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FEED ZONE CHARACTERIZATION BASED ON PTS FLOWING DATA AND GEOLOGICAL DATA OF WELL DRILLING A FIELD B

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ABSTRACT

Kamojang Geothermal is an active production field owned by PT Pertamina Geothermal Energy that contains 1 steam-phase fluid. This field often conducts production tests, one of which is the PTS flow test. This study aims to determine the relationship between the potential size of the feed zone and mineralogy. This research method begins with calculating and analyzing the flowing PTS. After the PTS calculation is complete, it is continued by making a composite log graph from the drilling geology data. The results show that the characteristics of reservoir mineral rocks are the appearance of epidote minerals and the caprock section is characterized by the appearance of clay minerals. In the reservoir zone, the feed zone was found at a depth of 1300 mMD and 844 mMD with mass rates of 62 t/h and 11.19 t/h, respectively. The distribution of the feed zone was found to contain epidote minerals as much as 1% of 67% of the altered andesite rock at a depth of 844 mMD and epidote minerals as much as 15% of 79% of the altered breccia rock at a depth of 1300 mMD.

Keywords: massrate, mineral, pts flowing, rock

I. INTRODUCTION

The Kamojang geothermal field is part of a volcanic complex that extends from West to East consisting of a series of Mount Rakutak, Lake Ciharus, Pangkalan Lake System, Mount Gandapura, Mount Guntur, and Mount Masigit. The geologic map of the Kamojang geothermal field area in Figure 2.1 based on Pertamina Geothermal Center (1975) conveys that the geologic structure of this area is controlled by the base caldera wall on the West side, a group of Northwest-Southeast trending normal faults in the North and a North-South trending normal fault on the East side. These North-South normal faults control the growth of several craters such as Leutak, Wakong, Saar, Manuk, and Pojok, which are the alignment of geothermal manifestations on the surface (Hilyah, 2016). The field has a fluid type that is single phase steam. The steam content of the Kamojang field is currently 99% of the best quality steam in the world. This geothermal is included in the volcanic formation system which is characterized by the abundance of volcanic rocks such as andesite and basaltic rocks.

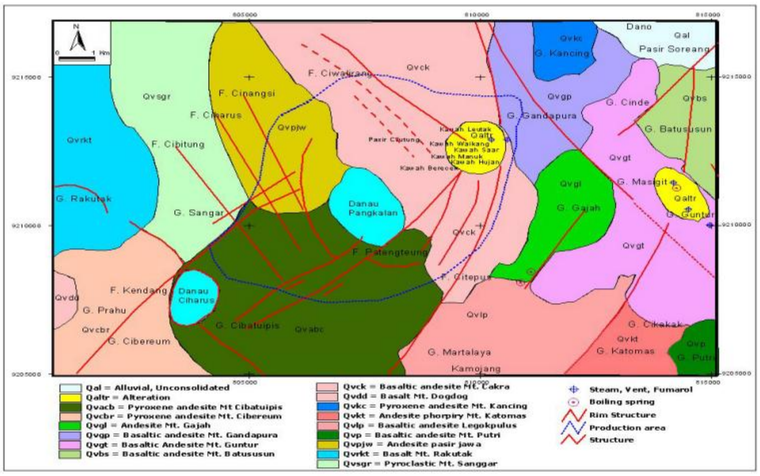

Figure 1. Geological Map of Kamojang & Surrounding Geothermal Area

Pressure Temperature Spinner (PTS) is a tool used to make measurements below the surface in geothermal wells that function to determine the pressure, temperature, and flow rate of production fluids including the location of the feed zone (Steingrimsson, 2013). Rock alteration is controlled by water-rock interaction in fractured and permeable areas to increase

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fluid flow. However, at a later stage, the alteration process of the host rock with primary minerals filling the fractures and altered to secondary minerals (open space) (Brehme et al., 2016). The PTS survey determines the type of fluid produced and the type of geothermal well reservoir. To determine the reservoir, pressure and temperature data must first be obtained, then the fluid characteristics or reservoir content of the geothermal well must be determined (Akbar, 2017).

Hydrothermal fluid is the presence of certain mineral accumulations in rocks that are traversed by hydrothermal solutions that flow in response to reactions between hydrothermal solutions and parent rocks that are next to them (Rahmaningrum, 2021). The hydrothermal alteration process causes mineral changes in andesite and forms secondary minerals due to the interaction between hydrothermal fluids passing through the overlying rock. Through this interaction, the fluid can change the mineral, chemical and physical composition of the rock (Riswandi, 2023). The set of alteration minerals occurs because there are changes in temperature and chemical properties of hydrothermal solutions in certain phases that have hydrothermal solution interactions with side rocks.

Based on previous research, PTS tests have been analyzed in the Kamojang area geothermal field wells. The results of the PTS log data interpretation showed the existence of three feed zones in the well. This feed zone is thought to be at a depth of 900, 1300 and 2900 meters. In this research, the author will analyze the feed zone with PTS flowing data and drilling geology data. The results of the data obtained will be used to determine the depth of the well feed zone, the vapor contribution of each feed zone (fracture zone) found, the nature of fluid flow in the well, then after that it will be associated with drilling geology data.

II. METHODS

Field analysis is carried out by directly observing how the PTS flowing data collection process uses wireline logging tools. This data collection takes a long time and is done repeatedly to get maximum data. This process will later be calibrated between the time on the tool and the time on the surface.

Literature study is done in several ways such as reviewing several explanations from engineers or other sources related to PTS flowing. After obtaining the PTS result data, a pivot will be made to short the data to make it easier to read the data. The raw data obtained are pressure, temperature, spinner, cable speed, and depth. Next is to determine the slope value of the well. The next few stages are determining the value of flow velocity, flowrate, and massrate from each depth of well A of field B. The following formula is used in calculating PTS flowing data:

$$\text{Slope} = \frac{RPM}{CS} \tag{1}$$

$$\text{Flow Velocity} = \frac{RPS}{Slope} \tag{2}$$

$$\text{flowrate} = 0{,}25\ x\ \pi\ x\ (ID)^2\ x\ \ FV \tag{3}$$

$$Massrate = Density\ x\ Flowrate\ /\ 60 \tag{4}$$

The second stage is to analyze the alteration minerals from the lithology of well A. This data will be used to create a composite log and compared with the flowing PTS data. Mineral data obtained in this well has several types, such as clay, calcite, epidote, and so on. There is additional data in determining the zone of host rock, namely MBT test data. This data is very accurate in determining the amount of smectite minerals in the well. After all the data has been processed, the next step is to analyze the relationship between feedzone and alteration minerals in well A of field B.

III. RESULTS AND DISCUSSION

Lithology and altered rocks in well A

The lithology of volcanic rocks in the Kamojang area originally came from various eruption sources influenced by tectonic structures and strong hydrothermal fluid alteration, making it very difficult to recognize the origin of the rocks. Therefore, the stratigraphy of the Kamojang geothermal field is organized on a layer-by-layer basis from the rock types obtained during drilling operations, while the naming is complemented by the alteration intensity. In the Kamojang area, including well A, it is estimated that the dominant rock types are breccia and andesite.

A B C

Figure 2. Altered rocks A) Altered andesite breccia B) Altered tuff breccia C) Altered Andesite

Andesite is an important volcanic igneous rock that forms in subduction zones and plays a major role in the volcanic activity that forms strato-volcanoes. The mineral composition and texture of andesite reflect the complex formation conditions and geological processes beneath the earth's surface. Andesite generally has an afanitic (fine-grained) to porphyritic texture, where large crystals (phenocrysts) are dispersed in a finer matrix. The altered andesite in this well has the characteristics of gray, gray-whitish, porphyritic texture, plagioclase and pyroxene phenocrysts embedded in afanitic basement. The altered andesite rock has an alteration mineral composition of Clay 1%, Calcite 5%, Chlorite 8%, Pyrite 8%, Epidote 5%, Iron oxide 1%, Secondary quartz 30%.

Tuff rock is a type of pyroclastic rock formed from fragmented volcanic material during volcanic eruptions. These rocks consist of fragments of volcanic ash embedded with fine ash or other volcanic matrix. Hydrothermal activity often transforms tuff into hydrothermally altered rocks that can increase storage capacity and thermal conductivity. This altered tuff breccia in well A has the characteristics of gray, whitish gray, green, blackish brown, brownish red slightly greenish yellow, fragmental texture, consisting of 60% tuff fragments and 40% andesite. The mineral composition contained in the altered tuff breccia rock is Clay 5%, Calcite 5%, Chlorite 8%, Pyrite 8%, Epidote 5%, Iron oxide 3%, Secondary quartz 25%.

Andesite breccia rock is a type of volcanic rock consisting of andesite fragments that are sharply angled and consolidated together by a fine matrix or other binding material. When viewed in the sample, the characteristics of andesite breccia rock are gray, whitish gray, green, blackish brown, brownish red slightly greenish yellow, fragmental texture. Altered andesite breccia consists of 30% tuff fragments and 70% andesite. The rock is strongly altered into the minerals Clay (Cl), Calcite (C), Pyrite (Py), Chlorite (Ch), Epidote (C), Iron Oxide (Io) and Secondary Quartz (SQ). The mineral composition contained in the altered andesite breccia rock is Clay 3%, Calcite 5%, Chlorite 8%, Pyrite 10%, Epidote 3%, Iron oxide 5%, Secondary quartz 30%.

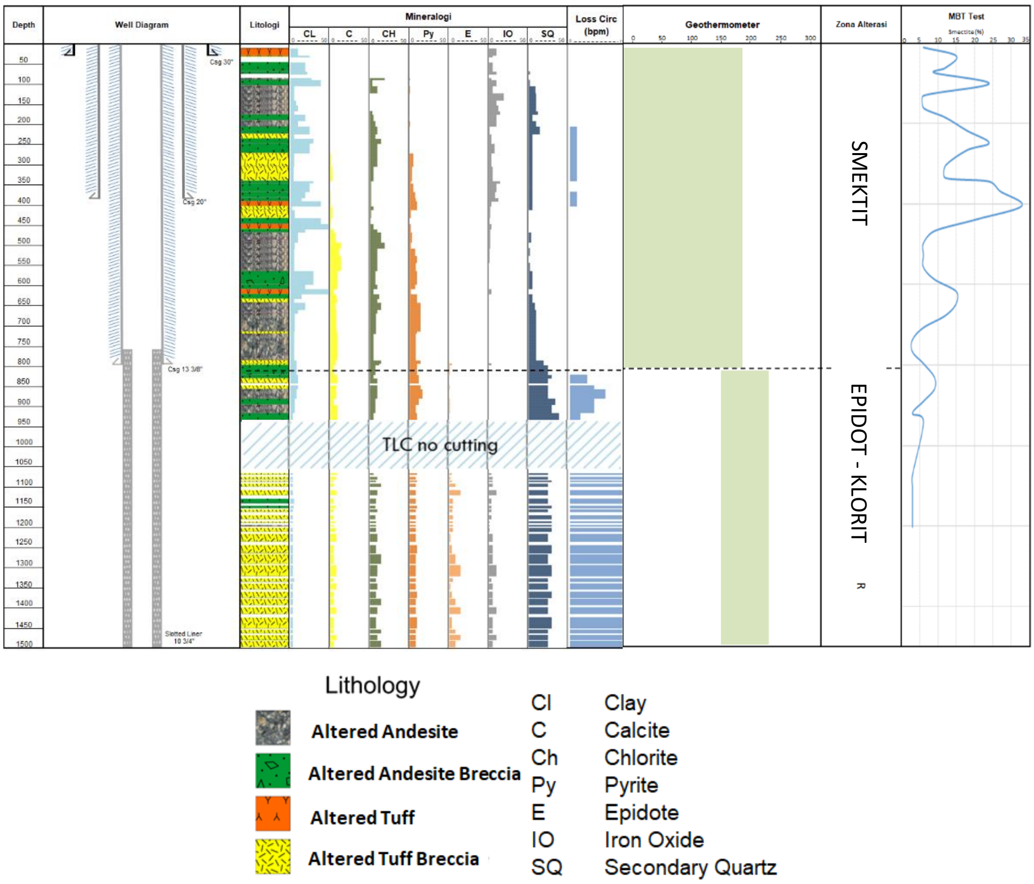

Figure 3. Lithology and alteration minerals of well A

When viewed from the lithology picture above, well A has 4 different types of rocks, namely andesite, breccia tuff, tuff, and andesite breccia. Of the four rocks, the more dominant rock in well A is the altered andesite breccia. This rock is present at almost every depth and appears more in the reservoir part of the well. When viewed from the characteristics of andesite breccia, this rock can create pores and allow for the formation of permeability in the subsurface.

Alteration Minerals

When viewed from **figure 3**, several alteration minerals were observed in place of primary rocks and minerals. Well A has several types of alteration minerals namely Clay (Cl), Calcite (C), Chlorite (Ch), Pyrite (Py), Epidote (E), Iron oxide (Io), and secondary Quartz (Sq). Starting at the well surface, chlorite commonly replaces glass in andesite and breccia rocks. Plagioclase is converted to clay, calcite, pyrite and quartz. Starting at a depth of 796 m, plagioclase is replaced by epidote and then pyroxene is converted to quartz and pyrite. Iron oxides are minerals made up of the chemical compounds iron and oxygen (silicates). The presence of these alteration minerals indicates different zones at each depth. The formation of hydrothermal minerals is influenced by temperature, pressure, host rock type, reservoir permeability, fluid composition and duration of activity.

Alteration Zone

This alteration zone is a collection of areas that show the spread of alteration mineral assemblages. When viewed in **figure 3**, there are two distinct alteration zones. The two alteration mineral zones are recognized based on the surface boundary between the caprock and the reservoir zone. These zones are the smectite zone and the quartz - epidote zone.

The smectite zone is characterized by the appearance of smectite minerals from the top of the surface to the reservoir boundary which is given a dashed line on the graph. This zone is characterized by the appearance of calcite, chlorite, and smectite. This zone can form at temperatures around 0 - 180o C In the figure there is a graph about MBT (Methylene Blue Test). This data is one of the most accurate and fastest methods in determining how much clay is in the subsurface. In the figure the clay in question is specifically smectite. The smectite content is very large at the clay cap and begins to decrease as it enters the reservoir. When viewed from the MBT graph, in the reservoir there is a little graph that shows the presence of caprock. However, in that case it is not a caprock, because in geothermal when smectite is less than 9%, it cannot be said to be a clay cap and there is a possibility that the reservoir is not smectite specific.

The Chlorite - epidote zone in this well is found at a depth of 1070 - 1503 m. Secondary minerals present in the chloriteepidote zone are characterized by the presence of epidote minerals which are high temperature minerals. In this zone, minerals such as clay, calcite, chlorite, pyrite, iron oxide, and secondary quartz are found. Chlorite here has a temperature ranging from 150-300o C. The epidote in the well here is a type of incipient epidote which is a type of imperfect epidote. This epidote is formed at temperatures ranging from 200 - 250o C. The presence of this epidote mineral is an indication that the area has entered the reservoir zone. Based on the division of alteration zones, this zone is included in the propylitic zone type. This zone is characterized by the presence of high temperature minerals such as epidote. Based on the temperature of mineral formation, the minerals present in propylitic alteration are formed at a temperature of 206-219 and the pH of the fluid ranges from 5-7, from intermediate to neutral.

Feed zone identification using PTS flowing data

In this data processing process, raw data is initially obtained, namely depth, temperature, cable speed and spinner rotation. This raw data is also a factor that can determine the indication of the feed zone. For this spinner data, 4 experiments were carried out with Log Up (LU) and Log Down (LD) 30 and 45. Log Up 45 is a unit that means 45 m/min. The results of PTS measurements taken at the initial stage are in the form of cable speed. Cable speed is the speed of the tool when going down the wellbore which is expressed in units of m/min. This measurement uses 4 trials in data collection with 2 variations of log up and log down, namely 30 m/min and 45 m/min. Because the data is very diverse, it will be shorted to 2 meters in well A by means of a pivot table.

After the calculation is carried out in accordance with the specified method, the final result obtained is a massrate graph to determine how much the steam production rate is in the well. Massrate or mass flow rate is a measure of the production rate of the amount of mass of a fluid flowing through a well per unit time. It is usually measured in units such as kilograms per second (kg/s) or tons per hour (T/h). This massrate is the final result of the PTS flowing survey calculation where the production flow rate and feed zone location of the well will be obtained. Before determining the massrate, first determine the flowrate value for each depth. This flowrate has the purpose of knowing how much fluid flow rate in volume units against time.

For Well A, when viewed on the temperature graph from the bottom of the well to the well head, it is above the BPD point. This feature concludes that the fluid is in 1 vapor phase. It is also known that the well is a superheat reservoir. The maximum temperature recorded in the well reached 219.34o C at a depth of 1406 mMD while the Boiling Point (BPD) was 207.11 ^{o}C at a depth of 1466 mMD. These temperatures indicate that the reservoir in well A belongs to the medium temperature reservoir system (125°C - 225°C). The maximum pressure of the well is 18.24 barg at a depth of 1470 mMD.

From this massrate graph, it is known that the profile of fluid velocity, mass flow, pressure, temperature resembles the profile of fluid velocity, mass flow, pressure and temperature observation.

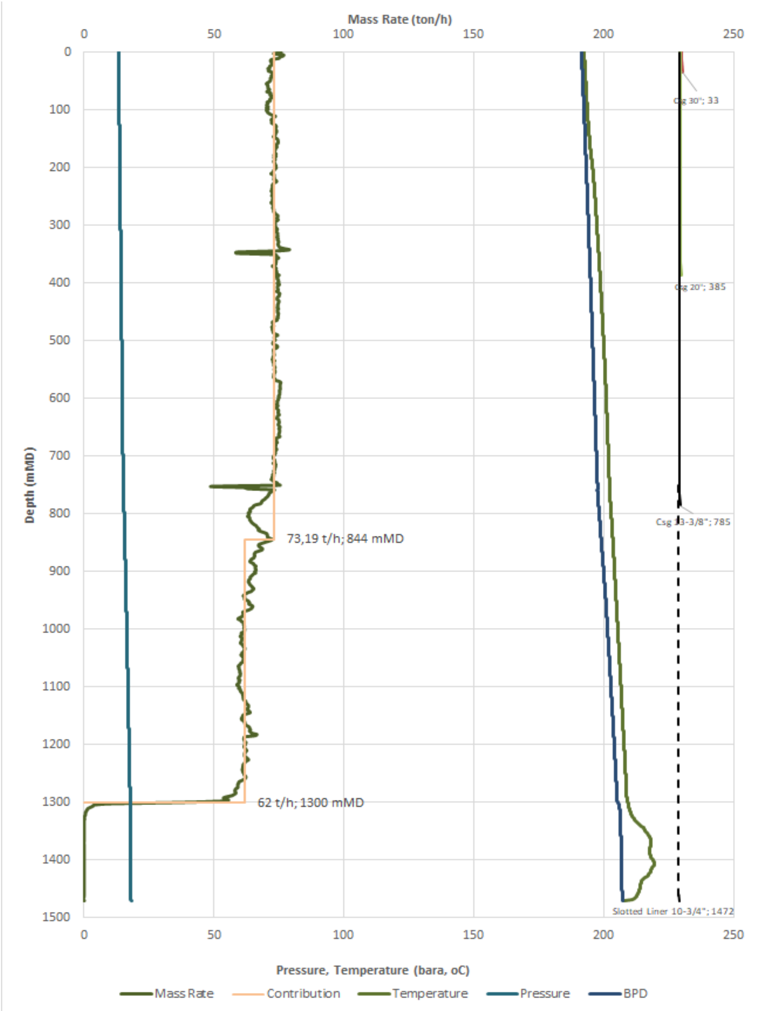

Figure 4. Massrate

The actual flow rate obtained from the measurement of PTS flowing well A has a total mass rate of 73.19 tons/h. This amount of massrate is obtained from 2 different depths, namely at a depth of 1300 mMD with a massrate of 62 t/h and 844 mMD with a massrate of 11.19 t/h. At a depth of 752 mMD there is a drastic decrease in fluid velocity but returns to its original state, it can be analyzed that it is not an indication of a feed zone because at that depth it occurs at the location where the pipe diameter changes and does not represent a change in mass flow but represents a change in pipe area (spike).

Relationship between PTS data and Drilling Geology data

When viewed from the composite log image there are well diagram data, lithology, mineralogy, lost circulation zone, and MBT. This data has a relationship between one another. The rock present in the caprock section is andesite because this rock has compact properties that have no pores or permeability. This zone is strongly characterized by the presence of clay minerals that have specific smectite. The dominant rock reservoir section is andesite breccia because it has permeability and pores. The andesite breccia rock in this well is a type of secondary permeability because the rock has been faulted.

The composite log graph shows that there are similarities between the lithology data, mineralogy data, and flowing PTS data. When viewed from the uppermost surface, caprock is characterized by the presence of smectite minerals shown in mineralogy and MBT data. Chlorite minerals can be said to characterize the zone as caprock, this chlorite functions in hot or high temperature rocks. This mineral can appear because at the beginning of geothermal formation in this area, the temperature was still very high. But over time, the temperature in field B has decreased due to frequent production and the flashing process. The geothermometer also shows that this smectite zone has a temperature ranging from 0 – 190 °C. The temperature in the flowing PTS data also shows that the surface temperature reaches 190 °C.

Well A has two feed zones at 844 m and 1300 m depth. This zone is on the liner and has entered the reservoir. This reservoir is characterized by the appearance of epidote alteration minerals that fill cavities in andesite breccia rocks. The epidote here is a type of imperfect epidote because the fluid is a type of 1 phase vapor. Therefore, the value of epidote present in the well is not enough. At the reservoir boundary there are only a few epidote minerals because the area is a reservoir transition zone. The reservoir zone is also characterized by the appearance of a lost circulation zone. This data is obtained in conjunction with the retrieval of drilling cores that are detected using sensors. The size of the lost circulation zone indicates that the zone has a lot of permeability. But when viewed from the type of mineral, this zone is included in the propylic zone which indicates that the permeability in well A is fairly low. However, to determine the productive permeability, PTS flowing data is needed to be more accurate. It can be interpreted that the temperature of the fluid that breaks through the rock through the fractures has a temperature of 206-219 °C with a neutral pH.

IV. CONCLUSION

Based on the identification results carried out on well A of field B, the following conclusions were obtained:

1. Mineral characteristics of reservoir rocks based on geological drilling data are the appearance of epidote minerals. Minerals such as secondary quartz, iron oxide, pyrite, chlorite and calcite are still present in the reservoir. The caprock is characterized by the appearance of clay minerals.
2. Indications of feed zone based on PTS flowing data can be found at a depth of 1300 mMD and 844 mMD with mass rates of 62 t/h and 11.19 t/h. The dominant rock in the reservoir zone is altered andesite breccia.
3. The relationship between feed zone and minerals from PTS flowing data and geological drilling data is the presence of epidote minerals when already in the reservoir zone. Feed zone depth of 1300 mMD has epidote minerals as much as 15% of 79% altered andesite breccia rock. Feed zone depth of 844 mMD has epidote minerals as much as 1% of 67% altered andesite breccia rocks. When viewed from PT and geothermometer data, there is a similarity in temperature.

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