Geochemistry analysis of geothermal water in Tulabolo Timur, Sulawesi, Indonesia

by Yayu I Arifin

Geochemistry analysis of geothermal water in Tulabolo Timur, Sulawesi, Indonesia

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Abstract. Gorontalo has several geothermal manifestations, such as Lombongo, Pangi, Libungo, Hungayono and Tulabolo Timur. Research on geothermal areas must be carried out to obtain surface and subsurface information, then the geothermal areas can be further developed. The purpose of this study was to analyse the geochemistry water of the geothermal water in Tulabolo Timur, Bone Bolango Regency, Gorontalo Province, Sulawesi, Indonesia. The research method is divided into field observations and laboratory analysis. Data processing using Atomic Absorption Spectrophotometer (AAS) for cation and anion test. Data processing using Picaro Water Isotope Analyzer for isotope test. Subsurface temperature is determined using the geothermometer Na-K Giggenbach formula. The results of this research show that the fluid type of Tulabolo Timur geothermal area is chloride and the origin of fluid is from deep reservoir. Geothermal fluid when it approaches the surface is not affected by surrounding rocks. Tulabolo Timur geothermal fluids are categorized in the upflow zone. Geothermal fluid when it reaches the surface is diluted with meteoric water. Meteoric water is infiltrated below the surface in the recharge area, which is located in the north and south of the study area. The subsurface temperature of Tulabolo Timur is included in the high-temperature system.
Keywords: Cation, Anion, Isotope, Chloride, Geothermometer.

1. Introduction

Eastern Indonesia is located in the convergent zone between three main plates and microplates namely; the Southeast Asian plate, the Pacific-Philippines sea plate and the Australian plate. These conditions form complex patterns of plate boundaries, active subduction and collision zones, neogen mountain belts and strike-slip zones (Hinschberger et al., 2005).

Sulawesi is located within the Neogen collision zone between Sundaland, or the Southeast Asian plate, and microcontinent originating from the Indian-Australian plate (Surono & Bachri, 2002). The North Arm Sulawesi is an active volcanic arc from Paleogene to Neogen (Kavalieris, et al., 1992). This condition is caused by the evolution of plate tectonics which collided with each other continuously and have implications for volcanism.

Volcanism has an important role in producing geothermal resources. Geothermal energy is heat energy from inside the earth that is transferred to the surface of the earth by conduction and convection (Suparno S, 2009). The high temperature geothermal system is located in the volcanic zone, continental ridge, and above the subduction zone (Kasbani, 2009).

The Tulabolo Timur area is located in Suwawa Timur District, Bone Bolango Regency, Gorontalo Province and has geothermal potential (Direktorat Panas Bumi, 2017). Geothermal potential can be classified based on the results of investigations from several studies such as geological, geochemical

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and geophysical research. There are several previous studies located in the study area and its surroundings, namely Apandi and Bachri, (1997), Mooduto, (2016), Direktorat Panas Bumi, (2017), Manyoe et al., (2017), Usman et al., (2019), Tolodo et al., (2019), and Sulaeman and Asngari, (2005).

There are no previous research on geochemisty analysis of geothermal water in Tulabolo Timur. This research aims to analyse the geochemistry of geothermal water in Tulabolo Timur, Sulawesi, Indonesia, to support geothermal data in the Tulabolo Timur geothermal area, Suwawa Timur District, Bone Bolango Regency, Gorontalo Province.

2. Method

2.1. Research Area

This research was conducted in the Tulabolo Timur area, Suwawa Timur District, Bone Bolango Regency, Gorontalo Province (Figure 1). Data is collected at two points, geographically at coordinates 00º28'12.3 " N and 123º17'15.0" E for the SN1 observation point and 00º28 '31.2 " N and 123º16'53.5" E for the SN2 observation point.

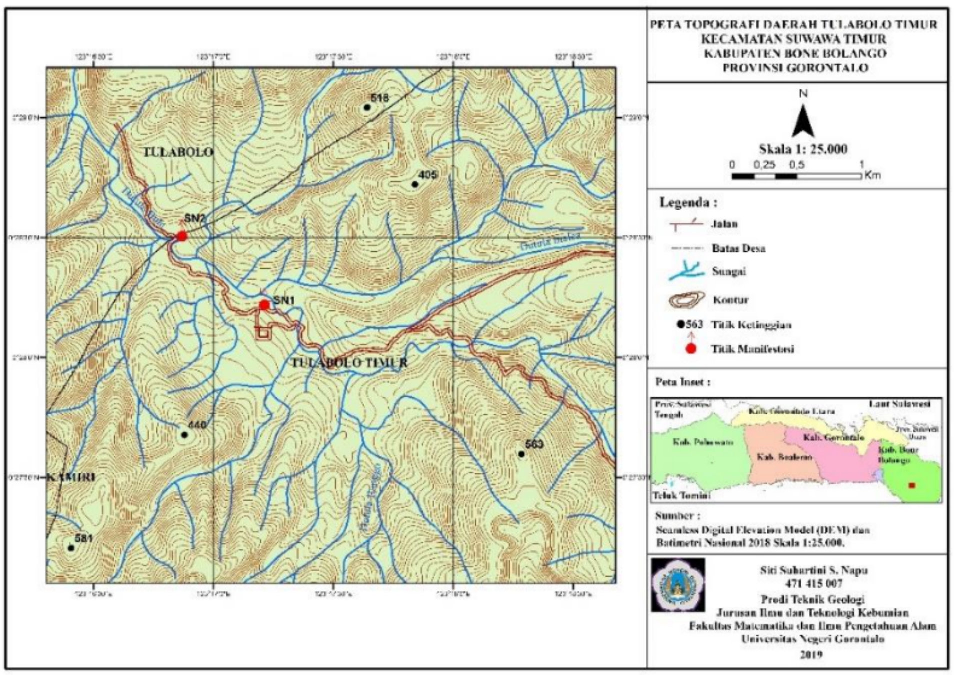

Figure 1. Research area map.

2.2. Research Methods

The method used in this study consists of taking data and samples of geothermal manifestations in the form of physical and chemical characteristics of geothermal manifestations. Data processing includes cation and anion tests using the Atomic Absorption Spectrophotometer (AAS) and isotope testing using the Picarro Water Isotope Analyzer. Analysis of cations, anions and isotopes of ^{18}O and ^{2}H using the Giggenbach (1988) diagram. Subsurface temperature is determined using the geothermometer Na-K Giggenbach (1988) formula, with the following mathematical formula (1):

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

3. Results and Discussion

3.1. Physical and Chemical Characteristics of Geothermal Manifestations

The SN1 geothermal manifestation is at coordinates 00º28'12.3 " N and 123º17'15.0" E. Geothermal manifestations are hot springs found at an altitude of 185 masl. Hot springs are in the breccia rock unit. SN1 hot springs have a pH of 6.3. Hot spring temperature is 50 °C. The temperature of cold water around the manifestation is 26 °C and the air temperature is around 30 °C. Hot springs are colorless, smell of sulfur, and taste salty. Sulfur deposits are found around hot springs. Flow discharge is 0.0030 m^3/s. Electrical Conductivity is 3734 µs/cm and the Total Dissolved Solids is 1867 ppm.

The geothermal manifestation of the hot springs at the second observation location is not far from the first observation location which is geographically located at coordinates 00º28'31.2" N and 123º16'53.5" E. SN2 hot springs are at an altitude of 129 masl. Hot springs are found in the breccia rock unit, but the lithological conditions at SN2 observation site are more weathered than SN1 observation site. SN2 hot springs have a pH of 6.3. The temperature of a hot spring is 47 °C. The temperature of the cold water around the manifestation is 26 °C and the air temperature is 30 °C. SN2 hot springs are colorless, smell of sulfur, and taste salty. Sulfur deposits are found around hot springs. Flowrate is 0.00015 m^3/s. Hot springs have an electrical conductivity value of 3674 µs/cm and a total dissolved solid is 1837 ppm.

The results of the cation test produce chemical elements such as Na^+, K^+, Li^+, Ca^{2+}, Mg^{2+}, Fe^{3+}. The Na^+ element in SN 1 is 120.95 mg / L and in SN2 it is 99.98 mg / L. The K^+ element in SN1 was 53.65 mg / L and in SN2 it was 46.15 mg / L. The element of Li^+ in SN1 is 2.22 mg / L and in SN2 is 1.52 mg / L. The element Ca^{2+} in SN1 is 120.95 mg / L and in SN2 is 99.98 mg / L. The Mg^{2+} element in SN1 is 38.66 mg / L for SN2 is 29.62 mg / L and the element Fe^{3+} in SN1 is 1.14 mg / L and SN2 is 0.56 mg / L.

The results of testing anion samples of geothermal water produce physical and chemical elements such as pH, EC, TDS, SiO_2, B, Al^{3+}, As^{3+}, NH4+, F^-, Cl^-, SO_4^{2-}, HCO_3^- dan CO_3^{2-}. Based on the results of laboratory analysis of geothermal water, the SN1 observation point has a pH of 7.16 and a pH of 7.07 for the SN2 observation point. EC value at SN1 observation point is 4020 umhos/cm and at SN2 is 3620 umhos/cm. Total Dissolve Solid of SN1 is 4050 mg/L and in SN2 is 3668 mg/L. The SiO_2 element in SN1 is 158.18 mg/L and in SN2 is 157.56 mg/L. Element B in SN1 is 6.32 mg/L and in SN2 is 6.11 mg/L. The element As^{3+} in SN1 is 0.40 mg/L and in SN2 is 0.20 mg/L. The NH_4^+ element in SN1 is 1.10 mg/L and in SN2 it is 0.86 mg/L. The Cl^- element in SN1 is 1252.44 mg/L and in SN2 is 1130.07 mg/L, the SO_4^{2-} element in SN1 is 111.24 mg/L and in SN2 is 40.00 mg/L and the element HCO_3^- in SN1 is 819.44 mg/L and at SN1 is 819.44 mg/L and at SN1 is 819.44 mg/L and SN2 is 798.90 mg/L.

The results of the isotope test using the Picarro Water Isotope Analyzer on geothermal manifestations samples in the study area get chemical elements such as ^{18}O and 2H. ^{18}O in SN1 is -5.82 while in SN2 is -5.81. The ^2H in SN1 is -37.13 and in SN2 is -38.31.

3.2. Cation, Anion and Isotope Test of Geothermal Water in Tulabolo Timur Area

3.2.1. Diagram of Giggenbach's Classification of Cl-SO$_4$-HCO$_3$

Based on the results of plotting data in the Giggenbach (1988) Cl-SO4-HCO3 classification diagram shows that the type of fluid from the geothermal research location both the SN1 observation point and the SN2 observation point are included in the chloride water type (Figure 2).

This type of fluid appears on the surface with clear/colorless physical features. According to Hutami et al., (2014) chloride geothermal fluid has a high concentration of Cl anions. The concentration of Cl anion is usually in the range of thousands to 10,000 mg/L. Cl concentration in salt

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water can reach 100,000 mg/L. Geothermal fluid in the study area has a Cl concentration of 1252.44 mg/L for SN1 observation points and Cl concentration of 1130.07 mg/L for SN2 observations.

Geothermal fluids that have high Cl concentrations and high TDS content indicate that hot springs circulate at high depths and temperatures. It means that the hot springs come directly from deepwater reservoirs (Nanlohi, F and Sundhoro, H., 2005). High TDS content in hot springs, especially Na and Cl ions, is the neutralization of acid gases resulting from the release of magma and surrounding rocks (Prasetio and Laksminingpuri, 2018).

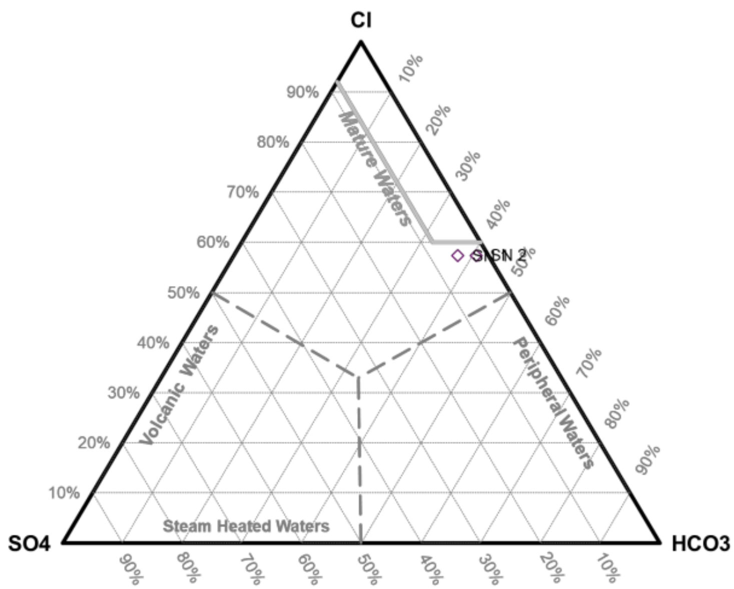

Figure 2. Giggenbach's Classification Diagram (1988) of Cl-SO_4-HCO_3 to determine the type of geothermal fluid

Based on Prasetio and Laksminingpuri (2018), the TDS content can be categorized high if the TDS content in geothermal fluids has values ranging from 1,300 ppm to 18,000 ppm. The TDS content measured in the field at SN1 observation point was 1867 ppm and at SN2 observation point was 1837 ppm, so the TDS content in Tulabolo Timur geothermal was relatively high. Based on Cl concentration and TDS content, the geothermal fluid of the Tulabolo Timur geothermal area is a fluid that originates from a subsurface reservoir and has a high temperature.

3.2.2. Diagram of Giggenbach, Cl, 100-Li and 25B classification

Based on the results of plotting in Cl, 100-Li and 25B diagrams show that the source of fluid comes from the reservoir because the Cl concentration is relatively high with respect to Li and B (Figure 3). This indicates that the geothermal fluid in the study area during its journey to the surface is not affected by the surrounding rocks.

Diagrams Cl, 100-Li and 25B show the levels of Cl elements do not reach the point of 100% so that the geothermal fluid can't be categorized as fluid from sea water. Geothermal fluid can be said to come from seawater if it has a Cl concentration reaching 100,000 mg/L and in the Cl diagram, 100-Li and 25B Cl concentration reaches 100%.

The B/Li ratio can be used to determine zones of upflow or outflow of geothermal fluid (Nicholson, 1993). Upflow zone is a zone of fluid discharge from the reservoir without reaction with surrounding rocks. The outflow zone is the zone of fluid discharge from the reservoir by the reaction with surrounding rocks. Upflow zones are marked with a low B/Li ratio, conversely if a high B/Li ratio indicates an outflow zone.

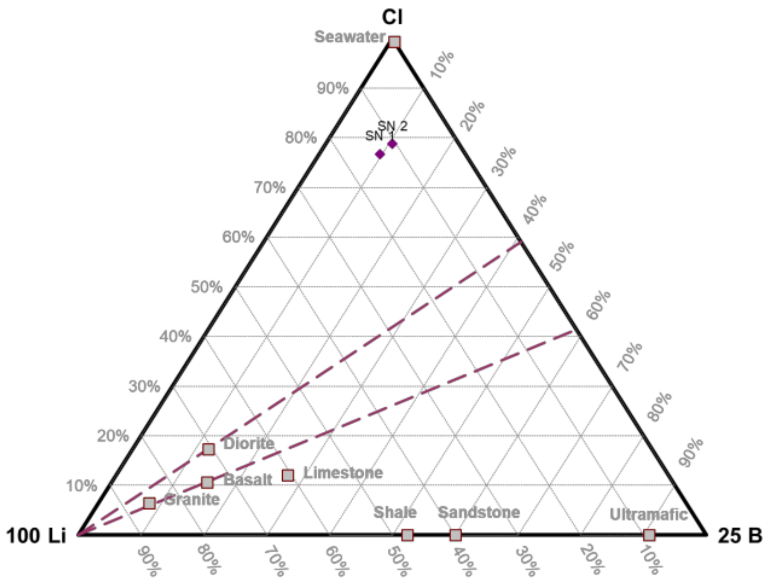

Figure 3. Giggenbach's (1988), Cl / 100-Li and 25B classification diagrams for determining geothermal fluid sources

Based on the Cl, 100-Li and 25B diagrams, Tulabolo Timur geothermal has a low B/Li ratio so that Tulabolo Timur geothermal fluid is categorized in the upflow zone. Diagrams Cl, 100-Li and 25B can also be used as an indication to determine geothermal systems. Geothermal systems with fluids that have high Cl content are old geothermal systems and have fluids originating from old bedrock (Strelbitskaya and Radmehr, 2010). Diagrams Cl, 100-Li and 25B show higher Cl element content compared to elements B and Li so that the Tulabolo Timur geothermal system is an old geothermal system and comes from old bedrock.

3.2.3. Na/1000-K/100-√Mg Classification Diagram

Based on the geochemical plotting on the Na/1000-K/100-g Mg diagram shows that all fluid manifestations in the study area are close to Mg (Figure 4). The high Mg concentration is an indicator of the process of mixing geothermal fluid with meteoric water. According to Ansori dan Wardhani (2015), geothermal fluids with higher Mg concentrations of Na and K or being close to Mg indicate that geothermal fluids are immature water.

Immature water or meteoric water is a geothermal fluid originating from near-surface water, which then enters the subsurface through permeable rocks or cracks in subsurface rocks. The immature water region indicates that the hot springs do not reach equilibrium, in other words having experienced a reaction with other elements when the fluid moves towards the surface (Utami dan Putra, 2018).

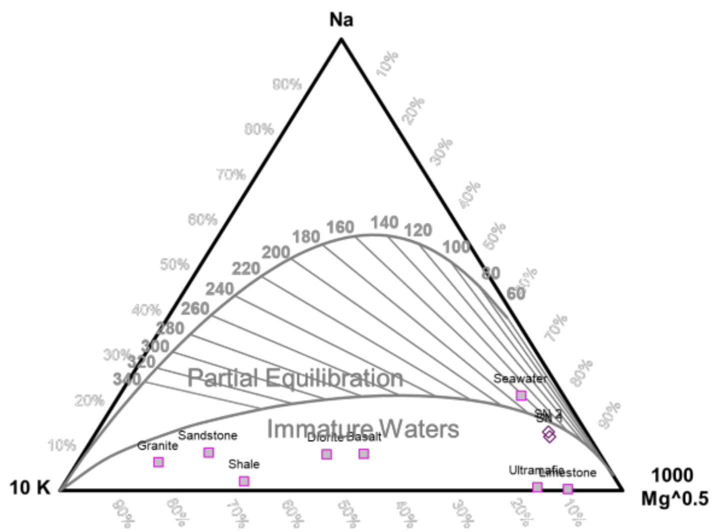

Figure 4. Giggenbach (1988) Classification Diagram, Na / 1000-K / 100-gMg to determine geothermal fluid sources

According to Nicholson (1993), hot springs that have high Mg concentrations have experienced mixing with meteoric water or groundwater that has high Mg concentrations. Thus, the geochemical ploting of the Na/1000-K/100-√Mg diagram shows that the geothermal fluid of the Tulabolo Timur region on its way to the surface has been diluted with meteoric water.

3.2.4. Isotop ^{18}O dan ^{2}H Deuterium

Based on the plotting data on the ^{18}O and ^{2}H isotope distribution diagrams (Figure 5) obtained from the sample hot springs the study area shows that the hot springs at the SN1 and SN2 observation points are close to the meteoric water line (MWL). This condition indicates that the hot springs in the research area before reaching the surface were contaminated by the water near the surface (meteoric water).

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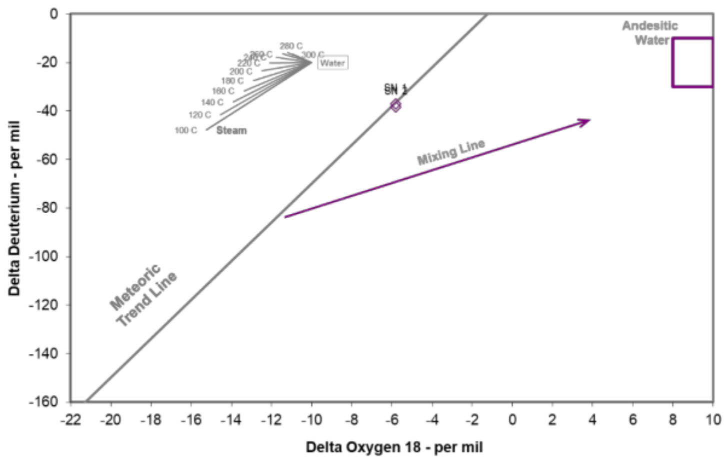

Figure 5. The ^{18}O and ^{2}H isotope distribution diagrams are used to obtain geothermal fluid sources and mixing with meteoric water

3.3. Subsurface Temperature in Tulabolo Timur

A geothermometer is an equilibrium between minerals and liquids that is affected by temperature and the rocks that pass through until fluids appear on the surface (Sulaeman and Asngari, 2005). Calculation of subsurface temperature by the geothermal method can be done on geothermal fluids with water types that have high Cl concentrations or fluids with chloride types.

This type of fluid has a good neutral pH to indicate subsurface temperatures by the geothermal method. Calculation of subsurface temperature is based on the chemical content dissolved in hot water (Sundhoro, 2007). Based on the new-K geothermometer formula (Giggenbach, 1988) the results of the calculation of the subsurface temperature of the study area with the SN1 observation point are 193.29ºC and the SN2 observation point is 185.6ºC.

Nicholson (1993) distinguishes the subsurface temperature of a geothermal system based on reservoir temperature levels. Reservoir temperatures ranging from <150 ° C are low temperature geothermal systems while ≥150 ° C are classified as high temperature systems. Referring to the classification of Nicholson (1993), the subsurface temperature of the Tulabolo Timur area, Suwawa Timur District, Bone Bolango Regency is included in a high temperature system. Based on the Cl-SO_4-HCO_3 diagram and the Cl, 100-Li dan 25B diagrams of geothermal fluid originating from the deep reservoir. Based on Na/1000-K/100-√Mg and ^{18}O and ^{2}H isotope distribution diagrams, geothermal fluid has experienced mixing with water near the surface.

Fluids originating from the reservoir are diluted when approaching the surface. Geothermal fluids initially had subsurface temperatures around 185-193ºC based on Giggenbach's subsurface temperature calculations (1988). When the process of the fluid reaches the surface, the temperature of the fluid changes to 47-50ºC, this temperature change due to the dilution with meteoric water when it reaches the surface

4. Conclusion

Types of geothermal manifestations in the form of hot springs with a temperature of 47°C - 50°C, pH 6.3, colorless/clear, smelling of sulfur, and taste salty. Sulfur deposits are found around hot springs. Broadcasting discharge is 0,00015 m3 / s - 0.0030 m3 / s, DHL (Electrical Conductivity) is 3674 µs / cm - 3734 µs / cm and TDS (Total Dissolved Solids) content is 1837 ppm - 1867 ppm. Fluid type from geothermal water is a type of chloride water and the source of fluid comes from a subsurface reservoir.

The subsurface temperature of the study area is 185.6 ºC and 193.29ºC. Geothermal fluid when it reaches the surface is diluted with meteoric water so that it experiences a decrease in temperature when it arrives at the surface.

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