The Identification of Natural Fractures in Inclined Highly Fractured Formation

Nabil Al-Adani*
Schlumberger, Calgary, AB
adani@calgary.oilfield.slb.com

and

Hanai Al-Khatib
Schlumberger, Calgary, AB, Canada

Summary

Most features, like fractures and faults can be identified on borehole images with reasonable confidence at the borehole wall. Based on the fracture appearance, the natural fractures might be distinguished from any other drill-induced fractures and qualified as productive features. However, this is all based on observed features on the borehole images at the borehole wall with no confirmation on the extent of these features into the formation.

By combining acoustic shear dispersion, shear anisotropy and Stoneley mobility analyses with high resolution borehole images, the fractures can be investigated beyond the borehole wall.

This is an integrated process to investigate the probability of observed geological features on the borehole images extending into the formation.

Introduction

Geoscientists have been trying to understand the fracture production mechanisms in both carbonate and clastic reservoirs. Unfortunately, the traditional logging approach has been of little value. For example, the orientation of many observed fractures appears similar to the drilling induced fractures that are created as a result of tensile failure near the borehole and parallel to the in-situe principle stress. When the current stress has a similar orientation to the paleo stress, the differentiation between the natural fractures and drilling induced fractures remain unresolved in some cases.

The introduction of high resolution borehole images allowed the identification of features at the borehole wall. Acoustic technologies enabled the analysis of the probability of these features extend into the formation.

Traditional acoustic shear anisotropy is not limited to imbalanced existance of far field stresses. Anisotropy is also influnced by the measurement inclination with respect to the beds, planar fractures, and microstructral layers. With dispersion analysis, the anisotropy source can be identified and compared with borehole images observations. If both confirm the observed feature, the probability of its existance in the formation increases.

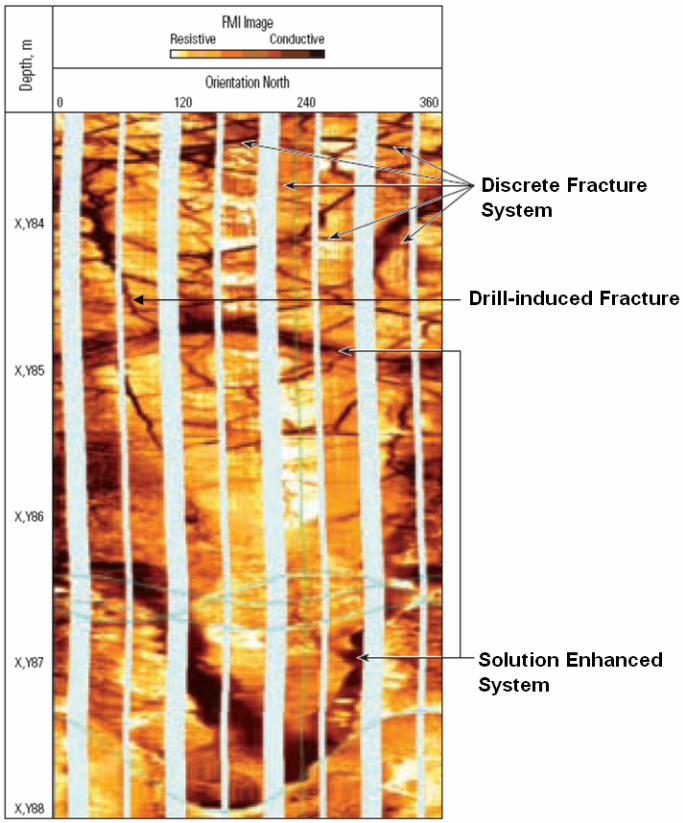
However, in case of non-planar features, like microfractures, which do not create any plane of symetry in the formation, the acoustic anisotropy will not be affected by microfractures. In addition, if the aperture of microfractures is smaller than borehole image resolution, then the borehole image will not be able to resolve them.

In this case, Stoneley wave is analysed to detect borehole fluid mobility into the formation. Then, by comparing with porosity profile, Stoneley will help to indicate microfractures presence.

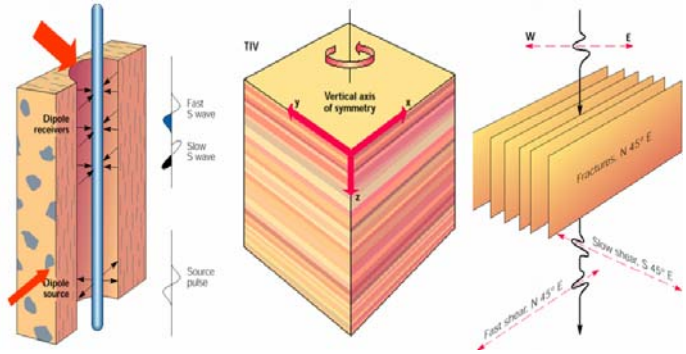
Theory and/or Method

The process of integration is composed of four main steps:

1. Borehole images are processed for structural and textural features. The analysis is performed with detailed feature classification, orientation and dip. It is essential to extract as much high confidence information as possible from the images.



2. Shear wave splitting analysis is performed to analyze plane of symetry orientation and degree of anisotropy. This is accomplished using Alford rotation on cross shear measurements. The evaluated cross-energy difference of the split waves may indicate the degree of anisotropy as well.
3. Shear dispersion analysis (Schlumberger Sonic Scanner Analysis) is used to identify the acoustic anisotropy source. This is essential as not all observed wave splitting is due to stress alone.



4. The features detected on borehole images are integrated with the acoustic anisotropy parameters in a proprietary Schlumberger 3D model using FracAniso technique. If observed bore hole images features are planar in the formation, the shear anisotropy will match the direction confirming that borehole images observed features extending into the formation.
5. Stoneley wave is analyzed using special technique for mobility detection in tight fractured zones. The evaluated Stoneley Index (StI) is compared with the measured porosity profile to analyze secondary porosity. StI will help in highlighting productive microfractures or "chikenwire" type fractures which are non-planar features.

Based on these analyses, the probability of natural fracture existance can be evaluated.

Conclusions

The integration of borehole images, shear anisotropy, shear dispersion and Stoneley waves allowe evaluating the probability and productivity of natural fractures. This approach provides confidence for establishing successful completion strategy and it is essential for developing a representative simulation model for reservoir performance evaluation.

Acknowledgements

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