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A Pore-Level Scenario for the Development of Mixed Wettability in Oil Reservoirs

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Abstract

Understanding the role of thin films in porous media is vital if wettability is to be elucidated at the pore level. The type and thickness of films coating pore walls determines reservoir wettability and whether or not reservoir rock can be altered from its initial state of wettability. Pore shape, especially pore wall curvature, is an important factor in determining wetting film thickness. Yet, pore shape and the physics of thin wetting films are generally neglected in models of flow in porous rocks. This paper incorporates thin wetting film forces into a collection of capillary tubes model to describe the geological development of so-called mixed-wettability in reservoir rock. Our model emphasizes the remarkable role of thin films.

New pore-level fluid configurations arise that are quite unexpected. For example, efficient water displacement of oil (i.e., low residual oil saturation) characteristic of mixed-wettability porous media comes about due to interconnected oil lenses or rivulets which bridge the walls adjacent to a pore corner.

Predicted residual oil saturations are found to be approximately 35 percent less in mixed-wet rock when compared to completely water-wet rock. Calculated capillary pressure curves mimic those of mixed-wet porous media in the primary drainage, imbibition, and secondary drainage modes. Amott-Harvey indices range from -0.18 to 0.36 also in good agreement with experimental values[1,2].

References and illustrations at end of paper

Introduction

The wettability of reservoir rock is a critical factor in determining the displacement effectiveness and ultimate oil recovery by drive fluids, such as water. Since the most wetting fluid tends to occupy the smallest and, hence, most hydrodynamically resistive pore channels while the least wetting fluid distributes to the largest and least resistive pore channels, wettability is a prime factor controlling multiphase flow and phase trapping. Therefore, understanding how wettability is established at the pore level is crucial if predictive flow models are to be developed.

Wettability in porous media is generally classified as either homogeneous or heterogeneous. For the homogeneous case the entire rock surface has a uniform molecular affinity for either water or oil. Conversely, heterogeneous wettability indicates distinct surface regions that exhibit different affinities for oil or water.

Three broad classifications of homogeneous wetting exist: strongly water-wet, strongly oil-wet, and intermediate wet. If smooth representative rock surfaces can be prepared, then contact angles for water-wet surfaces, measured through the water phase, are near zero. Whereas, for oil-wet surfaces they are near 180°. In the case of intermediate-wetting, the rock has neither a strong affinity for water nor oil, and contact angles range roughly from 45° to 135°[3].

Two types of heterogeneous wettability are generally recognized. Mixed-wettability refers to distinct and separate water-wet and oil-wet surfaces which coexist and span a porous medium. Dalmation, also speckled or spotted, wettability refers to continuous water-wet surfaces enclosing