Fracture Zone Analysis Based On Property Electrical Borehole Image Log And Geomechanic Geothermal Field Solok, West Sumatra

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Abstract. Prospective area of Solok geothermal lies in step over transtensional between two segments, Suliti and Siulak, Sumatra faults. Geological structure in this prospect area shows structural pattern controlled by “oblique divergent strike-slip fault system” (releasing bend) as a proceed of embraced movement from Sumatra fault and establishes “dilation zone” between those two segments, forming negative flower structure in direction of NW-SE and N-S. The pattern of geological structure is predicted to control the availability of solok geothermal system which in this case related to presence of surface manifestation. The pattern of geological structure is predicted to control the availability of solok geothermal system which in this case related to presence of surface manifestation. Surface manifestation indicates good permeability zone that can be used as flow path of geothermal fluid from reservoir

1. Introduction
Objective of study is Geothermal field of Solok area located in hills and mountains forming cone landscape and trace displacement of the centers of volcano eruption directing NW-SE located in Solok reg.text, West Sumatra province (Figure I.1). The result of this study is concluded by observation results of wellbore data, and laboratory analysis results. DST, and RFT. Smin had been obtained from hydraulic fracturing test, LOT or XLOT. The purpose of this study is to analyze rock petrophysical properties and then use it to calculate all critical fracturing pressure on SM-16 well in order to understand the rock behavior, the direction and pattern of the fracture which is permeable as a target of further drilling activities.

2. Geological Setting
Sumatra fault is parallel direction, embraced horizontal fault acrossing hanging wall block of Sumatra subduction from Sunda strait to the distributed spreading centers of andaman sea. MF is Mentawai faults. Generally, the basic concept of structural control of solok geothermal model is controlled by dilational jogs in extensional regime, horizontal fault regime which is controlled by the companion structural formation.
The regional stratigraphy of this study is based on the geological sheet maps from [1]. The field study is focused on the identification of structural geology, mapping and lithological characterization, and manifestation. Technically, the mapping is interpreted by analyzing straightness of SRTM satellite and landsat. The studied area is consisted of sedimentary rocks and metamorphic, intrusion rocks, volcano rocks, surface deposits. Sedimentary and metamorphic rocks are consisted of Barisan formation (Pb), member of limestone of barisan formation (Pbl), intrusion rocks consisted of granite rock (Kgr)

3. Result and Discussion

3.1. Geomechanic analysis method
Methodology used in this research is to use descriptive qualitative interpretation method, that is by processing the data of main rock, log well, Log FMI, some assumptions in measurement and calculation for geomechanical analysis. The analytical results obtained by with using parameters such as maximum horizontal stress ($S_{H\text{max}}$), minimum horizontal stress ($S_{H\text{min}}$), vertical stress ($S_v$), fluid pressure ($P_f$), and friction coefficient ($\mu$). Those parameters are analyzed based on the magnitude from other wells [2].

3.2. Petrophysical analysis
Rock physical properties and the interpretation of rock stratification on the complexity of prospective geothermal field Solok described by using data from gamma ray log, caliper log, resistivity log, and acoustic log which is available on well SM-16, which then integrated with borehole image log, and the cutting sample from drilling activity.

The cutting data (Table I) become the guidance on the interpretation of the rock zones lies near SM-16 well. The data from Sonic log is used to interpret the rock density by using Gardner equation, which then try to confirmed by using density data from the substance analyzer which is analyzed by XRF (X-Ray Fluorescence) Spectrometer. The limited of this density interpretation is that the data from XRF only taken from one depth sample, so then in further application of this density result is needed to confirm by another source data to make more accuracy on the interpretation.

On the other side, with using caliper log data, it is obtained that in the zone which is identified by cutting sample as Tuff zone, have tend to occur a wellbore break out condition, and the otherwise for the zone which is identified by cutting sample as Lava tend to have mudcake on the wellbore. This type of condition then become one of the condition that to be considered on the interpretation of rock zones lies near SM-16 well. The sample of interpretation result on SM-16 well which taken from interval 1156 – 1267 m (TVD) can be seen on (Figure 2).

![Figure 1. Geothermal prospective area around Solok regency, West Sumatra province.](image)
Table 1. Statistical value of log data of rock type sample which is taken from drill cutting sample.

On the interpretation of rock zones, the zone is classified into four classification, that is Tuff, Tuffaceous rock, Igneous Rock, and Clean Igneous Rock, since no characteristic and data that there is showing of other Rock kind (Sedimentary or Metamorphic rocks).

The Tuff zone type is classified into Tuff zone because it is tend to have lower resistivity, with average value 9.9 Ohmm, and highest GR and Sonic log with average value 71.7 API and 89.2 μs/ft. The Tuffaceous zone is the zone that identified as tuff zone that contain less or more igneous rock inside the matrix of the rock, or in some case in this well, there is very thin layer of igneous rock inside the body of tuff zone.

Figure 2. Sample of petrophysical log interpretation on Well SM-16, Geothermal Field Solok.

Table 2. Statistical value of log data on rock type of interpreted zone.
On the interpretation of this rock zones, the igneous rock type cannot be specifically identified, because the petrological data on this well not available on the depth which is logging activity occur.

The next classification is Igneous Rock, this type of lithology zone is identified as the zone of igneous rock that contain less tuff inside the matrix of rock zone or in some case in this well, there is very thin layer of tuff inside the body of igneous zone, and the Clean Igneous Rock is the zone of igneous rock that tend to have clean matrix, free from tuff, so its have highest resistivity with average 82.3 ohmm, and have the lowest GR and Sonic log with average value 54.5 API and 77.1 μs/ft. Statistical value of log data on rock type of interpreted zone can be see in Table 2.

3.3. Xrmi analysis

Image Log (XRMI) is used to obtain direct information from subsurface fracture orientation and distribution. Image Log has some other methods such as: electric, acoustic, radar, and ultrasonic.

Structural information from a wellbore can be coming from structural data during drilling, image log (XRMI). Based on this interpretation, the partially open and open fractures are extracted and converted into intensity log (Figure 3). The assumption behind intensity log interpretation is high intensity value will be close associated with fault and low intensity will be farther.

![Figure 3. Electrical Image data showing typical drilling induced tensile wall fracture s in a vertical borehole an inclined tensile fractures in a deviated borehole.](image)

3.4. Minimum horizontal stress (S_{hmin})

Value from minimum horizontal pressure (S_{hmin}) is obtained from hydraulic fracture test. Most effective methods in determination of minimum horizontal stress (S_{hmin}) on drilling well with hydraulic fracture test. The test is not always done at casing seats on some data. On geothermal field, usage of that test only limited to get FIT value, so limit value of casing strength can be obtained in holding formation pressure on the wellbore, but that value can’t be used as lower limit of minimum horizontal pressure value. It is because the obtained value not coming from rocks, but well casing instead. So, the value of minimum horizontal stress is obtained from [3].

\[
S_{hmin} = K (Sv-Pp)+Pp
\]
3.5. Maximum horizontal test ($S_{\text{Hmax}}$)

Stress direction can be determined by using geological appearance caused by drilling. This appearance occurs because there is concentrated stress on wall wells. Generally, determination of direction orientation $S_{\text{Hmax}}$ can be done by applying orientation direction induced tensile and breakouts, but on research area, the drilling well is oblique, so the direction can’t be applied directly; however, requires an equation to determine the direction of $S_{\text{Hmax}}$ orientation. The determination uses equation based on [4].

\[
\sigma_{\text{tmax}} = 0.5(\sigma_{zz} + \sigma_{\theta \theta}) + \sqrt{(\sigma_{zz} - \sigma_{\theta \theta})^2 + 4\tau_{\theta z}^2}
\]

\[
\sigma_{\text{tmin}} = 0.5(\sigma_{zz} + \sigma_{\theta \theta}) - \sqrt{(\sigma_{zz} - \sigma_{\theta \theta})^2 + 4\tau_{\theta z}^2}
\]

Based on analysis at each well, then maximum horizontal stress direction that works on each well are determined. Based on the result of observation on log image Solok wells, induced breakout generally maximum horizontal stress has relative direction NE-SW. Based on calculation result on SM-16 well, obtained $S_{\text{Hmax}}$ value 26.94-34.37 Mpa that formed on strike-slip fault regime (Figure 4).

![Figure 4](image)

**Figure 4.** Curve of SHmax on SM-16 well at Solok Field.

3.6. Geomechanical model

Based on result of calculation and analysis to vertical stress, pore pressure, minimum horizontal stress, direction and maximum horizontal stress at SM-16 well, then obtained that Solok Field is reverse fault. It can be seen from horizontal maximum stress value $S_{\text{Hmax}}$> minimum horizontal stress $S_{\text{hmin}}$> vertical stress $S_v$ (Figure 5).
To determine value from $S_{H_{\text{max}}}$ and $S_{h_{\text{min}}}$, on this research polygon stress is used. Polygon stress is a diagram consist of stress regime and value from $S_{H_{\text{max}}}$ and $S_{h_{\text{min}}}$ that needed for its forming breakout and induced tensile fracture. Based on (Figure 6) fracture direction induced-tensile and breakout on each wells, then, determined maximum horizontal stress direction that works in every wells. The result shows that maximum horizontal (Figure 7) stress direction on SM-16 well relatively west-east direction with azimuth direction N260°E.

Figure 5. Geomechanical model of SM-16 well.

Figure 6. Value of orientation direction $S_{H_{\text{max}}}$ on SM-16 by using module GMI-SFIB. Differences of $S_{H_{\text{max}}}$ value is obtained based on representative UCS i.e. 64.263 for volcanoclastic with value based on [4].
Figure 7. The orientation value of SHmax in SM-16 that calculated based on geomechanical parameters by using GMI-SFIB module.

4. Conclusion

Based on petrophysical analysis result, the type of rock consist near SM-16 well is interpreted as four type classification, that is Tuff, Tuffaceous, Igneous Rock, and Clean Igneous Rock with the average density of each rock 2.37, 2.42, 2.49, and 2.51 gr/cc. The complete result of rock physical properties analyzed from log data can be seen in Table II.

Polygon stress analysis result and geomechanical on each drilling wells show Solok Field is located on strike-slip fault regime. In-situ stress in Solok Field is $S_{Hmax}>S_v>S_{Hmin}$. It shows that orientation direction of maximum horizontal stress in SM-16 well consistent to regional stress direction affect by Semangko Fault N-S.

Fracture distribution with fluid flow can determine permeability zone on orientation direction NW-SE stress, the type of lithology that has differences, and geological structure factor of research area, which controls the surface manifestation.

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