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Critically-stressed Fracture Analysis Contributes to Determining the Optimal Drilling Trajectory in Naturally Fractured Reservoirs

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Abstract

This case study illustrates a critically stressed fracture analysis (CSFA) for three wells drilled in offshore Vietnam fractured granites.

A CSFA identifies fractures which are optimally aligned to fail in the present-day stress regime, and are most likely to be conduits to fluid flow. Identifying such fracture orientations is essential for optimal wellbore placement and drilling trajectory.

The fracture dip angle and azimuth were manually extracted from electrical and acoustic borehole images. Four pressure and in-situ stress support cases were analyzed and plotted on Mohr-Coulomb diagrams.

In the case of high-pressure fractures and efficient in-situ stress support, two fracture sets of possible critically stressed fractures are identified in stereograph plots: (1) striking circa N-S and dipping either to the East or to West with high dip angles around 75 degrees, and (2) striking NNW-SSE and dipping either to the ENE or WSW with dip angles around 75 degrees.

This CSFA shows that cemented and non-permeable fractures (non-hydraulically conductive) are not under a critical shear state for the in-situ stress tensor obtained in the field. However, critically stressed fractures can exist in the basement formation when they are hydraulically connected (open fractures), and highly pressurized, providing a Biot equal to 1. The optimum drilling trajectory that would intersect more CSF would be high-angle wells in the direction of NE-SW or W-E. A production logging tool (PLT) run in the follow up Well-4 confirms the results.

In the case of fractured granites it is critical to maximize formation evaluation information from the first few wells to evaluate the field potential before too much money is spent on appraising what could be an uneconomic reservoir. CSFA is an essential step for maximizing this information.

Introduction

This case study is based on Hoan Vu JOC (Joint Operating Company) data acquired in the naturally fractured granitic basement of the Cuu Long Basin, Vietnam, located about 150 km offshore from Vung Tau city.

The critically stressed fracture study was carried out from wireline, simultaneously acquired acoustic and resistivity borehole image logs in three exploratory wells; Well-1, Well-2, and Well-3. The wells were drilled over 2002-2006 and the CSFA study was completed in the first quarter of 2007.

The recommendation of optimum drilling trajectories towards productive fractures in the basement from the results of the critically stressed fracture study was confirmed from the PLT run in the Well-4.

Critically Stressed Fracture Methodology

The critically stressed fracture analysis consists of the following activities:

- Characterization and identification of the orientation of the natural fractures.
- Estimation of magnitude and direction of the three principal in-situ stresses acting in the reservoir.
- Projection of the far-field in-situ stress tensor onto the fracture planes to calculate the normal and shear stresses acting on each plane.
- Comparison of the stresses, plotted on a normalized Mohr-Coulomb diagram, and compared to the fracture shear failure envelope.
- Classification of the fractures as critically stressed if the ratio of shear to normal stress exceeds the shear failure fracture envelope.

Natural Fracture Classification

The first activity required for a critically stressed fracture analysis is the identification and characterization of the natural fractures presented in the reservoir. The