydrothermal system with geothermal water of Na-K-Cl-SO_4 type. (Table 1 and Figure 2) But that of well KE1-2 is of two phase hydrothermal system with low chloride—high sulfate water above deep water-dominated hydrothermal system. Geothermal fluids in the Shiramizugoe reservoir in the southern part of the Kirishima area are higher in salinity than these of Ginyu Fault reservoir in the northern part. Besides,enthalpy calculated by SiO concentration and Chloride concentration of the Siramizugoe and the Ginyu areas are grouped in Figure 3. Particularly, the discharge waters from wells KE1-9 and 11 in the Shiramizugoe area are high in both Chloride and sulphate, but pH is exceptionally low ranging from 2.4 to 2.9,while the discharge waters from other wells show near-neutral pH.

Discharge waters from wells KE1-7,17,19S and 22 penetrated into the Ginyu Fault reservoir are very similar in chemical property each other. And tracer test carried out between these four wells,revealed that each well was interconnected.

Thus, geothermal fluids in the Ginyu Fault reservoir have a homogeneous chemical property.

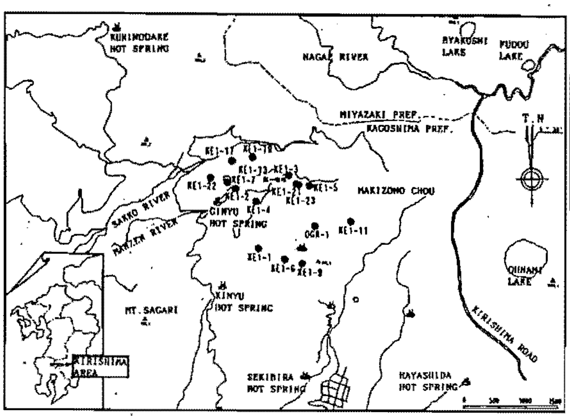

Figure 1. Map of the Kirishima geothermal area showing the location of exploration production wells

Table 1. Chemical analyses of discharge fluid from wells in the Kirishima Geothermal field

Location of wells		Ginyu Area						Shiramizugoe area	
		Ginyu Fault Reservoir					East of Ginyu Fault	near-neutral pH area	acid area
		Shallow zone	Deep zone						
Name of wells		KE1-2 (P)	KE1-7	KE1-17	KE1-19 (S)	KE1-22	KE1-5	KE1-6	KE1-9
Discharge water (mg/l)	pH	9.4	8.6	8.7	8.7	8.7	8.7	8.3	2.8
	Li	—	2.4	2.4	2.4	2.4	2.4	1.5	5.8
	Na	65	489	492	506	458	455	653	818
	K	13.2	61.6	61.6	61.0	61.6	59.5	78.3	190
	Ca	5.6	14.1	14.1	16.9	14.4	9.7	19.5	8.1
	Cl	38	840	840	862	845	825	1075	1180
	SO_4	104	194	194	203	192	142	79.9	364
	HCO_3	42.9	10	10	10	22	22	2.5	0
	B	0.25	41.5	42.9	44	42	40	53.7	84.3
	SiO_2	238	618	816	574	806	652	508	1000
	TRM	—	2201	2145	2258	2244	2059	2754	3635
Non-condensable Gas(%)	Gas volume	0.14	0.009	0.008	0.02	0.008	0.087	0.043	0.014
	CO_2	—	49.45	51.52	56.62	48.72	78.74	70.8	32.9
	H_2S		47.47	46.06	29.94	42.21	14.96	27.0	40.2
	H_2		0.11	0.16	0.3	0.26	0.14	0.1	20.5
	N_2		2.94	2.00	12.63	3.60	3.72	2.0	2.7
	CH_4		0.1	0.14	0.52	0.22	2.43	0.1	0.2
	R		-0.02	0.12	-0.01	0	0.01	0.4	3.5
Condensed water (mg/l)	pH	—	5.5	5.6	5.4	5.5	4.9	6.4	4.8
	Na	0.5	8.4	18.5	0.1	14	0.2	3.0	<0.1
	K	<0.01	1.0	2.9	ND	2.1	ND	0.11	<0.1
	Ca	0.5	ND	ND	ND	ND	ND	ND	<0.01
	Cl	0.01	2.9	28.9	0.2	19.5	1.2	17.3	6.6
	SO_4	54	3.4	9.2	0.9	7.8	0.5	15.6	34
	HCO_3	—	14	12	26	14	59	97	1.2
	SiO_2	14	12	14	<1	18	<1	<1	<1
Geothermometer (°C)	T-Na/K	—	238	232	234	238	241	—	—
	T-SiO_2(1)		242	242	237	241	246		
	T-SiO_2(2)		241	241	238	240	245		

TRM :Total Residual Matter

Non-condensable gas mainly consists of CO_2 and H_2S and small amounts of H_2 and CH_4. The ratio of non-condensable gas in steam is very low ranging from 0.01vol% to 0.1vol% after separation at atmospheric pressure.

The temperature of the Ginyu Fault reservoir was estimated by the geothermometer. The SiO_2 geothermometer indicates 236-242 °C and the Na-k geothermometer indicates 234-238 °C .These tempertures are in good agreement with the temperature logging data.

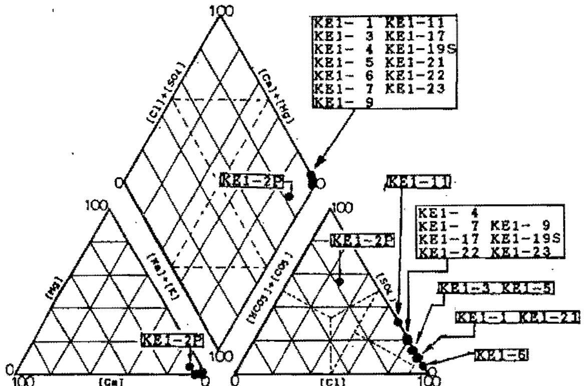

Figure 2. Classification of geothermal fluid in the term of relative main chemical composition

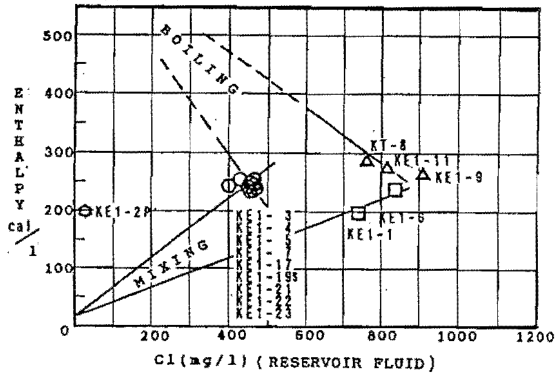

Figure 3. Relation of enthalpy and chloride in the Kirishima geothermal area

2.Geochemical interpretation of geothermal fluid in the Ginyu Fault reservoir

The ratio of Boron vs Chloride

Boron and Chloride are generally regarded as conservative components in geothermal water. Boron concentrations in rock are usually different according to rock type. So that it is known that the difference in the ratio of B/Cl of geothermal water is due mainly to difference in reservoir rock. As a result of chemical analysis of Boron and Chloride in discharge water and drill cores(Table 2), the ratio of B/Cl in the sedimentary rock of the Shimanto group which is the basement in the area is extraordinarily high compared to the ratio of B/Cl in Makizono lava,Iiino lava and Kirishima welded tuffs which are mainly composed of volcanic rocks. And discharge waters from wells KE1-7,17,19S and 22 penetrated into the Ginyu Fault reservoir are higher in the ratio of B/Cl than that of other area penetrated into volcanic rock. The ratio of B/Cl of the discharge waters from wells KE1-7,17,19S and 22 suggests that Ginyu Fault reservoir fluid passed through the Shimanto group.

The ratio of Boron vs Chloride of the Ginyu Fault reservoir fluids ploted in the figure 4 which was proposed by Shigeno and Abe(1981), reveals that they are the fluids possibly passed through marine sediment reservoir rock. This fact is in agreement with the result mentioned above.

Table 2. The molecular ratios of Boron and Chloride in geothermal fluid and rocks in the Kirishima geothermal area and other area

THE RATIO OF B/Cl IN ROCKS	VOLCANIC ROCKS	MAKIZONO LAVA	0.56
		IINO LAVA	0.32
		KIRISHMA WELDED TUFFS	0.83
	SEDIMENTARY ROCKS	SHIMANTO GROUP	16.7
THE RATIO OF B/Cl IN DISCHARGE WATERS	VOLCANIC ROCKS RESERVOIR	HATCHOBARU	0.04-0.05
		WAIRAKEI	0.03-0.1
		WEST BROADLANDS	0.03-0.1
	SEDIMENTARY ROCKS RESERVOIR	KAKKONDA	0.1
		NAGWHA	0.1 - 10
		EAST BROADLANDS	0.1 - 10
	THE GINYU FAULT RESERVOIR	KE1-7,17,19S,22	0.23

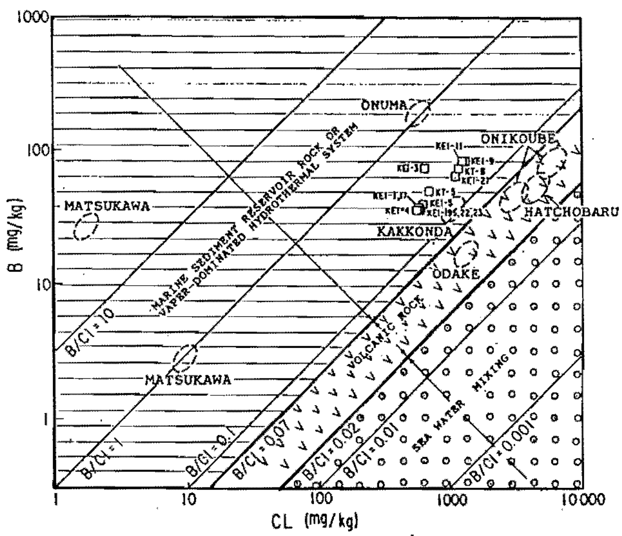

Figure 4. B-Cl systematics for estimation of reservoir rocks and conditions

Stable isotope

Surface water, such as seeping water and up stream river water, in the area 25Km by 10Km around the Ginyu area, were sampled and δD values and $\delta^{18}O$ values were analyzed 3 times per year. And δD values and $\delta^{18}O$ values of discharge water and steam from wells KE1-7,17,19S, and 22 penetrated into the Ginyu Fault reservoir were analyzed.

As the result, surface water in the Kirishima area has δD values and δ180 values of -34‰ to -50‰ and -6.2‰ to -8.2‰, respectively. The Ginyu Fault reservoir fluids have δD values and δ180 values of -45‰ to -49‰ and -5.5‰ to -6.4‰, respectively, which were obtaind by culculation of δD values and δ180 values of discharge water and steam. (Figure 5) The Ginyu Fault reservoir fluids are 2‰ enriched compared to the local meteoric water in δ180 value. (Oxygen-18 shift)

Then a contour map was drawn taking into consideration various effects such as soluble concentrations of surface water, altitude and seasonal variation. Surface waters having δD values similar to the Ginyu Fault reservoir fluid are distributed at the Ginyu area and the east of the Ginyu area, the critical line being -45‰ line. (Figure 6) Therefore, it is assumed that the origin of the Ginyu Fault reservoir fluid is probably derived from meteoric water heated under high temperature at depth and enriched in ^{18}O by exchange with silicates. This meteoric water may be the rain which precipitated in the Ginyu area and the east of the Ginyu area.

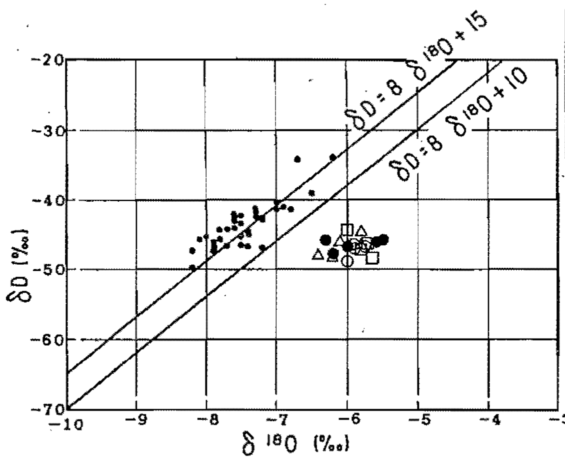

Figure5. Values of δD and $\delta^{18}O$ for samples of thermal and local meteoric water in the Kirishima geothermal area

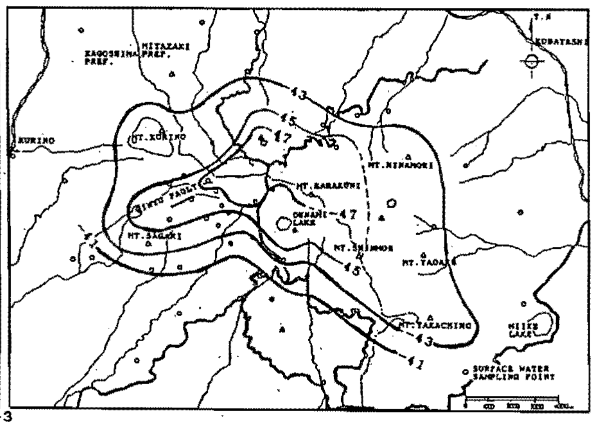

Figure6. The distribution of δD of local meteoric water in the Kirishima

Tritium

The tritium concentration in the rain water was apporoximately 10 tritium units before 1953 when a nuclear explosion test was carried out. But since 1953, the tritium concentration immediately increased, and amount to 1000 tritium units in 1963. At present tritium concentration is roughly equal to that before 1953.

The result of tritium measerment, the tritium concentration in the Ginyu Fault reservoir fluid is in the range of 0-1.5 tritium units. On the basis of a simple cyclic flow of water through the rock without dilution, the time of transit would be about 35 years. Thus, the geothermal fluid in the Ginyu fault reservoir would be derived from meteoric water which precipitated before 1953.

3.Conclusion

In conclusion, it is geochemically interpreted as follows.

Meteoric water which precipitated to the Ginyu area and east of the Ginyu area goes down to the depth of basement of the Shimanto group. Then it flows up toward the Ginyu Fault reservoir, during the course of which, heat exchange and reaction of water and rock occur, for the chemical elements finally to get to the values as confirmed by the analysis of discharge fluid from geothermal wells. It is assumed to take several decades for the precipitation to reach the Ginyu Fault reservoir.

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