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Abstract. Geochemical assessment was completed in Gunung Endut geothermal area to determine fluid characteristics discharging from their natural surface manifestations. Gunung Endut geothermal area is centralised in the western part of the region. Three surface manifestations located in Desa Handeuleum, Cikawah and Gajrug appears along the apparent structural (fault) line. Diluted chloride- carbonate water belongs to partially equilibrated group may indicate mixing between chloride water and groundwater. Quartz and Na-K geothermometer indicated reservoir temperature of 107 – 127 ºC and 111 – 132 ºC respectively. Geoindicators of Cl/B indicated that there are two separate reservoirs in the sub-surface. Geoindicators of Na/K and Na/Ca revealed that all the manifestations lie in the outflow zone of Gunung Endut geothermal area.

Keywords: geothermal, geochemical assessment, Gunung Endut, Banten

1. Introduction

Gunung Endut geothermal area is located in Lebak region, Banten province (Figure 1) and is currently stated as geothermal working area by the government [1]. Surface manifestations in a form of warm springs are mostly primitive and unutilized by the local residents. Previous geochemical assessment was reported by the Ministry of Energy and Mineral Resources suggesting that the speculative energy can reach up to 61 MWe [1]. This research focuses on geochemical fluid assessment in Gunung Endut geothermal area to investigate fluid type, reservoir temperature using geothermometry, common reservoir and the relationship between apparent geological structure as the main control for surface manifestations. A collaborative geological mapping in the area surrounding Gunung Endut, where most of its lithologies consists of quaternary volcanic deposits and limestone sediment deposits [2]. Previous geophysical studies in Gunung Endut area also indicated that faults and volcanic activities were the main control of surface manifestations and alterations [3].

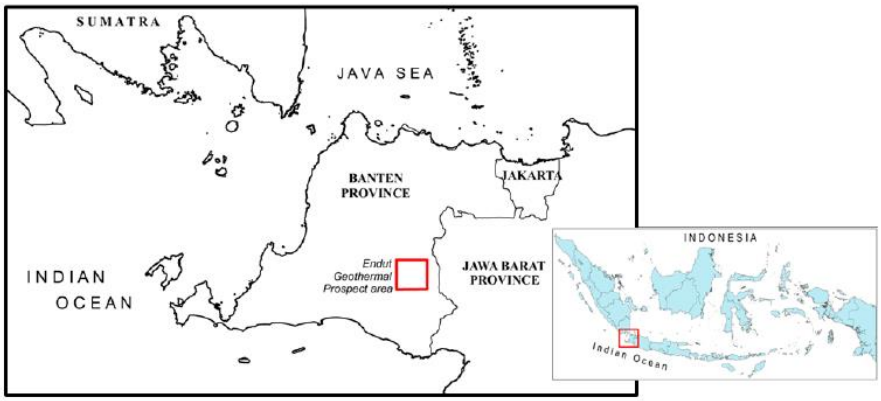

Figure 1. Gunung Endut geothermal area located in Banten Province, Indonesia [3].

2. Geological Settings

A collaborative geological mapping in the area surrounding Gunung Endut, where most of its lithologies consists of quaternary volcanic deposits and limestone sediment deposits [2]. Previous geophysical studies in Gunung Endut area also indicated that faults and volcanic activities were the main control of surface manifestations and alterations [3].

An updated geological mapping revealed that the lithologies of the area consists of Andesitic Lava (Qpal), Tuff Kasar (Qptk), Tuff Halus (Qpth), Volcanic Breccia (Qpbv) and Limestones (Tmg) (Figure 2). Two structural features of normal fault with strike/dip value of N45E/46º and horizontal fault with strike/dip value of N160E/32º were found in Desa Sobang and Desa Handeuleum respectively. Three surface manifestations were found in Cikawah and Handeuleum 10 km northwest from Gunung Endut and Gajrug 15 km north from Gunung Endut. Surface alterations were also obtained from the proximity of the surface manifestation. Altered rock analysed by XRD method and show hydrothermal minerals such as montmorillonite, calcite, and secondary quartz. Sample alteration taken around from Cikawah hot springs and indicated argillic alteration with temperature < 200ºC [4].

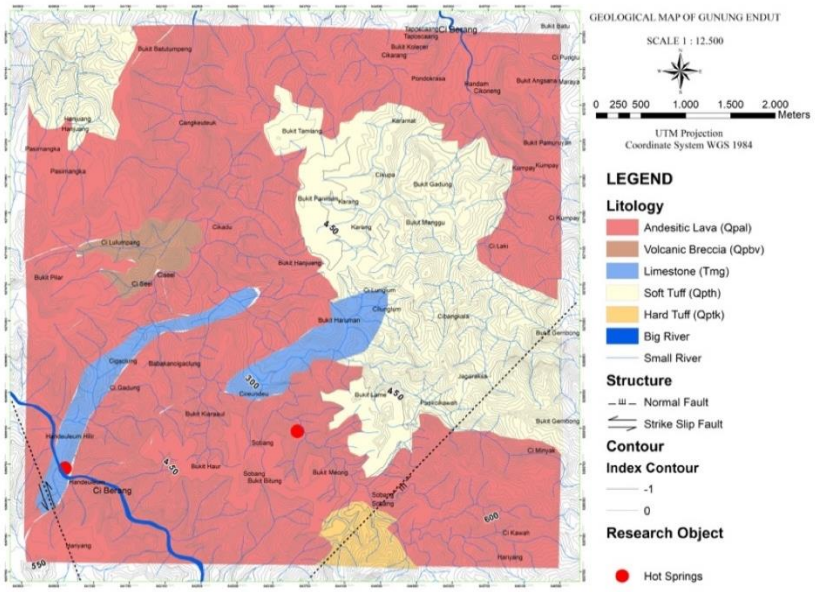

Figure 2. Geological map of Gunung Endut

3. Fluid Chemistry

Five samples from three different manifestations (CKW1, CKW2, HDL, GJG 1, GJG 2) were obtained and sampled according to the procedure [5]. The samples were collected both untreated and with treatment (the addition of HNO_3) [5]. Surface manifestation temperatures were recorded at 73 – 76 ºC and the pH of the water is almost neutral (between 6.8 to 7.3). Laboratory analysis of ion balance shows charge balance between -4 - 1% allowing all the samples to be used in the calculations [5]. Total dissolved solids ranges from two manifestations (Cikawah and Handeuleum) were reported at 160 – 358 mg/L indicating high content of Si, Na, K, and Ca. As for manifestation in Gajrug, total dissolved solids were reported at 350 – 529 mg/L. The waters in Gunung Endut geothermal area can be classified as diluted chloride-carbonate waters (Figure 3) with HCO_3^- species as the dominant anions. Bicarbonate waters can form due to heating condensation reaction with near surface ground water.

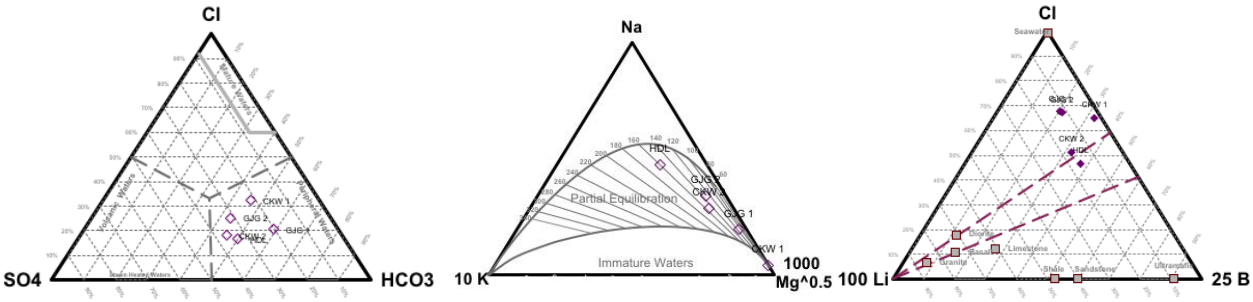

Figure 3. Ternary diagram of fluid samples obtained from Gunung Endut area. (A) CSH (B) NKM, (C) CLB

Samples from Cikawah and Gajrug (CKW 1, CKW 2 and GJG 1) shows an anomalous value of Mg indicating that the fluid has undergone a series of mixing with ground water. This also support the high content of HCO_3 in the fluid as the counter-ions for Mg possibly derived from the limestone lithologies.

4. Geothermometer

Reservoir temperature can be estimated using Na-K-Mg diagram [6] by plotting chemical compositions of Na, K and Mg. Quartz geothermometer is also applied to the data. Four samples indicate a partially equilibrated fluid but one fluid indicating an immature water meaning the interaction between host rock and fluid are not fully completed. These data are then calculated into each respective geothermometer.

Silica geothermometer predicted that the reservoir temperature lies between 100 – 127 ºC, whereas Na/K geothermometer predicted reservoir temperature between 56 – 132 ºC. Na/K geothermometer [7] was applied due to its compatibility with the fluid chemistry that contains high concentration of bicarbonate anion [5]. A mixing of groundwater can also affect the concentration of Mg and consequently affecting Na-K-Mg geothermometer calculation.

Table 1. Geothermometer calculation

Sample Name	$T_{Na-K-Mg}$ (Giggenbach, 1988)	Quartz	$T_{Na/K}$ (Fournier, 1979)	$T_{Na-K-Ca}$
CKW1	60	117	111	87
CKW2	150	100	56	8
HDL	160	127	132	79
GJG1	110	147	140	95
GJG2	130	107	91	57

5. Geoindicator

Fluid chemistry can also be applied as geoindicators [5]. Compositions of Na, K, Ca, and Mg can indicate whether the manifestation is an upflow or an outflow. High ratio of Na/K and low ratio of Na/Ca indicate an outflow zone. It is likely that all samples are an outflow zone of Gunung Endut geothermal area.

Common reservoir can also be determine based on Cl-Li-B ternary diagram and Cl/B ratio. Chloride and Boron are conservative ions that makes a reliable geoindicator [5]. Surface manifestations that lies in Cikawah and Handeulum shows similar value whereas manifestation in Gajrug shows a significant difference. It is likely that these 2 separates manifestations originate from two different reservoir, one that lies to the northern part and one that lies to the northwestern part of Gunung Endut respectively. Higher Cl content when compared to Li and B, indicates that the manifestation originate from an older hydrothermal system and the fluid were able to migrate through the basement rock [5].

Table 2. Geoindicator calculations

Sample Name	Na/K	Na/Ca	Mg/Ca	Cl/B
CKW1	163.8	6.4	0.112	50.0
CKW2	33.1	13.3	0.005	40.0
HDL	29.1	15.4	0.001	31.2
GJG1	72.7	13.0	0.021	83.3
GJG2	48.1	22.1	0.009	80.0

6. Geothermal system in Gunung Endut geothermal area

Fluid chemistry analysis revealed that all the manifestations found around Gunung Endut area are indicator of outflow zones. Outflow zone with dilute-bicarbonate chloride water is a typical manifestation for geothermal system in an eroded volcanic terrain [8]. Both normal and horizontal faults found near the manifestations are predicted to be the main control of the surface manifestations. Highly altered rocks appear as a result of the interaction between geothermal fluid and the surrounding rocks.
A geophysical study of magneto-telluric found some low resistivity pattern proximate to the manifestations and to the peak of Gunung Endut [3]. However, the heat source of the geothermal system is yet to be determined.

An upflow zone-type manifestations can likely be found at the central/peak of Gunung Endut. Surface alteration and structural pattern in the field may aid to the direction of the upflow zone. Further field mapping and alteration studies can help create a better conceptual model in Gunung Endut geothermal area.

7. Conclusion

Geochemical assessment of Gunung Endut area revealed that three surface manifestations are indicators of outflow zones bases on the geoindicator analysis. All fluid type has diluted-bicarbonate water with near-neutral pH with high concentration of Total Dissolved Solids. There are two apparent reservoir overlying to the north and northwest of Gunung Endut geothermal area. The distribution of surface manifestations is thought to be controlled by faults (normal and horizontal) based on field observation and the findings of altered rocks along the structural line. Reservoir temperatures were obtained using geothermometry and yield the temperature ranging from 107 – 127 ºC using quartz geothermometer and 111 – 132 ºC using Na/K geothermometer.

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