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Geochemical Analysis of Mount Pandan Geothermal Area in East Java Indonesia

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Abstract

The geochemistry method has been done to analyze the characteristics of geothermal fluid in mount Pandan area, East Java, Indonesia. Water sample was collected at two hot springs, Jari (Selo Gajah) and Banyukuning. The geochemical data was process using the spectrophotometric method to analysis the concentration of anions and cations that contained in hotsprings water. The geochemical analysis can shows information about the type and characteristics of the fluid to predict reservoir temperature. The results shown that the type of water in geothermal system from mount Pandan area are chloride and bicarbonate water. Meanwhile, the geothermometer analysis for Na-K-Ca shows the average of reservoir temperature is around 130ºC and classified into medium enthalpy system.

Keywords: *Geothermal, geochemistry method, type of water, reservoir temperature, medium enthalpy, mount Pandan*

1. Introduction

One of the biggest natural resources in Indonesia is geothermal. Geothermal is a source of heat energy contained in water vapor, hot water and rocks. The source of geothermal energy is formed naturally below the surface of the earth. There are 256 geothermal areas with a potential of 27,441 MWe, spread all over Indonesia [1]. According to General Directorate of EBTKE (2017), one of the geothermal potential area in Indonesia is Java island, mount Pandan [2].

Mount Pandan is a geothermal potential area that is estimated to have geothermal energy around 60 MWe, evidenced by the existence of hot springs in several locations, with surface temperature more than 35ºC and have a neutral pH of 7 [2]. One of the early stage to identified that the area have geothermal potential, is by determinate the characteristics geothermal fluid. Generally, one method that proper to used is the geochemical analysis [3]. Based on previous studies [4-9], this method is proven reliable to analyzing characteristics geothermal fluid. The main objective of this geochemical study is to determine the type of fluid manifestation and predict reservoir temperature geothermal from mount Pandan area, East Java, Indonesia.

2. Geology of the Research Area

Mount Pandan is located in the southern part of Bojonegoro Regency, East Java, Indonesia. This area has two main hot spring as geothermal manifestation. Jari hot spring has the coordinate position on 7º26.48′.16″ S and 111º48′28.12″ E with 225 mdpl in elevation, while Banyukuning hot spring has the coordinate position on 7º24′57.80″ S and 111º49′05.27″ E with 490 mdpl in elevation. The geothermal manifestation was classified as warm springs, neutral pH, high electrical conductivity, chloride and bicarbonate type of water. Reservoir temperature calculated by silica geothermometer is 158-166ºC with average ranges from 150-165ºC [2].

Based on the geological map, (Fig. 1) it is known that the constituent rocks in the study area consist mainly of sedimentary rocks such as carbonate clay rocks, clay rocks, and sandstones and volcanic rock units that are associated with geothermal manifestations in the form of alteration rocks. There are two types of geological structures that develop, a normal faults and horizontal faults. In general, mount Pandan geological structure orientation is dominated by the NE-SW and NW-SE directions, although there are several faults in W-E direction [10].

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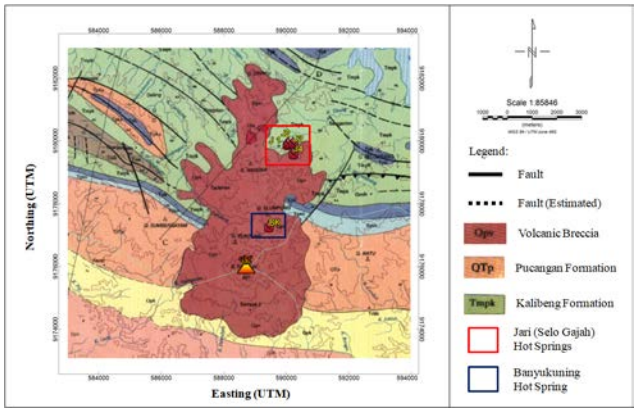

Fig. 1 Geological map of the research area [10].

3. Research Method

3.1 Geochimical Data

The location of this study is in the mount Pandan area. Water samples was collected at two hot springs Jari (Selo Gajah) and Banyukuning. There are four hotsprings for water sampling points are located in Jari and one spring in Banyukuning that can be seen in Fig. 1.

Fig. 2 Hot springs in mount Pandan area.

Table 1 shows the manifestation in two location (Jari (Selo Gajah) and Banyukunig). There are 4 hot springs measured in Jari (Selo Gajah) and 1 warm spring in Banyukuning which have temperature ranges from 37-58^{o}C.

Table 1: Temperature in mount Pandan hot springs

Hot Springs	Coordinate E/N (UTM)	T^{o}C	Elevation (m)
Jari (SG) 01	589988/9180578	50	214
Jari (SG) 02	590055/9180661	40	209
Jari (SG) 03	590276/9180647	48	204
Jari (SG) 04	590284/9180174	58	270
Banyukuning	589139/9176787	37	500

3.2 Geochemical Data Processing

The processing of geochemical data was conducted the spectrophotometric method to anaysis the concentration of

anions and cations contained in water sample. The spectrophotometric method is a quantitative measurement method based on absorption of electromagnetic wave radiation [11]. Fig. 3 shows the flow chart for geochemical data processing.

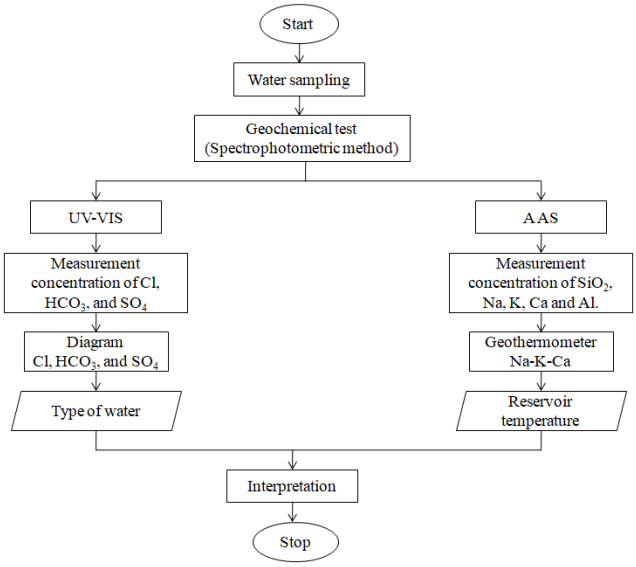

Fig. 3 Flowchart for processing geochemical data.

The chemical elements analysis of Cl, HCO_3, and SO_4 are used to determine the type of water by the trilinear diagram. The type of water in geothermal systems are usually in the form of chloride water, sulfuric acid water, and bicarbonate water. Chloride water (Cl) shows that hot water fluid comes directly from the reservoir without mixing with sampling rock and surface water. Thus, it appearsence on the surface can be used to determine the geothermal reservoir temperature. The pH of common water chloride is close to normal, but can be acidic weak depending on the dissolved CO_2 content [4].

Systems that dominated by volcanic rocks and bicarbonate water (HCO_3) generally formed in marginal areas and near with the surface, where CO_2 and water vapor condensed into groundwater, condensation of the steam can heat the groundwater or steam thus forming an HCO_3 solution. Bicarbonate water (HCO_3) is formed below the groundwater level which is generally a little acidic, but with the loss of dissolved CO_2, the degree of similarity of this water can be increased to neutral or slightly alkaline [5]. Sulfuric acid water is a fluid formed at shallow depths as a result of the condensation process from geothermal gas towards the surface which is characterized by SO_4 high values, and low pH of 2-3 [12].

Furthermore, chemical elements analysis of SiO_2, Na, K, Ca and Al, used to determine reservoir temperature which is calculated based on geothermometers. The type of geothermometer which will be used, depends on the most dominant chemical elements concentration and adjusted to the applicable limits for each geothermometer type. The right geothermometer used is a geothermometer Na-K-Ca [13].

The geothermometer Na-K-Ca can be used assumption, the presence of excess silica in geothermal fluids. In addition, aluminum (Al) is in a solid condition or very little concentration in the fluid [14]. The formula for calculated the geothermometer Na-K-Ca is [15] :

$$T^0 = \frac{1647}{\log(Na/K) + \beta\left(\log\left(\sqrt{Ca}/Na\right) + 2{,}06\right) + 2{,}47} - 273{,}15$$

$$\beta = 4/3 \; if \left(\log\left(\sqrt{Ca}/Na\right) + 2{,}06\right) \; positive\ value\ and\ T < 100^0C \qquad (1)$$

$$\beta = 1/3 \; if \left(\log\left(\sqrt{Ca}/Na\right) + 2{,}06\right) \; negative\ value\ T_{3/4} > 100^0C$$

According to [16], the classification of an area's geothermal system is based on the reservoir temperature. The low temperature systems have a reservoir temperature of <125˚C, a medium temperature system has a reservoir temperature range between 125-225˚C, while a high temperature system has a reservoir temperature >225˚C.

4. Result and Discussion

The results of the geochemical analysis from five hot springs can be seen in Table 2 :

Table 2: The result of geochemical analysis

Elements	SG 01	SG 02	SG 03	SG 04	BK
pH	6.6	6.5	6.8	6.6	6.2
Cl	2877	2977	5317	7897	577
SO_4	128.9	114.8	158.0	183.6	31.34
Na	2.571	1.2571	0.9570	1.455	0.7543
K	0.9551	0.9775	0.8551	1.2430	0.9324
Ca	1.4321	2.250	2.1431	1.255	1.342
Al	<0.101	<0.101	<0.101	<0.101	< 0.101
HCO_3	1649	1996	1745	2282	896.3
SiO_2	16.57	18.67	15.48	19.28	20.57

Information: Except for pH, all elements are in units of mg/L

4.1 Type of Water

The results of analysis the type of water can be seen in triangle diagram of Cl-SO_4-HCO_3 (Fig. 4). Fig. 4 shows that the Cl is the most dominant in SG 01, SG 02, SG 03 and SG 04, while BK as the main anion is HCO_3. According to [4-5], that the type of water in the geothermal system from mount Pandan area are chloride and bicarbonate water, as evidenced by the spring water in the Jari (Selo Gajah) a neutral approximatly pH of 6.8 and the Banyukuning spring have a acidic pH of 6.2 (Table 2).

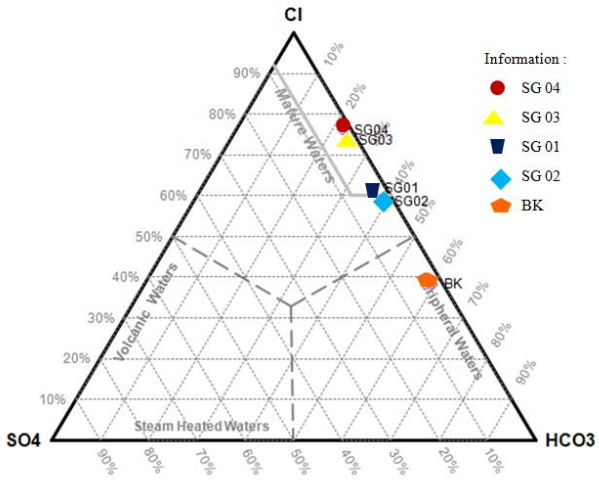

Fig. 4 Results of the geochemical analysis at diagram Cl-HCO_3-SO_4 .

4.2 Reservoir Temperature

The results of calculated the geothermometer Na-K-Ca can be seen in Table 3. Table 3 shows that reservoir temperature range from 108.1ºC to 139.2ºC, with the average of reservoir temperature is around 130ºC. Based on [15], the geothermal system from mount Pandan area can be classified into medium enthalpy system.

Table 3: The result of calculated the geothermometer Na-K-Ca

Hot springs	Type of water	Elements	ppm	Geothermometer (ºC)
SG 01	Chloride water	Na	2.571	108.1
		K	0.9551	
		Ca	1.4321	
SG 02		Na	1.2571	138.5
		K	0.9775	
		Ca	2.250	
SG 04		Na	0.9570	130.3
		K	0.8551	
		Ca	2.1431	
SG 05		Na	1.455	139.2
		K	1.2430	
		Ca	1.255	

5. Conclusion

The results of geochemical analysis shows that the fluid type in Jari (Selo Gajah) and Banyukuning are chloride and bicarbonate water. Meanwhile, based on the calculated of the geothermometer Na-K-Ca, geothermal system mount Pandan area has a reservoir temperature of 130ºC and classified into medium enthalpy system.

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References

[1] Maryanto S. (2018). "Microseismicty of Blawan hydrothermal complex, Bondowoso, East Java, Indonesia". Journal Physics .:Conf. Ser. 997 012019. *http://dx.doi.org/10.1088/997/1/012019.*

[2] General Directorate of EBTKE. 2017. "Geothermal Potential in East Java, Indonesia". (*In Indonesian*)

[3] Arnórsson, Stefán, Einar Gunnlaugsson and Hördur Svavarsson. 1983. "The Chemistry of Geothermal Waters in Iceland. III. Chemical Geothermometry in Geothermal Investigations". Geochimica et Cosmochimica Acta 47(3):567–77.

[4] Maryanto, S. 2017 AIP Conference Proceedings. "Geo Techno Park Potential at Arjuno-Wilerang Vulcano Hosted

Geothermal Area Batu, East Java, Indonesia (Multi geophysical approach)". *International Conference Global Resource Concervation*

[5] Maryanto S, Dewi CN, Syahra V, Rachmansyah A. Foster JH, Nadhir A, Santoso DR. 2017. "Magnetotelluric-geochemistry investigations of Blawan Geothermal field, East Java, Indonesia". *Journal Geosciences (Switzerland)* 7(2):41.

[6] Rahmawati, Maryanto, S, Susilo A. 2018. "Identification of Geothermal System and Potential Energy Cangar, East Java using Method Magnetoteluric and Geochemical Data". Universitas Brawijaya Malang, East Java. *Thesis Geophysics.* (*In Indonesian*)

[7] Gemilang A and Triandanu N. 2015. "Geology and Geochemistry Characteristics of Kepahiang, Bengkulu Province". Procceding Indonesia Conference on Geothermal, Mineralogy and Vulcanology. ISSN : 2476-9185. 19-21 October 2015. MIPA Center, Brawijaya University, Malang, Indonesia. Published by Bravoenergeobhas Research Group.

[8] Widiatmoko R. F, Hadi N. M, Kusnadi D, Iswahyudi S, and Fadlin. 2015. "Geology and study characteristic geothermal based on geochemical fluid analysis and land area Wae Sano, Sano Nggoang District, West Manggarai Regency, East Nusa Tenggara Province". Procceding Indonesia Conference on Geothermal, Mineralogy and Vulcanology. ISSN : 2476-9185. 19-21 October 2015. MIPA Center, Brawijaya University, Malang, Indonesia. Published by Bravoenergeobhas Research Group.

[9] Pratama A. B., Yanastyapricena I, Hidayat R. F, Sianturi E. P, Iswahyudi S, and Sari N. A. 2016. "Storage system and cycle system on non-volcanic geothermal system in Southern Kuningan, West Java". Procceding Indonesia Conference on Geothermal, Mineralogy and Vulcanology. ISSN : 2540-9298. 15-17 September 2016. MIPA Center, Brawijaya University, Malang, Indonesia. Published by Bravoenergeobhas Research Group.

[10] V. R. Bemmelen, M. Nyhoff, and The Haque. "The Geology of Indonesia". Nederland, 1949.

[11] Ármannsson, H. 2012. "Geochemical Aspects of Geothermal Utilization", *Comprehensive Renewable Energy*, Vol. 7

[12] Aribowo, Yoga and Heri Nurohman. 2012. "Study Geochemistry of Hot Water Prospect Area Geothermal Mount Kendalisodo Semarang Regency, Central Java, Indonesia". Journal of Engineering. 33 (1): 32-36. (*In Indonesian*)

[13] Karingithi, C. 2009. "Chemical Geotermometer for Geothermal Exploration. Short Course IV on Exploration for Geothermal Resources in United Nation University, Lake Vaivasha".

[14] Ermianto, Y.B and Aribowo, Y. 2011. "Study Geochemical of Geothermal Fluid in the Region of Nglimut Prospects, Mount Ungaran Limbangan Subdistrict, Kendal Regency, Central Java, Indonesia". Journal of Engineering, Vol. 32 No. 3, pp. 230-233 (*In Indonesian*)

[15] Fournier, R. O. and A. H. Truesdell. 1973. An Emperical Na-K-Ca Chemical Geothermometer for Natural Waters. Geochimica and Cosmochimica Acta.

[16] Honstein, 1990. "Introduction of Geothermal Prospecting". Geothermal Institude, University of Auckland, New Zealand.