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Using the Formation Breakdown Pressure Measured in Pre-frac Test to Predict Natural Fracture Swarms in Low Permeability Carbonate at the Wattenberg Field in the Denver-Julesburg Basin

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Abstract

Natural fracture swarms are usually a critical factor governing hydrocarbon production from the carbonate formation. In a low permeability carbonate reservoir at the Wattenberg field, the author has observed that natural fracture swarms are more likely to exist near such geology structure as fault. While faults can be easily identified by well logs when they are penetrated by well bore, it is almost impossible to describe faults when they are missed by the well bore. This paper presents a new method to predict faults and natural fracture swarms by analyzing the formation breakdown pressure recorded at pre-frac test in areas where faults are not encountered by well bore. Using this method, the author has successfully mapped the distribution of faults and natural fracture swarms in the Niobrara Formation at the Wattenberg field. This paper provides 1) the correlation between fault and the minimum horizontal stress; 2) the calculation of the minimum horizontal stress using pre-frac test; and 3) the fault description obtained by the minimum horizontal stress.

Introduction

The Niobrara formation at the Wattenberg field in the DJ basin is a sequence of marine shale, marl, and thin carbonate deposit. Three layers of carbonate, with a combined thickness of 45-100 feet, continuously cover the entire Wattenberg field. The permeability measured at the most permeable part of the formation is in the magnitude of micro-Darcy. Therefore, the Niobrara Formation at the Wattenberg Field has been classified as low permeability and economically marginal carbonate reservoir. A recent petrophysical study has successfully correlated well logging parameters with hydrocarbon production from the Niobrara Formation (Yang et al, 2007). As a result of this petrophysical study, Niobrara "fairways" have been delineated. While the production within Niobrara "fairways" is very encouraging, drilling activities outside of the sweet spots have been hamstringed by the lack of methods to describe the reservoir qualities of the Niobrara Formation.

When it comes to carbonate, natural fracture is usually considered the primary factor that affect the well performance. Similar observations have been made at the Wattenberg field. The author has observed that in wells where the Niobrara formation has been penetrated by faults, FMI logs usually display numerous natural fracture swarms around the fault planes. Subsequently, these wells usually outperform the offset wells. If fault distribution could be better described in areas outside Niobrara "fairways", natural fracture would be better characterized and more opportunities for drilling can be expected.

Faults have been frequently identified by well logs within the Niobrara interval. Well log is one of the most reliable methods to describe fault. When a fault has been penetrated by well bore, the fault can be identified by its missing section as apposed to offset wells. However, when a fault has not been penetrated by well bore, we usually do not know whether fault exists. To better describe natural fracture swarms associated with faults, we have to answer a critical question. In wells where well logging does not show any missing section or faults, how do we determine its relative distance to a fault? Is this well too far away from a fault, or is this well is very close to a fault? The point of this argument lies in the fact that, if the well is close to a fault, natural fracture still exists. In the opposite, natural fracture swarms may not be present if the well is too far away from a fault. The rest of the paper provides a new method to determine the relative distance of a well to a fault, even though the well bore does not penetrate the fault.

The distribution of minimum horizontal stress along a normal-slip fault

In order to better understand the distribution of minimum horizontal stress along a normal-slip fault, we have to examine its stress distribution under two scenarios; in situ status (the moment when fault is generated) versus current status.