PENYEBARAN INTENSITAS REKAHAN DAN APERTURE PADA RESERVOIR VULKANIKLASTIK

FRACTURE INTENSITY AND APERTURE DISTRIBUTION IN VOLCANICLASTIC RESERVOIR

Firman Herdiansyah1, Suryo Prakoso2, Muhammad Burhannudinnur1, Benyamin1

1Geological Engineering Study Program Faculty of Earth and Energy Universitas Trisakti, Jakarta, Indonesia

Email korespondensi: firman.herdiansyah@trisakti.ac.id

Abstract. Volcaniclastic reservoir in Indonesia is the significant production reservoir. Natural fractures are the most important factor in determining the quality and quantity of volcaniclastic reservoir to be revealed in detail. Image log and wireline log data that can be used to provide information and definitely natural fracture zone, both natural conductive fracture and natural resistive fracture. In this case of the research there are present in tuff which has natural fractures as secondary porosity. The fracture intensity and aperture were important parameters to calculate the fracture porosity values in each fracture zone. Direct measurements on the electrical image log can detect fracture intensity and aperture which is characterized by sinusoidal continues formed from resistivity or acoustic contrast. Multiplication fracture intensity and aperture will be used to calculate fracture porosity. Bulk modulus is used as a constraint to distribute I*A value. The higher I*A increasing the bulk modulus value, and I*A value increases in the area close to folds and in the area close to fault.

Sari. Reservoir vulkaniklastik di Indonesia merupakan reservoir dengan produksi yang signifikan. Rekah alami adalah faktor terpenting dalam menentukan kualitas dan kuantitas dari reservoir vulkaniklastik untuk diungkap lebih detail. Log image dan data wireline log dapat digunakan untuk memberikan informasi zona rekahan alami, dan rekahan konduktif serta rekahan resistif. Pada kasus penelitian ini, hadir tuf dengan rekahan alami sebagai porositas sekunder. Intensitas rekahan dan apertur menjadi parameter penting untuk menghitung nilai porositas rekahan pada masing-masing zona. Pengukuran langsung pada log image dapat mendeteksi intensitas rekahan dan apertur dimana dicirikan oleh sinusoidal yang dibentuk dari resistivitas ataupun kontras akustik. Perkalian antara intensitas rekahan dan apertur digunakan untuk menghitung porositas rekahan. Bulk modulus juga digunakan sebagai konstrain untuk mendistribusikan nilai I*A pada sumur yang tidak memiliki image log. I*A yang tinggi menaikan nilai bulk modulus, dan nilai I*A naik pada area yang dekat dengan lipatan dan yang dekat dengan patahan.

Sejarah Artikel :
- Diterima 4 Januari 2020
- Revisi 26 Maret 2020
- Disetujui 2 Mei 2020
- Terbit Online 25 Agustus 2020

Kata Kunci :
- Reservoir rekahan
- Apertur
- Vulkaniklastik
- Continues and discontinues
- Rekahan alami

Keywords :
- Fracture Reservoir,
- Aperture,
- volcaniclastic,
- Continues and discontinues,
- Natural fracture
INTRODUCTION

In volcaniclastic reservoir, natural fracture is one of the most important factor in determining the quality and quantity of reservoir that function as porosity. These fracture can be investigated and evaluated based on geological data that the log response using the acoustic sensors log and the properties of high-resolution electrical image log, these is obtained about fracture orientation, frequency, and apertures (Luthi and Souhaite 1990); (Aguilera, 1995); Wennberg, 1999). In contrast to matrix porosity which is relatively easier to calculate and estimating, fracture porosity is very heterogeneous and very difficult to estimate.

NFR (natural fracture reservoir) is divided into 4 types (Nelson, 2001) : [1] Type-1 natural fracture which provides the main storage capacity and permeability in the reservoir (matrix porosity and permeability is low), [2] type 2, where matrix permeability is low but the matrix may provide low-high porosity, [3] Type-3, which has sufficient permeability of fractures which is quite helpful to reservoir that has good matrix porosity and permeability, [4] Type-4, fractures unprovide porosity and additional permeability but creates anisotropy.

Porosity in volcanic reservoir can be present relatively high, depending on the volcanic process in the area. The alteration (tuff to clay) can reduce matrix porosity. But dissolution and fracture that occur can increasing porosity and permeability (Sruoga and Rubinstein 2007). To calculate and estimating fracture porosity, wireline log and image log (FMI) data are needed. Information on the FMI (Fullbor Formation Micro-Imaginer) needed to calculate fracture porosity is the fracture length, area, and aperture (fracture opening). The model used in estimating fracture porosity in this study is the HALO model, which reveals the concept of the damage zone of the fault plane. Fractures found around the fault plane are generally of high intensity and decreasing further away from the fault plane (Gutormsen et al, 2007).

Figure 1. Strike and dip Continues conductive fracture (left) and discontinues conductive fracture (right) and fracture orientation.
METHODS AND MATERIALS

Continues Fullbor Formation Micro-Imager

Fullbor Formation Micro-Imager (FMI) analysis is one of the important data and parameters to provide information of lithology and subsurface fracture patterns both conductive and resistive. FMI data which integrated with log and seismic data can be defining lithology, filled fracture zones, open fractures, and fractures due to drilling activities (tensile and breakout). These are function as porosity in other words, FMI can also show indicate of hydrocarbon prospect zones. Dip meter analysis is conducted to determine the bedding and strike fields and the fracture dip in the drill hole (figure 1).

The tadpole in the continues fracture will be restored corresponds to the dominant direction of the fracture to determine their dominant direction. The main strength of the reservoir is limited by dipmeter and constraint BHI reservoir model is a merging of direction information in the wellbore that can represent subseismic properties and provide local calibration for seismic attribute (Pöppelreiter, Crookbain, Sapru, & Lawrence, 2010). Conductive fractures on the image log are those that will be discussed in this research because they are open fractures that are considered to be fractures that can be increasing porosity (secondary). FMI providing detailed fracture mapping on drill holes, where the principle that works when open fractures intersect with drilling mud wells enters the fractures and electrical devices will measure the contrast between the fluid and the formation (Sibbit and Faivre 1985).

Figure 2. Bedding, erosion zone, and fracture zone and confirmation by log data and thin section
RESULTS AND DISCUSSION

Fracture Zone And Lithology

Fracture zones and lithology determination using FMI data integrated with log data showed in Figure 2. FMI data integrated with log and seismic data can be define lithology, filled fracture zones, open fractures, and fractures due to drilling activities (tensile and breakout). The low values of gamma ray shows lava lithology, this is also confirmed by thin section data. High gamma ray prices indicate that lithology is tuff. The FMI data shows that the tuff layer has been fractured. Tuff is separated into lithic tuff, vitric tuff, and crystal tuff based on petrography and based on log characters. Fractures in layered rock can be divided in two general category: limited to single bed and those formed by larger fractures which spread through many beds (Gross, 1993). From the results of thin section not only tuff but also tuff has been altered. The altered tuff shows increased gamma ray, increased conductivity, and reduced density. In contrast to tuffs, andesite lava has a high gamma ray, relatively higher resistivity values. The fracture zone is divided into static and dynamic. FMI is also used to identify prospect zones on each well. The prospect zone is an integration of FMI analysis images, resistivity and separation values between neutron and density (figure 3.).

Dark-colored fractures (open fractures) or also called conductive fractures on tuffs, resistive fractures or quartz-filled fractures on tuffs (Figure 4). The drill hole image data were analyzed using a rose diagram to determine the direction of the main force and the dominant direction of the fracture. furthermore, the conductive fracture intensity (continues conductive fracture) will be calculated to estimate porosity of fracture in the rock.

Figure 3. Fracture zones and hydrocarbon prospect zone were seen by log data and FMI.
Fracture Density

Fracture density depends on the type of lithology and thickness of the layer (Cacas, Daniel, and Letouzey 2001); (Peacock and Mann 2005). Therefore the facies model will greatly affect to controlling the presence of the fracture and their spread. Fracture density is the conversion of the number of fractures to each lateral grid which is then drawn on the map (figure 5). The number of fractures in each grid is created by ant tract model which is built based on numbers of fracture and the direction of the existing fractures. The area around the fault has high fracture density value, and long way from the fault the fracture density value decreases, this corresponds with the HALO concept.

Figure 4. Conductive and resistive fracture zone (quartz filled)

Figure 5. Fracture density which represents the fracture intensity.
Fracture Intensity Volcaniclastic

Total porosity and effective porosity (matrix porosity) are important parameters in sandstone and limestone reservoirs, in volcanic rock reservoirs besides these two porosity, fracture porosity is also an important parameter. To calculate fracture porosity on volcanic reservoir, previously fracture intensity must be calculated in each vertical and lateral grid on a well that has an image log (FMI).

Continuous and discontinues conductive fracture analysis is conducted to calculate fracture intensity on each well that has FMI data. Image log data is used to calculating area, fracture length, and amount of fractures in the grid area. The Area corresponds FMI size and scale. Fracture length, area in log image, and number of fractures are parameters for determining fracture intensity (fracture intensity* Aperture). It should be noted that to distribute I*A wells must have bulk modulus data (figure 6). Because bulk modulus is an index of the brittleness of a rock. The higher brittleness index, the higher bulk modulus value.

Bulk modulus is a constraint to spreading the value of I*A, then range of I*A value becomes a constraint in defining fracture quality (FQ). I*A values are adequate both in the area of the fold crest and around the fracture (figure 7). The fracture quality can be maximized in the tuff that has been fractured. FQ 1 is the best fracture quality, FQ 2 and FQ 3 are medium quality, and FQ 4 is the worst fracture quality.

Fracture porosity is calculated using the formula \( \Phi = \frac{W \times TA}{\text{Coverage}} \) where \( W \) is the aperture, \( TA \) is the fracture length in log image, and Coverage is the area according to \( \frac{1}{2} \) the circumference of tube. The I*A value result increases with proximity of the area to the fault plane, the value of I*A also increases when the area is an area with high fold intensity (curvature).

Figure 6. Crossplot of bulk modulus and fracture intensity*aperture (I*A) that function to distribute fracture intensity values to wells without FMI data.
Multiplication of fracture and aperture corresponds to the fold intensity and fracture intensity. Wherein the higher fold intensity, the $I^*A$ values will be high and the higher fracture intensity then the $I^*A$ values will be high. Likewise, the bulk modulus is high, $I^*A$ will be high with a linear relationship.

CONCLUSION

- Either conductive or resistive fractures in volcaniclastic reservoirs can be identified by the electrical image log and wireline log (log bulk modulus).
- $I^*A$ values that are defined using image log data (FMI) can be distributed to wells that no have image log data but they have no bulk modulus data, and these data is used as constraints in calculating estimated $I^*A$ values.
- The value of the bulk modulus (brittleness index) increases, will be causes an increase the $I^*A$ values, and otherwise.
- $I^*A$ value is high in the area that is close to the fold and the area close to the fracture, the further from the folds and fractures, these values also tend to decrease.

REFERENCES

1. Aguilera, R., 1995. “Naturally Fractured Reservoirs”. Penwell, 2nd ed., 521p.
2. Cacas, M. C., J. M. Daniel, and J. Letouzey. 2001. “Nested Geological Modelling of Naturally Fractured Reservoirs.” Petroleum Geoscience.
3. Gross, Michael R. 1993. “The Origin and Spacing of Cross Joints: Examples from the Monterey Formation, Santa Barbara Coastline, California.” Journal of Structural Geology.
4. Henrikson, A., 2002. "Fracture Interpretation Based On Electrical and Acoustic Borehole Image Logs". BRGM.
5. Luthi, Stepan M., and Philippe Souhaite. 1990. “Fracture Apertures from Electrical Borehole Scans.” In 1990 SEG Annual Meeting.

6. Nelson, R.A. (2001). Geologic Analysis of Naturally Fractured Reservoirs. 2nd ed. Gulf Professional Publishing.

7. Peacock, D. C.P., and A. Mann. 2005. “Evaluation of the Controls on Fracturing in Reservoir Rocks.” Journal of Petroleum Geology.

8. Pöppelreiter, Michael, Robert A. Crookbain, Ajay K. Sapru, and Mark J.F. Lawrence. 2010. “Applications of Dipmeter and Borehole Image Data in Static Models.” AAPG Memoir.

9. Sibbit, A. M., and O. Faivre. 1985. “The Dual Laterolog Response in Fractured Rocks.” In SPWLA 26th Annual Logging Symposium 1985.

10. Sruoga, Patricia, and Nora Rubinstein. 2007. “Processes Controlling Porosity and Permeability in Volcanic Reservoirs from the Austral and Neuquén Basins, Argentina.” AAPG Bulletin.

11. Wennberg O.P., Paludan, J., Dart, C., Salvini, F., 2001. “Structural Characterisation of A Fractured Reservoir Using Borehole Image: The Tempa Rosaa Field In The Southern Apennines Of Otaly”. Journal of Petroleum Geology (in press).