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Geothermal Temperature Slope at the KDD – 1 Well, Kadidia and Surrounding Areas, Nokilalaki, Sigi, Central Sulawesi Province

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Abstract
The need for alternative energy other than fossil energy is felt to be increasingly urgent for the fulfillment of domestic electrical energy. In meeting the demand for electricity, the government needs to investigate alternative geothermal energy, to find out the potential for geothermal energy to provide electricity. The realization of this policy is that the government conducts an integrated geothermal investigation to find prospective geothermal areas that can be developed as electric power. Nokilalaki District, Sigi Regency, Central Sulawesi Province is one area that has geothermal potential in Indonesia. The Kadidia geothermal area, Sigi Regency, Central Sulawesi Province is one of the volcanic geothermal fields that have good potential and needs to be investigated further, especially on geological conditions that affect the presence of geothermal energy. The research method used is the method of analyzing the results of field observations. From the observations, it was concluded that the KDD-1 temperature gradient well had a final depth of 703.85 m. The formation temperature is 96.87 ºC at a depth of 700-meters with an average slope value of 12.8 ºC/100 meters, and the estimated temperature at a depth of 1500 m (estimated top reservoir) is 220 ºC.

1. Introduction

The need for alternative energy other than fossil energy is felt to be increasingly urgent for the fulfillment of domestic electrical energy [1]. In meeting the demand for electricity, the government needs to investigate alternative geothermal energy, to find out the potential for geothermal energy to provide electricity [2]. The realization of this policy is that the government conducts an integrated geothermal investigation to find prospective geothermal areas that can be developed as electric power. The Kadidia geothermal area, Sigi Regency, Central Sulawesi Province is one of the volcanic geothermal fields that have good potential and needs further investigation [3]–[5]. To find out the geothermal aspect in this area, it is necessary to investigate using geological and geochemical methods[6], [7]. This investigation is intended to collect geoscientific data in the form of rock and fluid characteristics in the geothermal system [8]. The purpose of collecting geoscientific data is to determine the distribution of prospects (Vertical, Horizontal) and the magnitude of the potential in the resource class [9]–[11].

2. Methodology

This research begins with a literature review or study by observing reading from sources such as books, e-books, and journals written by several experts. Then field observations were made to obtain actual information in the field. Furthermore, the analysis of the observations, namely the Temperature Slope Analysis was carried out after performing the Logging Temperature on the KDD-1 borehole carried out at a depth of 150 m, 417.2 m, 513 m, and a depth of 700.50 m. In the Logging Temperature measurement, calculations are carried out using the Horner Plot method to get the formation temperature value (Initial Temperature) [9]–[11].

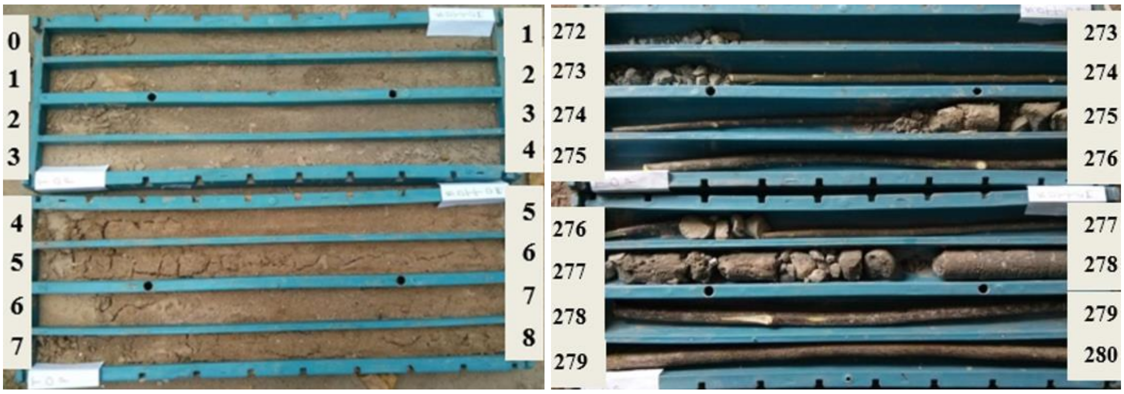

Figure 1. The core sample of 0 – 8 meter depth as an example of the soil layers (left), The core sample of 272 – 280 meter depth as an example of the conglomerate layers (right)

3. Results and discussion

3.1. Geology at KDD – 1 Well

3.1.1. KDD – 1 well lithology

The lithology of the KDD-1 well starting from a depth of 12.0 - 703.85-meters has undergone hydrothermal alteration with weak to moderate intensity changes (SM/TM = 10 – 65%) by anglicization, oxidation, and silicification alteration processes. The altered minerals are dominated by clay minerals of the type montmorillonite (smectite group) and illite, chlorite, and zeolite [12]. The lithology of the KDD-1 well from the surface to the final depth (703.85 m) based on megascopic analysis of drill core samples is composed of several units.

The soil layer was found at 0 to 12.0-meter depth intervals (see figure 1 left), brownish-yellow in color, reddish to slightly grey-black. Soil contains loose grains consisting of clastic detritus in the form of quartz, andesitic lithic detritus, granite, diorite. In this soil, quartz and black minerals are found in small quantities, which are thought to be mineral fragments from rock, and fracture filling minerals [12]–[16]. This layer acts as a cover layer and this rock has not undergone hydrothermal alteration.

The conglomerate layer was located at a depth of 12.0 - 47.45 meters, 80.45 - 109.70 meters, 162.05 - 183.50 meters, and 216.35 - 277.70 meters (see figure 1 right). The drill core is grey, brownish, yellowish-brass, whitish, slightly reddish, and blackish, mostly not yet compact. This conglomerate is composed of clastic detritus in the form of quartz, granitic lithic detritus, andesite, and diorite, with a rounded to angular shape with a base mass of clay and sand [16], [17]. Some of the rocks have undergone hydrothermal conversion into clay minerals and pyrites. In some places, claystone inserts are sticky (sticky).

The sandstone layer was found at depth intervals of 47.45 - 80.45 meters (see figure 2 left), 109.70 - 154.80 Figure 2. Core box depth of 8 – 16 meters is blackish grey, whitish, greenish, slightly yellowish-yellow, and brownish. This sandstone is fine-grained to coarse sand, circular in shape, packed closed, well consolidated, compact, and hard, consisting of quartz clastic detritus, black minerals, lithic detritus composed of andesite, diorite, and plant fossils [16].

The claystone layer was found at depth intervals of 183.5 - 191 meters, 197.45 - 200.45 meters (see figure 2 right), and often found as inserts in breccia and conglomerate rocks. The drill core is grey-black, slightly whitish, clay size, compact, there are plant fossils, weakly changed to clay, 10% sticky clay [16].

The Quartz sandstone layer was found at depth intervals of 277.7 - 376.75 meters (see figure 3 left). The drill core is greenish-grey in color, the size of the sand is fine to medium, the grain shape is moderately circular, packed closed, rather compact, the fragments are composed of quartz, lithic. There is a conglomerate insert and there is a parallel lamination. The rock is weakly changed to claystone which is sticky clay [16].

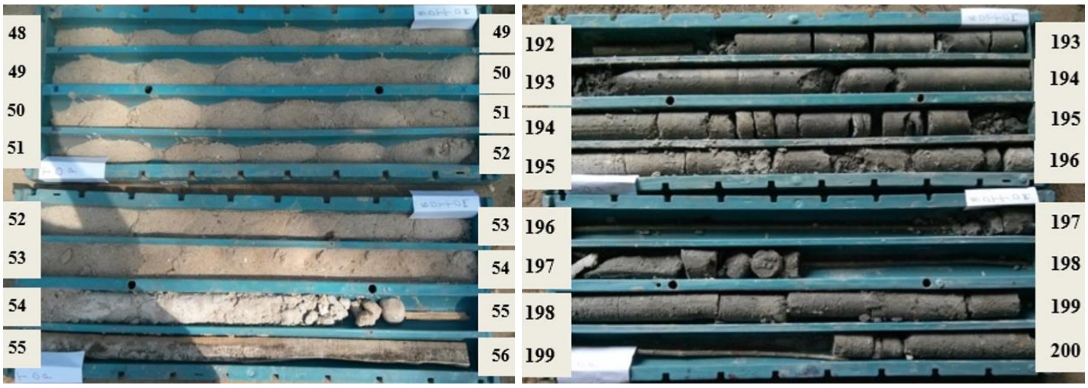

Figure 2. The core sample of 48 – 56 meter depth as an example of the sandstone layers (left), The core sample of 192 – 200 meter depth as an example of the conglomerate layers (right)

The sandstone with claystone inserts was found at depth intervals of 200.45 - 216.35 meters, 376.75 - 395.25 meters (see figure 3 right), and 489.5 - 524.30 meters. The drill core is grey-black, brownish, clay-sand grain size, circular grain shape, sealed, compact, fragments composed of quartz, lithic, clay matrix, sticky clay. Claystone as the insert is black, carbonate [16].

The conglomerate interchange with sandstone and claystone layer was found at depth intervals of 446.25 - 489.5 meters. Conglomerate drill core is grey in color, sand grain size is medium – gravel, open packed, poor sorting, grain shape is moderately rounded, compact, lithic polemic fragments (granite, sandstone), quartz, feldspar [13]. The sandstone is grey in color, the grain size is coarse to medium, packed closed, the sorting is medium, the grain shape is circular, the fragments are composed of quartz, lithic (granite, sandstone), feldspar, a little biotite. Black claystone, clay grain size [16].

The breccia interspersed with sandstone and claystone layer was found at depth intervals of 524.30 - 590.30 meters. The core of the breccia drill bit is greenish-grey – whitish, slightly blackish, and slightly brownish, the sand grain size is medium – gravel, open packed, poorly sorted, the grain shape is angular – moderately angled, compact, lithic polemic fragments (granite, andesite), quartz, feldspar, quartz veins, clay minerals, crushed in several places [13], [16].

The breccia layer was found at depth intervals of 590.30 - 703.85 meters (see figure 5). The core of the breccia drill is grey – brownish-grey – whitish, slightly greenish-black, medium grain size – gravel, open packed, poor sorting, angular grain shape – medium angle, compact, lithic polemic fragments (granite, andesite, quartz, feldspar, quartz veins, clay minerals, iron oxides, crushed in some places, medium to the coarse sand matrix, granite shards, quartz [13], [16].

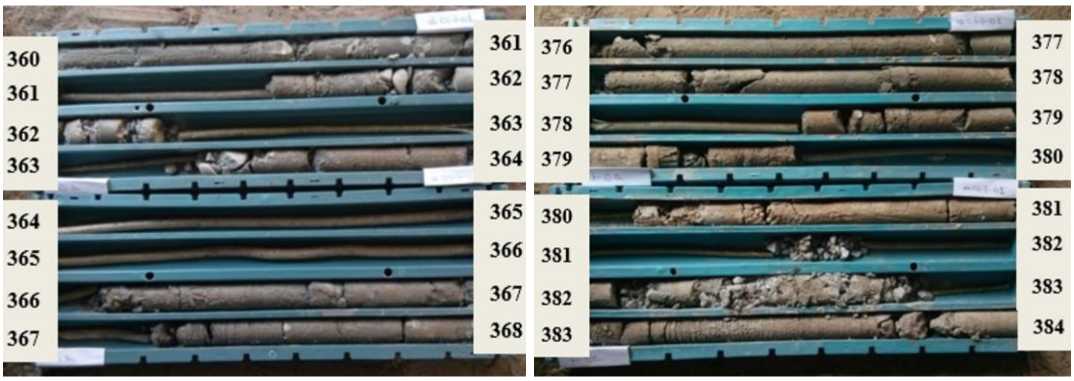

Figure 3. The core sample of 360 – 368 meter depth as an example of the quartz sandstone layers (left), The core sample of 376 – 384 meter depth as an example of the sandstone with claystone insert layers (right)

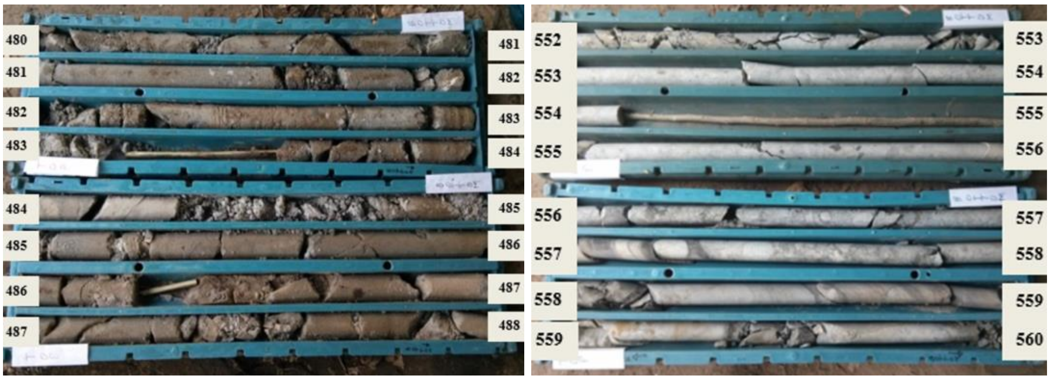

Figure 4. The core sample of 480 – 488 meter depth as an example of the conglomerate interchange with Sandstone and claystone layers (left), The core sample of 552 – 560 meter depth as an example of the Breccia Interspersed with Sandstone and Claystone layers (right)

3.1.2. Results of analysis of rock samples in the laboratory

Several rock samples from the KDD-1 well were analyzed in the laboratory to measure rock physical properties consisting of porosity, permeability, thermal conductivity, and rock density analysis. The results of the analysis show that the porosity values range from 5.69% to 44.89%, the permeability ranges from 0.00009 m Darcy to 25,42510 m Darcy [9], [10], the thermal conductivity ranges from 2.1 (BV/g/cm3) to 2.8 (BV). /g/cm3). The thermal conductivity and rock density values will be used to correct the formation temperature using the Horner Plot method[9], [10], [18].

3.1.3. Geological Structure of the KDD – 1 Well

The presence of geological structures in geothermal drilling wells can be interpreted from several structural characteristics such as rock physical properties (mylonitization and fractures) combined with drilling such as loss of circulation (total/partial) and the occurrence of drilling breaks [10], [18], [19]. During drilling activities, there has been a total loss of circulation (Total Loss Circulation) at a depth of 109.45 - 110.45 meters, then a partial loss of circulation (Partial Loss Circulation) of 40 liters/minute at a depth interval of 110.45 - 113.45- meters and at 113.45 - 154.80-meter depth intervals of 15 liters/minute. At a depth interval of 238.45 - 251.45-meters there is a partial loss of circulation (Partial Loss Circulation) of 20 - 30 liters/minute, and at a depth interval of 583.75 - 703.85-meters there is a partial loss of circulation (Partial Loss Circulation) of 10 liters/minute.

3.1.4. Temperature KDD – 1 well

The KDD-1 temperature gradient well from the surface to a depth of 703.85 m, is generally composed of uncompacted rock and hard rock that has joints and/or fractures at depth intervals of 109 - 154.80 meters, and mainly at intervals depth of 502.25 - 703.85 meters, so it is easy for caving to occur [20], [21]. From the data above, the KDD-1 well is in an intensive structural zone. The results of the measurement of the temperature inlet (Temperature in) and temperature out (Temperature out) of the KDD – 1 well from the surface to the final depth (703.85 m) ranged from Temperature in of 220 ºC - 370 ºC and Temperature out of 240 ºC - 380 ºC, with a difference in the inlet and outlet temperatures of 0.1 – 60 ºC.

Figure 5. The core sample of 480 – 488 meter depth as an example of the breccia layers

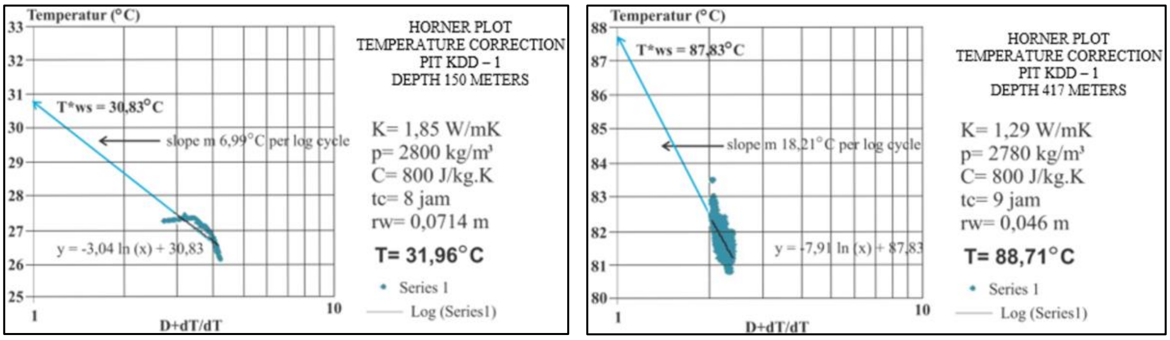

Figure 6. Horner plot at depth of 150 meters (left), Horner plot at the depth of 417 meters (right)

3.2. Geothermal Temperature Slope

Temperature logging measurements show that the temperature measured at a depth of 150 m is 26 ºC, with a maximum immersion temperature of 27 ºC (see figure 6 left), at a depth of 417.2 meters the measured temperature is 81 ºC with a maximum immersion temperature of 83 ºC (see figure 6 right), at a depth of 513-meters the temperature is measured as 87 ºC, with a maximum immersion temperature of 87 ºC (see figure 7 left), at a depth of 700.50-meters the temperature is 87 ºC, with a maximum immersion temperature of 91 ºC (see figure 7 right) [9], [10], [18].

During the drilling activities, there were several influxes of water from the depths, both hot water influx and cold-water influx. Hot water influx was found at depth intervals of 293.25 - 302.25-meters and at depth intervals of 502.25 - 593.15 meters. The presence of this influx greatly affects the reading of the rinse mud temperature value and the drill hole temperature [9], [10], [18].

In general, in the KDD-1 well there is a decrease in temperature (cooling) from a paleotemperature condition of 100 – 200 ºC (the temperature of altered mineral formation) to the current formation temperature of 97 ºC (the logging temperature measurement of the KDD well-1 well). This is probably caused by the recharge of meteoric water in the KDD-1 well in the fracture zone which is indicated by the presence of heulandite mineral (formed at a temperature of 200-350 ºC) which is a mineral of the zeolite group which is rich in H_2O. This fracture zone was formed due to the influence of the presence of the Kadidia Fault which is located close to the KDD 1 well [9], [10], [18].

In temperature logging measurements, calculations are carried out using the Horner plot method to get the Initial Temperature value (formation temperature). Based on these calculations, the formation temperature at a depth of 150-meter is 32 ºC (figure 6 left), at a depth of 417-meters is 89 ºC, at a depth of 513 m is 89 ºC, and at a depth of 700-meter by 97 ºC [9], [10], [18].

Based on the formation temperature at a depth of 700 meters, a thermal gradient value of 13 ºC/100-meter is obtained or about four (4) times the earth's average gradient (+ 30 ºC per 100 m). Furthermore, if the estimated top reservoir in the Kadidia geothermal area is about 1500-meter deep and the thermal gradient is assumed to be linear in the KDD – 1 well, then the formation temperature at that depth is around 220 ºC [9], [10], [18].

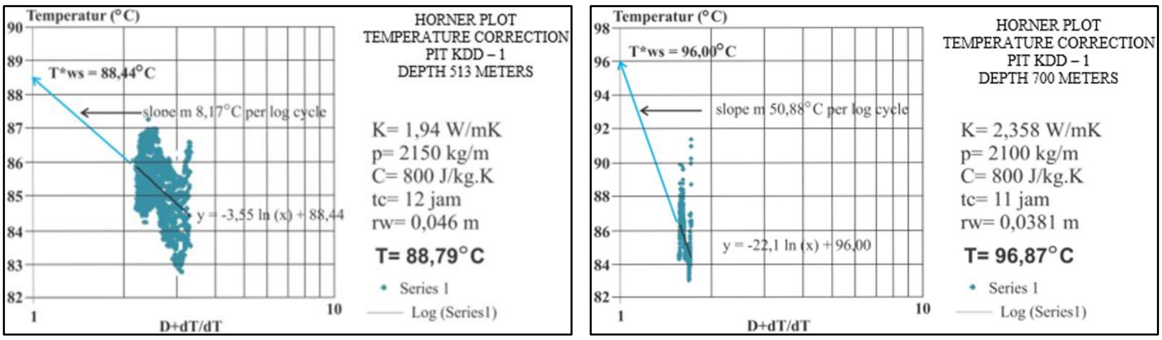

Figure 7. Horner plot at depth of 513 meters (left), Horner plot at the depth of 700 meters (right)

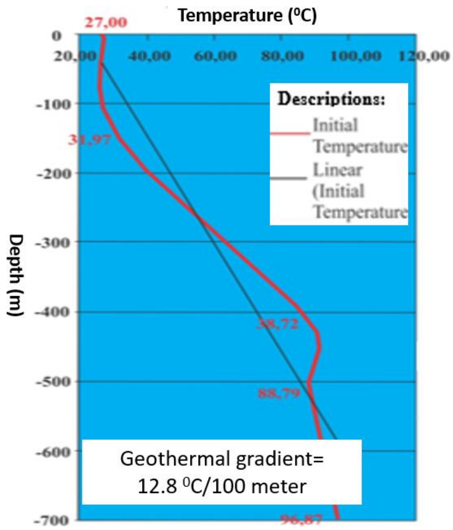

Figure 8. The temperature gradient in the well of KDD-1

4. Conclusion

Based on the results of research in Kadidia Village and its surroundings, it can be concluded that the KDD-1 temperature gradient well has a final depth of 703.85 m. The formation temperature is 96,87 ºC at a depth of 700-meters with an average slope value of 12.8 ºC/100 meters, and the estimated temperature at a depth of 1500 m (estimated top reservoir) is 220 ºC [20].

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