GEOCHEMICAL STUDY OF HOT SPRING WATER DISCHARGING ON THE NORTHEN SLOPE OF MT. MUAYAT IN THE KOTAMOBAGU GEOTHERMAL FIELD, NORTH SULAWESI, INDONESIA

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ABSTRACT

Nine water samples were collected from thermal spring, river, and shallow well at northern side of Mt. Muayat, Kotamobagu geothermal field. Temperature of waters, Electronic Conductivity (EC) and pH were measured on site and chemical analysis in laboratory. The analyzed results were plotted on Cl-SO_4-HCO_3 ternary diagram, and characterized into three groups of Cl-SO_4, and HCO_3 and alkali chloride waters. From Na-K-Mg plot, all hot spring water was determined as immature waters. The geochemical temperature calculated with quartz geotermometer showed in the range about 127-135°C, with Na-K geothermometer in a range 210-250°C. A conceptual model of hydrothermal system of the northern area of Kotamobagu was developed.

Keywords: Geochemical, hot spring, conceptual model, Mt. Muayat, Kotamobagu.

1. INTRODUCTION

The Kotamobagu geothermal field is located in North Sulawesi Province, Indonesia, 200 km to the southwest of Manado city, capital of the province (Fig.1).

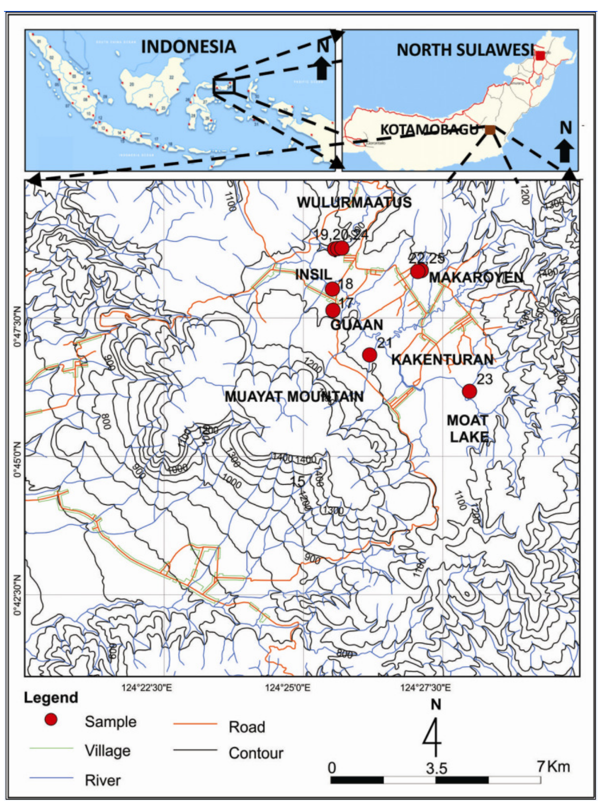

Figure 1: Location map of sampling point in the Kotamobagu geothermal field.

The field has been proved to be one of the geothermal prospects in Indonesia (Hochstein and Sudarman, 2008). PT. Pertamina Geothermal Energy (PT.PGE) conducted reconnaissance and feasibility studies in Kotamobagu and concluded that the field has high potential for power generation.

In 2011 two wells (KTB-B1 & KTB-B2) were drilled on the southern slope of Mt. Muayat. Results of production test as these wells were not successful because of low temperature, 160°C at well bottom, for both wells. Another potential site for development in Kotamobagu is north of Mt. Muayat where PT.PGE has a plan for drilling. However, no detail research on geochemistry has been conducted in this area. Thus, we have carried out geochemical survey in this area and tried to develop a conceptual model of hydrothermal system at Northern side of Mt. Muayat.

2. GEOLOGY

2.1. Geological Setting

Geological map of Kotamobagu is shown in Fig.2.

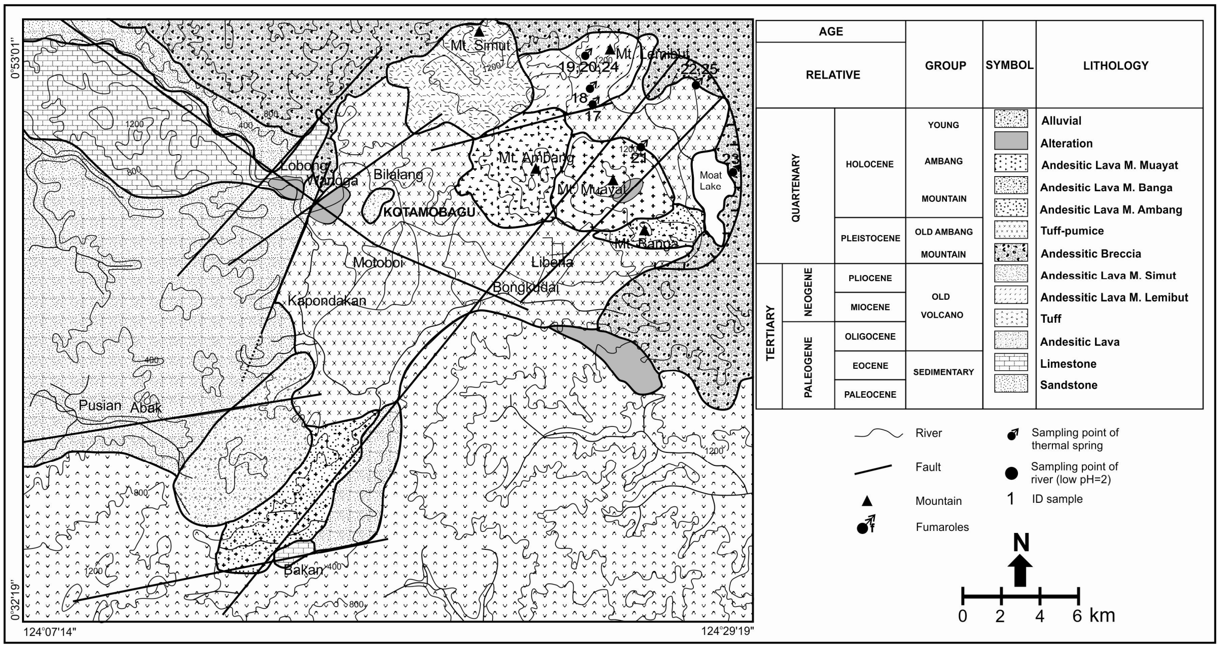

Figure 2: Geological Map of Kotamobagu (Modified from PT.PGE (2005)).

The area is covered by the Tertiary and the Quaternary rocks. The Tertiary sedimentary rocks consist of shale and sandstone with intercalation of limestone and chert, and are overlain by the Tertiary and Quaternary volcanic rocks. The Tertiary rocks are limestone and chert, and are overlain by the Tertiary and Quaternary volcanic rocks. The Tertiary volcanic rocks are the products of Old volcano and consist of breccia, tuff, andesitic lava, dacite and rhyolite to form Mt. Simut and Mt. Lemibut located to the north of Mt. Muayat. The Quaternary volcanic rocks consist of the Old and Young Ambang volcanic. Tuff-pumice and andesitic-breccia are the products of the Old Ambang Volcano. The Young Ambang volcanic rocks consist of andesitic lava and magma breccia are overlain Mt. Muayat, Mt. Banga, and Mt. Ambang asymmetrically.

2.2. Geological Structure

Faults in Kotamobagu have directions northwest to southwest, northeast to southwest and west to east as shown in Fig. 2. In this figure, the fault is indicated with solid line and the inferred fault with dashed line. A fault system with a direction of west to east which is crossing the sedimentary rocks controls the appearance of hot springs at Pusian and Bakan, located to the southwest and south of Kotamobagu. Another fault system with a direction of northwest to southeast controls the presence of hot springs at Lobong in the east of Kotamobagu (PT.PGE, 2005). Fumaroles on top of Mt. Muayat located in the east of Kotamobagu have a high temperature 102.7^{o}C and are associated with faults running northeast to southwest (PT.PGE, 2005). This fault system also controls an appearance of hot spring at Liberia village as well as Bongkudai village.

3. SAMPLING LOCATION

Water samples at nine locations in an elevation range from 997m to 1097m were collected from hot spring and shallow wells in the area 10 km NS and 10 km EW on the northern slope of Mt. Muayat as shown in Fig. 1 and Fig.2.

Sample MAKH-22 was collected at a natural discharge at an elevation 1097 m and MAKW-25 was collected from shallow well of 12 m depth in Makaroyen village. The number of the sample ID corresponds to that in Fig.1 and Fig.2. Two samples of natural discharges (WULH-19 and WULH-20) and one sample (WULR-24) of the river were collected at Wuluramatus village located of Mt. Muayat, about 8 km north of Mt. Muayat. Natural discharges on river bank were collected at Insil village (INSH-17) and (INSH-18). Sample KAKH-23 was collected from natural discharge near of the Moaat Lake that located in the east of Mt. Muayat. Sample at Guaan village (GUAH-21) was collected at farm with elevation 1064m on the north-eastern slope of Mt. Muayat.

4. SAMPLING METHOD AND ANALYSIS METHODS

All samples were collected in 250 ml polythene bottle after filtrating by 0.45μm membrane filter Water temperature, Electric Conductivity (EC) and pH were measured on site by portable instruments. The anion (F, Cl, NO_3, SO_4,) and cation (Na, NH_4, K, Mg, Ca) were analyzed using ion chromatography system (Dionex ICS-90). Bicarbonate (HCO_3^-) was measured using a titration method. Concentration SiO_2 and Fe total were measured by spectrophotometer (Hitachi U 1800) using the molybdate yellow method.

5. RESULT AND DISCUSSION

5.1. Water Chemistry

Analyzed results are summarized in Table 1.

Table 1: Results of chemical analysis of waters at Northern side of Mt. Muayat in Kotamobagu.

Sample number	Elev. m	Sample ID	Temp (°C)	pH (-)	Ec (field) µS/cm	HCO3	F	Cl	NO_3	SO_4	Li	Na mg/l	NH_4	K	Mg	Ca	Fe total	SiO2
17	1065	INSH-17	32.0	7.1	53.4	111	0	35.9	7.2	69.2	0	63.9	0.55	4.5	9.8	20.7	0.01	83.5
18	1049	INSH-18	31.2	6.6	462	129	0	50.4	10.9	68.6	0.07	60.8	0	9.0	6.1	20.3	0.09	86.6
19	998	WULH-19	37.0	6.6	943	92.7	0	152	0	81.9	0.08	131	1.63	16.4	15.8	32.1	0.09	95.9
20	997	WULH-20	39.0	6.7	1061	167	0	170	0	90.8	0.09	142	0	21.0	18.8	37.1	0.05	98.0
21	1064	GUAH-21	45.0	6.0	834	276	0	42.9	0	92.7	0.07	66.3	1.55	12.9	27.1	61.9	0.16	135
22	1097	MAKH-22	50.0	3.5	302	0	6.69	16.7	0	109	0	4.7	5.28	0.9	2.6	7.8	1.89	22.3
23	1073	KAKH-23	45.3	8.4	175	80.5	0	7.8	0	7.3	0	40.0	0.47	0.5	0	1.2	0.04	44.1
24	997	WULR-24	26.0	7.2	235	63.4	0	13.5	8.7	25.3	0	22.5	0.41	3.6	4.8	17.2	0.35	36.8
25	1096	MAKW-25	27.0	4.0	160	0	0	3.0	13.0	53.1	0	7.0	0.48	0.9	2.2	9.9	0.04	99.5

Samples of MAKH-22 and MAKW-25 show acidic as low as pH about 3 and has conductivities in the range from 160 to 302µS/cm. Other samples have pH of relatively neutral about 6-8. Samples of INSH-17 has low EC is 53 µS/cm and another has in the range; 160-1061 µS/cm for INSH-18, WULH-19, WULH-20, GUAH-21, MAKH-22, KAKH-23, WULR-24 and MAKW-25. Temperature of all hot spring waters shows in the range from 27 to 50°C and 26°C of the river.

Ternary diagram is plotted for Cl-SO_4-HCO_3 in Fig. 3.

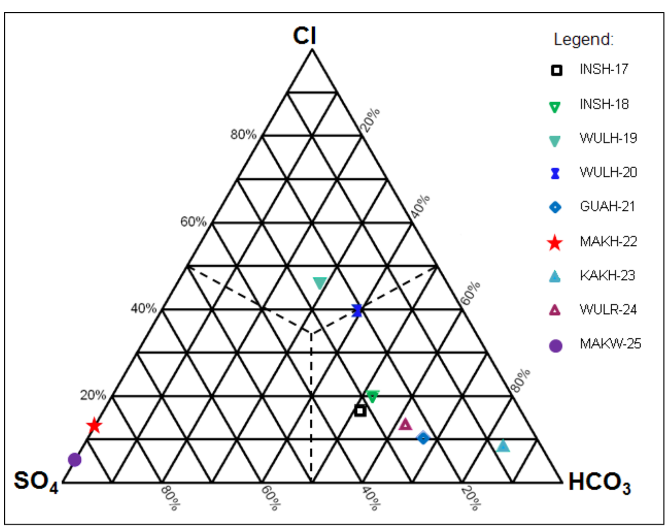

Figure 3: Ternary plot for Cl, SO_4 and HCO_3

From this figure, we can say there are three type of water;

1. Cl-SO_4 (MAKH-22 and MAKW-25),
2. HCO_3 (KAKH-23 and GUAH-21)
3. Alkali chloride (WULH-19 and WULH-20)

Sample plotted at near the corner of SO_4 on the SO_4-Cl axis (MAKH-22 and MAKW-25) is Cl-SO_4 type. This discharge may be directly delivered from a lateral flow of deep Cl-SO_4 water.
Samples collected at lower elevations on the northern slope of Mt. Muayat are plotted near on the corner of HCO_3 and are identified as of HCO_3 type. Bicarbonate water may occur near the surface in geothermal areas where steam containing carbon dioxide condenses into an aquifer. Under stagnant conditions, reaction with rocks produces neutral pH and discharges as hot springs such as in Kakenturan and Guaan (KAKH-23 and d GUAH-21).
Sample was plotted near the bottom in area of chloride and also plotted on line of limit between Cl and HCO_3 area are identified as alkali chloride waters. High concentration of Na, Cl and significant concentration of Bicarbonate in Wuluramatus, Table 1, (WULH-19 and WULH-20) may flow directly to the surface and discharge from boiling at deep, high chloride springs, whose pH ranges from near neutral to alkaline. The alkali-chloride waters come from the outflow of the deep neutral chloride waters.

5.2. Geothermometer

Quartz, Na-K, Na-K-Ca and Na-K-Ca-Mg geothermometers were used for temperature calculations; Quartz no steam loss and α-Cristobalite (Fournier, 1977), Na-K (Fournier, 1979), Na-K (Truesdell, 1976), Na-K-Ca (Fournier and Truesdell, 1973) and Na-K-Ca-Mg with Magnesium corrected (Fournier and Potter II, 1979).
Figure 4 represents the results of geothermometer computation showing the minimum temperature by quartz no steam loss is about 130-140°C; Na-K is about 210-250°C; Na-K-Ca is about 180-190°C for sample in the area of Insil and Wuluramatus (INSH-17, INSH-18, WULH-19, and WULH-20). The temperatures with the Na-K-Ca-Mg geothermometer were calculated in a range from 180 to 210°C for INSH-17, INSH-18, WULH-19, and WULH-20. Sample from Guaan has higher temperature compared to those from Insil, Wuluramatus, Kakenturen and Makaroyen (by Na-K is about 270-280°C). The maximal temperature at southern of Mt. Muayat about 260°C (Riogilang et al., 2011) is similar with Guaan 270-280°C. This implies hot spring in Guaan influence by Mt. Muayat system.

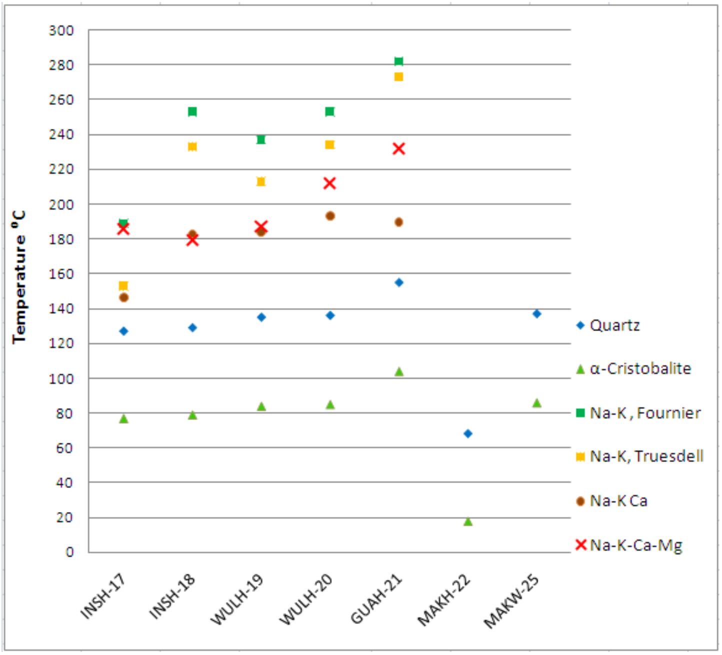

Figure 4: Calculated temperatures with Quartz geothermometers, Na-K, Na-K-Ca and Na-K-Ca geothermometer with Magnesium Corrected.

Data of samples waters are plotted on a Na-K-Mg diagram in Fig.5. All samples belong to a region of are immature waters.

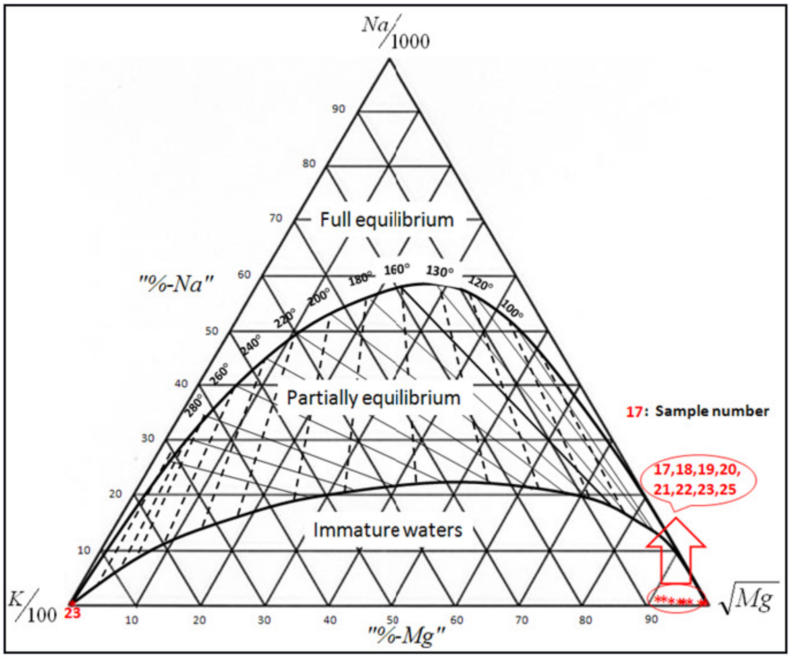

Figure 5: Ternary Na-K-Mg diagram.

5.3. Conceptual Model

On the basis of the results above, a conceptual model of a hydrothermal system in the northern area of Kotamobagu was developed as shown in Fig.6.

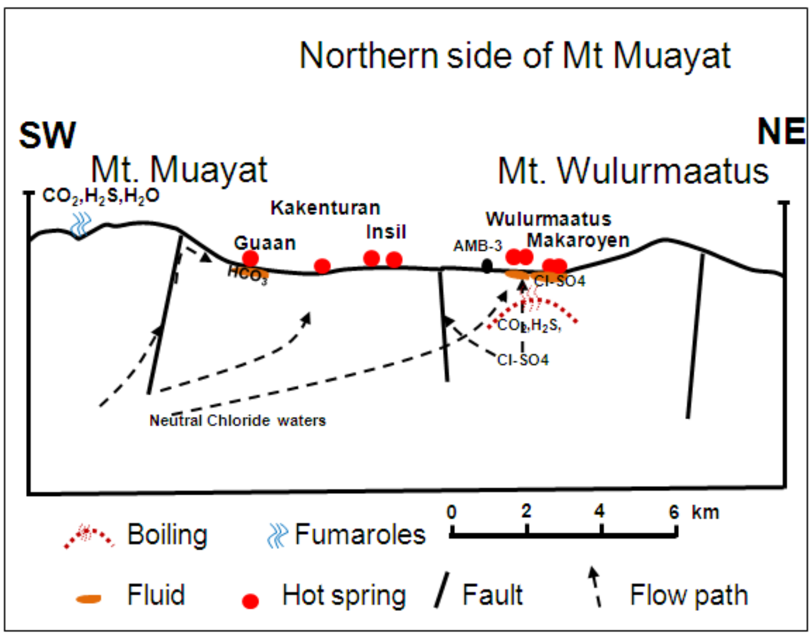

Figure 6: Conceptual Modelof northern side of MT. Muayat in Kotamobagu geothermal field. Figure is a modified of Conceptual model of Kotamobagu geothermal field, Riogilang et al.,2011.

The deep water below Mt. Muayat further flows north through fault systems and shallow aquifer to lower elevation and discharges to the surface. Neutral chloride waters flows laterally to the north of Mt. Muayat in the west of Makaroyen and discharges alkali-chloride water type at Wuluramatus village.

High temperature geothermal fluid of Cl-SO_4 type flows upward below Makaroyen and eventually starts boiling at depth, releasing H_2S gas which forms steam heated waters by mixing with oxygen rich surface water.

6. CONCLUSIONS

Geochemical studies in the Kotamobagu geothermal field are summarized as follows:

1. The water samples are divided into three groups: Cl-SO_4, HCO3 and Alkali-Chloride types.
2. Geochemical geothermometer presents temperature of 127-135°C by quartz geothermometer, 210-250°C by Na-K and of 180-210°C with Na-K-Ca-Mg geothermometer.
3. Conceptual model of a hydrothermal system in Kotamobagu was developed.

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