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Evaluation of gas wettability and its effects on fluid distribution and fluid flow in porous media

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Abstract: The special gas wettability phenomenon of reservoir rocks has been recognized by more and more researchers. It has a significant effect on efficient development of unconventional reservoirs. First, based on the preferentially gas-covered ability and surface free energy changes, definition and evaluation methods have been established. Second, a method for altering rock wettability and its mechanisms have been studied, surface oriented phenomena of functional groups with low surface energy are the fundamental reason for gas wettability alteration of rock. Third, the effect of gas wettability on the surface energy, electrical properties and dilatability are investigated. Last, the effects of gas wettability on capillary pressure, oil/gas/water distribution and flow are investigated with capillary tubes and etched-glass network models. The gas wettability theory of reservoir rocks has been initially established, which provides theoretical support for the efficient production of unconventional reservoirs and has great significance.

Key words: Gas-wetting, fluorocarbon copolymer, contact angle, capillary pressure, surface free energy, surface property, fluid flow in porous media

1 Introduction

The wettability of rocks near boreholes is a key factor that determines the position, flow and distribution of reservoir fluids in porous media and has a great effect on the oil-water relative permeability and oil recovery (Morrow, 1990; Jiang, 1995; Ogunberu and Ayub, 2005; Wang et al, 2011). As early as 1942, Buckley and Leverett (1942) recognized the importance of wettability on water flooding performance. Later, some researchers studied the effect of wettability on capillary pressure, relative permeability, initial water saturation, residual oil saturation, oil recovery and electrical properties of reservoir rocks (Morris and Wieland, 1963; Donaldson and Thomas, 1971; Menezes et al, 1989; Cockcroft et al, 1989; Jia et al, 1991; Buckley et al, 1995). Other authors investigated the result of wettability adjustment on reservoirs and well stimulation such as oil displacement efficiency improvement during water flooding and oil recovery increase (Wagner and Leach, 1958; Froning and Leach, 1967; Kamath, 1970; Morrow et al, 1973; Penny et al, 1983).

Wagner and Leach (1958) reported that it is possible to improve oil displacement efficiency by wettability alteration during water flooding. In 1967, Froning and Leach (1967) reported a field test in the Clearfork and Gallup reservoirs for improving oil recovery by wettability alteration. In 1983, Penny et al (1983) proposed a non-wetting approach (zero capillary pressure can be achieved by altering the water-solid contact angle to 90°) in fracturing treatments to control capillary pressure and enhance relative permeability. Their laboratory data and field applications showed impressive results: as employing this approach, due to longer frac lengths and higher fracture conductivities, the production following cleanup after fracturing in gas wells generally was 2 to 3 times greater than field averages or offset wells treated with conventional approaches. Zhou et al (1987) presented that the 'solid-gas wettability' was totally opposed to the solid-liquid wettability. They believed that the more lyophobic the solid becomes, the easier the solid is 'wetted' by gas and for gas bubbles to attach to it; on the contrary, the more lyophilic of the solid, the easier it is to be wetted by liquid and harder for gas bubbles to attach to it. By utilizing this wettability differences between gas and liquid, valuable minerals and gangue can be separated and purified in froth flotation.

Although so many researchers have recognized the results of reservoir wettability alteration and its effects on well stimulation, it was not until 2000 that the special wetting phenomenon 'gas-wetting' was firstly put forward by Li and Firoozabadi (2000a). In their paper, by using a

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