Geochemistry characteristics of the hungayono geothermal area for the development of clean energy in gorontalo province

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Geochemistry characteristics of the hungayono geothermal area for the development of clean energy in gorontalo province

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Abstract. Geothermal energy has great potential to provide clean energy so that the Sustainable Development Goals (SDGs) can be achieved. The purpose of this study was to identify the geochemical characteristics of the geothermal fluid in the Hungayono area. Geothermal fluid sampling is performed at two points of manifestation which have the highest temperature. The cation and anion testing of geothermal fluid using Atomic Absorption Spectrophotometer (AAS) and isotope testing using the Picarro Water Isotope Analyzer. Data analysis using Giggenbach diagrams. Hot spring temperatures are 54 - 60ºC. The deposits at the point of manifestation are iron oxide with neutral fluid pH. Based on the results of the analysis of cations, anions, and isotopes, the Hungayono geothermal fluid is a type of chloride fluid that has been mixed with meteoric water. Based on the geothermometer calculation, reservoir temperature is 232-234ºC. Hungayono Geothermal is a type of system with moderate to high concentration.

1. Introduction

Susitainable Development Goals (SDGs) are a global effort and action to reduce poverty and social inequality and protect the environment around the world. SDGs have 17 priority goals to develop, one of which is developing clean energy. Indonesia is one of the countries that has the potential to develop clean energy so that Susitanable Development Goals (SDGs) can be fulfilled. One of the clean energies that can be developed in Indonesia is geothermal energy. Based on data from the Geological Agency in 2009, Indonesia has geothermal energy reserves that are spread over 256 manifestation points, but only a few points are utilized. Geothermal energy development can be carried out by geothermal exploration consisting of geological, geophysical and geochemical surveys to determine the potential development of a geothermal point.

Gorontalo is a province in Indonesia which has 8 points of geothermal manifestation. The points of manifestation include the villages of Lombongo, Pangi, Dulangeya, Pentadio, Pohuwato, Diloniyohu, and 2 other points in the Libungo area [1]. Suwawa area is an area that has the most manifestation points in Gorontalo Province. There are about 5 points scattered in this area, namely in the Lombongo, Pangi, Libungo, Hungayono and East Tulabolo areas.

Research on geothermal geochemistry in Suwawa was only conducted in the Pangi, Pangi, and Lombongo areas [1]. In addition, other studies were conducted in the area of Libungo [2]. The research which was conducted in the geothermal manifestation area of Hungayono, Suwawa Timur District, Bone Bolango Regency, Gorontalo Province was only in the form of geological mapping [3].

Based on the above background, it is necessary to conduct further research on the geothermal manifestations of Hungayono. The follow-up research referred to is research on geothermal

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geochemistry in the Hungayono area, East Suwawa District, Bone Bolango Regency, Gorontalo Province. The purpose of this study was to identify the geochemical geothermal characteristics of the Hungayono area.

2. Methods

2.1. Location

The research location is located (**Figure 1**) in the area of Bogani Nani Wartabone National Park, Hungayono, Tulabolo Village, Suwawa Timur District, Bone Bolango Regency which is shown in Figure 1. Based on the survey results, there are seven geothermal manifestation points scattered in Bogani Nani Wartabone National Park, Hungayono. Geothermal fluid sampling was carried out at two manifestation points that had the highest surface water temperature and the manifestation was not contaminated with river water.

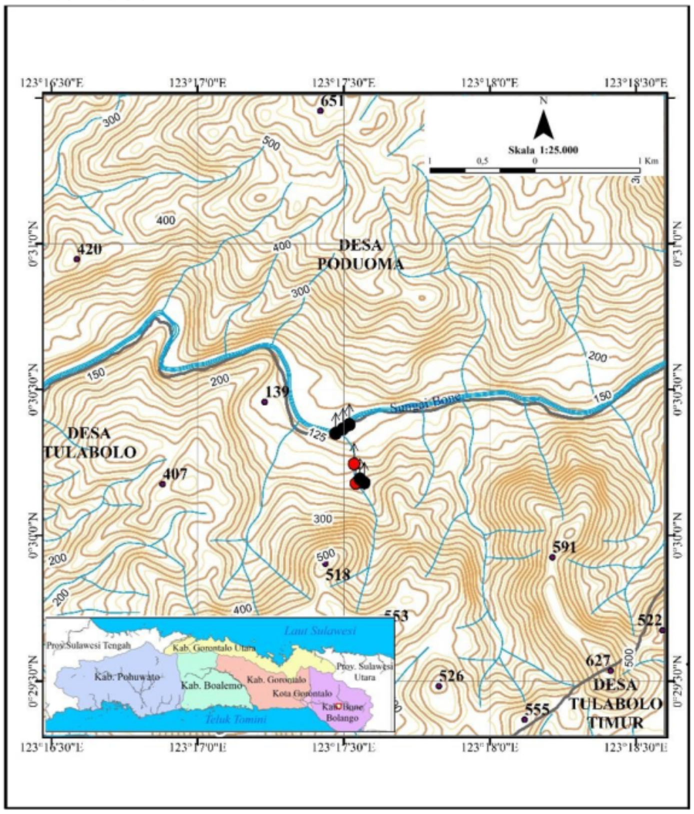

Figure 1. Topography map research location.

2.2. Research Methods

This research uses surface data survey methods and geochemical analysis of geothermal fluids carried out at the Central Laboratory of Coal and Geothermal Resources in Bandung. Surface data survey methods are carried out by taking surface data in the form of temperature data, pH, conductivity values, flow rate of manifestation, type of sediment. , taste, smell, colour, DHL (Electrical Conductivity). Surface temperature data were collected using an infrared thermometer. The pH data was collected using a pH meter and conductivity values were carried out using a conductivity meter. The manifestation flow rate, type of deposit, taste, smell, and colour were carried out by observing the surface manifestation. In addition to collecting surface data on geothermal manifestations, researchers also took water samples from geothermal manifestations for laboratory analysis. The number of water samples taken was 500 ml and 50 ml. A 500 ml water sample was used to test the geothermal fluid cations and anions. The 50 ml water sample will be used to test the geothermal fluid isotope.

Anion sampling is done by inserting geothermal fluid that has been filtered using filter paper into a 500 ml bottle. Cation sampling was carried out by inserting filtered geothermal fluid and adding HNO_3 acid into a 500 ml bottle. Isotope sampling is done by entering the filtered geothermal fluid into a 50 ml bottle.

Water samples taken from geothermal manifestations were then tested for cations, anions, and isotopes at the Laboratory of the Centre for Mineral, Coal and Geothermal Resources (PSDMBP), Geological Agency, Bandung. The cation test was carried out using an AAS (Atomic Absorption Spectrocopy) tool. Anion test with SiO2 and Al3 + parameters using AAS. Anion test with parameters B, HCO3-, and CO32- using titrimetry. Anion test with As3 + parameter using a colorimeter. Anion test with parameters NH4 + and F- using spectrophotometry. SO42- anion test using Turbidimetry and Cl- anion using Turbidimetry or Titrimetry. Isotope test using the Picarro Water Isotope Analyzer. This cation and anion test aims to determine the relative chemical content of geothermal fluids. This chemical content will be used as a reference for determining the type of geothermal fluid. The relative chemical content that will be used to determine the type of geothermal fluid is chloride (Cl), bicarbonate (HCO3) and sulfate (SO_4).

3. Results and Discussion

3.1. The Physics and Chemist Characters of Geothermal Manifestation

3.1.1. Geothermal Manifestation Point DT 1.1. The location of the first sampling is located at coordinates N 00º 30 '14.7 "and E 123º 17" 32.1 "with sample code DT 1.1. The geothermal manifestation at this point is in the form of hot springs. The geothermal manifestation of this first point is in a hilly area south of the Bone River. The area where this manifestation occurs is right above the travertine cave. Based on the survey results, the rocks around this manifestation are lapilli tuff rocks. Around this manifestation also scattered travertine deposits.

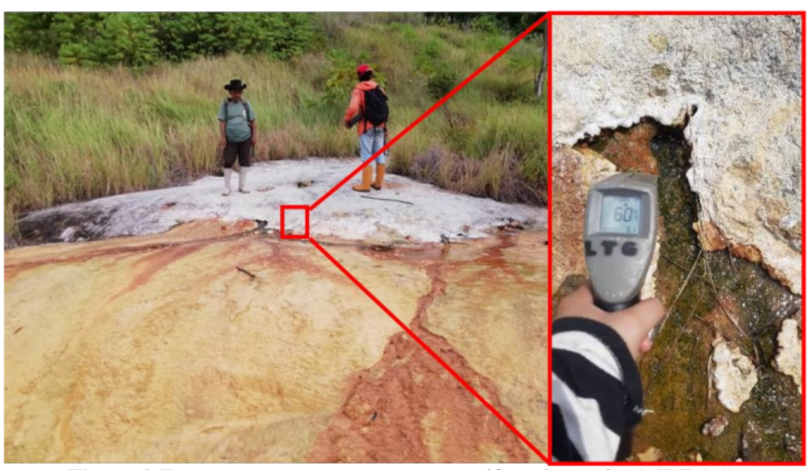

Figure 2.Temperature measurement at manifestation point 1 (DT 1.1)

Sampling was carried out at 1:19 WITA with sunny weather conditions and air temperature 33ºC. The geothermal fluid at DT 1.1 has a surface temperature ranging from 58.6 ° C - 60 ° C as shown in **Figure 2**. The physical characteristics of the water, the geothermal manifestation of this point is colorless, smells like rusty iron, tastes salty. The sediment around the DT 1.1 point is a reddish yellow iron oxide deposit. The measured electrical conductivity (DHL) of the geothermal fluid is 5138 µs / cm with the measured total dissolved solids (TDS) of 2746 ppm. The geothermal fluid DT 1.1 has a pH of 6.1. Around the point of manifestation there are travertine deposits.

3.1.2. Geothermal Manifestation Point DT 1.2. The second sampling location is located at coordinates N 00º 30 '10.7 "and E 123º 17" 32.5 "with sample code DT 1.2. The geothermal manifestations found in this area are in the form of hot springs. This manifestation is located ± 100 meters to the south of the first sampling site. The location of this geothermal manifestation is located in a hilly area south of the Bone River and is a nesting area for Maleo birds.

Sampling was carried out at 01.39 WITA, the weather conditions when sampling were sunny and cloudy. The air temperature at the time of sampling was 30ºC. The sample water at this point has a surface temperature of 54 ° C as shown in **Figure 3**. The physical characteristics of the water are colorless, smell of rusty iron, taste salty. The sediment at this point is a reddish yellow iron oxide deposit. Electrical conductivity (DHL) measured 5568 µs / cm with total dissolved solids (TDS) of 2851 ppm. The geothermal fluid DT 1.2 has a pH of 6.3.

Figure 3.Temperature measurement at manifestation point 1 (DT 1.1).

3.1.3. Type and the Origin of Geothermal Fluid. The determination of the type and original fluid is carried out by looking at the content of certain elements in the geothermal fluid sample. The elements contained in the geothermal fluid sample are tested in the laboratory using certain parameters. This element test is in the form of Element Cation, Anion, and Isotope Test. After being tested the test results were analyzed using the Giggenbach diagram to determine the type and origin of the fluid and to estimate the reservoir temperature from the geothermal system.

Table 1. Sample cation test results DT 1.1 and DT 1.2.

Sample Code	pH	DHL (µS/cm)	TDS (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	K^{+} (mg/L)	Na^{+} (mg/L)	Fe^{3+} (mg/L)	Li^{+} (mg/L)
DT 1.1	7,12	7100	5248	285,76	97,12	135,23	1359,76	4,38	3,67
DT 1.2	6,98	6850	5292	315,80	95,26	131,06	1280,97	2,29	3,46

Cation, anion, and isotope tests were carried out at the Central Agency for Mineral, Coal and Geothermal Resources Laboratory with cationic element parameters in the form of Ca2 +, Mg2 +, K +, Na +, Fe3 + and Li + as shown **in** Table 2. Before testing the element of cation, measurements were taken. pH value, Total Dissolved Solids (TDS), electrical conductivity (DHL) in the laboratory. Anion test was performed with parameters SiO2, B, Al3 +, As3 +, NH4 +, F, Cl-, SO42-, HCO3 +, and CO32- . The anion test results are shown in Table 1. Isotope tests were carried out with parameters 18 O and ²H. The results of the isotope test are shown in Table 3.

Table 2. Sample cation test results DT 1.1 and DT 1.2.

Sample Code	SiO_2	B	Al^{3+}	As^{3+}	NH_4^{+}	F	Cl^{-}	SO_4^{2-}	HCO_3^{+}	CO_3^{2-}
DT 1.1	190,35	11,45	0,07	0,20	1,30	0,0	2460,15	40,00	1066,38	0,00
DT 1.2	184,59	11,23	0,11	0,40	1,19	0,0	2460,15	35,00	1330,59	0,00

Table 3. Sample isotope test results DT 1.1 and DT 1.2

Sample Code	^{18}O	^{2}H
DT 1.1	-5,39	-37,61
DT 1.2	-5,50	-37,86

Based on the results of the cation, anion and isotope tests, the fluid type analysis was then carried out using the Giggenbach diagram [6]. The Giggenbach ternary diagram [6] used in this analysis is the Cl-SO4-HCO3 diagram, the Na-10K-1000 Mg^05 diagram, the Cl-100 Li-25 B diagram and the ^{18}O and ^{2}H (deuterium) isotope diagrams.

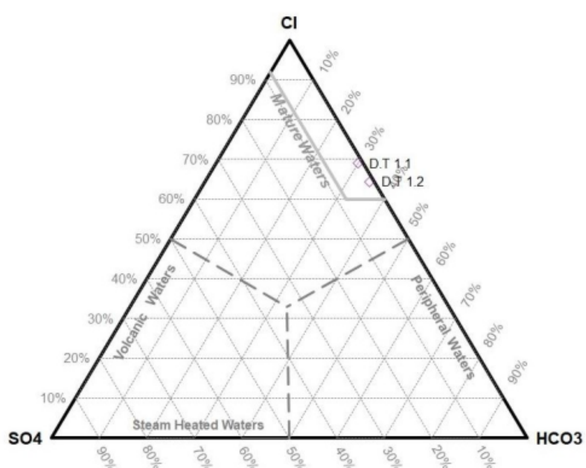

Figure 4. The results of the analysis using the Cl-SO4-HCO3 Giggenbach diagram.

The Cl-SO4-HCO3 diagram in Figure 4 is a diagram used for the analysis of the geothermal fluid type in the Hungayono area based on the concentrations of Cl, SO4, and HCO3. Based on the analysis of the Cl-SO4-HCO3 diagram in Figure 4, it shows that the points DT 1.1 and DT 1.2 have high Cl content so that they are plotted in the mature water area. This indicates that the geothermal fluid originates from a deep reservoir.

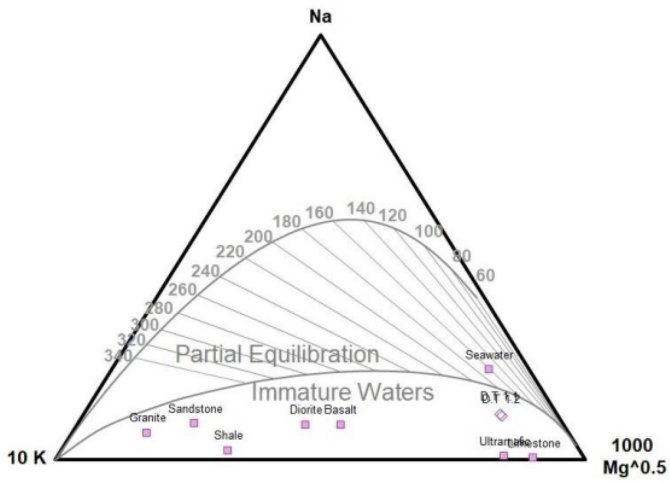

Figure 5. The results of the analysis using the Giggenbach Na-10K-1000 Mg^05 diagram.

The Na-10K-1000 Mg^05 diagram in Figure 5 is a diagram used to analyze the origin of geothermal fluids based on the concentrations of Na, K, and Mg. The cation test results plotted into the diagram show that the DT 1.1 and DT 1.2 samples are in immature waters. Based on the results of the diagram analysis, the manifestation points of DT 1.1 and DT 1.2 are not in the rock area. This indicates that there is no interaction between geothermal fluids and rocks around the geothermal system.

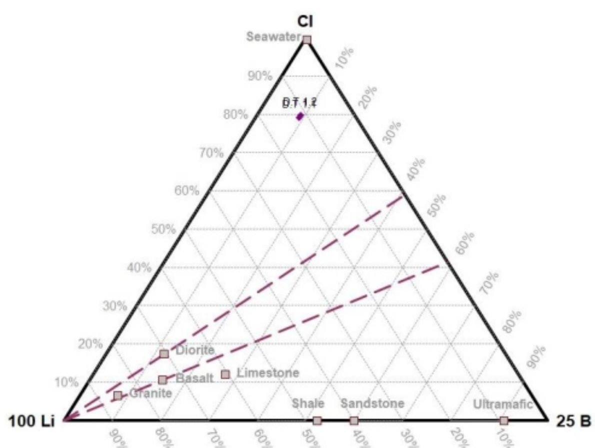

Figure 6. The results of the analysis using the Cl-100 Li-25 B.

The Cl-100 Li-25 B diagram in Figure 6 is a diagram used to analyze the origin of geothermal manifestation water and the zone where geothermal manifestations appear. Based on the results of processing and plotting data on anions and cations in the Cl-100 Li-25 B diagram, it shows that the Cl content is greater than the Li and B contents. upflow from the geothermal system.

Analysis of the ^{18}O and ^{2}H (deuterium) isotope diagrams was used to determine whether the geothermal fluid was mixed with meteoric water as shown in Figure 7. The data plotting results showed that the geothermal fluids DT 1.1 and DT 1.2 were in the mixing line area and almost approached the meteoric line. This indicates that there is mixing of geothermal fluids from reservoirs with meteoric water.

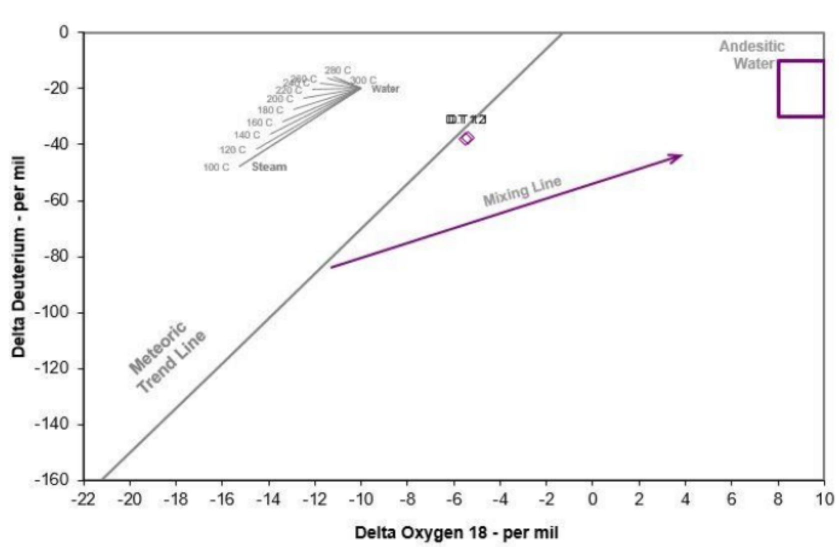

Figure 7.The results of the analysis using the ^{18}O and ^{2}H (deuterium) isotope diagram.

3.2. Reservoir Temperature

Based on the results of data analysis, it was found that the geothermal fluid type in the study area was a chloride fluid type. Estimation of the appropriate reservoir temperature for the type of chloride fluid is using a Na-K geothermometer. The geothermometer equation for Na-K is as follows:

$$t^0 = \frac{1390}{1.75 - \log\left(\frac{Na}{K}\right)} - 273.15 \quad (1)$$

The cation test results showed that the concentration value of the element Na in the DT 1.1 sample was 1359.76 mg / L. DT 1.2 sample contains a concentration of the element Na of 1280.97 mg / L. The concentration of element K in the sample DT 1.1 was 135.23 mg / L. The K element concentration in the DT 1.2 sample was 131.06 mg / L. The values of Na and K concentrations were calculated using the Giggenbach Na-K geothermometer equation (1). Based on the calculation, it was found that the reservoir temperature at DT 1.1 was 232°C. The subsurface temperature at DT 1.2 is 234°C which is shown in Table 4.

Table 4.Calculation of subsurface temperatures using the Giggenbach equation (1988)

Geothermal Manifestation Point	Na-K (Giggenbach, 1988) ºC
DT 1.1	232
DT 1.2	234

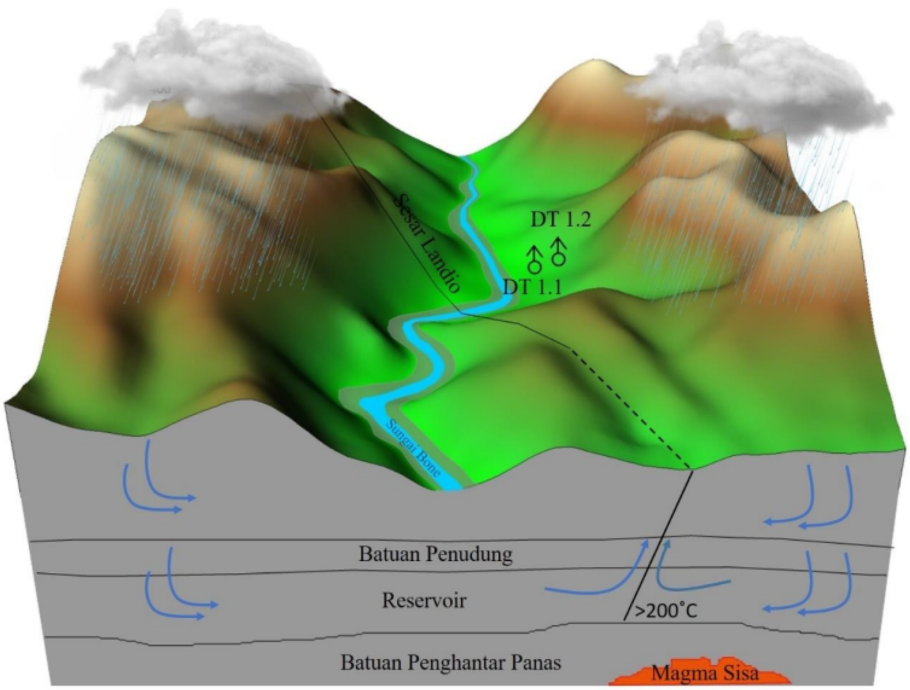

Figure 8. Hungayono Geothermal System Tentative Model

Based on the Geology of the Hungayono area [3], it can be interpreted that the Hungayono geothermal system consists of heat sources, conducting rocks, reservoirs and cap rocks. The tentative model of the Hungayono geothermal system is made in 3D as shown in Figure 8. The heat source in this system is thought to come from the residual magma that heats the rock above it in the form of Diorite then conduction heats the reservoir. The reservoir in this geothermal system is volcanic rock in the form of the Lapilli Tuff Unit which is equated with volcanic Pinogu rocks. The head rock is thought to be a change of tuff rock into clay due to hydrothermal processes. This is in line with research [4] which estimates that the heat source of the Suwawa WKP is magma residue, the reservoir of the Suwawa WKP geothermal system is volcanic Pinogu rock, and the supporting rocks are hydrothermal alterations.

The geothermal manifestation at Hungayono is thought to have emerged through the fracture. This fracture is caused by movement of the fault. The fault that is thought to affect the formation of the fracture in Hungayono is the Landio Fault. The Landio fault is a normal fault with a main force from the northwest to the east [3]. Geothermal fluids that have a reservoir temperature of 232-234ºC are expected to mix with meteoric water when approaching the earth's surface. This is what causes a decrease in temperature at the geothermal manifestation point of DT 1.1 and DT1.2.

The geothermal system based on reservoir temperature is divided into 2, namely a low temperature system and a high temperature system. Low temperature systems have a reservoir temperature <150 ° C, while high temperature systems have a reservoir temperature> 150 ° C [5]. The calculation results show that the reservoir temperatures of DT 1.1 and DT 1.2 reach> 200ºC. Based on the results of the reservoir temperature calculation, it indicates that the geothermal system in the study area is a high temperature geothermal system with high concentration.

4. Conclusion

Geothermal manifestations spread across Hungayono as many as 7 manifestation points. Research conducted on geothermal Hungayono produces geothermal physical and chemical characters, and determines the type of geothermal fluid based on the results of geochemical tests of water samples. Sampling was carried out at 2 points of manifestation which were coded DT 1.1 and DT 1.2. DT 1.1 point is found at the coordinate N 00º 30 '14.7 ", E 123º 17' 32.1". The manifestation points of DT 1.2 are located at coordinates N 00º 30 '10.7 ", E 123º 17" 32.5 ". Physical characteristics of the manifestations at both points are clear water, smell of sulfur, and taste sour. The geothermal deposits found at this point are iron oxide deposits. The flow discharge at DT 1.1 is 0.0004632 m3 / s while at DT 1.2 it is 0.000265 m3. The geothermal manifestation point of DT 1.1 has a surface temperature of 58.6 ° C - 60 ° C, a pH value of 6.1, a TDS (Total Dissolved Solids) of 2746 ppm, DHL (Electrical Conductivity) of 5138 µs / cm. The DT1.2 point has a surface temperature of 54ºC, a pH value of 6.3, a TDS (Total Dissolved Solids) of 2851 ppm, and a DHL (Electrical Conductivity) of 5568 µs / cm. Based on the results of testing and processing of geochemical data, it can be concluded that the Hungayono geothermal fluid type is chloride water. Based on the results of reservoir temperature calculations using the Na-K geothermometer, it was found that the reservoir temperature at DT 1.1 was 232˚C and the reservoir temperature was DT 1.2 is 234ºC.Based on the result, this manifestation has high concentration which is can be develop for clean energy.

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