Proceedings World Geothermal Congress 2023
Beijing, China, April 17 - 21, 2023

Attractive Potential of Geothermal System in Hululais Geothermal Field, Bengkulu, Indonesia

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Keywords: Hululais, Volcano-Tectonic, Permeability

ABSTRACT

Hululais Geothermal Field (HGF) is a liquid dominated system geothermal which is located on quaternary volcano-tectonic Hululais Volcanic Complex (HVC) and related to a prominent depression structure along an NW-SE trend axis along Bengkulu province. It is operated by PT Pertamina Geothermal Energy and currently ready to generate 2x55 MW.

The geology, geochemistry, geophysics and deep exploration drilling have been conducted to understand the geothermal system and locate the main components which control the system such as permeability, heat source, reservoir, caprock formation, and hydrothermal fluid flow direction. The Exploration phase result reveals that the permeability is associated with the formation and structural geology control. These permeability indicated by the presence of hot temperature above 260°C and fluid flows rate.

With this attractive subsurface condition and excellent exploration result, the discussion about HGF will be very interesting and can be a reference for geothermal development along the Sumatra especially in geothermal fields within a volcano-tectonic environment.

1. INTRODUCTION

The Hululais field in Rejang Lebong, Bengkulu Province, Indonesia is one of the geothermal working areas developed by Pertamina Geothermal Energy (PGE). The location that is close to the Sumatran Fault Zone (SFZ), which is a segmented major NW-SE strike-slip fault along the Sumatra Island, the HGF structural development and volcanism are influenced by the SFZ activity. Volcanism in HGF is related to the movement of the SFZ, HGF is one of the area where its volcanoes are influenced by the NW-SE structure and bounded by two segments from the SFZ, namely Ketahun Segment and Musi Segment. The faults from Musi Segment provide the pathways for magma to emerge from magma chamber to form NW-SE clustered volcanoes in the area forming the Hululais Brigade. These two factors play that is structural geology and volcanism activity, become the potential for primer and secondary productive permeability in HGF.

2. REGIONAL GEOLOGY OF HULULAIS GEOTHERMAL FIELD

Hululais Geothermal Field (HGF) area is bounded by two dextral strike-slip faults of Ketahun Segment to the north and Musi Segment to the south. These two segments are part of the Sumatra Fault Zone. The Musi Segment lies 70 km to the Air Keruh pull-apart basin in the southeast and has slip rate of 11 mm/yr. It is also interpreted to continue beneath the Hululais and Bukit Lumut mountain. Ketahun Segment has 85 km in length and at the southern tip of the segment, it ends at the 6-8 km wide dilatational step over onto the Musi Segment. As a result of the movement of two right stepping dextral strike-slip faults, the overlap area is the extensional overstep that is known as the pull-apart basin.

The Suban Agung, Bukit Beriti and Bukit Gedang volcanism are three main volcanisms part of Hululais Volcanic Complex (HVC) that directly affect the geothermal system of HGF, that covers around 70% of the surface within the area. Based on remote sensing and aerial photography, the rim of Bukit Suban Agung has an amphitheater shape that opens to the NE with a size of 2.5 kilometers in diameter. The rim with a diameter of more than 2 km can be categorized as a caldera. Based on that definition, the rim of Suban Agung can be named as Suban Agung Caldera. It is interpreted that Suban Agung Caldera is the product of Suban Agung Volcanoes that collapsed and produced debris avalanches during the Pleistocene Period. The morphologic signatures of collapse are characterized by a collapsed amphitheater and Hummock topography on the avalanche deposit. The Hummock topography of the ancient debris avalanche product is located on the northern part of HGF, approximately 8-10 km from the rim of Suban Agung. In several outcrops, the Hummock topography is comprised of cataclastic andesite. Rounded pumice fragments and rounded andesite fragments are found in the northern part of the area that is probably from the reworked ignimbrite. This reworked ignimbrite deposit may reflect there was a huge caldera explosion.

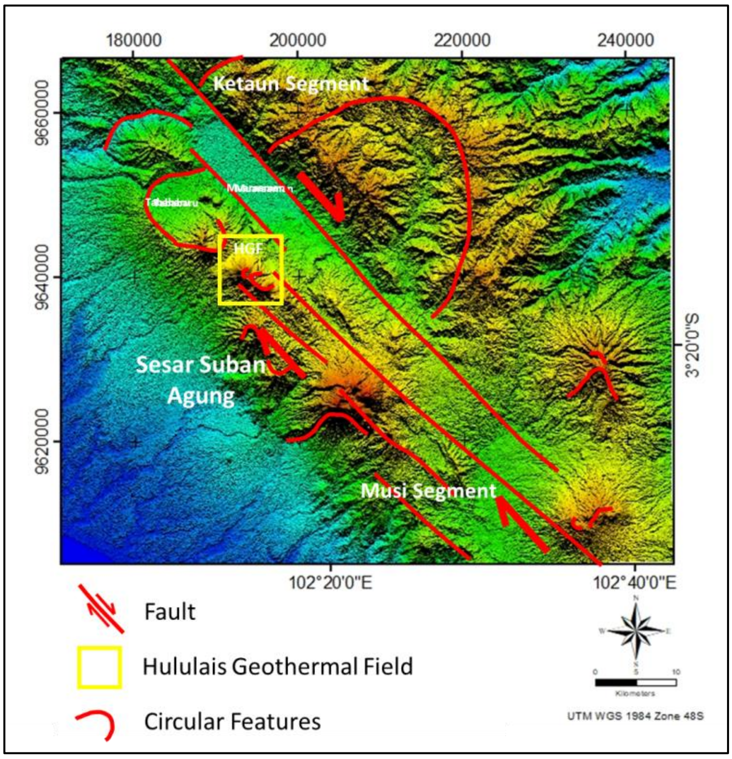

Figure 1. Location of Hululais Geothermal Field near the Musi and Ketaun Segment and is also in a volcanic complex

3. PERMEABILITY CONTROL OF HULULAIS GEOTHERMAL FIELD

The HGF already drilled of 24 wells consisting of 9 production wells and 12 injection wells. To determine the quality of wells, certainly well measurements are carried out, one of them is PTS measurement. The completion test data such as pressure, temperature, spinner data (PTS) during injection and heat up temperature is used to confirm the feed zones. In Glynn-Morris, et al., (2011), PTS data could be analyzed further to infer the nature of the permeability whether it has diffuse or sharp profile. Diffuse profile reflects the more widespread and less concentrated permeability due to formation permeability or diffuse interconnected fracture set. Sharp profile reflects the more concentrated permeability due to a sharp structural geology, or a concentrated fault and fracture cluster. These data are used to analyze what controls the feed zones permeability on each well and rank each factor area.

Apart from PTS data, plot data of the loss circulation and drilling break ratio (ROP/WOB) is also used. Ratio of the rate of penetration (ROP) and the value of the weight on bit (WOB) interpreted that smaller ROP value presuppose easier bit to penetrate the rock that is penetrated, this illustrates that the rock that is penetrated has low rock hardness or it is also possible to have lots of fractures. Whereas a low WOB value indicates that large compressive strength is not required to penetrate the rock. So by getting a large drilling break ratio, it is possible to get a permeable zone. Then the subsurface fracture data is also used, which will show that the higher the fracture accumulation value, the more intense the fractures are found around the drilling wells.

As an example in this discussion is the feedzones data in clusters E and P, these two clusters describe the upflow zone and the outflow zone, where cluster E as a production well describes the upflow zone and cluster P as a reinjection well describes the outflow zone. These two clusters are productive clusters which are the backbone of HGF, also both these wells targeting have a different targets.

Figure 2. Location of Cluster D and E in Hululais Geothermal Field

3.1 CLUSTER D

Cluster D is a reinjection cluster whose drilling target is directed to cut the Cemeh fault. One of the wells in this cluster it is observed that feedzones are concentrated between -800 masl to -1000 masl where the largest feedzones are located at two depths, around 800 masl and -1000 masl. While the feedzones at a depth of -1100 masl and -1250 masl have a minor contribution. The existence of these feedzones is reflected by the sharp flow rate deflection in the two largest feedzones where the other feedzones have a sloping profile. PTS temperature and heating show that after a depth of -1150 masl the permeability of this well begins to decrease.

Feedzones at -800 masl and -1000 masl depths are characterized by an increase in the drilling break ratio and an increase in circulation loss. All feedzones in this well are located in altered andesitic breccia lithology. Even though at a depth of -1100 masl, the loss circulation rate has increased and total loss circulation has occurred, however the contribution of feedzones at that depth is minimal. This condition shows that the feedzones around cluster D are controlled by two permeability controls, secondary permeability which is at the top at -800 masl and -1000 masl elevations which has a large contribution, and primary permeability control around -1100 masl and -1100 masl elevations even tough has a smaller contribution (Figure 3)

3.2 CLUSTER E

Of the four wells in cluster E whose drilling intersects to the Suban Agung fault, the analysis is represented from the one of the wells. The main feedzones in this well are located at depths of 110 to 90 masl and between 30 to -75 masl. Meanwhile, the deeper feedzones, around -375 masl and -550 masl also contributed significantly. The major feedzones between 110 and 90 masl may be concentrated at 100 masl because there is a spike in the temperature profile during injection. The convective temperature profile starts from around 200 masl down to the bottom of the well. Based on the fluid velocity pattern, the major feedzones in this well have a sharp graphic profile, this profile is accommodated by fractures that are spread over several depths.

At a depth of about 100 masl, the drilling break ratio increases and is also observed to correlate with total loss circulation. Other feedzones are indicated by higher and increasing drilling break ratios at -75 masl, -400 masl, and -550 masl. In this well, you can also see the distribution of the direction of the geological structure in the dominance of the northwest-southeast trending pattern. The geological structures that are visible are not only joint products, but also the distribution of geological structures in the form of faults ranging from 125 masl to -750 masl. At a depth of around -640 masl, although based on spinner data there is no contribution to that depth, it can be seen that the intensity of the geological structure has increased. The last lithology encountered before the occurrence of TLC was volcanic rocks, namely andesitic rocks. This condition shows that the feedzones around cluster E are controlled by secondary permeability which is a product of geological structure (Figure 4).

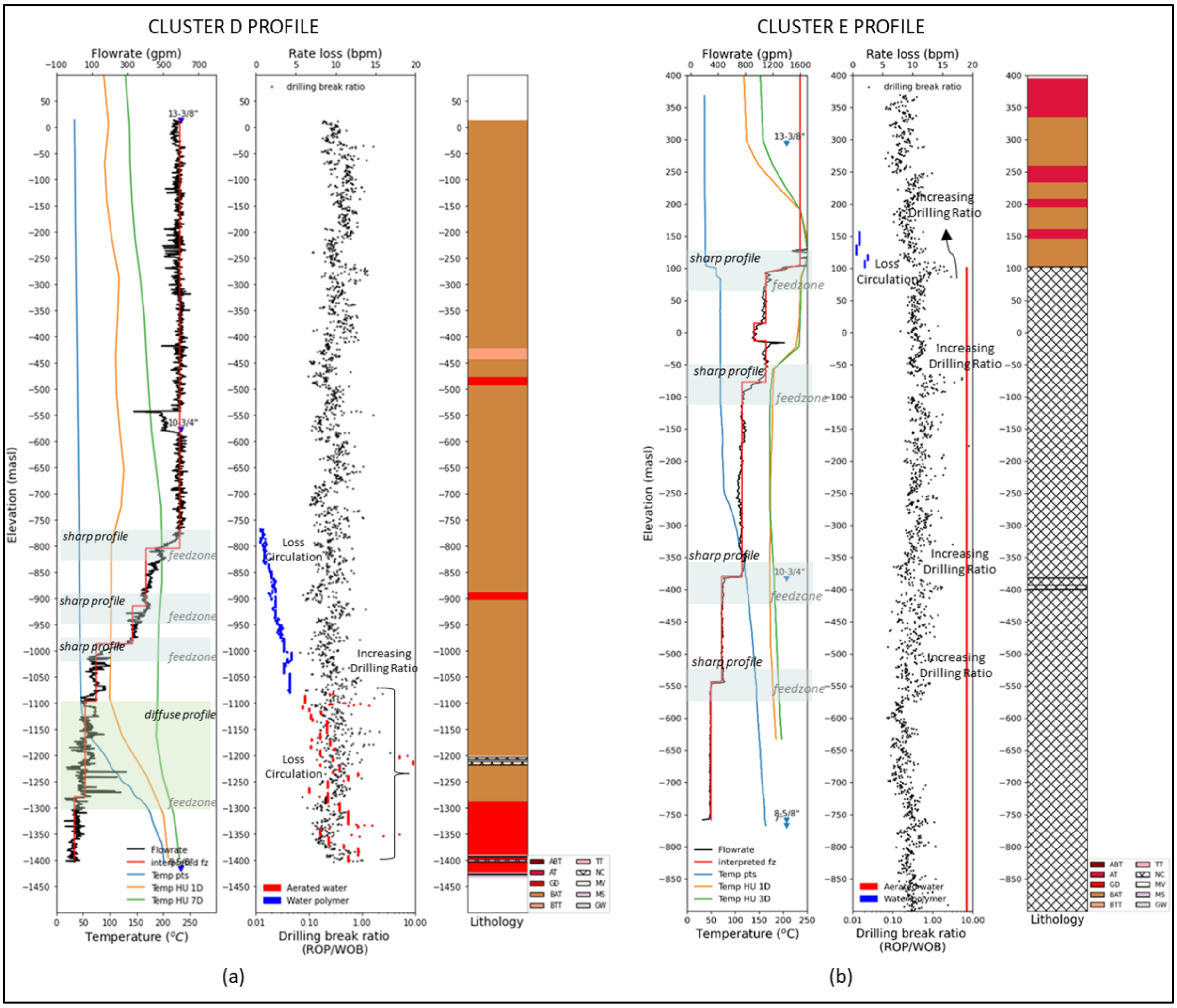

Figure 3. Fluid velocity graphic describes the permeability control of the wells in Hululais Geothermal Field

4. CONCLUSIONS

From the group plots of data that have been carried out in identifying permeability controls, it can be seen that there are two permeability controls that actively control the Hululais Geothermal Field, the primary permeability control which appears to be present around the cluster reinjection D which is the outflow zone of HGF, although at some depths there is also minor secondary permeability control, which may occur due to lithology control below the surface. The dominance of the secondary permeability control which is present in the around cluster E which is upflow zone and production area whose wells penetrate the geological structure of the Suban Agung fault. The result of the study reveals that there is strong evidence the HGF controlled by volaco-tectonic.

By knowing the contribution of this permeability control, it shows that the geological structure analysis and stratigraphic analysis which are carried out systematically help in understanding the permeability control and flow patterns of geothermal fluids, which will be very useful in conducting reservoir model simulations and determining make-up drilling targets.

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