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Integrated Modeling and Statistical Analysis of 3-D Fracture Network of the Midale Field

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Abstract

As the maturation of conventional oil reserves pushes the industry to explore challenging reserves, state-of-the-art reservoir characterization becomes an integral part of any exploration and production venture. Naturally fractured reservoirs are good examples of such challenging fields. Oil recovery performance estimation from such reservoirs requires a good understanding of reservoir structure and its effect on the dynamics of the process. Addressed in this work is one of the critical issues for fractured reservoirs—that is characterization and 3-D modeling of a fracture network.

In this study, we employed an integrated solution by combining "direct" and "inverse" approaches to fracture network characterization in a stochastic numerical model. Static geological data obtained from cores and well logs were used together with dynamic data such as well test response to build 3-D discrete fracture network models. We utilized the data obtained from the fractured carbonate Midale field in Canada. The on-going CO_2 injection project requires a reliable description of the fracture system and matrix characteristics in the field for reliable performance analysis.

Fracture network constructed from static data was calibrated and validated using well test (interference drawdown and pulse) data. Matrix and several fracture parameters including fracture length, density/spacing, aperture, connectivity, and orientation were evaluated in sensitivity studies to determine which characteristics have a higher influence on the accurate match to well test response. We utilized the factorial experimental design to optimize the number of simulations needed for a sensitivity study and history match. The sensitivity analysis revealed a strong influence of matrix quality on the pressure response. Geological conditions and fracture properties specific to this field explained such distribution of matrix and fracture influence. Through this analysis we were able to clarify the role of fractures in the overall field performance. Matrix/fracture interaction was suggested to be a factor deserving attention. In a general sense, the approach used in this study proved to be useful to integrate fracture data from different sources, as well as to assess its reliability and relative importance.

Introduction

Naturally fractured reservoirs (NFRs) present numerous challenges for geologists, geophysicists and reservoir engineers[1,2,3,4,5,6]. Extensive characterization coupled with modeling is the key for understanding the performance of NFRs. Such reservoirs need to be treated specifically from the first steps in development. Relatively simple methods used to investigate the properties of rock matrix need to be reinforced by additional procedures and analyses to determine fracture characteristics. Usually, this may not be enough. An NFR study would be incomplete without an accurate description of the interaction between the two media: natural fracture network (NFN) and matrix blocks[7]. Only when armed with the complete set of data and applicable analytical tools can one hope to construct a valid representation of an NFR.

In this study, we apply a widely accepted integrated approach to characterize the matrix-fracture system of the Midale field in south-eastern Saskatchewan. Often serving as an example for classical NFR in literature, Midale is a unique field, which makes it a perfect case study for several reasons. The field produces light oil from a mature carbonate reservoir. During its 50 year history—Midale was discovered and put into production in 1953—the field has gone through all stages of development. Nine years of primary production were followed by waterflooding, which was later supported by extensive infill drilling, including vertical as well as horizontal wells, raising their total number over one thousand. Currently Midale is undergoing a full-field CO_2 flooding, which became possible largely thanks to the success of the pilot CO_2 flood project in late 80s. Massive amounts of data and experience were accumulated throughout the years. Moreover, considerable research was conducted into matrix and fracture characterization and production mechanisms[8,9,10,11,12]. It suggests the influential role of the fracture network on reservoir performance at all stages of production. Though there has been a considerable effort to