PS Integrating Borehole Imaging and Full Waveform Dipole Sonic Data to Estimate Fracture Porosity in Tight Formations: A Workflow for Accurate Characterization of Natural Fractures

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Abstract

This paper introduces an integrated workflow that combines high-resolution electrical borehole imaging and full waveform dipole sonic data to estimate fracture porosity in tight formations. The study focuses on the Cambro-Ordovician tight sand reservoir in the Central Ahnet basin, Algeria. Three wells were selected for analysis to assess natural fractures using Formation Micro-Imager (FMI) images and Sonic Scanner data. The classification of fractures based on Sonic Scanner data resulted in the identification of 267 open fractures and 231 closed fractures. An advanced processing workflow was applied to estimate kinematic and hydraulic aperture, enabling the characterization of fracture porosity and identification of three sets of open natural fractures. Accurate fracture characterization is crucial for optimizing production and recovery in fractured reservoirs, and this study highlights its importance. The workflow demonstrated its applicability in estimating fracture porosity and provides valuable insights for reservoir management and development strategies. The results obtained from the application of the workflow in the Cambro-Ordovician tight sand reservoir showcase its effectiveness in enhancing reservoir performance.

Keywords:

Fracture porosity, Sonic scanner, Borehole imaging, Natural fractures.

References:

A. Allaoui et al., “The lower Silurian black Shales from the Ahnet basin (SW Algerian Saharan platform): a comprehensive mineralogical study and paleoenvironmental implications,” Arab. J. Geosci., vol. 15, no. 11, p. 1103, 2022.

Ifrene, G. E. H., Irofti, D., Khetib, Y., & Rasouli, V. (2022). Shear Waves Anisotropy and Image Logs Integration for Improved Fracture Characterization. 56th U.S. Rock Mechanics/Geomechanics Symposium, ARMA-2022-0319. https://doi.org/10.56952/ARMA-2022-0319

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Introduction

- This paper introduces an integrated workflow that combines high-resolution electrical borehole imaging and full waveform dipole sonic data to estimate fracture porosity in tight formations.
- The study focuses on the Cambro-Ordovician tight sand reservoir in the Central Ahnet basin, Algeria.
- Three wells were selected for analysis to assess natural fractures using Formation Micro-Imager (FMI) images and Sonic Scanner data.
- The classification of fractures based on Sonic Scanner data resulted in the identification of 267 open fractures and 231 closed fractures.
- An advanced processing workflow was applied to estimate kinematic and hydraulic aperture, enabling the characterization of fracture porosity and identification of three sets of open natural fractures.
- Accurate fracture characterization is crucial for optimizing production and recovery in fractured reservoirs, and this study highlights its importance.
- The workflow demonstrated its applicability in estimating fracture porosity and provides valuable insights for reservoir management and development strategies.
- The results obtained from the application of the workflow in the Cambro-Ordovician tight sand reservoir showcase its effectiveness in enhancing reservoir performance.

Objectives

The primary objectives of this study are as follows:

- Investigation of the spatial distribution of fractures and their influence on reservoir parameters.
- Identification and characterization of open fractures that play a significant role in enhancing productivity in the vicinity of the wellbore.
- Characterization of the natural fracture sets within the study area, encompassing crucial parameters such as dip, azimuth, aperture, and porosity.

Area of Investigation

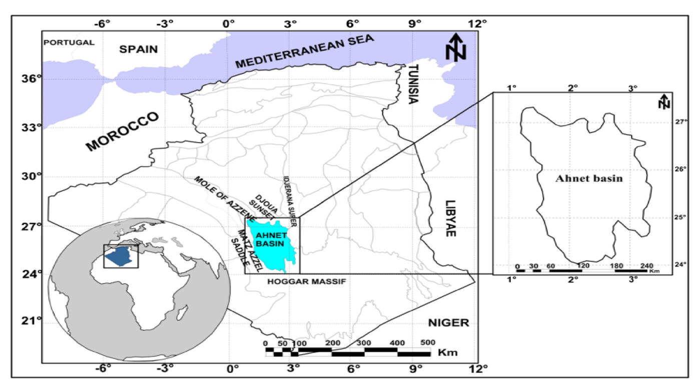

Fig 1. Area of study (Allaoui et al., 2022)

The Ahnet basin is part of the Western province of the Saharan Platform, Southern Algeria. It is primarily a gas province in terms of petroleum system, and its reservoirs under the Paleozoic sedimentary layer are mostly compact.

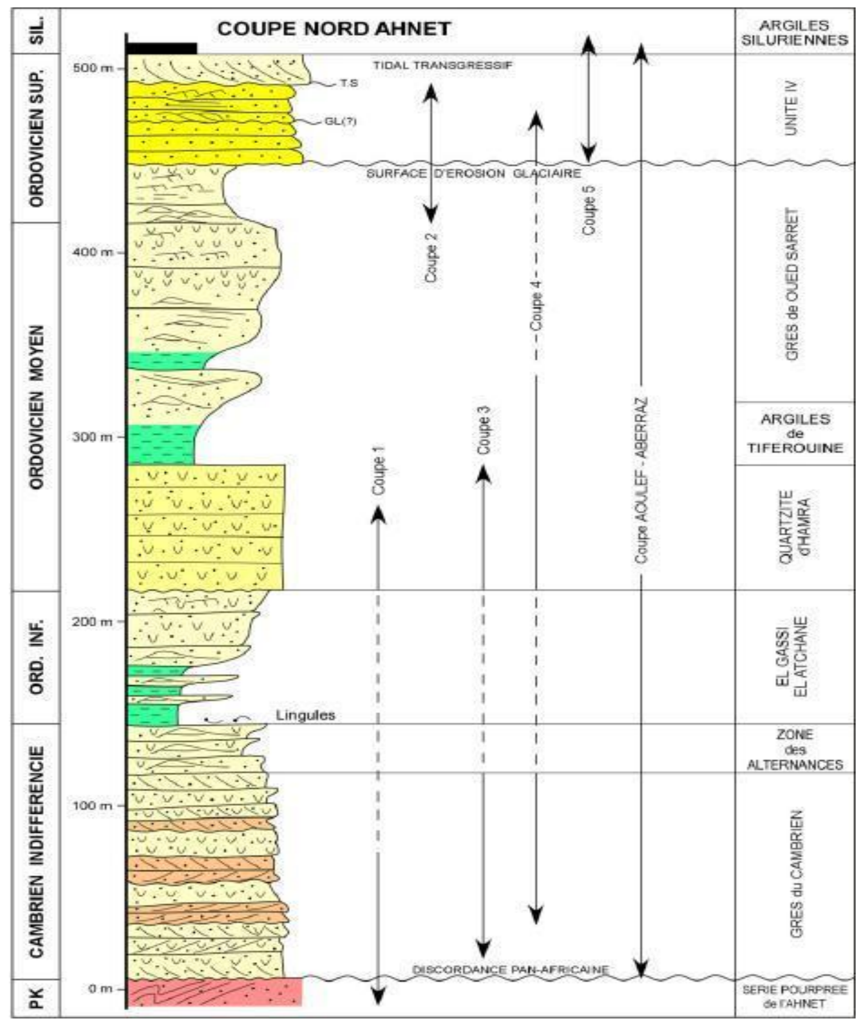

Fig 2. Lithostratigraphic column of the Cambro-Ordovician formations in the Ahnet Basin (Sonatrach, 2011)

Methodology

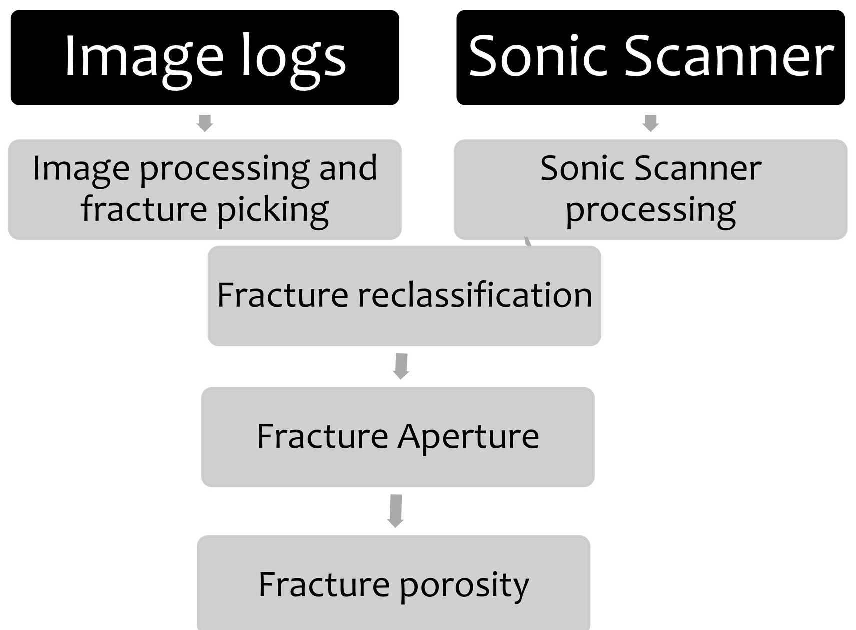

Fig 3. Workflow used in this study to estimate the fracture porosity

In order to distinguish between open and filled fractures, fast and slow shear dispersion plots were utilized, providing additional insights into the characteristics of the fractures. Anisotropy, or directional variation in the elastic properties of rock, can occur due to fractures present in rock formations. The varying velocities of shear waves in different directions through the rock are caused by acoustic anisotropy. By integrating this technique with image logs, the fractures were differentiated as either open or closed.

Open Fractures identification

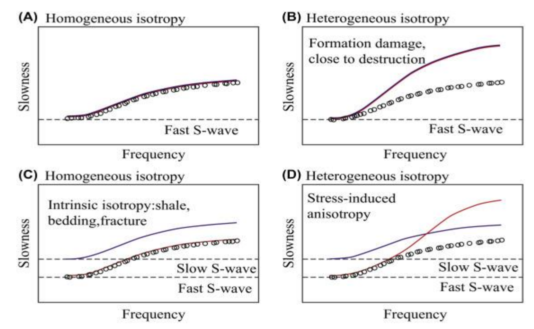

Figure 4. Flexural wave characteristics of different types of anisotropic strata. The Redline and blue lines are the fast and slow flexural vase dispersion curves, respectively. Black circles are the flexural wave dispersion curves based on the theoretical model (Arroyo Franco, J. L., De, G.S., et al. 2006.)

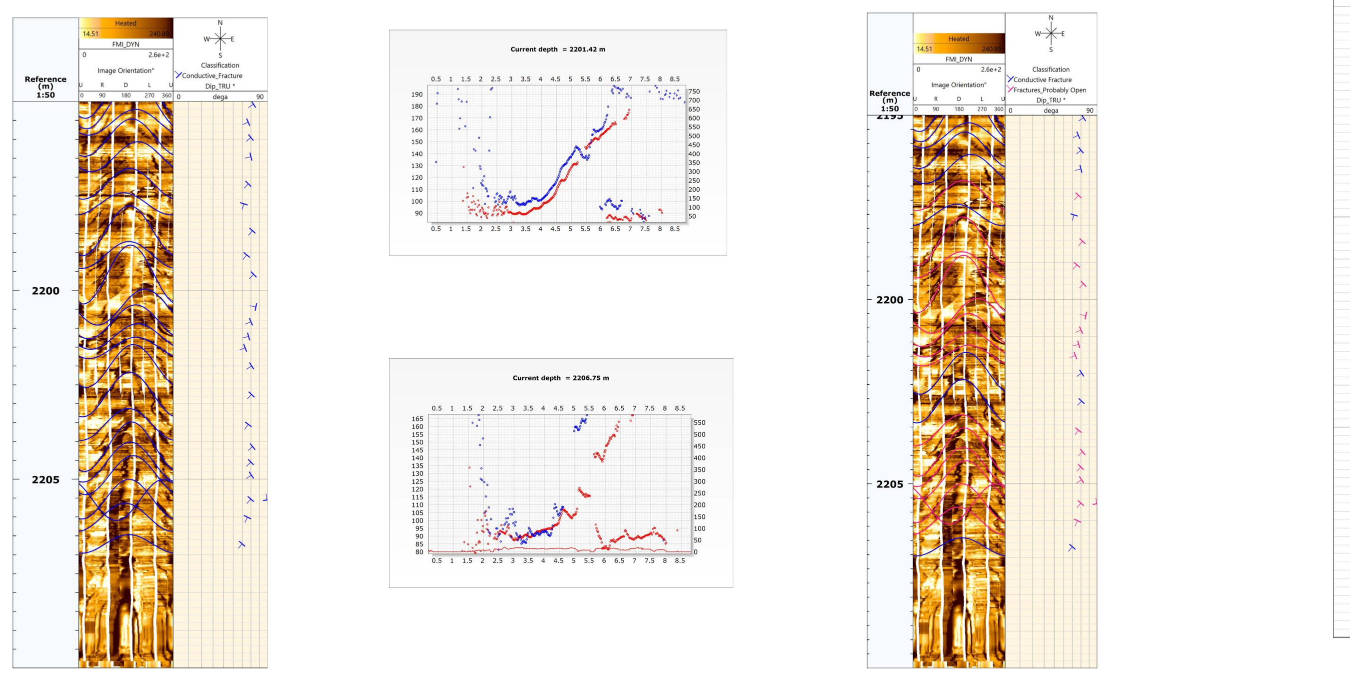

Fig 5. Open and closed fracture distinction using the anisotropy plots.

Aperture and porosity estimation

In order to determine the porosity of the fracture, it is crucial to compute the fracture width. To achieve this, the Luthi and Souaite's (1990) equation is employed to calculate the aperture.

$$w = cAR_m^b R_{xo}^{1-b}$$

W= Fracture Width in mm
Rm= Mud Resistivity
Ro= Formation Resistivity
A= Additional current into the formation
c and b are tool parameters

Results

Fig 6. Left: Cross plot of maximum horizontal stress. Right: cross plot of closed and open fractures

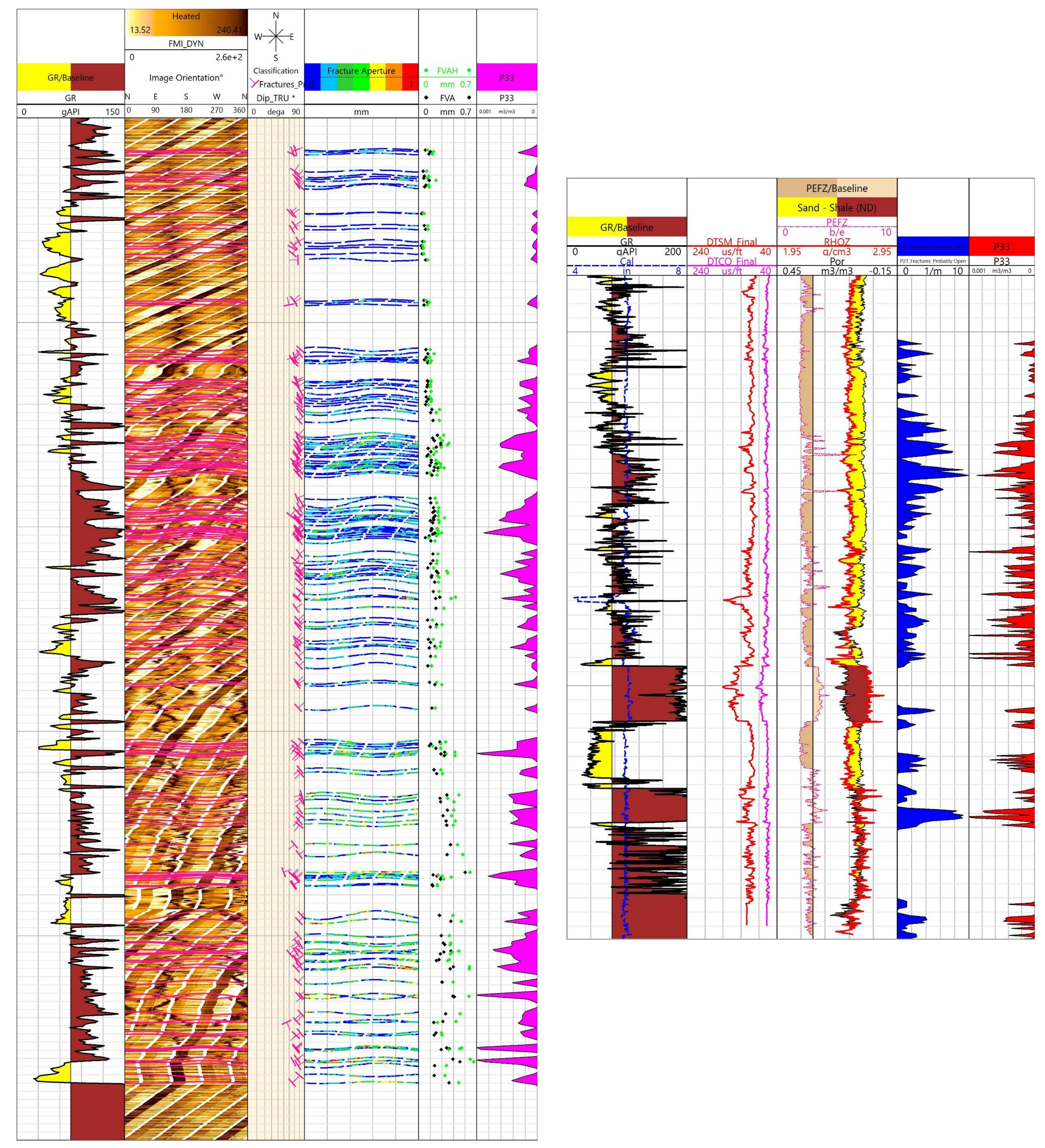

Fig 7. Fracture porosity estimation

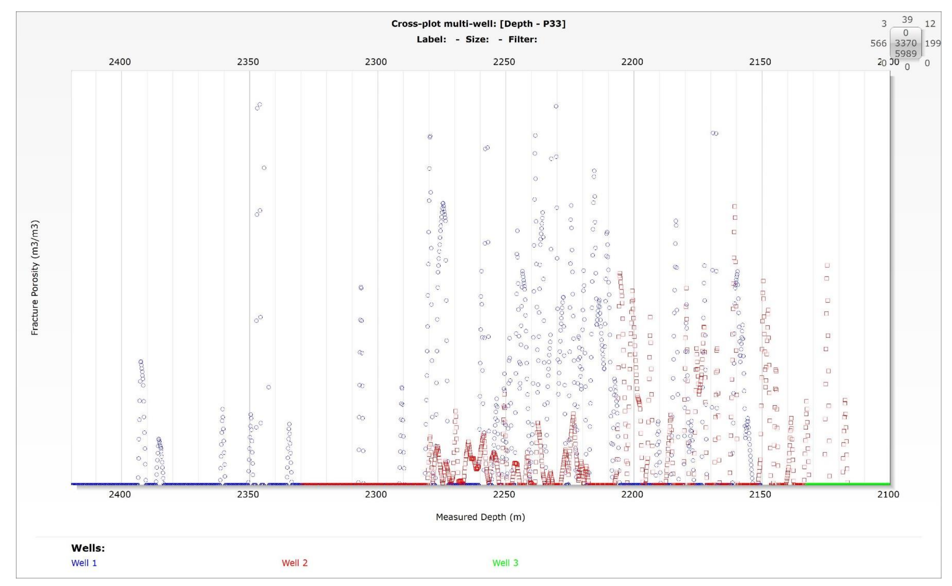

Fig 8. Fracture porosity evolution with depth

Conclusions

- 426 resistive fractures were discerned.
- To retrieve high confident and reliable data, and in absence of cores, Sonic Scanner tool was integrated and 267 open fractures were recognized.
- The natural open fractures are oriented N140, which correspond to the direction of the maximum horizontal stress
- This workflow allowed for an accurate estimation of fracture porosity

References

- Luthi, S. M., & Souhaite, P. (1990). Fracture apertures from electrical borehole scans. Geophysics, 55(7), 821-833.
- A. Allaoui *et al.*, "The lower Silurian black Shales from the Ahnet basin (SW Algerian Saharan platform): a comprehensive mineralogical study and paleoenvironmental implications," *Arab. J. Geosci.*, vol. 15, no. 11, p. 1103, 2022.
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- Sonatrach report