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Changing characteristics of ultralow permeability reservoirs during waterflooding operations

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Abstract: The characteristics of ultralow permeability reservoirs changed after waterflooding. Thin-section analysis and scanning electron microscopy (SEM) of core samples from inspection wells indicated that calcite and barite were formed in ultralow permeability reservoirs during waterflooding operations. Some asphaltene precipitates on the surface of formation rock would influence the reservoir porosity, permeability, wettability, and electrical properties. In this paper, the changes of physical, electrical, and fluid properties of ultralow permeability reservoirs during waterflooding operations were analyzed. This provides important information to improve waterflooding performance in ultralow permeability reservoirs.

Key words: Ultralow permeability, waterflooding, reservoir change, waterflooding characteristics

1 Introduction

Low-permeability reservoirs in the Changqing Oilfield are characterized by low pressure coefficient and low natural drive energy. Water is required to be injected into the formation to provide sufficient drive energy to displace the crude oil and then enhance the ultimate recovery. The injection water, mainly taken from the Luohe Formation, has low salinity and is of the sodium-sulfate type. However, the formation water in the Chang 6 reservoir is of the calcium-chloride type, incompatible with the injection water, so scale is formed in the reservoir during waterflooding operations. This results in changes in the petrophysical properties of the reservoir, such as porosity and permeability. Many studies have focused on changes of petrophysical properties of medium to high permeability reservoirs during waterflooding operations (Yue, 1999; Zhang et al, 2000). Most research revealed that reservoir porosity and permeability increased and heterogeneity weakened to some degree after waterflooding (Wu, 2006; Huang et al, 2000). A few scholars have studied the effect of the water injection process on the petrophysical properties of low-permeability reservoirs (Abbasi et al, 2012; Wang et al, 2011; Xu et al, 2012). Several researchers thought that after waterflooding the reservoir porosity and permeability decreased due to grain migration and clay swelling induced by injection water in low-permeability reservoirs (Al-Muhaidib et al, 2012; Ghafoori et al, 2012). Based on the data from 9 inspection wells and the analysis of scaling origin, new minerals of calcite and barite are shown to be formed in the process of water injection. Through analyzing the relationship of calcite and barite generated during waterflooding operations, the characteristics of low permeability reservoirs during waterflooding operations is further revealed.

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2 Experimental

The contents of anions and cations in water were determined by ion chromatography and inductively coupled plasma-atomic emission spectrometry. Morphology and composition of minerals in core samples were identified with Leica 4500P polarizing microscope and Quant 400 scanning electron microscope. Porosity and permeability were measured with a CMS-300 core measurement system (American Core Laboratories).

3 General geology and inspection well design of reservoir

The Chang 6 Formation is one of main producing formations in the Changqing Oilfield. This reservoir consists of low-permeability, sandstone, with a permeability of 1.0×10^{-3}-3.0×10^{-3} μm^2 and a porosity of 11%-15%. Its pressure coefficient is low (0.7). It is a well-sorted and fine-grained feldspar sandstone, with a high textural maturity and low mineralogical maturity. Most of the minerals have high sensitivity to acid, but low sensitivity to water. The cement content is about 10% mostly calcite, hydromica, chlorite and the zeolite laumontite.

The formation water of the study area is closed primary water, with a salinity of about 100 g/L. The water is of the calcium-chloride type. The injection water is of the sodium-