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Irreducible Water Saturation Has Been Determined As the Key Factor Governing Hydrocarbon Production from Low Permeability Carbonate at the Wattenberg Field in the Denver Julesburg Basin

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Abstract

It is commonly known that geological structure and its resultant natural fractures are the predominant factors governing hydrocarbon production from carbonate reservoirs. Through a detailed petrophysical study on a low permeability carbonate play, the authors have obtained new understandings toward the reservoir properties of low permeability carbonate. First, in absent of major geological structures, reduced relative permeability to hydrocarbon is the primary trapping mechanism. Second, the irreducible water saturation range for low permeability carbonate increases significantly. Third, the enlarged irreducible water saturation range makes the curve of relative permeability to hydrocarbon much steep. Therefore, the relative permeability to hydrocarbon is very sensitive to water saturation, and formation water saturation becomes a critical factor affecting hydrocarbon production. The results of this petrophysical study have been successfully applied to identity the "fairways" among a huge low permeability carbonate deposition.

Introduction

The Niobrara Formation at the Wattenberg Field in the Denver-Julesburg basin is a low permeability carbonate reservoir (Figure 1). It continuously exists throughout the entire field. The Niobrara is a sequence of interbedded carbonate and marine shale. The gross thickness varies approximately from 250 to 350 feet. The permeability tested to the carbonate part is in the order of micro-Darcy. Largely because of it extremely low permeability and unconfirmed potential, this carbonate play used to be treated as a secondary objective for 10 years (between 1996 and 2006) by most operators at the Wattenberg field.

Started a few years ago, operators have renewed their interests toward the Niobrara Formation. Numerous pilot projects have been conducted by either separately completing or re-completing the Niobrara Formation. Before any wells are drilled, the first question operators have to answer is where are the best parts of the Niobrara Formation among such huge field as Wattenberg covering approximately 3600 square kilometers (more than 42 townships). In other words, how to define the boundaries dividing economic area and non-economic ones?

Many carbonate reservoir related paradigms have failed to find their usefulness at the Wattenberg field. For example, in typical carbonate formation natural fracture resulted from geological structure is a critical factor governing hydrocarbon production. At the Wattenberg field, many wells tested along two well-defined major faults are not better in performance than others. In order to find the petrophysical factor that controlling hydrocarbon production, the authors carried out a petrophysical study and found the method to delineate the "fairways" where the Niobrara Formation performs better than other part of the field.

The correlation between well-log calculated water saturation (Sw) and well performance

This petrophysical study is supported by a wealthy well log data resource, which includes digital well logs collected from more than one thousand wells where the Niobrara Formation has been penetrated when deeper formations were originally the primary targets. Using self-developed computer programs as well as commercial ones, we calculated the representative well log parameters of the Niobrara Formation, such as the porosity, SP, formation water saturation, and the cross-over area between the neutron and density curves. In order to search the distribution patterns of these parameters, we mapped these parameters. Their distribution patterns helped us identify the areas where the Niobrara reservoir quality is better than that of other part of the field.