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Effect of Fractional Wettability on Multiphase Flow Through Porous Media

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ABSTRACT

The concept of fractional wettability is examined. Fractional water wettability of a reservoir rock is defined as the fraction of the internal surface area that is in contact with water. Capillary pressure and relative permeability of unconsolidated sand are shown to be functions of fractional wettability.

INTRODUCTION

The petroleum industry has long recognized that wettability of reservoir rock has an important effect on multiphase flow of oil, water and gas through reservoirs. As early as 1928 the American Petroleum Institute sponsored a study of wettability as part of API Project 27 at the U. of Michigan.[1] Despite 30 years of research, there is still little exact knowledge of the wettability of reservoir rocks.

There are two parts to the wettability problem. After agreeing to a uniform nomenclature in regard to wettability,[2] the first question to be answered is, "What is the in situ wettability of a given reservoir rock?" If this can be answered the next question is, "What part does wettability play in determining the characteristics of multiphase fluid flow through the rock?" This paper represents an oblique attack on the problem of wettability. No attempt is made here to answer the basic question of wettability in situ. Instead the consequences of the concept of fractional wettability are examined. Multiphase flow in sandpacks is shown to be highly influenced by fractional wettability.

Jennings[2] has given a definition of wettability and the other terms used in discussing wettability. These terms must be applied to the physical situation existing in reservoir rock. A survey of the pertinent literature from 1928 to 1956 indicates that the concept of a contact angle was applied to reservoir rock in the same way it would be applied to a flat, homogeneous surface. Attempts were made to state quantitatively the wettability of a reservoir rock in terms of a contact angle which was presumably constant at all points on the very rough and heterogeneous interior surface of a porous rock. Calhoun, *et al*,[3-6] prepared synthetic consolidated and unconsolidated porous media in which they claimed there was a known uniform contact angle. They then showed the effects on the capillary pressure and relative permeability characteristics of varying this angle.

The API Project 47 at the U. of Texas[7] and others[8] have made extensive studies of an indirect approach to the contact angle through the use of heat of wetting data. Even if successful, however, this approach also states the wettability of porous rock in terms of a contact angle which is uniform over the entire surface. If the angle varies from one part to another on the internal surface, there is no way of determining from the measurements the area distribution of contact angles.

In 1956 Brown and Fatt[9] suggested that the concept of a contact angle, as applied to reservoir rock, be abandoned. This suggestion was made because it is known that the internal surface of most reservoir rocks is composed of many different minerals, each with a different surface chemistry and a different capacity to adsorb surface active materials from reservoir fluids. Furthermore, the operation of a contact angle in determining the form of a fluid-fluid interface is difficult to picture in the very complex geometry of a pore.

Brown and Fatt proposed that the wettability of reservoir rock be stated in terms of the fractional internal surface area that is in contact with water or oil. All surfaces on which there is water are called water-wet; surfaces on which there is oil are called oil-wet. The fractional water wettability is then stated as a number which represents the fraction of the internal surface that is in contact with water. A symmetrical statement can be made for the fractional oil wettability.

The concept of a fractional wettability as previously stated has in its favor the recognition of the heterogeneous mineral composition of most reservoir rocks. Another point in its favor is that fractional wettability can be measured quantitatively with relative ease. Holbrook and Bernard[10] use a simple dye adsorption test to obtain fractional wettability of reservoir rocks. Amott[11] uses a combination of imbibition and displacement to arrive at a wettability index of reservoir rocks which seems related to fractional wettability in the range 0.25 to 0.75 fractional water wettability.

Jennings[12] has shown the changes in relative permeability that take place when a porous material is changed from unity to zero fractional water wettability. He also shows that reservoir rocks in their natural state, but at room temperature and atmospheric pressure, have relative permeability characteristics which would indi-

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[1]References given at end of paper.

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