Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Characterization of Naturally Fracture Geothermal Reservoir with Electrical Borehole Image in Central Sumatera Basin

Friska Agustin[1], Merandy Pala'biran[2], Chalid Idham Abdullah[1], Benyamin Sapiie[1], Malik Awab[3]

[1]Geology Engineering Study Program, Faculty of Earth Sciences and Technology, ITB

[2]Mechanical Engineering Study Program, Faculty of Mechanical and Aerospace Engineering, ITB

[3]GADA Energi

Friskaagustin.ITB@gmail.com

Keywords: Central Sumatera Basin, Great Sumatera Fault, Fracture modelling, Borehole-image log, and Geothermal.

ABSTRACT

There is a prospective area of a geothermal field in the central sumatera basin, which lies in step over transtensional between two segments, Suliti and Siulak, and Sumatra faults. Geological structure in this prospective area shows structural pattern controlled by a pull apart basin system embraced by movement from a transform fault system (SFZ) and establishes a dilation zone between those two segments, forming negative flower structure in the direction of NW-SE and N-S. The pattern of geological structure is predicted to control the availability of a geothermal system which in this case is related to presence of surface manifestation. Surface manifestation indicates a good permeability zone that can be used as a flow path of geothermal fluid from the reservoir. Heterogeneity encompasses the specific rock mechanical properties which is diverse over time and how it changes the deformation process and resultant structure itself. The pattern of geological structure and fracture channel properties in this study is predicted and modelled using an analysis of the fracture zone by combination of electrical borehole image log and petrophysical analysis methods, then confirmed by a geomechanical model. The objective of this research is to perform detailed subsurface analysis on a geothermal field in the central sumatera basin so as to determine the availability of geothermal system which in this case related to presence of surface manifestation.

1. INTRODUCTION

The objective area of this study is the geothermal field of the central sumatera basin area, located in hills and mountains forming cone landscape and trace displacement of the centers of volcano eruption directed NW-SE located in central sumatera basin regency, West Sumatra province. The result of this study is concluded by analyzing results of wellbore data.

Fracture characterization and modelling activity itself has been perform by several authors. Fang, et al. (2017) has explained the algorithm to modelling discrete fracture network (DFN) with using seismic data, core analysis data, and petrophysical well log data. Ja'fari, et al. (2012) try to modelling fracture density by using petrophysical logs from 12 well, and the fracture density data from 2 wells, then using metaheuristic method to generate fracture density from the log which contained image logs. This method is also similar to the work of Martinez, et al. (2002). Tokhmeci, et al. (2010) also proposes a method for the estimation of fracture density by using a petrophysical log which is in terms of an energy log.

The method for generating field fracture density by the authors mentioned was typical when having limited image log data but having all petrophysical logs. The main problem of this field is the only data available is image log without convention log data or core data.

So the main purpose of this study is to analyze field fracture properties from six representative wells which only have image log data (Figure 1), and then use it to model fracture kinematics and distribution over the field, in order to understand the direction and pattern of the fracture which is permeable as a target of further drilling activities.

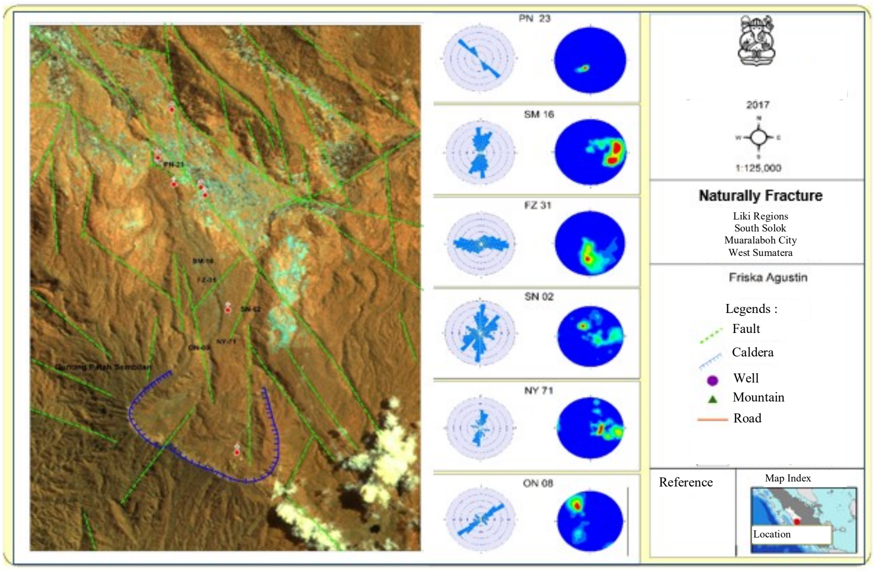

Figure 1 : Geothermal prospective area around Central Sumatera Basin.

2. GEOLOGIC SETTING

Sumatra fault is in a parallel direction, embraced horizontal fault across 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 the central sumatera basin geothermal model is controlled by dilatational 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 Rosidi, et al. (1996). The field study is focused on the identification of structural geology, mapping and lithological characterization, as well as 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, and 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). Jannata, et al. (2013) also has modelled vulcanostratigraphy in the area of study. This vulcanostratigraphic spread is referred to as a marker or characterizer in the area. The study was caused by the nature of the formation at each well drilling location in the central sumatera basin geothermal system which spread wide. Case study in the central sumatera basin geothermal system is controlled by the Sumatran Fault system, firm orientation and lithology in each drilling well that varies.

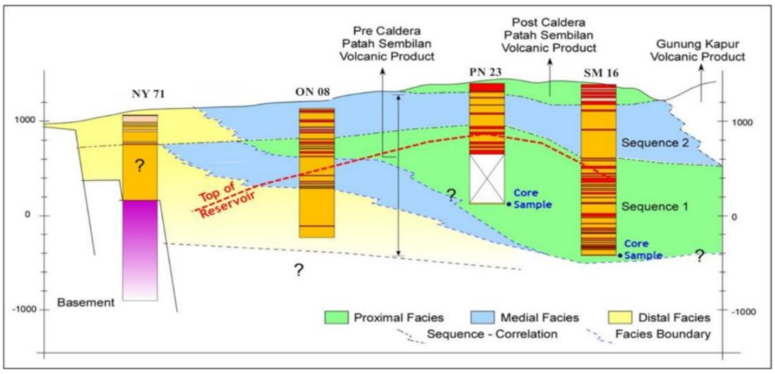

Figure 2 : Vulcanostratigraphic model of the central sumatera basin prospective area geothermal system (Jannata et al., 2013).

3. FRACTURE IDENTIFICATION

The analysis is to take account of fracture feature which showed by the image log appearance and dip log data. The several basic type of image log feature appearances are shown in Figure 2. This kind of appearance is used to be the standard identification method for image log analysis in this study.

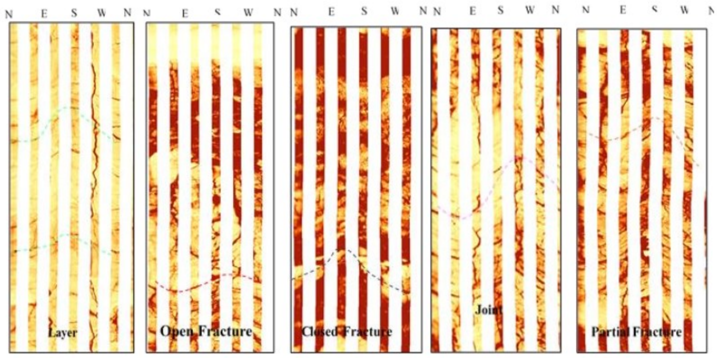

Figure 3 : Several types of image log feature appearances on the well of study area.

The analysis of natural open fractures can serve as the basis for determining direction of the working stress at the moment. The natural cracks are open due to the working stress at the moment. In this study, the cracks interpreted only as conductive and partial fractures. Critical interpretation was performed on wells PN-23, SM-16, NY-71, ON-08, SN-02, and FZ-31. The results of the interpretation of the PN-23 well show that it has good conductive and resistive fractures with a NW-SE relative direction with the dominance of magnitude ranges from the average direction N 335°E (Figure 4). Resistive fractures have a relatively more variable stance and tilt because of the repeated formation process, while the fracture conductive based on fractures that are open and when done drilling is still open, the fracture will be filled with mud drilling. The results of the fracture interpretation will be information such as the depth of the fracture, style and slope of the fracture plane, and the space between fractures. This information will be analyzed using histograms, rosettes and stereonets. Analysis 64 data fractures with intensity of 2 fractures per meter from depth 655 m up to 673 m (measured depth) and not specific for each lithology or zone.

On well SM-16 fracture analysis was carried out for all parts of drilling from depth 269 m up to 1294 m (measured depth) and is not specific for each lithology or zone. For fracture analysis of 807 data intensity of three fractures per meter (Figure 4). The results of the fracture interpretation will be information such as the depth of the fracture, style and slope of the fracture plane, and the space between fractures. This information will be analyzed using histograms, rosettes and stereonets. Fracture naturally has a NE-SW direction with a predominance of magnitude ranging from average N 35°E of 891 fracture data.

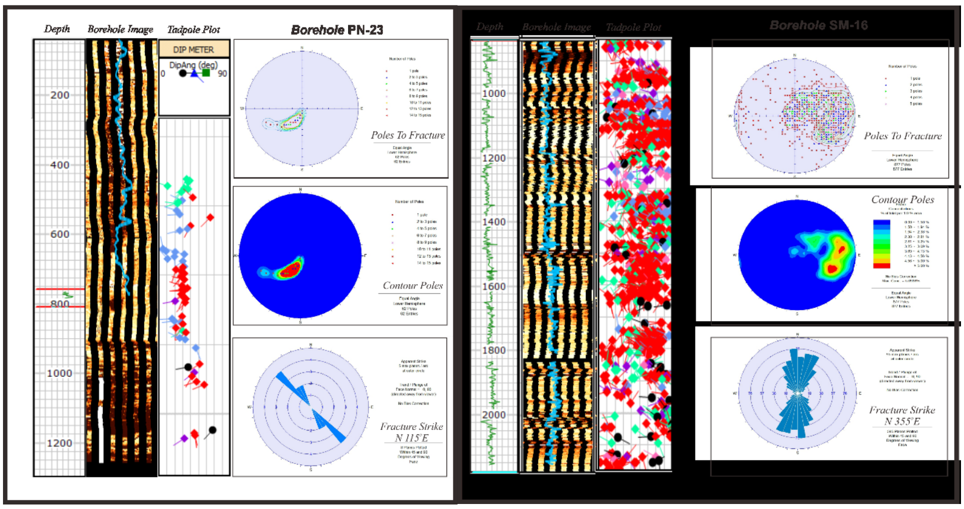

Figure 4 : Image log, dipmeter tadpole, rosettes, and stereonets of wells PN-23 and SM-16.

Fracture analysis is carried out for all parts of drilling from depth 906.5 m to 2061.5 m (measured depth) and not specific to any lithology or zone for well FZ-31. Natural fractures have a WNW-ESE orientation direction of 835 data with the intensity of two fractures per meter with the dominance of magnitudes ranges from average directed N 295°E (Figure 5). For well SN-02 fracture analysis was carried out for all drilling sections from a depth of 458 m to 870 m (measured depth) and not specific to each lithology or zone. Natural fractures have orientation directions NE-SW and NW-SE from 1403 data with the intensity of 3 fractures per meter data fracture with magnitude dominance the average range is N 40°E (Figure 5).

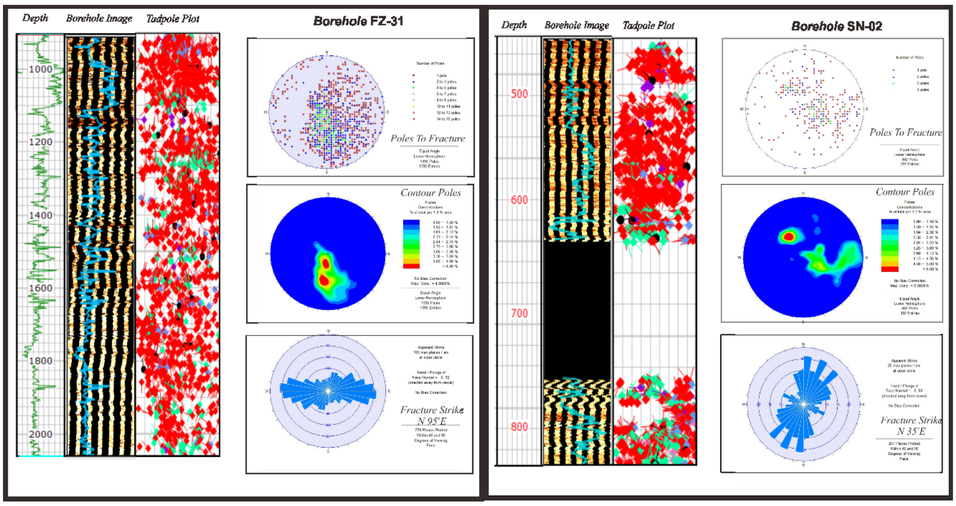

Figure 5 : Image log, dipmeter tadpole, rosettes, and stereonets of wells FZ-31 and SN-02.

Fracture analysis was carried out for all drilling sections from a depth of 991 m to 1099 m (measured depth) on well NY-71 and is not specific for each lithology or zone. Results the interpretation of the NY-71 well show natural fractures which consist of 167 data intensity of two fractures per meter. The results of the fracture interpretation will be information such as the depth of the fracture, style and slope of the fracture plane, and the space between fractures. This information will be analyzed using histograms, rosettes and stereonets. Fracture naturally has the relative direction of N-S with the dominance of magnitudes ranging from the average N 345°E direction from 891 fracture data (Figure 6).

The ON-08 well fracture analysis was carried out for all drilling sections from a depth of 246 m to 2081 m (measured depth) and not specific to each lithology or zone. Results of the interpretation of the ON-08 well shows the natural fracture has direction of NW-SE relative orientation of 1441 data intensity of two fractures per meter with the dominance of magnitudes ranging from the average trending N 335°E (Figure 6).

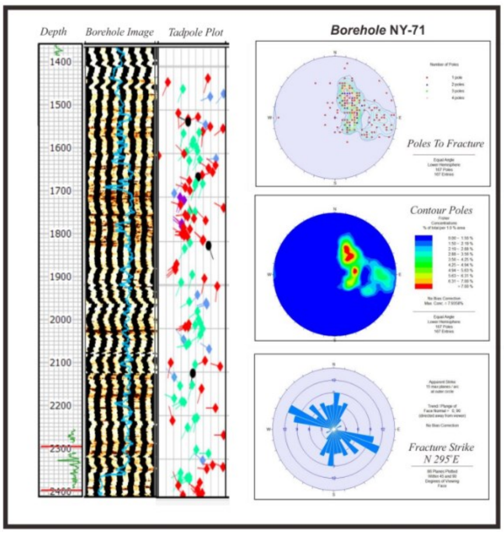

Figure 6 : Image log, dipmeter tadpole, rosettes, and stereonets of well NY-71.

4. FRACTURE INTENSITY AND MODELLING

To know the information about fracture intensity from this area of study, an analysis of image log of the six wells are performed. The amount of fracture which is open, partial, and closed fracture is measured on the specific well interval to be fracture intensity. All fracture intensity from each well is showed on the Figure 7.

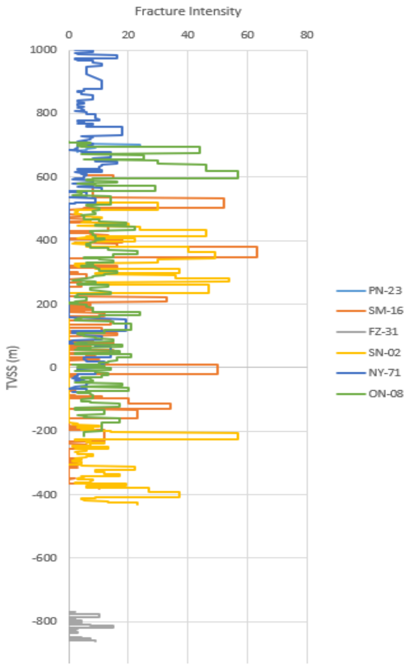

Figure 7: Fracture intensity derived from image log data each well.

From Figure 6, it can be seen that not every well has complete image log data to fully representative the wellbore conditions. Well FZ-31 and PN-23 have the least image log data to give the fracture intensity value. From Figure 6 it can be seen that well NY-71 has maximum number fracture intensity around 18, ON-08 around 58 on 600 m TVSS, SM-16 is 62 on 380 m TVSS, and SN-02 is 58 on -200 m TVSS. This fracture intensity data then used to be distributed on the reservoir model, which has been built by using geological information data which contain 32 key faults. The initial model with representative fault that control the area of this study can be seen on Figure 8. The model geometry itself is built with size 18.75 x 13.13 x 1.7 km and total 21.53 million grids.

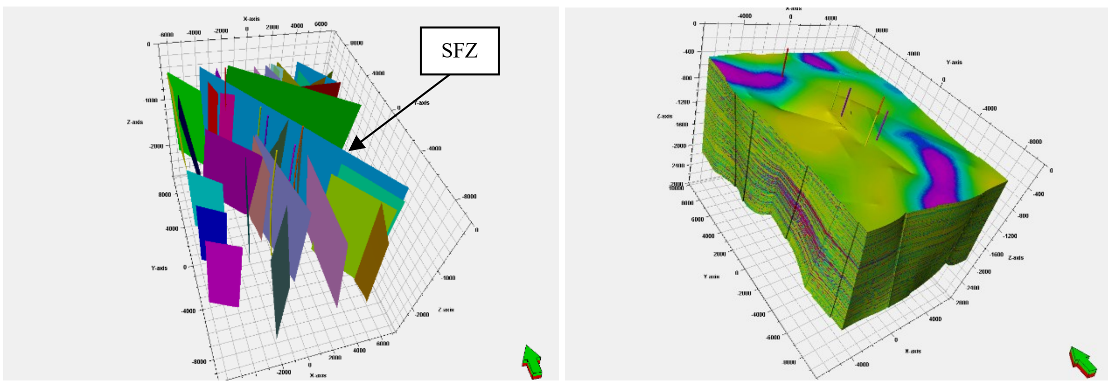

Figure 8 : Fault model around six well and fracture intensity distribution.

On the surface of 3D model, the distribution of fracture is highly concentrated on the northwest and southeast area of the field. On the other hand by viewing the sideview or the cross section of the model, the potential of area with highly fracture concentration is on the southwest of the field, on around depth 864 m to 1399 m (measured depth). This cross section can be seen on the Figure 9, which showing the depth interval having many layers with high fracture intensity represented by more red color index.

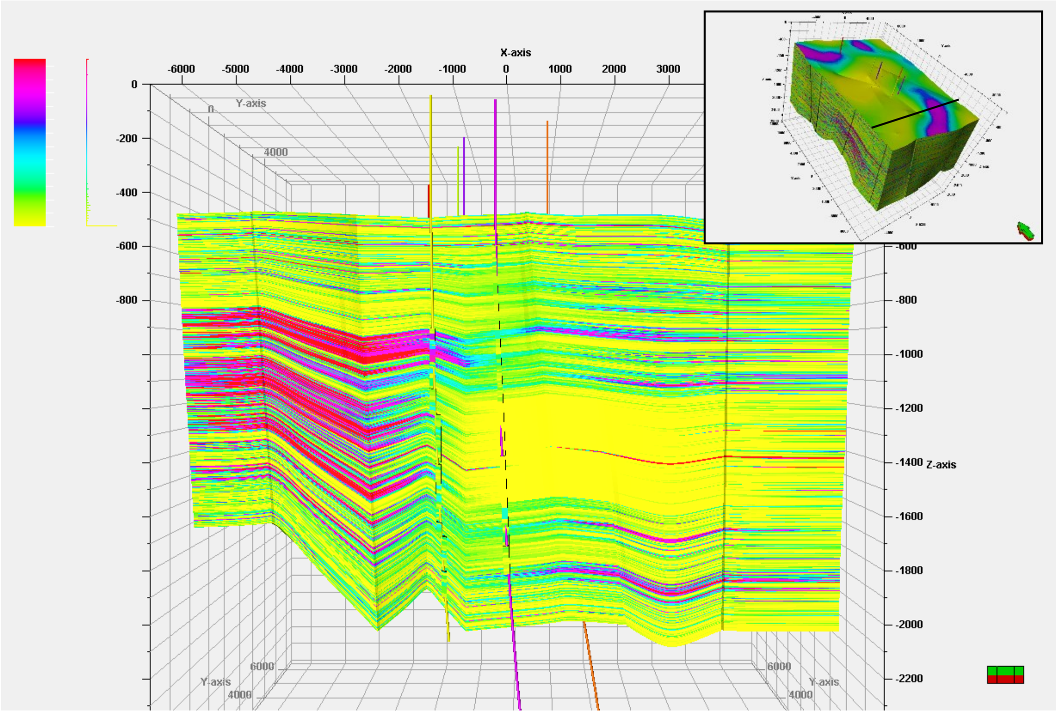

Figure 9 : Cross section of fracture intensity of the field from to west to east.

By using averaging technique, the fracture distribution data can be more easily viewed and analyzed. The 2D average fracture data showed in Figure 10. On Figure 10, it can be seen that average of fracture distribution is highly distributed on the southwest (SW) area of the field, with a maximum value of the fracture intensity being 32. The second prospective area is on the northeast (NE) of the field, near SM-16 and FZ-31 well. These two areas of the high intensity fracture distribution can be good and prospective area for the further central sumatera basin geothermal field area development, with new proposed drilling for production and injector well.

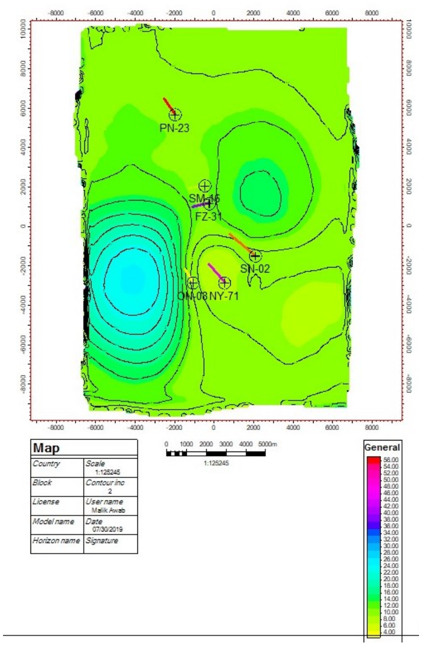

Figure 10 : 2D average fracture intensity distribution map around area of study.

5. CONCLUSION

From this study it can be found that the geothermal prospective area of the central sumatera basin is very controlled by natural fracture occurrence. The main direction of the fracture of each well is N 335°E for PN-23, N 35°E for SM-16, N 295°E for FZ-31, N 40°E for SN-02, N 345°E for NY-71, and N 335°E for ON-08. From fracture intensity modelling and distribution, the highest fracture intensity on the field is in the southwest (SW) area of the field. The second prospective area is on the northeast (NE) of the field, near the SM-16 and FZ-31 wells. This study has done without using any wireline log data, which is also not available in this study activity. Further study for this prospective area is can be done with more accuracy by combining with wireline log data or geophysical data if it becomes available.

REFERENCES

Fang, J., et al.: Discrete Fracture Network Modelling in a Naturally Fractured Carbonate Reservoir in the Jingbei Oilfield, China, Energies 10(2), (2017), 183.

Martinez, L.P., et al.: Identification and Characterization of Naturally Fractured Reservoirs Using Conventional Well Logs, University of Oklahoma, Oklahoma (2002).

Ja'fari, A., et al.: Fracture Density Estimation from Petrophysical Log Data Using the Adaptive Neuro-Fuzzy Inference System, Journal of Geophysics and Engineering. Eng. 9 (2012), 105-114.

Jannata, I.S., et al.: Preliminary Geology Model of Muara Laboh Facies and Porosity Assessment, *Proceedings*, The 13th Indonesia International Geothermal Convention dan Exhibition 2013, Jakarta (2016).

Rosidi, H.M.D., et al.: Geologic Map of the Painan and Northeastern Part of the Muarasiberut Quadrangles (0714-0814) Sumatera, Geol. Res. Dev. Centre (GRDC), Bandung (1996).

Tokhmechi, B., et al.: Estimation of the Fracture Density in Fractured Zones Using Petrophysical Logs, Journal of Petroleum Science and Engineering, Journal of Petroleum Science and Engineering Vol 72, Issues 1-2, (2010), 206-213.