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# Geophysical Exploration in Hot Springs Region Soppeng Regency, Indonesia

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# Geophysical Exploration in Hot Springs Region Soppeng Regency, Indonesia

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**Abstract:** Surface water is coming from rivers, rain, lakes, seas, and others seeps into groundwater, flows and comes into contact with the magma or hot, frozen bodies, boils and then forms water and steam (hydrothermal), due to specific gravity, temperature, and its pressure, this steam and hot water flows back to the surface through the fracture fields in the earth's crust. The research purposes are to identify the types of sediments and minerals found in the Hot Water Regions precisely located in Bulue Village, Marioriawa District, Soppeng Regency, South Sulawesi Province. This research uses the X-Ray Diffraction (XRD), resistivity meter, Electrode (potential electrode and current electrode) and Res2Dinv software for calculating the apparent resistivity based on the Wenner-Schlumberger configuration geometry factor and minerals dominance. Geoelectric results show silt and clay sediments are found to be dominant in Soppeng Regency hot springs. Silica is the central part that forms the rock, both rocks and rocks sediments. Furthermore, the result of X-Ray Diffraction (XRD) of mineral for three soil samples is dominated by Sodium-potassium to Aluminosilicate (41%), Sanidine (35%), Sanidine (equal to 47%) (Sanidine is mineral found mostly in volcanic rocks).

## 1. Introduction

One of the necessities of human life is energy resources. The availability of non-renewable energy resources such as petroleum fuels that are currently in a depletion condition is an important issue [1]. It is due to high–exploitation to meet the energy needs in various sectors. Today, geothermal resources become one of the alternative energy sources developed by many countries in the world [2].

Geothermal energy is the energy of natural resources in the form of hot water or steam formed in the reservoir in the earth through heating of subsurface water by a hot igneous rock [3,4]. The surface water coming from rivers, rain, lakes, seas, and others seeps into groundwater, flows into contact with magma bodies or hot igneous rocks, boils and then forms water and steam (Hydrothermal) [5].

Due to its density, temperature, and pressure, these steam and hot water flow back to the surface through the fracture fields in the earth's crust [6].

The existence of a geothermal under-surface resource often indicated by the presence of geothermal surface manifestations, such as warm soil, steamy surface, hot or warm springs, hot water pools, fiery water lake, fumaroles, geysers, hot mud puddles, sintered silica, altered rocks. Appearance on the surface is estimated to occur due to heat propagation from below the surface or due to fractures that allow geothermal fluid to flow to the surface [1].

Indonesia is a potential area of natural resources, including geothermal resources due to lies in the volcanic arc [7]. They provide total geothermal energy potential is 29,000 MW or 40% of the world's geothermal resources [8]. However, Indonesia uses only 5% of the reserves as most of these sources are located in protected forests and areas [9]. One of the potential geothermal regions of Indonesia is in Bulue village, Soppeng Regency, South Sulawesi. This area characterized by hot water pools located in some places [10]. The organic structure of normal Lejja faults that have north-west-south-south-south direction is right in the village of Bulue. The responsibilities are in the fault zone part of the sinistral (fracture with horizontal direction) shear fault north-west-south-south-east. Fault Lejja controls the emergence of Lejja hot springs which is the potential for geothermal heat. However, the condition is a surface manifestation of a geothermal system has not been explored so far by many researchers [7].

This research has objectives to identify the types of sediments and minerals found in the Hot Water Regions precisely located in Bulue Village, Marioriawa District, Soppeng Regency, South Sulawesi Province. We used Geophysical measurement with 2-dimensional (2-D) resistance method to physical parameters (resistivity) owned by rocks below the surface of the area [11,12].

## 2. Research Methods

### *2.1. Study Sites*

This research conducted in Bulue Village, Marioriawa District, Soppeng Regency, South Sulawesi Province. The geomorphology of Bulue Village dominated by steep hills, bumpy hills and plains [13]. Stratigraphy can be grouped into four units of rock from old to young namely; sedimentary rock units in the form of stuffed sandstone and blackish brown sandstones, andesite lava units, andesite piroksen-diorite (Qtla) units, and surface sediment (alluvium) [14].


**Figure 1.** Geophysical Measuring Point Location

Types of soil contained in Soppeng Regency include Latosol, Grumusol, Mediterranean Chocolate, Regulos, Alluvial, Litosol Dark Chocolate; with variations in the distribution of soil types in each district [13]. The research process from measurement to data analysis in the laboratory conducted from April to May 2017. The point of measurement location as follows:

- The location of the measurement points 1, is at 4°9'8.67" S and 119°47'19.41" E with an elevation of 187 m. Sub-surface section for position one located on the left which is ± 50 m from the hot springs.

- The location of the measurement points 2 is 4°9'7.26" S; 119°47'19.34" E with an elevation of 185 m. Sub-surface section for position two located at the top of which is ± 100 m from hot springs.
- The location of the measurement points 3 is at 4°9'5.85"S; 119°47'21.39" E with an elevation of 188 m. Sub-surface section for point 2 located on the right which is ± 200 m from hot springs.

### *2.2. Data Collection*

Field data was collected by the configuration of Wenner-Schlumberger and vertical sounding technique by using meter resistivity measuring instrument as well as Electrode (potential electrode and current electrode).

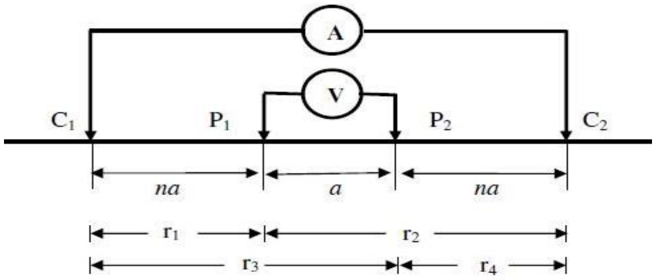


**Figure 2**. Configure Wenner-Schlumberger

This configuration is a combination of the Wenner configuration and Schlumberger configuration. In the measurement by the spacing factor (n) = 1, the Wenner-Schlumberger configuration is similar to the measure in the Wenner configuration (distance between electrode = a), but on the step with n = 2 and so on, the Wenner-Schlumberger configuration is the same as the Schlumberger configuration the current electrode and the potential electrode are higher than the distance between the potential electrode). To collect data in the form of rock samples or mineral sediments at each point of measurement that has determined. From this sample will then analyze using XRD so we can know the type of minerals in the example.

In science, the way it can be used to harness geothermal energy is to utilize Geophysics. Geophysics is the study of the earth by using physical parameters. In this case, the target is subsurface. Material parameters used are mechanical parameters which include seismic, gravity, magnetic and resistance method types [15]. The geolocation method of resistivity or type resistance is one of the kinds of geoelectric methods used to study the subsurface by study the nature of the flow of electricity within rocks beneath the earth's surface and to study the properties and characteristics of the material microstructure is a vital identification step [16]. The measurement of this geoelectric method is carried out by injecting an electric current through two current electrodes and measuring the voltage difference results on two potential wires plugged into the ground [17].

### *2.3. Data Processing*

The data obtained from field measurements are the potential difference (V), electric current (I) and spacing of the electrode (a). The data are then used to calculate the apparent resistivity based on the Wenner-Schlumberger configuration geometry factor. In Pseudo-resistivity cross-section analysis using Res2dinv which is a computer program that can automatically draw or create a subsurface 2-dimensional (2D) model from geoelectric survey data [18]. This program uses forward modeling techniques from apparent resistivity data measurements to obtain the opposite results [19]. The samples collected in the field are further down to the laboratory to be tested using X-Ray Diffraction (XRD) is one of the necessary non-destructive analyses to explain all types of materials, from liquids, powders, and crystals.

## 3. Result and Discussion

### *3.1. Cross-section Resistivity of Inversion*

The results of the three measuring points cross-section resistivity can see as follows:

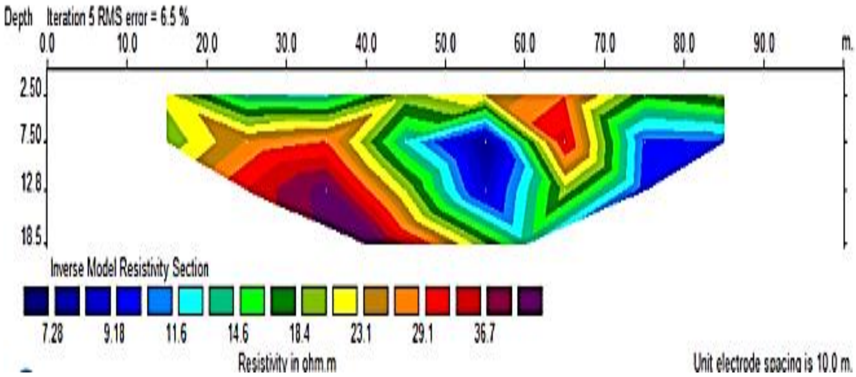


**Figure 3**. Cross-section Resistivity of Inversion at Point 1

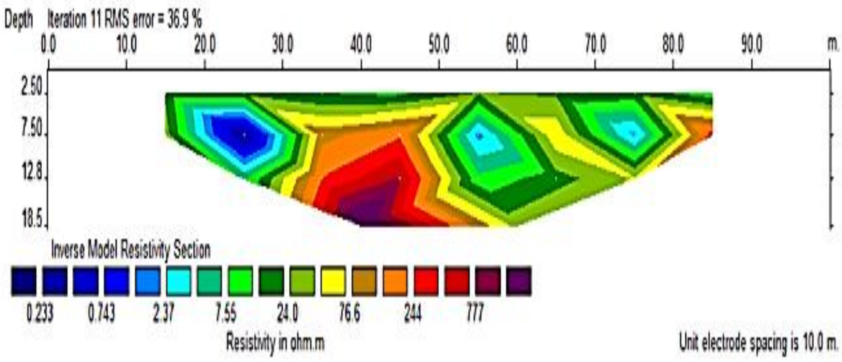


**Figure 4**. Cross-section Resistivity of Inversion at Point 2

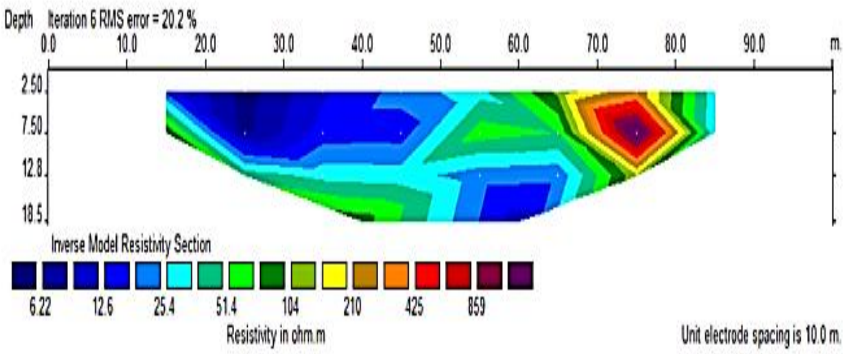


**Figure 5**. Cross-section Resistivity of Inversion at Point 3

Figure 3 shows cross-section resistivity of inversion at point 1 in the first trajectory of data retrieval is carried out on the left side which is about ± 50 m hot springs with a path length of 100 m, from the results of geophysics processing on the first dominant path found clay except at resistivity 11.6 Ωm - 18.4 Ωm there is silt and sandy land. The clay layer also referred to as a soft layer, generally the thin layer composed of soils composed mostly of tiny grains.

This minimal resistivity value (<10 Ωm) thought to be related to geothermal sources, where the lower the resistivity value, the higher the conductivity of material [20]. In this layer, there is a sandstone clay that has porosity and permeability both to accommodate and drain the fluid to the surface. So suspected sandstone clay is a reservoir. However, looking at its shallow position, it is not supposed to be a geothermal reservoir area but a groundwater reservoir

In a study conducted [21], in South Malta, Idaho showed a transition between low and high resistivity observed along the boundary of this study, at low resistivity zones ranging from 10 to 30 Ωm at a depth of 30 meters (at 100-180 m horizontal intervals) observed as dominant high liquid content. Low resistivity is predicted from high clay material as it can directly found in the research location that the material is rich in clay. Then the resistive zone is evident in the horizontal interval of 50-250 m. The high resistivity of this layer shows that it consists of consolidated rocks, and this segment can be considered a landslide rock. Also, the undulating boundary interpreted as a failure surface.

A case study from the Lapseki area, Turkey, clearly shows a low resistivity zone geometry (2-4 Ωm) between horizontal distances of approximately 27-40 m visible deep clay thickness together with sand which tends to show high resistivity value (> 6 Ωm) [22].

Figure 4 shows cross-section resistivity of inversion at point 2 as for the results on the measurement point 2; the more dominating color is the green color ranging from green to light to light green, at any resistivity value in the form of sandstone or sandstone except at the resistivity value of 7.55 Ωm. Resistivity value 244 Ωm - 777 Ωm there is clay soil, silty soil, basalt rocks filled with moist soil and bedrock filled with dry soil.

At the point of measurement two, there is a geothermal reservoir that suspected of clay sand because it has porosity and permeability both to accommodate and drain the fluid up to the surface. Geothermal liquid stored in the repository will flow to the surface through fractures in the rocks so that the geothermal manifestations appear on the surface of hot water.

Figure 5 shows cross-section resistivity of inversion at point 3 the results on the trajectory of 3 colors that dominate the blue color ranging from dark blue to bright blue, at each resistivity value of silt soil except at the resistivity value of 210 Ωm there is a denser rock filled with moist soil. The resistivity value is large enough to reach 200 - 859 Ωm, allegedly as lava rock. The hydrothermal system has a resistivity range of 10-200 Ωm and lava rocks of 200-10,000 Ωm [23].

According to [24], in a study conducted in Range Paeroa, Waikato - New Zealand showed resistivity values obtained over 300 Ωm at a depth of 900 meters and then at the bottom of 500 meters resistivity value also decreased to 100 Ωm. In other areas, a decrease in resistivity values with similar depths suggests that there is a young rhyolite dome material and volcanic ash this area is characteristic of the volcanic zone [25]. From the interpretation that has done, the potential of hot water is allegedly still significant enough to see from the 2-D cross-sectional image shows that the carrier layer of warm water properties is quite thick [26]. However, this is always a guess as this research is still a preliminary study, so there is always a need for more research to prove the truth. So, it cannot drain water if there is no fault in this layer of rock [27].

According to [28], hydrothermal alteration of the host rock also produces highly conductive clay species, which significantly reduces the resistivity of the rock matrix. Also, the resistivity of both the rock matrix and the geothermal fluids decreases with increasing temperature [29]. These three factors all contribute towards a high contrast in electrical resistivity between a region containing cold groundwater and one that includes geothermal [24].

### *3.2. X-Ray Diffraction (XRD) Sample Measurement*

Test results from 3-point sample measurement with X-Ray Diffraction (XRD) can see as follows:

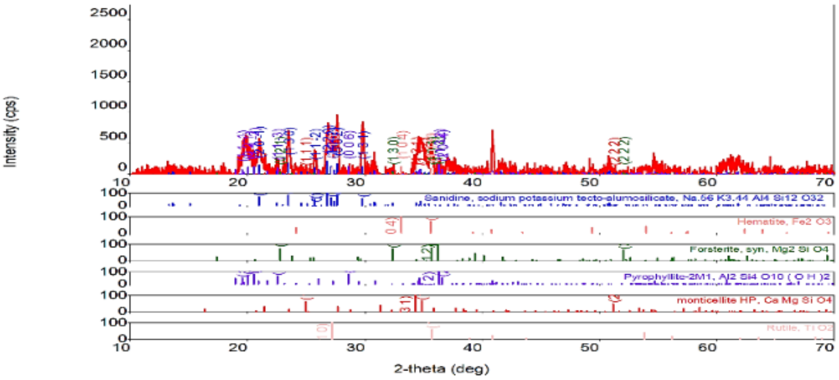


**Figure 6.** Result of X-Ray Diffraction (XRD) Sample Measurement Point 1

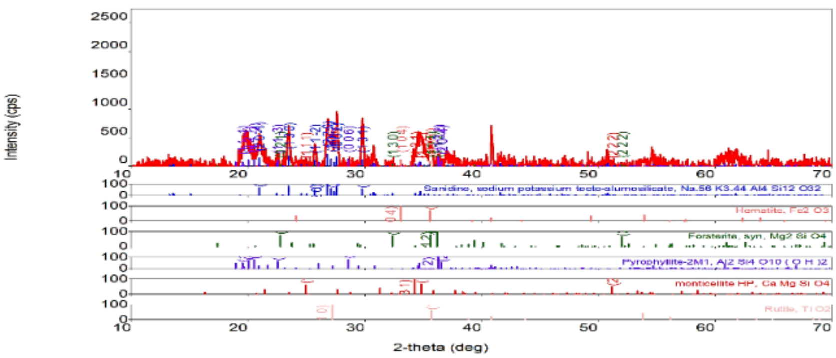


**Figure 7.** Result of X-Ray Diffraction (XRD) Sample Measurement Point 2

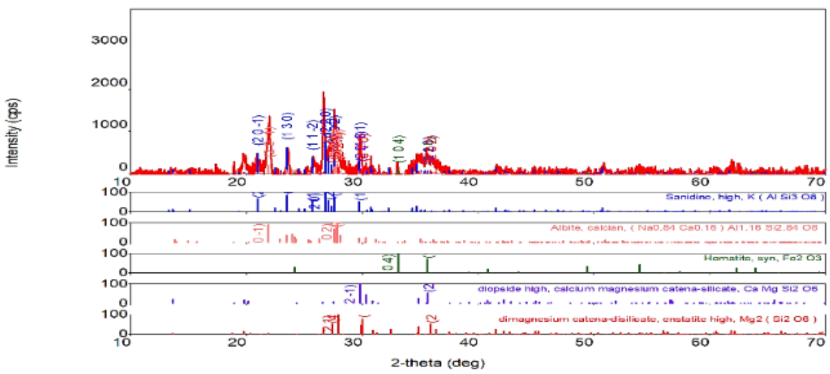


**Figure 8.** Result of X-Ray Diffraction (XRD) Sample Measurement Point 3

Figure 6 shows the result of X-Ray Diffraction (XRD) sample measurement point 1. For the first soil samples meticulously using XRD, there is sanidine, sodium potassium tecto-alum silicate with chemical formula $Na_{56}K_{344}Al_4Si_{12}O_{32}$, hermatite with chemical formula $Fe_2O_3$, Forsterite, Sync with chemical formula $Mg_2SiO_4$, Pyrophyllite-2M1 with chemical formula $Al_2Si_4O10$ (OH) 2, and monticellite HP with $CaMgSiO_4$ chemical formula. The percentage of mineral content of sample 1 indicates that the dominant component of mineral sediment sample 1 is sodium potassium tecto-alumosilicate 41% and Pyrophyllite-2M1 38%, and Forsterite, syn 11%, and some minerals in small amount, i.e., hermatite equal to 4%, Rutile at 4% and monticellite HP at 2%.

Figure 7 shows the result of X-Ray Diffraction (XRD) sample measurement point 2. The second soil samples using XRD contain iron (III) oxide, magnetite with chemical formula $Fe_3O_4$, Sanidine, high with Chemical Formula K ($A_lSi_3O_8$). Anorthite with chemical formula Ca ($A_{l2}Si_2O_8$), dimagnesium catena-disilicate, with the Chemical formula $Mg_2$ ($Si_2O_6$), diopside HP, magnesium calcium with chemical formula $CaMgSi_2O_6$, and Rutile, sync with chemical formula $TiO_2$. The percentage of mineral content of sample 2 shows that the dominant composition of mineral sediment 2 examples is Sanidine, 35% high, Anorthite 30.5%, 16% magnesium catena-disilicate, HP diopside, magnesium calcium 11% and some minerals diiron (III) oxide, magnetite of 4.2%, and Rutile, sync 3.22%.

Figure 8 shows the result of X-Ray Diffraction (XRD) sample measurement point 3. The third soil sample using XRD is Sanidine, high with chemical formula K (Al Si3 O8), Albite, calcian with chemical formula ($Na_{0.84}$ $Ca_{0.16}$) $Al_{1.16}$ $Si_{2.84}$, Hematite, Sync with chemical formula $Fe_2$ $O_3$, diopside high, calcium with Ca Mg $Si_2$ $O_6$ chemical formula, dimagnesium catena-disilicate, enstatite high with chemical formula $Mg_2$ ($Si_2$ $O_6$).

In the present study, geochemical and geoelectrical studies were carried out to identify the nature and subsurface structure of the slip surface of a shallow landslide. Geochemical characteristics of samples extracted from the clay-rich slip surface showed the presence of a mixture of clayey silt (32.5%) and sand (67.5%) as size fractions, and Si (23.24%), Fe (12.2%), Al (9.51%) and C (8.34%) as element composition. The slide associated with the presence of abundant clay content of the slip surface represented [22].

Because of the effect of the perturbation, the current will spread through the earth medium and radiate toward the radial. The magnitude of the radial current can measure in the form of a potential difference at a specific place on the surface of the soil so that the subsurface rock resistivity information [26,30–33]. Variations in rock resistivity may show differences in composition, thickness or contamination level. Natural materials such as soil, sand, and rocks contain minerals with different chemical compositions and crystal structures. It is an identification that distinguishes one element from another. Therefore, in addition to physical, mechanical tests, a material such as a sediment type should be investigated using XRD that aligned with the type resistance method.

The source of geothermal energy comes from the magma that is in the earth [34]. The magma conducts heat conductively to the surrounding rocks. The temperature also results in the convection fluid flow of hydrothermal in the pores of the cliff. Then this hydrothermal fluid will move upward but not to the surface because it retained by an impermeable layer of rock. With the waterproof layer, the hydrothermal system contained in the geothermal reservoir separated from the shallower groundwater [35]. However, up to now, it cannot be known for sure whether the hot water comes from heating the underlying rocks of magma below the source point or just a flow of hot water from another area that comes to the surface due to a crack in the rock which is the flow of hot water.

## 4. Conclusion

Sediments contained in Lejja hot water baths of Soppeng Regency from each measurement point by looking at dominant cross-section Resistivity in the form of silt and clay soils. Then the XRD result obtained by minerals is dominated by sodium-potassium tecto-aluminosilicate in soil samples at the first point, for soil samples at the second position is governed by Sanidine and soil samples at the third spot is overlooked by Sanidine, wherein sanidine is a mineral found in many volcanic rocks. The lack of geothermal exploration is to used as environmentally friendly alternative energy, in addition to the cost of building a costly plant. If you want to develop this potential, of course seriously, constraints about the area for geothermal energy development is not an excuse. There are still many potential locations in Indonesia that can manage well. It is desirable that there is in-depth research related to the geothermal area because the geothermal area in hot water area is only used as recreation area of bathing by local people. The fact that geothermal mining activities have little impact on the environment, pollution levels, and pollution is much safer than current fossil fuel mining. Although the utilization of geothermal energy in Indonesia has not maximized, Indonesia is one of the world's top producers of geothermal energy by utilizing the world's 3rd ranked geothermal according to the International Geothermal Association. Regarding ranking can be considered good, but regarding fulfillment needs are still far from enough words.

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